Some Problems in Growing Sugar Beets

George H. Coons

Sugar beets are grown for sugar in 22 States—Michigan, Ohio, Indiana, Illinois, Wisconsin, Minnesota, Iowa, Kansas, Nebraska, South Dakota, North Dakota, Colorado, Montana, Texas, New Mexico, Utah, Idaho, Oregon, Washington, Arizona, Wyoming, and California. They are grown in New Mexico, Arizona, Utah, Nevada, California, and Oregon for seed.

Almost 20 percent of the national sugar requirement is obtained from the domestic production of sugar beets. Beet sugar produced in the United States is in demand for food and for the chemical, pharmaceutical, fermentation, and heavy industries.

The byproducts of the sugar beet—tops, molasses, and pulp—are used chiefly as a feed for livestock. Beet molasses is also highly important in the fermentation industry, particularly for the production of citric acid. Beet pulp, the slices of beet from which the sugar has been extracted, is fed in wet or dry form to cattle.

Nearly 670,000 acres of sugar beets were harvested in 1952. On that acreage 10,217,000 tons of sugar beets were grown and were processed in 68 factories. The approximately 1,532,000 tons of sugar (raw value) produced from the sugar beet roots contributed nearly 20 percent of the estimated national sugar consumption of 7,900,000 tons. Production in 1951 was much like that of 1952, 700,000 acres being...
harvested and about 10,500,000 tons of sugar beets being grown. In 1950, on 924,000 acres, 24.5 percent of the national sugar requirement was produced.

Disease-resistant varieties have been used almost exclusively to grow the American sugar beet crop. To obtain the seed for growing the commercial crop of sugar beets for the factories to process, the industry maintains several seed-producing enterprises.

Beet sugar can only be produced in factories equipped to carry on the complicated chemical processes necessary to extract and purify the sugar that is stored in the roots. Usually the beets are grown within a radius of 40 to 60 miles of the factory. A highly intensified culture on the best lands nearby is the result; on the farms themselves, sugar beets are usually the main cash crop, and farmers have been tempted to grow beets on the same fields repeatedly rather than to make them part of a rotation system. Twin problems of diseases and lowered fertility consequently have arisen; indeed, the history of the industry as it moved from the Eastern States westward, and then sought in place after place for suitable production areas, reflects the damage done by curly top, leaf spot, and root diseases.

Curly top by 1926 had caused repeated failures of the sugar beet crop in States west of the Rocky Mountains. In years of outbreak, the average acre yields from some districts dropped from an expected 15 tons to 5 tons or less. The history of sugar beet culture in the Truckee project of Nevada, Salt River project of Arizona, Delta and other areas in Utah, the San Joaquin Valley of California, the Yakima Valley of Washington, and many others is all much the same—a brief period of fine prospects and then crop failure because of curly top, with ultimate abandonment of sugar beets by farmers.

Congress in 1929 appropriated funds for investigations of curly top and the beet leafhopper. All aspects of the problem were attacked quickly. Thanks also to some earlier research, progress in the development of varieties resistant to curly top was immediate. By 1933, seed was being increased of the resistant variety that was introduced in 1934 as U. S. 1. Since then, U. S. 1 and the other resistant sorts that followed in quick succession—U. S. 34, U. S. 33, U. S. 12, and U. S. 22—have removed from western agriculture the threat of crop failure from curly top.

It cannot be said that curly top is vanquished. Severe exposure in the worst years still takes its toll. But farmers may now plant the new varieties with confidence that the crop will be carried through to a reasonably high yield despite disease.

Meanwhile the producers farther east were being plagued by sporadic epidemics of leaf spot. Leaf spot, caused by the fungus Cercospora beticola, blights the tops so that root growth is dwarfed and the percentage of sucrose is cut. Its effects are less dramatic than those of curly top, but it occurs more widely and is more damaging to the industry.

Leaf spot is a wasting disease. It can reduce tonnage and sucrose enough to make the beet crop unprofitable to farmer and factory. The blight years are those in which rainy periods are frequent in the early half of the season and total rainfall is abundant—the very conditions that should give a bumper crop bring only disappointment as wave after wave of leaf blighting occurs. In epidemic years, leaf spot may kill back the entire foliage bouquet several times in a season. New growth is pushed out only to be blighted in 2 or 3 weeks. Replacement of blighted leaves is at the expense of root growth and stored sugar, hence the crop is lacking in weight and quality. Between 1915 and 1930, blight years were frequent. Factories in the Midwest and in the more eastern districts were in financial distress.

The first leaf spot resistant variety, U. S. 217, was introduced in 1938 by the Department of Agriculture. Its
average production of sugar was 5 percent more an acre than that of the susceptible European varieties. It was soon replaced by U. S. 200 x 215, a hybrid variety that served the industry from 1940 to 1944. It gave higher root yields than U. S. 217 and was at least 8 to 10 percent superior to European varieties if leaf spot was prevalent. U. S. 215 x 216 was introduced in 1945. It became the leader in the humid area. Without leaf spot, it is as productive as the nonresistant European types; if leaf spot is serious, it is at least 15 percent superior in production of sugar.

Still another disease contributed earlier to the general instability of our beet sugar industry—the seedling and root disease complex that farmers call black root. It occurs all over the United States but is worse in the humid area. The primary cause of black root of seedling beets is the water mold, *Applanomyces cochlioides*. Other damping-off organisms are associated in the seedling disease complex but are less important or more readily controlled. Black root may kill so many of the seedlings that the stands after thinning are below or on the border line of profitable production. If rainfall in spring is slightly above normal or if the soil is infested with damping-off organisms, the initial stands of seedlings are so reduced by fungi that only gappy stands can be left after thinning.

Heavy planting rates were used formerly in an attempt to have extra large numbers of seedlings from which a fair stand of thinned beets could be saved. In recent years, to save manpower in singling sugar beets, seeding rates have been reduced. Destruction of the meager initial stands by black root thus causes even greater damage than before. According to factory records, parts of Michigan and Ohio often have had average stands in their fields considerably below 70 percent—much too low for profitable growing of the crop.

In seasons of severe black root, re-planting of 25 percent of the acreage around a factory has been necessary. The sugar beet cannot attain stable production and full mechanization is not possible until disease-safe varieties are available. U. S. 216—a leaf spot resistant inbred—was also found to be outstanding in its resistance to black root. The superimposing of resistance to black root upon resistance to leaf spot seems entirely feasible in varieties built around U. S. 216 and its close relatives. A number of selections resistant to black root have been made from varieties resistant to leaf spot. Varieties that were ready for introduction in 1953 combine resistance to leaf spot with moderate resistance to black root. They are equal to nonresistant strains when disease is absent and superior when leaf spot and some black root occur. Plant breeders hope they will solve the problem of black root.

**WEATHER CONDITIONS**

Sometimes produce effects on sugar beets that resemble symptoms of disease. Hot, dry winds may cause scorching of the edges of leaves. Such leaf scorch should not be confused with blighting by fungus. Sugar beets are relatively hardy, but early frosts may injure the emerging plants. Such an injury may be distinguished readily from damping-off of seedlings.

Heavy fall frosts kill the upper leaves, which become black and water-soaked and then dry out and turn white. Growers recognize this condition, even though they might not understand the effects of severe freezes and the reduction in sucrose of the roots that may follow. Low temperatures in late October or November may kill all leaves. If warmer weather follows, the killed foliage is replaced by a new growth at the expense of the food reserves in the root, thus lowering the sucrose percentage. Often a farmer is puzzled by sugar tests after a freeze that show a much lower sugar content than the earlier tests. Wherever feasible, after tops are severely frozen the harvest should be delayed to permit...
the foliage to be replaced and the plant again to store sugar in the roots.

A bolt of lightning may kill all plants in an area 10 to 50 feet in diameter in a field. The plants die suddenly, as if affected by disease. Each day for nearly a week the circle of dead plants widens. The lightning, hitting the field just after the surface soil was wet by rain, distributes itself and grounds through the beet roots, electrocuting them. The least affected plants in the outer parts of the circle die more slowly.

Hail may cut and bruise petioles and crowns of plants but (except when the plants are very young) does not kill the beets. The plants put out new leaf growth. The loss caused by hail is therefore according to the amount of injury to foliage, except that wounds may offer points for the entrance of disease organisms. Because sugar beets can recover from hail injury, farmers in districts subject to frequent hailstorms include this crop in their farming program as a safeguard.

Shortages of nutrients in the soil produce definite reactions on the sugar beet plants. A deficiency of phosphate produces telltale effects that are especially marked on the older leaves, which then curl upward and inward. The edges of the leaves and the tissue between the veins die and turn black. An affected plant stands out markedly from its neighbors. A single plant may show this evidence of phosphate deficiency—the surrounding plants being apparently normal—or a number of plants in a group may be affected. Less severely affected plants show reduction in growth, greater susceptibility to black root, and secondary invasion by weak parasites of the Cercospora beticola spots on the leaves. The enlargement of the lesions by the secondary organisms that follow leaf spot is so striking in fields deficient in phosphate that the cercospora spots, instead of appearing grayish brown, take on the form that growers call black blight.

When the soil is low in boron, the heart or bud leaves turn black, and half-grown leaves around the bud may be darker green than normal and distorted. A black or brown scableness develops on the inner face of the petioles. The scabby streaks are crossed by breaks that produce ladder markings. Cankers may occur in the flesh of the roots about one-fourth inch under the skin. Affected tissues turn pale brown or gray. The dead tissue may be sterile at first, but later secondary organisms such as Phoma betae may invade it.

Shortage of potash is characterized by a bronzing of the foliage. Manganese deficiency causes whitish spots on the younger leaves. A lack of magnesium shows up by producing pale blotches and whitened leaf margins of the maturing leaves. Sulfur deficiency, known to be characteristic of some Oregon soils, gives a pale-yellow cast to the foliage. Nitrogen deficiency shows itself by producing a yellowing of the foliage, particularly the older leaves. A severe shortage of nitrogen depresses growth and makes the plants pale yellow and unthrifty.

The application of adequate amounts of the fertilizer element that is lacking controls the deficiency diseases. Heavy dosages of phosphate may be necessary. Minute amounts are needed of some, such as boron. Where 400 to 500 pounds an acre of superphosphate (15 percent P₂O₅) would be applied to meet a serious phosphorous deficiency, boron is added in the form of borax at not more than about 10 to 12 pounds an acre, unless the soils are known to have the capacity for fixing boron. With such soils, much heavier treatments are given.

Leaf spot, a seed-borne, fungus disease, has been found everywhere that the sugar beet is grown. It attacks leaf blades, petioles, seed stalks, and floral parts, on which it forms small, necrotic spots. The spots on the leaves are circular with grayish centers. With a hand lens, one can see pin-point black
SOME PROBLEMS IN GROWING SUGAR BEETS

... dots in the center of the spots. The spots occur so densely in heavy infections that the whole leaf may be speckled. Often the spots run together. As the disease progresses, the leaves turn yellow and brown and finally die. On the petioles and seed stalks the spots are large and elongate and have conspicuous grayish centers. The floral envelopes that dry and form part of the seed ball show the lesions of the fungus on the bracts and old ovary tissue. The fungus (Cercospora beticola) does not attack the root.

The fungus has a rather simple cycle of infection—spot formation, spore formation, reinfection. It is known only in its asexual stage. Commonly the leaf spot organism is brought to the field in the lesions on the seed ball. When sugar beets follow sugar beets, however, diseased material from the previous crop leads to early and severe infection.

The fungus on a seed ball or on the infected leaves and petioles left as the trash from a previous crop (or from a weed host) remains alive and starts to grow in the spring. Spores are produced that are blown by the wind or dashed by rain to the young beet plants. As the seedlings push out from the seed balls, occasionally a ball is carried above ground by the developing plantlet. Then the fungus develops on the infected floral parts, and spores are produced. The spores infect the cotyledons. Typical cercospora spots can be found by search on the cotyledons of the young plants in any field. Obviously the old leaves and petioles from an infected previous crop would supply a very heavy inoculation if beets were to follow beets. The fungus grows rather slowly in cool spring weather. About 3 weeks are required for the cycle from spore to spore. The growth rate is much faster in warm weather.

Cotyledon infection in early April leads to spore production in early May. If rainy periods are numerous in May or June, two or three cycles of the fungus may occur. Each spot that arises from spore infection produces in its turn countless spores, which, when spread in the field by wind or dashing rain, produce new infections, thereby widening and greatly extending the circle of affected plants. If weather conditions favor growth and sporulation and if frequent rains supply the moisture necessary for infection, then leaf spot—starting on one infected plant in about 100 or 500 in a field—becomes by mid-July (as the circles of infection overlap) an entrenched disease affecting all the older leaves on most of the plants in the field. With such a start, unless August is very dry, ordinary light rains are enough to bring about severe blighting and death of the foliage.

When leaf spot had to be controlled by spraying or dusting with fungicides, treatment had to be started before the middle of July to keep the fungus from becoming prevalent in the field. The fungicides used for direct control were bordeaux mixture (applied as a spray) or monohydrated copper sulfate and lime (applied as a dust). Fixed copper dusts later were used. If the disease was severe enough to do heavy damage, the fungicides, properly and plentifully applied, produced average gains of about 2 tons of roots an acre and a two-unit increase of sucrose in comparison with untreated parts of the fields.

Resistant varieties have given such good control of leaf spot that it is no longer necessary to spray or dust sugar beet plants. They yield well, so no penalty is involved in their use in blight-free years. In the more eastern districts, the “U. S.” varieties have given exceptionally high percentages of sucrose and high tonnage.

The resistant varieties are not immune to leaf spot but the degree of resistance is such that no crop failure occurs, and, even in epidemics, the sugar beets hold their foliage—green and functional—until the leaves are fully mature. Blighting and killing down of tops from leaf spot no longer occur. Such a loss of tops would make...
it inefficient to use the Scott-Urschel type of beet harvester, which carries the lifted sugar beet plants up to the topping disks by grasping the tops between rubber-faced belts. The saving of the tops means also that there is definite gain in the feed value from the crop. The roots of resistant varieties keep better in storage since they have higher sucrose and are better nourished than roots from the blighted plants.

Downy mildew, caused by *Peronospora schachtii*, attacks the foliage of sugar beets in the coastal area of California. The fungus is not known elsewhere in the United States except on sugar beets grown for seed in Oregon and Washington, where humidity often equals that of the California fog belt. The hosts of the fungus are *Beta vulgaris* (sugar beets, red beets, mangel-wurzels) and *Beta maritima* (the sea beet). No other species of *Beta* or other genera are known to be attacked. The mildew attacks the young growing leaves, which thicken, curl, and eventually die. It is a disease of late winter and early spring. The dead parts turn brown or black. When the disease is active, the sooty-gray growth of sporophores and spores of the fungus identify downy mildew.

Young plants may show the disease on cotyledons, primary leaves, and growing points. Ordinarily the beet has reached the 4- to 10-leaf stage before conditions favor the attack by the fungus. The disease seldom kills the plant, but checks growth and destroys the primary bud. Subsequent growth has to be from accessory buds. Recovery from mildew commonly occurs when weather becomes warmer and drier in late spring.

The fungus produces resting spores and perennial mycelium. These remain alive in the trash and debris from an affected crop and presumably are sources of infection to a crop of sugar beets planted on the same field. The fungus also is carried on seed. In addition to these sources of infection, conidia from living beet plants may be carried by the wind to nearby sugar beet fields. If they land on a film of water on a beet leaf, they germinate and cause infection. Then the fungus occupies the beet tissue and produces fruiting threads on the beet tissue and an enormous number of spores. The spores again spread the fungus in the field. Under favorable conditions, susceptible varieties may become 80 to 100 percent infected. A resistant variety such as U. S. 15 under similar conditions may show infection of 1 to 10 percent, and recovers better than susceptible types do.

Downy mildew no doubt could be prevented by copper sprays or dusts, but resistant varieties are good enough to control downy mildew satisfactorily. Breeding work started in 1945 seeks to combine resistance to downy mildew and rust, the character for nonbolting, and adequate resistance to curly top to give a variety that is adapted for winter plantings and is disease-safe.

The fungus produces resting spores and perennial mycelium. These remain alive in the trash and debris from an affected crop and presumably are sources of infection to a crop of sugar beets planted on the same field. The fungus also is carried on seed. In addition to these sources of infection, conidia from living beet plants may be carried by the wind to nearby sugar beet fields. If they land on a film of water on a beet leaf, they germinate and cause infection. Then the fungus occupies the beet tissue and produces fruiting threads on the beet tissue and an enormous number of spores. The spores again spread the fungus in the field. Under favorable conditions, susceptible varieties may become 80 to 100 percent infected. A resistant variety such as U. S. 15 under similar conditions may show infection of 1 to 10 percent, and recovers better than susceptible types do.

RHIZOCTONIA FOLIAGE BLIGHT, caused by *Pellicularia filamentosa*, may attack leaves of beets if weather is moist in June or July. The strains of the fungus causing foliage blight are nonpathogenic to half-grown or mature roots. The fungus attacks only leaf tissues and the tender fibrous roots of seedlings. On the leaves, black spots from one-quarter to one-half inch across are formed.

Affected tissue dies and dries, and the primary spot soon becomes surrounded by a circular zone of secondary spots. With the hand lens one can see the *Rhizoctonia* threads on the leaf surface. The dead areas break away from the sound tissue, and the leaves get a ragged look. About 3 weeks after infection, a filmy, gray-white growth appears on the leaf surfaces. It is the spore-bearing stage. The growth consists of threads and spore-bearing structures called basidia. Air currents and rain spread the spores, so that a single
primary infection may become the center of an infected circle 15 to 30 feet in diameter. The original source plant usually can be recognized by its older infection. The air currents may carry the fungus far wider in the field and set up foci beyond the area of heaviest infection.

The disease has been found in Maryland, Virginia, Michigan, Ohio, Minnesota, Nebraska, and Colorado. In most fields, in a dry spring, it occurs only in trace amounts, but losses may be serious if the spring weather is wet.

It commonly has been overlooked or confused with cercospora leaf spot, and outbreaks on resistant varieties, said to have been caused by leaf spot, sometimes actually have been caused by this Rhizoctonia. Dry weather in midseason usually checks the foliage blight, so that as yet no direct control measures have been taken against it.

Because the fungus persists in the soil, a good rotation practice, in which beet crops are spaced at least 4 or 5 years apart, helps reduce primary infections.

A RUST FUNGUS, Uromyces betae, causes a serious leaf disease of sugar beets in the coastal areas of California. Affected plants take on a rusted appearance—leaves, petioles, or seed stalks are covered with minute pustules filled with a rusty brown powder, the spores of the fungus.

The rust apparently attacks only plants in the genus Beta. The fungus occurs in Europe and Asia Minor. It has been collected on Beta lemata-gona, B. trigyna, and B. intermedia in Turkey. It occurs generally on B. maritima in Europe and on B. patellaris in the Canary Islands. In the United States it has been found in California and Oregon, where it may do considerable damage to sugar beets and red garden beets, and in Arizona and New Mexico, where it was of minor importance.

The rust apparently persists over off-seasons in volunteer plants or in trash and debris. Presumably it has been introduced into United States as pustules on seed. The occasional appearance of beet rust in Arizona and New Mexico may be attributed to seed-borne infection.

The damage done by beet rust on winter-planted beets has been recognized by the industry, but no direct control measures have yet been used against it. The only control achieved so far has come from use of resistant varieties. U. S. 15 has definite resistance to beet rust; its good performance in winter plantings in California, in comparison with other varieties, has been due largely to its resistance to rust and to downy mildew, as previously discussed.

SEVERAL MINOR DISEASES affect the foliage of sugar beet.

A bacterial disease, black spot (Pseudomonas aptata), seldom does damage in sugar beets grown for sugar but has been known to blight plants grown for seed in Oregon. No control measures have been developed for it.

A leaf spot caused by Ramularia beticola damages sugar beets grown for seed in Oregon, Washington, and northern California. The spot is of the same size and character as cercospora leaf spot, but its center is white, not gray, and the small tufts of fungus growing in the spot are white and not black, as with cercospora. The fungus, apparently limited by climate, grows only in cool places. Cercospora beticola grows best when day temperatures exceed 75° F. Sugar beets that are resistant to leaf spot are also resistant to ramularia leaf spot. If necessary, ramularia leaf spot in sugar beets could be controlled in seed fields by spraying with copper sprays.

A leaf spot of minor importance is caused by the fungus Phoma betae. Affected leaves show tan, round spots, up to one-half inch in diameter and characterized by a series of concentric markings. Affected leaves may be found here and there in the field by midseason. Usually the small fruiting bodies of the fungus can be found forming a series of concentric rings on
the dead tissue. The fungus attacks the seed stalks and seed balls of the sugar beet and is definitely known to be seed-borne. *Phoma betae* causes a serious seedling disease of sugar beets, and is especially important as a cause of rotting of the roots in storage. No control measures have been worked out for the disease on the leaves.

Saltgrass rust, *Puccinia aristidae*, often attacks sugar beets in the Western States. It should not be confused with the beet rust caused by *Uromyces betae*. The salt-grass rust produces its telial and uredial stages on *Distichlis* species and its pycnial and aecial stages on a very wide range of host plants. Its fruiting bodies often can be found in spring on seedling sugar beet plants. The yellow cluster cups and the swollen overgrowth dotted with pycnia are conspicuous. No control measures are necessary because the fungus does not produce any lasting injury.

**Black Root** is the common cause of poor stands wherever sugar beets are grown. The diseases that reduce or destroy seedlings are called black root because of the appearance of dead or dying plants. Of the many fungi able to attack seedlings, *Pythium* species, *Phoma betae*, *Rhizoctonia solani*, and *Aphanomyces cochlioides* are the most serious. If the seedling is killed during germination or a week or two after it emerges from the soil, the attack is acute. All the organisms listed can produce such effects under certain conditions of soil and climate.

Plants that escape the acute form may be subject to the chronic form of black root. That form does not kill the plant but causes death and sloughing-off of lateral roots or terminal parts of the taproot. *A. cochlioides* chiefly produces the chronic type. The black root it causes may persist throughout the life of the plant. Affected plants show a great lag in growth in comparison with healthy plants because of the persistent and continued attack on the feeding roots. When a plant diseased with chronic black root is carefully removed from the soil, most of the lateral roots will be found dead and blackened. The main root will show bunches of dead, black side roots, which indicate that as one root was killed the plant pushed out others, which succumbed in turn.

In the early stages of black root, the leaves may become yellow and mottled, possibly because of a poisoning effect of the fungus. Because affected plants never establish proper root relationships in the soil, they remain stunted and may never reach marketable size. When the terminal part of the taproot is killed, the root becomes sprangled as lateral roots replace the killed terminal.

The fungi causing seedling diseases are found everywhere in the United States. They do greatest damage in sections of greatest rainfall. In the West there is reasonable assurance that properly planted and watered seed will give a good stand of seedlings, regularly distributed in the row. In the humid area there is no such assurance. Emergence of seedlings may be irregular, or most of the plants that do appear may die from acute seedling disease or become infected with chronic black root.

Among the organisms causing black root, only *Phoma betae* is known to be seed-borne. The others probably are present in any field likely to be planted to sugar beets. The amount of injury they do is tied in with their prevalence in the soil. This is greatly influenced by the crops that are grown ahead of the sugar beets. Legumes such as alfalfa, sweetclover, and the clovers also are subject to the same damping-off organisms that attack sugar beets; hence, they harbor and increase them. Furthermore, the roots and residues from the legumes are favored food-stuffs for these black root fungi and they bring about their strong build-up in the soil. Weeds such as red root pigweed (*Amaranthus retroflexus*) and related species also increase the degree of soil infestation. Corn, soybeans, and small grains, however, repress the
sugar beet pathogens, probably because their residues are cellulosic and support an entirely different fungus flora, and one that is antagonistic to the flora supported by residues from legumes and sugar beets. Organisms in the soil have their cycles of development which are influenced by the nature of the food supplied by crop residues, with soil moisture and soil temperature acting as controlling factors on when and how fast the organisms grow.

When it was discovered that residues from legume crops build up black root infestation in the soil and that the contrary effect is produced by corn stover and corn roots, and when it was found that after 2 or 3 months the residues from legumes disintegrate and no longer favor the black root fungi, the proper ways to clean up soils and to utilize sod-forming legume crops to precede sugar beets were shown.

For badly infested soils, the growing of a corn crop immediately to precede the beet crop is an effective clean-up measure against black root. With such crop sequence, good stands of sugar beets can be obtained in fields that have had a long history of black root damage. The practice is now followed in many districts. Since plowing under cellulosic materials tends to lock up nitrogen, applications of fertilizers rich in nitrogen are made at planting time and often as side-dressings.

If sugar beets are to follow alfalfa, sweetclover, red or crimson clover, then a proper timing of the operations in fitting the soil for the beet crop must be observed. If the legumes are plowed in late fall or early spring, then the residues offer the black root fungi abundant food which the organisms use just as soon as the soil warms up in the spring. Thus, planting time and the germination of the sugar beet seed will come just when the black root fungi are at their peak of development.

An entirely different set-up is presented if the legume sods are plowed in late summer or early fall. The alfalfa or clover roots die, and the black root organisms flourish during September and October, using up the nitrogen and quickly soluble carbohydrates. When these are gone the cellulose framework of the residues supports a different set of fungi, and the forms that produce black root are crowded out.

Thus, by timing properly his plowing of legume sods, the farmer can gain the advantages that come from growing legumes and avoid the very definite bad effects that the legume sods exercise if they are plowed too late in the fall or in the spring immediately before beet planting.

Black root of sugar beets is so serious in its effects on stands in the more eastern sugar beet growing districts that the relationship of the various crops to the prevalence of the disease-producing organisms is stressed. The experimental work on which the conclusions are based is described in some detail as a means of relating the laboratory and greenhouse experience with what the grower himself can observe on his own farm. The method used in following the increases and decreases of black root fungi in soil has not been the well-nigh impossible job of finding these microscopic forms and counting them, but instead the amount of killing of sugar beet seedlings that takes place in a soil flat treated in a given way is taken as the direct indicator of what is happening.

It has been found that if reel clover, sweetclover, alfalfa, or other legume is grown in a flat in the greenhouse for about a month and this growth turned under, and then after a week or 10 days sugar beet seed is planted, the stand of sugar beets obtained is very poor—usually not over 10 percent. The soil without legumes gives a stand of from 50 to 75 percent. If corn is grown for a month, and then the young plants turned under, and after a week or 10 days sugar beet seed is planted in the flat, the stand is nearly 100 percent.

The flats that failed because a legume was grown, if planted to corn,
can be made to give nearly 100 percent stands of sugar beets. The flats giving fine stands can be made to fail simply by planting legumes for a month, turning them under, as a preliminary treatment before planting sugar beet seed.

That these results are brought about by changes in the black root organisms in the soil has been shown by treating the soil initially with formaldehyde to kill the black root organisms. With such soil, after the formaldehyde vaporizes and disappears, it makes no difference whether a legume or a corn crop precedes the beets or if the beets are grown on fallowed soil; all give 100 percent stands.

These effects are related to the nutrition of the soil organisms. This is shown by incorporating nitrogen-bearing materials such as ground legume hay, dried blood, cottonseed meal, or urea into the soil. Those substances increase the amount of damping-off of sugar beets over that which occurs when the soil is untreated. On the other hand, if ground cornstalks, corn meal, ground filter paper, or sugar is put into the soil the stands of beets are improved over those in nontreated soil.

If alfalfa hay is incorporated into the soil and the sugar beets started directly thereafter, bad effects on stands are noted. After 2 or 3 weeks in the warm greenhouse, however, the stands following the addition of alfalfa residues are greatly improved. In other words, when the nitrogenous substances and soluble carbohydrates are used up, the effects from the cellulose portions appear.

The conclusions from these experiments have been tested by field experiments and observations in Michigan, Minnesota, Colorado, South Dakota, and other States. Replicated tests have shown that the effects in the field of the legumes and corn as preceding crops for beets are comparable to those of the greenhouse cultures. But if the alfalfa and sweetclover sods are turned under in August, September, or possibly even October, and if the conditions of moisture and temperature permit disintegration of the residues, stands are good in the sugar beets planted the following spring. This is in sharp contrast with the prevailing poor showing of the sugar beets in the spring-plowed part of the experimental plots.

If the farmer understands what takes place in the soil when he incorporates the crop residues, he may use legume sods to advantage with sugar beets. A blanket recommendation to plant sugar beets on legume sods without specification of the time of turning-under the sods is ill-advised and may invite an outbreak of black root.

A rather definite relationship exists between soil fertility and the incidence of black root. Tests in many localities have shown the effectiveness of adequate phosphate applications. In a test at Holgate, Ohio, superphosphate (15 percent) at a rate of 200 to 400 pounds an acre increased stands and nearly doubled the sugar production. A complete fertilizer, 2-16-8, at 500 pounds an acre doubled yields and gave the highest sugar.

The increase of the aphanomyces type of black root, as well as the acute forms, seems related to the progressive lowering of the supply of available phosphate that has taken place on many soils of Michigan, Ohio, Minnesota, and other States. Evidence is available that a low status of plant nutrition, especially with phosphate, reduces resistance to *Phoma betae* of stored sugar beet roots. Deficiency of phosphate appears to lower the resistance of young sugar beet plants to *A. cochlidioides*. Abundant evidence is at hand that raising the fertility level of the soil, particularly with respect to phosphate, reduces resistance to *Phoma betae* of stored sugar beet roots. Deficiency of phosphate appears to lower the resistance of young sugar beet plants to *A. cochlidioides*. Abundant evidence is at hand that raising the fertility level of the soil, particularly with respect to phosphate, can bring about decisive reduction of losses caused by *A. cochlidioides*. Fertilizer practice with sugar beets has shown marked improvement in recent years, but many farmers still apply fertilizers so sparingly that little or no benefit is obtained.
Treating seed with copper, mercury, and other fungicides helps prevent acute phases of black root. Even better are organic mercury compounds, such as Ceresan and New Improved Ceresan. They used to be the standard treatments, but Arasan, Phygon, and other nonmetallic fungicides have mostly replaced the mercurials for seed treatments. Treatment of seed gives fairly satisfactory stands of seedlings if the exposure is not extremely severe. When soil infestation is high and soil moisture conditions are favorable, seed treatment is not enough to assure a stand. Seed treatment does not prevent the chronic form of black root caused by *A. cochlioides*.

Effective control of black root is not simple. Many factors of the environment affect it: The field chosen for the beet crop must be plowed at the proper time and its fertility must be high. Liberal application of commercial fertilizer is needed. Seed treatment to protect against acute forms of the disease is necessary. When the beets emerge, prompt cultivation assists in soil aeration and may prevent an excessive loss of stand.

Those general measures will prevent the acute forms of damping-off. The chronic type, caused by *Aphanomyces*, is to be met by use of resistant varieties. They give excellent results. By 1953 and 1954, they will be available for the worst-affected sugar beet districts.

**Rhizoctonia** crown rot (*Pellicularia filamentosa*) occurs on half-grown or nearly mature sugar beet roots. *Rhizoctonia solani*, the pathogenic stage of the fungus, also causes decay of the fleshy parts of the root. Plants here and there in the field die. The leaves turn brown or black, wither and dry, and persist on the dead crown. The entire crown or only a part of it may be rotted. The disease spreads along the row, rather than across rows, so that one or two affected plants commonly are found on either side of the disintegrating plant first to show crown rot. The fungus causing crown rot is in all agricultural soils and is capable of persisting indefinitely. The spore stage of the fungus probably does not constitute a significant factor in its spread.

Sugar beet seedlings attacked by *Rhizoctonia* may be killed outright or only cankered. The cankered plants continue to grow, and some recover. Such plants, however, may develop crown rot. Sugar beets will be found in July and August with their crowns cleft horizontally, much as if injured with a hoe. The cause is a canker contracted in the seedling stage. Rapid growth cracks the flesh away from the dead spot. The fungus then advances into tissue as a crown rot. *Rhizoctonia solani* comprises countless strains or biotypes. Some cause diseases. Some are nonvirulent forms. The highly virulent strains can penetrate sound tissue; they can invade without wounds. The fungus persists in the soil. Continuous cropping with beets or other susceptible types of crops increases the infestation. *Rhizoctonia* causes a serious disease of potatoes, but apparently the strains attacking potatoes are different from those that cause root rot of sugar beets. The Rhizoctonias that attack cereals also seem different from those that attack sugar beets, legume sod crops, and vegetables. The disease is worse when the level of nutrients is allowed to drop.

Selections of sugar beets made under conditions of severe *Rhizoctonia* attack have shown outstanding resistance to a few strains of the fungus, but this resistance has failed with exposure to other strains. The outlook for the control of crown rot by breeding *Rhizoctonia*-resistant varieties is not promising because of the enormous number of biological strains of *Rhizoctonia*.

Sanitation measures should be used, especially proper crop rotations, to reduce the prevalence in the soil of the *Rhizoctonia* strains that attack beets. Sugar beets may be grown following corn, small grains, potatoes, soybeans, and probably field beans without seri-
ous loss from *Rhizoctonia*, as these crops do not build up strains that are highly virulent against sugar beet. The control of *Rhizoctonia* by rotations also has direct relation with the reduction of seedling disease. Sugar beets should not be grown on legume sods unless these sods are plowed in late summer or early fall, so that the residues disintegrate fully in winter.

**Fusarium yellows** (*Fusarium conglutinans betae*) affects sugar beets in Colorado, Nebraska, South Dakota, Montana, Wyoming, and possibly other States. It causes wilting of the plants. The characteristic symptom is a yellowing and dwarfing of the foliage of the half-grown plants. Affected leaves become pale yellow and mottled. The pathogen belongs to the group of fungi that invade the water-conducting tissues of the plant. With fusarium yellows of sugar beet, the central core of the root turns yellow, or brown, and eventually black. Surrounding tissues may also be injured. The fungus gives off toxic substances that cause wilting and collapse of the leaf tissues when carried upward in the transpiration stream. In a diseased root that is cut lengthwise, the diseased vascular system shows up as a yellow or brown discolored area. That and the effects on the leaves make it easy to recognize the disease.

The fungus can persist in soils for many years. With ordinary rotation practices, the organism has not shown the capacities for soil infestation that characterize related organisms that cause cabbage yellows, celery yellows, aster wilt, tomato yellows, flax wilt, and cotton wilt. With continuous culture of sugar beets for 5 years, incidence of disease increased until about 40 percent of the crop was affected.

No effective control measures are known for fusarium yellows. No resistant varieties have been introduced. The disease is worse when crop rotation is neglected. Heavy dosage with P2O5 fertilizer is beneficial. Fields that one time showed infection of more than 10 percent have been greatly improved and incidence of disease lessened by growing alfalfa 3 years, and some crop such as corn, lima beans, or cantaloups 1 year, before growing sugar beets again. The sugar beet crop was given adequate fertilization with superphosphate.

**Bacterial canker** (*Phytomonas beticola*) can cause overgrowths on petioles or on the root, but are chiefly to be found on the crown. The central parts of the overgrowths are water-soaked and yellow. These are cells of the sugar beet root that are almost completely invaded by the organism.

Bacterial canker occurs in Virginia, Maryland, Michigan, Wisconsin, Colorado, Wyoming, New Mexico, and Utah. No other natural hosts are known.

The disease normally affects a plant here and there in the field but sometimes the galls have been found on almost every plant. Such an outbreak follows a hailstorm that has wounded the crowns and afforded entrance for the bacteria. The bacteria have been found in agricultural soil and have been isolated from irrigation water. The organism can persist a long time in the soil. It does only minor damage to the sugar beet. No specific control measures are used other than crop rotation, in which beets do not occur more often than once in 4 or 5 years, and good fertilization.

**Sclerotium root rot** (*Sclerotium rolfsii*) in 1933 and 1934 killed entire fields of sugar beets in California. The fungus growth, a coarse, rapidly growing mycelium, can invade sound or wounded root tissue and quickly rot it. The fungus attacks many vegetable crops in the South. It was serious on carrots and peas in southern and central California. Sugar beet roots rotted by *Sclerotium rolfsii* are covered with a filmy, whitish growth, on which the fungus forms its resting bodies—small, brownish, seedlike bodies about the size and appearance
SOME PROBLEMS IN GROWING SUGAR BEETS

of a radish seed. Thousands of these sclerotia are formed on rotted roots and identify the organism. The fungus requires warm soil conditions. Attempts to grow sugar beets in Louisiana and southern Texas have largely been fruitless because of *Sclerotium rolfsii*.

The disease in California was found only in a few fields. The California Agricultural Experiment Station cooperated with the industry in making a survey of *Sclerotium*. Soils were sampled and laboratory tests were made to determine the degree of infestation. Seriously infested fields were taken out of beet production and planted to alfalfa and other nonsusceptible crops. The practice of returning dump-dirt of the beet receiving stations to the fields was prohibited in order to prevent introduction of the fungus into clean fields.

If the disease appeared in the field in serious amount, heavy applications of nitrogen—usually accomplished by adding nitrogen as ammonia gas to the irrigation water—checked it. The steps taken in California controlled the disease and removed it as a threat to sugar beet production.

**THE SUGAR BEET NEMATODE**, a parasitic worm, is one of the worst pests of the sugar beet. Failure to practice proper crop rotation leads to serious infestation.

Practical control depends on starving out the nematodes by rotation of beet crops with crops not attacked by the nematodes. Usually such crops are grown for 5 years between sugar beet crops. Alfalfa, grains, tomatoes, potatoes, beans, peas, and sweetclover may be used as rotation crops. Cabbages, cauliflower, table beets, mangel-wurzel, turnips, rutabagas, and radishes must be avoided as they are attacked by the sugar beet nematode and not only permit the nematodes to increase instead of decrease, but are often injured severely. Special attention should be given to weed control during the rotation period as the sugar

beet nematodes can also live on many common weeds. Thus, in California, mustards in alfalfa fields must be killed. The long period between beet crops is necessary because the female sugar beet nematode develops into a tough cyst which remains in the soil for many years. Enclosed in the cyst are eggs with larvae which can remain alive and capable of attacking plants for many years. In the absence of a host crop, only a small proportion hatch each year and die of starvation and other natural causes, so that it takes several years to reduce their numbers sufficiently so that a good sugar beet crop can be grown.

Success of the 5-year period, or more, between beet crops in restoring the land to its former productivity for sugar beets is remarkable. It should not, however, encourage the grower to follow up with a second crop of sugar beets, since the starvation period does not kill all nematodes and sugar beets will have brought back a high nematode population.

**ROOT KNOT NEMATODES** cause distinct knots or galls on the roots of sugar beets. These are generally more numerous on the lighter type soils than on the heavier ones, but may be a serious problem wherever sugar beets are grown. They also are controlled by soil fumigation or by crop rotation, but since no cyst is formed shorter rotation periods can be used. Since several species of root knot nematodes attack sugar beets and these differ in their host relationships, no definite rotation system can be specified. Rotation details must be worked out on a local basis.

**AMONG THE MINOR ROOT DISEASES** is verticillium wilt, caused by *Verticillium albo-atrum*. It occurs to a limited extent in Colorado and Nebraska. It is serious in the Yakima Valley of Washington. The foliage becomes yellow and dries. Roots show only slight evidence of small, blackened fibrils here and there in the flesh. The lateral root
through which the fungus entered the plant usually can be detected because it becomes black and water-soaked. Probably crop rotations with several years between sugar beet crops would reduce the incidence of the disease.

Crown gall, caused by Agrobacterium tumefaciens, is an overgrowth that usually takes the form of a smooth gall or knot on the shoulder or central part of the beet root. It is caused by the same bacterial organism that attacks fruit trees and other plants. Occasional affected plants have been found in nearly all sugar beet districts. The overgrowth excites attention because frequently the gall is as large as the beet root itself. No control measures are necessary as the disease is limited on sugar beets.

Texas root rot, caused by Phymatom trichum omnivorum, attacks sugar beets in New Mexico and Arizona, on soil in which Texas root rot, well known as a cotton disease, occurs. The tissue of an affected plant is rotted completely. The fungus produces a thin, feltlike coating of hyaline or yellowing mycelium on the surface of the root. It advances on the root surface as a whitish or yellow fan-shaped growth. Sugar beets are not grown for sugar production to any extent in areas where Texas root rot is common. No loss in the seed-producing areas of Arizona or New Mexico has been reported.

**Storage Rots** are caused by Phoma betae, Botrytis cinerea, Rhizopus nigricans, Rhizoctonia solani, several species of Fusarium, and other fungi.

To prevent cold weather from interfering with harvesting, factories in nearly all the beet-growing districts must accept deliveries of sugar beet roots in excess of their capacity for prompt processing—so huge tonnages of roots are piled at the factories and their receiving stations.

The roots stored in the huge piles are alive; like all living things, they respire. Respiration involves the oxidation of the sucrose in the root. Temperature influences the rate of respiration; therefore, if the storage piles are kept cold, the loss of sugar from respiration is at a minimum. Because respiration produces heat, if a storage pile contains layers of dirt and masses of leaves and trash, the dissipation of heat by air currents may not take place and a chain of conditions is set up that leads to the generation of heat in pockets of the pile. First, respiration is accelerated; finally, roots become subject to fungus rots, and the rotting organisms feeding on the rich sugar stores of the roots produce excessive heating in the piles. These manifest themselves as "hot spots." In some years the losses from storage rots are staggering.

Experiments by Myron Stout and Charles A. Fort a few years ago started active prevention of sugar losses from stored sugar beets by cooling the roots by forced ventilation of the piles with chill night air. Engineers at beet sugar factories promptly capitalized on this finding, and today piles of sugar beets at the factories very commonly have ventilating ducts laid through them. Thermostats are located at critical points to control the operation of blowers. Cold air is forced through the piles by blowers as the temperatures within the piles may require.

Sugar losses still occur with roots in storage piles, and after a period in storage such losses may sharply rise. Studies to reduce losses further are continuing. Beets grown with abundant nutrients, particularly phosphorus and nitrogen, and with adequate soil moisture, are resistant to storage rots, particularly to Phoma betae. Drying in the field before piling has bad effects on keeping qualities. High temperatures have been shown to break down the resistance of roots to the attack of organisms that ordinarily are saprophytes unable to attack a live root. Thus, a period of 60° F. is enough to change the character of the sugar beet root so that the bread mold, Rhizopus nigricans, can rot the tissue.

Roots have been exposed to invasion by Phoma betae and Botrytis cinerea, chief roters of roots in storage, and
SOME PROBLEMS IN GROWING SUGAR BEETS

the most resistant roots selected. Progenies from such selections keep better than parents. Sugar beets with good keeping quality may be bred, since apparently this is governed by the genetic make-up of the sugar beet.

Beet mosaic occurs in Colorado, Nebraska, Utah, Idaho, Oregon, California, and other Western States. This virus disease produces mottling of the young leaves of sugar beet. Sometimes veinlet clearing develops on the youngest leaves of an affected plant. The green peach aphid (Myzus persicae) and other aphids transmit the virus from plant to plant.

The disease is apparently limited to the sugar beet, red garden beet, chard, and mangel-wurzels. Spinach and other plants have been artificially inoculated.

Other than in California, mosaic is chiefly to be found close to infected commercial seed fields or near breeding stations where mosaic-affected roots are carried over winter for transplanting in spring. Ordinarily it is not prevalent beyond the flight zones of aphids—usually a matter of a few miles. In California, mosaic is very common. Since sugar beet crops overlap from year to year and seed crops of both sugar beet and red garden beet are grown, there is no break in the cycle of development. Furthermore, the aphid vectors are abundant and have year-round activity. The absence of mosaic in the more eastern beet-growing sections, such as Michigan, Ohio, and Minnesota, is not understood. It is probable that wherever the virus has been introduced, a cycle of development has been broken because affected plants have not been overwintered.

Any damage that sugar beet mosaic may do to sugar beets grown for sugar has not been appraised. It is known that plants affected with mosaic are significantly poorer than healthy plants as seed producers. As yet no control measures are employed against sugar beet mosaic, or its insect vectors.

Savoy, which is a virus disease that is transmitted by the lacewing bug, Piesma cinerea, curls and distorts the leaves and dwarfs the root of sugar beet. The disease also affects red garden beet, chard, and mangel-wurzel, but is not known on other hosts. Usually the disease appears as a plant here and there in the field, but 10 to 15 percent Savoy has been found in fields bordering wood lots or weedy areas where the insect could overwinter. The disease occurs from Maryland and Virginia westward through Wyoming and Montana, but it has not been found in sugar beets west of the Rocky Mountains—although the insect vector occurs throughout the United States.

The most definite symptom of Savoy is the swelling and thickening of the veins. Their growth is reduced and they show up as prominent network on the under side of the leaves. The leaves curl and roll downward. The tissue between the veins bulges out; the whole leaf becomes whiplike and distorted. The roots show darkened vascular rings, the flesh between becoming glassy white. Affected plants make very limited growth, and the roots show much reduced sugar storage.

Ordinarily the disease is minor in its effects, the lessened growth being compensated by greater growth of the neighboring plants. No direct control measures are employed against the disease.

Virus yellows, long known as the most serious disease attacking sugar beets in Europe, was found in 1951 in Michigan, Colorado, Utah, Oregon, and California. It is probably widespread in the United States and may have been here for some time but overlooked. This virus is spread by aphid vectors, of which the green peach aphid, Myzus persicae, is most important. Only the older leaves show the disease symptoms. They turn a greenish yellow, particularly at their tips. The veins stay greener than the interveinal tissue. The leaf blades