Frontiers

of PLANT SCIENCE

FALL ISSUE

1961

A SPECIAL ISSUE: *The Role of the Station Today*

Autumnal abundance, an end-product of research on plants . . . see page 9.

THE CONNECTICUT

AGRICULTURAL EXPERIMENT STATION

NEW HAVEN

GENETICISTS

Fashion Better Plants For Better Living

Harry T. Stinson, Jr.

GENETIC IMPROVEMENT of plants is essentially a synthetic process. Using genes as his raw materials, the geneticist attempts to fashion new hereditary constitutions better than any in nature. Discovery of the genetic principles and procedures which best accomplish this goal is our challenge.

Hybrid vigor, a salient feature of hybrid corn, is under study in tobacco by Seaward A. Sand. With leaf yield as a criterion, he finds that hybrids in tobacco do not manifest hybrid vigor or that the magnitude of vigor is slight. Moreover, new inbreds obtained by self-pollinating the hybrid may be superior to the hybrid itself, another marked departure from the behavior of corn hybrids. These observations raise interesting questions concerning the genetic systems in tobacco, a self-pollinated plant, and corn, a crossbred organism.

Dr. Sand also has results suggesting that genes in tobacco may be able to substitute for the shade tent. By judicious selection and crossing he has made progress in developing openfield strains whose leaves possess many of the cigar wrapper qualities of shade-grown tobacco.

Built-in genetic resistance is one of the most satisfactory protectants against the ravages of fungi and insects. In chestnuts it is the only hope of restoring these trees to our forests, nut orchards, and yards. Continuing work begun by A. H. Graves and others, Richard A. Jaynes is transferring genetic resistance to the blight fungus from the oriental species to various American species selected for their timber, nut, or shade tree attributes.

Recognizing the need for good early market tomato varieties and hybrids, Carl D. Clayberg is intercrossing early and disease-resistant varieties to incorporate genes for earliness and genes for resistance to wilt and virus diseases into single lines. Fabrication of disease and insect-resistant strains is also under way in tobacco by Dr. Sand and Gordon S. Taylor. Dr. Sand is developing shade tobacco hybrids which combine genetic immunity to ozone damage with resistance to mosaic virus.

In his efforts to tap the available gene supply, the geneticist often must first discover ways to break the genetic barriers preventing exchange of genes between species. We seek means for manipulating these barriers in tobacco, tomatoes, corn, African violets, and gloxinias.

Illustrating the tricks we must play is Dr. Clayberg's discovery of a method for transferring genes from the miniature to the common florist's gloxinia. These two species cannot be crossed directly, but a hybrid between the miniature and a third species will cross with the common gloxinia. The third species thus acts as a bridge permitting passage of genes from the miniature to the common gloxinia.

Dale Moss and I have shown that corn plants differ in their capacity to utilize sunlight. These studies point to the value of corn as a tool for investigating the genetic control of light-dependent growth responses. Genetic modification of the physiology and morphology of corn plants offers promise as a means for increasing their efficiency in using sunlight, and thus also increasing their productivity.

COSTLY DETASSELING ELIMINATED

Our research, initiated by D. F. Jones, on the inheritance of cytoplasmic pollen sterility in corn has played a significant part in eliminating the costly detasseling process in the production of hybrid seed corn. Dr. Sand and I are investigating cytoplasmic pollen sterility in tobacco and corn, and I am studying the inheritance of chloroplast characters in the evening primrose. In this way we gain information on the imperfectly understood role of cytoplasmic inheritance in plants.

The synthesis of true-breeding hybrids has long intrigued plant breeders. A mechanism which accomplishes this is the unusual chromosome behavior of the evening primrose, a common roadside weed. Using irradiated tomato chromosomes, Dr. Clayberg is exploring the possibilities for building this mechanism into the tomato. I have encountered certain features of the primrose itself which may provide clues on the origin of the true breeding character in these plants.

Woody ornamental plants, increasingly important in Connecticut, have been relatively unexplored by the geneticist. With this in mind we are "tooling up" for new investigations. Dr. Jaynes is assembling a collection of hollies to be used in developing hardier types for this area. He is also undertaking improvement of mountain laurel by crossing it with related species. An assemblage of azalea species will furnish material for study of barriers to interspecific hybridization in these plants. New ideas for shade and flowering trees may come from a growing collection of trees tailored to suit the city and suburban dweller.

The investigations described above represent efforts to improve plants by controlling their heredity. We recognize, however, that the success of these efforts often depends on how well we understand the behavior and properties of the genetic elements we seek to control. Among the distinguishing features of genetic material is its ability to mutate, and having been altered, to reproduce itself in the new form. Knowledge of mutation processes provides insight into the structure and function of hereditary elements.

Dr. Sand is examining gene mutation in tobacco by studying "unstable genes" that undergo frequent mutations, apparently back and forth from one form to another. Information on mutations of hereditary components in the cytoplasm is meager. I am investigating mutations in chloroplasts, vital cytoplasmic constituents of the green cells in plants.

New Publications

Publications listed below have been issued by the Station since you last received FRONTIERS. Address requests for single copies to Publications, Box 1106, New Haven 4.

Entomology

C 218 Termites in Buildings

Plant Pathology

B 639 Fungitoxicity of Carbamic and Thiocarbamic Acid Esters

Report on Inspection

B 645 Commercial Feeding Stuffs. 1960.

Soils and Climatology

B 644 Deep Tillage and Root Growth

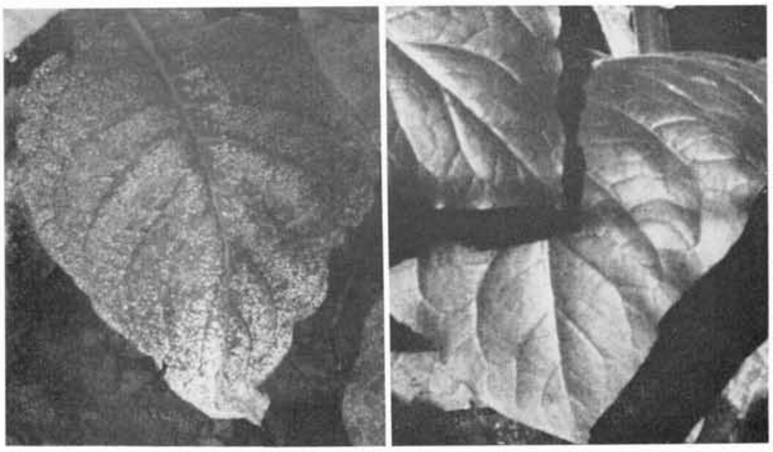
C 219 Improving Nursery Soil by Addition of Organic Matter

BETTER UNDERSTANDING OF

PLANT ENVIRONMENT

USEFUL IN FIELD AND FOREST

Paul E. Waggoner



Plant pathologists Saul Rich and Gordon Taylor, concerned with tobacco and its environment, have shown that treated shade cloth can protect leaves from fleck caused by ozone. At left, an unprotected check, at right, leaves grown under a shade tent on which an "antiozonant" material was applied in stencilled dots.

SINCE 1956 and the addition of "climatology" to the title of this Department, its staff has become concerned with plant environment, above as well as below the soil surface.

Connecticut is mostly covered by trees and is especially known for its water resources. Forest and water, therefore, have been the particularly important environment and object of new study, while forest and plant nutrition have maintained their classic importance in our research. Research in climatology did not spring forth fully developed at the moment of its announcement. But after five years, accomplishments can be seen.

Foreseeing the future through the analysis of historical observations is the classic problem in climatology. Because rainfall and the daily maximum and minimum temperatures reveal climate in rough outline, and because they are observed at many stations (25 published in Connecticut alone), their analysis is of first importance. When we began our work, a suitable method of estimating the probability of rainful was available but none for cold and heat. Christopher Bingham, building on the work of C. I. Bliss of this station, has now provided a method of estimating temperature probabilities.

Since the sun's intensity annually follows a sinusoidal course and the temperature imperfectly follows the sun, Mr. Bingham found that a harmonic equation $y = a_o + a_1 \sin t + b_1 \cos t \ldots$ is a rational means of describing the annual temperature course and removing the expected temperature for a given week from further calculations. The year-to-year variations in temperature then become the basis for probability estimates applicable in the future.

Mr. Bingham next considered the frequency distribution of these variations for each week and found that distribution close enough to normal so that this well-known curve could be used. Finally, he has combined this knowledge with a means of estimating the weekly variances or dispersions of the distributions. The completed methodology is now being applied by cooperating scientists throughout the Northeastern states to provide an atlas of temperature probabilities. Thus this statistical method is being used to transform recorded data into probabilities of coming events.

Besides anticipating future weather, one may wish to do something about it. The efficient place to do something is where the climate is created. This is where solar and long-wave radiation are absorbed, long-wave radiation is emitted, water evaporated, and air and soil are heated. Since this place of climate creation is mundane soil or leaf surface, mundane methods may suffice to change the climate in which the plant grows.

Garden-variety weather modification has, therefore, been the subject of a series of studies: hot caps and plastic covers, shade tents and forests, plastic and hay mulches. The studies have begun with observation and analysis of the flow of energy to and from the sheltered surfaces and continued by observation of the climate created. They have concluded with experiments in effects upon plants. Recently trees and shrubs have been exposed to the changed soil temperature and moisture caused by a translucent film or mulch, which warms, and hay mulch, which cools the daytime soil. These experiments have revealed unexpected and sometimes beneficial changes in soil pests and nutrients, in survival, in chlorophyll content, in flowering, and in growth of the plants.

Plants also change the climate. Stephen Collins found that red maple grows faster and longer in the field than in the forest. He was not surprised, therefore, to find that when leaves of the shading oak were eaten by gypsy moth larvae and the young maples beneath received more sunlight, these maples had a longer "growing season." They exceeded both their own growth in years before and the growth of other maples in non-defoliated woods in the same year. Thus, the insect changed the climate, benefiting the understory of the forest.

The amount of light also changes with the passing of clouds and of the hours. Although we knew that light is the essence of photosynthesis, we did not know whether "much" was better than "some." Learning this depended upon a measuring device that would respond to the unceasing changes of the weather. Dale N. Moss and John D. Hesketh have such a device, an infrared gas analyzer which can tell — from minute-to-minute — how much carbon dioxide is removed from the air by photosynthesis. Needless to say, the response of plants to many other factors in the complex and changing environment can best be determined by this nearly instantaneous observation of synthesis.

Recently Dr. Hesketh has learned that although many kinds of plants cannot benefit from more than one-quarter the intensity of midday sunlight, others — like sugar cane and corn — can. Earlier, Dr. Moss had found that the essential difference in growth between a vigorous hybrid and its struggling inbred parent was because the hybrid had more leaves to use light.

Water is another factor of the environment that affects plants greatly, while the plants in turn transpire water and indirectly affect our water reservoirs. For several years, Messrs. Downs, Jacobson, and Waggoner have subjected tobacco in the field but beneath a plastic shelter, to periodic droughts, observing any seasonal susceptibility. Fortuitously we learned that luxurious water makes tobacco highly susceptible to the leaf injury called fleck. The prime effort, however, has gone into the observation of growth and chemical composition.

Water Movement a Physical Problem

Although water has great biological effects, its movement through soil, stem, and leaf is primarily a physical problem. Stephen L. Rawlins has therefore begun thermodynamic observations of water relations.

The announcement of these new studies is prominent in this description of our work, but investigations in the classic fields of forestry and soil science occupy most of us.

In the forest, George R. Stephens, Jr., is attempting to speed the flowering of trees through nutrition, pruning, and changes in soil temperature and water. A. R. Olson is collecting ornamental native shrubs that have proven their adaptability to Connecticut by growing in the forest.

A multitude of soil types cover Connecticut, and David E. Hill is investigating their suitability as sites for septic tanks and factories, for forests and farms, as well as refining their classification through mineralogical observations.

Charles R. Frink is studying a particular class of minerals, clay, the active ingredient of the soil that stores or traps the cations that nourish roots. He is investigating the differences between the formation of aluminum oxides in solution and in soil, seeking an understanding of the formation of interlayers that change the exchange capacity of clays.

The Morgan test for nutrients available to plants was devised at this Station nearly 30 years ago. It is still the basis for most soil tests in New England, perhaps in the entire Northeast. After a lapse of many years, research in soil testing is again active here. Doyle E. Peaslee is improving the test for calcium as the first in a series of improvements in the Morgan test, the prime contribution of this Department.

ORGANIC ACIDS KEY SUBSTANCES OF PLANT BIOCHEMISTRY

Hubert B. Vickery

Everyone who has tasted a lemon has learned at least one fact about organic acids. They are sour, and we associate this taste with unripe fruits and with many kinds of leaves. This simplest of all chemical tests suggests that organic acids are common in plants; in fact they are present in all plants and often in extremely large amounts. As much as one-quarter of the solids in a green tobacco leaf consists of organic acids, and malic acid alone may account for one-sixth of its dry weight. The malic acid in the leaves picked as a crop from a one-acre field amounts to about 200 pounds.*

Why do plants accumulate such phenomenal quantities of organic acids? What are they there for, and whatever it is they do, how do they do it? These are some of the fundamental questions that plant biochemists ask themselves, and the Biochemistry Department has been concerned with such matters for the past 35 years.

The commonest organic acids in fruits and leaves are malic acid, well-known in sour apples, citric acid present in all citrus fruits and in pineapples, and oxalic acid of which there are large amounts in rhubarb and spinach. The tobacco leaf contain substantial amounts of all these together with small amounts of a dozen or more other acids the names of which would mean little except to a chemist.

The problem of the biochemist is to discover the relationships among these substances, and to determine their function in the tiny but amazingly efficient chemical laboratories known as plant cells.

To a chemist, an organic acid is a substance that contains a carboxyl group, a chemical radical that is formulated CO_2H. This formulation at once gives a hint of the function of acids; they obviously have something to do with carbon dioxide the chemical formula of which is CO_2. When carbon dioxide is taken up by the plant a reaction occurs in which a carboxyl group is attached to some suitable substance. This is one step in the sequence of chemical reactions by which the plant acquires carbon from the air, and the whole complex process which brings about the assimilation of carbon is known as photosynthesis. Essential factors in this process are the green chlorophyll of the leaf and the supply of energy from sunlight.

When carbon dioxide is eliminated from a plant, a carboxyl group disappears. This carboxyl group represents the end result of a process in which carbon in some other form such, for example, as sugar, has been oxidized. All oxidation processes liberate energy; a burning match liberates it as heat and light, but oxidations that take place in the living cell make *chemical* energy available for the formation of substances useful to the plant. Oxygen is taken up by the plant, and the end-product of the reactions that occur is carbon dioxide. This process is respiration and is characteristic of all living things.

The Fundamental Processes

Photosynthesis and respiration, then, are the two fundamental chemical processes of the cells of the green leaf. Organic acids play a part in both as intermediate substances.

These terms, however, are extremely broad ones. Among the great accomplishments of biochemistry in the past few decades has been the dissection of these processes into a series of successive steps each of which involves the reaction of a single substance, the "substrate," which is frequently an organic acid, with a specific enzyme (which is a protein) under the control of a third substance known as the "coenzyme" to produce a product, also often an organic acid. The product is in turn used as the substrate of the next reaction in the sequence, and there may be dozens of such steps each requiring its specific enzyme and its controller coenzyme before a moderately simple substance such as glucose is oxidized to carbon dioxide and water.

It is the function of the present-day biochemist to search for and demonstrate the existence of these steps, to recognize the substrate, if possible to isolate and characterize the enzyme,

* The malic acid, if it could be isolated, is worth much more than the tobacco: the current price is about $60 a pound.

and to show the relationship between the substrate and the product.

Some of the current investigations in the Biochemistry Department may be cited as illustrative of how these problems are approached. Fundamental to any study is the development of an analytical method to measure the amount of the substrate and the product of an enzymatic reaction.

Attila Klein, who is concerned with the problem of whether or not isocitric acid is metabolized in the leaves of the Bryophyllum plant in which this rare acid accumulates in large amounts, is trying to find a method to determine it in the presence of citric acid. We know that it is metabolized when introduced into the tobacco leaf, and the question arises wherein lies the difference between the behavior of isocitric acid in these two plants?

Kenneth R. Hanson is engaged in preparing by chemical methods compounds analogous to chlorogenic acid in an effort to throw light upon the manner in which this substance is formed by natural methods in the potato tuber. Carl C. Levy and Milton Zucker last year set up an hypothesis to account for this, but proof of its validity can be had only when specimens of the substances they supposed to act as intermediates in the successive steps of the reaction are in hand for testing.

Lester Hankin is studying the effect upon the protein content of the livers of rats when they are fed upon a purified diet that contains orotic acid. These animals promptly develop enormous concentrations of fat in the liver, and the protein content is diminished. The problem is to detect whether these phenomena are related, and if so in what way.

Israel Zelitch has found that the infusion of trace amounts of any of a number of α-hydroxysulfonates into tobacco leaves prevents wilting. These substances are compounds derived from simple aldehydes and they behave as inhibitors of the enzyme which normally oxidizes glycolic acid to glyoxylic acid, a fundamental reaction now thought to be concerned with respiration. The maintenance of the turgidity of the leaf was found to be attributable to the closing of the stomata under the influence of the inhibitor.

It would seem, therefore, that glycolic acid oxidase has something to do with the sensitive water relations in the guard cells which operate to open and close the stomata. The problem is to discover the identity of the substance in these cells which changes in concentration in such a way as to close the stomata when the inhibitor of glycolic acid oxidase is present.

These experiments indicate that chemical control can be exercised under laboratory conditions over the loss of water from plants. Furthermore, this can be done without interference with the normal reactions of photosynthesis. It remains for the future to discover whether practical applications can be developed which bear upon the problem of water conservation on any significant scale; however, a hint of this possibility is provided.

My own work is mainly concerned with the effects of culturing tobacco leaves upon solutions of various organic acids in order to obtain information upon the metabolic pathways whereby these substances are transformed. These studies provide information upon the enzyme systems present, and help to account for some of the changes that occur during the curing of the tobacco leaf.

Each of these investigations centers around the behavior of one or another organic acid. As information about these substances accumulates, it becomes more and more evident that they are indeed the key substances of plant metabolism.

TOBACCO LABORATORY IMPORTANT TO VALLEY

Gordon S. Taylor

NESTLED NEAR THE CENTER of Tobacco Valley is the Station laboratory in Windsor. This location facilitates service to growers in the area and makes possible research under local growing conditions, highly important in studies of the largest crop of the area, tobacco. Research past and present covers tobacco culture from seed to seed.

Of special note from past work is the early development of a basic fertilization practice for Valley cigar tobacco that held for over 40 years until the advent of synthetic binder on cigars changed the type of tobacco needed from Connecticut. We then took a new look at fertilizer needs and the research results called for cost reduction in organic nitrogen sources such as cottonseed meal.

How roots reach this fertilizer and respond to soil tillage practice also has been studied by Henry C. De Roo. Development of a method to hold roots in their normal position as the soil is washed away led to new knowledge that loose, uncompacted, soil is important for best growth and good anchorage against lodging.

Plant breeding has been, and continues to be an important research area. In the forties genetic crosses of shade types to broadleaf and other strains with subsequent careful breeding by Station scientists led to Connecticut 49 and Connecticut 15, two shade grown wrapper lines that completely replaced the common Cuban strain and formed the basis for essentially all of the presently grown strains.

Currently an extensive breeding program has led to a shade grown wrapper line that resists a serious trouble called fleck and a broadleaf binder line that resists the ubiquitous tobacco mosaic virus. Elsewhere in this issue, Dr. Stinson mentions other considerations in tobacco breeding.

Pest control with chemicals has been a continuous field of research. Results have led to several general practices including control of the treacherous blue mold disease in seedbed and field with the fungicide zineb; insect control with a host of ever developing insecticides including chlordane, DDT, and malathion; and control of soilborne nematodes with ethylene dibromide and dichloro-propenes.

An exciting new development of the last two years has been the possibility of controlling an air-pollution caused leaf spot, called fleck, by controlling high levels of ozone with antiozonants. Saul Rich and I have shown that an antiozonant compound stenciled on shade cloth effectively protected plants on high ozone days in 1961. The Station has pioneered this approach to alleviation of air pollution damage.

Continuous work on tobacco curing has led us to a study by John Ahrens of bulk curing for cigar-binder type tobacco. This method of forcing conditioned air through packed masses of tobacco is at the practical stage for cigarette tobacco and may well be an answer to handling cigar binder leaves picked by machine.

Chemical weed control in tobacco, nursery, and lawns also receives research attention at Windsor along with soil testing and problem solving for local citizens.

All in all, the Windsor Laboratory extends the arms of The Experiment Station to an important area of Connecticut agriculture — Tobacco Valley.

FINDING ANSWERS FOR THOSE WHO NEED TO KNOW

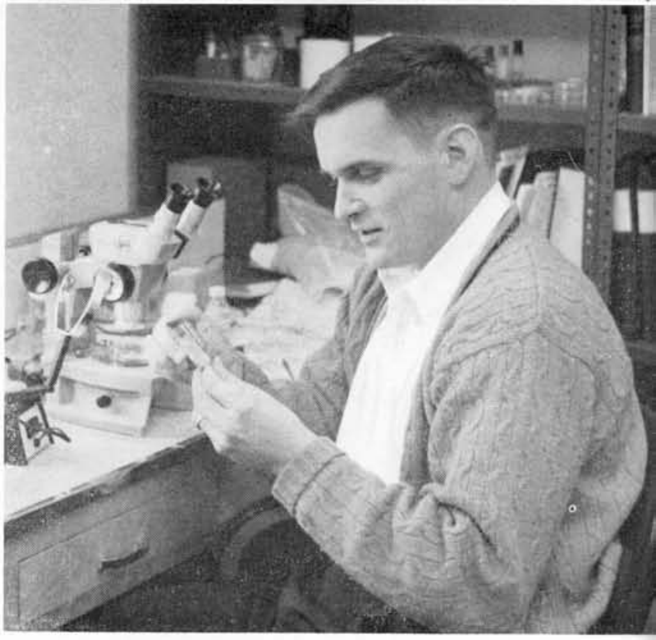
IT MAY BE that the Yankee peddler, when his load of tinware and notions grew too heavy for his back, gave rise to the old adage "You can't do business from an empty wagon." For 86 years this oldest experiment station, created to put science at work for Connecticut citizens, has distributed some exceedingly useful scientific wares.

The wagon of the Station has long since been far from empty. Where does the stock in trade come from?

From all over the world, these days, wherever a new method or material offers promise of utility in Connecticut, whether in field or forest, or on the front lawn to control crabgrass.

But always most important are the ideas — the theories if you will — that arise in the inquiring mind of a man who knows how to treat those ideas, to follow them where the evidence leads, and finally to spell out new knowledge.

The photographs on these pages show a few of the people at this Station who work at this exciting business of discovering new knowledge. Finding answers is their first duty. Otherwise the wagon of the Station would have only second-hand goods. Reporting what research has disclosed — and what it means — is equally important. In a sense this reporting is the counterpart of the honest labeling Connecticut citizens like to see on what they pay for.



CLOCKWISE AROUND THE PAGES . . .

Richard A. Jaynes weighs hybrid chestnuts, a part of the long program to fashion chestnut trees to replace, at least in part, the tree so important to Connecticut.

Joy Jacobs, in a Department of Entomology culture room, takes care of hundreds of house flies. Studies of the different strains in plastic "apartments" give information on the development of resistance to insecticides.

Stone flies have relatives in distant lands. Stephen W. Hitchcock, concerned with classification of these aquatic insects, examines specimens from Malaya.

Richard A. Botsford at the infrared spectrograph, used to identify materials.

Diagnosis of diseases and related disorders of plants is the responsibility of Mrs. Frances W. Meyer and Gerald Walton. Hundreds of callers receive these personalized reports of research in plant pathology, so save crops and plants.

Henry C. Engelhardt, superintendent of Lockwood Farm in Mt. Carmel, sees that field plots are cared for, despite unorthodox treatments and unusual crops.

John Hesketh, left, is one of the Soils and Climatology staff studying light and photosynthesis. Attila Klein, a biochemist, studies organic acids in leaves.

Mrs. Richard Grossi prepares depression slides for testing fungicides. The test material is put in first, then fungal spores are added to determine toxicity.

Janetha Shepard examines a sample of flour to determine contaminants, if any.

Wilting tobacco leaves helped Israel Zelitch to show laboratory control of water loss without interfering with photosynthesis, a clue to conservation of water.

Here representing the many who help to make sure that inquirers find the best answers available is Karen Nelson, Station switchboard operator.

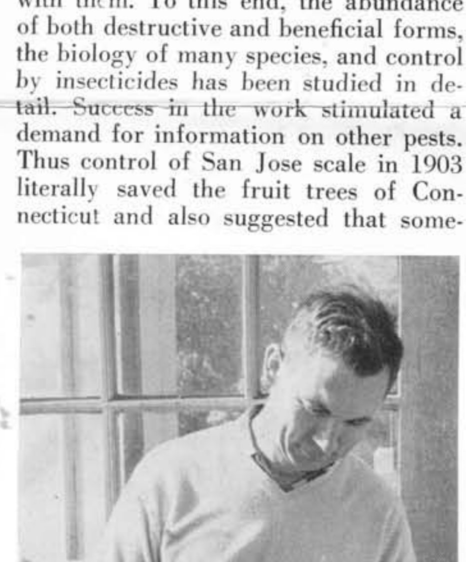
LIKE THE EYE OF A FLY,
INSECT CONTROL HAS MANY FACETS

Neely Turner

THE STATION is prepared . . . to identify . . . useful or injurious insects, and to give information on the various subjects of Agricultural Science, for the use and advantage of the citizens of Connecticut, says the Station Report for 1877.

To meet this responsibility, entomologists investigate both harmful and beneficial insects, develop and test practical ways of controlling destructive or annoying species, and carry out such regulatory measures as are specifically assigned by the General Assembly.

Insects have been present on the earth longer than most higher forms of life. They are here to stay, and it is our job to collect the information needed to cope with them. To this end, the abundance of both destructive and beneficial forms, the biology of many species, and control by insecticides has been studied in detail. Success in the work stimulated a demand for information on other pests. Thus control of San Jose scale in 1903 literally saved the fruit trees of Connecticut and also suggested that something equally effective could get the worms out of fruit.



Study and control of insect pests on pines and elms is the responsibility of Charles C. Doane.

An enormous amount of information on three or four hundred pest insects and the problems of controlling them has been put in the records. This has enabled people to control serious pests but has not eliminated the insects. It has contributed to a general understanding of the problem and shown that something different must be done if the pests are to be eliminated.

There are definite reasons for continuing study. Whether we like it or not, the use of insecticides has been the only practical way yet discovered to stop damage or annoyance from large numbers of insects promptly. But the "perfect insecticide" which kills only the pest insect and is not toxic to anything else is yet to be discovered. Each promising new material must be tested for effects on plants and on animals other than pest insects, and the potential toxicity of residues measured. Since San Jose scale developed resistance to lime sulfur solution in 1909, it has been necessary to seek and find insecticides to control resistant insects.

Farmers and gardeners continue to bring in plants from every continent, and plant breeders create new varieties. Some native insects find these more acceptable than their natural hosts. Many insects have come in from abroad, and find both the climate and hosts suitable for survival. This transfer is by no means ended; the alfalfa weevil showed up in Connecticut about 1958, and the face fly, a serious pest of livestock, in 1959.

Abandoned farms grow up in brush and later into woodlands. The trees offer a good environment for many insects. As long as these are abandoned farms no one minds the insects. When they become dwelling places for suburbanites the insects become a nuisance.

Insects themselves change. Adaptation and evolution did not stop with Darwin, it is still continuing. Thus the corn leaf miner was a curiosity for years, but has "suddenly" become a serious pest.

Finally, an increasing number of people are concerned about the general use of insecticides. When this use was confined strictly to agricultural crops, they left it to the farmers to worry about the effects on nature. The spectacular toxicity of DDT has certainly stimulated people to use insecticides for many more pests than in the past. This raises the question of the long-term effects of such widespread use.

To answer these complex problems requires a staff of competent entomologists studying, testing, and observing results. Those responsible for this technology are C. C. Doane for elms and pine; James B. Kring for tobacco and potatoes, Richard J. Quinton for fruit, vegetables, and forage; and John C. Schread for flowers, nurseries, and ornamental plants. Mosquito control is handled by Robert C. Wallis, and the face fly by W. T. Brigham.

IDENTIFICATION SERVICE POPULAR

Diagnosis of species responsible for insect damage, identification of insects, and consultation on control measures is essential for effective and efficient control of pests. It is needed particularly by people relatively unfamiliar with insects and insecticides. J. Peter Johnson is responsible for this important function.

There is always the hope that some way of coping with pest insects other than use of insecticides can be developed. So a substantial portion of our investigation is directed at greater knowledge of behavior, genetics, physiology, parasites, predators, and diseases of insects.

Raimon L. Beard is studying the long-range effects of insecticides on populations of insects, the physiology of digestion in insects, and the insect venoms, which he calls nature's insecticides. Stephen W. Hitchcock is investigating the complex ecology of some pests of woodlands, and particularly the habits of effective parasites. He is also interested in insects that live in water, because these can be a blessing in a trout brook or a curse in a water reservoir.

Charles C. Doane is determining the intimate biology of a scale insect that threatens death to red pine in southern Connecticut. Robert C. Wallis seeks a complete knowledge of the breeding habits of our mosquitoes and their role in transmission of disease.

James B. Kring is finding the factors that effect the abundance of wireworms and the complicated behavior of the aphids. Neely Turner is studying the causes of the explosive outbreaks of insects that seem to be cyclic in abundance.

David Leonard is seeking attractants for the apple maggot fly. He is also studying the relationships of the chinch bugs which infest grasses.

Many Regulatory Duties

The regulatory work assigned to the Station by statute is of a type that can best be done by a state organization. Inspection of nurseries has as its purpose the certification of plants as reasonably free from serious insect pests and plant diseases. Thus plants bought by Connecticut citizens can get off to a good start. This work is supervised by Deputy State Entomologists W. Theodore Brigham and Ralph Cooper.

The gypsy moth statute directs us to determine areas in which the gypsy moth threatens defoliation in those towns where citizens are interested in spraying. If the town governments decide to spray, Mr. Cooper's staff determines the areas in detail and provides assistance in arranging for spraying. The towns are reimbursed for part of the cost.

Under the air-spray statute, areas for which permits are sought are inspected and permits issued if the treatment is necessary and the materials effective; with due consideration for the rights of adjoining property owners and for possible hazard to wildlife.

The statute on ribes eradication to prevent damage from white pine blister rust authorizes us to assist in determining the areas needing attention and to supervise work financed by towns and owners of pine stands.

Inspection of bees for foulbrood has been done for many years. Possible revision of this system is now under study.

The entire staff endeavors to meet everyday needs efficiently and promptly. Those responsible for studies of more long-range importance work with vigor and all the imagination at their command to open the door for more lasting solutions to insect problems.

The Cover Photo

The roadside market of Albin Olszewski on West Main Street in Avon suggests the abundance of autumn in Connecticut. The agricultural technology responsible for the miracle of American abundance of food rests on a firm foundation of science, science put to work for society.

PLANT PATHOLOGISTS

FINDING NEW WAYS TO CONTROL DISEASE

A. E. Dimond

The Department of Plant Pathology and Botany, one of the oldest in the country, specializes in plant diseases and their control.

In 1888 when Dr. Roland Thaxter was appointed to the Station staff, he had first to learn what diseases were of major importance, then how to control them. His pioneering studies on the causes of disease in plants and on the value of Bordeaux mixture as a fungicide are still model investigations.

Now, 73 years later, we learn of the diseases attacking Connecticut crops in the same way Thaxter did. We examine the many ailing plants brought to the Station by farmers and gardeners. Mrs. Frances Meyer and Gerald Walton diagnose the trouble and draw on a vast store of information on control, the contribution of many workers over many decades.

As in Thaxter's day, the discovery of new methods of disease control is the concern of all plant pathologists. Many diseases are controlled by fungicides, but it is extremely difficult to learn how fungicides kill. J. G. Horsfall, Saul Rich, and R. J. Lukens bring their knowledge of chemistry and biology to bear on this aspect of plant disease control.

Assay Methods Widely Used

Fungicides, however contrived by the chemist, must be selective in their action. They affect biological processes, and they must be tested or assayed biologically. Methods of biological assay developed by Dr. Horsfall some 20 years ago are widely used by scientists throughout the long process of evaluating and developing new fungicides.

Nabam and zineb, both widely used in agriculture, were developed at this Station with the cooperation of industry.

Lawns are the biggest crop in Connecticut. What better one could be chosen for fungicidal investigations? E. M. Stoddard, still active in research after retirement from more than 50 years of service here, and R. J. Lukens are developing better methods of controlling turf diseases.

Brown patch, a common trouble on lawns, is caused by a fungus that attacks the roots of grass. By injecting nabam solutions under pressure beneath the turf, Stoddard and Lukens discovered a simple and effective method of controlling brown patch and related diseases — and did more than control disease. On golf greens, soil compaction was overcome by the injection of large volumes of solution, and the greens "played" better as a result. Now they have found that a simple drench with nabam solutions, applied without special equipment, controls brown patch.

Unanticipated Findings

Fruits of our fungicidal studies have been harvested where they were least expected. Research by Saul Rich on fungicides led to his observation that certain compounds, applied as sprays in the field, prevented ozone damage. The outcome of this observation is mentioned by Dr. Taylor on page 5.

The chemotherapy of plant disease has slowly changed from a possibility to a reality. Mr. Stoddard's successful cure on a commercial scale of geranium plants suffering from foot rot is a clear case of therapy. Now growers save diseased plants that formerly were lost by Stoddard's method of applying a soil drench containing oxyquinoline sulfate and streptomycin.

Our reasearch on control of Dutch elm disease and Verticillium wilt of potato seeks compounds that will move in the plant and either modify it so that it becomes resistant to the disease or that will kill the fungus causing the trouble inside the plant.

Systemic fungicides are hard to find, because fungitoxic molecules are likely to injure the plant or else the plant degrades the molecule so that it is no longer fungitoxic. However, some progress is being made with quaternary ammonium compounds, which become fixed to woody tissue and render it unpalatable to fungi.

Dr. Edgington is exploring the ways in which structure of these compounds can be altered to permit a controlled movement in the plant, while retaining their fungitoxic activity. Also he is investigating compounds that modify the

Sydney W. Gould

Jane Decker, at left, John Ebinger, and Judy Hirtle assist Mr. Gould in Plant Index compilation.

Putting Plants in Their Places

PUNCHED CARDS are about to write books at this Station—books that will ultimately give scientists the most complete plant directories ever known. The project is sponsored jointly by the New York Botanical Garden and the Station, under a grant made by the National Science Foundation to Sydney Gould. Mr. Gould and his staff are using punched cards to codify the names of plants, where they are found in the world, who first described them, what scientific names they have been given, and where these descriptions can be found. Such information is now widely scattered. Once the information is coded on punched cards, machine sorting, duplicating, printing, and tabulation makes possible a wide range of compilations for an almost equally wide range of needs. Taxonomists around the world will be among the first to find use for the International Plant Index.

growth of trees. Some of them reduce the size of the water-conducting vessels in the stem. This apparently makes advance of the fungus more difficult. Such compounds might slow the progress of Dutch elm disease so that infected branches could be pruned out, thus saving the life of the tree.

Chemotherapy studies have been guided to some extent by our knowledge of how fungi cause plants to wilt and the stem to become discolored in wilt diseases. Dr. Edgington and I are examining the relation of water transport through the xylem to the induction of wilt by vascular fungi.

I am measuring the concentration of oxygen in the water-transporting tissue of the stem and petiole. The low oxygen tension in the tissues inhabited by wilt-inducing fungi may determine what products the fungi form and thus effect the development of symptoms in the plant. Such studies point the way to potential control measures for the wilt diseases.

Disease-causing fungi in the soil often are aided in entering plants by the feeding of nematodes, microscopic eelworms that live in the soil.

Patrick M. Miller, who investigates many problems involving nematodes in relation to plants, has given newly transplanted fruit trees a head start by applying small quantities of nematocides and fungicides under plastic mulch. Dr. Miller finds, and growers confirm, that trees treated in this way may grow twice as much in their first year as do trees transplanted in the ordinary way.

Dr. Miller has also shown that a fungicide in the soil may worsen attack by nematodes and a nematocide may make root disease more serious; together they may control root troubles satisfactorily.

Many people wonder whether we really need to use so many pesticides on our foods. If we could control plant disease without pesticides, there would be no problem. Some soil fungi that live on decaying matter are known to hold disease-causing fungi in check. If such "friendly" fungi could be encouraged, some root diseases could be controlled biologically. Dr. Saul Rich, working with Drs. Miller and Edgington, has controlled Rhizoctonia on cotton by enriching the soil with antibiotic fungi.

A department of plant pathology and botany deals also with healthy plants and with control of weeds. Not too many years ago the chemical herbicides had the reputation of being tricky and unreliable in practice. John Ahrens, at the Tobacco Laboratory, has found that many of the herbicides offered for sale today are quite dependable and safe to use repeatedly, when carefully and properly applied. He has directed his attention to control of unwanted brush along roadsides and other rights of way, and the control of crabgrass in lawns and weeds in plantings of tobacco and nursery stock.

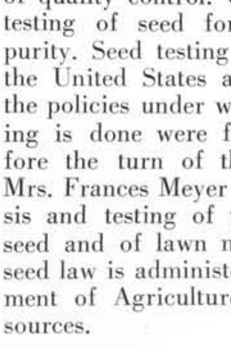
Research on the components of leaves and how they arise is the interest of Milton Zucker, in cooperation with members of the Departments of Biochemistry and of Genetics. From the green of freshly harvested leaves, tobacco turns to a golden brown during curing. A part of this change is related to the oxidation of chlorogenic acid, a compound that occurs in many living cells. Because its role in curing of tobacco is so important, Dr. Zucker seeks to learn from what materials chlorogenic acid arises and what conditions favor its formation. As a result of these studies, one may be able to cure tobacco of more uniformly high quality.

Studies on the protein components of leaves and how they arise are of interest to all who produce leaves for food or feed, because the proteins are one of the basic types of food. Dr. Zucker, with Dr. Stinson of the Genetics Department, is studying the ways in which proteins are formed.

Not all proteins are equally suitable for food, and Dr. Zucker is studying the relation of protein formation to its availability as food. His studies are directed toward increasing the nutritional values of forage crops for livestock.

The Station performs many services of quality control. One of them is the testing of seed for germination and purity. Seed testing was introduced to the United States at this Station, and the policies under which most seed testing is done were formulated here before the turn of the century. Today, Mrs. Frances Meyer conducts the analysis and testing of vegetable and field seed and of lawn mixtures. The State seed law is administered by the Department of Agriculture and Natural Resources.

Mr. Jacobson Retires



H. G. M. Jacobson

H. G. M. Jacobson retires this month after 35 years. An authority on Connecticut soils, he has made the suggestions that put results of soil tests to work for thousands of farmers and gardeners. He is one of the Station experts who in the 20's and 30's made the only complete survey of Connecticut soils.

THEY TAKE THINGS APART FOR PROTECTION OF THE CONSUMER

Harry J. Fisher

THE ANALYTICAL CHEMISTRY Department of this Station is the only general analytical laboratory* supported by the State of Connecticut. We are consequently at times called on to conduct analyses by nearly every department of the State government, including the State Police, the State Department of Health, and the State Supervisor of Purchases.

This is in addition to our regular statutory work on dairy products, other foods, drugs, cosmetics, animal feeds, and pesticides for the Commissioners of Agriculture and Consumer Protection. We also make such analyses as are required in connection with research at this experiment station and the station at Storrs.

A large proportion of the Department's time is devoted to analysis of foods, drugs and cosmetics. Connecticut had a general food law in 1895 (eleven years before passage of the Wiley law of 1906) which was the first to be administered by a state agricultural experiment station. Every year from 1896 to the present this Station has issued a food and drug report detailing the results of its examinations. At the present time some 2,000 samples are tested each year. These Food and Drug reports have frequently included original information on the composition and analysis of foods and drugs and have acquired an international reputation in their field.

Most of the food analyses are made by A. F. Wickroski, Sherman Squires, and Raymond E. West, and those of drugs and cosmetics by Richard Merwin. Feed and fertilizer analyses are handled by Miss Helen Kocaba, Werner Mueller, and Walter Oliver, and pesticide analyses by Lloyd Keirstead. Richard Botsford runs our spectrograph and infrared apparatus, Miss Janetha Shepard is our microscopist and does the chemical testing in animal poisoning cases, and Dr. Lester Hankin oversees the vitamin assays.

Under the Food, Drug and Cosmetic Act of 1939 (as amended) the taking of samples and enforcement of the law is now the responsibility of the Department of Consumer Protection, and the Station's duties are confined to analyzing samples and reporting whether they are or are not adulterated or misbranded.

One class of foodstuffs, milk, has always been given particular attention. In the early days the Station did all chemical testing of milk samples. Routine butterfat determinations were transferred to the State Department of Health in 1939, but from 1935 to the present we have regularly assayed all brands of vitamin D milk in the State for the Commissioner of Agriculture and Natural Resources and his predecessors.

For the past three years tests for vitamin A, thiamine, riboflavin, and niacin in multi-vitamin milks have been added. As a result of our work in a survey of the Connecticut milkshed begun in 1958 (when over 700 samples were analyzed) all traces of DDT have been removed from the Connecticut milk supply.

FIRST IN THE NATION

Originally the Station and the Analytical Chemistry Department were one, because, when the General Assembly authorized the establishment in 1875 of what was the first agricultural experiment station in the United States, it specified that the Station's duties were to analyze commercial fertilizers. From that time on, all work on analysis and control of commercial fertilizers has been the responsibility of the Station, which has administered the 1882 fertilizer law and its later amendments up to the present day.

Results of fertilizer inspections are published annually. This report includes information on many of the fertilizers sold only in small packages — a Station service to home gardeners and those who grow house plants for enjoyment.

Other primarily agricultural laws whose administration (except for enforcement provisions) is the responsibility of the Analytical Chemistry Department are the feed and pesticide acts.

All commercial feeds sold in the State must be registered with the Station, and samples of these are collected by the Station inspector, analyzed in our laboratory, and the results published in an annual report. Because the 1895 Connecticut Food Law defined food to include "every article used for food or drink by man, *horses or cattle*," almost by accident this State became the first to have an animal feed law. The present law was passed in 1925.

Originally feed analyses included no more than determinations of protein, fat, and fiber plus occasional microscopic checks on the ingredients present. In 1937 vitamin D assays of poultry feed supplements by chick feeding were added at the request of poultrymen, and since 1955 other vitamins have been tested for by microbiological methods. From 1949 when the first anti-coccidial drug (sulfaquinoxaline) was added to commercial poultry feeds up to the present time there has been a continually growing number of added drugs whose presence and proportion must be determined for the proper control of commercial feedstuffs.

There is no registration under the Connecticut Insecticide and Fungicide Law, but otherwise our functions under that law are similar to those under the feed law, although it has not been possible to do as much inspection of pesticides as of feeds.

One of our duties requiring the most man-hours per sample has been the service offered to veterinarians of testing animal remains in cases of suspected poisoning; approximately 180 samples are examined each year. Our spectrograph has been of great help in this field in enabling us to detect rapidly such heavy-metal poisons as lead, mercury and thallium.

While the department is primarily a control laboratory, it has a proud tradition of original work. Among those who made important contributions during its earlier years were Johnson, Jenkins, Winton, Street, and Bailey. Dr. Samuel Johnson had already started to develop fertilizer analysis in the United States 20 years before the Station was founded. Andrew Winton pioneered in the microscopy of foods. John P. Street published much on the composition of

(Continued on page 12)

* There are specialized laboratories in Hartford of the State Department of Health and in Portland of the State Highway Department.

From the Director

James G. Horsfall

HEREWITH IN FRONTIERS our story on what we do at the Station. Usually FRONTIERS reports the stories from our basic research — the new ideas in science, new uses for these ideas. In this issue we try to summarize our services to citizens of Connecticut, what we do, what we can do.

Simply stated, we want to know why plants grow green.

Our curiosity knows no bounds. It leads us into the farthest crannies of plant science. Our 86 years of experience tells us and you that whatever we learn will be useful, if not today, then surely tomorrow. What we learned years ago about pesticides and their detection helped the nation survive the cranberry crisis. What we learned about 8-hydroxyquinoline on elm disease enabled the florists to solve a geranium disease. What we learned about fertilizers and feeds and nutrition helps keep milk and eggs and meat on our tables.

To delve into plant science across the board, we must be scientists with backgrounds across the board and diverse talents. We are cytologists, pathologists, zoologists. We are entomologists, physiologists, climatologists. We are chemists. We are mathematicians and statisticians. We are geneticists and physicists.

We work with earth and its mundane mantle, with the commonplace and the magnificent. We work with tomatoes and tobacco and telephone poles — but also with the birds and the bees, the flowers, and the trees. We like green pastures and corn fields rustling in the August night — and we like green grass in the lawn. We seek out the ways of the gypsy moth and other insects, that temporary controls may be effective. But we search also for more "natural" ways to antiquate these same control measures.

We work with Christmas trees and chrysanthemums. We work with Asiatic beetles, African violets, European corn borers, with Dutch elm disease, Japanese beetles, and English peas, with Boston ivy, Indian corn, and Irish potatoes.

We work with water in the rain, with water in the plants, with water in the streams and reservoirs. Many thoughtful citizens think that our nation may run out of water before it runs out of food. The foliage of plants returns to the air 60 per cent of the water that falls on the land. The plants get first choice of the rain that falls. How and why? This we want to know. We have discovered a chemical that will reduce the foliage demand for water. Is this practical? Is it feasible? Time and the plants will tell — if we keep asking.

We study air pollution because plants show damage from air pollution before you and I do. We study stream pollution for the same reason. Insects and plants suffer first.

We are the scientific detectives who solve or try to solve the "whodunits." May we help you?

Take Things Apart (from page 11)

patent and proprietary medicines. E. M. Bailey added to our knowledge of the composition of lesser-known foods and special foods for diabetics.

Coming down to present days, the late Waddy Mathis pioneered in the use of the emission spectrograph for the quantitative determination of major mineral elements in agricultural products, and Richard Merwin started the development in the United States of official methods for drugs in feeds. Some of these methods were original with him, and many of the others were modified as a result of his studies.

Special mention should also be made of the work of Lloyd Keirstead on spray residue determinations. All of these methods for the determination of parts-per-million quantities of organic pesticides in foods are complicated and require high technical competency even when the details have ostensibly been worked out and published by others.

During the "cranberry scare" of two years ago, for example, it became imperative to determine promptly whether there was any aminotriazole in the cranberries and cranberry sauce on sale in this State. We assigned to Keirstead the task of surveying the whole market supply within 15 days. With all published methods known to be of uncertain accuracy and precision, he had to be pretty good—and willing to work long hours overtime — to succeed, as Keirstead did with Miss Sunrae Agostini's aid.

Our present fields of interest for such time as we can spare from our routine duties are in the development of chemical methods for the determination of drugs in feeds and pesticides in foods, the use of the infrared spectrophotometer both in analyzing pesticides themselves and for determining them in minute quantities in animal and vegetable material, and the devising of chemical methods to determine other food additives.

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