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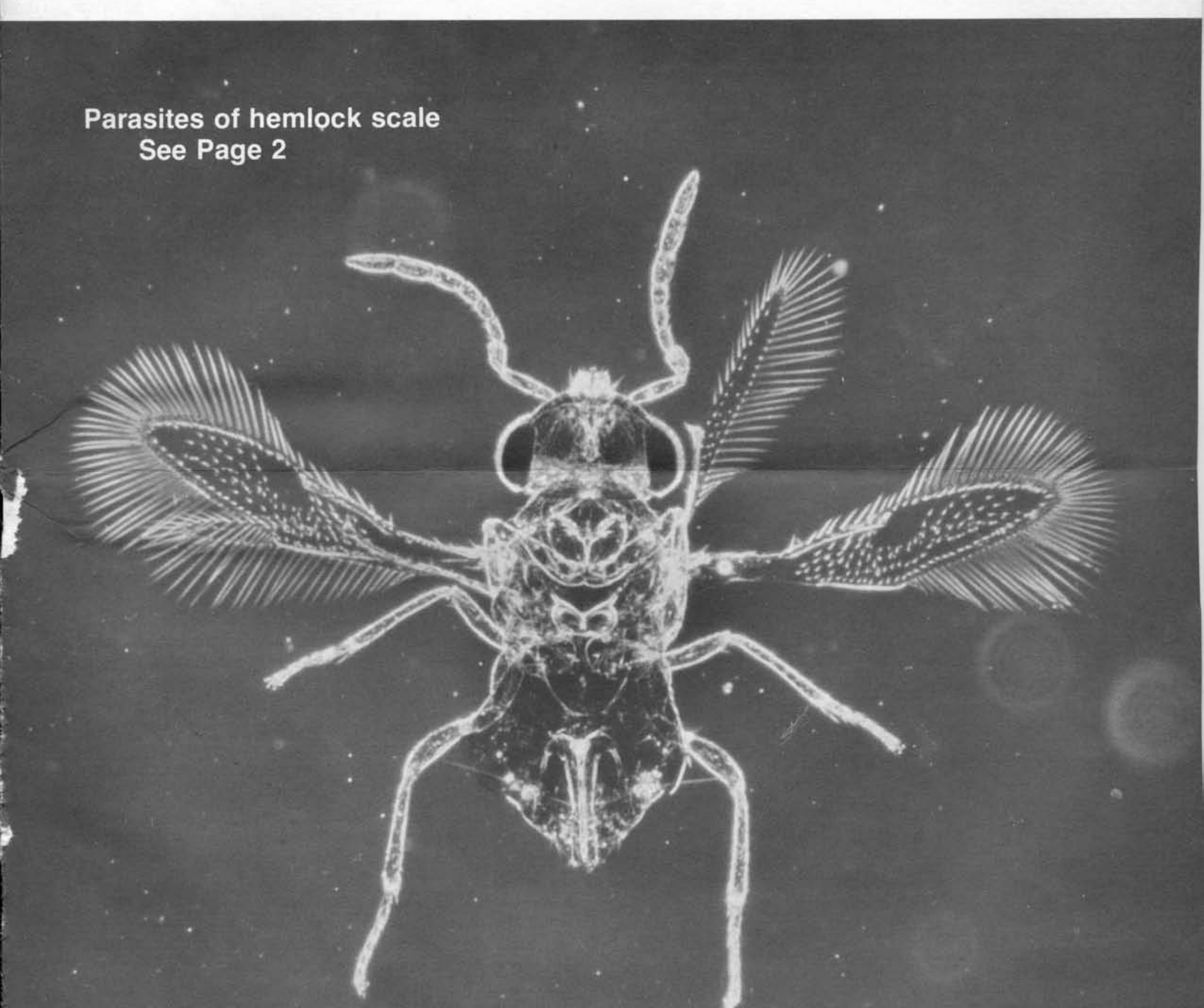

Photomicrograph by Michael Fergione

THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION NEW HAVEN

Two parasitic wasps have potential for controlling hemlock scales

By Mark S. McClure

Our hemlock forests in southwestern Connecticut are being threatened by two tiny sap-feeding insects which belong to the group known as scales. For most of their lives they remain motionless beneath waxy, shield-like coverings which give infested hemlock foliage a scaly appearance.

Despite the minute size of these scales, their threat to our Eastern hemlock, *Tsuga canadensis*, is as frightening as the names they bear: *Fiorinia externa* and *Tsugaspidiotus tsugae*. They arrived from Japan some 70 years ago on evergreens shipped to New York and New Jersey and now occur in several Northeastern states. Both species colonize the undersides of the needles (Fig. 1). Their feeding can cause reduced growth, discoloration and loss of needles, and death of trees within 10 years where infestations are severe.

Last winter Michael Fergione and I surveyed the infestation in Connecticut. We began in Fairfield County where infestations seemed to be heaviest. We sampled forest and ornamental hemlocks at 279 sites at approximately 1 mile intervals along roadways in 31 towns in Fairfield and New Haven Counties. Aided by a microscope, we determined the kinds and numbers of scales occurring on 200 young needles on the two branches sampled.

The heaviest infestations were in the five southwesternmost towns of Fairfield County where we found no uninfested sites among the 49 sampled (Fig. 2). In Greenwich, the most heavily infested town, trees at 15 of the 18 sites were severely attacked. Infestations were generally less severe in towns to the northeast of

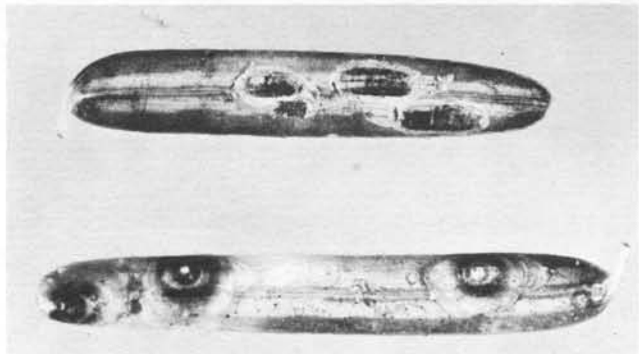

Fig. 1. Adult Females of *Fiorinia externa* (top) and *Tsugaspidiotus tsugae* (bottom) feeding on the undersides of hemlock needles.

The wasp concentrates on branches and on trees where scale densities are highest and intensifies its attack as populations build

Greenwich. One exception is an isolated heavy infestation of *F. externa* in a residential area of New Haven where the scale was probably introduced on infested plantings.

The location of The Montgomery Pinetum in Cos Cob and The Bartlett Arboretum in Stamford within the most heavily infested area of Fairfield County provided a rare opportunity for determining the susceptibility to attack by hemlock scales of numerous native and exotic evergreens. Our examination of 50 species of conifers at these parks revealed that the scales were able to colonize and mature on 9 species of fir, 3 of cedar, 12 of spruce, 12 of pine, 2 of yew, 4 of hemlock, and on Douglas fir. Extensive discoloration and loss of needles occurred only on hemlocks where scale densities were high. The lower scale densities on the other evergreens likely indicate resistance. However, some scales were able to mature and reproduce on these trees. This suggests that in time races of scale may develop which could become more serious pests of these now resistant evergreens.

I learned from studies of scale dispersal that crawlers, the tiny wingless juveniles which hatch from the egg, can be carried alive for considerable distances by the wind. I used 3×2 inch glass slides coated with silicone grease to monitor airborne crawlers around an infested hemlock grove in Westport. Following the 28-day trapping period, microscopic examination of the slides revealed that these potential colonists are carried for at least 105 meters and primarily in the direction of the prevailing wind. Wind has most likely been responsible for the slow but relentless spread of hemlock scales into southwestern Connecticut from New York and New Jersey.

I have found that excellent control of *Fiorinia* hemlock scale can be achieved using dimethoate or acephate as a foliar drench during peak abundance of crawlers (mid-June and mid-September in Connecticut). However, I have also found that in spraying large trees (greater than 12 meters in height) or forest trees, complete coverage of the foliage is extremely difficult to attain. Incomplete coverage allows some scales to survive but completely eliminates natural enemies. Consequently, the surviving scales flourish and in-with that of the vulnerable stage of *T. tsugae*, but less so for *F. externa*. Therefore, in Connecticut *A. citrinus* likely has a greater potential for biological control of *T. tsugae*.

The adult wasp lays one of its 60 to 70 eggs into an immature scale. The young wasp developing within (Fig. 3) prevents the scale from reproducing and eventually kills it. Unparasitized females of *F. externa* on the average lay 13 eggs and those of *T. tsugae* lay 52 eggs during their lifetimes. These data indicate that the scale population will not increase if the mortality rate is roughly 86% for *F. externa* and 96% for *T. tsugae* during each generation. I have found that *A. citrinus* parasitizes more than 50% of both scales in some areas of Connecticut and as many as 96% in some others. At Westport, percent parasitism of *F. externa* more than doubled in a year, increasing from 29% in May 1976 to 61% in May 1977. I also found that the wasp concentrates on branches and on trees where scale densities are highest and intensifies its attack as scale populations build from generation to generation. This increasing parasitism as scale density increases is a desirable quality of a biological control agent.

Because protection of our hemlock forests from scale insects may well depend upon the success of biological control, I am continuing my research to determine the most effective means of using parasitic wasps to battle hemlock scales.

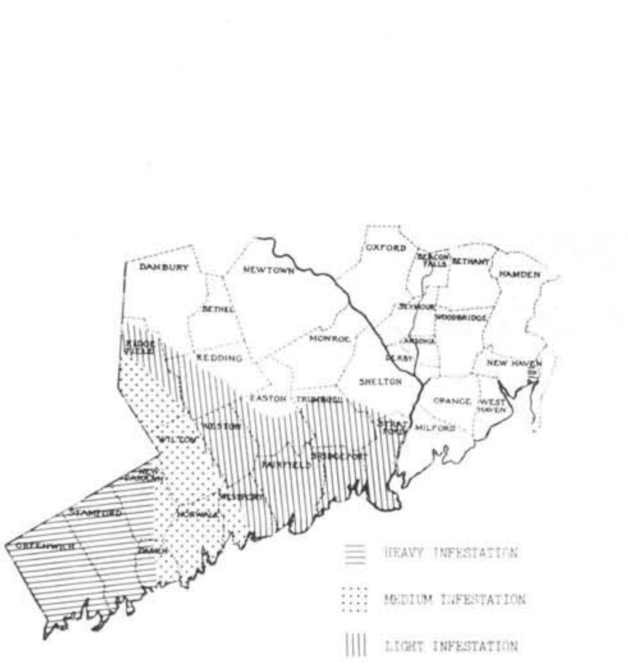

Fig. 2. Extent of the hemlock scale infestation in Connecticut. The *Fiorinia* scale is also found in one area of New Haven, 20 miles from the limits of the general infestation.

crease to population densities that even exceed those on unsprayed trees. Therefore, decisions to apply insecticides should be made judiciously, especially in forests where scale populations may resurge due to incomplete spray coverage.

I sought natural enemies of the scales throughout southern Connecticut. I collected predators on a white sheet held below infested branches, which I beat with a stick. Several spiders, two predaceous mirid bugs, a coniopterygid or a dusty wing, and the twicestabbed lady beetle were common in many infestations. However, there were not enough of them to significantly reduce scale populations. To survey for parasites of scales, I placed infested foliage in sealed cardboard tubes fitted with glass vials. Adult parasites are attracted to light when they emerge from scales, so they enter the vials where they can be collected, identified, and counted. Using this technique I found a small parasitic wasp called *Aspidiotiphagus citrinus* prevalent in hemlock scale infestations. Adults of this delicate wasp (cover), all of which are females, are smaller than the head of a pin. Another small wasp, *Aphytis* nr. *aonidiae*, also attacks hemlock scales in Connecticut but is less important in controlling the scale.

My recent studies have concentrated on evaluating the potential of *A. citrinus* to regulate scale populations. I am collecting scales and their parasites from infested hemlocks at several locations in Connecticut each week.

I illuminate needles and attached scales from below and observe the parasites with a dissecting microscope. This procedure allows me to monitor survival and development of the scale and wasp and determine the compatibility of their life cycles.

In Connecticut *F. externa* has one plus a partial second generation each year while *T. tsugae* has two complete generations each year. The parasite also has two complete generations each year on both scales. Peak abundance of adult wasps is well synchronized

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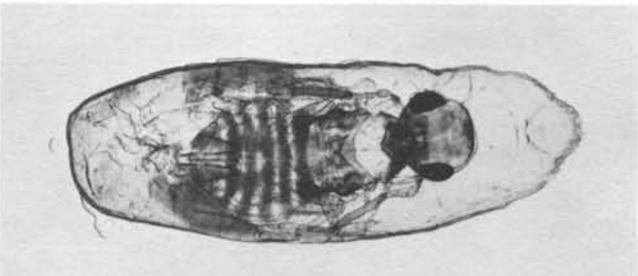

Fig. 3. Pupa of the hemlock scale parasite, *Aspidiotiphagus citrinus*. Note the similarities between the pupa and the adult, which is shown on the cover.

Collecting ticks and searching for tick-borne diseases in Connecticut

By Louis A. Magnarelli and John F. Anderson

We have found spotted fever-group organisms in less than 1% of the 3,000 ticks examined

TICK-BORNE DISEASES—Rocky Mountain spotted fever (RMSF) and babesiosis—have been reported in nearby states; 5 cases of RMSF are thought to have originated in Connecticut since 1965, but no cases of babesiosis are documented. The occurrence of these diseases in the Northeast and the presence of ticks in Connecticut which are able to spread the rickettsia that causes RMSF and the protozoan that causes babesiosis have led us to a study of ticks. These studies are being carried out in collaboration with scientists of the U.S. Public Health Service in Hamilton, Montana.

Last year, 77 percent of the 1,115 human cases of RMSF reported in the United States were on the East Coast. Eleven of these cases were in New England, and 41 were from Long Island.

Babesiosis is a disease of rodents that has been receiving increasing attention in recent years because humans were infected on Nantucket Island. This disease also occurs on Cape Cod and on Long Island.

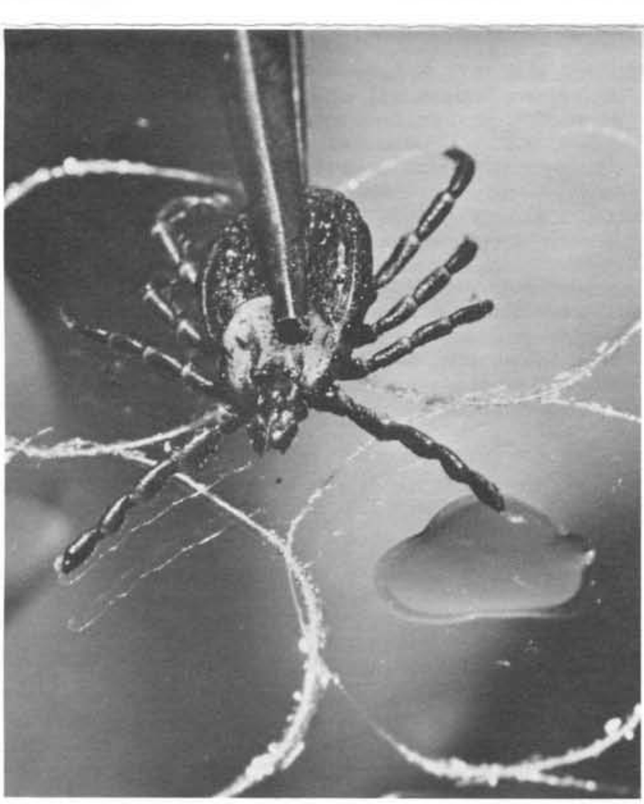

Fig. 1. Collecting a blood sample from a female *Dermacentor variabilis* for laboratory examination.

Our first task in the surveillance of spotted-fever rickettsia and babesia was to determine the distribution and relative abundance of ticks in Connecticut. We have captured ticks by using carbon dioxide-baited traps (which simulate the carbon dioxide given off by animals), by removing them from wild mammals, and by dragging flannel cloth over vegetation. Ticks grab the flannel as they would a moving host. We have also received ticks from Department of Environmental Protection staff, health officials, and the general public.

We have found 10 tick species on white-footed mice, redback voles, raccoons, opossums, skunks, squirrels, woodchucks, beaver, porcupine, dogs, cats, deer, horses, or humans. Ticks are more readily spotted on the shoulders, ears, eyelids, and around the mouth of wild animals, but are found on other body regions as well.

Dermacentor variabilis, the chief vector of the rickettsial agents that cause RMSF, is one of the more abundant species. Adults are found throughout most of the state from April through late August. *Ixodes scapularis*, a tick which transmits babesia, is not as widely distributed, but is abundant from March through December in some areas of southern Connecticut. Both of these ticks bite man and dogs as well as a variety of wild and domestic animals.

Ticks require blood from vertebrate animals to successfully complete their life cycles. However, they can live for extended periods on fats stored in their bodies if suitable hosts are not available.

The life cycle of the American dog tick, *D. variabilis*, is an example of the complex life cycles of ticks. The females lay eggs on soil in grassy fields or near woodlands. The six-legged larvae that emerge live near rodent runways until they find suitable hosts. When a larva encounters a host, it clings to the fur, and then crawls to a suitable place to imbed its mouthparts. After it has acquired sufficient amounts of blood, the larva drops from the host and molts to a nymph.

A nymph is larger than a larva, and it has eight legs. It also lives near rodents and feeds on their blood. After the nymph is engorged, it will drop from the host and transform into an adult. The adults seek larger mammalian hosts, upon which they feed and

Fig. 2. An engorged tick on a raccoon ear.

mate. They rest on tips of vegetation at roadsides and along trails waiting for raccoons, opossums, dogs, or similar hosts. Ticks will cling to the hosts as they move past and imbed their mouthparts into the host's skin to feed. When a female tick has obtained sufficient blood to nourish her eggs, she drops off the host, and after a few days, she may deposit as many as 15,000 eggs. Upon the completion of the egg laying process, the female tick dies. Since mature *D. variabilis* prefer medium to large-sized hosts, it is the adult tick which people encounter on their pets or on visits to tick-infested areas.

RMSF can be transmitted from infected female adult ticks to offspring through the eggs, and the rickettsia can be passed through the larval and nymphal stages to the adult stage. An uninfected tick can acquire the rickettsia by feeding from an infected animal.

In a typical test for spotted fever-group organisms, we amputate a portion of the tick's leg and place a drop of its clear blood in a predesignated area on a glass slide (Fig. 1). The slide is stained with two types of dye and examined under a microscope. If we see rickettsiae in the blood cells, we remove more tissues. These tissues are stained with a specific antibody which will fluoresce (when viewed under special lighting) if spotted fever-group rickettsiae are present. Tests on laboratory mice are needed to tell us if the rickettsiae are of the type that can infect man.

We found spotted fever-group rickettsiae in less than 1% of the 3,000 ticks examined. Because we have been unable to isolate these organisms from mice, we are unable to conclude that the rickettsiae are infectious to man. None of the ticks mailed to us by citizens were found infected with rickettsial organisms.

We are supplementing these tests with examinations of blood from wild animals because antibodies form in the blood of those exposed to rickettsial organisms. We have used an agglutination test to detect antibodies in blood from 1,110 wild mammals. In this test, a drop of the animal's serum is diluted with a buffer solution and combined with a highly purified antigen. If a granular precipitate known as an agglutinin forms, antibodies are present. We have found antibodies in 16% of the raccoons, about 3% of the deer, 2% of the mice, and 1 out of the 2 squirrels tested.

To determine the incidence of babesia infection in rodents, we collected blood from white-footed mice from all parts of the state. Some blood samples were inoculated into hamsters, while others were prepared for direct microscopic viewing. Examinations of blood smears prepared from the hamsters at weekly intervals and from wild mice showed no evidence of infection. However, we found antibodies to babesia in blood of some of the mice. We have concluded from these findings that babesia is present but rare in Connecticut.

As with babesia, the RMSF organism does not appear to be prevalent in Connecticut. The low number of infected ticks, the sparsity of human cases, and the small number of wild mammals with antibodies in their blood suggest that the incidence of RMSF in Connecticut is very low compared to the levels of infection in Long Island.

Fig. 3. An adult *D. variabilis* hanging onto a blade of grass awaiting a vertebrate host.

Food production in Connecticut

By Charles R. Frink

Connecticut farmers produced food equivalent to 21.8% of that eaten in 1974 by the 3 million people of Connecticut.

THE CONCERN OF CONNECTICUT CITIZENS for the future of our food supply is reflected in recent studies of the need for agricultural land in our state. Central to this concern is the question of how much food we actually produce. I have attempted to answer this question in two ways: first, by examining the pounds of food produced and consumed as reported in the most recent Census of Agriculture (1974), and second, by analyzing our expenditures for food. I have also examined trends in food production in Connecticut during the past 25 years.

The 1974 Census of Agriculture and the annual series entitled *Agricultural Statistics* provide the basis for Table 1 on food grown and eaten in Connecticut. Connecticut's citizens were assumed to consume food at the national rate, and the population was taken as 3 million.

Despite their present adversities of expensive fuel costs, expensive freight rates, and expensive land, Connecticut farmers produced food equivalent to 21.8% of that eaten in 1974 by the 3 million people of Connecticut. Eggs lead the list, with modest exports, followed by dairy products, fresh fruits (principally apples, peaches and pears), potatoes, poultry, and fresh vegetables.

Table 1. Food production and consumption in Connecticut, 1974.

	Average U.S. consumption	Connecticut		
		Consumption	Production	
Food	lbs/capita/yr	lbs x 10^6	lbs x 10^6	%
Meat	165.2	496	23.3	4.7
Poultry	50.3	151	21.6	14.3
Fish	15.1	45	—	—
Eggs	36.6	110	113	102.7
Dairy products	335	1005	601	59.8
Animal fats and oils	11.8	35	—	—
Vegetable fats and oils	41.4	124	—	—
Fresh fruit	76.2	229	54.2	23.7
Processed fruit	54.1	162	—	—
Fresh vegetables	164.4	493	54	11.0
Processed vegetables	63.7	191	—	—
Potatoes	97.0	291	59.8	20.5
Beans, peas, nuts	17.8	53	—	—
Flour and cereal	138	414	—	—
Sugar, other sweeteners	114.5	344	—	—
Coffee, tea, cocoa	13.2	40	—	—
Misc. crop products	23.7	71	—	—
Sub total animal products	614	1842	759	41.2
Sub total plant products	804	2412	168	7.0
TOTAL	1418	4254	927	21.8

In 1974, the total expenditure for food in the U.S. was $149.3 billion dollars. To calculate the farmer's share of the $149.3 billion I must subtract the marketing cost for U.S. farm products, which is defined in *Agricultural Statistics* as "the difference between total civilian expenditures for domestic farm-originated food products and the farm value or payment farmers received for the equivalent farm products". The marketing bill was $93.9 billion, leaving the farmers $56.0 billion. Since the population of the U.S. in 1974 was 211,523,000, the per capita annual cost of food was $705.83. Of this, the middleman received $441.08, and the farmer received $264.75.

We can now use this national average to determine how much food was produced in Connecticut. In 1974, the cash income of Connecticut farmers (excluding greenhouse, nursery and tobacco) was $146,647,000. If farmers received $264.75 per person that they fed, Connecticut farmers fed 553,900 people or 18.5% of 3 million Connecticut citizens. This is close to the 21.8% in Table 1, which was based on production and consumption.

Estimating food consumption from the cash income of farmers, I calculated the amount of food produced in Connecticut at 5-year intervals beginning with 1949, the first year for which comparable data are readily available. The results are shown in Table 2.

Table 2. Trends in food production in Connecticut, 1949-1974.

Census Year	Food Produced as a Percentage of Consumption
1949	50.4
1954	48.5
1959	35.9
1964	30.5
1969	24.3
1974	18.5

This is a steep and practically linear decrease during the past 25 years. It suggests that if we are to continue to produce food in Connecticut, we had best move promptly and decisively.

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Are septic systems effective in removing nitrogen and phosphorus from wastewater?

By B.L. Sawhney and J.L. Starr

The results demonstrate that soils effectively remove phosphorus, but not nitrogen, from wastewater

Over one million people in Connecticut live in homes using septic systems for the disposal of wastes. However, household wastewater contains appreciable quantities of phosphorus and nitrogen. If not removed by the soil surrounding a septic system, these nutrients can enhance the growth of weeds and algae in nearby lakes and streams.

In addition, excessive nitrate nitrogen in drinking water may be a health hazard to infants and ruminant animals. Therefore, we need to know the efficiency with which both nutrients are removed from the water that moves through septic system drainfields.

We selected a site at Avon, Connecticut where a septic system had been serving a two-family house for six years. The system is designed so that wastewater from the house can be diverted to either of two drainage trenches. This allowed us to divert the flow to one side while instrumenting the other side with water sampling devices.

To obtain effluent samples at different depths and distances from the trench, we installed suction probes at 0, 15, 30, 60 and 90 cm below the trench and at distances of 20, 50, 80 and 110 cm beside the trench at various depths. We also installed tensiometers to estimate soil moisture at the time of effluent sampling. Thus, a total of 40 suction probes and tensiometers were placed in and around the trench.

Each suction probe and tensiometer consisted of a 2-cm diameter and 5-cm long ceramic cup cemented to lengths of polyvinyl chloride tubing corresponding to depths at which the probes and tensiometers were to be placed in the soil. Nylon tubing of 0.15 cm diameter connected suction probes to vacuum bottles which collected effluent samples.

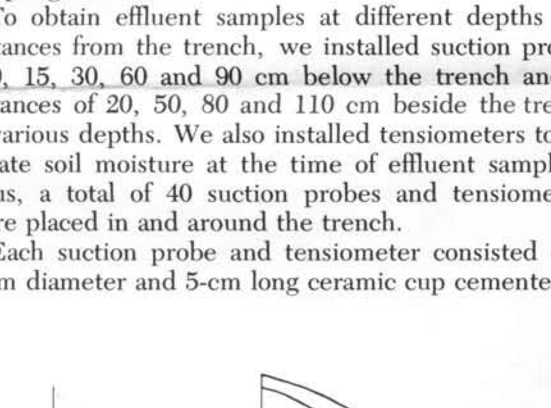

Fig. 1. Movement of phosphate into soil surrounding a septic system drainfield. Concentrations of phosphorus in soil solutions at different depths and distances around the trench are given in mg/l.

Our analyses of samples collected weekly showed that soon after a septic system is put into use, the effluent in the trench begins to pond. Ponding results from reduced infiltration caused by the formation of a thin slime layer on soil surfaces. Tensiometer readings indicated that the soil at 15 and 30 cm depths below the trench became saturated within a few days but remained unsaturated at greater depths.

After the septic system had been in operation for eight years, the concentration of phosphorus in the solution decreased from 9.9 mg/l inside the trench to 0.4 mg/l at the 60 cm depth (Fig. 1). The results clearly demonstrate the effectiveness of the soil in removing phosphorus from wastewater. As the water table remained several meters below the drainfield, only minimal additions of phosphorus to groundwater would be expected for years.

Whereas most of the phosphorus in wastewater is inorganic, most of the nitrogen in the effluent entering the trench is in the organic form. As the effluent also contains some dissolved oxygen, many species of bacteria which can degrade organic materials flourish in this environment. Consequently, about one third of the organic nitrogen is mineralized to ammonium nitrogen (NH_4-N), producing approximately 30 mg/l NH_4-N in the wastewater above the slime layer. This NH_4 moves slowly with the effluent which is low in oxygen immediately below the slime layer. However, as the soil is unsaturated below the 30 cm depth, oxygen may enter this region from the side and be used to convert organic carbon to soluble carbon and NH_4-N to nitrate nitrogen (NO_3-N). Use of soluble carbon by soil bacteria drastically reduces its concentration between 30-60 cm. As the ratio of soluble carbon to NO_3-N drops below 1.25 at the 60 cm depth, denitrification of NO_3-N to N_2 gas and its loss to the atmosphere is restricted. Thus, the NO_3-N reaching this depth is transported freely through the soil to groundwater. After about a month, a steady state relationship be-

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Nitrogen and Phosphorus (*Continued*)

tween NH_4-N, NO_3-N and soluble carbon appears to develop, as illustrated in Fig. 2. If the effluent containing 30 mg/l NO_3-N enters a well, the NO_3 content of the well water may increase above the public health standard of 10 mg/l for drinking water. If the effluent enters a lake or river it would add readily available NO_3-N for weed and algae growth.

Thus, our experiments show that deep soils continue to remove phosphate from septic system effluent for a number of years. Shallow soils with high or perched water tables may permit undesirably large concentrations of phosphate to reach groundwater. On the other hand, soils do not appear to effectively remove nitrogen from domestic wastewater.

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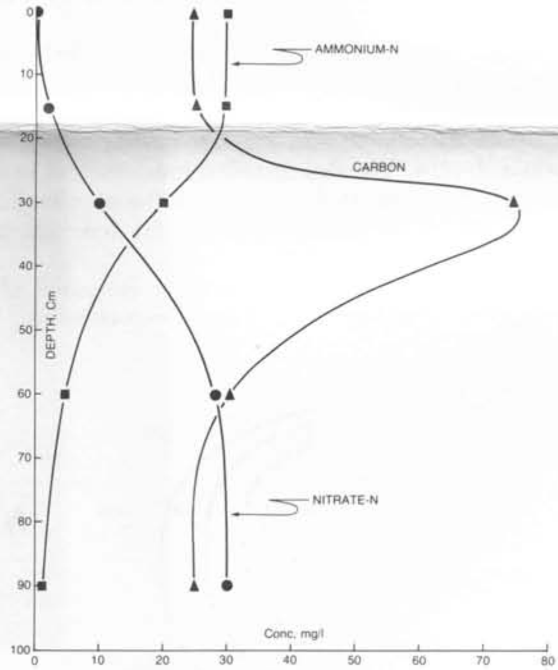

Fig. 2. Movement of ammonium-N (NH_4-N), nitrate-N (NO_3-N), and carbon below the trench.

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