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Frontiers of Plant Science

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THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION NEW HAVEN

Our Tidal Marshes– What Are They Made Of?

David E. Hill
Department of Soil and Water

LITTLE HAS BEEN KNOWN about the organic and inorganic sediments that are the soil of Connecticut wetlands. During the last two years, however, soil scientists at this Experiment Station, in cooperation with the Soil Conservation Service, extended our regular soil survey to a detailed study of the marshes in Connecticut and Rhode Island. We collected samples from many marshes to develop a classification system and to interpret their physical and chemical properties in terms of use. The properties we studied—acidity, salinity, organic matter, thickness of the layers, particle size, and clay minerals—are related to growth of plants, drainage, corrosion of metal and concrete, and strength of the sediment as well as classification.

To digress briefly, other scientists have studied plant and animal life on the marshes and learned how marshes have developed through the ages. Botanists have established that most plant species have a narrow range of salt tolerance and are markedly affected by the constant changes in salt concentration at the surface of the marsh. Biologists studying animals, shellfish, and fish have shown the importance of marshes in the life cycle of many creatures that are essential links in the food chain. Geologists discovered, by radiocarbon dating, that the marshes we know today formed only in the last 2,000 to 3,000 years. But the last glacier finally melted about 11,000 years ago. In the intervening time, 8,000 years or so, most of our marshes did not exist. The areas they now occupy were either above sea level or were open protected bays. Silt and clay, eroded and winnowed from the bottom of Long Island Sound and carried inland by tides, finally settled in these bays. These sediments and the plants that eventually became established on them have gradually built thick deposits because the sea level has risen on the Connecticut shoreline as much as 33 feet in the last 11,000 years.

The properties of these organic and inorganic layers form the framework of our classification system. Essentially, we found four types of marshes in Connecticut and Rhode Island: deep, shallow, and very shallow coastal marshes, and estuarine marshes.

The coastal marshes are segregated by thickness of the peaty surface layer and texture of the underlying mineral layer (Table 1). The salt content of these marshes is greater than 10,000 parts per million, and salt grasses thrive here.

The estuarine marshes that border several of our large rivers and streams have the same range of thickness as the coastal marshes. They are, of course, diluted with fresh water and so less salty. These marshes are inhabited by tall reeds and sedges. Portions of our coastal marshes, now protected by tide

The Shoreline Wetlands

Some 20 years ago, I shared a seat on the New Haven line with a commercial artist who lived on the Maine coast. He went into the city every few weeks, he said, incident to making a living. "That's a long ride," I said, "couldn't you find a place you like on the Sound?" He looked out the window—somewhere between Clinton and New London—at the flatland and the water. "I'll travel a long way," he said, "to live clear of these marshes."

Other people view the tidal marshes differently. Some like to live or summer with ready access to their boat and the Sound. Others make their living from activities that began when men saw where the waters meet the land of Connecticut, and found the littoral good, for their soul, their commerce, and their stomach. And many are concerned as the biological complex of marshlands is irrevocably upset by filling or draining.

To paraphrase Will Rogers, they're not making marshland anymore. So far as we can see, there will be no more in our lifetime. Disregarding the conversion of marshes by man, more acres are being removed by erosion than are being created as the sea slowly rises.

Protection of the public interest in future modification of Connecticut tidal marshes is the purpose of Public Act 695, passed by the General Assembly in 1969. These marshes are defined in the Act by the plants that grow on them. Dr. Hill, a soil scientist, reports here on the properties of the marsh sediments themselves. A more detailed description and map of the tidal marshes of Connecticut and Rhode Island is given in a new Station Bulletin, available as the edition permits, on request to Publications, Box 1106, New Haven 06504. Ask for Bulletin 709.—*Editor* gates, are taking on the appearance of estuarine marshes as salts have progressively leached from their surface since the gates were installed for mosquito control.

We have discovered, by studying the clay minerals in marsh sediments, that the vegetation and chemistry of the marsh has changed as the sea level has risen since the last glacier melted. Vermiculite and illite, two dominant clay minerals in marsh sediments, present a clear geographic pattern. Vermiculite, the most common clay mineral in surface layers of upland soils, dominates the clay in estuarine marshes along our rivers. Its source is eroding land. Illite, the most common clay mineral in our ocean bottoms, dominates the clay in coastal marshes. It comes from the eroded bottom of Long Island Sound.

Changes in chemistry and vegetation throughout their history have been verified at two of our sampling locations at the mouths of the Connecticut River and the Pettaquamscutt in Rhode Island. Vermiculite clay, deposited from fresh water streams when the sea level was much lower, predominates at the base of both marshes. As the sea level rose, tides gradually began to influence deposition, the source of the sediment shifted from land to sea bottom, and illite gained dominance in the sediments at the top of the marsh. Botanists, studying plant remains at the base and surface of the marshes, have discovered that tall reeds and sedges that grow at low salt concentrations gradually yielded to salt-tolerant grasses; further evidence of change produced by the encroaching sea.

Surveys of the physical and chemical properties of marsh sediments predict what happens when we cover them with fill or dredge them and heap them upon the land elsewhere. The peaty surface layers, 4 to 5 feet thick, contain 45 to 73 per cent organic matter (Table 1). The remaining portion is silt and clay trapped by marsh vegetation at high tide. The silty substrata in our deep coastal and estuarine marshes contain little organic matter, but over 95 per cent silt and clay. Only in the shallow and very shallow coastal marshes, mostly east of the Connecticut River, does sandy material lie reasonably near the surface. Sediments rich in organic matter, silt, and clay are weak and unstable, and when drained, shrink and subside.

The chemistry of marsh sediments also changes when they are drained or dried. The pH of peaty or silty sediments rapidly decreases and becomes extremely acid and highly corrosive as sulfides in the sediment are oxidized to sulfates and sulfuric acid. Spoils heaped upon the land remain very acid. If, however, the spoils are alkaline and contain appreciable amounts of shells from former marine life, the carbonates in the shell neutralize much of the acid formed and the pH decreases very little.

It is little wonder that marsh sediments are difficult to work with when disturbed. They are then both physically and chemically unstable. Evidence of this instability abounds along the Connecticut shore.

Tall reeds and sedges thrive near the brackish water of this estuarine marsh in Clinton. *U.S.D.A. Soil Conservation Service photo.*

Table 1. Properties of marsh sediments

Layer	*Depth in feet*	*Acidity* *Initial pH*	*Dried 18 days pH*	*Organic matter %*	*Texture* *Sand %*	*Silt %*	*Clay %*
			Deep coastal				
Peaty surface	0–4	6.5	3.8	45	–	–	–
Silty substrata	4–16	6.5	3.0	10	5	78	17
			Shallow coastal				
Peaty surface	0–4	6.6	4.4	54	–	–	–
Sandy substrata	4–6	–	–	4	78	16	5
			Very shallow coastal				
Peaty surface	0–1	6.2	3.8	55	–	–	–
Sandy substrata	1–3	7.0	3.7	1	95	3	2
			Estuarine				
Peaty surface	0–5	6.1	4.2	73	–	–	–
Silty substrata	5–12	6.6	2.5	21	3	78	19
			Drained spoil				
Peaty	–	3.6	3.6	42	–	–	–
Silt and clay	–	2.2	2.2	12	6	77	17
Silt, clay, and shells	–	7.7	7.0	8	16	65	19

How Plants Trap Ozone

Saul Rich and Harley Tomlinson
Department of Plant Pathology and Botany

THE AIR POLLUTANTS that man produces in such abundance are shared by all living things. Just as the toxic gases sulfur dioxide and ozone enter our lungs, so they also enter the leaves of plants. We know that these gases enter plants because they injure leaves only when the stomata, the tiny breathing pores of leaves, are open and so allow the gases to penetrate. Once inside the leaf, the pollutants are removed from the atmosphere. Is this the only way that plants can remove air pollutants? To answer this question, we investigated how plants remove gaseous pollutants from the air. When we found out, we were able to calculate whether plants can remove enough pollution to benefit us.

In our experiments we studied the uptake of ozone by plants. We chose ozone because it is the air pollutant that most commonly injures leaves of plants in Connecticut. Our apparatus was a plastic box, into which we pumped ozone, with an attached meter that measured the concentration of ozone within the box. When the concentration of the gas reached a predetermined level, we stopped its inflow and measured how quickly the ozone disappeared. The rate of ozone disappearance was measured with the box empty and with plants in the box.

To learn whether ozone must penetrate the leaves to be removed from the atmosphere, we measured ozone depletion by plants with the stomata of their leaves in different stages of openness. We could do this by controlling light, because stomata gradually open in the light and close in the dark.

In some experiments we started with plants that had closed stomata. The plants were placed in the box and exposed to light. The ozone depletion was measured as the stomata opened. Then the experiments were repeated beginning with other plants that had open stomata. These plants were placed in the box, the lights were turned off, and again ozone depletion was measured as the stomata closed. Each time we measured ozone uptake, we also measured the openness of the stomatal pores with a diffusion porometer.

We learned that bean plants with closed stomata remove very little ozone, and hence, the outside surface of bean leaves does not destroy much ozone. The ozone must enter through stomata to be removed from the atmosphere. More precisely, we learned that the rate of ozone removal by leaves is regulated primarily by the size of the stomatal opening. The larger the stomatal opening, the faster the uptake. These experiments gave us a measure of how much ozone could be removed from a polluted atmosphere by each square inch of leaf surface.

Stomata are open during the day when the foliage is exposed to light. This means that the capacity of plants to remove ozone is greatest during the day. Fortunately, the greatest concentration of ozone at ground level also occurs during the daytime. Most ozone at ground level is generated by the action of sunlight on other pollutants, mainly from automobile exhausts. Once the sun sets, no more ozone is generated, and what ozone remains usually disappears rapidly. In Connecticut, plant damaging concentrations of ozone are rarely detected during the summer much earlier than 10 a.m. or later than 9 p.m. So the time that we are most likely to have our air polluted by ozone is the very time that plants would have open stomata and be most efficient as air scrubbers.

We measured the effect of stomata on ozone with Paul E. Waggoner, chief climatologist at the Station. The results suggested to him that the factors regulating the uptake of ozone are the same as those that control the loss of water vapor and uptake of carbon dioxide by leaves. Recently, Dr. Waggoner and his colleagues have devised mathematical models and used computers to predict how rapidly water vapor is lost by transpiring forests. With our laboratory data, he was able to compute how effectively forest canopies could cleanse ozone from a polluted air mass.

Our laboratory studies and subsequent computer analysis showed that plants can remove enough ozone from the air to benefit us. For example, we studied what happens when a mass of polluted air containing 150 parts of ozone per billion parts of air (ppb) passes over a forest of trees 15 feet tall. We chose

150 ppb of ozone as the concentration in the polluted air because this is what we find in the air of Connecticut on a fairly polluted day. The computer analysis told us that if such an air mass stood over the forest for one hour, the air filtering down to the forest floor would have only 60 to 90 ppb of ozone remaining. The rest would have been taken up by the canopy of leaves. If the polluted air mass stood over the forest for 8 hours, the air filtering down to the forest floor would have only 30 ppb of ozone left.

These studies told us other things. For instance, taller trees would remove more pollution than would shorter trees. The larger the stomatal pores and the more numerous the stomata per square inch of leaf surface, the more effective are the leaves in removing ozone from the air. If we were intending to use plants as air purifiers, such information could guide us in our selection of plants.

Some plants that are damaged by air pollutants lose part of their natural capacity as air purifiers. Further, not all mechanisms of smog resistance improve the ability of plants to clean air. For example, the ozone-resistant onion developed by scientists at the University of Wisconsin resists ozone because its stomata closes when the plants are exposed to ozone. We know now that plants having this type of resistance would remove little ozone from polluted air. It is important then that when we seek plants that resist our pollutants, we try to find plants that clean the air as well.

Our experiments were limited to the cleansing of ozone from the atmosphere by plants. But the same kinds of studies can be done with other pollutants. In fact, British scientists have already observed that leaves absorb more sulfur dioxide when their stomata are open instead of closed.

It is satisfying to learn that the plants that we like because they make the hills green are cleansing our air. And it is important to discover and develop the kinds of vegetation that cleanse most effectively.

August 12
Plant Science Day

Long before the dawn of the age of ecology, the Station began to study various aspects of the Connecticut environment—and to report the results of this research through the written and spoken word, field meetings, and otherwise.

Plant Science Day is one of the opportunities Connecticut citizens have to see for themselves how the staff undertakes field research, and to learn of other investigations in progress. Dr. Lester Hankin is general chairman for the Plant Science Day to be held at Lockwood Farm in Hamden on August 12.

How Crops Grow—
a Century Later

Eleven distinguished scientists give their views on plant science and related fields in a new book published by the Station. The papers included in the book were given at the Station a year ago as a series of lectures commemorating the publication in 1868 of "How Crops Grow," an agricultural classic by Professor Samuel W. Johnson. He was an early advocate of public support for scientific research, and director of this Station from 1877 to 1900.

In the new book, "How Crops Grow—a Century Later," Director James G. Horsfall writes on Johnson as a student and salesman of science. Dr. Hubert B. Vickery, biochemist emeritus at the Station, reviews Johnson's career as a scientist and teacher.

Other contributors are Dr. F. C. Steward, Cornell University; Dr. Paul J. Kramer, Duke University; Dr. Martin Gibbs, Brandeis University; Dr. O. E. Nelson, Jr., Purdue University; Dr. Sterling B. Hendricks, U. S. Department of Agriculture; Dr. Harold J. Evans, Oregon State University; Dr. Arthur Kelman, University of Wisconsin; Dr. Perry L. Adkisson, Texas A & M University, and Dr. Leland J. Haworth. Dr. Peter R. Day, head of the Station Department of Genetics, edited the papers.

Copies of the book, Bulletin 708, are available. (See *New Publications*, page 7.)

Head New Departments

Charles R. Frink

Paul E. Waggoner

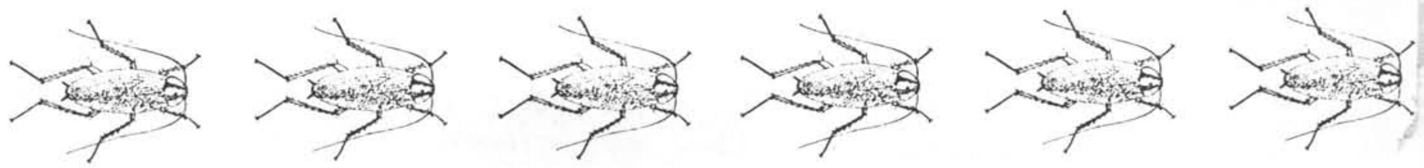
The Station staff conducting research in ecology, soils, and related subjects has been reorganized into two new departments. The Board of Control selected Dr. Charles R. Frink to head the Department of Soil and Water and Dr. Paul E. Waggoner to head the Department of Ecology and Climatology.

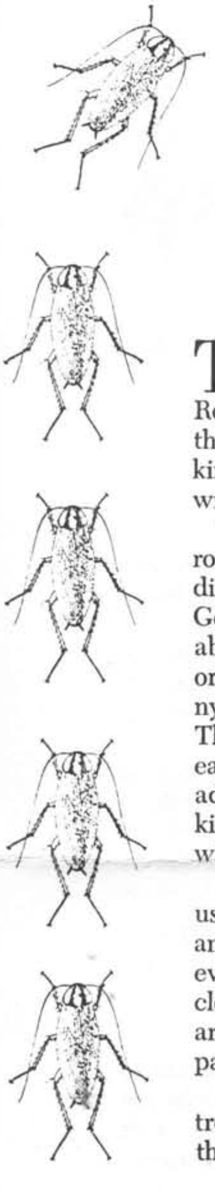
Dr. Frink came to the Station in 1960 after receiving the doctorate at Cornell University. An authority on the chemistry of soils, he is presently investigating the nutrient balance in Connecticut lakes and rivers, and the recycling of nutrients on farms.

Dr. Waggoner, who is also vice director of the Station, has been on the staff for 19 years. His investigations have concerned the climate of shade, protection of plants from the cold, principles of mulching with plastics, water conservation through manipulation of stomata, and microclimates in plant communities. He received his doctorate from Iowa State University.

The Cover Photo

The Oyster River meanders southward and joins the westward flowing Back River as both enter Long Island Sound at Old Saybrook. These rivers drain about 425 acres of tidal marsh now virtually encompassed by residences and commerce. At the right, North and South Coves of the Connecticut River are also surrounded by some 250 acres of salt marsh. *Photo by Keystone Flying Service.*





At Home in Connecticut

The Wily Cockroach

Richard C. Moore
Department of Entomology

THE COCKROACH is probably the oldest winged insect, dating back more than 300 million years. Roaches originated in the tropics, and have spread throughout the world. Of the more than 5,000 known kinds of roaches, only a dozen or so are associated with man and his way of life.

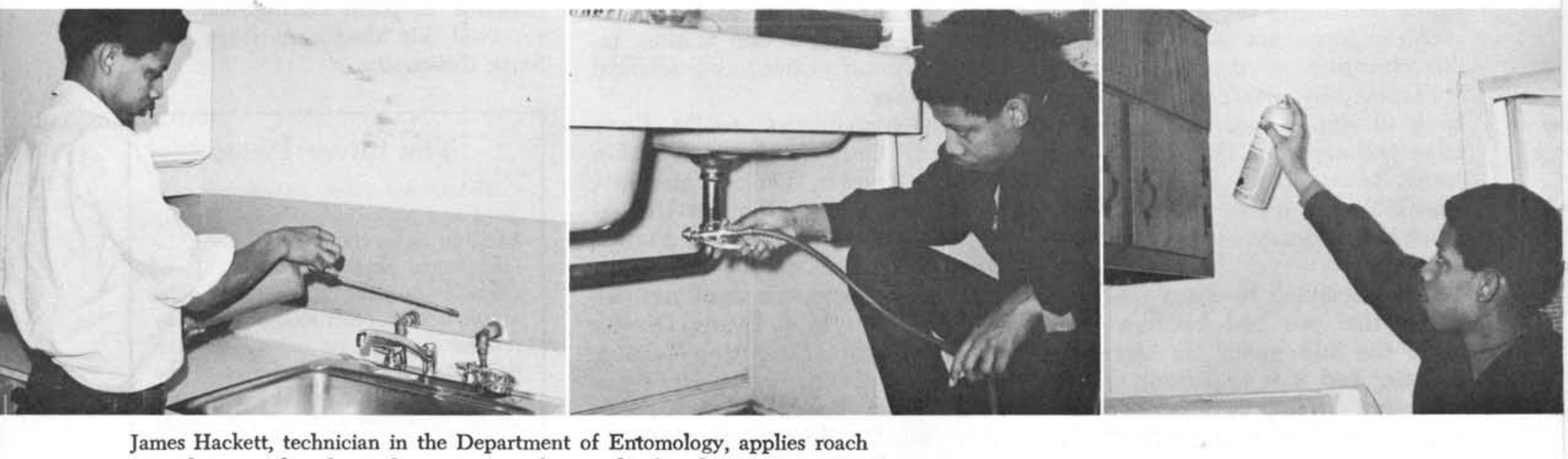
The German cockroach is the most important cockroach in Connecticut and is becoming increasingly difficult to control, especially in cities. The female German roach carries her egg capsule attached to her abdomen for about a month, and then drops it a day or two before the eggs are ready to hatch. About 30 nymphs hatch from the eggs in the leathery capsule. The nymphs go through four feeding stages. After each stage they shed their skin, finally emerging as adults. Since they reproduce much faster than other kinds of roaches, large populations can build up within several months.

The German roach eats almost all the kinds of food used by man. It is usually found in kitchens, pantries, and bathrooms. In heavily infested dwellings, however, roaches may be found in furniture, in clothes closets, and in pictures or books. Roaches in these areas can feed on crumbs, clothing, bookbindings, paper, and glue.

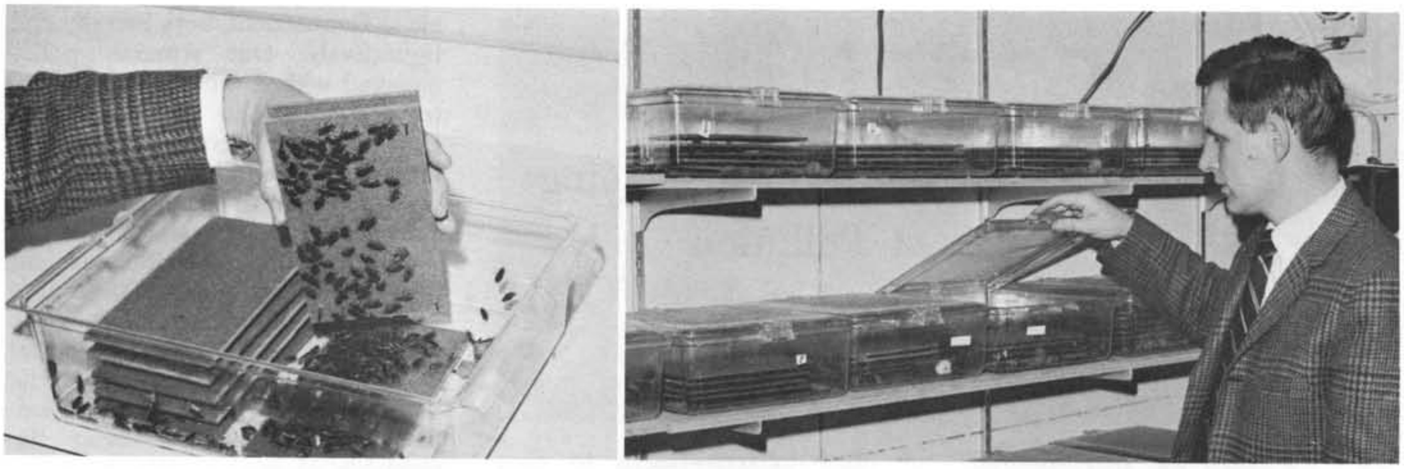
The control method generally used today is "spot treatment," that is, insecticides are applied to out-of-the-way areas normally used as harborages and breeding places; sprays are applied to baseboards and to other routes of travel normally used by the cockroaches when looking for food. Monthly and sometimes weekly treatments are applied because of the relatively short residual effectiveness of some of the commonly used insecticides. Many apartment houses are treated on a complaint basis, which means only some of the units in a building are treated regularly, and only a small part of a building is treated. This gives the surviving roaches an opportunity to move into untreated areas. This method is costly when treating a large number of dwelling units and may be ineffective in controlling this roach.

Good results were obtained in controlling the German cockroach during the years before they developed insecticidal resistance to chlordane. Some of the currently used insecticides are much more toxic than chlordane but have shorter residual activity. Dr. Walter Ebling, entomologist at the University of California, finds that many good insecticides repel roaches and thus are not effective roach killers. His recent research has shown that boric acid, a weak insecticide, is more effective than some powerful ones because it is only slightly repellent. Boric acid is a stomach poison, ingested as the roach cleans itself.

Various baits can be used to lure the roaches to a toxicant. To control German cockroaches, baits must be placed in all areas where the insects run. Com-



James Hackett, technician in the Department of Entomology, applies roach control materials where the pests are frequently found in apartments.



At left, a cockroach "apartment house" used at the Station for rearing cockroaches used for control experiments. At right, Mr. Moore and an array of cockroach-rearing containers.

binations of dusts or baits with sprays can be very effective if all apartments in a building are treated. The problems we have with this roach are a rapid reproduction rate and high adaptability, plus the repellency of some commonly used insecticides, plus the development of insecticidal resistance. All contribute to the difficulties of control. Accessibility, cost, and sanitation problems are other major considerations if all dwelling units in a housing project or an apartment building are to be treated periodically.

I have sought to develop an inexpensive and safe method to control this pest insect for 3 months or longer following the initial treatment. To achieve this goal, I have tested insecticidal sprays combined with dusts or baits. The sprays are first applied to the surfaces in an apartment where a dust or bait would not adhere, or would be unsightly. The dust or bait is then applied in small amounts to cracks and crevices, underneath and behind appliances, in corners of cabinet shelves, and in other areas where roaches are found. Emphasis is placed on treating all apartments in a building regardless of the infestation level. This prevents roaches from moving into previously uninfested apartments while controlling them in infested apartments.

I have worked in several public housing apartment buildings in New Haven, and I am grateful to the residents for their help and cooperation. The treatments were evaluated by using a flushing spray and comparing the number of roaches flushed immediately before treatment with those flushed at 1-month intervals after treatment. One of the treatments tested was the use of a pyrethrin aerosol bomb spray followed by dusting with boric acid powder. Other treatments used were Baygon® insecticidal spray followed by applications of either boric acid powder or Baygon® 2% roach bait. The boric acid powder was screened through a flour sifter and in some tests a small amount of Cab-O-Sil® was added as an anti-caking agent to prevent clumping. The bait used was formulated as "crevice-size" particles. Both bait and powder could easily be applied with a small hand duster. One advantage of using the pyrethrin aerosol is that little or nothing had to be removed before treating. Both Baygon and pyrethrin sprays are repellent to the German roach, so they may learn to avoid surfaces treated with these insecticides. Roaches not killed by direct contact with these materials will succumb, however, when they invade areas treated with the dust or bait.

Using these materials I found that combination of pyrethrin aerosol spray-boric acid powder, Baygon spray-boric acid, and Baygon spray-Baygon bait controlled German cockroaches for 1 month in all apartments where tests were conducted, and in most apartments for 3 months. Pyrethrin aerosol or Baygon spray combined with boric acid powder plus Cab-O-Sil controlled this roach in the majority of apartments for 3 months.

Many of my tests are made in cooperation with the New Haven Health Department and the New Haven Housing Authority as part of a demonstration program to control cockroaches in New Haven public housing. To these authorities I express my thanks.

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.

Soil Science

B 706 *The Charlton Soils.* D. E. Hill and A. E. Shearin.

Ecology

B 707 *The Forests Anticipated from 40 Years of Natural Transitions in Mixed Hardwoods.* G. R. Stephens and P. E. Waggoner.

B 709 *Tidal Marshes of Connecticut and Rhode Island.* D. E. Hill and A. E. Shearin.

C 232 *DDT in Fish.* Neely Turner.

Science, Society, and Agriculture

B 708 *How Plants Grow—A Century Later.* Edited by P. R. Day.

Entomology

B 710 *Control of Scale Insects and Mealybugs on Ornamentals.* J. C. Schread.

Plants Gave Early Warning of Pollution

James G. Horsfall
Director

As I scribbled the first editorial for *Frontiers of Plant Science* in 1948, the awesome explosion of the population had already begun with a great surge of post-war births. By now we can all see the effects as crowding of the people, crowding of cars on the roads in the cities, crowding of smog particles in the air, crowding of algae in our lakes.

Even as the ink was drying on my essay, the plants of Connecticut were telling us that things were going awry. It was in that very year that green scum in Lake Zoar clung to swimmers, while the rooted plants fouled the propellers of their boats. Eutrophication had set in at Lake Zoar, and the word, algae, entered the householders' lexicon.

Eutrophication is a monstrous word to describe the death throes of a lake mortally wounded by the phosphates and nitrates from the wastes of man. However monstrous the word, at the Station we had to set out on the road to solve the problems, and so we began our research on eutrophication in 1948.

A year or so later, as the population explosion engulfed still more of the environment, another kind of plant—tobacco—began to complain at our Laboratory in Windsor. We now know that those tobacco plants were telling us that smog had arrived in Connecticut by 1950. The citizens didn't yet know it, but the tobacco plants did. Whereupon we began research in air pollution.

At first, we did not know it was air pollution. We saw a new disease and named it weather fleck. Benefitting from the wonderful wisdom of hindsight, we now know that we should have called it just fleck, because the weather as provided by God had not really changed that much. Man had changed the weather, not God.

Hartford, where weather commentators Mark Twain and Charles Dudley Warner once lived, had picked up their challenge. Its citizens were no longer just talking about the weather. They were doing something about it. Through the flatulence of their cars and the belching of their stacks they were pouring tons of filth into the air, and changing the weather in the nearby tobacco valley. The plants were clearly complaining.

Thus, there were changes in the air of Connecticut, both literally and figuratively. Our research policy changed with it. The Board of Control moved first in 1956 to set up a Department of Climatology. My editorial for the fall issue that year discussed the new department.

Into this department went all of the ecological research that we had been doing for more than a half century. Now, with this new issue of *Frontiers*, the Board of Control announces that ecology enters the name of a new Department—Ecology and Climatology—under the chiefship of Paul E. Waggoner.

The intensification of eutrophication demands that our work on soils and water be harnessed together, and so the Board of Control also announces the creation of a new Department called Soil and Water, under the chairmanship of Charles R. Frink.

These changes in structure recognize the high priority that the Station Board of Control gives to useful, imaginative research on the environment that is our heritage.

We ask that the scientists in these two departments help us find ways to keep from going over the hill to the poorhouse—ecologically speaking, of course.

A Note to Readers

When you move, or if your address shown below is incorrect, please notify the editor, giving both your old and new Zip Code numbers. If you no longer wish to receive this publication, please let us know.

We always welcome your comments.

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Bruce B. Miner, *Editor*

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Director

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