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TOBACCO SUBSTATION AT WINDSOR

REPORT FOR 1933

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Most of the experiments conducted at the tobacco substation at Windsor are parts of long time projects continued over a number of years. This report includes a discussion of progress during the 1933 season on some of the projects but reports on others are reserved until they are more nearly complete. More time has been devoted this year to investigations of tobacco diseases than heretofore. Therefore more space in this bulletin is given to these and rather less than usual to fertilizer experiments. Although there still are, and always will be, fertilizer problems, and the work on them will be continued, it is felt that many of the most urgent ones have been answered by previous experiments.

The most pertinent results obtained from intensive work on one disease, begun by the senior author in 1933, are reported here. This will be followed by the investigations of other diseases as quickly as time and resources will permit.

Another new project in 1933 was in the initiation of experiments in growing potatoes on old tobacco land. These have to do with fertilizers primarily, but also include spraying for control of insects and diseases. This work has been undertaken because many tobacco growers, during the years of depression and contraction of tobacco acreage, have turned a considerable part of their tobacco land over to potatoes. Years of heavy fertilization for tobacco have accumulated large reserves of some food elements, phosphorous, for example, and have made other changes in the soil, so that the fertilization of potatoes on tobacco land is a different problem from that on other types of land in the state. The potato experiments are being carried on in cooperation with the departments of Botany, Entomology and Soils of this Station and the department of Agronomy at the Storrs station. The results for 1933 are published in the Director's Report, Bulletin 357.

The season at Windsor in general was too dry for best growth of the tobacco crop, especially during the later half of June and all of July and August. It was necessary to irrigate several of the fields twice during this period. Rainfall records for the season of 1932 and 1933 are given in Table 1. The crop, however, was above the average in weight and of good quality. There was no damage by hail or wind.

Table 1. Distribution of Rainfall in Inches at the Tobacco Substation, Windsor, 1932–1933.

By 10-day periods

Year	May			June			July			August	
	1–10	11–20	21–31	1–10	11–20	21–30	1–10	11–20	21–31	1–10	11–20
1932	.87	.02	.76	.26	2.38	.22	1.08	.73	2.18	1.39	2.34
1933	.58		1.00	1.49	.39	.08	.33	1.34	.76	.89	.58

By months

Year	May	June	July	August (total)
1932	1.65	2.86	3.99	5.72
1933	1.58	1.96	2.43	3.42
Mean*	3.60	3.08	4.37	4.29

*Average from the Hartford Weather Bureau records for the past 74 years.

PYTHIUM DAMPING-OFF AND ROOTROT IN THE SEED BED

P. J. Anderson

A damping-off and rootrot disease of seedlings became so prevalent and widespread in the early seed-bed period of 1933 that it appeared to be an epidemic and gave rise to apprehension that a new disease had invaded the state. Closer investigation, however, showed that it was not a new but an old disease that is present to some extent every year. Ordinarily it is not considered of serious importance. The reason for its destructive increase and epidemic prevalence in 1933 is not apparent. Since it became a source of considerable expense to growers who lost a part or all of their beds and were obliged to purchase plants elsewhere, an investigation was undertaken with the object of discovering some method of controlling its ravages.

This section presents in a preliminary way some of the practical findings. More technical phases are reserved for publication elsewhere.

Symptoms

It will first be necessary to describe the symptoms or "ear marks" by which one may distinguish this from various other seed-bed troubles.

The symptom that the grower usually notices first shows shortly after the germinating seedlings become visible. At this time the plants have developed the first pair of tiny green leaves (cotyledons). The plants begin to disappear. Every day when the grower examines the beds he finds that there are not so many plants as he thought were there the previous day. The "stand" becomes thinner and thinner. In many cases this continues until there are not enough plants left to pay for further care and the beds are abandoned, or until the stand is so reduced that there are not enough plants to set the intended acreage.

The cause of such continuous disappearance of plants can be determined by a close examination of the beds at this early stage. Looking carefully, one finds that many of the little seedlings are unable to stand upright and have fallen over to lie prostrate on the soil surface, (Fig. 64 and Fig. 65, A). It will be observed that the stems (hypocotyls) of such prostrate plants are withered and lifeless. This dead part of the hypocotyl may be only a short portion just at the surface of the ground or the shrivelling may extend well up, even to the base of the cotyledons, in which case it gives the appearance of a white or straw-colored string connecting the first leaves with the soil. Depending on the moisture conditions, the cotyledons may remain green for several days or may rot and disappear very quickly.

Another symptom that is characteristic is the presence of small plants

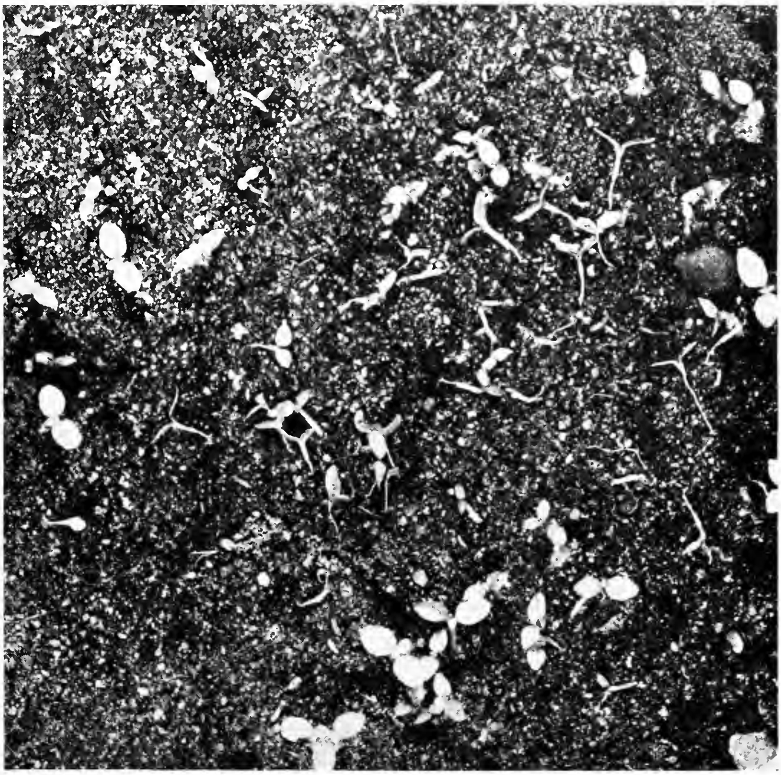

FIGURE 64. Damping-off of young seedlings. Note shrivelled hypocotyl of prostrate plants. Enlarged 3 diameters.

with sound stems but not attached to the soil at all. They are either lying prostrate or entirely inverted, with the naked blunt stubs, where the roots should have been, standing upright. In this case, the hypocotyls are still sound but the roots have been completely rotted away. The little plants, therefore, have no anchorage and when splashed by water from sprinkler, hose, or rain, they topple over and either recline on their sides or are completely upside down with the root stubs standing up in the air. The disease is the same as the damping-off described above but in this latter case the roots only are affected while in the former, it is the stem which dies first—although microscopic examination shows that also in damping-off the roots are diseased.

Another symptom of the same disease may appear at a somewhat later stage. After the plants have developed 4 to 6 leaves, one notices patches in the bed where the plants stop growing and the leaves fade out to a pale yellow. Then, beginning with the lower, the leaves turn almost white and finally die. This causes the death of many of the smaller plants. The above-ground appearance of such affected plants is not different from that of plants affected with the black rootrot. No amount of watering or fertilizing will start the plants in these spots growing. Examination of the roots under a hand-lens or dissecting microscope shows that some or all of the rootlets are withered. Unlike the other rootrots of tobacco, this disease does not cause the roots to turn brown or black. They remain white or very light in color as long as they are beneath the soil. If the plants are pulled the flimsy rotted roots remain below and are not noticed, but if the soil is carefully removed by gentle washing in water, they may be found readily. Their collapsed condition can be determined by teasing them apart under a dissecting microscope when it will be found that they have no turgor or coherence and the rotted outer cortex slips easily from the central strand.

Microscopic examination of the tissues characterized by any of the above symptoms shows abundant oospores and mycelium of the fungus described below.

The condition of the older plants described above could not properly be called damping-off. The term "damping-off" is applied to a disease characterized by collapse of infected tissue at the base or ground level of the stem — although it is now generally recognized that when damping-off occurs the roots are also affected. When, however, *only* the roots are affected while the stem remains healthy, we can properly refer to the disease only as a rootrot. For the sake of clarity it seems advisable to call this disease the *Pythium damping-off and rootrot.*

This disease should not be confused with "bed-rot," a wet, brown, slimy rotting of the stalks at a later stage — usually when the plants are about large enough for transplanting. Bed-rot in all cases observed here is caused by other fungi and its control is a problem quite different from that of the disease under discussion here.

Cause

Damping-off is not caused by too much water or too little ventilation or overcrowding, although these conditions may favor it. The primary cause is invasion and destruction of the hypocotyl or roots by a parasitic fungus (*Pythium debaryanum* Hesse)*. This fungus is not usually visible to the naked eye except that sometimes under very damp conditions it may be seen as a white felt of fine threads like spider webs or cotton fibres

*Dr. Charles Drechsler of the U. S. Department of Agriculture has kindly confirmed the writer's identification of this fungus.

spreading over the surface of the wet soil around the dying plants. These fine threads are continuous but branching tubes which in the young growing condition are filled with living protoplasm. This weft of tubes, called the mycelium, makes up the body of the fungus. The mycelium continues to branch and grow for an indefinite period beneath the soil and is probably present in all of our soils. It is not necessary that the tobacco plants be present; it may live for an indefinitely long time on the organic materials in the soil or in water and grows very rapidly. The writer has found that on artificial media, in pure culture, the mycelium will spread as much as ¾ of an inch in one day. It produces several kinds of spores (Fig. 65, D to J) which serve the same purpose as the seeds of higher plants. Some of these spores have heavy walls (Fig. 65, F19 and H) and serve to keep the fungus alive under adverse conditions of drying out or freezing; others are thin-walled and short-lived (Fig. 65, D, E) and probably serve more for rapid distribution. Such spores may be carried about by wind* or by water. Its rapid growth, omnipresence and many methods of rapid dissemination explain why the disease is so difficult to control.

In germination, the tobacco seed swells and then bursts open at one end from which emerges a white, rapidly elongating "shoot," the tip of which is the primary root and the upper end of which is the hypocotyl. The cotyledons (Fig. 65, A) or first leaves, above the hypocotyl come out of the seed coat last. Just as soon as the tip of the primary root emerges, it is susceptible to attack by any branch of the mycelium which may come in contact with it. No part of the root or hypocotyl is resistant at this stage, but the point of attack is usually close to the point of union between root and hypocotyl, therefore near the surface of the soil. When a hypha (branch of the mycelium) comes in contact with the epidermis of the plant, it swells into a knob at the tip, from which it passes as a narrowed much constricted tube, through the wall and into the interior of the cell (Fig. 65, C). Once inside the cells of the host plant, it lives upon and destroys the living cell contents, branches freely and spreads between and through the cells of all the parts of the hypocotyl or roots (Fig. 65, B). This causes the cells to fall apart and collapse, and soon the little plant topples over and dies. All this happens with extreme rapidity. In inoculation experiments in pure culture, the tissues were found to be thoroughly permeated with the threads of the parasite in less than 24 hours after the fungus came in contact with the plants. After killing the tissues, the fungus produces spores inside the plant and at the same time some of the hyphae grow out into the surrounding air or soil, passing through the outer wall of the epidermis as a much constricted neck with enlargements of the hypha on either side.

It is doubtful whether any seedling attacked in the hypocotyl at this stage ever recovers. Later, at about the stage when the true leaves (above the cotyledons) develop, the stalk becomes resistant and there is little danger of further loss from hypocotyl infection. If infection is in the roots, however, the attack is not so sure to be fatal. On the other hand resistance does not seem to develop at such an early stage. When some

*Hoffman (17) found the spores in air currents 30 feet above the ground.

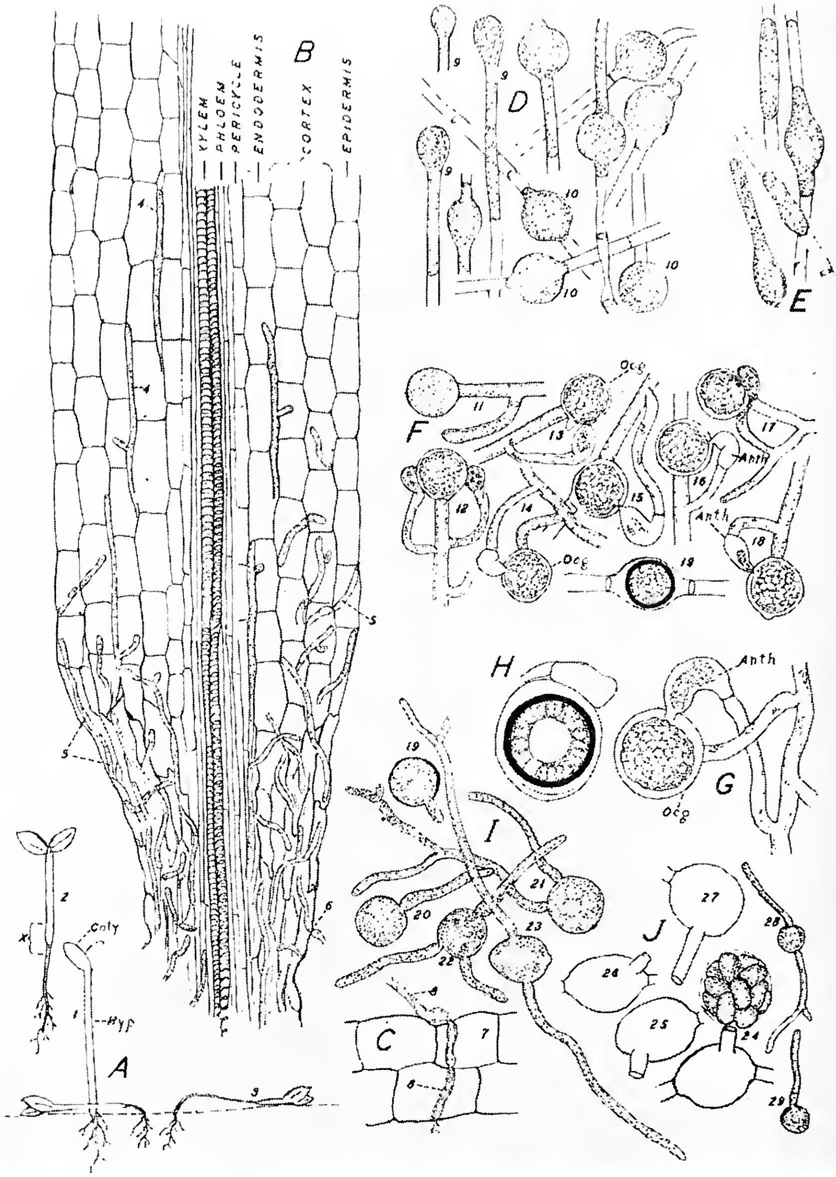

FIGURE 65. Stages in the development of the damping-off fungus, *Pythium debaryanum*.

EXPLANATION OF FIGURE 65.

A Tobacco seedlings 10 days old (x 4)
  1. Healthy seedling. *Hyp.*, hypocotyl. *Coty.*, cotyledon
  2, 3. Diseased seedlings with shrivelled hypocotyls.

B Highly magnified (x 160) longisection of hypocotyl at point marked X in A, 2. Shows cellular structure and invasion of the cells by the fungus mycelium.
  4. Intercellular mycelium
  5. Intracellular mycelium
  6. Point of entrance of mycelium into the epidermis.

C Entrance and penetration of cells (x 320)
  7. Epidermal cell of hypocotyl
  8. Mycelium, constricted at the cell walls.

D Conidia (Asexual spores) (x 300)
  9. Young stages of development
  10. Mature conidia

E Chlamydospores (x 300)

F Oospores (Sexual). Stages of development (x 300). *Anth.*, antheridum. *Oog.*, oogonium.
  11. Youngest stage
  12 - 18. Later stages
  19. Mature oospore.

G Antheridium and oogonium (x 500)

H Cross section of mature oospore (x 560) showing empty antheridium above, oogonial wall, heavy oospore wall and central drop of reserve substance.

I Stages in germination of conidia (x 300) with 1, 2, or 3 germ tubes.

J Zoosporangia (x 330)
  24. Cluster of zoospores at mouth of exit tube.
  25, 26, 27. Empty zoosporangia after contents have passed out through exit tubes to form zoospores.
  28, 29. Germinating zoospores.

of the rootlets are killed, others are developed from the root or hypocotyl above. These may be attacked in turn and there results a struggle between the host and the parasite which causes dwarfing and etiolation but not always death of the plant.

This later infection resulting in dwarfing of older plants was not so common or serious in 1933 as the infection in earlier stages. Rootrot of younger seedlings resulting in complete loss of the root system before four leaves were developed was very prevalent this year.

Distribution of the Disease

Damping-off diseases of seedlings produced by species of Pythium have been described from most countries and on a great variety of cultivated plants, including beets, tomatoes, cress, celery, peppers, cabbage, corn, sugar cane, coniferous seedlings and others too numerous to mention here specifically. Some of these diseases are caused by the same species of Pythium described here, others by different species of this genus, but the symptoms and course of the diseases are quite similar. Also many damping-off diseases are caused by other genera of fungi.

On tobacco, this disease, or a similar one caused by species of Pythium, has been found in widely separated regions. Descriptions given in published articles or notes are for the most part not in sufficient detail for one to be sure that the writer had under observation the same disease, caused by the same organism, that we have here.

In 1900 Raciborski (24)* found *Pythium vexans*** attacking over-crowded or weak tobacco plants in Java.

In 1912 Serbinov (26) found a damping-off disease of tobacco seedlings very destructive to tobacco beds in southern Russia (Crimea). He described and figured the disease and the causal organism in considerable detail giving to the organism a new name, *Pythium perniciosum*. The disease as described by him has all the symptoms that we have observed here and one might judge the two to be identical. However, the causal fungus he found has somewhat different morphological characters.

In 1919 Subramanium (28) in India described what appears to be the same disease on tobacco and gave to the fungus the new name *Pythium butleri*.

Drechsler (9) has recently found *P. aphanidermatum* in diseased tobacco seedlings from Sumatra.

Pythium debaryanum as a cause of damping-off of tobacco seedlings has been reported by Johnson (19) in Wisconsin in 1914, Reinking (25) in the Philippines in 1919, Doran (8) in Massachusetts in 1928, and Nolla (22) in Porto Rico in 1932.

In local lists of parasitic fungi, *Pythium debaryanum* has also been reported on tobacco in Germany, Turkey, Rhodesia, and Sumatra (21).

In Connecticut, Clinton (7) first reported a damping-off of tobacco (in greenhouse in 1906) caused by a species of Pythium. In recent correspondence Clinton states, "In 1920-21, when we made a disease survey on tobacco in this state, we found *Pythium debaryanum* as a common trouble in seed beds. I have a list of from 15 to 20 seed beds where we found it each of those years and I have known it occurring before and after those years."

The writer has at various times during the last 10 years found a Pythium in diseased seedlings which he has referred to *P. debaryanum*. He reported successful treatment for its control with acetic acid in 1928 (3).

Probably tobacco in most or all of the tobacco growing regions of the world suffers from Pythium damping-off and rootrot to a greater or less degree but it appears that the disease is not always produced by the same species of Pythium. The observations of Clinton, Doran and the writer, previously mentioned, show that it is a wide-spread disease of long standing in the Connecticut Valley. It is probably responsible for a larger proportion of poor stands and failures in seed beds than has been suspected.

Influence of Environmental Conditions

It is well known that certain conditions of the environment may modify considerably the severity of damping-off diseases caused by Pythium. Most important of these are temperature of the surrounding air and soil, humidity of the air or percentage of moisture in the soil, percentage of

*Numbers in parenthesis refer to Literature Cited on p. 353.

**Butler (6) later presented reasons for doubt as to the correct identity of this species since *P. vexans* is not known to be parasitic.

organic matter, and degree of acidity of the soil. Atkinson (4) says "The trouble is favored by damp soil, comparatively high temperatures, and humid atmosphere."

Temperature. In the literature of *Pythium debaryanum* and of closely related species of Pythium one finds numerous references to the effect of different temperatures on the growth of the fungus and on incidence of the disease. Some are based only on observation, others supported by controlled experiments.

Johnson (19) found 33° C. to be the optimum temperature for growth of *Pythium debaryanum* and its growth very slow below 16° C. He, therefore, recommended keeping the temperature of the seed bed low as a means of checking the disease.

Flor (10) found the rate of growth of the cane rootrot Pythium, as tested in pure culture, increased regularly with rise in temperature up to 30° C. but diminished above that point. When, however, he investigated the influence of soil temperatures (ranging from 15° to 35° C.) on infection and injury to roots he found that the amount of injury increased as the temperature decreased, being most severe at 15° C.

Johann et al (18) also found the Pythium causing rootrot of corn more injurious at low temperatures.

Hawkins (15), working with *Pythium debaryanum* which causes "leak" of potatoes, found the minimum temperature for growth of the fungus to be 5° C., the optimum 30° to 35° C., and the maximum 35° to 40° C.

Harter and Zaumeyer (11) found the wilt disease of beans (caused by *P. butleri*) was dependent on a high temperature (30° C. or above) and that it caused no damage at low temperatures. They considered temperature a more important factor than humidity in the incidence of this disease.

Alexander, Young and Kiger (1) found the Pythium disease of tomato seedlings most destructive at 18° to 24° C (65° to 75° F).

The most exact and complete experiments on the relation of temperature to *Pythium debaryanum* were conducted by Hemmi (16) in soil tanks with thermostatically controlled temperatures. He found the damping-off of cress seedlings most severe between 22° and 27° C. However, even with a temperature as low as 15° C. he considered the fungus still a dangerous parasite. When, in other experiments, he controlled the temperature of both soil and air, 80 per cent of the plants were diseased at temperatures between 20° and 30°, decreasing below 20°, but even at 10° there was an infection of 24 per cent of the plants. At temperatures higher than 30°, seed germination was inhibited, therefore there was no chance of control by keeping the temperatures high.

All the investigators agree that these fungi grow best at a relatively high temperature, around 30° C. (86° F.), but some have found infection of the plants more severe at lower temperatures. The range of greatest infection found by Hemmi, 68° to 86° F., corresponds fairly well with the temperatures for best germination of tobacco seed. Even at 10° C. (which is below the point where tobacco seed will germinate) infection was severe. It is obvious then that the disease cannot be controlled by regulation of temperature. It is possible that it might be less severe at low temperatures but this matter requires further experimentation before any recommendations for tobacco beds can be made.

Moisture. The name "damping-off" was applied to the disease because it was usually found to be most severe in damp places. DeBary (5) considered moisture the most important environmental condition favoring the disease.

Johann et al (18) found the Pythium causing rootrot of corn more pathogenic in wet than in dry soils.

Flor (10) also found that the injury caused by the Pythiums parasitic on corn increased with the increase in moisture content of the soil, and was severe only in those soils which contained over 50 per cent of their moisture-holding capacity.

Harter and Zaumeyer (11) emphasized the importance of the air moisture as contrasted with soil moisture. The bean wilt caused by *P. butleri* was severe even in an extremely dry soil when the relative humidity of the air was high.

Johnson (19) found both high air moisture and high soil moisture favorable to damping-off, pointing out that air humidity permits aerial spread of the fungus from plant to plant. Growth through the air is more rapid than through the soil. He attributes the greater prevalence of damping-off in thick sowings to increased humidity thus produced.

As a means of combatting damping-off it is often recommended that the moisture of soil and air be kept at a low level. Such advice for germinating tobacco seed (the stage of infection) is of little practical benefit. Tobacco seed are sowed very close to the surface of the soil; in fact many of them lie on top of the soil. If the soil becomes dry during the germination stage, the seedlings die. Since constant moisture at this time is essential, the conditions favorable to infection cannot be avoided.

Composition of the soil. Several writers have stated that the disease is favored by increased organic matter in the soil. This conclusion is apparently based only on observations. No published experiments to substantiate it have come to the notice of the writer. The fact that the saprophytic existence of Pythium in the soil is dependent on the presence of dead organic matter supports such a conclusion. Tobacco growers find, however, that a soil with considerable organic matter is more favorable for the production of good plants than one without much vegetable matter, as, for example, pure sand. It is quite unlikely that they would wish to forego this advantage for the sake of any benefit that might come from a possible reduction in damping-off.

Reaction of the soil. Like other fungi, Pythium requires for its best development that the medium in which it grows be within a certain range of acidity. At more acid reactions its growth is inhibited and finally stops. There is also a degree of alkalinity at which it will not grow.

Flor (10) found that the sugar cane Pythiums grow best in a neutral or somewhat alkaline medium. The optimum growth was at 8.3 pH. At the other extreme, growth was inhibited by increasing acidity until it ceased entirely at 4.6.

The writer found that when the tobacco Pythium was grown in pure culture media ranging from 7.0 down to 3.0 pH, growth was not inhibited by acidity until 5.0 pH was reached. Below this point, growth became progressively less until it stopped completely at about 4.0 pH.

In soil tests to determine the effect of different degrees of acidity on germination of tobacco seed, it was found that in soils testing 4.0 pH or lower the germinating seedlings failed to establish themselves. Apparently these very acid soils contain some soluble substance which is toxic to the roots. If, therefore, a degree of acidity can be found which permits the plants to grow normally but at the same time checks the development of the fungus it must be in the range between 4.0 and 5.0 pH. Soils above 5.0 showed considerable damping-off; from 4.85 downward there was decreasing severity of infection. The range of safety, however, is so narrow that it seems doubtful whether a method of control based on adjustment of the soil reaction could be practical for the average grower.

In the present state of our knowledge of the influence of environmental conditions, it seems doubtful whether any changes the grower can effect in natural conditions in the seed bed at this early stage of development can be depended on to control damping-off.

Control

Since the causal fungus lives in the soil and infection occurs for the most part below or just at the surface of the ground, it is obvious that any contemplated method of control, to be successful, must be aimed at elimination or checking of the fungus in the soil. Covering the above ground parts of the plants with a protective spray is of no benefit. Johnson (19) found that spraying with Bordeaux mixture after the plants were started gave negative results. The writer also, during the course of the experiments described below, sprayed infected flats at intervals of two or three days with Bordeaux mixture. This treatment was started just as soon as the first seeds began to crack. The plants damped off badly, however, and at the end of the experiment there were just as many living plants in the unsprayed as in the sprayed flats.

In the experiments discussed below, the soil used was a sandy black loam taken from the seed beds of a grower in Hockanum where the disease was so serious in 1933 that the beds were a total failure. Flats measuring 18 by 10 by 4 inches were filled with this naturally infested soil and kept in the greenhouse at temperatures of 60° F. at night and about 70° during the day with occasional bright days when the temperature rose during the middle of the day to 80° F. The experiments were made during October, November and December of 1933 and January of 1934. The Cuban Shade Variety of seed was used throughout. A measured equal quantity of seed was sowed in each flat. In order to keep an optimum humidity of the air and surface of the soil for germination, the flats were started under a hot bed sash which was hinged to the side of the greenhouse bench, thus approximating the conditions of an ordinary seed bed. After the seed had germinated and most of the cotyledons had spread — about 10 days — the flats were removed to the open benches of the greenhouse. Observations on the amount of damping-off in each flat were recorded at frequent intervals. When the plants had developed about six leaves and were judged to be beyond the susceptible stage, all were pulled and counted. The "check" or control flats contained untreated soil and were seeded at the same time as the treated flats and kept under the same conditions.

Sterilizing the Soil with Steam. The object of this method is to raise the temperature of the top soil sufficiently to kill the mycelium and spores of the causal fungus; then to grow the seedlings before the fungus threads grow back to the surface. This is the method in common practice here and in other cigar leaf sections of the country. The inverted pan system is used almost universally for this purpose. It kills not only this fungus but also other pathogenic fungi and bacteria, insects and weed seeds. Yet most of the serious cases of damping-off found in 1933 were in beds which had been steamed. It is apparent that steaming has not controlled this disease. The fault, however, lies not in failure of the treatment to kill the fungus, but in the ability of the fungus to rapidly reinfect the soil after sterilization. Steaming sterilizes only the top four to six inches of soil. The fungus remains alive in the soil below that depth and starts growing back up just as soon as the soil begins to cool off. We have previously mentioned the extreme rapidity of growth of Pythium — three-fourths of an inch in a day. The rate of growth is also favored by lack of competition in a sterile soil. By the time the seeds are germinating, the fungus is again in position to infect, or the fungus may be introduced by water, air currents, tools, or by other means.

In order to see whether infection is prevented by steaming, one flat was steamed for 20 minutes at 100 pounds pressure under the pan and as soon as cooled was immediately seeded along with an unsteamed flat. Both were kept in the greenhouse under conditions which would offer little opportunity for reinfection.

Soon after germination, damping-off appeared on the check flat but not on the steamed flat. Germination, however, was not good on the steamed flat and many of the plants remained yellow and stunted with poorly developed roots. This condition often develops in beds which have been seeded too soon after steaming and is probably due to accumulation of ammonia in a freshly steamed soil. Analyses showed more than twice as much ammonia in the steamed soil as in the check soil. The stand on the check flat became thinner throughout the experiment due to damping-off. At the end of 5 weeks there were 1087 plants alive on the steamed soil and only 184 on the check flat.

This experiment shows that the disease can be controlled by steaming if one guards sufficiently against reinfection. As a practical method of control in the seed beds, however, it cannot be depended on because reinfection is too difficult to prevent. This fact is not an argument against the general practice of steaming the soil, but it indicates that in places where damping-off and early rootrot is a serious factor some other method of control must be used.

Drenching the Soil with Formaldehyde. Drenching the soil with formaldehyde, and thus killing damping-off fungi before seeding, is a method used for many years, not only in tobacco beds but for many other seedlings and cuttings. As commonly practiced, formaldehyde is diluted with water at a ratio of 1 to 50 and sprinkled on the soil at the rate of one-half gallon to the square foot. This completely saturates the soil and reduces it to mud. As soon as it is somewhat dried out, the soil must be stirred several times until the fumes of formaldehyde have gone off. If seeded too soon, many of the plants will die. This method involves a delay of about 10 days or even longer in rainy weather, and therein lies a serious objection.

Johnson (19) conducted extensive experiments with the formaldehyde drench method and found it effective in controlling damping-off.

The present writer made a test in which one flat was treated at the above mentioned rate. After stirring the soil at intervals several times, the seed was sowed a week after treatment of the soil. This interval was found to be too short since it resulted in delayed germination and some injury. Damping-off, however, did not develop in this flat at any time. Although the plants in the untreated check flat were more numerous at first, damping-off began as soon as they germinated and continued until, at the end of 4 weeks, there were 285 plants alive as compared with 755 in the treated flat.

It is apparent that the disease can be controlled by this method, but in order to avoid chemical injury it is best to wait longer than a week to allow the fumes to escape. No attempt was made to determine how long the sterilizing effect of formaldehyde continues. Thus the question of how soon the fungus may reinfect remains to be answered.

Formaldehyde Dust as a Soil Disinfectant. The previously mentioned objection to the formaldehyde drench method may be eliminated by substituting formaldehyde dust. This method was recently developed by Alexander, Young and Kiger (1) in Ohio for controlling damping-off of tomato seedlings. Commercial 40 per cent formaldehyde is sprayed or sprinkled on some absorptive dust at the rate of 15 parts by weight of formaldehyde to 85 parts of the dust. This treated dust is then distributed over the surface of the soil and thoroughly mixed into the upper 2 or 3 inches of soil with a rake. The seed is sowed immediately, thus eliminating the delay which the drench method requires. The gas passes out into the soil at a rate which produces a concentration sufficient to inhibit growth of the fungus but not strong enough to injure the germinating seedlings. Various absorptive materials such as finely ground charcoal, diatomaceous earth, kaolin, swamp soil or other soils containing a high percentage of organic matter have been used.

Since no tests of this material against damping-off of tobacco have been published, the writer ran three series of experiments in flats in the greenhouse with the infested soil previously mentioned.

In the first experiment, finely ground charcoal was used as a carrier. Since it was feared that tobacco seedlings, on account of their very small size, might be injured by seeding immediately after treating the soil, flats were treated one and two days previous to sowing the seed and compared with those in which the seed was sowed just after treating. The rate of application was one and a half ounces of dust to the square foot of soil. To a fourth flat no dust was applied. All were watered heavily at the time of sowing. Just as soon as the cotyledons appeared, damping-off became

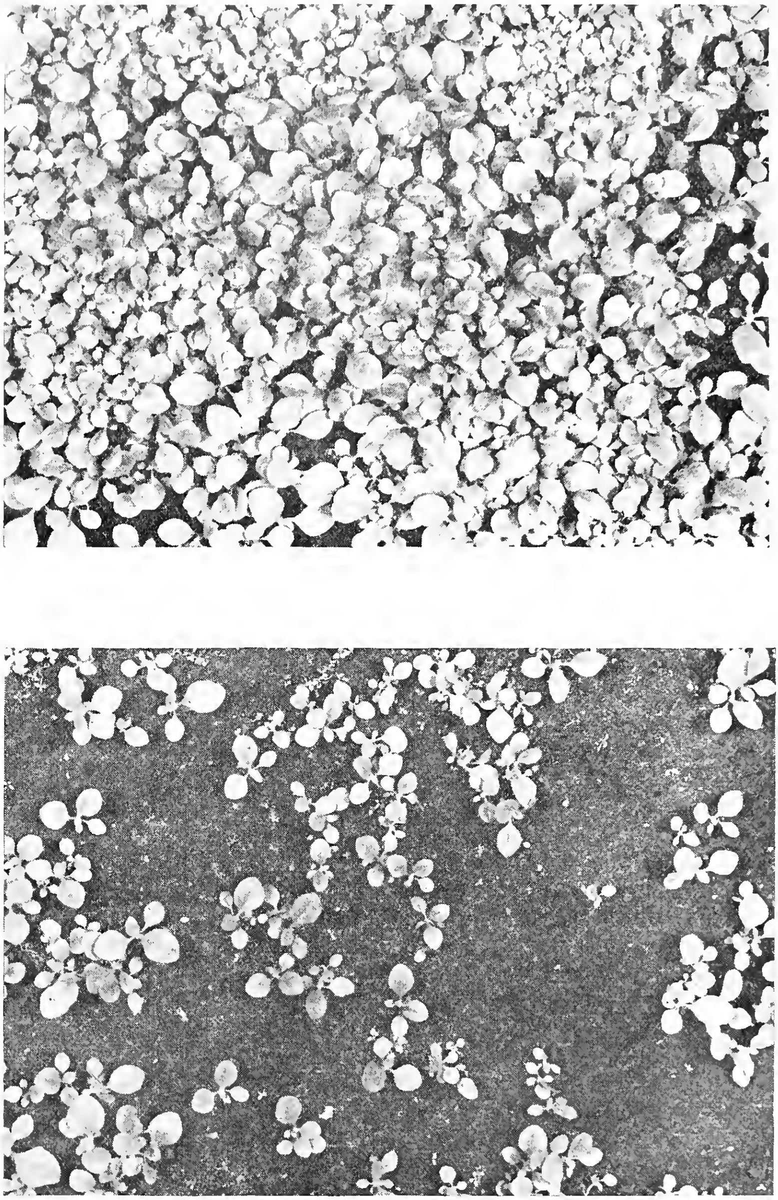

FIGURE 66. Control of damping-off and rootrot by treating seedbed soil with formaldehyde dust. Plants 4 weeks old. Bed shown above treated at rate of 1½ oz. to square foot. Bed below, not treated.

prevalent in the untreated flat and caused great damage thereafter. A small number damped-off on the treated flats but the disease never became serious. After 35 days all plants were pulled and counted. The results presented in Table 2 show that the control was good in all of the flats but best in the flat that was seeded the same day as treated (Fig. 66). No injury from the formaldehyde appeared. Therefore, in all subsequent experiments the seed was sowed just as soon as the soil was treated.

The second experiment was to test different rates of application of the dust. Four flats were treated respectively with 0, ¾, 1½, and 2½ ounces of dust to the square foot. As in the previous test, damping-off appeared early and caused serious loss in the untreated flat. None whatever appeared in any of the treated flats. The results presented in Table 2 show that any of these rates are satisfactory.

The object of the third experiment was to see whether a swamp soil (mostly decayed vegetable matter) would give as good results as the charcoal dust. The soil was dried thoroughly, sifted and then mixed with the formaldehyde at the same rate as in the previous experiment. Two flats were treated and one left untreated. No damping-off appeared in the treated flat except on one small spot an inch in diameter. The check flat damped-off badly. The results, as indicated in Table 2, were just as good as where charcoal dust was used.

TABLE 2. FORMALDEHYDE DUST EXPERIMENTS

Time of application	Amount to square foot	Severity of disease	No. of live plants at end of test
a. Testing effectiveness of charcoal dust used at different times			
Two days before sowing	1½ oz.	Trace	1086
One day before sowing	1½ oz.	Trace	1112
At time of sowing	1½ oz.	Trace	1416
Check	No treatment	Severe	178
b. Testing effectiveness of different amounts of charcoal dust			
At time of sowing	¾ oz.	None	1434
At time of sowing	1½ oz.	None	1830
At time of sowing	2½ oz.	None	1908
Check	No treatment	Severe	553
c. Testing effectiveness of different amounts of humus dust			
At time of sowing	1½ oz.	None	2071
At time of sowing	2½ oz.	One small spot	2056
Check	No treatment	Very bad	369

Considering the formaldehyde dust experiments as a whole, it is apparent that this method gave the best control of any of the various methods tried. Under the conditions of these experiments it was entirely satisfactory. Experiments on a larger scale in seed beds, however, are necessary before a recommendation for its general use can be made.

Formaldehyde dust is now offered for sale by several commercial concerns and distributed by farmers' supply houses. In this form, however, the cost is considerably higher than for the home-made material. Because the escaping fumes of formaldehyde irritate the nose and eyes it is best to make the mixture of formaldehyde and dust in a closed container such as a tight barrel or iron drum. After the ingredients are put together the barrel may be rolled about until the mixture is uniform. If the mixture is still "lumpy" it may be necessary to pass it through a sieve. After preparation, it should be stored in air-tight containers until used.

Sterilizing the Soil with Acetic Acid. This method is the same as the formaldehyde drench except that a 1 per cent solution of acetic acid is substituted for the 1 to 50 formaldehyde solution. Doran (8) found this method effective against damping-off of tobacco. The writer also published experiments (3) which corroborated Doran's results.

During the present investigation another test was made in which one flat was treated with 1 per cent acetic acid solution at the rate of 2 quarts to the square foot of soil while a second flat was left untreated as a control. The seed was sowed 1 week after the soil was treated. Damping-off developed early on the control flat. When the number of living plants was counted at the end of 6 weeks there were 302 plants in the control flat and 1013 in the treated. No damping-off was observed at any time in the treated flat.

Experiments to determine the minimum time between treatment and seeding showed injury on all flats sowed within a week after treatment. Some injury was evident even when sowed seven days after treatment. The delay in sowing the beds constitutes an objection to the acetic acid method.

This treatment, however, prevented completely the appearance of damping-off under the conditions of the experiment. There appears to be no reason why it should not be satisfactory in the beds if the grower does not object to the delay.

Soil Treatment with Sulfuric Acid. This method has been used successfully in preventing damping-off of coniferous seedlings in forest nurseries (12, 13, 14, 27, 29).

One flat was treated with 1 per cent solution of sulfuric acid at the rate of 1 quart to a square foot of soil. The seed was sowed 1 week later. The seed started to germinate but the plants were never able to develop roots and establish themselves. At the end of 4 weeks, not a single plant was alive. The soil before treatment tested 5.15 pH. Three weeks after treatment it was 3.30. Since in other tests it was found that the plants would not start in a soil as acid as 4.0 pH it is assumed that the injury was due to the extreme acidity.

No weaker solutions were tested because this preliminary test indicated that this method under any conditions would probably not be safe to recommend. It also involves considerable delay between time of treating and sowing and thus presents the same disadvantage as drenching with formaldehyde or acetic acid.

Treating the Soil with Copper Carbonate. Nolla (22) was able to control damping-off in tobacco beds in Puerto Rico by application of copper carbonate to the soil at the rate of 4 grams to the square foot mixed thoroughly with the soil before sowing the seed. Another application at the same rate was made a week after germination by dusting the material over the surface and watering heavily. Under some conditions, however, he found that this treatment injured the plants.

In our own experiments at Windsor, two flats were treated at the same rate and in the same way as recommended by Nolla. One flat was seeded at the same time without treatment. It was planned to repeat the application a week after germination in one of the treated flats, but so much injury resulted from the first treatment that no second application was tried. The seed in all the flats germinated but those in the treated flats much more slowly than the check. Most of the seedlings failed to establish any root system. Our observations confirm in every particular the statement of Nolla that "the injury in the copper carbonate treated beds was manifested in much delayed germination and the few seedlings that developed were stunted and yellow."

This experiment shows that, at least in this soil, copper carbonate is quite toxic. Copper salts are known to be toxic to green plants when present even in weak concentration in the soil solution. No further experiments were tried with this or other copper salts because it seemed doubtful whether it could ever be safe to recommend generally the mixing of a copper salt in the soil even though it was found to be safe in some cases.

Treating the Soil with Bayer Dust. Bayer dust was selected as an example of the organic mercury compounds which have been widely recommended for seed and soil disinfection. Nolla (22) tried Bayer Dust at rates of 1 to 4 grams to the square foot and found that none of the applications caused injury to the tobacco seedlings, but that, on the other hand, they did not control damping-off. Major (20), experimenting on control of black rootrot of tobacco in Canada, found that when he treated the soil with 12 or more grams to the square foot the plants were stunted.

In the one experiment which was made at Windsor the soil was treated with three grams of Bayer Dust to the square foot and thoroughly mixed with the top inch of soil. After heavy watering, the seed was sowed, covered with a very thin layer of soil and then watered again. Although there was some germination, the seedlings died and at the end of four weeks there was not a plant left. Even at this weak concentration this material appears to be very toxic to the plants.

Treating the Seed with Bayer Dust. The seed was shaken with a small quantity of Bayer Dust in a flask until all the seeds appeared covered with dust. One flat was seeded in the usual way. Germination appeared normal but most of the plants failed to establish a root system and fell over flat on the surface of the ground when watered. Many of the hypocotyls shrivelled with infection. In other cases where the roots were lacking it was not always possible to tell whether the roots had been killed by Pythium or were prevented from growing on account of the toxic salt.

In either case, the treatment was a failure and cannot be recommended against damping-off.

Seed Treatment with Cuprous Oxide. Treatment with cuprous oxide which was used successfully by Pirone (23) in 1932 to combat damping-off of spinach on Long Island, has recently been adopted and widely recommended for the control of damping-off of a variety of crops. It has not been tried previously for tobacco. The aim of the treatment is to cover the seed with a fungicidal substance which will prevent entrance of any infecting fungus before germination. Also it is assumed the fungicide will sterilize a narrow zone of soil immediately surrounding the seed.

In our experiments, seed was mixed with the red copper oxide at the rate of one part of fungicide to 15 parts of seed and thoroughly shaken in a flask until all seeds were covered with a uniform dust layer. The flats were then sowed with the treated seed in the usual way. The treatment apparently stimulated germination since the treated flats were up two days before the checks. During the first week after cotyledons appeared there was no damping-off in the treated flats but considerable in the control flats. After that, however, damping-off, and more especially the Pythium rootrot type, became prevalent in the treated flats. At the end of five weeks there were 838 plants in a treated flat as compared with 542 in the check. In a second experiment the corresponding figures were 1161 and 655. It appears from these experiments that cuprous oxide gives some control in the early stages of damping-off but that as soon as the growing shoot or root has left the seed a little way, it is beyond the protecting influence of the dust and infection occurs as usual. Treated in this way, the "stand" is somewhat better than in the check flats, but control is not as complete as by other methods such as disinfecting the soil with formaldehyde dust. The cuprous oxide treatment involves the least amount of labor or expense of any of the methods tried. No injury to the seedlings was observed.

Summary

A damping-off and rootrot disease caused by the parasitic fungus *Pythium debaryanum* Hesse, is often responsible for complete or partial failure of seed beds.

The damage is most severe when the seeds are just germinating and shortly afterward. This is not the same as "bed rot," a disease which affects the plants in the bed when they are older.

It is not practical to control the disease by regulation of such environmental conditions as moisture, temperature and soil reaction, because the same conditions which are most favorable for its spread are also the best for germination of the seed and early growth of the seedlings.

Steaming the soil has not controlled it because the fungus grows so rapidly and reinfects so easily. Neither can it be controlled by spraying with Bordeaux Mixture.

Seed treatment with red oxide of copper or with Bayer Dust has not given satisfactory control.

Drenching the soil with formaldehyde solution or acetic acid is subject to the objection of too long a delay before the seed may be sowed.

Excellent control in greenhouse tests has been obtained by mixing formaldehyde dust at the rate of 1½ ounces to the square foot with the top soil just before seeding.

This formaldehyde dust may be made at home by mixing 15 parts by weight of formaldehyde with 85 parts of ground charcoal or dry swamp soil or other soil containing a high percentage of organic matter.

The cost of the formaldehyde is about two cents for each pound of dust. Since one pound will treat 10 square feet, the actual cash outlay is less than four cents a sash (three by six feet). The computation assumes that the grower mixes his own dust.

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HOW TO PREVENT "GREEN MOLD" OR "MOSS" IN THE SEED BEDS

P. J. Anderson

In the early seed bed period while the soil must be kept constantly moist to insure good germination, many growers are troubled with a surface growth of a bright green scum which has received the popular name of "moss" or "green mold." Both of these names are unfortunate because this is neither a moss nor a mold but consists of a surface growth of one or more species of green algae. None of these algae are parasitic on tobacco seedlings but their dense growth may smother the sprouting seeds. There is considerable difference of opinion as to the extent of the damage, but at least such a condition is not desirable.

It is a common practice to sprinkle a thin coat of sharp dry sand over the ground to check the green growth. The benefit derived, however, is probably more imagined than real. Applications of Bordeaux Mixture at intervals of two or three days give much better control, but there may be some injury to the germinating seeds if this treatment is started before the cotyledons appear.

A completely satisfactory method of control for "green mold" was discovered during the course of the experiments on Pythium damping-off and rootrot previously described. When the soil at time of seeding was mixed with the formaldehyde dust (as described on p. 347), not a trace of "green mold" appeared at any time on these beds. On the untreated flats sowed at the same time, the surface became completely covered with green growth of algae. Apparently formaldehyde is quite toxic to these organisms.

THE USE OF SULFATE OF AMMONIA IN TOBACCO FERTILIZER MIXTURES

T. R. Swanback and P. J. Anderson

Sulfate of ammonia, containing about 20 to 21 per cent of nitrogen, has for many years been one of the cheapest sources of nitrogen and is widely used on many crops. Naturally it has found its way into many commercial fertilizer mixtures for use on tobacco fields.

It is well known that different nitrogen-furnishing materials may have different effects on the yield and quality of the tobacco crop. Such differences arise from variation in rates of availability of the nitrogen, presence of other beneficial or detrimental elements in the material, or physical and chemical changes induced in the soil. The suitability of sulfate of ammonia for tobacco mixtures depends, therefore, not so much on its cost as on its effect on yield and quality of leaf as compared with the effect of other nitrogenous materials.

The first field plots laid out after the establishment of the tobacco substation at Windsor were devoted to a comparison of different nitrogen sources, of which sulfate of ammonia was one. During the following 12 years this was supplemented by two other long-time field experiments and by laboratory analyses. Progress reports on these various tests have been included at times in our annual reports. Since we have now reached some quite definite conclusions, it seems proper to summarize all the experiments dealing with sulfate of ammonia and to present the conclusions.

In the first field tests, which were concluded in 1926, there were included (1) plots on which the mixture contained one-fifth of the nitrogen of the formula from sulfate of ammonia and (2) plots on which one-half of the nitrogen was in sulfate of ammonia. After careful analysis of the results obtained from the crops of 1925 and 1926, the following statements were published in our report for 1926, page 32, concerning the plots on which one-fifth of the nitrogen was from sulfate of ammonia: "The grade index was lower, indicating that the quality was not quite so good. Notes taken at the time of sorting and burn tests also confirm this statement." Concerning the plots where one-half of the nitrogen was from sulfate of ammonia: "It will be noticed that the grade index for the sulfate of ammonia was the next lowest of all the plots. The percentage of dark leaves was higher on these plots than for any other treatment. The quality at time of sorting was rated as low as any. There was considerable white and prominent vein. When burn tests were made, these plots rated the lowest of any in fire holding capacity and color of ash. Sulfate of ammonia keeps up the yield (for two years) but produces tobacco of poor quality and poor burn."

In order to study more accurately the effect of this and other nitrogenous materials, another set of four plots was laid out in 1926 in which there was only a *single* source of nitrogen in each plot. Sulfate of ammonia alone was applied to one plot year after year, nitrate of soda to another, cottonseed meal to a third and urea to the fourth. The other fertilizer elements, potash, phosphorus, lime and magnesia, were applied in optimal quantities and in equal amounts to all plots. This has now been continued for eight years. The yields and grade index for these plots are presented in Tables 3 and 4.

During the first six years, the growth of tobacco on the sulfate of ammonia plot was luxuriant. The leaves were dark green and never showed any signs of nitrogen starvation such as was apparent during most of the time on the nitrate of soda plots and, during some years, on the cottonseed meal plots. During wet years, however, there was some magnesia-hunger chlorosis which always appeared first and most severely on the sulfate of ammonia plots. During later years, however, this was corrected by increasing the magnesia applications on all

Table 3. Single Sources of Nitrogen. Summary of Yields 1926–1933

Source of nitrogen	Acre yield by years							
	1926	1927	1928	1930	1931	1932	1933	Ave.
Sulfate of ammonia	1482	1386	933	1436	1678	1731	736	1340
Nitrate of soda	1440	688	585	802	728	1682	1762	1098
Cottonseed meal	1228	1131	696	1374	1582	1703	1812	1361
Urea	1350	1166	876	1510	1761	1734	1813	1460

Table 4. Single Sources of Nitrogen. Summary of Grade Indices 1926–1933

Sources ot nitrogen	Grade index by years							
	1926	1927	1928	1930	1931	1932	1933	Ave.
Sulfate of ammonia	.370	.333	.357	.366	.352	.334	.100	.316
Nitrate of soda	.353	.130	.158	.186	.100	.412	.459	.257
Cottonseed meal	.288	.297	.299	.411	.380	.377	.436	.355
Urea	.375	.350	.443	.415	.449	.375	.424	.404

plots. By 1932 the growth was becoming uneven; patches appeared on which the plants were short and the leaves very dark. The next year, this condition had spread over the entire plot. Many of the plants died in the field, the others were stunted and very dark green. When some of the plants were dug and the roots examined, a considerable part of the root system was found to be dead and brown, symptoms much like those of brown rootrot. The plot as a whole was so poor that it was not worth harvesting. Appearance of this plot in the field is shown in Fig. 67.

With respect to the quality of the tobacco grown on the sulfate of ammonia plot during the years of this experiment the following undesirable features were noted: (1) The cured leaves are always darker in color than those from the other plots. The percentage put into the grade "darks" is invariably highest on this plot. (2) It has been noted at time of sorting each year that the veins tend to be more prominent. (3) The leaves are thicker and coarser. These observations are in accord with those of the first experiment and with those of the third field test mentioned below. (4) Also the combustion characters were the same as in the first experiment, i.e., the fire holding capacity was low, the color of ash dark, coal band broad, the taste and aroma inferior to that of tobacco from the other plots.

This whole combination of undesirable characters of the crop has so consistently followed the use of sulfate of ammonia on different fields

Figure 67. Sulfate of ammonia plot—between the two sign boards—July 1933. Note uneven stand and stunted growth.

through a long series of years, that we are fully warranted in concluding that they are direct effects of the use of this material.

An adequate explanation of each of these effects is not yet at hand. Some of the links in the complicated chain of cause and effect have been revealed, however, by laboratory tests and analyses. One naturally turns first to the changes induced in a soil through application of sulfate of ammonia. That this treatment makes the soil constantly more acid is a known fact fully established by many investigators. Soil reaction tests on these plots made at monthly intervals during the experiments have shown that the soil on the sulfate of ammonia plot has become very acid. At the start of the experiment in May, 1926, it tested 5.2 pH; May, 1927, 5.0; July, 1928, 4.66; July, 1929, 4.41; July, 1930, 4.0; July, 1931, 4.20; July, 1932, 3.91; July, 1933, 3.61. There are seasonal and monthly fluctuations but always this plot is more acid than any of the others and the general trend is constantly toward greater acidity. At reactions as low as 4.0 or lower, tobacco does not grow normally and this factor alone is sufficient to account for the stunted and unhealthy condition of the plants in the last years of the experiment.

The effect of the treatment on the supply of some nutrient elements in the soil was determined by M. F. Morgan of the Soils Department. His analyses, presented in Table 5, show that in June, 1933, seven years after starting the experiment, the amount of nitrate nitrogen was less than in

Table 5. Analyses of Soil from the Single Source of Nitrogen Plots June 15, 1933. Pounds per Acre

	Source of fertilizer nitrogen			
	C. S. meal	Nitr. Soda	Sulf. ammonia	Urea
Nitrate nitrogen	50	100	50	80
Ammonia nitrogen (Available)	20	8	40	12
Phosphorus (Available)	120	80	60	140
Potassium (Replaceable)	320	320	160	240
Calcium "	600	600	150	200
Magnesium "	80	160	30	40
Aluminum "	8	2	10	12
Manganese "	20	10	30	40

the soil of other plots but the ammonia nitrogen was higher; the phosphorous was lower; the three bases, calcium, magnesium and potassium, were much lower; and the manganese was high.

Previous investigations here have shown the injurious effect of increased manganese on tobacco. Manganese toxicity may be expected in any soil when it becomes sufficiently acid.

Sulfate of ammonia exhausts the mineral bases of the soil more rapidly than the other nitrogenous materials considered here, because, (1) it contains in itself no mineral base; (2) its ammonium base is changed in the soil to nitric acid; and (3) thus it introduces two acid radicals (sulfate and nitrate) which must combine with bases in the soil. The bases are thus either leached away or, in the first crops of the series, may be taken into the plant in larger amounts. Ultimately, however, the soil supply is exhausted and the plants show a shortage. Chemical analyses of the leaves have shown that this actually happens; particularly is the percentage of magnesium reduced. Here is apparently one explanation of the darker ash. Our previous studies on magnesia have shown that a good supply of this element in the leaf is necessary to insure a white ash. With a dark ash is also associated poor aroma and taste. Analyses have also shown that the use of sulfate of ammonia increases the sulfur content of the leaf, a condition which is known to reduce the fire holding capacity. There is thus at hand an explanation of the effect of sulfate of ammonia on the combustion properties of the leaf.

Why sulfate of ammonia should cause the leaves to be so much darker, heavier, and prominently veined is not so readily explained. These characters are like those produced in tobacco by an over supply of nitrogen and one might suspect that in some way this material increased the total nitrogen, or supplied it to the plant at an unfavorable time or in an unfavorable form. However, chemical analyses thus far made, fail to show an appreciably increased quantity of total nitrogen in the leaves.

Since some of the unfavorable effects on tobacco are a result of acidity of the soil induced by sulfate of ammonia, a possible remedy was suggested in application of sufficient lime to neutralize the acidifying effect. In order to test this, a third series of plots was laid out in 1932. On four of the plots, sulfate of ammonia was the only source of nitrogen. On three other plots, a standard formula with nitrogen from cottonseed meal, linseed meal and dry ground fish was used. Two of the sulfate of ammonia

Table 6. Sulfate of Ammonia Tests of 1933. With and Without Lime

Fertilizer treatment	Plot No.	Acre yield		Percentage of grades								Grade index	
		Plot	Ave.	L	M	LS	SS	LD	DS	F	B	Plot	Ave.
Sulf. of Am. with lime	N13–1	1912		5	6	35	3	40	1	10	0	.435	
	N13–3	1994	1953	4	7	27	4	47	1	10	0	.409	.422
Sulf. of Am. without lime	N13–2	1896		4	5	32	4	41	2	11	1	.413	
	N13–4	1659	1778	2	4	28	4	45	4	13	0	.380	.397
No sulf. of Am. and no lime	N59	1940		14	11	24	4	33	1	13	0	.476	
	N59–1	2050	2008	16	12	27	2	31	1	10	1	.506	.492
	N59–2	2036		15	11	27	3	32	0	11	1	.495	

plots were limed with high calcic limestone at the rate of 1,000 pounds to the acre in the spring of 1932. Since this did not sufficiently neutralize the acidity, another application (this time, 1200 pounds of magnesian lime) was made in the spring of 1933.

Despite the lime application, there was no difference in growth. All the sulfate of ammonia plots, limed and not limed, were somewhat less luxuriant in growth and of a darker green color than the check plots. At time of sorting, the leaves as compared with the check plot tobacco, were darker, heavier and more "veiny." The sorting records of the seven plots for the 1933 crop are presented in Table 6, and the summary of the two years in Table 7. Particularly striking in Table 6 is the difference of about 10 per cent in the percentage of "darks" between the sulfate plots and the checks. This tendency is the same as found in the other two experiments. The figures in Table 7 indicate that there has been some increase in yield from the use of lime on sulfate of ammonia plots but the grade index is not raised.

This set of plots will be continued for some years and final conclusions must await further results. Results already at hand do not indicate that the bad effects of sulfate of ammonia can be overcome by liming.

In this third series, no tests have been made to determine the effects of the treatment on the burn characters. In a previous set of experiments on this same field, however, it was fully demonstrated that sulfate of ammonia reduced the fire holding capacity of the tobacco and that the addition of lime did not sufficiently correct it (Tob. Sta. Bul. **10**: 27. Rept. for 1927).

TABLE 7. SULFATE OF AMMONIA TESTS, WITH AND WITHOUT LIME. SUMMARY OF 1932 AND 1933

Fertilizer treatment	Plot No.	Acre yield			Grade index		
		1932	1933	Ave.	1932	1933	Ave.
Sulfate of Ammonia with lime	N13–1 N13–3	1845 1996	1912 1994	1937	.379 .404	.435 .409	.407
Sulfate of Ammonia without lime	N13–2 N13–4	1895 1861	1896 1659	1828	.436 .457	.413 .380	.422
No sulfate of Ammonia and no lime	N59 N59–1 N59–2	2035 2051 2031	1940 2050 2036	2024	.404 .420 .429	.476 .506 .495	.455

Conclusions

In all experiments of this 12 year period, there are certain effects constantly associated with the use of sulfate of ammonia:

1. It makes the soil more acid and, if used in sufficient quantity through a sufficiently long period, acidity increases until tobacco will no longer grow.

2. Other soil changes include depletion of the mineral bases, increase in the ammonia nitrogen with decrease in percentage of nitrate nitrogen, decrease in available phosphorus and increase in soluble aluminum and manganese.

3. Sulfate of ammonia makes the cured leaves darker, thicker, and more prominently veined.

4. With respect to combustion characteristics: The fire holding capacity is reduced, the ash is darker, coal band wider, taste and aroma inferior.

NITROPHOSKA FERTILIZER TESTS

T. R. Swanback

Nitrophoska (No. 3) is a commercial fertilizer mixture containing 16.3 per cent nitrogen, 16.3 per cent phosphoric acid, and 20 per cent potash. It is claimed to be a chemical mixture rather than a mechanical one, containing no chlorine, since the potash is present in the form of sulfate. If such a fertilizer, containing the three important elements in a very concentrated form, were found to be suitable for tobacco, it is obvious that it would mean considerable economy in cost of the material and of handling.

It is a common belief among growers in the Connecticut Valley, however, that the bulk of a good fertilizer should be made up from organic material, from which Nitrophoska is practically free.

In order to give this material a thorough trial and at the same time test it in comparison with a fertilizer containing considerable organic material, a field experiment was begun in 1929. A set of 6 plots was laid out on Field I at the station farm. This field has always produced good (Havana Seed) tobacco with yields probably above the average of this district. Two plots were used as controls and were fertilized according to the following formula:

Cottonseed meal	1765	pounds	per	acre
Castor pomace	740	"	"	"
Nitrate of lime	260	"	"	"
Sulfate of potash	164	"	"	"
Carbonate of potash	123	"	"	"
Precipitated bone	222	"	"	"
Magnesium carbonate	36	"	"	"
	3310	"	"	"

These materials furnished 200 pounds of nitrogen, 160 pounds of phosphoric acid and 200 pounds of potash to the acre and in addition some 200 pounds of lime and 40 pounds of magnesia.

Two other plots received a fertilizer where Nitrophoska as nearly as possible substituted for one-half of the nutrients in the formula above. Finally the remaining two plots were fertilized with Nitrophoska and some magnesian lime with urea added to bring the nitrogen up to 200 pounds per acre. All the plots with their respective treatments remained in the same location throughout the five years during which the experiments have been carried on. Progress reports on these tests have been published in Connecticut Agricultural Experiment Station Bulletins 326: 377-379; 335: 252; and 350: 478-479. Final conclusions from the five year trial are presented herewith.

All through the growing seasons practically no difference in growth could be observed in the field between the tobacco on the control plots and on those fertilized with Nitrophoska. Observations on the tobacco at time of sorting have shown that the check plots in most cases produced tobacco satisfactory in quality, while the half and all Nitrophoska produced dark and veiny tobacco.

From the records of yield and grading for 1933 (Table 8) it appears that a decrease in yield and grading is produced through the use of Nitrophoska. That this tendency is consistent is shown in Table 9 where a summary of four years' results is given.

In view of the rather unfavorable results obtained with Nitrophoska under the conditions of the experiment it should hardly prove worth while to use this material as a fertilizer for tobacco in the Connecticut Valley.

Table 8. Yield and sorting records of Nitrophoska plots. Crop of 1933

Proportion of Nitrophoska	Plot No.	Acre yield		Percentage of grades								Grade index	
		Plot	Ave.	L	M	LS	SS	LD	DS	F	B	Plot	Ave.
	N28	2039		11	11	32	2	32	1	10	1	.483	
None	N28–1	1926	1892	8	10	30	2	34	1	13	2	.445	.464
Half	N29	1918		4	9	39	2	33	1	11	1	.447	
Nitrophoska	N29–1	1839	1879	8	5	38	3	30	3	12	1	.456	.451
All	N30	1936		5	7	37	2	35	1	12	1	.440	
Nitrophoska	N30–1	1683	1810	6	6	35	5	31	3	13	1	.434	.437

Table 9. Nitrophoska series. Summary of four years'* results, 1930, 1931, 1932 and 1933

Proportion of Nitrophoska	Plot No.	Acre yield by years					Grade index				
		1930	1931	1932	1933	Ave.	1930	1931	1932	1933	Ave.
	N28	1884	1793	2070	2039		.491	.493	.439	.483	
None	N28–1	1829	1764	1974	1926	1910	.464	.481	.482	.445	.470
Half	N29	1810	1813	2016	1918		.457	.451	.455	.447	
Nitrophoska	N29–1	1934	1856	1866	1839	1886	.453	.478	.386	.456	.448
All	N30	1915	1813	1957	1936		.435	.440	.437	.440	
Nitrophoska	N30–1	1875	1820	1839	1683	1857	.473	.446	.381	.434	.436

*No sorting records are available for 1929 since a hail storm destroyed the tobacco on August 1.

COMPARATIVE STUDIES OF FUELS FOR CURING

O. E. Street

The experiments conducted in 1932 to determine the relative merits of processed charcoals (Eastman Charkets and Ford Briquets) as compared to lump charcoal were continued in 1933. The equipment and technique as described in Bulletin 350 were employed with only a few changes.

Chamber No. 1, which proved to be inefficient due to location, was not used in the present tests. The fuels were rotated in the other three compartments, and accurate records obtained of temperature and fuel consumption.

It was found that the processed fuels could be used more efficiently if the pits were shallow, as the volume of fuel required was not as great as with lump charcoal. The use of a small box-like sheet iron container, 9 by 11 inches and 5 inches deep, fitted with a perforated bottom for ventilation, was successful. The bottom ventilation, however, was unnecessary, as the fuel burned freely with the ventilators closed. A still simpler container, and one that was more efficient was observed in connection with other experiments. This was a granite-ware hand wash basin of about 12 inches diameter and not over 4 inches deep. Used with Eastman Charkets, these containers were very convenient in many respects. Shallow depressions were scooped out of the shed floor in which to place the basins, and the fires started by moistening a few lumps of the fuel with kerosene. The loss of fuel which occurs in pits in the soil was eliminated entirely. At the end of the firing period, the basins were turned upside down and the fires thus smothered without dust. The heat produced by the fires did not damage the basins.

In the present experiments, tests were made on the second, third and fourth pickings of shade tobacco grown on the station field. Two sample hands to a pole, taken from the general tobacco, were marked for studies of the effect on grading.

The fuel and temperature records for the experimentst are shown in Table 10.

TABLE 10. SHADE TOBACCO FIRING EXPERIMENTS. FUEL AND TEMPERATURE RECORDS

Run	Chamber	Fuel	Fuel consumed pounds	Average chamber temp. °F.	Average outside temp. °F.	Gain °F.	Fuel consumed in pounds per degree gain	Length of run
	3	Lump charcoal	147.5	91.35		9.03	16.33	
1	2	Ford Briquets	117.5	91.40	82.32	9.08	12.94	48 hrs.
	4	Eastman Charkets	118.5	91.54		9.22	12.85	
	4	Lump charcoal	172.0	88.46		14.70	11.70	
2	3	Ford Briquets	181.5	85.72	73.76	11.96	15.17	48 hrs.
	2	Eastman Charkets	160.0	88.73		14.97	10.69	
	2	Lump charcoal	170.75	86.10		18.27	9.35	
3	4	Ford Briquets	178.5	85.59	67.83	17.76	10.05	48 hrs.
	3	Eastman Charkets	159.5	87.69		19.68	8.03	

Summary

Fuel	Fuel consumed pounds	Weighted averages—144 hours			
		Chamber temp. °F.	Outside temp. °F.	Gain °F.	Fuel consumed in pounds per degree gain
Lump charcoal	490.25	88.64		14.00	35.02
Ford Briquets	477.5	87.57	74.64	12.93	36.93
Eastman Charkets	438.0	89.32		14.68	29.83

This table differs from Table 19 in Bulletin 350 in that one column "Fuel consumed in pounds per degree of temperature gain" is added. The figures in this column are valuable in showing the relative efficiency of the fuels in a single unit of measurement.

It will be observed that the three runs were made under widely different outdoor temperatures. The first run was made during rather hot weather, the second with normal seasonal temperatures, and the last in a period of cold weather. While the total fuel consumption in the first run was low, the efficiency as measured by the consumption in pounds per degree gain was also rather low. This efficiency increased as the outdoor temperature decreased, at least for the conditions of these experiments.

With the exception of the first test, Ford Briquets was the highest in fuel consumption, and the lowest in average temperature maintained and gain over outdoor temperature. This was due to the nature of the fuel, which possesses a low porosity due to the use of a starch binder. Hence the burning of this fuel is more nearly a surface reaction. In consequence of this difference, a larger mass of fuel was needed to maintain a comparable temperature and the fuel consumed in pounds per degree gain was high, especially when the outdoor temperature was low.

The most efficient fuel in each case was Eastman Charkets, with lump charcoal second in two out of three cases. This difference over the entire period is indicated in the summary which shows lump charcoal 5.5 per cent and Eastman Charkets 24 per cent more efficient than Ford Briquets. A similar trend may be noted for 1932, where Ford Briquets had the lowest temperature gain, but was 3.9 per cent more efficient than lump charcoal and only 5.6 per cent less efficient than Eastman Charkets.

The grading of the samples cured in the various chambers is shown in Table 11.

TABLE 11. DISTRIBUTION OF GRADES OF SHADE TOBACCO CURED BY VARIOUS FUELS. PERCENTAGE OF GRADES

Second Picking

Fuel	LC	LC_2	YL	LV	LV_2	V	VL	VL_2	AL_2	ML	XL	XL_2	S_2	WV	XX	Grade Index
Charcoal	.9	10.6	11.5	.3	32.8	18.8	.3	9.1	.3	1.8	8.5	3.6	.9		.6	1.425
Briquets	.3	5.2	2.3	5.5	37.7	27.5	.6	6.1	.1	2.9	6.1	3.2	.6	.6	1.3	1.499
Charkets	1.6	5.8	7.3	1.0	29.6	19.9	1.0	17.3	.3	2.1	6.5	5.0	1.0		1.6	1.372

Third Picking

Fuel	LC	LC_2	YL	K	LV_2	V	VL	VL_2	AL_2	ML	XL	XL_2	TOPS	XX	Grade Index
Charcoal	0.6	0.8	2.8	2.5	3.1	15.9	1.1	27.1	0.3	19.5	4.8	16.7	2.0	2.8	.973
Briquets		3.4	2.0	3.1	5.4	11.8	2.3	27.0	.6	11.3	19.8	2.3	1.4	9.6	1.035
Charkets		1.5	1.2	1.2	.4	6.2		47.1		15.2	6.2	17.1	.4	3.5	.936

Fourth Picking

Fuel	K	LV_2	VL_2	AL_2	ML	XL	TOPS	XX	Grade Index
Charcoal	.2	4.3	3.2		17.3	3.9	69.0	2.1	.369
Briquets	1.5	1.9	2.3		13.6	2.3	76.9	1.5	.327
Charkets	1.4	1.8	4.5	.7	16.9	2.0	71.3	1.4	.356

The tobacco used for these samples was obtained from a single row in the middle of each bent, this being the only tobacco available. Soil differences related to position in the field almost entirely account for the grade index differences. Comparative grade indexes in the first run show no difference between the grading of tobacco cured with Charkets or Briquets and their corresponding checks, while charcoal was comparatively higher. In the second run, there were no real differences between the samples here reported and their checks, while in the last run, all lots had very low values.

A supplementary test on Havana Seed tobacco was conducted in compartments 16 by 32 feet, with 12 fires to a compartment. The results are shown in Table 12.

Table 12. Havana Seed firing experiments, 1933.
Fuel and temperature records

Run	Chamber	Fuel	Fuel consumed pounds	Average chamber temp. °F.	Average outside temp. °F.	Gain °F.	Fuel consumed in pounds per degree gain	Length of run
	5	Ford Briquets	349	76.30		9.20	37.93	
1	6	Lump charcoal	352	78.98	67.10	11.88	29.63	24 hrs.
	5	Lump charcoal	244.5	79.73		10.04	24.35	
2	6	Ford Briquets	167	79.40	69.69	9.71	17.20	24 hrs.
	5	Lump charcoal	518.5	76.46		10.64	48.73	
3	6	Eastman Charkets	366	78.14	65.82	12.32	29.71	24 hrs.

Summary of Runs 1 and 2

		Fuel	Fuel consumed pounds	Chamber temp. °F.	Outside temp. °F.	Gain °F.	Fuel consumed in pounds per degree gain	
		Ford Briquets	516	77.85		9.46	54.54	
		Lump charcoal	596.5	79.36	68.39	10.97	54.33	

In this test, compartment No. 5 was at the end of the shed and compartment No. 6 adjacent to it. Consequently compartment No. 5 was more difficult to heat. In the first run, in which Ford Briquets were used in this compartment, the gross consumption of fuel was not greatly different from charcoal in compartment No. 6, but the net temperature gain was much lower. When the fuels were interchanged, the charcoal still maintained the higher temperature, but a considerably larger amount was used. If the two runs are summarized it will be seen that their average fuel consumption per degree gain was almost identical. The difference in porosity is again a contributing factor in the lower temperature gain of the Briquets.

No opportunity was available to make a check test for comparison with the third run. However, it can be compared with the second run. This last test was made under conditions of low outdoor temperature, and the fuel consumption under poorly insulated shed conditions was high for both fuels.

TABLE 13. DISTRIBUTION OF GRADES OF HAVANA SEED TOBACCO

Fuel	Percentage of grades								Grade Index
	L	M	LS	SS	LD	DS	F	B	
Charcoal	4	2	24	1	46	3	20		.363
Briquets	8	4	28	1	36	4	18	1	.410

In the second run, the consumption of charcoal per degree gain was 41.6 per cent higher than the consumption of Briquets, while in the third run it was 64.0 per cent higher than the Charkets. As it is apparent from other data that charcoal and Briquets are about equally efficient, the greater efficiency of Charkets is quite evident.

Sorting records of samples for the comparison between charcoal and Briquets are shown in Table 13. Here again the higher grade index of tobacco fired with Briquets is apparent.

Discussion

The results of tests conducted for two years to determine the merits of processed charcoals as compared with lump charcoal have indicated that Ford Briquets are not greatly different in efficiency from the unprocessed material, while Eastman Charkets have some advantage.

Measured in fuel consumed per degree gain over the entire period of 264 hours, lump charcoal was 0.4 per cent more efficient than Ford Briquets, and Eastman Charkets 12.1 per cent more efficient than charcoal. The Ford Briquets, due to their low porosity, could not be forced and consequently low temperature readings were more commonly found with this fuel than either of the others. Charcoal burned the most freely of the three fuels, to the extent that care had to be taken to avoid too high temperatures during the day. The temperature fluctuations with charcoal sometimes were as much as 5 degrees in an hour. Hence the average temperature maintained by charcoal tended to be made up of readings which deviated more widely from the mean than was the case with the other fuels.

The Eastman Charkets, possessing a greater density than charcoal, and yet sufficiently porous to permit free burning, usually maintained the most uniform temperature. It was also possible to keep the temperature more nearly at the desired level since a smaller volume of fuel was added at any one time, and the fires were not smothered by the large bulk of fresh material as was usually the case with charcoal. Regulation of the total volume of burning fuel in the pit was an effective means of regulating the temperature level.

Conclusive evidence was not obtained that any of the fuels had a consistent effect on the grading of the tobacco, if due weight was given to other factors.

The relative cost of the lump charcoal remains as its greatest attraction. In 1933, charcoal could be obtained for approximately $14 a ton in loose carload lots, freight paid, as compared with $28 for the processed fuels under like conditions. Such factors as reduced handling and haulage charges, lower loss by breakage and pulverization, and greater cleanliness, are in favor of the processed fuels. It is quite likely that the use of such fuels will be confined to the curing of shade tobacco, in which case the higher initial cost is not a prohibitive factor.

SHADE CURING EXPERIMENTS IN 1933

O. E. Street

The experiments on curing initiated in 1932 in the Gershel-Kaffenburgh Tobacco Company sheds were continued in 1933 on first picking tobacco. The object of these experiments was to determine the effect produced on tobacco by differences in:

a. Position of leaves in the curing shed
b. Time of picking in relation to rains
c. Type of soil
d. Humidification

Experimental procedure

The studies were conducted on first picking tobacco gathered from the field during a period from July 10 to July 14. In order to obtain a complete record, one sample lath, strung with colored string and tagged, was placed on every pole in 2 sheds. The tobacco for these samples was selected at random from the entire lot of tobacco being used to fill the shed. Each sample tag was marked with the tier, bent and pole, and record kept of the source of the tobacco and the time of picking. Both the shed fitted with humidifying equipment and a check shed were sampled in this fashion, and records of temperature and humidity obtained by means of hygrothermographs.

Filling of the humidified shed was commenced on July 10, and about one-third filled before night. A heavy rain during that night halted operations and filling was resumed and completed on July 12. Firing was started the same night and continued for 54 hours at an average temperature of 85° F. A very damp period of 40 hours necessitated a refiring of 37 hours at an average temperature of 86° F. The weather was very favorable for curing and the humidifying apparatus was not turned on until July 24, a period of 12 days from the start of the curing. During the balance of the curing period, 17 days, the equipment was in operation a total of 62 hours in 9 days. A relative humidity of above 80 per cent was maintained during most of the 62 hour total period by the use of the upper humidifying line alone.

The check shed was filled immediately after the humidified shed, on July 13 and 14. Firing was commenced the same evening and continued for 48 hours at an average temperature of 88° F. The tobacco cured quite rapidly, and as dry weather followed the firing period, a second firing was not needed.

The tobacco from both sheds was taken down August 22, placed in the bulk August 24 and remained in the bulk until October 14. The tobacco from the humidified shed reached a maximum temperature of 110° F., from the check shed a maximum of 112° F., with a final temperature of 107° F. in both bulks. The sample hands were sweated with their respective bulks, and separated out when the bulks were taken down.

All sample hands were examined and notes taken on colors and texture before sorting. The samples were grouped according to the factors to be studied, namely, vertical and horizontal position, time of picking and location by fields, and sorted into commercial grades.

Vertical position in shed

The effect of vertical position was studied in the tobacco from both sheds. The results in the humidified shed are shown in Table 14.

TABLE 14. SORTING RECORDS OF SHADE TOBACCO CURED IN A HUMIDIFIED SHED
a. EFFECT OF VERTICAL POSITION

Description	Percentage of Grades													Grade Index
	L	LL	LC	LC_2	YL	LV	LV_2	V	XL	XL_2	S1	S2	XX	
Picked before a rain														
Tier 9	0.7	18.6		29.1	12.6	8.6	4.0	8.6	2.6	2.0	10.6	1.3	1.3	2.056
8	4.7	6.1	23.5	19.7	9.4	1.4	8.4	11.3	2.3	2.3	9.4	0.5	1.0	2.106
7		7.6	13.8	15.8	11.8	2.1	10.3	18.6	6.2	4.1	4.8	2.8	2.1	1.796
6	0.8	7.3	22.8	16.7	13.1	6.5	10.2	10.5	2.0	3.2	4.1	2.4	0.4	2.083
5	3.5	6.9	27.1	16.8	10.3	4.2	6.4	6.9	3.1	0.4	11.8	1.5	1.1	2.159
4	3.3	14.9	15.3	18.2	12.7	3.6	4.4	13.8	4.7	0.7	6.9	0.4	1.1	2.207
3	3.5	9.2	17.1	20.2	14.0	5.3	7.9	10.1	1.8	2.2	4.8	3.5	0.4	2.055
2	5.4	6.3	18.3	12.9	12.5	9.6	12.5	14.2	1.7	2.1	3.7	0.4	0.4	2.218
Picked two days after a heavy rain														
Tier 8		10.1	11.6	11.6	4.4	5.8	10.1	31.9	2.9	1.4	2.9	4.4	2.9	1.867
7		3.2	22.5	5.7	3.5	12.4	15.2	27.6	4.4	1.3	1.9		2.2	2.019
6		4.4	7.9	6.4	3.0	10.8	25.6	36.0	2.2	2.2	0.3	0.5	0.7	1.844
5	0.7	4.0	9.4	8.0	4.5	14.9	18.4	32.1	2.9	2.1	1.2	0.2	1.6	1.917
4	0.2	3.2	8.9	6.7	2.7	10.1	20.9	37.3	2.4	2.0	1.7	1.7	2.2	1.764
3	2.6	11.5	8.9	16.1	6.1	13.1	14.0	17.4	2.6	1.3	4.8	0.9	0.7	1.961
2	4.0	13.3	11.5	11.2	4.7	13.8	19.1	12.4	2.0	2.4	3.3	1.8	0.5	2.340
1	1.3	4.5	6.3	6.0	3.6	19.9	25.9	25.4	3.6	1.2	0.9	0.9	0.5	2.027
b. EFFECT OF HORIZONTAL POSITION IN THE BOTTOM TIER														
Outside poles	1.2	2.4	12.8	12.1	5.4	15.8	19.4	23.7	4.8	0.6	0.6	0.6	0.6	2.006
Next to outside poles	0.6	6.9	4.0	4.0	1.7	23.2	30.7	21.4	2.3	1.7	1.2	1.7	0.6	2.091
Inside poles	2.0	4.1	3.7	3.3	3.7	20.4	26.9	29.4	3.7	1.2	0.8	0.4	0.4	1.977

*See Bull. 334, p. 178, for explanation of grade index. The comparative values for the different grades of shade tobacco in 1933 were as follows:

L	5.00	LV	3.00	ML	.50
LL	4.25	LV_2	1.75	S1	.70
LC	3.00	V	1.25	S2	.30
LC_2	1.75	XL	1.25	XX	.15
YL	1.25	XL_2	.75		

It will be seen that the results varied between the tobacco picked before and after a heavy rain. In the first case the poorest tobacco was found in the seventh tier, immediately above the plate line. This tobacco was directly underneath the upper line of atomizers and was considerably darker than any other comparable lot, as indicated by the high percentage of V's. The best grade index was found on the second tier. It may be noted that the percentage of light tobacco of high quality, LL's and LC's, tended to increase up to the sixth tier. The percentage of olive leaves of high quality, LV's and LV_2's, did not vary regularly with position. Spotted leaves of light color, LC_2's, and YL's, were most abundant in the peak tier, and stained leaves were also common here. The colors were generally very light, however, sometimes to the point of being pale yellow.

An entirely different picture is presented by the tobacco picked after the rain. In this case, the seventh tier was among the best in grade index, being exceeded only by the second and first tiers. The percentage of LL's and LC's in the seventh tier, and of L's, LL's, and LC's in the second tier, was the highest in the lot. It is apparent that these tiers had a balance between temperature and relative humidity that somewhat retarded the rapid cure of the thin nitrogen-loaded leaves picked after a rain, and this retardation tended to produce lighter colors. The high grade index of the bottom tier is due to the large percentage of leaves in the LV grade, exceeding any other tier by one-third, with the light grades of the LC type very low. In this lot the fourth and sixth tiers had the highest percentage of V's and the lowest grade indices.

The effect of vertical position in the check shed is indicated in Table 15. (p. 370). Here the tobacco is divided according to fields, with field I picked on Thursday and field 7 on Friday, both after the rain. In the tobacco from field I, the better grade indices are found on the fifth tier and below. The eighth tier is superior to both the seventh and sixth, and slightly better than the fourth, although this last difference is not significant. The second tier is again the best, and it is apparent that the moisture relations were more favorable below the plate line, which in this shed nearly coincided with fifth tier. Above this point, all the lots had more than 30 per cent of V's; below it less than 30 per cent of V's, with corresponding increases in the thinner and more valuable LV_2 and LV grades. This agrees rather well with the results on the comparable lot, (picked after the rain), in the humidified shed, where better grade indices were found in the positions having the greatest moisture supply. The percentage of LV's on the second tier, 27.1, is significant.

The effect of vertical position on the tobacco from field 7 is not apparent, as the entire lot of tobacco was rather poor.

Horizontal position

A further study on the tobacco in the humidified shed was the effect of the horizontal position in the bottom tier (Table 14). It is to be noted that the poles next to the outside wall of the shed presented radically different curing conditions from those nearer the center. This is evidenced by the higher percentages of LC's and LC_2's and the lower percentages of LV's and LV_2's. The agents in this difference were undoubtedly the lower temperature near the walls during firing periods, and perhaps the more

TABLE 15. SORTING RECORDS OF SHADE TOBACCO CURED IN A CHECK SHED
a. EFFECT OF VERTICAL POSITION

Treatment	Percentage of grades													Grade Index
	L	LL	LC	LC_2	YL	LV	LV_2	V	XL	XL_2	S1	S2	XX	
Field 1.														
Tier 8	4.3	7.3	2.0	2.3	1.5	13.9	20.5	35.3	3.1	1.2	3.5	3.1	2.0	1.939
7	0.8	1.6	3.9	5.5	0.8	15.7	26.4	32.6	1.8	3.6	4.9	0.8	1.6	1.760
6	0.4	1.4	6.0	3.5	2.1	14.1	25.4	34.5	1.4	5.6	3.2	1.4	1.0	1.733
5	2.9	5.3	6.0	7.4	0.7	19.3	27.8	21.4	2.9	0.7	3.2	2.1	0.3	2.092
4	3.2	2.2	5.0	6.9	2.6	14.1	28.5	29.6	1.1	2.9	2.5	1.4		1.906
3	2.0	4.1	8.2	6.2	2.0	20.5	24.6	21.5	4.1	0.7	2.7	2.0	1.4	2.051
2	4.5	3.1	3.8	5.6	1.4	27.1	21.2	21.5	3.1	2.1	3.1	2.8	0.7	2.125
Field 7.														
Tier 6		0.9	3.6	10.7	4.5	5.3	39.3	*20.5	4.5	5.3	4.5		0.9	1.560
5			5.2	2.6	3.5	13.0	44.4	*20.0	2.6	6.1	1.7		0.9	1.694
4		0.8	8.2	15.6	4.1	9.8	32.0	*21.3	3.3	1.7	2.4		0.8	1.437
3	0.9	1.4	1.8	0.9	0.5	14.8	34.1	*38.3	1.8	3.2	1.4		0.9	1.640
2		0.5	0.9	0.9		22.2	32.9	*33.3	3.5	3.5	0.5	0.5	1.3	1.684
1		1.9	4.6	7.0	6.5	12.5	17.9	*41.2	2.2	4.1	0.6	0.6	0.9	1.568
b. EFFECT OF TYPE OF SOIL														
Field 1	2.6	3.0	5.8	5.9	1.8	19.1	25.5	25.7	2.5	2.4	3.0	2.0	0.7	1.995
2	1.6	3.3	4.3	6.9	5.3	11.2	22.2	23.1	2.8	3.7	12.2	2.5	0.9	1.706
7	0.2	0.7	3.2	4.7	1.9	14.6	35.8	*29.1	3.0	3.8	1.8	0.1	1.0	1.663
c. EFFECT OF HUMIDIFICATION														
Humidified	2.2	7.4	13.5	12.8	7.1	10.3	15.1	20.8	2.8	1.8	4.0	1.2	1.0	2.057
Check	1.6	2.7	4.7	5.8	2.9	16.0	24.8	29.3	2.8	3.1	3.8	1.4	1.1	1.744
Humidified—Monday	3.2	8.4	20.0	17.2	12.0	4.9	8.4	11.8	3.0	2.0	6.7	1.5	0.9	2.115
Humidified—Wednesday	1.4	7.1	11.0	9.4	4.2	12.4	18.6	26.9	2.7	1.9	2.2	1.0	1.3	2.018
Check—Thursday	2.6	3.0	5.8	5.9	1.8	19.1	25.5	25.7	2.5	2.4	3.0	2.0	0.7	1.995
Check—Friday	0.2	0.7	3.2	4.7	1.9	14.6	35.8	*29.1	3.0	3.8	1.8	0.1	1.0	1.663

*40% of V's very dark, properly belong in ML's.

rapid moistening by natural means at other times. From the notes taken before sorting, similar conditions, but to a less marked degree, were found to prevail up to the sixth tier. It was noted that the tobacco on the poles next to the center of the shed was almost always more olive in color than that nearer the walls of the shed. It seems evident that the open space up through the center of the shed, varying from one to three feet in width, serves as a flue during the firing periods, while the walls are relatively cool.

Picking in relation to rains

The effect of picking before and after a rain may be seen from the summarized data in the last part of Table 15, under the entries "Humidified-Monday" and "Humidified-Wednesday." The entire humidified shed was filled with tobacco from a uniform field rather above the average in the quality of tobacco produced, the only variable between the two lots being a rain of about 1.25 inches which intervened between the pickings.

The tobacco picked before the rain had from 80 per cent to 180 per cent more of the light brown grades, except LL's, than that picked after the rain, and averaged 89 per cent more of all grades from L's to YL's. With respect to the olive grades LV's to V's, the tobacco picked after the rain averaged 130 per cent more. These lots varied in one other respect, the percentage of stained tobacco being greater in the tobacco picked before the rain. The difference in grade index was not great as the light olive grades are as valuable as the light brown grades. The most significant difference beside the marked one of darkness of color, was the more uniform color distribution on the tobacco picked after the rain and the relative absence of stained leaves.

Type of soil

A summary of the effect of soil and other environmental factors on the grade distribution is also shown in Table 15. The tobacco from these 3 lots was all cured in the check shed, with no one lot favored by position. Field I was characterized by favorable topography and good drainage, the soil being a sandy loam. Field 2 included some sandy knolls, and tended to be too light. The area of field 7 included in this comparison was characterized by a heavy soil with poor drainage, on which the growth was slow. The fields were picked in the order mentioned, only field 7 being picked on the second day of filling the shed.

Despite the fact that it was picked only three days after a rain, field 2 illustrates the characteristics of shade tobacco grown on light sand knolls. While light grades of high value are not abundant, the YL grade is nearly three times as abundant as in field 1, and the S1 grade over four times. The YL grade consists of leaves that have light spots or mottlings, while the S1's are leaves of light yellow color with reddish staining from the midrib and secondary veins. These symptoms are the same as is found in tobacco that has been underfertilized.

The tobacco from the low area in field 7, although it had one more day to recover from the effects of the rain, was still the darkest of all the lots studied. Included in the V's was a grade known as ML, a thin leaf but one almost or completely black. The prevalence of a grade as dark as ML's in the first picking indicates poor growth and an oversupply of unassimilated nitrogen in the leaf.

Humidification

The effect of humidification, summarized in Table 15, cannot be evaluated by comparing the entire sheds and disregarding the component factors that influenced the behavior of the tobacco. Neither can the tobacco picked Monday and placed in the humidified shed be used in the comparison, as it was dry-weather tobacco and all the other lots were picked after a rain, or the tobacco picked Friday from field 7 and placed in the check shed, as it was an inferior lot.

If the comparison is narrowed down to the tobacco picked on consecutive days, and placed in the two sheds, it will be seen that almost no difference in grade index is to be found between the humidified and the check lot. The curing season was naturally quite favorable, periods of high humidity being rather common during the first two weeks the tobacco was in the sheds. The fact that the tobacco below the plate line in the check shed was better than that above would indicate that moisture conditions were quite favorable for the main body of the shed. Considering the multiplicity of factors that enter into the final product, the graded tobacco, it does not seem possible to attribute any particular benefit to the humidifying system under the conditions of these experiments.

Summary

With references to vertical position, the better tobacco was usually found below the plate line of the shed. This was particularly true with tobacco picked after a heavy rain and was correlated with a more adequate moisture supply, which retarded the curing of the thin leaves and thus produced lighter leaves. The second tier from the bottom had the highest grade index in all cases. With dry-weather tobacco the same general trend was present but was less marked. Tobacco in the peak tier was often too yellow and mottled.

Horizontal position was significant in the bottom tier, and produced some difference up to the sixth tier. The tobacco nearest to the outside walls of the shed had a greater percentage of light brown grades, while that in the interior of the shed showed more olive leaves. This effect was due to the temperature differences during firing, the center of the shed acting as a flue.

The effect of time of picking in relation to rains was very clearly shown. Tobacco picked during a dry period was predominantly light brown in color, with some mottling and staining. Tobacco picked after a heavy rain was characterized by olive shades, but the distribution of color on the leaves was more uniform.

Soil type was shown to be very important. Tobacco from light sandy knolls had a "starved" appearance and was rather badly stained and mottled. Tobacco from heavy, water-logged soils was very dark and inferior.

Additional humidification by mechanical means failed to show any advantage during the past season.

THE PRESERVATIVE TREATMENT OF SHADE TENT POLES

HENRY W. HICOCK *

A considerable part of the cost of shade tents is for poles to support the wire and cloth. These poles should be light, reasonably strong, should hold staples well, be durable in contact with the soil and inexpensive. In the past, poles of native chestnut have admirably fulfilled all these requirements. Some poles of this formerly valuable species can still be obtained but most of them were killed by blight and have been dead many years and give poor results in service. Moreover, it will be only a few years before no native chestnut poles can be obtained. Of other native species, the heartwood of red cedar, black locust and white oak only are equal to chestnut in natural durability in contact with the soil. Red cedar and locust are not sufficiently abundant to satisfy all demands for posts and poles while white oak is satisfactory only if sawed to exclude sapwood.

In anticipation of the need in the near future of a substitute for chestnut, the Connecticut Agricultural Experiment Station, in 1928, began a series of experiments with the wood of several native species to determine whether any of them could be satisfactorily used in place of chestnut if given preservative treatment.

The Experiments

In June, 1928, forty seasoned poles[1] each of white pine, pitch pine, gray birch, red maple and popple were treated[2] as follows:

(1) Fifty poles (10 of each species) were given a full pressure treatment for their entire length by the American Creosoting Company in the same manner as for railroad cross ties[3]. A heavy impregnation of the sapwood throughout the post was secured by pressure treatment.

(2) The butts of 50 poles were given an Open Tank treatment with creosote[4]. In this process, the butts of the poles to a height 6 to 12 inches above the ground level are immersed in hot creosote maintained at a temperature of 220° F. for three hours. They are then kept for an equal length of time in cool creosote (not over 100° F.) and then transferred to an empty tank to drain (see Fig. 68). By this process the sapwood of the butt is wholly or partly impregnated for a distance equal to the depth of the liquid in the tanks. The tops of 25 of these poles (five of each species) were further treated by dipping for 10 minutes in hot creosote. The tops of the balance were left untreated.

(3a) Twenty-five poles (five of each species) were painted with a brush for their entire length with two coats of hot creosote[4] applied 24 hours apart.

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(1) Since these poles were to be used for experimental purposes only, the tops were cut off to facilitate handling.

(2) For a detailed discussion of preservative treatments see "The Preservation of Structural Timbers" by Howard F. Weiss, McGraw-Hill Book Co., 1915.

(3) The preservative used was a mixture of 70 per cent coal tar creosote and 30 per cent coal tar.

(4) See next page.

(3b) The butts only of 25 poles (five of each species) were brushed with two coats of hot creosote[4] applied 24 hours apart. The tops were left untreated.

(4) Thirty poles (six of each species) received no treatment.

(5) Twenty poles (four of each species) were treated by inserting two rings of "Treater Dust" (a highly poisonous arsenious compound produced in copper smelting) in the hole when the poles were set. The tops received no treatment.

FIGURE 68. Simple equipment for treating poles by the open tank method. Creosote in barrel on left is heated to 220° F. by charcoal fire in pit under end of 2 inch pipe return coil. Cold creosote bath in second barrel. Third barrel is for draining excess creosote. Tops of poles cut off in this experiment.

Immediately after treatment all posts were set to the usual depth for tent poles in a moderately heavy soil at the Tobacco Sub-station in Windsor.

Condition of poles after five years

Treatments

Full Pressure Treatment. All poles treated by this process were sound throughout after 5 years service. Unquestionably, pressure treatment will give the best results as far as length of service is concerned. However, either very expensive equipment must be installed or the timber taken to some central plant with consequent heavy transportation costs. Moreover, in pressure processes the tops and butts of poles received equal

(4) Coal Tar Creosote, grade 1, A. W. P. A.

treatment. This means that the tops are more heavily and consequently more expensively treated than is justifiable for a small pole.

Open Tank (hot and cold bath) Treatment. The butts of all but two poles treated by this method were sound after five years service in the soil. The equipment for open tank treatment can be assembled quite cheaply by anyone and is therefore well suited to the small user. The operation of the plant is quite simple. Native species which, untreated, are serviceable for only two years in the soil, have an estimated life of eight years or more after receiving open tank treatment.

Brush Treatment. Brush treatment is entirely superficial and little or no impregnation of the wood results. Dipping may be classed with brushing but is probably slightly more effective because the preservative flows into season checks and other openings which are impossible to reach with a brush. Brushing is the least expensive method of applying preservative. The butts of pitch pine poles treated by brushing were sound after five years in the soil. The butts of poles of all other species showed indications of interior rot at the end of three years and had become entirely unserviceable in five years. The process is not recommended for butt treatments if an impregnation method can be used. With most native species it will probably increase the natural life in the soil one to two years.

"Treater Dust." The butts of all poles set with this material in the hole were sound after five years service in the soil. While the cost of this material is quite low and while the results compare favorably with impregnation treatments after five years, this compound cannot be recommended on account of its extremely poisonous nature.

No Treatment. With the exception of pitch pine, the butts of all poles which were set untreated had become entirely unserviceable at the end of three years. The butts of untreated pitch pine poles were sound at the end of three years but had become unserviceable in five years.

Treated versus untreated tops. With few exceptions the untreated tops of popple, gray birch and red maple poles had become unserviceable at the end of five years. The untreated tops of white and pitch pine poles showed very little indication of decay after five years. The tops of all poles which had either an impregnation treatment (full pressure) or a superficial treatment by brushing or dipping were, with very few exceptions, sound and serviceable at the end of five years.

The above results indicate that the tops of poles need some kind of preservative treatment to maintain a balance of life between top and butt. Heavy impregnation of tops such as is secured by pressure treatment probably involves an unjustified expense. Moreover, pressure treated poles are likely to "bleed" in warm weather, especially if tar is used, and this may prove injurious to tobacco. A superficial treatment of tops by dipping or brushing and an open tank treatment of butts has maintained a satisfactory balance of life between top and butt for a period of five years. Poles treated superficially do not "bleed" unduly but whether or not even a small amount of "bleeding" will injure tobacco remains to be determined. If injury does result it may be necessary to treat tops with an inorganic salt solution instead of creosote.

Species

Of the five species for which five year service records are available, pitch pine seems to satisfy best the requirements for tobacco poles. The wood is naturally quite durable, is reasonably strong and tough and can be readily treated. Moreover, it is locally abundant in the tobacco region. White pine is not recommended because its wood is low in all strength properties and does not treat readily. Of the three broadleaved species, gray birch will probably not be used to any extent because it seldom grows large enough or straight enough for a tobacco pole. Popple and red maple should both make good tobacco poles with preference going to the latter because of its greater strength and toughness, its abundance and the fact that it can be treated more effectively.

An immense amount of small pole material of red and scotch pine, especially of the latter, will become available within the next 10 years as thinnings from forest plantations. The wood of these two species is intermediate between white pine and pitch pine in strength properties and can be treated with extreme ease. It was found that the several species of oak could be treated effectively with a relatively small quantity of preservative. Objection may be raised to oak for tobacco poles on account of its hardness and weight. The hardness of oak would render stapling somewhat difficult although it is believed that this would not be a serious drawback as workmen became accustomed to stapling in a hard wood. As far as weight is concerned it is believed that oak poles could be used in considerably smaller diameters than are at present specified for chestnut and still be sufficiently strong because oak is from 30 to 100 per cent stronger than chestnut in all requisite strength properties. For comparison of strength properties of various woods see Table 16.

Seasoning. All poles which are to be treated should be peeled and thoroughly seasoned. The procedure recommended is to cut and peel the poles in the spring when the bark is "slipping" and pile them "log cabin style" in the woods where they will season slowly without severe checking, and to treat them the following winter.

Conclusions

The results of experiments covering a period of five years demonstrate that poles of several native species will, if given preservative treatment, prove satisfactory substitutes for chestnut.

At the present time, pressure treated poles are not recommended because of the high cost and because the tops "bleed" in warm weather.

An impregnation treatment of butts with creosote by the open tank (hot and cold bath) process together with a superficial treatment of tops by dipping for a few minutes in hot creosote seems to result in a reasonable balance between life of butt and life of top.

Injury to tobacco from superficial treatment of pole tops with creosote remains to be tested. Should injury result, experiments with an inorganic salt as a substitute for creosote will be needed.

From the standpoint of physical properties, abundance, adaptability to treatment and demonstrated results, pitch pine and red maple seem to best fulfill the requirements for tobacco poles. However, from more recent experiments, for which there are at present no service records available, it would seem that the several species of oak and red and Scotch pine may also be sources of pole material.

TABLE 16. COMPARATIVE STRENGTH PROPERTIES OF WOOD

Species	Bending strength	Hardness
White or gray birch	90	108
Butternut	94	80
Aspen (popple)	97	76
Red cedar	98	162
Chestnut	100	100
Sassafras	104	120
Tulip	104	80
Pitch pine	118	112
Red pine	125	92
American elm	125	132
Red maple	137	158
Pin oak	141	222
Black oak	144	208
Red oak	146	206
White oak	150	216
Yellow birch	156	172
White ash	166	214
Scarlet oak	169	240
Black birch	172	208
Pignut hickory	212	
Black locust	232	322

These index figures are based on Table I, Technical Bulletin 158, U. S. D. A., converted on the basis of chestnut equal to 100.

TOBACCO INSECTS IN 1933

DONALD S. LACROIX

Prevalence of Various Species

The eastern field wireworm, *Pheletes ectypus* Say, was present in its usual abundance during the early part of the season.

The potato flea beetle, *Epitrix cucumeris* Harr., appeared in unusual abundance during June, but the increase in population during July was slow in reaching its peak. All types of tobacco were infested with this insect, Shade Grown and Havana Seed suffering more than Broadleaf.

A few specimens of the tobacco flea beetle, *Epitrix parvula* Fabr., were taken on Shade Grown tobacco in Windsor.

Tobacco horn worms, *Phlegethontius quinquemaculata* Haw., and *P. sexta* Johan., were more prevalent on sun grown tobacco this season than last. Injury from these was considerably greater in the Housatonic Valley district.

The tobacco thrips, *Frankliniella fusca* Hinds, caused a large amount of damage (Fig. 6) to Shade Grown and Havana Seed tobacco throughout the Connecticut Valley, but was not found on the Housatonic Valley tobacco.

Only two small infestations of the stalk borer, *Papaipema nitela* Guen., came to our attention.

The tarnished plant bug, *Lygus pratensis* Linn., caused but little trouble generally.

The tobacco budworm, *Heliothis virescens* Fabr., was found on but one plantation in Windsor.

Various species of grasshoppers were present in small numbers.

Aphids were very numerous on Havana Seed in the Housatonic Valley.

Tobacco Thrips*

Because of the unusually heavy infestation of this insect this season every effort was employed to find a satisfactory method of control.

TABLE 17. INSECTICIDES TESTED FOR TOBACCO THRIPS CONTROL

Insecticides	Number of Thrips on 10 leaves					
	July 7, 1933		July 14, 1933		July 21, 1933	
	Dead	Alive	Dead	Alive	Dead	Alive
Dusts						
Cubor dust	0	42	0	31	1	56
Nicotine (4%) dust	1	21	1	24	0	19
Activated Pyrethrum "A"	2	33	1	24	0	41
Activated Pyrethrum "C"	2	26	0	33	0	39
Rotenone dust	1	37	1	27	0	24
Check	0	59	0	42	0	67
Sprays						
Cubor spray (1–200)	29	12	13	6	21	18
Jap soap (1–100)	25	3	10	4	15	27
Nicotine sulfate and soap (1–400)	21	13	17	13	23	21
Nicotine sulfate and penetrol (1–400)	17	15	24	17	19	19
Pyrethrol (1–200)	26	11	29	14	31	11
Check	0	54	0	29	0	49

It became quite apparent that there was a correlation between moisture and thrips population. During hot dry seasons, the insect is quite serious, but during rainy seasons or even years having normal rainfall, little is seen of it. June, July and early August in 1933 were extremely dry, so that in many cases tobacco was irrigated. On the irrigated portions, thrips caused less injury than on those not irrigated.

The response of tobacco thrips to moisture was observed by spraying infested leaves (in the field) with water. The insects immediately began to run around nervously, and when one came in contact with a droplet of water, it would change its course and run in another direction. It was noticed during and after a rain, that the thrips were less numerous on tobacco foliage, and often were entirely absent.

**Frankliniella fusca* Hinds.

There seemed to be no correlation between temperature and thrips abundance. Several times during the summer, population counts were made on 10 marked leaves to determine this. Thrips damage as it appears on the cured leaf is shown in Fig. 69.

FIGURE 69: Thrips damage. White veins on a cured leaf due to thrips infestation during the growth of the plant.

Because many growers are equipped to apply insecticides as dusts, several dusting materials were tested. All dusts tried in 1933 were found to be ineffective, acting only mildly as repellents. This may be due to the fact that the tobacco foliage is covered with glandular hairs which catch the dust particles and hold them above the leaf surface, so that the thrips can run along depressions next to the midrib and major leaf veins without actually coming in contact with the dust. On the other hand, sprays containing pyrethrum, or nicotine sulphate gave much better results, as can be seen from Table 17. Dates of application were June 27 and July 6, 14 and 20.

The sprays and dusts were applied at weekly intervals throughout July, the latter at rates of from 8 to 12 pounds to the acre, depending upon the size of the plants.

None of the materials applied caused any injury to the leaf. However, it was observed that sprays of any kind applied when the weather was hot (and when the tobacco was badly wilted) did have a tendency to injure leaf tissue.

Flea Beetle Control

The use of barium fluosilicate dust for controlling the potato flea beetle on tobacco was continued this season. There was abundant opportunity to observe the effect of this material when used commercially. A tobacco by-product known as Richmond Filter dust proved to be a very satisfactory carrier for this insecticide, and left little or no visible residue.

Several observations on the plots dusted and sprayed for thrips showed that the pyrethrum dusts killed flea beetles, as also did the sprays, but the dusts were more effective for controlling them. This is possibly due to the fact that the sprays are of little value after they have evaporated and the dusts remain effective for some time after they are applied.

Wireworm Control

The past season's work in wireworm control, centered on three materials, namely; calcium cyanide, carbon disulfide emulsion, and chlor-picrin.

In preliminary tests, these materials were used side by side on the same plot. In later tests they were used on separate plantations. In the first mentioned, the calcium cyanide was placed in furrows 4 inches deep and immediately covered with soil, (used at a rate of 100 pounds per acre); the carbon disulfide emulsion was diluted 1 to 200 with water and applied in furrows 3 inches deep at the rate of 1 quart to 2 linear feet of furrow; the chlor-picrin was poured into holes 3 inches deep and 18 inches apart; 1 ounce of the liquid to each hole. All of these treatments were on infested tobacco soil, and each placed in infested rows of plants.

Three days later the soil was examined for a distance of three linear feet in each row. In the case of the cyanide plot, dead worms were found on both sides within six inches of the center of the row; on the carbon disulfide emulsion plot, a few living worms were found, and no dead ones; on the chlor-picrin plot many dead larvae were found within a seven inch radius of each hole treated and no living ones. The weather was hot during these tests.

On another plantation, 1 acre of infested tobacco soil was treated with 100 pounds of calcium cyanide applied with a corn planter directly to each row of young tobacco plants and at a depth of from 2½ to 3½ inches. (Seventy-five per cent of the larvae were in the top 3 inches of soil at that time). Four days later, an examination of the soil indicated approximately a 66 per cent kill. The weather during these operations was cold and there were intermittent rains. Had the soil been warmer, the percentage of kill undoubtedly would have been greater.

Thus far, calcium cyanide drilled into the infested rows, has proved to be the most economical method of wireworm control. This is substantiated further by tests conducted by Anderson and Britton in 1925.

Many experiments with chlor-picrin were carried on during the summer of 1933. This material is a heavy, clear liquid, very volatile, non-explosive and terribly pungent. It is extremely toxic to insects, but not so toxic to man, as the fumes drive persons to search for fresh air.

After many trials, it was found that this material could be emulsified with fish-oil soap, diluted with water and applied to the soil in any desired quantity.

In actual tests for toxicity, five wireworms were placed in containers (the latter being salve-boxes covered with 50 mesh screen). These were buried (on edge) at 3-, 6-, 9-, 12-inch levels in the field*, 1 row being treated and the other left for a check. The chlor-picrin emulsion was poured into a 3-inch furrow and covered with soil. Examinations were made 48 hours after application. Treatments started with 100 milliliters of the emulsion to 5 liters of water down to 12 milliliters to 5 liters of water with the material applied at the rate of 1 liter per linear foot of row. One hundred per cent kill was observed in every case except the last (12 milliliters chlor-picrin emulsion to 5 liters of water). It did not penetrate to the 12-inch level, as the larvae were alive there.

Several tests on tolerance of tobacco plants to chlor-picrin showed that the material is extremely toxic to young plants even at the greatest dilutions mentioned above. Plants may be set in the field seven days after the chlor-picrin has been applied full strength, and about five days after it has been used at the weaker dilutions, but do not seem to grow as fast as tobacco planted in untreated soil.

Since the fumes from chlor-picrin are so irritating to the eyes and nose, it is absolutely necessary to use a gas mask when handling it.

Distribution of Wireworm Larvae in Tobacco Soil

During the season of 1932, soil on an infested plantation was examined at intervals, to determine the distribution of wireworm larvae at different times of the year and to observe any other activities of this pest.

Similar observations were made during 1933 and the results are included in Table 18. As was true in 1932, the larvae were concentrated in greater number in the tobacco rows. Continued feeding throughout the summer was noticed also this year. Most of the larvae remain below the 3-inch level except during a short period at about the end of May, when a large percentage of them are near the surface.

*Merrimac coarse sandy loam.

TABLE 18. DISTRIBUTION OF WIREWORM LARVAE IN SOIL OF TOBACCO PLANTATION, WINDSOR, CONN. SEASON OF 1933

		Number of larvae in soil						Soil Temperature	
Date	Depth	In row		Between rows		Total	Per cent	°F	Remarks
May 29	0″– 3″	7		4		11	64.7	77	
	3″– 6″	4		1		5	29.4	70	
	6″– 9″	1		0		1	5.8	66	
	9″–12″	0		0		0	0.0	66	
	12″–24″	0		0		0	0.0	66	
		12	70.5%	5	29.5%	17			
June 27	0″– 3″	0		2		2	4.4	78	
	3″– 6″	4		3		7	16.2	72	
	6″– 9″	15		8		23	53.4	71	
	9″–12″	5		3		8	18.3	68	
	12″–24″	3		0		3	6.9	68	
		27	62.7%	16	37.3%	43			
July 10	0″– 3″	0		1		1	5.0	64	Plantation irrigated 24 hrs. previous to these investigations
	3″– 6″	5		1		6	30.0	68	
	6″– 9″	7		3		10	50.0	68	
	9″–12″	2		1		3	15.0	68	
	12″–24″	0		0		0	0.0	68	
		14	70%	6	30%	20			
July 29	0″– 3″	0		0		0	0.0	68	First 4 inches soil extremely dry
	3″– 6″	1		0		1	4.0	68	
	6″– 9″	7 (1 Pupa)		1		8	32.0	68	
	9″–12″	7		1 (Pupa)		8	32.0	68	
	12″–24″	8		0		8	32.0	68	
		23	92%	2	8%	25			
Aug. 25	0″– 3″	1		0		1	3.2	70	
	3″– 6″	1		1		2	6.4	69	
	6″– 9″	9 (1 Pupa)		1		10	32.2	69	
	9″–12″	5		6		11	35.4	69	
	12″–24″	4		3		7	22.5	69	
		20	64.5%	11	35.5%	31			
Sept. 30	0″– 3″	1		0		1	4.0	54	
	3″– 6″	2		2		4	16.0	58	
	6″– 9″	2		3		5	20.0	60	
	9″–12″	7 (1 Adult)		3		10	40.0	66	
	12″–24″	5		0		5	20.0	66	
		17	68%	8	32%	25			
Oct. 28	0″– 3″	0		0		0	0.0	48	Cold rain for 12 hrs. just previous to these investigations
	3″– 6″	0		2		2	11.1	46	
	6″– 9″	3 (1 Adult)		0		3	16.6	46	
	9″–12″	6		2		8	44.4	46	
	12″–24″	3		2		5	27.7	46	
		12	66%	6	33%	18			