

Frontiers of Plant Science

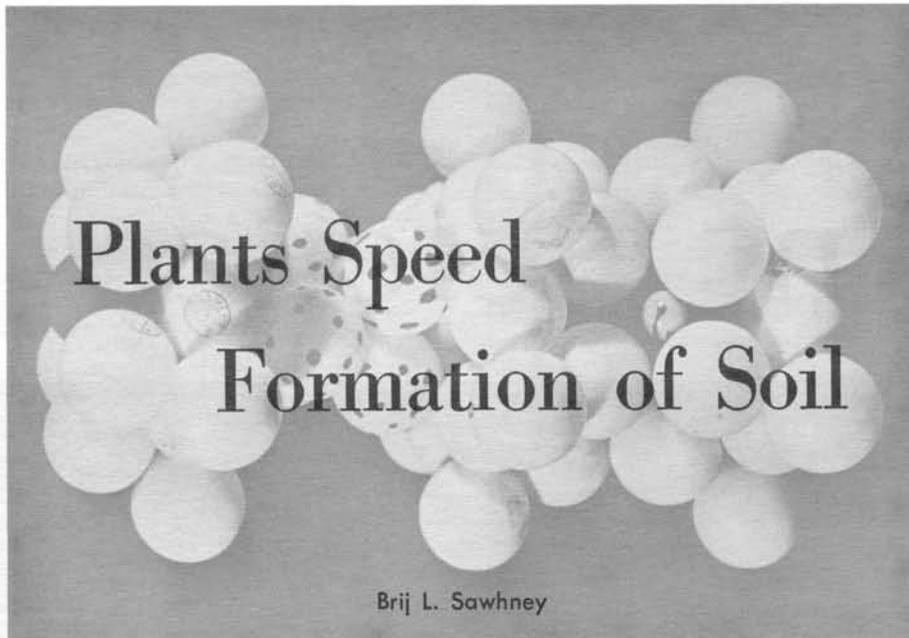


Brij L. Sawhney analyzes clays to learn how plants speed soil formation . . . page 2

THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION

NEW HAVEN

Established in 1875 by the General Assembly



Plants Speed Formation of Soil

Brij L. Sawhney

The weathering of rocks creates tiny clay particles. Each particle may consist of several hundred mica plates, so small that they can be identified only by electrons or X rays. Plants not only feed upon the nutrients stored on the clays but also change the clays of the soil.

Background photo shows molecular structure of clay.

of mica. In the field, biotite (a form of mica) has been changed to vermiculite by growing crops of wheat upon it.

Our soil in Connecticut is acid, however, and most of it grows trees. Since a large portion of the potassium for feeding the trees comes from mica, an understanding of the weathering of mica by trees is particularly important. Furthermore, in some forested acid soils, a bleached zone containing amorphous or non-crystalline clay is known to develop beneath the forest litter. (Such soils occupy vast acreages of land throughout the world and are known by their Russian name, Podzols.) As tree growth is affected by such soils, so is the formation of these soils affected by the trees.

For these reasons, J. R. Boyle and G. K. Voigt, of the Yale School of Forestry, and I investigated the weathering of biotite mica by roots of tree seedlings and associated microorganisms. We also studied the effect upon mica of the organic acids which are released either from the living tree roots or from decaying trees. We found that mica weathered much differently in these acid environments than in salt solutions or in the neighborhood of wheat roots and their associated microorganisms.

The dramatic differences shown by the different weathering agents is one of the most pleasing outcomes of this investigation. These can be seen in the photographs. When the original flake shown in Fig. A is placed in an organic acid, the weath-

THE SOIL MANTLE of the earth provides a vast and changing spectacle which we cannot resist investigating. In addition, the soil is our principal means of sustenance. This lends importance and even urgency to learning how plants feed upon the soil and how the soil is changed by their feeding.

Of the mineral components in the soil, clay is the most important because it stores most of the plant nutrients and holds much of the water. In Connecticut, this clay is predominately vermiculite that is formed by the weathering and expansion of mica in the bedrock. A small speck of unweathered mica may contain several thousand mica units, each consisting of a layer of alumina sandwiched between two layers of silica. These units are negatively charged and have cavities in their surfaces. Positively-charged potassium ions fit into these cavities, and hold the units together in a mica particle.

When the mica is weathered, the potassium ions are replaced by hy-

drated ions such as calcium, and the negative charge on its surfaces is decreased by several chemical changes including the oxidation of its iron. Consequently, the mica units are held together less tightly than before and become the expanded vermiculite lattice of our clay. These alterations give the clay the important property of ion exchange. Biologically, this new property is of great importance: a storage site for nutrients is created. The nutrient elements, such as calcium, reside on the exchange sites of the clay and can be taken up by plants. At the same time, they are retained tightly enough to prevent their loss by leaching through the soil profile.

In order to understand this course of weathering, the investigator tries to simulate the process in his laboratory. Several investigators have weathered mica to vermiculite by leaching mica with solutions of calcium or magnesium salts or by treating mica with chemicals which extract potassium from the interlayers

ering produces a translucent band along the edges of the flake as seen in Fig. B. The weathering band advances and eventually covers most of the flake; photographs B, C, and D show the changes in the same flake after one, two, and three weeks in one molar oxalic acid. Similar but slower advance of the translucent band was produced by *Aspergillus niger*, a fungus, growing in an 8% glucose solution, Fig. E, or by a solution inoculated with a suspension of soil from a tulip poplar stand, Fig. F. Both E and F show flakes after eight weeks' weathering.

This is strikingly different from the weathering caused by salt solutions or by wheat. When placed in salts, the band of weathering, Fig. G, is a dark one rather than transparent or translucent.

The darkening of the band by salt solutions has been attributed to the replacement of the potassium between the mica layers of the hydrated cation of the salt. The translucent band produced by the acids and seen in the photographs is at-

tributed, on the other hand, to the removal of iron and magnesium from *within* the mica crystal. The organic acids extract iron, magnesium, and aluminum, leaving behind a fragile silica matrix seen as the translucent band. This silica matrix disintegrates easily and the mica structure collapses.

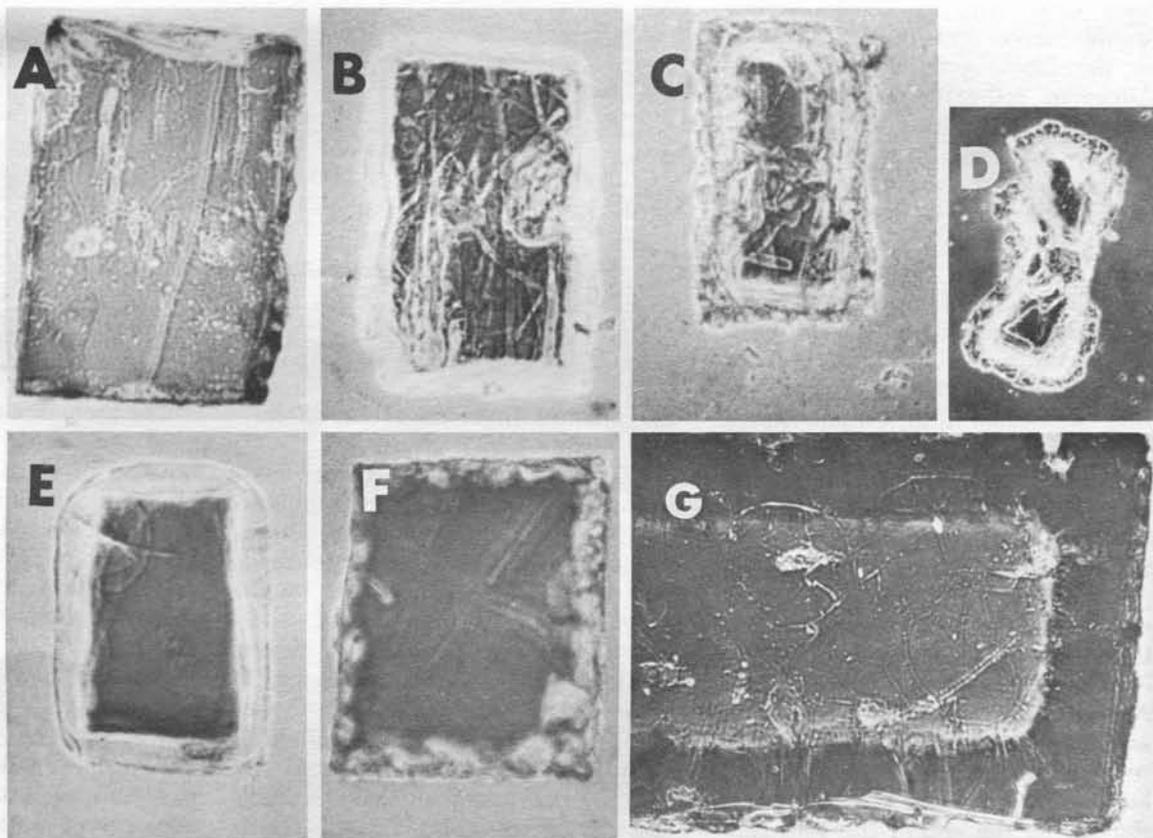
An examination by X rays of the products of weathering confirmed what could be seen in the pictures. Weathering by salt solutions expanded the mica units from 10 to 14 angstroms. But weathering by organic acids and by solutions growing microorganisms destroyed the original, regular structure of the mica and left only an amorphous residue. Apparently, weathering of micaeous minerals by microorganisms and acids is responsible for the bleached zone containing amorphous clay in the podzols of the cool forest. Thus, the organic substances from tree roots and the associated microorganisms play an important role in the weathering of bedrock and the forming of our soils.

Contributors

Brij L. Sawhney, soil scientist, has been a member of the Station staff since 1958 except for 2 years with the Canada Department of Agriculture. Born in Rajoya, North-West Frontier Province, Pakistan, he earned his doctorate in soils at the University of Wisconsin in 1957. Much of his work has been on the sorption and fixation of cesium by clays.

Saul Rich, who writes in this issue on air pollution, is a plant pathologist. His research at this Station during the past 20 years has dealt with fungicidal mechanisms, physiology of fungi, and disease control as well as with effects of air pollutants on plants.

George R. Stephens is primarily concerned with research on tree physiology and ecology. A full-time member of the staff since 1961, his graduate study was at Yale University.



Our Gasping Plants

Saul Rich

TRUE, plants don't gasp. But our Connecticut plants are growing in an atmosphere that sickens them, and if they could gasp they would. How did the farm air get that way?

By now most of us are aware of air pollution and may even know that air pollutants can injure plants. We may not realize, however, that air pollution is another of the problems arising from the very human desire for a more abundant life.

In America, this more abundant life became possible as our nation industrialized. Since people go "where the action is," they flocked to the cities to be near the jobs and the excitement. But all farmers couldn't leave their farms or the city people would starve and be forced back to the land. American cities and American industries could expand only so long as our agriculture could produce an adequate supply of food.

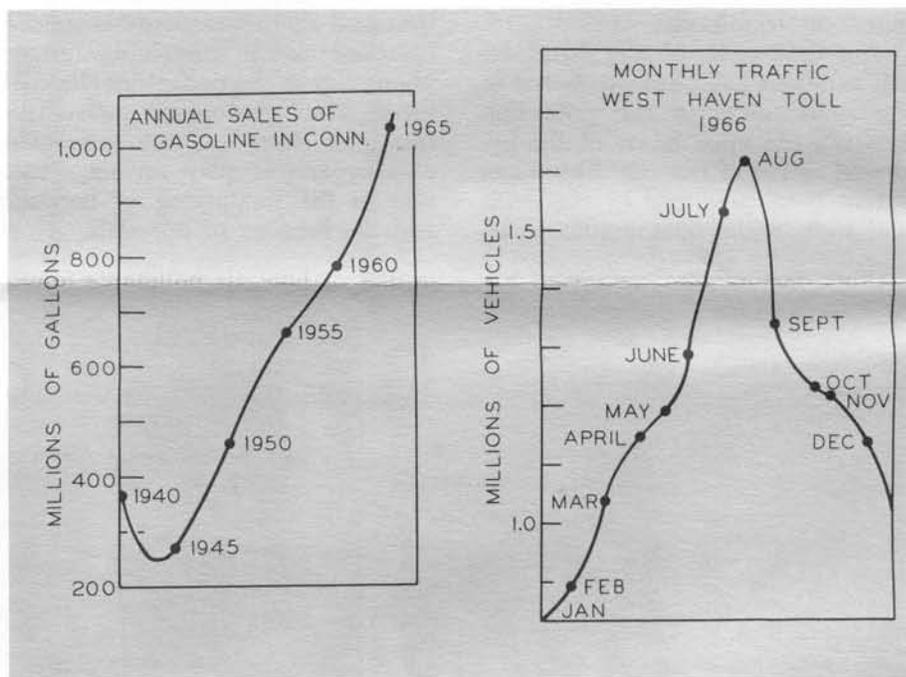
Our increasingly productive agriculture resulted from two things: mechanization and scientific farming. It is an odd twist of fate that Eli Whitney lived and worked within a few hundred yards of the present location of The Connecticut Agricultural Experiment Station, the first established in the United States.

Whitney's cotton gin pointed the way to farm mechanization, the Experiment Stations injected science into the nation's agriculture. It was the increasing agricultural productivity that loosened the bonds which tied the American population to the land.

In 1790, it took the labor of four American farmers to feed themselves and have enough food left over to supply one townsman. As the land became more fruitful, the population shifted. By the end of the 19th cen-

tury less than half the American population lived on farms. By 1940, for every American on the farm there were three Americans who lived in cities. Since 1940, over 15 million Americans have left the farms. This has been described as

now, most of us in Connecticut live in an urban environment. Connecticut farms may look rural but most of them are subjected to an urban atmosphere. It is the pollutants in this urban atmosphere that are injuring our crops.



the greatest mass migration in human history.

Of the 11 million Americans who live on farms today, about 5 million are considered farm workers. These 5 million produce enough to feed the other 195 million of us, with some left over to ship abroad.

With an assured food supply, we are becoming ever more urbanized. One estimate states that by 1980 we will have 75% of the U. S. population occupying only 2% of the land. If this is correct we can look forward to a truly crowded future. Even

The air pollutants that concern us most are those produced by the burning of fossil fuels such as coal, oil, and gasoline. The energy so produced provides us with the heat for our homes, with the electricity to run our many household conveniences, and with power for transportation.

It is our love affair with the automobile that is producing the most problems. The air pollutants that have caused the most crop damage in Connecticut are spewed from the exhausts of automobiles. These ex-

haust gases contain nitrogen oxides and unburned hydrocarbons which react in sunlight to give ozone and other photochemical oxidants that can injure plants.

When we understand the source of air pollution damage to plants, we realize why our crops have been showing such damage since the early 1950's. As gasoline burned in automobiles is the raw material for these air pollutants, we can follow the trend by graphing the annual sales of gasoline in Connecticut. In 1940, 382 million gallons of gasoline were sold. During the war years the sales went down, but by 1946 sales once again equalled the pre-war figure. In 1950, when air pollution damage to Connecticut crops was first brought to our attention, 520 million gallons of gasoline were sold in the State. Sales have continued to increase every year. By 1965, over a billion gallons were sold. The human population of Connecticut has increased by 50% since 1950, but the population of Connecticut-registered motor vehicles has increased by 100% in the same period.

Other factors also aggravate air pollution damage to crops. Because these air pollutants are produced by energy in sunlight, they are most likely to occur when the sunlight is most intense. This would be during the summer months, our growing season. It is during the summer also that most of us take our automobile trips and so produce the most exhaust fumes. This pattern can be illustrated by the graph of the monthly traffic passing through the West Haven toll station on the Connecticut Turnpike. The graph shows that the traffic is heaviest just when our main crops are most lush. Recently the Governor's office predicted that the miles of motor vehicle travel in Connecticut may increase about 70% by 1985. Our crops won't like it.

Just how often we get a crop-damaging dose of air pollution depends very largely on the weather. On most days there is sufficient air movement to disperse and dilute the pollutants. They are diffused into the 6 miles of troposphere that cover us and cannot then be detected by

plants or instruments. However, when we get a temperature inversion, the air pollutants may be restricted to a layer 500 to 1500 feet high. In this much smaller volume of air, pollutants are concentrated to 20 to 60 times what they would be on a gusty, well-ventilated day.

Plants being more sensitive than people to these air pollutants, the accumulation of a crop-damaging dose may happen more often than people realize. Both at the Valley Laboratory, Windsor, and here in New Haven we measure the ozone concentration in the air by means of a very sensitive ozone-meter. When this sniffing device detects more than 5 parts of ozone per hundred million parts of air, we know that plants may be injured that day. During the middle of the 1966 growing season, for example, we recorded such periods on the 27th and 28th of June, and on the 12th, 13th, 18th, 25th, and 26th of July. Connecticut crops must have done a lot of gasping in 1966.

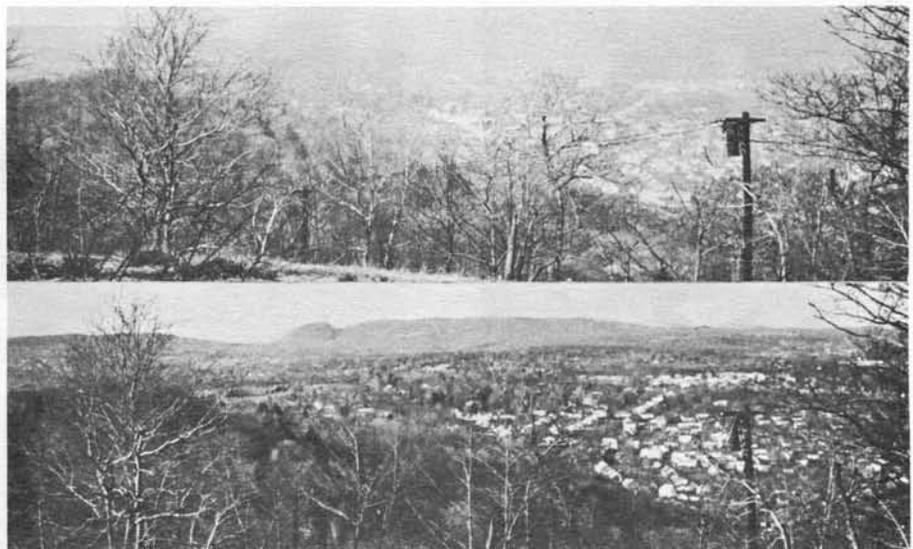
Such frequent periods of air pollution raise other problems. In our studies of how air pollutants injure plants, we compare the metabolism of healthy plants to that of plants which have been exposed to air pollutants. We have to make certain that our healthy plants have not been breathing fouled air. To insure this, we have equipped one of our

greenhouses with a huge air filter. All outside air pumped into this greenhouse passes through layers of finely divided charcoal that filters out the pollutants. Now we know that plants grown in this greenhouse have not been contaminated before we use them in our experiments.

One important reason for our study is to find how best to protect plants from air pollutants. At present, the only adequate method we have is to select and breed our plants for resistance to these gaseous poisons. In fact, most tobacco plants grown in the Connecticut shade tents this year had just such genetic resistance. We must realize, however, that such plants show a degree of resistance. They are not immune. Even these plants are injured when exposed to a high enough dose of ozone.

This leads us to wonder what we may expect in the future. Will air pollution become worse? We can only compare our situation to others. This year in New Haven we recorded a high of 17 parts of ozone per 100 million parts of air. Compare this to the 73 parts of ozone per 100 million parts of air reported from California in 1967. Can it happen here?

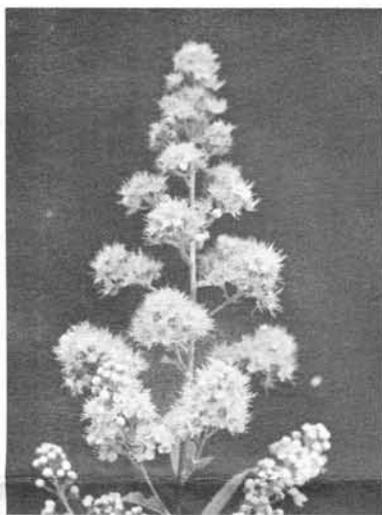
Until urbanologists solve the problems of congested cities, plant scientists must seek ways to protect plants subjected to the urban environment.



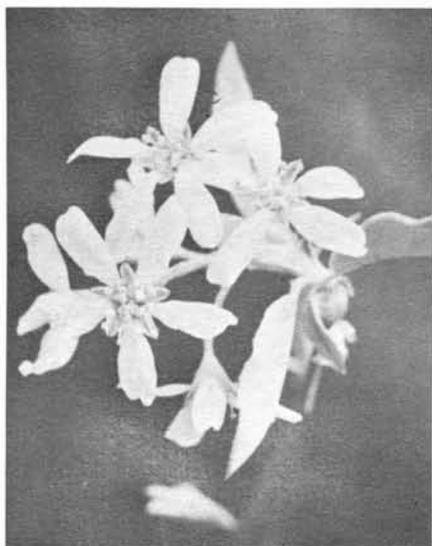
Air-polluting haze shrouds the Sleeping Giant in the top photo, compared with the view on an equally bright day with a low level of pollution.

Native Shrubs For Variety

George R. Stephens



Meadowsweet *Spiraea latifolia*



Shadbush
Amelanchier canadensis

OUR CONNECTICUT HILLS are dotted with many species of native shrubs, an array occupying every ecological niche from watery bog to arid sand barren. Because of their diverse habits of growth and their attractive flowers, foliage, or fruit, these native shrubs offer interesting variations from the exotics which presently fill our shrubberies. By and large, these natives are acclimated and have immunity or, at least, tolerance to pests.

At Lockwood Farm in Mt. Carmel the late A. R. Olson assembled a collection of 45 species in an open field to observe their performance as ornamentals. Some, such as swamp azalea from the bog or native yew from the cool, dark forest have suffered, but most grow well with a minimum of care.

Careful selection of species will satisfy any site, wet or dry, and can provide for a succession of bloom from April to September. Many also offer colorful autumn foliage, or fruit attractive to bird or man.

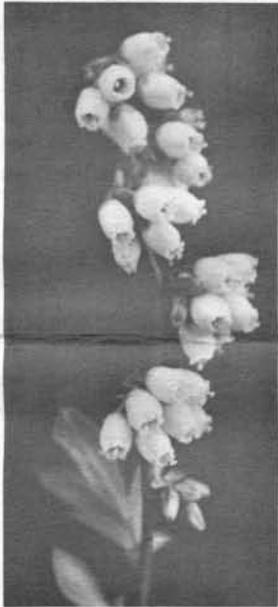
Few of these shrubs are grown commercially. Although some can be grown from seed, cuttings, or layers, all can be successfully transplanted from the wild. Early spring is best and effort should be concentrated on careful removal of roots. Because wildlings from woodlands or old fields often are misshapen, the tops of all except coniferous evergreens may be removed two inches above the ground line. Although bloom will be sacrificed for two or three years, the new growth will produce an esthetically pleasing plant.

A note of caution—Wild plants may not be removed from public land. Removal from private land requires consent of the landowner. Indeed, transport of mountain laurel from the land of another requires written permission of the owner.



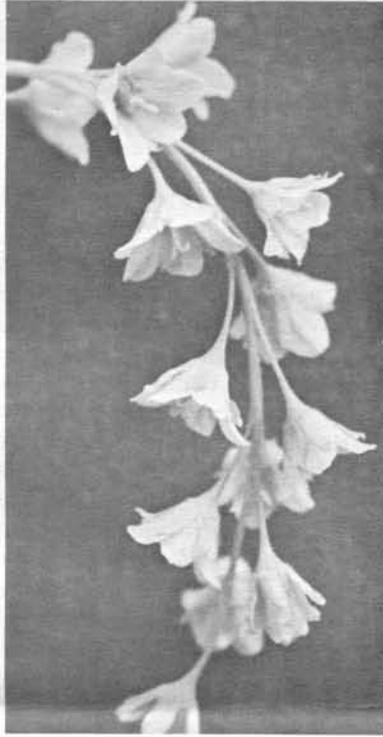


Buttonbush
Cephalanthus occidentalis

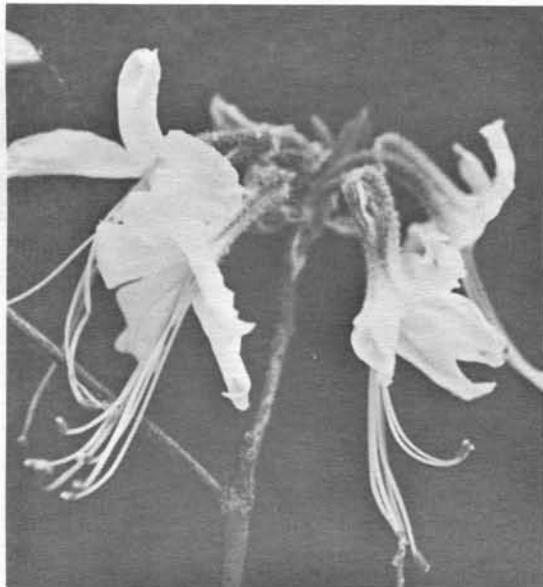


Highbush Blueberry
Vaccinium corymbosum

Striped Maple
Acer pensylvanicum



Pinxterbloom
Rhododendron nudiflorum



Achievements Recognized

Dr. David E. Hill, Department of Soils and Climatology, received the Certificate of Merit award of the Federated Garden Clubs of Connecticut in October for his contribution to the field of conservation through research on water disposal in Connecticut soils.

Dr. Saul Rich, Department of Plant Pathology, was named a Fellow of the American Phytopathological Society at its meeting in Washington in August.

The Eastern Branch of the Entomological Society of America presented its Meritorious Award to Neely Turner for his "outstanding contributions of broad significance to the science of entomology and his outstanding service to the profession of entomology," in Baltimore on October 31. Mr. Turner is chief entomologist and vice-director of the Station.

Tsunami

(Continued from page 8)

along the agricultural shore? The time lag will be long, I think. It may be that its effects will fade before reaching shore.

Some counterforces are becoming visible, notably the strong evidence that Congress is getting tired of subsidizing research that does not aim to produce results useful to society. It is probable that "pure research" will be redefined more in line with that used at our Station since 1869 when S. W. Johnson published his book on "How Crops Grow." We believe that we can advance the frontiers of science by aiming to understand how useful crops grow as well as by understanding how wild plants grow. After all, Mendel used garden peas to establish his great law of inheritance.

These two forces, disenchantment with research not likely to yield useful results and redefinition of "pure research," could serve to damp the tsunami before it reaches the cities on shore and creates a still more serious problem for the mayors.

Photos by George R. Stephens



Tsunami In the Agricultural Ocean

James G. Horsfall
Director

surface of the ocean. This great wave, called a tsunami, sweeps across the face of the deep and crashes on shore as a tidal wave that tears coastal cities apart.

Two forces have operated during the last dozen or so years to create a tsunami on the agricultural ocean. The first force originated with agricultural economists who wrote books and lobbied in legislative halls saying that every third agricultural scientist should be plowed under to reduce the input of technology into agriculture, thus inducing an economy of scarcity. This force has cooled the ardor of many young scientists for transposing science into agricultural technology.

In the meantime a great enthusiasm has been whipped up across the nation to glamorize the so-called pure science, which the first Director of the National Science Foundation defined as science for its own sake and without regard to practical use.

As a result of the discouragement by economists of applied research and the encouragement by others of pure research, many scientists have simply deserted agricultural research. Thus, the effort to improve agricultural technology is diminishing across the nation in the face of our assumption that it must increase geometrically.

So we have a tsunami sweeping across the agricultural ocean that originated in the earthquake set off by those who have advocated a great reduction in agricultural research. Will this tsunami one day sweep destructively into the cities

(Continued on page 7)

MANY CITY OFFICIALS in the U.S. wringing their hands about the explosive growth of cities. They are concerned, and justly so, about crowding, air pollution, sewage disposal, vermin in the slums, but I have never heard of a single one wringing his hands about where the food for the megalopolis will come from. The city dweller takes his food for granted; witness the prayers offered each week at service clubs just before the members sit down to their meals together. Seldom does the prayer any longer thank God for the "food we are about to receive."

This astonishes me, and my astonishment is compounded when I consider that this occurs in a really hungry world, with nearly half its inhabitants undernourished or even starving. Upon further cogitation, however, my astonishment is assuaged when I realize what a tremendous tribute this is to the farmers and the agricultural scientists of the nation.

When I discuss the matter with my urban friends, they assure me of their faith that science will con-

tinue to provide the technology farmers will need to save us from starvation even in a hungry world. This faith rides aboard the assumption that agricultural technology can be improved geometrically as fast as if not faster than the geometric rate of population growth. On account of the past geometric increase of technology, the acre yields of corn have tripled in the *last* thirty years. If the rate is to continue to increase geometrically, the yields must be, not just tripled, but quadrupled and more in the *next* thirty years. Can the technology; will the technology increase that fast?

Let us examine some forces that bear on the assumption that technology will improve so we can continue to be luxuriously fed. The very existence of our massive food-production capability sets up forces that push in the opposite direction. This is another manifestation of the "balance of nature" so dear to the hearts of ecologists.

May I use the analogy of the tsunami? An earthquake under the sea sets in motion a great wave on the

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