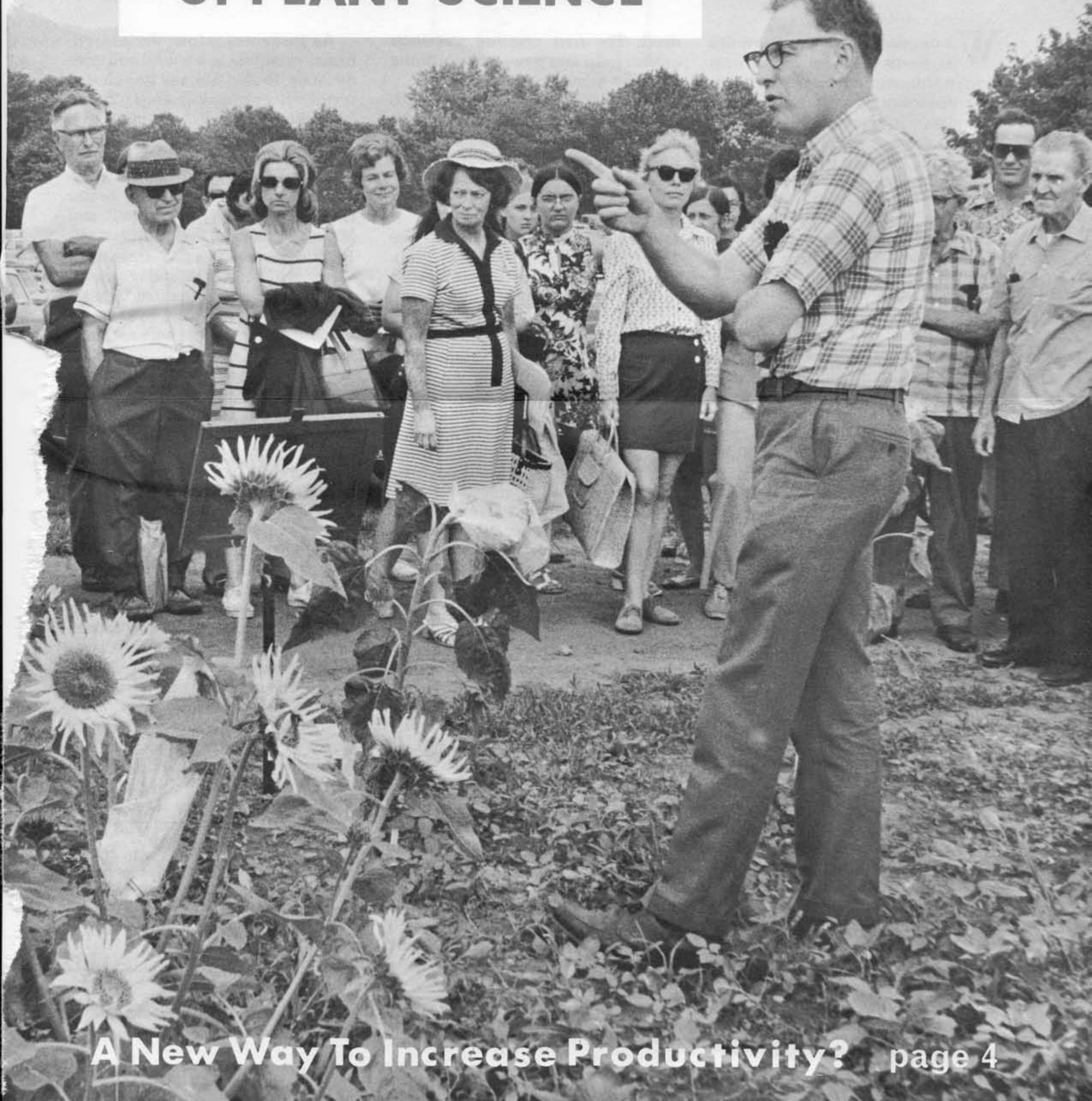
FALL 1972

FRONTIERS of PLANT SCIENCE



A New Way To Increase Productivity? page 4

Two Birds With One Stone

We Can Reclaim Plant Nutrients From Many "Waste" Materials

Bruce B. Miner

We understand that a new era in waste disposal and utilization in Connecticut lies just ahead. The objective is to salvage metal and glass for recycling, extract gas and oil from garbage, and use the heat from burning refuse to generate electricity.

Such a program, operating statewide, is a far cry from the town and city dumps of not so many years ago, where youths could while away an afternoon shooting rats. Now, of course, many of our towns operate sanitary landfills, and in several of our cities, incinerators first reduce solid wastes to more manageable proportions.

At the Experiment Station, in the meantime, we are investigating the disposal or recycling of biological or biodegradable materials. These biological techniques may supplement the new plan, because it can hardly be expected to include all crop wastes on fields, manure from barns, leaves, and septic tank effluent in the suburbs. All of these materials contain plant nutrients, notably nitrogen and phosphorus. The market value of these nutrients may be small, but the costs of disposal sometimes are considerable. Some biological disposal methods may, of course, eventually be incorporated into the plan for municipalities.

One conventional method of recycling leaves and other materials from plants is composting. During the past year, Raymond P. Poincelot published a Station bulletin on the biochemistry and methodology of composting. This review of past and current research proved to be a very popular booklet indeed. The first printing was soon exhausted, and requests continue to come in every day.

You may have heard Dr. Poincelot on Plant Science Day, August 9, when he commented on his experience in composting leaves, pharmaceutical wastes, sewage sludge, and paper. As you might expect, he found that it takes a long time to compost materials like paper or leaves, containing a large amount of cellulose.

When the carbon/nitrogen ratio of materials in a compost pile of leaves was adjusted by adding ammonium sulfate, nearly twice as much cellulose was decomposed in 200 days as in a compost pile of leaves alone. Meanwhile, only about one-fifth of the cellulose in leaves and paper alone had been decomposed in 200 days.

Dr. Poincelot did establish that leaves, with pharmaceutical wastes or sewage sludge, or both, composted reasonably well, measured by the rate of decomposition of cellulose.

The pharmaceutical wastes he used came from a citric acid production process, and the wild penicillium they contained proved to be effective in decomposing cellulose in the compost pile.

Station scientists are searching for fungi or bacteria more effective in decomposing cellulose, but results so far are inconclusive.

The experiments this year at Lockwood Farm show that digested sewage sludge and leaves can be satisfactorily composted. Quite possibly the addition of a little ammonium sulfate, or larger amounts of sewage sludge, would have speeded the process.

As gardeners know, the conventional compost is a useful soil conditioner. It also has a little value as fertilizer, containing about 2 percent nitrogen and 1 percent each of phosphoric acid and potash.

Similar in some ways to composting is the liquid-mulch technique developed in 1970 by Lester Hankin, George Stephens, and Milton Zucker of the Station staff. In this process, a small amount of water is added to vegetable wastes, and the mixture shredded to form a slurry. This is treated with an enzyme derived from a soft-rot organism, allowed to stand 24 hours, and the rather thick liquid resulting is applied as a mulch. The application may be at the rate of 1 to 2 acre inches. Within a few days the decomposing material will have dried, forming a paper-like mulch.

In 1971, this mulch was effective in keeping down weeds in vegetable plantings, but in 1972 the excessive rainfall in June caused the mulch to disintegrate so completely that weeds and grass flourished in the test plots. This failure to act as an effective mulch is of little consequence in woodlands, where the material has also been applied experimentally.

Dr. Hankin suggests that the slurry might be dried and perhaps be useful as an animal food supplement, or a soil conditioner. The dried, shredded material might al-

Cover Photo

Dr. Israel Zelitch tells visitors how sunflowers are useful in his studies of photosynthetic efficiency, a new approach to higher yielding crop plants.

so be useful as a short-term substitute for peat in soil mixes for bedding plants.

Practically, the liquid garbage technique calls for separation of paper, plastics, glass, bones, and the like from essentially vegetable matter. What can go into the mix is roughly what formerly was eaten by garbage-fed hogs. And direct application of the material in liquid form would be limited to the crop-growing season, that is, when the ground is not frozen.

Sewage sludge disposal on the soil seems a logical way to dispose of the 150,000 tons produced in Connecticut each year. On the other hand, Station research begun a score of years ago shows that the sludge can be toxic to plants unless the soil is carefully managed.

No detrimental effects are apparent, however, after a 2-year study by Brij Sawhney and Wendell Norvell on vegetables grown in soil treated with as much as 130 tons of sludge to the acre.

At the Valley Laboratory in Windsor, Henry C. De Roo has shown that a mixture of 20 percent sewage sludge, 40 percent sand, and 40 percent peat moss is a very satisfactory "soil" for chrysanthemums grown in containers.

The water-borne waste in effluents from septic tanks will be with us to a greater or lesser degree for many years to come, for many residences in the open country will never be served by sewers. One survey shows that about 40 percent of Connecticut homes now have septic tank systems. In this connection, Station studies of soil, soil water percolation, and retention of nutrients by soils have proved to be invaluable. These studies, by David E. Hill of the Station staff, enable appropriate officials to see that septic tank fields are adequate.

Currently, Dr. Hill and Dr. Hugo F. Thomas, of the Department of Environmental Protection, are authors of a new Station bulletin on the use of natural-resource data in land and water planning. Representatives of many state and federal agencies have contributed to this study. Basically, it brings together in compatible form a vast amount of data recorded for different purposes over a period of years.

The intent is to show how this information can be brought into

(Continued on page 7)

Lockwood Farm visitors see vegetables grown on soil treated with sewage sludge at the rate of 130 tons or less to the acre.

Dimond Award Winner

John Massaro, left, receives the scroll designating him the first winner of the annual Albert E. Dimond award, a cash stipend and the opportunity to conduct research at the Station for 6 summer weeks. Saul Rich, head of the Department of Plant Pathology and Botany, made the award, presented in memory of the late Dr. Dimond of this Station.

Single copies of the following are available on request to Publications, Box 1106, New Haven 06504. Include your ZIP number, please.

How Does Your Garbage Grow? George R. Stephens. Plant Science Day talk, 1972

Soft-rot Research Yields Liquid Garbage. Lester Hankin. Frontiers, May 1972

The Purifying Power of Soil, David E. Hill. Frontiers, November 1971

Percolation Testing for Septic Tank Drainage, David E. Hill. Station Bulletin 678, 1966

Plant Nutrients and Animal Waste Disposal. Charles R. Frink. Station Circular 237, 1970

The Biochemistry and Methodology of Composting. Raymond P. Poincelot. Station Bulletin 727, 1972

Increasing Plant Productivity by Slowing Respiration

Israel Zelitch
Department of Biochemistry

The "Green Revolution," which has seen the yields of some food crops at least doubled by the use of fertilizer and genetic methods, may have reached a plateau.

It is now becoming harder to "squeeze" out higher yields by increasing the utilization of minerals and fertilizer. Thus research at the Station is concerned with raising crop plant productivity by increasing the 90 to 95 percent of "dry matter" which comes from airborne carbon dioxide (CO_2) in sunlight.

Some of this CO_2, which is made into food by the plant during photosynthesis, is returned to the air in a process similar to an animal's exhaling. Scientists have therefore asked the question, is all this "loss" of CO_2 necessary, or can some of it be retained for larger crop yields? Some experiments at the Station on this problem hold promise that much more CO_2 can be retained.

It is well known that some species such as corn and certain weeds naturally consume more CO_2 in light (photosynthesis) and have higher productivity than most other species. The overall equation of photosynthesis is generalized in Equation (1), which summarizes how carbohydrate is synthesized by green plants from CO_2.

Plants also release carbon dioxide by a process of respiration that is very similar to the one animals possess, as shown in Equation (2).

Since photosynthesis and respiration occur at the same time, photosynthesis must be greater on a daily basis or plants could not accumulate food or grow. The overall net gain in dry weight is thus determined by the total quantity of photosynthesis less the loss by respiration.

Respiration cannot be eliminated entirely because it is essential for many plant processes, just as it is for animals. However, it has recently been recognized that most plant species have a unique form of respiration that occurs only in plants and only when they are in the light. This light respiration, or photorespiration as it is called, is faster in bright light than the more common kind and is apparently wasteful because it releases CO_2 that has recently been fixed during photosynthesis.

In fact those crops with slow rates of photorespiration are known to have a greater productivity, as shown in Table 1. Here the estimated average yields of several leafy crops have been compared. Yields of corn silage and sugarcane are more than double those of spinach, tobacco, and hay grasses, even though they all receive about the same energy from the sun. The higher yielding species have a slower photorespiration, and this largely accounts for their greater productivity. Such observations have stimulated attempts to decrease photorespiration in order to obtain greater CO_2 uptake and retention during photosynthesis in crops that are not as productive as corn.

Our work has shown that the CO_2 released during photorespiration comes mostly from the breakdown of glycolic acid. This compound is synthesized by leaves in sunlight during photosynthesis, as summarized in Equation (3).

Enzyme systems are also present in plants that can revert glycolic acid back to CO_2 (Equation (4)).

Photorespiration would be decreased if the synthesis of glycolic acid were blocked (inhibition of Equation (3)) or if its reaction to produce CO_2 were slowed (Equation (4)). In this way, by increasing the net uptake of CO_2 one might well convert an inefficient species (spinach, tobacco,

Photosynthesis

$$(1) \quad CO_2 + 2\,H_2O + \text{light} \longrightarrow \underset{\text{(carbohydrate)}}{(CH_2O)} + H_2O + O_2$$

Respiration

$$(2) \quad (CH_2O) + O_2 \longrightarrow CO_2 + H_2O$$

Synthesis of Glycolic Acid

$$(3) \quad 2\,CO_2 + \text{light} \longrightarrow \underset{\text{(glycolic acid)}}{CH_2OH\text{-}COOH}$$

Breakdown of Glycolic Acid to CO_2

$$(4) \quad CH_2OH\text{-}COOH + O_2 \longrightarrow \underset{\text{(formic acid)}}{HCOOH} + H_2O + CO_2$$

hay grasses, and also wheat, beans, and potatoes) into one as productive as corn or sugarcane. Corn leaves normally synthesize glycolic acid more slowly than leaves of inefficient species. This helps explain their slow photorespiration.

We are just beginning to find compounds that inhibit the reaction summarized by Equation (3). Biochemical substances have already been described that effectively slow the reaction shown in Equation (4) in the laboratory. When such inhibitors are added to tobacco leaf tissue and photorespiration is thereby blocked, net CO_2 uptake shows a large temporary increase (Table 2). These experiments suggest that it might well be possible to convert an inefficient photosynthetic species (tobacco in this instance) into an efficient one if the reactions represented by Equations (3) or (4) were regulated.

Table 1. Estimated average market yields in pounds

Crop	Fresh weight per acre*	Dry weight per acre per week of growing season
Corn silage	23,600	417
Sugarcane	54,000	450
Spinach	5,800	116
Tobacco	1,945	224**
Hay	4,000	180

*Average market yield from Agricultural Statistics, U.S.D.A. 1969.

**A yield of stalk equal to 90 percent of the yield of leaf was added, giving a total of 3,140 pounds per acre estimated dry weight.

Peter Day of our Department of Genetics and I have also been experimenting with techniques for selecting and breeding individual tobacco plants that naturally have a slow rate of photorespiration.

Most recently individual plants of a standard tobacco variety, Havana Seed, were found that had slower than usual rates of photorespiration for this species. Such plants were self-pollinated and the progeny examined for photorespiration and photosynthesis for three generations. Those plants with unusually high rates of photosynthesis always had a slower photorespiration, and about one-third of the progeny in each generation had unusually fast rates of net photosynthesis. Results from two individual plants in the third generation are shown in Table 3.

Table 2. Effect of inhibitor of Equation (4) reaction on carbon dioxide intake for tobacco leaf tissue in light, 95°F.

Photosynthetic rate
Micromoles of carbon dioxide per gram of fresh weight per hour

Leaf tissue in water	Leaf tissue in inhibitor solution
48	169

Table 3. Variation of photorespiration and net photosynthesis in tobacco plants

Slow photorespiration plant		*Fast photorespiration plant*	
Photorespiration index	1.7*	Photorespiration index	3.7
Net photosynthesis**	23.4	Net photosynthesis	17.0

*1.7 times greater than respiration that occurs only in darkness.
**Milligrams of carbon dioxide per square decimeter of leaf area per hour.

The average photosynthetic rate (CO_2 uptake) in the plant with slow photorespiration was very rapid for this species and was 38 percent greater than for the fast photorespiration plant. These results clearly show that large differences in photorespiration can occur in normal-appearing plants in the same species. This suggests that large increases in net photosynthesis and plant productivity may be achieved by decreasing photorespiration through selection and breeding in a suitable genetic background.

Governor Presents First Jones Medal

Governor Thomas J. Meskill presented the first Donald F. Jones gold medal to Dr. George W. Beadle, a Nobel laureate in Medicine and Physiology, at a ceremony on September 14 marking the opening of the Donald F. Jones auditorium at the Station.

Dr. Beadle, president emeritus of the University of Chicago, later delivered a Donald F. Jones Memorial Lecture on "The Mystery of Maize—an Interdisciplinary Saga."

Governor Meskill said that Jones' invention of hybrid corn is in the front rank of Connecticut "firsts," and that an unusual ear of corn from Connecticut is one of the ancestors of high protein corn now helping to overcome malnutrition in many areas. Governor Meskill is president of the Station Board of Control.

Warren Thrall, vice president of the Board, formally presented the auditorium to Station Director Paul E. Waggoner.

Accepting the auditorium, Director Waggoner said that it will be used both to report the Station's useful research and as a meeting place for agriculturists,

Thomas J. Meskill George W. Beadle

from those who tend flower pots to those who farm hundreds of acres. All of these citizens, he affirmed, are stewards of the land and landscape of Connecticut.

In his lecture, Dr. Beadle explained why, in his opinion, a wild grass called teosinte may properly be considered the ancestor of modern corn.

The complete renovation of the auditorium was made possible by the Jones Fund.

Report on Defoliators

John F. Anderson
Department of Entomology

GYPSY MOTHS and elm spanworms were again prevalent in many areas of Connecticut during the summer of 1972. Noticeable defoliation was apparent on an estimated 513,880 acres, 141,227 acres less than recorded in 1971.

A comparison of noticeable defoliation, by counties, during the last two summers is shown in the accompanying table. Caterpillars increased in 1972 in Litchfield, Middlesex, New London, Hartford, and Tolland Counties. Gypsy moths were the dominant insect in the extreme eastern portions of Connecticut. Elm spanworms and gypsy moths were often both present in other parts of the state.

The elm spanworm was the most abundant caterpillar in the western and central portions of the state in 1970 and 1971. The decline of this defoliator in Fairfield and portions of New Haven counties in 1972 was caused primarily by a small wasp parasite known as *Ooencyrtus clisiocampae*. This previously unreported parasite of the spanworm was isolated by Harry K. Kaya and me in 1971, and some notes on its biology were published in the May 1972 issue of Frontiers. We found that this parasite had destroyed over 95 percent of the elm spanworm eggs during the summer and fall of 1971 and predicted that caterpillars would not be abundant in southwestern Connecticut during the summer of 1972.

The parasite this year has apparently destroyed most of the eggs of the spanworm which were laid in July and which would have hatched into caterpillars in 1973. The parasite passed the winter and spring as a larva inside the egg shell of the spanworm and emerged as an adult at the same time adult spanworms laid their eggs. Adult *Ooencyrtus clisiocampae* began immediately to parasitize the new eggs and in some areas such as Watertown, over 90 percent of the host eggs were destroyed by the end of July 1972. A second generation of adult parasites emerged during the latter part of August and in areas east of the Connecticut River, the parasite became abundant enough in late summer to parasitize most of the eggs.

Other important parasites of the spanworm include a small wasp which parasitizes eggs in April and May, and flies which kill the larger caterpillars. The wasp is known as *Telenomus alsophilae* and parasitized 20 to 30 percent of the eggs in central Connecticut last spring. The parasitic flies are known as tachinids and were numerous enough in some areas to kill 45 percent of the caterpillars.

The elm spanworm has a complex of parasites of which *Ooencyrtus clisiocampae* is by far the most important. These parasites have become abundant enough to have suppressed populations of spanworms to non-nuisance levels. Except for possible localized infestations in northeastern Connecticut, this insect probably will not be a problem in 1973. Unfortunately, the gypsy moth does not have nearly the number of effective parasites and is expected to cause defoliation in several areas next summer.

Noticeable defoliation by county in Connecticut.

County	*Acres defoliated by year* 1971	1972
Litchfield	60,532	110,840
Middlesex	50,534	94,160
Fairfield	188,435	1,920
New Haven	135,259	48,080
New London	60,373	82,860
Windham	69,099	35,480
Hartford	71,458	85,060
Tolland	19,417	55,480
Total	655,107	513,880

Harry K. Kaya brings down a tree to examine the upper bole where many elm spanworms lay their eggs.

New Publications

The following new Connecticut Station publications have been published since the last issue of Frontiers. Requests for copies should be addressed to Publications, Box 1106, New Haven 06504. As readers understand, results of many other scientific investigations at the Station are published in professional journals. During the past 6 months, 55 such articles have been submitted for publication.

Corn Blight (Plant Pathology)

B 729 EPIMAY, A Simulator of Southern Corn Leaf Blight. Paul E. Waggoner, James G. Horsfall, and Raymond J. Lukens.

Inspections and Analyses

B 728 76th Report on Food From Connecticut Markets and Farms. J. Gordon Hanna.

B 730 Commercial Feeding Stuffs Inspection Report for 1971. J. Gordon Hanna.

B 731 Commercial Fertilizers Inspection Report for 1971. J. Gordon Hanna.

B 732 Pesticides Inspection Report for 1971. J. Gordon Hanna.

Plant Breeding

C 246 Evaluation of Tomato Varieties for Resistance to Ozone. Carl D. Clayberg.

Soil and Water

B 733 Use of Natural Resource Data in Land and Water Planning. David E. Hill and Hugo F. Thomas.

C 245 Artificial Root Media and Other Fertilizations for Container-Grown Chrysanthemums. Henry C. De Roo.

Reclaiming Nutrients

(Continued from page 3)

focus on specific problems in land-use planning. The interpretation system is based upon the use of uniform-scale maps, each of which delineates a different limiting factor in selection of a solid-waste disposal area in a portion of the Somers area northeast of Hartford. By overlaying the maps, areas with limitations are blocked out and the "open" areas are those free from excessive slope, shallow bedrock, water table close to the surface, likelihood of flooding, and other limitations.

The Somers area was not selected because of a current problem there, but because a wide range of soil types, bedrock, and hydrology was represented, and the data needed for this approach to land-use planning were available.

Dr. Stephens and Dr. Hill of the Station, and University of Connecticut colleagues, have been experimenting for 3 years on disposal of poultry manure in woodlands. They have found that approximately 32 tons of the material to the acre may be a practical and safe rate of annual application. There was no odor problem after the first day, no fly problem, and the thin crust of material disappeared into the litter after a few rainy days.

Ground water samples from the forest soil showed no increase in nitrogen content months after the waste was applied. Pine tree needles were greener a few weeks after applying the poultry manure, which of course is high in nitrogen content.

Compost, garbage mulch, soil and water studies, and application of poultry manure to woodlands—these are Connecticut Station approaches to some of the many problems of recycling biologically degradable materials. A first step in learning more about these continuing investigations is to request copies of the publications noted on page 3 as well as some of the new bulletins listed on page 6.

Rubbish Mulches for Petunias

Patrick M. Miller

Plant Pathology and Botany

Farmers and homeowners know that mulching with compost, hay, or plastic sheeting can increase plant growth. Other materials usually discarded as rubbish may also be used as mulch. We tested the effect of some of these materials on the growth and flowering of petunias at Lockwood Farm.

Equally fertilized plots were mulched with one of the following: two thicknesses of newspaper; manila bags cut open to form single sheets; 30-inch squares of asphalt roofing paper; a 3-inch layer of grass clippings; and a 3-inch layer of salt hay. The edges of the paper mulches were buried in shallow furrows, and the paper was slit at intervals to allow water to pass through the soil. Petunia seedlings were planted through holes made with a trowel. For comparison, petunias were planted in unmulched plots and were weeded once a month.

A period of dry weather shortly after the plots were planted showed how well mulching saves soil moisture. As soon as the transplants started to grow, the plants in the mulched plots spurted ahead. Two months later, the plants in the plots mulched with the paper materials and salt hay were about a fifth to a third larger than the plants in the unmulched plots. The plants in the plots mulched with clippings were almost twice as large. Undoubtedly, the grass clippings provided nutrients as well as mulching benefits.

The mulches not only slowed drying of the soil, but also prevented the growth of weeds that rob the garden of moisture, plant nutrients, and sunlight.

In addition to producing larger plants, mulching also increased the number of flowers. The plants growing in plots with the paper materials and salt hay all produced from 50 to 80 percent more flowers than the plants growing in the unmulched plots. In the plots mulched with grass clippings, the plants produced even more flowers—almost three times as many as on the plants in the unmulched plot.

We also used these plots to find out if such mulches affect populations of meadow nematodes. The meadow nematode is a destructive plant parasite common in Connecticut, and plants generally grow more when these microscopic worms are removed from the soil. We have found in the past that mulches of compost or black plastic sheeting will reduce populations of meadow nematodes. Consequently, we examined the soil in our petunia plots to see what had happened to the meadow nematodes. We found that compared to the unmulched plots there were 75 percent fewer nematodes in the plots mulched with grass clippings, 63 percent fewer in the plots mulched with newspaper, 50 percent fewer in the salt hay plots, and 25 percent fewer in the plots mulched with paper bags. The roofing-paper mulch appeared to increase the number of meadow nematodes.

These experiments demonstrate that some materials that we now throw away can be used to give us more flowers.

Public Trust in Science and Scientists

Paul E. Waggoner

FLUCTUATIONS in the value of the currency, including our dollar, have set me to thinking about the value of another currency—the scientific currency of public trust in science and scientists.

Reserves stand behind our national currency. What comparable "gold" stands behind the public trust in science and scientists at this Station?

A couple of attributes that might come to mind at first are (a) this Station investigates biology that matters to people in this part of the world and (b) these investigations help people meet practical needs. For example, scientists here study crops and their pests because people want food. Or, our staff investigates forests and gypsy moths because our citizens are upset by barren forests and crawling caterpillars. Our useful discoveries are known to readers of Frontiers. These range from hybrid corn to a quick test for lead poisoning in children, and from vitamins to the wasp that freed Fairfield County from the elm spanworm.

But these attributes that first come to mind are not the essential gold behind the scientific currency.

To find this essential gold we can go back to Galileo. Before him scholars had reasoned, argued, and concluded that bodies of different weights would fall at different speeds. Galileo thought otherwise, and in a popular story, he settled the argument by a simple experiment. He rolled a little ball and a big ball off the tower of Pisa. Of course, they hit the ground at practically the same time. Galileo experimented, he told it like it was, and the argument was over.

This device of letting Nature and experiment settle questions is, I believe, the real gold that secures the scientific currency.

Easily Devalued

Unfortunately, the gold is easily lost and the scientific currency, like the money in our pockets, is easily devalued. For example, the editor of a biological journal recently reported that an author felt his article would be acceptable only if it followed the popular, sensational line. Here is a warning that the essential gold of sticking to experiment and results may be in jeopardy and the currency may be devalued.

Scientists, I am sure, are as concerned as other citizens about the future of the world. They are trying hard to apply research to the problems of our troubled world. When they try too hard, when they extrapolate too far, they may end up giving advice instead of information. This devalues the scientific currency.

A lesson I learned shortly after arriving at this Station years ago illustrates the easy road to devaluation.

The task of writing a description of potato diseases was assigned to me. I wrote the information about the diseases. Then I went on energetically to advise potato growers, writing which sprays and other disease controls they *should* use. My manuscript didn't get far. It was pointed out that I had ended up giving advice rather than information. My revised manuscript stuck to a description of the diseases and to reports of which disease controls worked well in experiments. I correctly left it for the growers to decide what they *should* do.

As long as scientists stick to experiments and straightforward reports of research they fulfill an invaluable and unique role. They also build the reserves behind the scientific currency.

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Bruce B. Miner, *Editor*