Cotton plant 72 days after planting and 18 days after gibberellin treatment. Arrow shows the top of the plant at time of treatment, which was normal "cut-off" date. Increased fiber length and thickness, and more bolls set per acre are the practical advantages of treatment. More research of this type will be undertaken in 1958

Gibberellins for Agriculture

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Gibberellins do for plants what nutritional supplements do for animals—supplement the environment in such a way as to encourage the plant's normal physiological processes to produce the best in yield and quality

A FULL YEAR'S field experience has shed much light on the potentialities of gibberellins in commercial agriculture. The surge of wide-eyed stories of freakish or spectacular effects that followed the gibberellins' public introduction less than two years ago has subsided, and serious attention is now focused on practical, economical uses for these materials in crop production. Their effects in such applications may be less spectacular than those which first caught the public fancy, but they are far more significant from the technological or economic point of view.

The gibberellins are a striking example of the expansion of biochemical knowledge relating to human and animal health and nutrition to include plant biochemicals. This trend finds agricultural research and production specialists cooperating to advance progress with plants in a direction that has been outstandingly successful with animals, namely, supplementing the environment with chemicals that help normal physiological processes to give the best in yield, quality, and profits.

Significant progress is being made in this direction with the gibberellins, growth-stimulating chemicals that have a vitamin-like effect on many plants. This new tool, in the hands of biochemists, plant physiologists, agronomists, and even entomologists and pathologists, is stimulating the development of new knowledge and improved agricultural production practices, and pointing the way to steady progress in plant pharmacology. The chemicals are produced by a fungus, in fermentation processes akin to those which produce penicillin, streptomycin, and other antibiotics that are also finding increasing utility on the farm.

The gibberellins give man control over plants never before possible, for they complement or supplement natural growth-promoting substances that occur in plants. Their "triggering" effect seems in most cases to set off established mechanisms within seeds and plants, causing normal or characteristic growth. Otherwise inhibited because of light, temperature, other environmental factors, or other substances in the plant that have net effects opposite to those of gibberellins, such growth or continued development is often important to crop production as a whole.

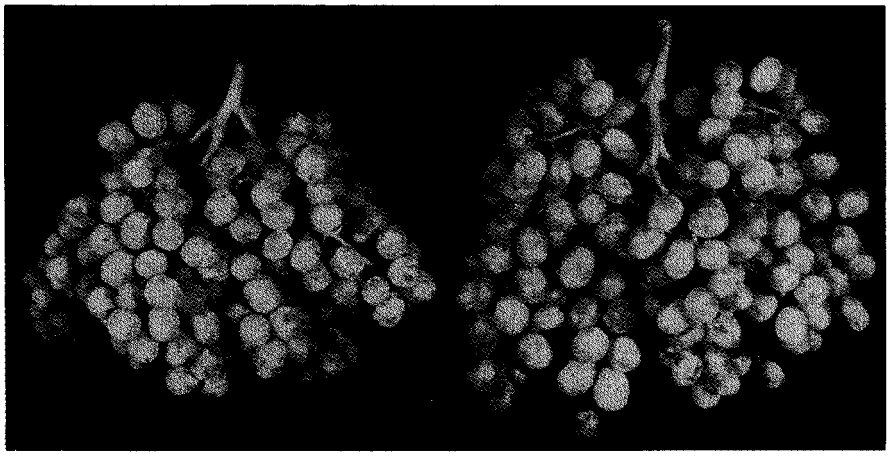
It is significant that these new tools do not supply energy, initiate abnormal types of cell division, or generally change the chemistry of the plant. Exhaustive tests have disclosed no toxicity to animals or plants, nor any persistent residue. Gibberellins are compatible with practically all chemicals with which they might be used

on plants. So they can be integrated into several useful agricultural practices as compound formulations or as standard formulations of gibberellins alone. The basic formulations being produced as concentrates are suitable for use directly or with only simple blending with standard diluents. When handled in this way the complex molecule retains its maximum quality and effect. Very small quantities—usually only a few grams per acre —are needed, but they should be in the proper formulations.

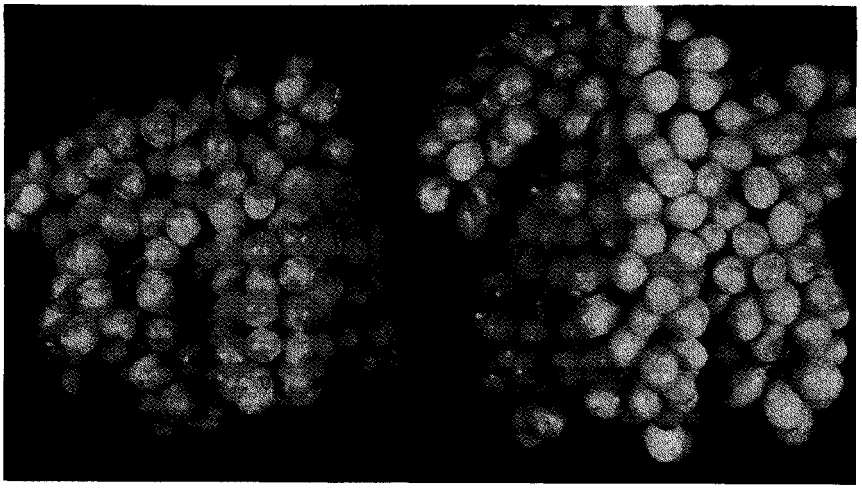
What Gibberellins Do

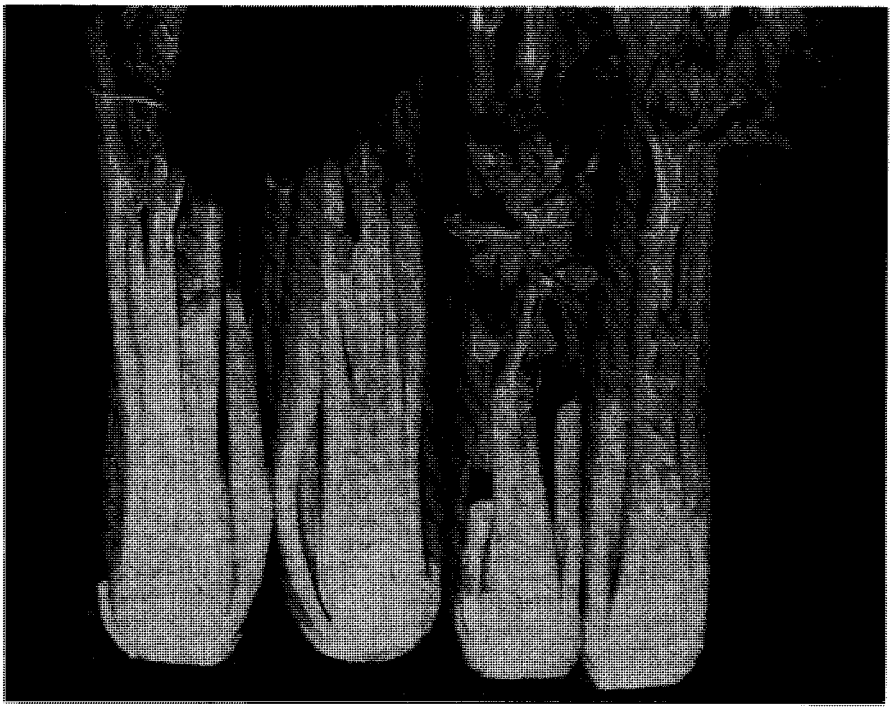
The specific effects of gibberellins are as diverse as the physiological processes of the plants concerned. To comprehend the stimulus and response, one often has to know the growth characteristics concerned. A long list of responses has been reported, and defined to some extent. The rate of application, timing, and even the extent of the response require individual consideration, but the variety of specific effects, on "type" plants, is informative. Among the effects are these:

- Embryo development, germination, and seedling emergence have been accelerated.
- Classically "dormant" seeds, such as those of wild oats, have been induced to germinate promptly.
- Early seedling growth can be stimulated, with cell division increased to elongate the stems.
- Pedicel, peduncle, or leaf growth can be accelerated and increased.
- Shoot growth of woody plants can be produced from "dormant" terminal buds, and accelerated through elongations as a result of cell division.
- Cell division has been stimulated, and occasionally cell elongation as well, as a result of normal meristematic activity.
- Stem or shoot elongation is caused by cell division in one direction, and lateral growth has also been induced as a result of cambial cell division.
- Upright or semiprone plants grow taller, and truly prone plants spread out further laterally.
- Apical dominance of a few plants can be broken, with side shoots developing.
- Biennials can be induced to behave as annuals, although they may require partial cold treatment.
- Flower induction has been hastened, and made largely but not



Thompson seedless grapes at harvest. Bunch at top left got no gibberellin, that at top right got 5 p.p.m., bottom left got 20 p.p.m., and bottom right got 50 p.p.m. Effect is to increase size of grapes and lengthen cluster





Celery stalks at left received gibberellin and, as a consequence, are filled out. Increased weight per acre is another result. Untreated celery is at right

necessarily completely independent of photoperiod.

- Parthenocarpic fruit set has been achieved, by direct or systemic effect.
- Pollen tube growth can be stimulated to set some self-sterile or conditionally self-sterile fruits, or to prevent the set of some self-sterile fruits.
- Pollen development has been prevented by heavy applications at the time of flower bud differentiation.
- Increased growth of pedicels, florets, seedless grapes, cotton fibers, or cherry fruits has been induced.
- Translocation from foliar applications can overcome tuber dormancy, and stimulate stolon growth.

The gibberellins are absorbed and translocated rapidly in many—not all—plants, but are not stored or otherwise retained by the plant tissue.

On Specific Crops

Many experiment stations, some with projects that have continued for several years, and industrial research and development groups have been working to define practical uses for gibberellins. Much work is still under way, and more uses will be forthcoming. Merck & Co. has conducted or sponsored numerous field studies over the past two years with Gibrel, its trademarked brand of the new plant growth stimulant. Here are the findings from some of its more advanced studies on specific crops:

Grapes. One of the most striking effects of the gibberellins is to increase the size of seedless grapes, and lengthen the cluster. Applications at or shortly after the grapes are in bloom have produced this remarkable effect, and may eliminate the need for costly thinning of clusters and girdling of vines of Thompson seedless and Black Corinth grapes to obtain desired size.

Vegetative growth of the stems and stemlets enlarges the structure of the cluster, permitting larger berries to develop without crowding. At the same time, gibberellins stimulate the berries themselves to grow larger. The grapes develop normally, and contain when mature the desirable amounts of solids, sugar, and acid. One early-season application is sufficient; there are no residue problems.

There are many practical advantages, particularly increased yields as well as savings in thinning and girdling. In addition, the striking improvement in size and appearance of Thompson seedless grapes opens the possibility of a premium market.

Relatively small amounts of gibberellins are required for effect—for Thompson seedless from 8 to 16 grams, and for Black Corinth 4 to 8 grams per 100 gallons of spray are useful levels.

Research is continuing on other varieties of grapes; both eastern grapes and western wine grapes respond with looser clusters which increase the effectiveness of disease and insect control measures. Also, Concord grapes appear to respond with some promise of increases in total yield.

Potatoes. Gibberellins spur seed potatoes to sprout, resulting in more uniform emergence and promising yield increases up to 30%.

All potatoes, both "rested" and newly harvested, respond with prompt and uniform growth of sprouts that improve yield. This effect is particularly useful during cold, wet weather which often interferes with the sprouting and emergence of potatoes. Growers should now be able to wait for a truly frost-free planting date, and then apply gibberellins to get prompt growth.

Gibberellins speed the late and slow-sprouting potatoes so that they come up with the best in the stand. The "vitamin-like" effect of a tiny bit of material stimulates seed pieces to sprout promptly and vigorously.

Application of gibberellins can be combined with the regular practice of dipping potatoes for disease control before planting, or achieved through a separate dip. A single gram of technical potassium gibberellate will treat about 10 tons of potatoes when formulated properly. There are no residue problems, since the amount used is very small and does not persist in the new plants.

Tomatoes in Texas. Far-red rays of the sun, characteristic of clear late-summer days, sometimes inhibit the growth of tomatoes in Texas. The tomatoes set fruit, but it fails to reach normal size.

Weekly sprays of a gibberellin at the rate of about 4 grams per acre keep the fruit developing to marketable size. Successful treatment calls for a liquid spray applied at the rate of 2 quarts per acre and prepared so as to include a small amount of *p*-chlorophenoxyacetic acid. Suitable formulations will soon be available.

Celery in Northern States. Gibberellins, applied three weeks before harvest at the rate of 3 grams per acre, have produced from 10 to 12% more crates of celery per acre in the northern states. This application stimulates the celery stalk to produce a thicker and larger heart and a thicker stalk and bunch over-all, with no sacrifice in quality. Other tests indicate that no residue persists on or in the celery.

When gibberellins are applied to celery in southern growing areas, however, the net effect is only a taller plant with more top to trim off, and a tendency to bolt. Growth seems to be so rapid in these areas under normal conditions that application of gibberellins is not desirable.

Celery harvesting on the Bolthouse farm in Michigan, where application of 3 grams of gibberellin per acre produced 10 to 12% more crates per acre

Spinach—In Cool Weather. Fall-grown spinach responds to gibberellins by promptly starting regrowth after initial cuttings. In this case, gibberellins apparently release the plant from the growth-inhibiting effect of adverse cold weather. Treatment at the rate of 6 grams per acre enables growers to count on several cuttings from fall-grown spinach.

Spinach actually responds to gibberellins whenever application is made. In warmer weather, the treatment produces somewhat faster growth and a more upright shape, permitting easier mechanical harvest.

Cotton Seed Treatment. Research has shown that the faster emergence of gibberellin-treated cotton seed is actually due to a faster development of the embryo. All varieties have shown the same type of response—faster emergence even under optimum conditions. The effect is greater when early-season plantings encounter cold, wet weather, and should serve to reduce seedling damage. At from 1 to 2 grams per 100 pounds of seed, gibberellins permit good seed to be used more efficiently by speeding it through a sensitive stage, ahead of weather and weeds.

The other general benefit is faster early seedling growth—taller and larger seedlings during the first few weeks. Also a general effect, this permits working the dirt up to the plants earlier to give them better access to moisture and fertilizer. All

this tends toward better use of good seed, good cultural methods, and good crops.

Soybeans. Treating soybean seeds with gibberellins speeds emergence and results in a longer stem. Faster emergence enables farmers to begin weed control early. The longer stem should result in higher realized yields because of less loss during harvest. (In many cases under the present practice the cutter-bar slashes through the lower pods, causing substantial harvest losses.) An increase of 1 to 2 inches in bean height should overcome much of this loss, and this possibility is being studied carefully.

In the South where soybeans are planted after small grains are harvested, speed of emergence and a uniform stand are vital factors in getting the crop to maturity before the growing time runs out. Gibberellin seed treatment is expected to increase the chances of success.

Peas and Beans. Peas and beans emerge up to a third faster when treated with from 0.25 to 0.75 grams of gibberellins per 100 pounds of seed in a suitable "slurry" formulation. Gibberellins perform best during cold, wet weather when the seeds are normally slowed down or the stand may be completely destroyed. Seedling growth is much faster, enabling the plants to develop even in adverse weather at a rate that minimizes danger from insects and diseases. Faster emergence of beans may be particularly helpful in avoiding outbreaks of maggot.

Eventually, gibberellin treatments should produce both dry beans and snapbeans that can be more efficiently combined and harvested.

The ability of gibberellins to maintain growth of canning peas through adverse weather makes it possible for the grower more accurately to plan deliveries to the viner. Some tests show promise of both yield increase and quality improvement.

Small Grains. Gibberellins may prove to be particularly useful in helping produce a successful stand of small grains during adverse weather in the fall and spring. By treating the seed with as little as 0.25 grams of gibberellin per 100 pounds, farmers can get an increased rate of emergence, which appears to be desirable particularly during cold, wet weather.

For fall planted grains, faster and more complete emergence would promote the growth to withstand freezing winters. And a thicker stand usually indicates increased yield.

For spring-planted small grains, faster and more complete emergence means more growing days early in the season, when moisture conditions usually are more favorable. This factor may help corn overcome the effects of summer drought, even without very striking growth responses. Some work has shown that corn roots, as well as top growth, may be stimulated during the first weeks of growth.

Cotton. The responses of cotton to gibberellins are encouraging for both yield and quality. Varietal differences, timing, and rates of application are problems requiring continuing research before definite recommendations can be made.

Research shows that Acala 4-42, Paymaster Stormrider, and Deltapine-15 will set more bolls when from 1 to possibly 6 grams of gibberellins per acre is applied. The same varieties also have been induced to go on growing and producing bolls after the normal "cutout" time. Another fairly general effect of such applications is increased fiber thickness. Furthermore the length of fiber has sometimes been increased by 0.04 to 0.25 inches. Larger acreages will be treated with gibberellins in 1958, to expand knowledge and speed progress toward general commercial usage. At present, there is strong indication that improved yields and quality of fiber may prove commercially practical.

Forage and Grasses. The application of 3 to 10 grams of gibberellins per acre, in a suitable formulation and at just the right time, breaks the dormancy of Bermuda grass, bluegrass, and several other turf or pasture grasses. This effect will be useful in speeding the onset of active growth in the spring, and overcoming "winter dormancy" in the southern latitudes.

An ideal use on range, pastures, and lawns would be application of the usual amount of fertilizer with enough gibberellins to stimulate dormant or slow-growing grasses to begin vigorous growth promptly. Gibberellins appear to have a place as a growth-initiating or dormancy-breaking aid to the usual spring fertilizer schedule on responsive grass varieties.

The effect on grasses does not produce any significant change in the composition, and the total weight increase is proportional to the stimulation. Bermudas are most responsive, Bahia and some western range grasses next. When alfalfa stubble is sprayed, prompt growth is resumed. Dichondra is responsive, but Zoysia responds only while it is growing; its dormancy is not broken as is that of the others.

Research is continuing, and large-scale field trials now in progress are expected to show the best ways to use gibberellins on forage and grasses, possibly during 1958.

Vegetables. Work continues with tomatoes, peppers, parsley, asparagus, spinach, lettuce, and similarly responsive crops. New knowledge is developing formulations that may expand the number of crops to include some originally considered much less responsive.

Several very interesting potentials include seed treatment to achieve greater vitality and permit direct seeding of crops now transplanted. Furthermore, adding gibberellins to transplant water probably is desirable for speeding plant growth. Another possibility is to add gibberellins to the soil of flats at seeding time, or in the field—either to the soil or to the plants—when growth of young plants is slow.

Once the plants are growing there is less need for stimulation of most vegetables, but carefully timed applications of the right formulation may improve the yield, the quality, or both.

Combinations

Research in the general field of gibberellins is developing combinations, as with some auxins, that have broader effect. Also, the variable response of different plant types is being overcome in some notable instances by special formulations. In the field, the general utility of gibberellins is leading to the development of many parallel uses. It appears that development of all these potentials promises to extend the present type of research program far into the future, with real and increasing benefits to agriculture.

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