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Harvest in New Haven's inner-city garden. See Page 2

THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION NEW HAVEN

Increasing vegetable yields from sandy urban soil

By David E. Hill

VEGETABLES GREW LAST SUMMER in a community garden in downtown New Haven in spite of the sandy soil and rocky debris left behind from demolition of the buildings that previously occupied the site.

After looking over the proposed garden site with Maishe Dickman of the Greater New Haven Arts Council one cold March morning, my first reaction was: "You've got to be kidding." However, what the site lacked in topsoil and fertility was soon to be made up by hard work and enthusiasm of the gardeners.

Dickman, who was coordinator for the community garden project, had come to the Experiment Station to find out what plants would grow in the existing soil and what could be added to the soil to make the crops grow better.

The Connecticut General Assembly enacted Public Act 75-497 in 1975 allowing vacant public lands to be used for gardens. The State Department of Agriculture has compiled an inventory of suitable state land and receives applications from the public for use of these vacant tracts. The act also enables Connecticut's towns to develop similar programs on municipally owned vacant lots. At least 63 community gardens were established in 45 towns throughout the state in 1976, providing food and recreation for over 5,000 citizens.

Because of the poor soil on the site, I saw an opportunity for experiments with soil treatments to learn how urban gardens could be best established on vacant land. I also worked with 61 families who were able to grow some of their own food a short distance from the New Haven shopping district.

Knowing that the largest problem, other than the lack of nutrients, was the low water-holding capacity of the soil, I designed several experiments to find the best conditions for plant growth.

In the first plot, I had a 3-inch layer of leaf-mold rototilled into the soil to a depth of 6 inches; in the second plot, 6 inches of a finer textured topsoil was spread over the sandy soil; in the third plot, sheets of newspaper mulch were buried to reduce evaporation; and in the fourth plot, I grew vegetables under the same conditions as the other urban gardeners.

All of my plots received optimum fertilization, based on soil tests, and were watered from a nearby hydrant as needed. The vegetables grown included string beans, onions, summer and fall squash, tomatoes, cabbage, broccoli, eggplant, peppers, lettuce, beets, and carrots.

The leaf-mold plot produced consistently higher yields.

The harvest began on July 6 and continued until October 15, after the first hard frost. I obtained comparative yields by weighing all harvested vegetables.

The native soil in the untreated and paper-mulched plots was 83 to 95% sand. Based on texture, the soil was a loamy coarse sand on the untreated plot and a coarse sand on the paper-mulched plot. Table 1 shows that less than 1 inch of water was retained in the upper 6 inches of soil at field capacity, with only 0.5 inch available for crop growth. Because many plants use as much as 0.2 inch of water per day, both plots could be out of water in 2 to 3 days.

The paper-mulch covered plot was the sandiest of all, and it contained the most stones. In fact, it appeared to have been part of an old gravelled driveway. Under these circumstances, the water-holding capacity was probably less than 0.5 inch, but the paper mulch improved it slightly. The greatest benefit of the mulch was a reduction in weeds—the plot required little attention other than watering.

The plot with the topsoil contained 72% sand, and was classified as a sandy loam. Its moisture-holding capacity was 25-35% greater than the native soil—a 3 to 4 day supply.

In the leaf-mold plot, although the mineral fraction was nearly 90% sand, the organic fraction was 3- to 4-fold greater than in the other plots. This organic matter allowed nearly 2 inches of water to be held in the upper 6 inches. Almost a 7-day supply, 1.3 inches, was available to plants. All crops on this plot resisted wilting

Table 1. Physical Properties of the Garden Plots.

	Organic Matter (%)	Volume Stones (%)	Inches of Water at Field Cap.	Inches of Water at Wilting Point	Inches of Water Available to Plant
Leaf mold	16.1	18	1.9	0.6	1.3
Topsoil	4.0	10	1.2	0.5	0.7
Paper mulch	5.6	39	0.8	0.3	0.5
Untreated	5.2	28	0.9	0.4	0.5

2 to 3 days longer after watering or rainfall than the crops in the other plots.

However, this increased moisture-holding capacity created a problem in early May during a period of wet, cool weather when deeply planted bean and squash seeds rotted and had to be replaced. Small, shallowly planted seeds did not rot. All seeds germinated well on the other plots.

Plants in the leaf-mold plot were the largest, followed by those in the topsoil plot. Plants in the paper-mulched and untreated plots were the smallest.

At times, tomato plants on the paper-mulched and untreated plots were affected by droughty conditions, and blossom-end rot damaged tomato fruit on both plots. This physiological damage is caused by an imbalance between the water needs of the plant and the supplying power of the soil. The greater available moisture in the leaf-mold and topsoil plots prevented this damage.

The leaf-mold plot produced consistently higher yields. Pepper and onion harvests were 140% more than on the untreated plot. The yields of carrots, lettuce, eggplant and tomatoes were 25 to 45% higher on the leaf-mold plot than on the untreated plot. Only the yields of squash and beans on the leaf-mold plot failed to exceed the yields on the untreated plot, due to the germination problem in the wet soil.

The yields of most vegetables on the topsoil plot were intermediate as compared to the leaf-mold plot. Those on the paper-mulched plot were about the same as on the untreated plot.

Based on the cost of produce at local food stores at the time of harvest, I estimate that each 20 × 20 foot plot produced \$75-\$100 worth of food. Multiplied by the 76 plots on the ¾-acre site, this means that \$5700-\$7600 worth of food was grown on the inner-city land that appeared so unpromising earlier in the season, even without the benefit of moisture-conserving organic matter.

The experiments show that leaf-mold appears to be the most promising organic amendment to improve the moisture-holding capacity on such sandy, rubble-filled soils of vacant inner-city lots.

As a result of our experiments, the City of New Haven is composting 750 cubic yards of leaves, which will be spread on the garden plots in the summer to help increase yields.

In addition to the experiments, the urban garden was clearly a success on a social level as well. As part of the Arts Council-sponsored project, children made scarecrows to adorn the garden, and adults and children worked together to grow some of their own food and learn about nature.

It also was clear that the potential of a vacant lot is greater than it first appears to a scientist who is used to farming suburban soil. A piece of land, a group of people with gardening zeal, leaf-mold to help increase yields, and a little technical assistance is all that is needed to turn a vacant lot into a flourishing garden.

Analysts help keep food pure

By Paul Gough

THE DEPARTMENT OF ANALYTICAL CHEMISTRY at the Experiment Station annually tests over 2,000 official samples for the Department of Consumer Protection, which is responsible for enforcing the state's pure food and drug laws. The items tested range from vegetables and canned goods to meats and natural foods.

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Many of the samples are fresh meats that could be adulterated with undeclared or excess added water, excessive fat, or undeclared fillers or preservatives.

Fifteen of 338 ground meat samples were found to have excessive fat (more than 30%), two had added water, and one had 24.9% rather than the "not more than 24%" fat claimed on the package.

Nineteen of the 108 official frankfurter samples were deficient in one or more ways. Ten contained excessive fat; four contained excess added water; six had excess or undeclared nonfat dry milk or soy flour; and one had more than the permitted 0.5% phosphate.

Twenty-nine of the 148 sausage samples had undeclared or excessive added water, one contained undeclared monosodium glutamate and another contained BHT, a preservative. Four samples of bologna passed all 25 tests.

Vitamin and iron enrichment is required for flour, bread, rolls and macaroni and noodle products. The analysts found two of eight samples of flour, eight of 20 macaroni products and one of 56 bread products to be low in vitamins or iron. They also found four egg noodle samples deficient in egg solids, including one that contained none.

Cooking oils are examined for volume and contents. Seven of the 12 samples of olive oil claimed to be pure were found to be adulterated with other oils—two contained no olive oil. Seven of the 22 tested failed to meet their olive oil claims and eight of 34 samples failed to contain the net amount of oil indicated on the label.

Natural foods and other products are also scrutinized by station analysts. They found, for example, that a "natural" toothpaste contained synthetic cleaners and that three samples of organically-grown or health foods had measurable pesticide residues.

None of the 421 samples of food and 64 samples of milk tested for pesticide residues were in excess of the allowable levels.

Dried "Hawaiian pineapple," which was supposed to have no preservatives, was found to have 242 parts per million of sulfur dioxide. Further, the container from which the sample was packaged said the pineapple was "Made in Taiwan." Also, a check on a scale indicated that the inspector who purchased the sample was overcharged by two cents.

In checks of dairy products, analysts found "goat's milk cheese" that was made from cow's milk, and ice cream in which vegetable fats were substituted for the required milk fat. A new test procedure had to be developed for the ice cream samples.

Perhaps the most unusual item tested during the year was a group of plastic hot drink cups.

A consumer complained that similar cups disintegrated when filled with tea and lemon. The analysts confirmed that the walls would be attacked by the contents, especially when a lemon peel touched the cup.

They also found that pieces of some cups would dissolve completely if placed in lemon oil and warmed. Hot tea alone had no effect on the cups.

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Role of mosquito feeding habits in longevity, disease spread

By Louis Magnarelli

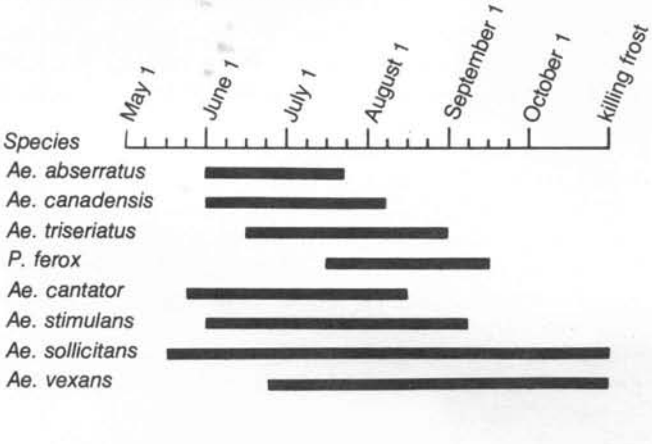
I have found that a large proportion of the females feed on sugars, even before they seek mates or blood meals.

MOSQUITO-BORNE ENCEPHALITIS has occurred in adjacent states, and cases of dog heartworm have been confirmed in Connecticut. The potential for spread of these diseases leads to studies of the vectors.

Each of the 40-odd mosquito species found in Connecticut is biologically different: immatures can live in woodland pools, tree holes, marshes, ponds, tin cans or swamps; female adults of one species live longer than those of other species; flight range varies; choice of hosts differs; and populations fluctuate in response to weather and time of year.

Stagnant water is necessary for hatching mosquito eggs, which are deposited in water or on moist surfaces near water. After hatching, larvae pass through four stages before pupating. The adult emerges within 3 to 7 days. Although the life cycle is the same for all mosquitoes, the timing (Fig. 1), host selection and habitat (Table 1) vary with the species.

Fig. 1. Presence of female adults in a Guilford salt marsh and Mt. Carmel woodlands during 1976.



Relatively little is known about how encephalitis and dog heartworm epidemics originate. Therefore, the main objective of my research is to identify the chief mosquito vectors of disease pathogens to humans and dogs. By studying mosquito feeding habits and longevity, I found that females of several common woodland and salt marsh mosquito species survive long enough to acquire a pathogen from one host and transmit it to another.

As it is difficult to observe mosquitoes feeding on birds and other wildlife in forests and marshes, I collected females that were attracted to me or blood-engorged individuals that were resting on vegetation near aquatic habitats. I concentrated on those that had obtained blood meals because it is during the act of biting that disease pathogens can be acquired from animals or can be injected into hosts along with an anti-coagulant. Females need blood proteins to nourish their eggs to maturity.

I have performed hundreds of serological tests on adult females to determine the animals they have fed

Table 1. Host feeding patterns and habitats for common mosquitoes having potential for spread of disease pathogens in Connecticut.

Species	Hosts	Habitat
Ae. abserratus	mainly mammals, sometimes birds	woodland
Ae. canadensis	mainly mammals, sometimes birds, frogs	woodland
Ae. cantator	mainly mammals, sometimes birds, frogs	salt marsh
Ae. stimulans	mammals	woodland
Ae. sollicitans	mammals	salt marsh
Ae. triseriatus	mammals	woodland
Ae. vexans	mainly mammals, sometimes birds	pasture, woodland
P. ferox	mainly mammals, sometimes birds	woodland

upon. In a typical test, a blood-filled mosquito abdomen is placed into a solution to stabilize the pH and dilute the blood. After centrifuging to separate the blood solution from insect body parts, the blood is drawn into capillary tubes for exposure to antisera. Roosters are injected with blood from various animals to produce commercially available antiserum. A whitish precipitate, which forms in the capillary tube as the heavier antiserum passes down through the matching blood, identifies the blood source.

Using this test, I have been able to identify which mosquito species feed heavily on dogs, and thus are potential vectors of dog heartworm and likewise, those species that are possible vectors of encephalitis viruses to man and horses.

The eight species listed in Table 1 are primarily attracted to humans and dogs, but their hosts also include cows, horses, rabbits, raccoons, opossums, deer and squirrels. Serological tests disclosed that most of the other mosquito species found in Connecticut are not as specific in selecting human and dog hosts. A limited number of these had ingested bird and amphibian blood.

One mosquito that does not normally feed on humans, *Culiseta melanura*, spreads eastern encephalitis viruses in bird populations, so it was important to identify which species could acquire viruses from birds and spread them to man or other mammals. I found that *Ae. abserratus, Ae. canadensis, Ae. cantator, Ae. vexans,* and *P. ferox* have this potential.

When a mosquito bites, her mouthparts penetrate the skin of the host and enter a small blood vessel; she withdraws blood for about two minutes. If she is interrupted by wind or movements of the host before completing a blood meal, she must attempt to feed again from the same animal or find another host to accumulate sufficient blood to nourish her eggs. I have found that multiple feeding is greatest among *Ae. canadensis, Ae. cantator,* and *Ae. triseriatus*. Thus, their potential for acquiring pathogens and transmitting them to new hosts is increased.

Although blood feeding is essential for reproduction and pathogen transmission, nectar feeding is also significant because female mosquitoes that have taken plant sugars live longer than those that have not. Male mosquitoes do not feed on blood. Thus, they depend entirely upon sugar sources for energy. I have found that a large proportion of the females feed on sugars, even before they seek mates or blood meals. Sugars increase a female's ability to spread disease agents by prolonging her life and thus enabling her to visit several vertebrate hosts.

Sugars can be obtained from overripe fruits, flower nectars, and plant juices, and they may be used immediately for energy for flight and reproduction or can be converted to and stored as fats. Nectar sugars can be easily detected by a simple chemical test. My tests showed that a significant number of females had fed on nectar sugars, regardless of their age, stage of egg development, or whether they had been biting, resting or laying eggs. I concluded from this that nectar feeding is characteristic of all species and is widespread.

My recent studies on *Ae. sollicitans*, an important pest in coastal areas, indicate that males and females obtain nectar sugars from lighter-colored wildflower blossoms. I have also found that salt marsh mosquitoes prefer certain plant species, regardless of whether the plant is at high or low relative densities and that they congregate in areas where flowering plants are abundant before their flights inland. If we are able to identify more clearly when and where mosquitoes obtain sugars and how they locate and select carbohydrate sources, we may gain insight which may help in developing new control strategies.

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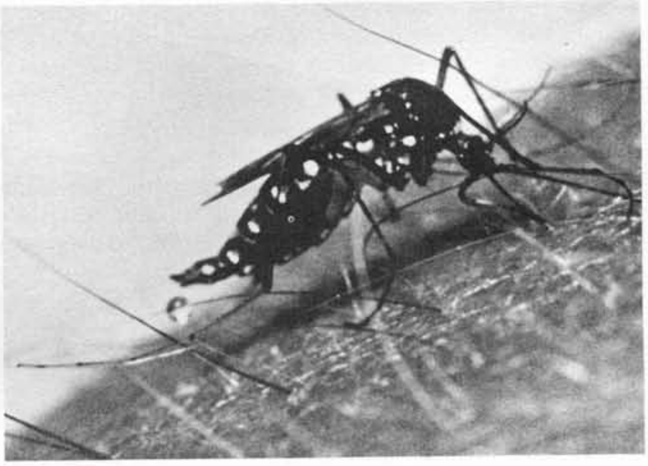
Fig. 2. *Aedes* mosquito blood-feeding on human host.



Injecting elms for control of Dutch elm disease

By J. E. Elliston and G. S. Walton

Some of the largest trees received more than 30 gallons of liquid within a few hours.

INJECTION OF MATERIALS into trees and other plants has been practiced for centuries. The purposes have have diverse: from adding scents, colors and flavors to flowers and fruits; to introducing poisons to kill the plants, the organisms within them, or those that consume them. We are testing this method for use in the fight against Dutch elm disease.

To understand the injection process, it is helpful to know how the water-conducting system of a healthy tree operates, for it is this system that distributes the materials. Water is carried from the roots, where it is absorbed, through the outer layers of wood (sapwood) to the leaves, where it is lost by evaporation (transpiration). The number of layers (annual rings) involved depends on the type of wood the tree produces, that is, whether it is diffuse-porous or ring-porous. In trees with diffuse-porous wood, such as birches, fruit trees, and maples, the water-conducting vessels are small and are distributed more or less uniformly across the annual ring. Many annual rings are required to carry the water. In trees with ring-porous wood, such as elms, ashes, chestnuts, and oaks, each annual ring has two distinct regions: an inner ring of large-diameter vessels (spring vessels), produced early in the growing season, surrounded by an outer layer of more dense wood containing small-diameter vessels and other cell types (summerwood). The spring vessels of the newest annual ring carry most of the water that passes through a ring-porous tree.

Water moves upward through the tree primarily in response to suction generated by transpiration. During midmorning to late afternoon, leaves tend to lose more water than the roots can absorb, creating a partial vacuum within the trunk. In diffuse-porous trees, the vacuum is divided among many annual rings and, thus, is slight in any given ring. In ring-porous trees, the vacuum is concentrated in the outermost rings. For this reason, trees with ring-porous wood are easier to inject.

Confinement of water transport to a few annual rings makes elms and other ring-porous trees especially vulnerable to vascular wilts, diseases whose target is the water-conducting system. Vascular wilts usually kill these trees rapidly. In elms, the most serious vascular wilt is Dutch elm disease, caused by the microscopic fungus *Ceratocystis ulmi*.

Dutch Elm Disease

Dutch elm disease is named for the country where it was first intensively studied. The fungus was introduced into this country by way of Europe in the 1930's. The American elm, *Ulmus americana*, which had never experienced this enemy, had developed no resistance to it. A devastating disease resulted.

A highly susceptible tree and a well-adapted fungus are only two of the factors responsible for the seriousness of this disease. To eliminate trees in a wholesale manner, the disease agent must be able to move easily from tree to tree. Except where elms are grown close together, it is dependent on two insects for its spread: the European elm bark beetle, *Scolytus multistriatus*, and the American elm bark beetle, *Hylurgopinus rufipes*. These beetles prefer weak and diseased elms as breeding sites. The fungus that causes Dutch elm disease grows and sporulates in the galleries made under the bark by the beetles. Here the young beetles accidentally pick up the fungus and carry it from elm to elm as they feed. Were it not for these beetles, Dutch elm disease would be a minor problem. Along city streets where elms grow within 30-40 feet of each other, the disease is also spread through grafts that form between their root systems. When one tree in such a group becomes infected, the fungus moves easily across these junctions, infecting trees sequentially.

Spread by beetles is most important in late spring and early summer. During this time the newly formed large-diameter vessels are just under the bark. The beetles, newly emerged, seek out vigorous trees and feed in twig crotches. Here they chew away the bark and occasionally break into the newly developed vessels. If a beetle is carrying spores of the Dutch elm fungus, the spores may be deposited in the spring vessels where they can do maximum damage in the shortest possible time. Feeding that occurs later is

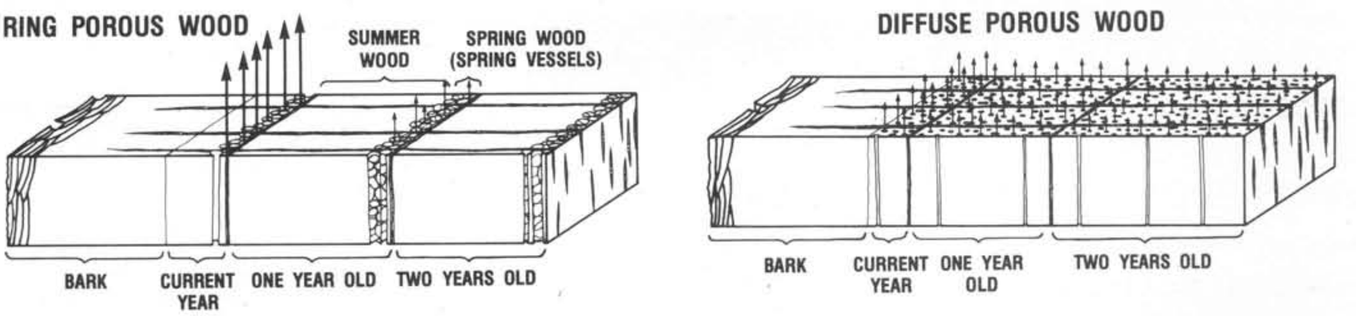


Fig. 1. Comparison of ring-porous and diffuse-porous wood. Water moves through ring-porous wood primarily in the spring vessels of the newest annual ring. Many rings contribute to water transport in diffuse-porous wood.

For many years Dr. A. E. Dimond and his colleagues at the Experiment Station sought chemicals that were toxic to *C. ulmi*, harmless to the tree, and that could be readily introduced into and distributed within it. In those days promising materials were pumped into the ground, sprayed on the trunk or foliage, or desposited in holes bored in the trunk. Although many chemicals and methods were tried, none proved satisfactory.

Since that time a new method and a new chemical have been developed that have brought us closer to Dr. Dimond's goal. The method is pressure-injection; the chemical is methylbenzimidazole carbamate, MBC for short, a derivative of benomyl fungicide. Although benomyl is toxic to the fungus, it is not very soluble in water and tends to block vessels near the injection sites. MBC is water-soluble and matches benomyl in toxicity to *C. ulmi*.

Several types of injection apparatus have been devised and tested at the Station over the past 3 years. Most of these leak excessively or penetrate too deeply into the wood, blocking the functional vessels and depositing the material in the deeper sapwood and heartwood where it does little good.

Last year we developed a new apparatus that overcame these problems. It is a less expensive and simpler version of an apparatus developed by the USDA Forest Service.

The injection procedure involves drilling shallow holes into the trunk at 6 to 9 inch intervals around the base and nailing the injectors over them. Rubber gaskets between the injector and a smooth depression countersunk in the bark form a tight seal. Because the diameter of the hole is greater than that of the injector pipe, the functioning vessels remain open to free flow of the injected solution. The injectors are connected in series to a spray tank containing the solution to be injected. Air is vented from the tubing, then the solution is injected into the tree at 20-30 *psi*.

Our largest test was conducted last spring and summer on the campus of Trinity College in Hartford. Approximately 50 elms, ranging in diameter from 3 to 45 inches, were injected during June with several concen-

less likely to lead to serious infection because by then the spring vessels are buried under summerwood and are not easily severed. Thus, spores are less likely to enter the most active part of the water conducting system.

Although research has not yet provided a complete answer, we believe we know roughly how the fungus kills the trees. It produces minute single-celled spores called bud cells, which divide repeatedly to produce more of their kind. These spores, being unusually small, are carried easily in the large vessels to the young stems and leaves. We believe they become trapped by the perforation plates at the ends of the vessels, germinate, and in some way stimulate surrounding cells of the plant to grow extrusions (tyloses) out into the vessels, gradually plugging them. Blockages develop in many vessels, preventing movement of water into stem and leaf tissues beyond them. In some branches the water supply is cut off suddenly, in others gradually. The final result is the same: the leaves wilt and die. When this happens, the mechanism that draws water into the stems is destroyed, and the stems also wither and die. Since water is no longer moving upward in the vessels, the fungus can more easily make its way downward to junctions with other branches and to the roots. Once in the roots, it can move rapidly into nearby vessels that are still functioning and be carried up the tree to other branches and leaves. Many elms infected in late spring die the same year, since the fungus can rapidly make its way through the entire tree.

Elms resistant or tolerant to Dutch elm disease have water-conducting systems that are constructed differently from susceptible elms. The vessels are smaller and do not conduct water as easily. When the fungus enters these trees, the spores remain localized and are usually barricaded quickly within a few vessels, thus preventing spread and serious disease. Such trees may lose a few branches but seldom die from Dutch elm disease.

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trations of Lignasan, a commercially available formulation of MBC. Several diseased elms were included. The suction provided by the large canopies of some of these trees was so great that they could actually take up the solution without tank pressure. Some of the largest trees received more than 30 gallons of liquid within a few hours.

We measured the MBC content of branches from the tops of the treated trees approximately 2 and 12 weeks after injection. To get some of these samples from 40 to 60 feet above the ground, we went up in "cherry picker" lifts provided by a local arborist. More than 6000 leaves and 2000 stems were analyzed.

We learned several important things from the experiment: (1) the new injectors worked well, (2) under the conditions used, it was easier to obtain complete distribution with small trees (less than 10 inches diameter) than large trees, (3) the distribution was better with high than with low concentrations of the chemical, and (4) over the 12-week period, the concentration of the chemical in the leaves and stems dropped approximately 80%. Most of the chemical left in the tree at the end of the growing season appears to be lost when the leaves fall. Thus, an injection in spring is good for only one year. We also discovered that the chemical does not enter badly diseased parts of the tree. This is not surprising, for liquid must be drawn by functioning leaves. A combination of dead or dying leaves and blocked vessels in diseased areas prevents this.

Results so far suggest that vessels at a given injection site are connected with specific regions above. If this is true, one way to achieve a more complete distribution in large trees would be to move the injection sites closer together. With an apparatus that requires large injection holes, this could be very harmful to the tree. Clusters of small injectors may be better than a single large injector because the smaller wounds should heal

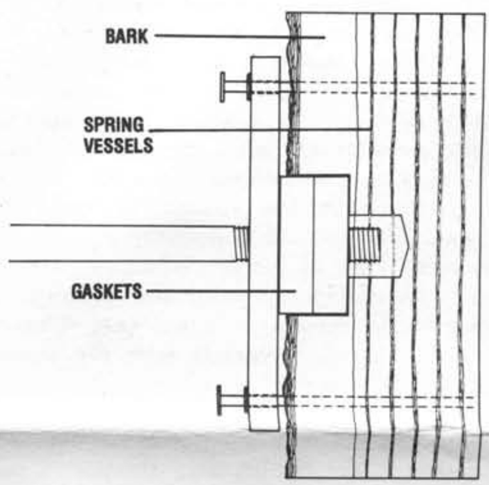

Fig. 2. Relation of injector to tree. Note that the hole drilled in the sapwood is larger than the injector pipe, allowing free access of the solution to the vessels of the outer annual rings.

faster and vessels over a larger area would receive the injection.

Another approach would be to inject chemicals into exposed roots rather than the trunk. Because a single large root likely supplies water to a relatively large portion of the branch system, material injected there may reach a much greater part of the crown than the same amount injected into the trunk. These possibilities will be investigated during the next few years.

The Dutch elm fungus is showing signs of resistance to MBC, which may limit its value as a direct control. However, MBC should remain useful for tracing the water-conducting systems of trees and for developing more efficient methods of injecting trees with beneficial chemicals.

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