Frontiers

of PLANT SCIENCE

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A Connecticut orchardist poses with plant pest control equipment in the spring of 1905 . . . see page 4.

THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION

NEW HAVEN

A. E. Dimond, chief of the Department of Plant Pathology and Botany at the Station since 1950. Counterclockwise, his predecessors and their terms as chief of the department. The following article is by Dr. Dimond.

75 YEARS

of Productive Research in Plant Pathology and Botany

Scab lesions on this potato show the monogram of Roland Thaxter as he etched it on the growing tuber with the causal organism more than 70 years ago.

James G. Horsfall, 1939-1950

THE DEPARTMENT of Plant Pathology and Botany at the Station is now 75 years old. It is appropriate to evaluate accomplishments of the past and assess the prospect ahead. When this department was established, plant pathology and experimental botany were in their infancy. A little more than a century ago the Irish famine was caused by a plant disease, but at the time the cause was unknown. A little more than 75 years ago the first effective fungicide was discovered quite accidentally in a French vineyard. The life span of this department is only slightly shorter than that of the germ theory of disease. Much of what is known about plant diseases today has been discovered within the 75-year history of this department.

To observe the 75th anniversary, a two-day program of symposia was held at the Station on May 7 and 8. These symposia were made possible by income from the Lockwood Trust, an endowment of the Station. They were attended by distinguished scientists from Argentina, Australia, England, Canada, Japan, the Netherlands, and the United States. The symposia dealt with historical aspects of plant pathology and with subjects of current intensive investigation.

The discussion on 75 years of Plant Pathology followed a banquet on May 7 with E. M. Stoddard as toastmaster. Dr. G. L. McNew of the Boyce Thompson Institute for Plant Research, Yonkers, N. Y., dealt with the changing concept of plant pathology over the past 75 years, and Dr. J. G. Horsfall, Director of the Station, presented a vignette of Dr. Roland Thaxter, first mycologist of the Station and head of the department from 1888 to 1891.

The beginning of the department was modest. In 1887 Congress passed the Hatch Act, which made money available to the states for agricultural research. This act was influential in the founding of many state experiment stations. This Station had been established 12 years

Ernest M. Stoddard, 1937-1939

George P. Clinton, 1902-1937

William C. Sturgis, 1891-1902

Roland Thaxter, 1888-1891

earlier, and Director Samuel W. Johnson, after due reflection on the matter, decided to use Hatch Act funds to equip and staff a biological laboratory. Thus in 1888, Dr. Roland Thaxter was appointed mycologist and set out to determine the important diseases attacking crops of Connecticut and the best methods of controlling them.

In the 3 years that Dr. Thaxter was at the Station, he established an enviable reputation for significant work, both in finding new information and in advising growers about their problems. He studied the diseases then attacking onions grown in the Westport and Wethersfield areas, and his publication on this subject is still a classic of its type. He determined the cause of potato scab and described the responsible organism for the first time. One of the potatoes that he used to prove that *Actinomyces scabies* is the cause (he named it *Oomyces scabies*) is still preserved in the department and bears his monogram in the form of scab lesions (see photograph on page 2). Downy mildew of lima bean was discovered here and the fungus named by Thaxter.

Thaxter also made significant contributions to methods of controlling plant disease. Bordeaux mixture, the first fungicide to be used as a protective spray against plant disease, had in 1885 been reported by Millardet in France, but its usefulness had not been fully explored. Thaxter himself constructed a sprayer from a copper washboiler and tested the value of Bordeaux for control of disease on crops in the State, starting in 1888. He was also the first to use a fungicide in the soil to control disease in plants, and his studies using sulfur for this purpose were an early and significant step in the development of modern soil fungicides.

Thaxter established a pattern of significant work that has been an inspiration to his successors. Though he returned to Harvard in 1891 to work on the description of obscure fungi, he conscientiously applied himself to practical problems while at the Station.

Thus Thaxter established the dual activity pattern which the department has followed ever since. Only by discovering new principles can scientists continue to serve mankind effectively. But as Thaxter did, an investigator must reduce his knowledge to a practice that others can use, and he must give this information to all who ask.

Dr. William Sturgis succeeded Thaxter and was head of the department from 1891 to 1902. When he resigned he had brought together a considerable body of knowledge about plant diseases and their control, about tobacco culture under cloth and the design of curing barns. Sturgis published spray calendars, and started to bring together what later became the Plant Pest Handbook. He gathered together the knowledge that was needed to serve the grower effectively at a time when communication was difficult and knowledge about the causes of disease was expanding rapidly.

A homemade sprayer used by Thaxter in 1888. The tank is a small copper washboiler.

His successor, Dr. G. P. Clinton, continued gathering this knowledge. A systematic worker, he carefully recorded the outbreaks of disease in the State and their severity. He expanded the activities of the department; one of his first new staff members was E. M. Stoddard, who has been with us since 1909. Until Clinton retired in 1937, he worked steadily to determine the cause of new diseases, and was as much respected by fellow scientists as by growers. He was influential in organizing growers associations to facilitate exchange of practical scientific information. Clinton, like Thaxter before him and Dr. Horsfall afterwards, was elected to the National Academy of Sciences for his significant contributions to plant pathology, especially for his studies on the smut fungi. Membership in the Academy is the highest honor a scientist in the United States can receive from his fellow scientists.

Marking 75 years of research in plant pathology and botany at the Station, scientists from this country, Canada, and abroad met in New Haven on May 7 and 8. Speakers and chairmen, from left to right, were Seymour S. Block, Gainesville; B. J. Samborski, Winnipeg; Ernest Sondheimer, Syracuse; E. M. Stoddard, New Haven; J. M. Daly, Lincoln; R. J. Lukens, New Haven; J. W. Mitchell, Beltsville; M. L. Zucker, New Haven; H. D. Sisler, College Park; David Davis, New York City; S. E. A. McCallan, Yonkers; Saul Rich, New Haven; G. L. McNew, Yonkers; Alfred S. Sussman, Ann Arbor; D. R. Whitaker, Ottawa; E. Y. Spencer, London, Ontario; L. V. Edgington, New Haven; Joseph Kuć, Lafayette; E. B. Cowling, Yale; J. G. Horsfall, New Haven; L. P. Miller, Yonkers; R. J. W. Byrde, Bristol, England; R. G. Owens, Yonkers; M. A. Stahmann, Madison, Wisconsin; Ikuzo Uritani, Japan; A. E. Dimond, New Haven. Fifteen former members of the staff in Plant Pathology and Botany attended the meeting.

Thaxter, Sturgis, and Clinton together headed the department for the half century when plant pathology was essentially a descriptive science. During those years, many new diseases and their causes were recognized, and control methods were systematically developed. The reputations of these men reflect their skill in identifying the fungi responsible for plant disease and in learning about the stages through which the fungi must pass in order to produce disease. Their most essential piece of laboratory equipment was the microscope.

On Clinton's retirement in 1937, E.M. Stoddard became the acting head. Both botany and plant pathology were in a stage of transition to experimental sciences. Stoddard showed his bent for adapting to the changing times by discovering a new virus disease of peach, the X disease, and, after describing it and working out a control measure that was effective, began some experimental studies with the virus, in the hope of inactivating it in the tree. These studies led, in the 1940's, to the inactivation of the virus by sulfanilamide.

The Botanical Laboratory of the Station about 1905.

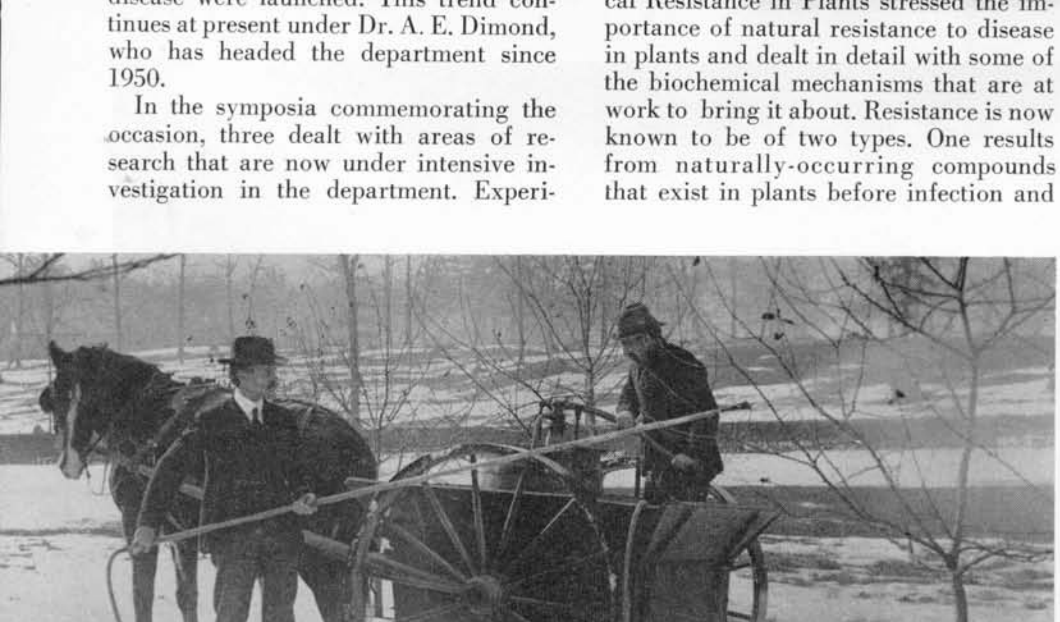
Fungicide Studies Begun

With the arrival of Dr. James G. Horsfall as head of the department in 1939, the emphasis in the investigational work of the department shifted to experimentation. Studies on fungicides were begun at once. Within a few months of his arrival, studies on chemotherapy of elm disease were launched. This trend continues at present under Dr. A. E. Dimond, who has headed the department since 1950.

In the symposia commemorating the occasion, three dealt with areas of research that are now under intensive investigation in the department. Experimental work on plant diseases thrives on an exchange of ideas. Good ideas in science frequently come from discussion and even argument, from people putting their heads together at the right time and in the right environment. Symposia have proven their value in stimulating thought and investigation.

In keeping with this principle, the symposia dealt with Natural Biochemical Resistance to Disease in Plants, Plant Chemotherapy, and Fungicidal Action.

The symposium on Natural Biochemical Resistance in Plants stressed the importance of natural resistance to disease in plants and dealt in detail with some of the biochemical mechanisms that are at work to bring it about. Resistance is now known to be of two types. One results from naturally-occurring compounds that exist in plants before infection and serve to exclude disease-producing organisms. A second type of mechanism is based on biochemical systems that go to work rapidly when a plant is invaded and cause infection to be abortive. As more is learned about the latter type of mechanism, investigators are finding that phenolic compounds and phenol-producing systems play an important role in these reactions. In these days of emphasis on biochemistry, avoiding the use of pesticides where possible, the topics and discussion in this symposium were most timely.



Once the lime-sulfur pesticide was concocted (see cover photo) orchardists had no easy way to get it onto the trees to control diseases and insects.

Plants May Be Made Resistant

The symposium on Plant Chemotherapy dealt with a subject long under investigation in the department, a subject closely related to the mechanisms of biochemical resistance to disease. Experience in chemotherapy has shown that a susceptible plant can be converted into a resistant one by introducing appropriate compounds. These may act directly to exclude a disease-producing germ or indirectly by altering the makeup of the plant so that it becomes resistant. Thus, by supplying the necessary starting materials for disease resistance, one may produce plants that resist disease by the same mechanisms that occur naturally in other plants.

The symposium on Fungicidal Action also dealt with a subject long under investigation in the department. Fungicides generally have had a longer useful life than many antibiotics and insecticides. In medicine and in agriculture, bacteria and insects soon develop resistance to a toxic agent, but fungi have not developed resistance to fungicides in practical situations. When a toxic agent is highly specific in its action, an organism may develop resistance to the agent by finding an alternate pathway around the stage

Science at Work

1963 Field Meeting

Wednesday, August 14

Lockwood Farm Mt. Carmel

of metabolism that is blocked by the toxic agent. But when a toxic agent acts on several metabolic pathways simultaneously, the organism has little opportunity to develop resistance. This is one reason why studies on mode of action of fungicides are important. When fungicides with specific modes of action are developed, fungi resistant to them are likely to develop.

Studies on the relation of chemical structure to biological activity are equally important. When one finds an active molecular grouping, he can frequently improve its activity by modifying the neighboring groups somewhat. Gradually, scientists are learning the effect of a modification upon activity and upon the side-effects that often accompany fungicidal action. A special phase of this matter is related to the necessity for a fungicide to enter fungal cells readily. This can be encouraged by attaching to the fungicidal molecule groups that give it the right balance between fat and water solubility.

With the closing of the symposia, the department begins its second 75 years of activity. We are impressed with the tradition behind us and with the magnitude of the task ahead. May we be as productive as our predecessors have been!

Landmarks . . . Department of Plant Pathology and Botany

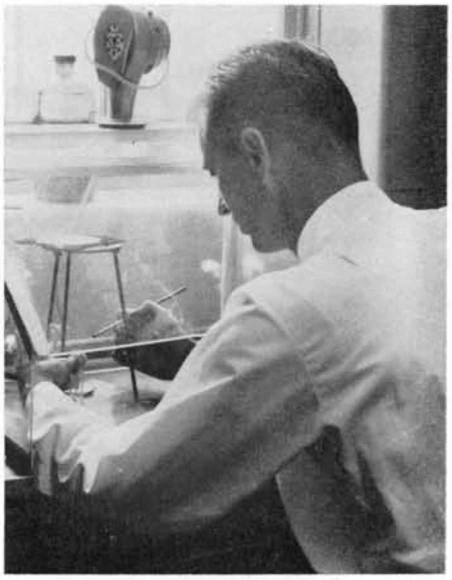
1889	Studies on Bordeaux mixture
1889	Cause of downy mildew of lima bean described
1889	Sulfur used as the first soil fungicide
1891	Cause of potato scab described
1910	Oospores of *Phytophthora infestans* found
1933	X disease of peach described
1940	Research on plant chemotherapy begun
1943	Ethylene bisdithiocarbamate fungicides reported
1943	Action of chelating fungicides reported and explained
1945	Publication of "Fungicides and Their Action"
1947	Research on antisporulants begun
1952	Studies on wilt pathogenesis begun
1952	Evaluation methods for plant chemotherapy
1955	Publication of "Principles of Fungicidal Action"
1959-60	Publication of "Plant Pathology, an Advanced Treatise"
1960	Use of antiozonants reported to control ozone injury

The Cover Photo

In 1905, when fruit growers were of necessity their own manufacturing chemists, Josiah Merriman of Southington posed with his portable steam boiler and other apparatus for preparing lime-sulfur, one of the few effective orchard pesticides known to his generation. That era is long gone. Farmers are no longer manufacturing chemists. They rely on industry for the products industry can best produce. And they rely on scientists for the kinds of new knowledge that science can best discover. Among these scientists are the plant pathologists at the Experiment Station, who this year mark their 75th anniversary. The spiral test plots at Lockwood Farm in Mt. Carmel, shown at the left, are tools of science used by these plant pathologists to give growers safe and effective ways to protect crops, without steam boilers in the fields.

A Natural Control of Wireworms

James B. Kring



Dr. Kring inoculates a culture medium with "a bacterium armed with a chemical insecticide."

THE COMPLEX interrelationships between the animals and plants that inhabit the soil and their environment are the workings of an almost unknown world.

Primitive man may have looked at the soil and wondered at it. The scientist today does the same, but with far greater wonder, for his knowledge of the infinitesimal reveals vast areas of ignorance the primitive man could not comprehend.

The story I have to tell of the soil and its inhabitants concerns wireworms and a bacterium. Wireworms are the shiny, tough-skinned larvae of the click beetles or snap-jacks. The bacterium is one of the myriad of organisms that speed the incorporation of plant material into the soil.

Wireworm larvae feed on the roots and underground parts of plants and even on other animals in the soil. In Connecticut fields, wireworms may kill tobacco transplants and corn seedlings or riddle both seed potatoes and new potatoes.

Tobacco and potato growers have observed that when a vigorous cover crop of winter rye is plowed under in the spring there is little trouble with wireworms. On the other hand, when a winter-hardy cover crop is not used or the land is left idle, wireworms are often a problem.

Two explanations have been advanced for this cover-crop protection from wireworm ravages. First, it was suggested that the spring feeding of the wireworms was completed on the green rye plowed into the soil. Second, it was proposed that the wireworms found such an abundance of food that they did not concentrate on newly planted crops.

A wireworm killed by one of the bacteria that breaks down organic matter in the soil.

These explanations were not completely satisfactory. Giving wireworms an abundant diet of rye might be expected to bring more trouble in the late summer and fall, and in succeeding years.

I examined rye plants after they had been plowed into the soil and found that the wireworms were indeed feeding on the roots and leaves and tunnelling into the buried stems.

When the same plants were examined in the soil 2 weeks later, however, they were slimy and had begun to decay. The wireworms were swollen and distended.

In the laboratory when the food of the wireworms is allowed to decompose to this stage, wireworms also die. Here, too, their bodies are distended. High mortality of the wireworms may be the reason why the field problem fails to intensify when cover crops are plowed under.

Sometimes when the wireworms were removed from the decaying plant material to a new environment they recovered. This indicated that the toxic effect of the decaying vegetation might be a gas or chemical rather than a disease organism. However, when the wireworms were caged with decaying plants, but were prevented from reaching them, the odor was terrific but the wireworms survived.

I found that oxygen depletion by the decay organisms was not the explanation for wireworm mortality. Examination of the blood and the internal organs of the infected larvae gave no indication of disease activity. However, when we placed an affected larva on the surface of a culture plate of potato dextrose agar, an almost pure culture of bacterium developed. Yet, healthy larvae placed on these same plates wallowed through the colonies, nipped at the dead larvae, and survived.

As so often is true, we had all the pieces of a jigsaw puzzle; the problem was to fit them together.

In reading about plant diseases I was reminded of two things. We know that different culture media often select or favor the development of different species of bacteria, and that bacteria growing on different culture media produce different chemicals in the media.

Possibly I had selected, by using potato dextrose agar, an associated but unimportant bacterium. Or perhaps the bacterium growing on the potato dextrose agar did not produce the chemical that was toxic to the wireworm.

Several kinds of media were inoculated with the bacterium, and healthy wireworms were placed in these dishes after the bacterium had begun to grow. On potato dextrose agar plates the wireworms, as before, lived; on brain-heart-infusion agar plates, and several others, they died.

The results were proved and confirmed. The bacterium was isolated again and again from laboratory cultures where wireworms had died.

As before, larvae removed in time from active colonies of the bacterium revived. So it could be expected that wireworms could escape from the toxin in the field. A heavy rye cover crop provides an abundance of food for the bacterium and less chance for escape of the wireworms.

In these days when biological control has great allure, it is interesting to speculate on the usefulness of this knowledge.

The bacterium in this case is *Pseudomonas fluorescens* Migula, as identified by Miss Elizabeth Murphy and Miss Ann Sedgwick of the Connecticut State Department of Health. This bacterium is generally considered non-pathogenic to animals, but inoculated into rabbits it is reported to produce a localized abscess. It is closely related to *Pseudomonas aeruginosa* (Schroeter) which is slightly pathogenic to rabbits, guinea pigs, rats and mice, and possibly man.

Getting Apple Trees Off To a Good Start

Patrick M. Miller

SEVERAL DANGERS face a newly planted tree or shrub. Consider for a moment the plight of a small apple tree yanked from a moist home in a nursery, and planted in a strange soil full of lurking nematodes or root-rot fungi. Then the young tree has to fight with weeds for water and nutrients and to search for water if a drought occurs.

Tests have shown that helping the young apple tree to overcome some of these troubles gives bigger trees. Placing a small amount of fungicide and nematicide around the tree at planting time takes a little extra time but helps reduce injury by fungi and nematodes for a few weeks. The roots can grow in peace. A mulch above ground reduces weed growth and water loss; thus the tree has more food and moisture. Does the tree like this pampering?

Some of the 20 McIntosh apple trees planted in 1960 certainly did. Ten of these trees had a fungicide, pentachloronitrobenzene (PCNB for short), and a nematicide, dibromochloropropane (DBCP), mixed with soil around the roots at planting time to control root-rot fungi and nematodes. Then the soil surface around five of these trees and five untreated trees was covered with 3-foot squares of plastic mulch. Five trees were left to fend for themselves. The mulch remained around the trees for 3 years, but no further soil treatment with PCNB-DBCP was made.

That apple trees liked the coddling at planting time was evident when the trees given both the PCNB-DBCP soil treatment and plastic mulch put out twice as many new shoots and roots as the trees without any treatment. Trees helped with just the pesticides or mulch grew about 40 per cent more shoots and roots than the untreated trees. Controlling soil pests at planting time, and mulching, produced bigger and better apple trees.

The question arises as to the necessity of using a fungicide, a nematicide, and the mulch. When you plant a tree, root-rot fungi, such as *Rhizoctonia solani*, may cause injury in one location, nematodes in another. Other areas may have both fungi and nematodes or neither. Thus the fungicide-nematicide combination will not always increase growth because there may be no pests to control, but it has given extra growth when used with a plastic mulch where the moist soil favors fungi.

At about 3 cents a tree for the PCNB-DBCP, the cost of treatment is trivial. Use of plastic mulch has consistently increased growth of apple trees. The plastic increased growth more than a straw mulch. Combined with the soil treatment of PCNB-DBCP, plastic mulch produced bigger and sturdier apple trees.

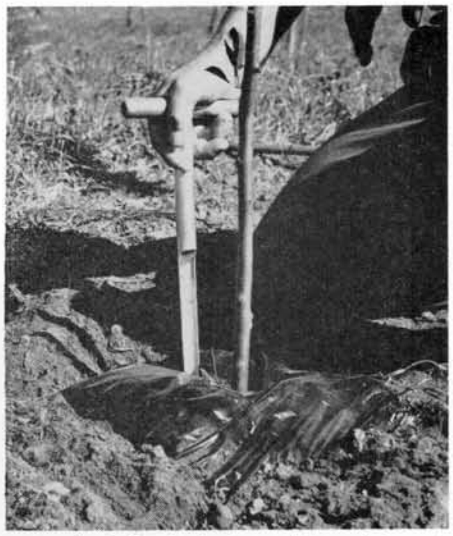
Can this mulch and soil treatment combination be used to increase growth of other plants such as nursery stock? Apparently so. Most plants suffer from attack by root pests and drought just as fruit trees do. Many of them would grow better if protected from these enemies at planting time. Workers in greenhouses and nurseries found long ago that preventing injury to transplanted seedlings and cuttings gave better plants. Can preventing injury to larger plants such as trees and shrubs be less important? Use of safe fungicides and nematicides should increase growth of most plants. The usefulness of a particular combination of PCNB-DBCP may be limited — it has reduced growth of yews and andromeda — but other soil treatments that will control fungi and nematodes without injury to sensitive plants should be available in the near future.

Plastic mulch increased growth of andromeda over the first season, doubled the number of flower buds, and produced greener leaves on both andromeda and yews. Plastic mulch also has increased survival of roses planted with partially dried roots and increased the survival of young maples during a severe winter. Thus plastic mulch can increase survival and growth of young plants in many situations.

The PCNB-DBCP soil treatment and plastic mulch affected the soil microflora as well as the plant. Not all of the changes were expected or favorable. Plastic mulch increased the growth of the root-rot fungi and of other microorganisms in the soil which prey on injurious nematodes. Thus meadow nematodes were reduced three-fourths by late summer under black plastic mulch. At the same time that PCNB was reducing the amount of *R. solani* on the apple roots, it also reduced growth of those predatory microorganisms controlling the nematodes, and meadow nematodes became far more numerous wherever PCNB was used. There was no reduction in nematodes by black plastic mulch if PCNB was used.

In another test in 1961, meadow nematode populations were more numerous in unmulched soil following use of DBCP or PCNB in 1960, but no increase occurred in soil treated with these pesticides and covered with plastic mulch. Black plastic mulch has many effects on both the microflora and the roots.

In all tests so far with apple trees the benefits have far outweighed the disadvantages, and the trees have prospered. Several thousand fruit trees in Connecticut have been treated with some or all of these materials in the past few years. With other plants, combinations of fungicide or nematicide different from those used for apple trees may have to be employed to avoid injury.



A patch of black plastic mulch, and 3 cents worth of materials that kill nematodes and fungi, help transplanted apple trees take hold in their new location.

A Natural Control

(continued)

Although this bacterium is already widely distributed, its possible toxic effects on man and animals call for careful investigation before it is used as a manipulated biological control. We do know that this bacterium has an active role in the natural decay or destruction of organic matter in the soil, and as a side effect reduces the numbers of one of the competitors for our food.

Here, it seems, is a bacterium armed with a chemical insecticide. Commercial agriculture provides the arena wherein the susceptible animal meets the bacterial toxin.

This research revealed no cure-all remedy for wireworm depredation. Rather, we now have more answers and more questions.

This is a normal consequence of research, and in the process we profit from new knowledge and discover new wonders to challenge our imagination.

From the Director

WE ARE PROUD TO RECORD in this issue of *Frontiers* the diamond anniversary of Plant Pathology and Botany, second oldest department of this Station.

The first department was Analytical Chemistry. It established the worth of a scientific laboratory devoted to the commonweal. The major function of Analytical Chemistry was and is to apply the precise methods of chemistry to assure the quality of certain commodities offered for sale in Connecticut.

The Department of Plant Pathology and Botany, first called Mycology, was established to learn new facts as well as to give citizens immediate answers. New facts help people do what they could not do before.

Plant Pathology was the first of the Station departments to have scientific research as its major objective. Results came fast. For example, the onion smut disease had plagued growers for generations. Roland Thaxter, the first plant pathologist at the Station, showed that this disease is caused by a fungus, and that sulfur applied to the soil controls the disease.

The new knowledge discovered by Thaxter enabled the onion grower to do something he could not do before. And it established an entirely new principle in plant disease control—soil treatment. From this work stems the scientific treatment of soil today for such maladies as club root of cabbage, Japanese beetle grubs in the lawn, and other pests of plants.

In ways like this are the discoveries of science extended. Thaxter, who struggled in the face of skepticism to introduce the concept of basic research into the work of the Station, was aided and abetted by Director Samuel W. Johnson. Their idea was extremely difficult to sell 75 years ago.

By committing the Station to basic research, Thaxter helped to lay the groundwork for imaginative inquiry that led to our discovery of the significance of amino acids in the diet, the co-discovery of vitamins, the invention of hybrid corn, and other contributions to science.

But science, by its very nature, often outruns public acceptance. Though Thaxter began his work here in 1888, some are only now becoming aware of its significance. The story of Thaxter bears retelling, for with maturity of institutions, as of men, comes a sense of perspective.

So it was fitting that the symposium marking the 75th anniversary of Plant Pathology at this Station brought together scientists from North America and from several countries abroad. They met here to pay respect to Thaxter and his ideals, to compare their findings with those of their fellow scientists, and to renew the personal ties that speed the flow of new knowledge.

James G. Horsfall

New Publications

Ecology and Forestry

B 653 Three Decades of Change in an Unmanaged Connecticut Woodland, Stephen Collins.

B 656 Plants, Shade, and Shelter, Paul E. Waggoner.

Entomology

B 655 The Gypsy Moth Problem, Neely Turner.

Dr. Zelitch Promoted

Dr. Israel Zelitch will become head of the Department of Biochemistry at the Station on July 1 when Dr. Hubert Bradford Vickery retires.

Dr. Zelitch became a member of the Station staff in 1952, after a year as postdoctoral fellow of the National Research Council, at the College of Medicine, New York University. He is a graduate of the Pennsylvania State University and received his doctorate at the University of Wisconsin in 1951.

In 1960 Dr. Zelitch spent 6 months at Oxford University where he studied respiration and photosynthesis and the enzyme systems that support these processes in leaves. His study in Great Britain in the laboratory of the renowned biochemist Sir Hans A. Krebs was made possible by a fellowship awarded by the Guggenheim Foundation.

Dr. Zelitch has made significant advances in knowledge of enzymes concerned with respiration in plants, and the biochemical control of stomata in leaves.

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BRUCE B. MINER, Editor