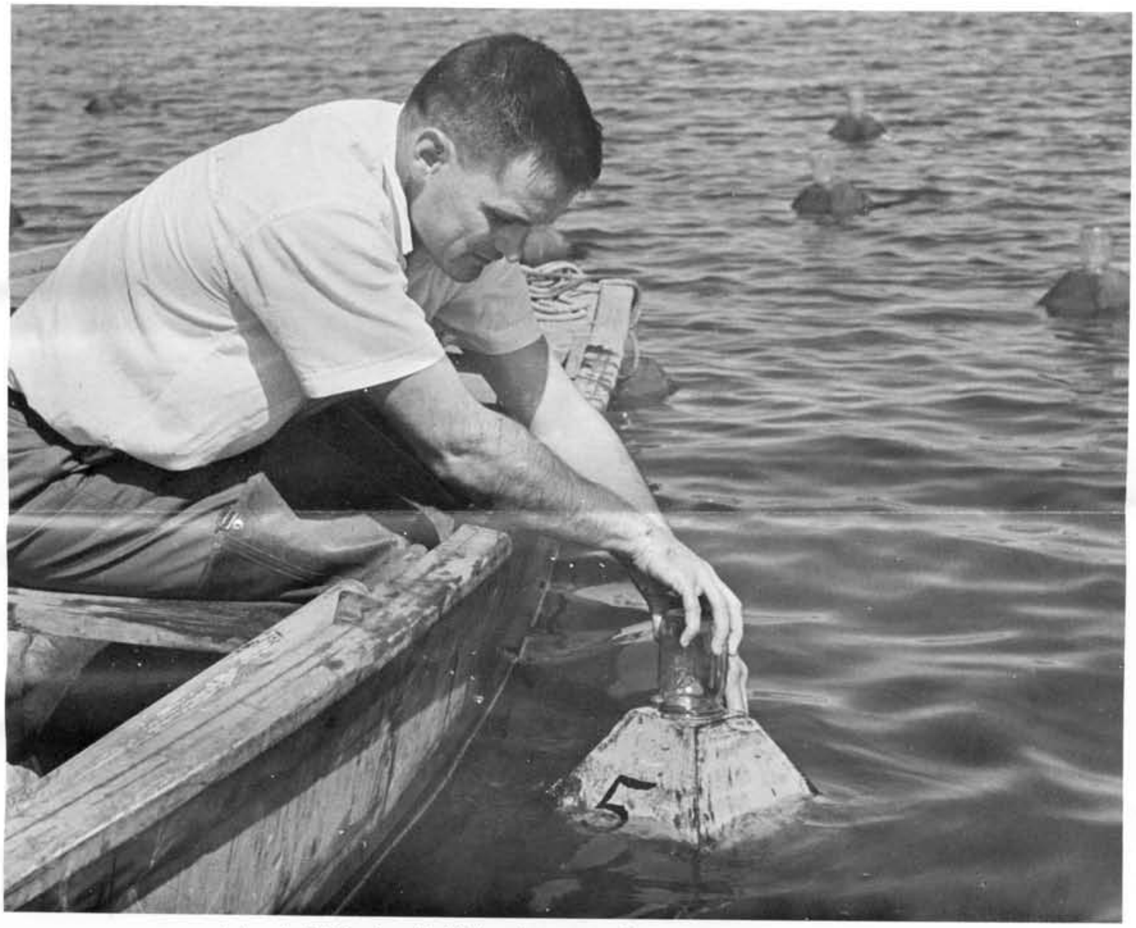
A paper that is green inside and out is on the right track—E. B. White

FALL 1966

Frontiers of Plant Science



Entomologist Stephen W. Hitchcock removes glass jar from trap that contains adult midges emerging from measured underwater area. Story on page 6.

THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION **NEW HAVEN**

Established in 1875 by the General Assembly

Connecticut Lakes Accumulate Nutrients

Charles R. Frink

LORD BYRON once said, "Till taught by pain, men really know not what good water's worth." While he had in mind someone dying of thirst in the desert, we are all becoming rather painfully aware of some of the other attributes of good water. We do not like to swim in lakes covered with scums of algae. Neither do we like to spend half our time unwinding weeds from the propeller of our outboard when we could be fishing or water skiing, and finally, no one cares too much for the aroma of rotting weeds and algae piled up on the shore.

Where do these weeds and algae come from? Since they are plants, they need plant food to grow, and they grow very vigorously when supplied with nitrogen or phosphorus or both. This brings us then to one particular aspect of good water, namely what is the fate of nitrogen and phosphorus when they enter the watershed of a lake?

First, what are the principal sources of these two nutrients, nitrogen and phosphorus? The one which comes to most people's minds immediately, of course, is a sewage treatment plant. I should make it clear here that I don't mean the kind of plant which is dumping raw sewage into the river—this is a problem for the health officer, not for a soil chemist. What I am referring to is the typical present-day treatment plant employing some sort of microbial degradation process to remove most of the suspended solids.

The result, of course, is not "night soil" as it is known in the Far East, but an effluent rich in soluble inorganic nitrogen and phosphorus—in other words, a good rich liquid fertilizer. Unfortunately, the better the treatment plant—that is the greater the removal of solids—the better is the fertilizer solution it produces. This is one of the more unfortunate aspects of the urbanization of our rural areas. As a town becomes a city, people want city water, gas, electricity, and all the other benefits of city life, eventually including sewers and a treatment plant.

While city water is admittedly a great improvement over the old hand pump, septic tanks—where there is enough suitable land—are a much better method of waste disposal than is a sewage treatment plant. In fact, the Experiment Station at Pennsylvania State University is essentially converting a treatment plant, which presently serves about 20,000 people there, back to a septic tank. They are pumping the effluent from the plant out on the ground and thus disposing of the water, irrigating and fertilizing a crop, and recharging the ground water all in one fell swoop.

Before we conclude that sewage plants are all bad, however, we must realize that for thousands of years nature has been pouring water into the lake and with it the nutrients dissolved in the water from fields and forests in the watershed. However, watersheds vary: the runoff from cultivated farm land is high. There is little vegetation to hold it back, and the dissolved nutrient content is high owing to heavy use of fertilizer. On the contrary, the runoff from forested land is low in both nutrient content and volume.

Obviously, before concluding that the sewage waste is causing the algae and weeds to grow, we must measure the relative contributions from all these nutrient sources. Presently, we are making such measurements in one lake in Connecticut, and thus we hope to be able to assess more accurately the contributions from sewage wastes and other sources.

Turning next to the problem of what happens to nitrogen and phosphorus once they are washed into the lake, we find that while the water evaporates, runs or is pumped out, the nutrients tend to remain behind in the weeds and algae. This brings us to the most important aspect of the accumulation of nutrients in a lake. When the weeds and algae die and sink to the bottom, this is not the end of the nitrogen and phosphorus they contain. The organic matter is decomposed by bacteria in the bottom muds and most, if not all, the nitrogen and phosphorus is released ready for another cycle of growth. Thus, we can see that if all the nutrients were prevented from entering the lake, it would go on producing a yearly crop of weeds and algae for some time. The obvious question here is how long would this process continue, and we must admit that so far we don't know.

At this point, you might very well be tempted to ask, "What does the Connecticut Agricultural Experiment Station have to do with all this?" The study of lakes is called limnology and we don't have a limnologist on our staff and we certainly don't have a Department of Limnology. What we do have, however, are climatologists who understand the problem of runoff from watershed. Thus, we can evaluate the nutrient contributions from this source. We have plant physiologists who understand how plants grow and therefore can tell us how aquatic weeds grow. We have plant pathologists who understand the mechanisms of herbicides, so they can advise us when we need a weed or algae killer. We have analytical chemists who can analyze the water, weeds, and mud for us, and finally we have soil scientists whose specialty is studying the release of nutrients from soil. Since the bottom of a lake is not much different from a flooded rice paddy or a waterlogged soil, we can expect soil scientists to be able to apply their know-how to the problem.

As a soil chemist, I am working on the chemistry of phosphorus in the bottom sediments. While both nitrogen and phosphorus occur either as soluble compounds in the water, or organic forms in the weeds and algae, phosphorus also forms insoluble precipitates with iron, aluminum, and calcium. In fact, much of the phosphorus stored in the bottom of a lake is in these insoluble inorganic compounds.

I should explain here, that when I say insoluble I mean that when you mix a solution of two chemicals, say iron and phosphorus together, a precipitate forms. However, enough phosphorus remains in solution to support the growth of algae. In fact, the mineral can slowly dissolve to provide a continuous supply of phosphorus for many months. Since these compounds are much like those which are found in soils, we can use the methods of soil chemistry to study them.

We start with a bottom mud sample. We separate out the sand, silt, and clay fractions. Next, using various techniques, we try to identify the various forms of phosphorus. One of these is the mineral apatite. Although it doesn't look it, apatite is the same calcium phosphate mineral which forms the enamel on your teeth. After grinding apatite we can take a picture of it with X rays. The X ray doesn't look like one your dentist takes, but from it we can identify the mineral.

We can also use our soil-testing procedures to measure the available phosphorus in the bottom mud. Finally, we can grow plants in these muds. Once we have learned what forms of phosphorus are available to the weeds and algae, perhaps we can devise treatments to make the phosphorus less available, or to remove it from the mud by harvesting the weeds and algae. In fact, the ways of science are such that some other method, which we haven't even been able to imagine yet, may become apparent when we learn more about the cycling of phosphorus through the mud.

Weeds and algae thrive in some nutrient-rich lakes and ponds.

News Notes

Director James G. Horsfall received the Bronze Medal, highest award of the Federated Garden Clubs of Connecticut, at the annual meeting of that organization in New Haven on October 5. Dr. Richard A. Jaynes, geneticist, received the certificate of achievement in horticulture for his development of hybrid chestnuts.

Dr. William L. George, Jr., has been appointed to the Station staff in Genetics.

Dr. Robert D. Harter, soil chemist, began work in August with Dr. Charles R. Frink on the chemical aspects of lake water and underwater soils as they relate to growth of weeds and algae.

Dr. Saul Rich was installed as president of the Society of Industrial Microbiology at its mid-August meeting in Maryland.

Richard T. Merwin retired from the staff in analytical chemistry on October 1. Mr. Merwin is widely known among official chemists, particularly for his work on drugs in feeds, and on cosmetics.

Contributors

Dr. Stephen W. Hitchcock and Dr. John F. Anderson are entomologists principally concerned with studies of aquatic insects and mosquitoes, respectively.

Dr. Charles R. Frink is a soil chemist studying clays in soils.

Dr. Sven Wihrheim, a native of Austria, is investigating the life cycle and control of the tobacco cyst nematode.

New Publications

The publications listed below have been issued by the Station since you last received FRONTIERS. Address requests for copies to Publications, The Connecticut Agricultural Experiment Station, Box 1106, New Haven, Connecticut 06504.

Entomology

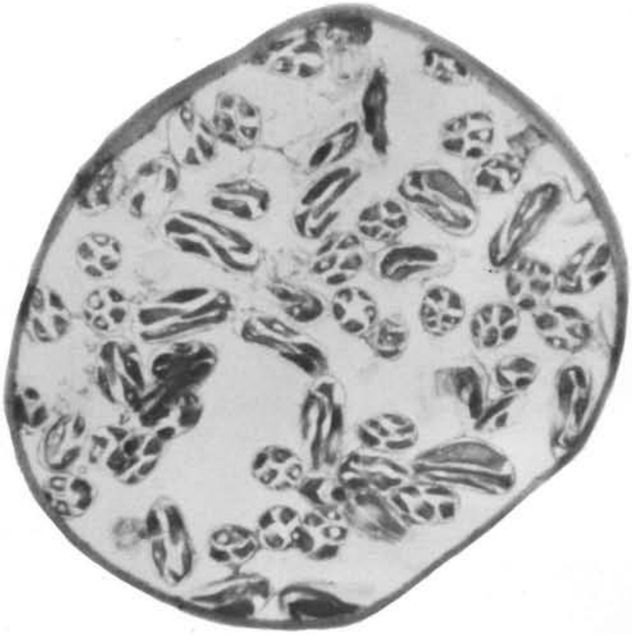
B677 *Biosystematics of the "Leucopterus Complex" of the Genus Blissus.* David E. Leonard.

Soils

B678 *Percolation Testing For Septic Tank Drainage.* David E. Hill.

Report on Inspection

C228 *Commercial Fertilizers, 1965. Part I: Compliance With Guaranties.* H. J. Fisher.



Cross-section of a cyst shows a large number of nematode eggs (in various positions) containing dormant larvae coiled and ready for release.

Chitin Protects Nematode Larvae

Sven E. Wihrheim

NEMATODES are abundant in the soil around the roots of plants. Even though they are among the important forms of life in the root zone, we may be unaware of these tiny, wormlike creatures because of their microscopic size and their protected position in the soil. Nematodes abound in almost any environment, but are dependent on water. So numerous are they that a scientist once remarked, "If all the matter in the universe, except the nematodes, were swept away, our world would still be dimly recognizable; we would find its mountains, hills, valleys, rivers, lakes, and oceans represented by a film of nematodes."

Most soil nematodes live on decaying organic matter and thus play a vital part in soil fertility. However, a small group attacks the roots of plants. These parasitic nematodes are so common that a crop is rarely free of attack. Since nematodes are so very small, many are necessary to harm a plant. Among the root parasites, those in the genus *Heterodera* are unique. Eggs are protected in a cyst that is formed from the body wall of the mother. After her death, this wall toughens, and is resistant to drought, temperature changes, and chemicals.

Examples of these cyst-forming nematodes are the potato, sugarbeet, cereal, and pea cyst nematodes. As a group, they damage crops all over the world. One species occurs in Connecticut: the tobacco cyst nematode. It was introduced, probably from Sumatra.

The tobacco cyst nematode weakens, but usually does not kill the plant. It injures roots directly and soil fungi invade roots through these wounds. Both of these affect the ability of roots to absorb nutrients from the soil.

When tobacco is grown for many years on the same land, populations of the tobacco cyst nematode increase. Their attack on roots causes a reduction in yield. The damage can best be controlled by reducing the number of nematodes in soil. Because the tobacco cyst nematode attacks only tobacco and related plants, one method of reducing the population is by crop rotation. Numbers of nematodes can also be reduced by chemical control, but in tobacco this tends to change leaf quality. Because these methods are not feasible with tobacco, we have studied the biology of the tobacco cyst nematode in order to find the weaknesses in its life cycle.

Eggs and larvae of the tobacco cyst nematode (*Heterodera tabacum* Lownsbery) overwinter in the cyst in the soil. The larvae then emerge and migrate through the soil, stimulated and attracted by tobacco roots. Larvae penetrate the roots and develop into young nematodes. The females soon begin to swell, split the surrounding tissues as they grow, and burst through the root to the outside. The head remains embedded in root tissue. The mature female cysts glisten like white pearls at first, but soon after fertilization, turn brown. From then on, the cyst functions only as an egg container for the numerous young larvae, coiled up inside the egg. The cyst is about 1/50 inch in diameter and is the only stage in the development of the nematode visible without a microscope.

Soil solutions contain some substances that stimulate the cysts, and others that poison them. The tobacco cyst nematode lives in a soil teeming with other microorganisms. These interact with the nematodes themselves and affect their hatching rate. Some microorganisms stimulate and others repress the hatching of the tobacco cyst nematode, as our studies have shown. Such microorganisms probably release chemicals that change the permeability of the cysts. The importance of stimulatory or toxic substances released by microorganisms or produced by other organic substances in the soil has been stressed by the findings of Dr. P. M. Miller of this Station.

He has found that some organic fertilizers reduce nematode infestation of the tobacco plant.

In further studies here, the ability of compounds to penetrate through the cyst wall has been studied by means of autoradiography. This technique is based on incorporating radioactive isotopes into biological material and determining where the radioactivity appears after cysts are exposed. Radioisotopes are detected by placing a photographic emulsion over very thinly sliced sections of cysts and developing the emulsion after it has been exposed for a long time to the radioactivity. In these studies, radioactive phenylalanine passed through young cysts with no hindrance and was found within the egg.

In mature brown cysts, however, although the cyst wall was not so permeable, some radioactive phenylalanine passed through the wall into the liquid surrounding the egg. A smaller amount of the labelled compound passed into the egg, but very little was found within the young larvae, which are coiled up within the egg in their dormant state.

Later studies showed why radioactively labelled compound does not penetrate readily into the egg. Studies on the roundworm *Ascaris lumbracoides* in human medicine have shown that the eggs are covered with chitin, the horny organic compound that is also an important component of the bodies of beetles. In our research a variety of delicate chemical tests on a microscopic scale showed that the skin of the curled young larvae indeed contains chitin.

In another experiment, cysts were exposed to an enzyme that dissolves chitin. After exposure, these cysts showed a 28 per cent increase in permeation of radioactivity into the whole cyst. Apparently then, chitin functions as a barrier within the egg and the cysts. The fully developed young larvae within the eggs are stimulated into moulting and subsequent hatching as these barriers are removed.

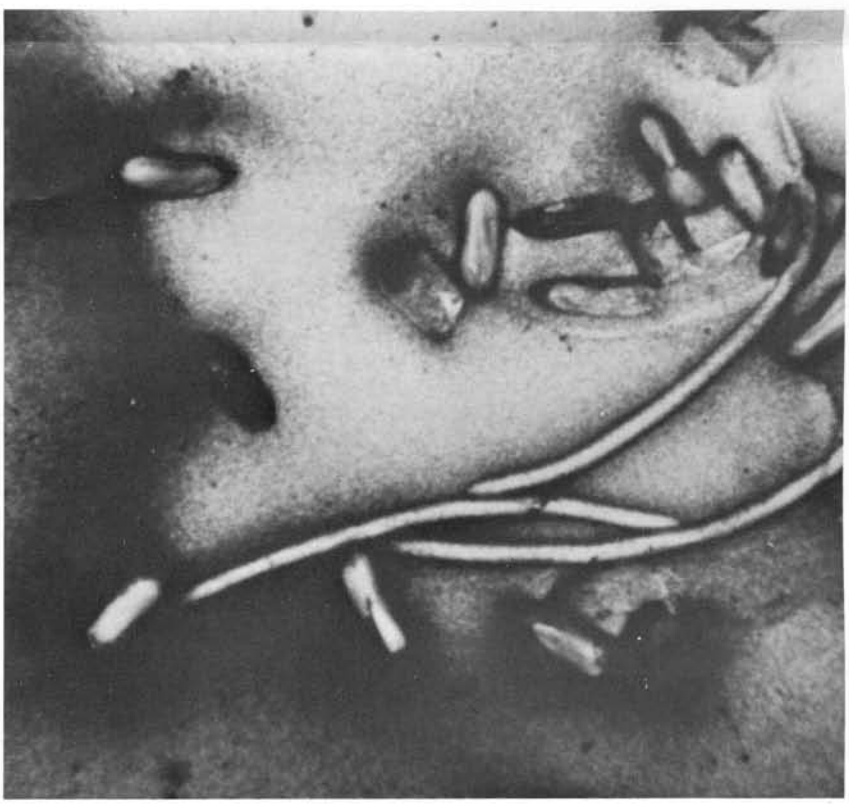
Next, the effect of various compounds on the permeability of the cyst was studied. The nematodical poison DD increased permeation by 60 per cent, whereas a material that stimulates hatching of larvae in cysts decreased permeation by 40 per cent. The first result was expected. A poison usually increases permeation. The result with the hatching promoting agent was unexpected because such a compound should start many enzymatic reactions and make the egg more permeable.

These findings contradict that rule and strengthen the suspicion that young larvae themselves respond to a suitable stimulus. In the head of the larvae of the tobacco cyst nematode is a chemoreceptor, known as the amphid, which responds to stimuli such as these, and the larva breaks through the egg wall with the help of the spear that it uses for penetrating roots.

We learned that behind a fairly permeable cyst wall and eggshell the dormant larva is coiled up. There the young larva is well protected by its chitinous shell, but, on the other hand, its fully developed sensory receiving organism is ready to react. The larva can be compared to a coiled spring and the sensory organism to a receiver which is ready to react, ready to uncoil the spring and send it out toward the origin of transmission.

This trigger reaction occurs whether its source is a plant root transmitting the hatching agent to the larvae, or the agent is released by microorganisms, or is a byproduct of organic materials added to the soil. This ready state of the larva may also make it more vulnerable to toxins released by microorganisms, simply because of the readiness for release.

Organic fertilizers are known to alter both the numbers and kinds of soil microorganisms. The potential value of using such fertilizers to reduce numbers of nematodes in soils is, indeed, a promising area for investigation.



Autoradiograph shows three larvae and several eggs of the tobacco cyst nematode. A radioactively labelled compound (dark areas in the photograph) does not penetrate larvae or eggs readily because they are protected by chitin.

This plastic cylinder, a core sampler, is pushed into the mud. Then the sample is subdivided by plastic blades to keep larvae in sub-samples of known depth.

15 Billion Midges– More or Less

Stephen W. Hitchcock and John F. Anderson

PEOPLE notice insects for many reasons. Some insects, such as butterflies, are pretty to see. Others force their attentions upon us by stinging or biting. Still others are important as pollinators or as vectors of disease. But most insects just *are*. They are all about us but their presence goes unnoticed.

Sometimes inconspicuous and harmless insects become pests, however, when they appear in enormous numbers. Mayflies emerging from the Mississippi River can be so numerous that snow plows are used to clear their dead bodies from bridges. Along lake and bay fronts from the Atlantic to the Pacific and from the lake regions of the North to the swamp areas of the South, non-biting mosquito-like midges have at times occurred in such numbers as to restrict outdoor activities and cause traffic hazards.

Only recently, however, have there been reports of overwhelming populations of midges along shore property in this state. We are interested in the biology of these insects and the reasons for such outbreaks as well as methods that might be used to suppress future outbreaks. The area chosen for study this past summer was South Cove in Old Saybrook where chironomid midges have been troublesome to some residents during the past few summers.

Midges in Old Saybrook belong predominately to the species called *Tendipes atrella* and emerge from the rich muddy bottom of the shallow waters of South Cove near the mouth of the Connecticut River. During late fall and winter, the blood-red larval forms, known as "bloodworms," may burrow deeply into their muddy environment. With the arrival of spring and warmer temperatures, larvae move upwards to the top 1- to 3-inch layer of mud and resume their development toward adulthood. Larvae begin pupating in May and June and soon change into winged midges.

Shortly thereafter, mating occurs and the females deposit from 300 to 600 eggs in a gelatinous matrix that quickly settles to the bottom of the cove. Embryonic development is very rapid, with small larvae hatching within four days. Larval development continues throughout midsummer, and by late summer pupation is soon followed by another swarm of adult midges. Two adult generations a year seem to be the rule, at least in this latitude. The insect overwinters in the bottom of the cove as a larva.

Although adults are the stage that cause nuisances, by far the greater part of the insect's life is passed as a larva. Much of our work this past summer has centered around these juvenile stages. In order to study insects buried in mud below the water, it is necessary either to go down where they are or to bring them up where we are. We have done both. For example, to determine the location and density of larvae within the cove, many collections of mud and larvae were taken with a sampling device called an Ekman dredge. These samples were brought back to the laboratory where they were washed through a series of graded screens to separate the insects from the mud.

Our studies have shown that ap-

Dr. Anderson dredges a sample of mud from a bottomless drum used to make a test area for insecticide studies.

Mrs. Bess Kennedy washes a sample of mud through screens which retain larvae.

proximately 90 per cent of the cove has a soft muddy bottom, a habitat ideally suited for larval growth, as indicated by the numbers of larvae. Upwards of 4,000 larvae per square foot were found.

Using a lower average of 1,000 larvae per square foot, we estimate that in midsummer there were 15,000,000,000 chironomid larvae in the South Cove. This astronomical number takes some meaning when we realize that in these few acres of a single town, there were more than four and one-half times as many of these insects as there are people in the world.

As we studied the biology of this midge, we were particularly struck by the drama that attended its transformation from a juvenile aquatic stage to an aerial adult.

On warm summer evenings just after sunset, pupae begin rising towards the water surface from their burrows in the cove; each one buoyed by a small bubble of air that carries it upward. As hundreds, and thousands, then hundreds of thousands of pupae move towards the surface, minnows flash through the multitude, gorging themselves on the feast. Once at the surface, each pupa makes a series of thrashing pulsations, the pupal skin splits and the adult midge emerges. Within seconds, the midge is on its maiden flight, but is soon back on the water a few yards distant. After a few more short, pilot flights, the midge is airborne and moving with the wind towards the leeward side of the cove. By midnight the emergence has ended, the surface of the water is left covered with innumerable floating pupal skins, and the cove is once more quiet until the next evening when this frantic process of life is repeated.

Once ashore, male midges have a conspicuous habit in common with other related flies. They dance in towering swarms above objects that contrast sharply with the surroundings. These "swarming markers" can be trees, boats, large stones, or even chimneys. Swarming generally occurs about sunrise or just before sunset. When dense, the swarms appear like small tornadoes or wavering streams of smoke and give the illusion, above chimneys, that furnaces are being run in midsummer.

The "air-space" above trees and house tops and the cove proper is not wholly reserved for adult midges. We saw swallows by the hundreds glide and skim through the rising and falling swarms, each one easily picking up an early-morning or late-evening meal. Even though minnows feed on the midge larvae within the cove and swallows abound in the air above, these predators have not reduced the population of midges appreciably.

If natural biotic forces do not keep these midges in check and if citizens feel they ought to be controlled, how then can midge populations be suppressed?

The use of insecticides to control the larvae is a possibility. However, this is the type of habitat in which insecticides may seriously upset existing faunal relationships. We must evaluate such effects very carefully before considering use in this situation.

There are several other possibilities also, such as increasing the salinity of the water, changing the bottom of the cove, or even enhancing the current flow, but these methods are obviously difficult. Perhaps continued study will show a simpler and less expensive way to keep down the numbers of insects.

Hanna Appointed – Dimond Honored

J. Gordon Hanna, formerly research associate at Olin-Mathieson Chemical Corporation in New Haven since 1959, became head of the Department of Analytical Chemistry on August 1. Mr. Hanna was previously on the staff of General Aniline and Film Corporation, Linden, N. J.

He succeeds Dr. Harry J. Fisher, now Chemist Emeritus. Dr. Fisher came to the Station in 1921 and was named department head in 1945.

H. J. Fisher

A. E. Dimond

Dr. A. E. Dimond, head of the Department of Plant Pathology and Botany, was made a Fellow of the American Phytopathological Society at its annual meeting in August. Fellowship is the highest honor awarded by the Society. Dr. Dimond and 10 other plant pathologists from the United States took part in a seminar with Japanese scientists at Gamagori, Japan, late in May.

J. Gordon Hanna

James G. Horsfall
Director

A Renewable Resource

AGRICULTURE is a remarkable industry. It does not destroy the resource that nourishes it. In colonial days Connecticut had some bog iron, some copper, cobalt—even gold! It also had forests and farmlands: resources all. The iron, the copper, and the cobalt are gone. The forests were destroyed to produce the charcoal to smelt the iron and the copper, and while the iron and the copper disappeared, the trees grew back. They could produce more charcoal today to smelt more iron if there were more iron today. The forest is a renewable resource. The iron was not.

Connecticut farmers and farmland fed the millhands that smelted the copper and the iron. The farmers and the farmland still produce. Modern "millhands" still fabricate metals, but the metals come from far away—not from Connecticut. Our farmlands not only continue to produce as they did in Revolutionary times—they do much better. For example, an acre now yields about four times as many bushels of potatoes as then. Here is a renewable resource indeed. Farmland can, in fact, improve with time, as the ancients learned when they let fields lie fallow. Put modern agricultural technology to work on old soils, and they may yield better than ever before.

Barring actual destruction by erosion, even deliberate abuse of farmlands does not necessarily destroy them. The land is renewable. In Illinois, for example, test areas on the old Morrow Plots grew corn, and only corn, for 80 years without application of fertilizer, lime, or manure. During all this time, yields trended downward as corn plants sapped elements from the soil. When lime and commercial fertilizer were then added, corn yields shot up higher than the pristine levels.

Science and technology can restore farmlands but cannot put iron back into the Litchfield hills. The new agriculture, however, has enabled farmers to stay in business on those old hills and to increase their efficiency.

Another example comes to mind. The gold has gone from Central City in Colorado. It is a ghost town. I have seen the open staring eyes of the abandoned mines running back into the hills from the old dirt roads. While Central City was harvesting its gold, Greeley, a few miles away, was harvesting its beans and wheat.

Central City destroyed its means of support and died. Greeley depended on a renewable resource. It lives and prospers.

Agriculture does not exploit its riches. It husbands them. A farmer has been called a husbandman since the beginning of our written history. The fraternal order now known as the Grange still proudly displays its original name—Patrons of Husbandry. Only in recent years have the colleges of agriculture seen fit to change the names of animal and poultry husbandry departments to animal and poultry sciences. Science is now more stylish than husbandry. Husbandry may well suffer.

The people of the world should thank their respective gods that agriculture, being at heart husbandry, does not destroy the great resource that feeds them. In this country, cities and their suburbs may destroy the land that feeds us. Highways may destroy the land that feeds us. Airports may destroy the land that feeds us, but agriculture does not.

Connecticut may some day regret that our houses and industries and supermarkets are in the fertile valleys rather than on the hills where the land is not fertile for food crops. The nation may live to curse the bulldozer, symbol of progress in the 20th century as it covers fertile soil with crushed rock, cellar holes, concrete, and asphalt. Who knows? The nation is still young.

James G. Horsfall

Frontiers of Plant Science

Vol. 19 November 1966 No. 1

FRONTIERS OF PLANT SCIENCE is a report on research of The Connecticut Agricultural Experiment Station Published in May and November. Available to Connecticut citizens upon request.

BRUCE B. MINER, *Editor*