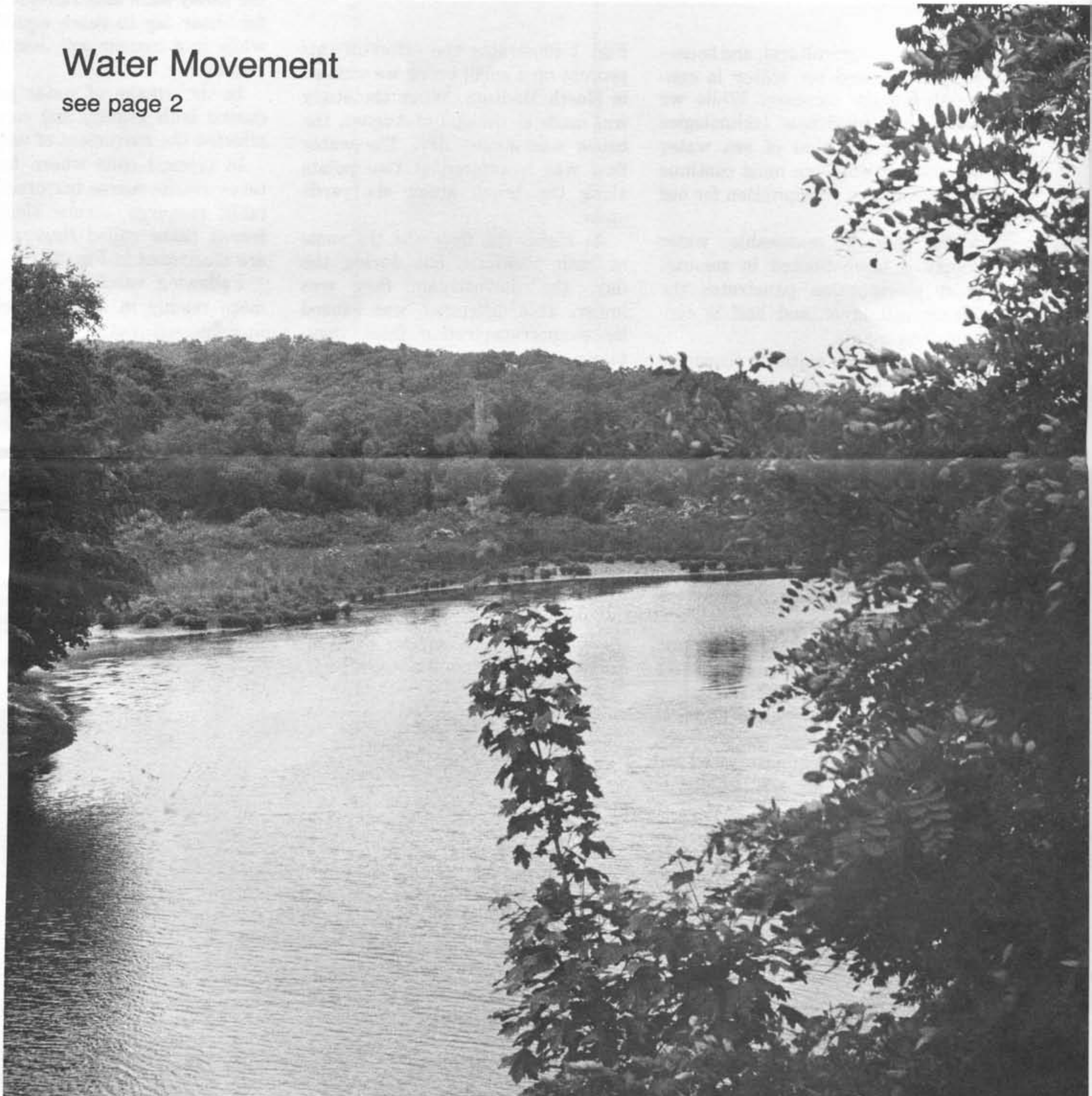
FRONTIERS
of PLANT SCIENCE

SPRING 1974

Water Movement

see page 2



THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION NEW HAVEN

Water movement in soil: up, down, and around

By J.-Y. Parlange

INDUSTRIAL, agricultural, and household demand for water is constantly on the increase. While we need more, until new technologies such as desalination of sea water become available, we must continue to depend upon precipitation for our water.

This highly seasonable water supply is often limited in amount. Most precipitation penetrates the porous soil layer and half is consumed by plants.

Because much water is consumed by plants, it is important to understand how water is taken into roots and also how the underground water aquifiers are recharged.

Since soil removes harmful chemicals or pathogens such as those in the effluent from septic tanks, it is also important to understand the process of recharge so we may be sure its purifying capacity is not exceeded.

The water level in a well represents the upper surface of the water table. Below this point, the soil is saturated with water, and no air is present. Above this water level, the soil is said to be unsaturated and both water and air are present in the pores.

The water table varies with the weather and the levels of other water bodies such as lakes, rivers and the ocean to which it is connected.

In the summer plants growing in unsaturated soil release water into the air through the leaves before it reaches the water table. The water table may be greatly reduced by water pumped upward by plants particularly in late summer or early fall. Fig. 1 illustrates the effect of this process on a small brook we studied in North Madison. When the study was made at the end of August, the brook was almost dry. The water flow was monitored at two points along the brook about six yards apart.

At night, the flow was the same at both positions, but during the day, the downstream flow was lower. This difference was caused by evapotranspiration from vegetation along the banks of the brook.

For the two days recorded in the figure, the flows are not equal until a lag of four hours after sunset. This lag is traceable to the unsaturated soil layer and reflects its properties.

The two curves separate at sunrise. Water moves upward from the water table and is replenished by the brook as roots remove water from the unsaturated soil.

Evapotranspiration ceases after sunset, but water is still removed from the brook by a process similar to the movement of water against gravity in a capillary tube.

The time to reach equilibrium is characteristic of the soil type. In the sandy loam illustrated it takes a four-hour lag to reach equilibrium, while in a coarser soil, less time is required.

In the uptake of water just discussed both gravity and capillarity affected the movement of water.

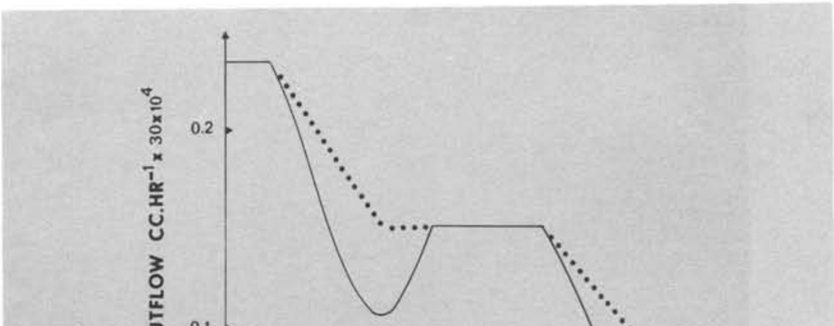
In layered soils where fine textures overlie coarse textures, water table recharge occurs along preferred paths called *fingers*. These are illustrated in Fig. 2.

Following rainfall, water moves more readily in a coarse soil than in a fine soil, but at the same time, water does not easily enter the coarse layer below a fine layer.

This somewhat paradoxical situation is due to capillary action. Only after the fine soil has been saturated will upward suction of capillary forces disappear, allowing water to enter the coarse material.

However, if one imagines a slab

Fig. 1. Outflow from a brook in cubic centimeters per hour on two successive days in August 1973. The solid line is the outflow downstream and the dashed line is the outflow upstream. The latter is larger after sunrise (8:00 a.m. EDT) and remains larger even after sunset (6:00 p.m. EDT), until about 10:00 p.m. The difference between the two curves is caused by the *upward* movement of water from the water table.



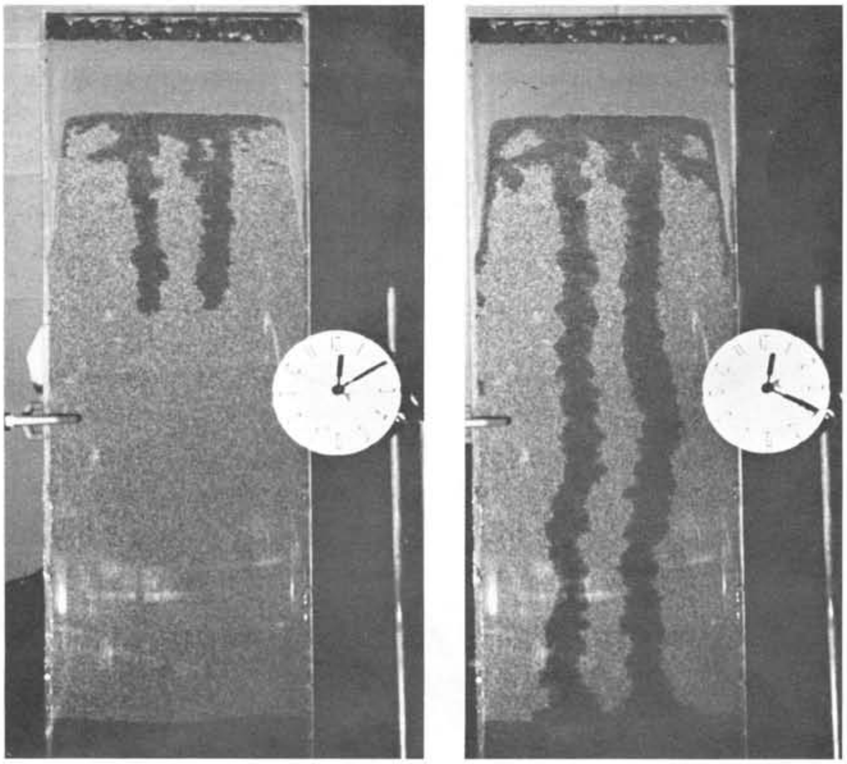


Fig. 2. Movement of fingers *downwards* in a layer of coarse sand surmounted by a layer of fine sand. The fine sand is saturated with water and the coarse sand is dry except for the region occupied by the fingers. On the left the fingers have just formed. Later, on the right, the fingers have reached the bottom of the chamber.

of fine water-saturated porous material with air beneath instead of coarse material beneath, water does not enter the air space uniformly. Instead, droplets form underneath and eventually fall into the air.

If we substitute a coarse sand layer for the air as in Fig. 2, droplets still form but they are absorbed by the coarse layer as if by blotting paper, and fingers move downward at a uniform speed. This speed called the *saturated conductivity* of the coarse material is expressed in cm./ sec., and characterizes the effect of gravity on water movement.

These fingers could have great importance in predicting the amount of rain or irrigation necessary to recharge the ground water supply. Clearly small volumes of water can penetrate deeply as fingers in the soil and quickly reach the water table.

This mechanism also offers a possible explanation of the deep penetration of pollutants—such as nitrates—observed in regions of limited rainfall.

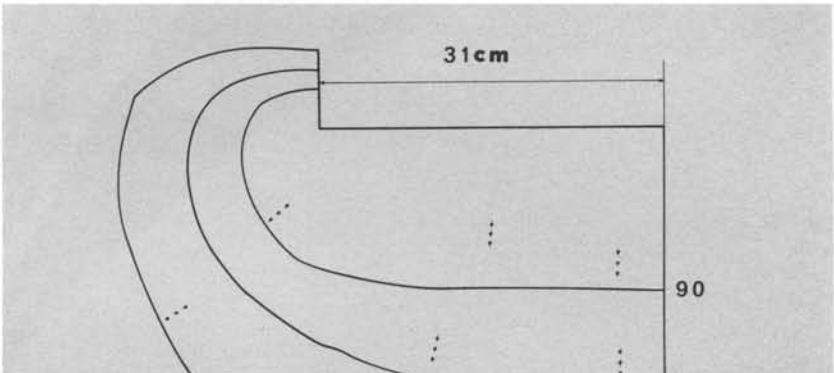
A second process of recharge, primarily affected by capillary forces is illustrated in Fig. 3. There we see the cross-section of a fine sandy loam soil under a trench of septic tank drainfield. The wetting front is indicated for various times. The amount of soil wetted by the time the front reaches the water table indicates the capacity for pollutant removal.

The time must be long enough so that the purifying processes are completed before the effluent reaches the water table.

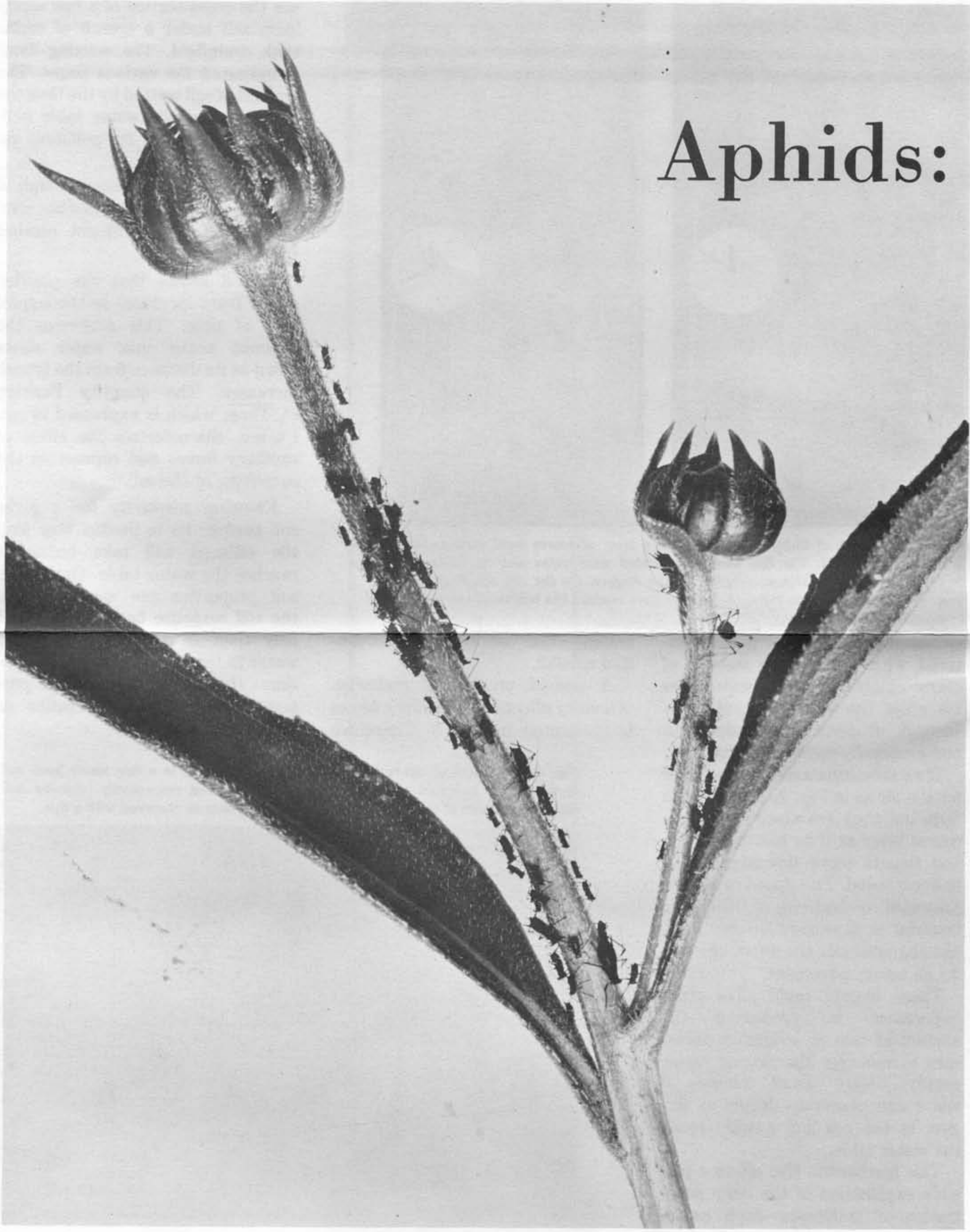
Fig. 3 shows that the position of the front increases as the square root of time. This expresses the common sense that water slows down as its distance from the trench increases. The quantity Position $/\sqrt{\text{Time}}$, which is expressed in cm. $/\sqrt{\text{sec.}}$ characterizes the effect of capillary forces and represents the *sorptivity* of the soil.

Knowing sorptivity for a given soil permits us to predict how long the effluent will take before it reaches the water table. Only when soil properties are measured can the soil response be predicted, and only then is it possible to apply water to that soil in a way that optimizes the return, whether the purpose is irrigation, fertilization or pollutant removal.

Fig. 3. Movement of the wetting front *around* a trench in a fine sandy loam soil. Positions are indicated after 90, 210 and 450 minutes respectively. Arrows indicate the direction of the flow of water at various points as observed with a dye.



Aphids: t



iny and confusing

By James B. Kring

APHIDS may be tiny, but they are complex, fascinating and destructive insects.

Aphids are destructive because they may spread plant virus diseases or inject toxic saliva into plants. They also can make plants unsightly with their excreted honeydew and shed skins.

I have identified more than 325 aphid species in Connecticut, but many more remain to be discovered.

They are fascinating because almost every rule established for them seems to have an exception.

For example, without mating most aphid females can give birth to live young females. But as days shorten, these aphids will produce male and female offspring that must mate to produce overwintering eggs.

Another interesting exception is that many kinds of aphids are wingless most of their lives. However when a colony gets crowded these species will develop winged forms that can fly to new food sources.

Almost any plant that grows in Connecticut is capable of supporting at least one type of aphid during the year. Many plants, such as apple, maple, and willow trees, may even be infested with several kinds at the same time. The only plants that I have ever seen that escape aphid attack belong to the Equisetacae family—the horsetails.

Aphids on sunflower

Aphids from a crowded colony normally fly toward light from the sky. However, after several hours they fly away from the sky and start searching for suitable plants near the ground.

Their small size prevents observations in the field, but aphids may be studied under controlled conditions in a flight chamber in the laboratory.

Using such a chamber, I have been able to demonstrate that green peach and bean aphids from crowded colonies will fly hardest toward a source of ultraviolet light such as the sun.

After migration, they select yellow objects upon which to alight. Aphids generally will not alight on reds, oranges, and greens unless these colors are mixed with large amounts of yellow. The reflectivity and attractiveness of yellow objects is increased by small amounts of white.

Knowing that aphids will fly away from ultraviolet light when they are ready to land on food plants, I reasoned that reflective mulches would help keep hungry aphids away from plants.

My experiments show that aluminum foil or a new kind of mulch coated with wet-ground-mica paint will protect plants from aphids by reflecting ultraviolet light from the sky.

Although aphids are attracted to yellow objects, flight chamber tests show that they are not attracted to yellow bug lights. When these lights are turned on, aphids land on the walls instead of on the light. This is because the entire flight chamber is bathed in yellow light.

Selecting the right color flower pot can help keep aphids from alighting on plants. I have found through experiment that green, yellow, and gold-colored pots are much more attractive to aphids than orange, red, blue, white, or silver pots.

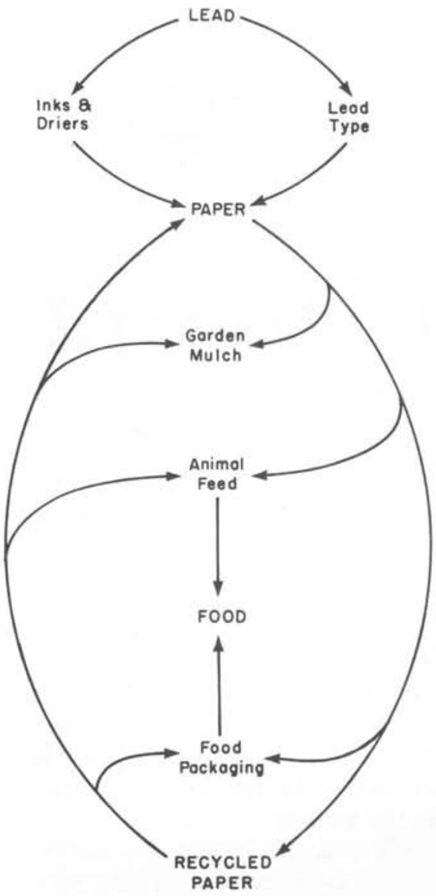
Since a single aphid female can produce 60 to 100 young in a summer month and these offspring are ready to produce their own nymphs in three to four days, their numbers can easily get out of hand.

Until an effective birth control method is found for aphids, we will have to continue to rely on studies of aphid ecology and behavior to help keep their numbers down to acceptable levels.

Closeup of aphids on roseleaf

Piecing together the lead puzzle

By Lester Hankin
Gary Heichel
and Richard Botsford



LEAD is a useful metal. It is used in storage batteries, in paint, in gasoline, and in countless other products essential to modern man.

But lead has a nasty side because children may become retarded or die if they eat chips of leaded paint or other materials containing lead.

Although lead poisoning from paint has drawn much attention, our research suggests that there may be more insidious sources of lead.

We were asked for assistance by a New Haven area health director who wanted to track down the source of lead in the blood of a child who did not appear to have been exposed to leaded paint. The child did, however eat non-food items such as soil, leaves, and grass. The health director suspected these were contaminated by lead from exhausts because the child lived near a major highway. We found out later that the child also liked to eat newspapers and magazines.

Each of these materials was examined for lead at the Experiment Station. Grass, soil, and leaves from the child's yard had from 14 to 53 parts per million (ppm), and newspapers had from 2 to 10 ppm, but magazine pages ranged from 8 to 3,600 ppm. Significantly higher levels were found on pages printed in colored rather than black ink.

We studied a magazine printed locally and found that the colored inks used on multi-colored letterpresses contributed to lead on the printed pages. Yellow ink had the most lead—29,000 ppm; red ink was next with 4,100 ppm, blue ink was next with 445 ppm, and black ink had the least, 275 ppm.

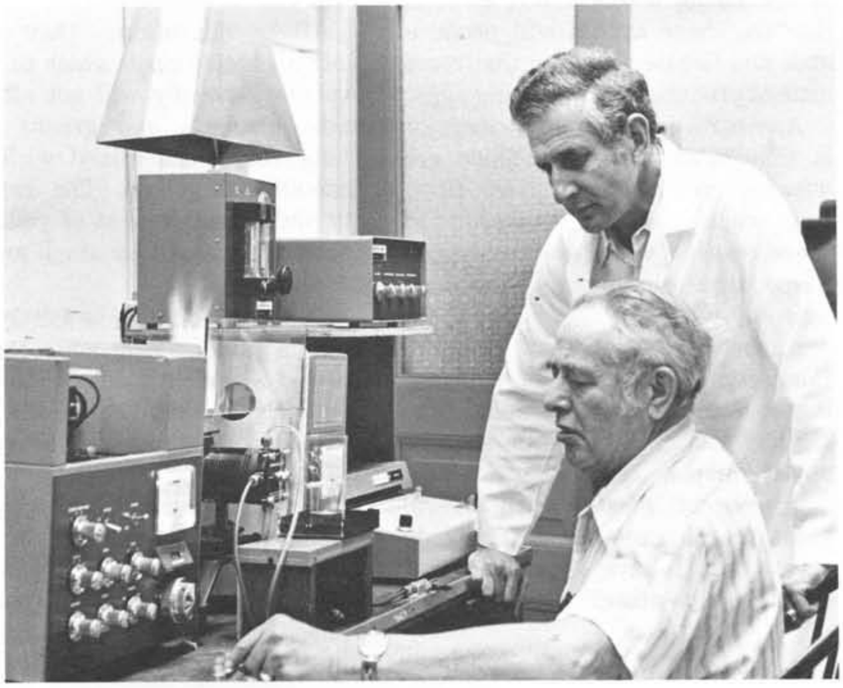
We calculated that the child would have to have eaten much (6 to 30 grams daily) soil, leaves, or grass before his intake reached a dangerous level. Pediatricians suggest that 0.3 mg is the hazardous daily dose.

But, according to our data, a dangerous dose could come from daily consumption of only four square inches of a magazine page that contained 2,800 ppm. Thus, it appeared that magazines were probably the source of lead in the child's blood.

Since letterpress inks are not confined to reading matter, we started to examine lead in brightly colored polyethylene food bags. The printed portions of bread, candy, snack, and cereal wrappers had from 425 to 23,000 ppm on them.

Far more lead was found on bags that had orange or yellow as the

Richard Botsford, seated, conducts a lead test as Lester Hankin looks on.



predominant color than on bags that had nearly clear backgrounds with little lettering or other printing.

No evidence of excessive lead was found in candy or bread samples that had wrappers rich in lead. Both foods had less than 1 ppm despite the lead-printed covering.

The ink on the bags could, however, be removed by gentle rubbing. Because some purchasers may reuse such bags for lunches or for food storage, a warning against reuse of polyethylene bags was issued by Barbara Dunn, commissioner of consumer protection.

Tests of a wide variety of other food wrappers revealed 8 to 10,000 ppm lead on the paper wrappers of such products as candy, lollipops, chewing gum, frozen confections, bakery products, and confection-filled straws. In some samples, paper was probably the principal source of lead because the unprinted paper had up to 58 ppm.

Since two different sizes of the same kind of candy were tested and one wrapper was found rich in lead and the other was found essentially lead-free, the same manufacturer may use both leaded and lead-free inks.

Our results suggest that paper recycled from waste printed with lead type or with colored inks contains more lead than paper made from waste printed with black ink or by a lead-free process like offset. We also found that recycled newsprint is six-fold richer in lead than virgin newsprint.

Since paper is often used to mulch vegetables, we experimented with lead-containing paper that might be used as a mulch. When we treated papers around vegetables with the equivalent of 8 weeks of the moderately acid rainfall that might be experienced in the Northeast, negligible amounts of lead leached from the papers. Thus, we concluded, there seems little danger of lead contamination to plants from mulch.

These studies show that lead may show up in some surprising places, but so far we can be reassured that it has not been found in food, or leaking into the soil in significant amounts.

NEW PUBLICATIONS

Seven new publications have been issued by the Connecticut Station since the last issue of *Frontiers*. Requests for copies should be addressed to Publications, Box 1106, New Haven, CT. 06504.

The results of many other scientific investigations carried out by Station scientists are published in scientific journals. During the past six months 80 such articles have been submitted for publication.

B 740 Cockroach Proofing. Preventative Treatments for Control of Cockroaches in Urban Housing and Food Service Carts. Richard C. Moore

B 741 Pesticide Inspection Report for 1973. J. Gordon Hanna

B 742 Commercial Fertilizers Inspection Report for 1973. J. Gordon Hanna

B 743 Commercial Feeding Stuffs Inspection Report for 1973. J. Gordon Hanna

B 744 Gypsy Moth: Aerial tests with *Bacillus thuringiensis* and Pyrethroids. Harry K. Kaya, Dennis M. Dunbar, Charles C. Doane, Ronald M. Weseloh, and John F. Anderson

B 745 78th Report on Foods From Connecticut Markets and Farms, 1973. J. Gordon Hanna

B 746 Commercial Fertilizers Special Inspection, February 1974. J. Gordon Hanna

Editorial

(continued from back page)

occurred in winter. We then went on to more and more complex schemes, even weekly adjustments according to the remaining quota, the weather of the past week, and the average weather for the coming week. Logically this seems more precise and safe.

Experiment proved, however, that the following simple scheme was as good. Start the autumn with a fuel reserve of about 1/12 the annual use and with the thermostat turned down 4 degrees F from normal. At the beginning of winter, turn the thermostat up 2 degrees F if much fuel has been saved, and turn it down 2 degrees F if the reserve is badly depleted. At the beginning of spring, turn the thermostat down 2 degrees F if the reserve is depleted.

In the 45 years of experiment, thermostats were adjusted only 56 times, half the winters were spent with thermostats only 2 degrees F below normal, thermostats were lowered 8 degrees F only once during the spring, and monthly quotas were exhausted only twice in 45 years for a total of 5 days. This simple scheme seems to provide the maximum comfort with minimum hazard while saving 15 per cent.

My editorial has two morals: agricultural experiment can open the way, and we can experiment with the weather as well as talk about it.

PLANT SCIENCE DAY

Lockwood Farm, Hamden

Louis M. Thompson of the College of Agriculture, Iowa State University, Ames, will discuss weather and food during his Samuel W. Johnson Memorial Lecture at 12:45.

AUGUST 7

THE CONNECTICUT
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Director

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Saving fuel is like planting tomatoes

By Paul E. Waggoner

MEETING a fuel quota by turning down the thermostat and planting tomatoes early are akin: both are gambles with the weather. If Nature's dice turn up warm weather, one has plenty of fuel or harvests tomatoes before others do. But if her dice turn up cold weather, the fuel quota runs out or the tomato plants are blackened by frost.

Several years ago experiment stations began calculating odds from old weather records to make the farmer's lottery with frost a rational one. Those same weather reports may now be used to estimate the odds of a cozy home versus an empty fuel tank.

The first essential in calculating the odds is faithful observation of the weather. Thomas Jefferson watched the weather, and in Connecticut C. L. Gold, who was of a family who helped found this Station, began a long series of observations at his farm on Cream Hill in 1896. At the Lockwood Farm of this Station, the superintendent trudges out each evening, reads the maximum and minimum thermometers, measures rain or snow, and sends the results to the Weather Service. These and other weather observations were converted to computer cards by Experiment Stations about 1960. The Weather Service now punches the newer records, thus keeping them up-to-date.

The next task is discovering something that bears on our affairs in these records that have been so faithfully recorded. If we are interested in setting out tomatoes the critical matter is the last day in spring when the temperature falls to 32 degrees F. If we tabulate these dates for, say thirty years, we shall find half before and half after the average last date of freeze, and these last dates grow rarer and rarer as they are further from the average. We know that setting tomatoes out in central Connecticut on April 21 is a 1 in 4 long shot and on May 14 it is a surer, 3 in 4 shot. We even have calculated the odds for when a hotcap will be both adequate and necessary.

So much for the ground work by agriculturists. Enter the time of fuel shortages for our homes, shops and greenhouses. People who were accustomed to the security of a certain fuel supply suddenly were faced with an uncertain one and joined the farmer and gardener in Nature's weather lottery.

The key question is how many degrees should we turn our thermostat to save 15 per cent of our fuel when we don't know how cold the season will be? It's a gamble, but the odds can be calculated from the same records that yielded the odds on frost.

First, we must find something in the records bearing on our affair; it is degree-days. Degree-days are the difference between an inside temperature and an outside one. Fuel consumption goes up and down with degree-days, so they can help us learn from old weather records the odds of keeping our houses as warm as possible but still saving 15 per cent of the fuel we would otherwise use.

With 45 years of Hartford weather imprinted on a magnetic tape, J.-Y. Parlange and I took to the computer, experimenting first with a 4 degree F adjustment that would save 15 per cent—on the average. Monthly fuel quotas were exhausted half the time and the outages mostly

(continued on page 7)

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Vol. 26 No. 2 May, 1974 ISSN 0016-2167 Paul Gough, *Editor*