Chemicals and Plant Growth

Ever since Percy W. Zimmerman discovered that certain chemicals can change the growth of plants in one way or another, we have had a succession of developments that have given us better apples, larger prunes, potatoes that store better, ways to kill weeds in grainfields without injuring the crop, and a broadened knowledge of plant science. Dr. Zimmerman was born in Manito, Ill., in 1884. He was a plant physiologist at the Boyce Thompson Institute from 1925 until his death in 1958. In his discovery of the first use for plant-regulating chemicals, he used indoleacetic acid to induce stems to develop roots. The reproduction of many kinds of valuable plants thus was made easier. Only three chemical regulators were known at first, and they were scarce and expensive. More than a thousand organic compounds have been used since in experiments to control the growth and behavior of crop plants. New ones are discovered each year.

Chemists can readily make practically all of these compounds, only a few of which are found in plants. The chemical regulators can be absorbed by leaves, stems, flowers, and roots. Only minute amounts are needed—a few grams, for example, are enough to prevent fruit from dropping in an acre of orchard. The compounds act somewhat as animal hormones control the growth and development of animals. Fertilizer chemicals are different, because they furnish some of the building blocks of which plants are made. Regulating chemicals determine to some extent when and how the building blocks are used.

Plants can be made to behave in widely different ways with regulating chemicals. The buttons on the end of lemons can be made to remain attached during storage and thus protect the fruit from rot. Some fruit, such as bananas, can be made to ripen rapidly and develop better flavor than untreated ones. Malt production can be improved. The cost of thinning crops such as apples can be reduced. Properly used, the substances increase the size of some fruit, such as blackberry and prune. Some kinds of valuable plants cannot readily be propagated vegetatively. The Dr. Dresselhuys and E. S. Rand varieties of rhododendron are such plants, but small amounts of 2,4,5-T, a chemical used to kill some weeds, cause cuttings from them to root readily. Commercial preparations for stimulating roots on cuttings usually are available where garden supplies are sold.
Some farmers use regulating compounds on early clusters of tomato flowers, which otherwise often fail to produce a full set of fruit, especially during cool, cloudy weather. Tomato plants in a greenhouse may not produce good pollen during cloudy days of winter. A spray containing beta-naphthoxyacetic acid or another appropriate regulating chemical can be used to increase the productivity. Under some conditions, however, fruits from certain varieties of greenhouse tomatoes, such as Globe, produced with chemical regulators, fail to keep as long in storage as do those grown from pollinated flowers.

Some fruit, particularly apples, may fall from the trees before harvesttime. They may thus be bruised and of lower quality. The formation of an abscission layer, which weakens the stem, can be retarded with a minute amount of a regulating substance, such as naphthaleneacetic acid. Stems of pears can be strengthened similarly. Regulating chemicals are sprayed on thousands of acres of orchards each fall as an aid in harvesting the crops. Because the chemicals practically eliminate the premature falling of the fruit, some growers tend to delay harvest too long, and the fruit may become overripe on the tree. The improper use of the chemicals can result in crop loss. Apples sprayed improperly to prevent drop may cling to the tree so tightly that they may be hard to pick. The proper chemical, dosage, and time of application must be considered for maximum benefit.

Regulating chemicals to be effective must be absorbed by plants and be translocated readily from one part of the plant to another.
Indoleacetic acid, rubbed on the stem of this plant, caused it to produce roots. This was the first response to growth regulators found to be generally useful.

Plants can absorb many kinds of chemicals into their roots and then move the substances upward through their stems into the leaves along with the water, which is moved in the same direction. Plants can move some regulating substances, such as 2,4-D, from a leaf downward to the stem and then upward to the tip of the plant. The total distance covered may be as much as several feet. That discovery led in part to use of the substances as herbicides. A little 2,4-D, placed on a few leaves, eventually reaches the growing tip of the plant and sometimes reaches the roots. Excessive amounts of 2,4-D reduce or prevent growth, and often the plant is killed. The use of 2,4-D as a weedkiller followed research on regulating chemicals.

Even some closely related plants respond differently to the same regulating chemical. We can use 2,4-D to retard the drop of Stayman Winesap apples, but it is not effective in retarding drop of McIntosh apples. The difference in sensitivity is thought to be due
Stem curvatures are a means of finding new chemical regulators. The new chemical is rubbed on stems to make the test.

The rate of water loss of harvested snap bean pods can be slowed down by treatment with the chemical parachlorophenoxyacetic acid.

partly to a difference in the rate that the plant breaks down the compound and inactivates it once it is inside the plant. Such a difference may also account in part for the differential effects obtained with selective herbicides of the regulator type. Because the most effective regulators often are those that the plant can readily absorb and translocate, we have tried to learn how to increase the ability of plants to take up and translocate them.

A way has been found to change the molecular structure of some regulating chemicals so that plants are better able to absorb and translocate them. Some regulators are translocated from leaves to
The potatoes on the right were dipped in a chemical regulator that kept them from sprouting during storage.

In experiments, 2,4-D reduced growth of sprouts on stored turnips.
Ryegrass is a quick test for the presence of very small amounts of potato sprout inhibitor.

A scientist tests the strength of the stem of an apple on a tree sprayed with naphthaleneacetic acid. The chemical makes the fruit remain attached to the tree until harvesttime. The large pile of apples at the right fell from the nearby unsprayed tree.
the roots, from which enough is exuded into the soil to bring about growth responses in nearby plants. An understanding of how the chemicals ooze from roots may be useful in developing compounds that protect plants from disease organisms that attack the roots. Many kinds of regulators have been tagged with radioactive elements, such as carbon and iodine, so that we can trace their movement through plants. We can follow their absorption and translocation and their metabolism as they are changed by the plant or broken down into other substances. Naphthalenelactamide, for example, was absorbed by bean leaves, metabolized, or converted to another compound. Then a second metabolite was detected as the compound moved from the leaf to the stem. Still other metabolites were made by the plant after the growth regulator had reached the stem. Much is yet to be learned about movement and metabolism of regulators by plants, and radioactivity will no doubt help us gain this information.

Gibberellic acid has accelerated the growth of some kinds of plants by increasing the rate at which they assimilate carbon and build up solid matter. This regulator has been used experimentally to bring about many different responses, including rapid elongation of stems of slow-growing trees, production of flowers in a year on plants that usually require 2 years, and improved quality of flowers for display. Gibberellic acid has been used commercially in only a few ways. Its use has led to improved production of Thompson's seedless grapes.

A new family of regulating chemicals retard rather than stimulate plant growth. Some kinds of plants, such as chrysanthemum and azalea, can be dwarfed in a way that is often beneficial, since the plants take up less space, require less pruning, and develop a usually pleasing foliage. The use of regulating chemicals in developing plants with hybrid vigor is a new step. Male-sterile cotton plants have been produced experimentally with a chemical spray, a response that may be helpful in the production of improved cotton. We expect that other valuable responses in crop plants will be developed. For example, seasonal low temperatures limit the places where many plants, such as citrus, peach, and azalea, can be grown. We need a chemical method of increasing the resistance of plants to low temperatures; some progress has been made. We may sometime increase the resistance of some kinds of plants to drought or to a high salt content of the soil with retardant chemicals. We can speed up the rate that fruits ripen, but we need a safe chemical means of retarding ripening that will help to reduce the refrigeration now required.

It may be possible with chemical regulators to improve the palatability and nutritive value of some plants used as food. Regulators are used to improve the storage quality of some vegetables, but we
The first experiment showing that 2,4-D killed dandelions in a lawn without injuring grass.

Aeration apparatus used to study the movement of chemical regulators out of the roots of plants.
John W. Mitchell shows how the chemical retardant Amo-1618 regulates the height of sunflowers when applied to leaves of the young plants.

still need more effective chemicals for the purpose. Retardant chemicals may be used in the future to limit the growth of undesirable plants and to slow down the growth of plants used as ground cover so they will require less care. The overall growth and to some extent the chemical composition of some forage crops may eventually be controlled with chemical regulators. (John W. Mitchell and Paul C. Marth)
One way to follow the movement of a regulator in a plant is to tag the chemical regulator with a radioisotope such as C¹⁴. A picture showing movement of the chemical regulator is made by placing a film close to the plant for exposure to the radioactivity.

Kentucky Wonder and other varieties of pole beans can be experimentally made to grow as a bush-type bean when treated with the retardant Amo-1618.

Elongation of young wheat plants can be retarded and tillering can be increased experimentally by the use of a chemical retardant.