Breeding Healthy Potatoes

by F. J. STEVENSON and ROBERT V. AKELEY

Our standard kinds of potatoes are hard to beat in yield and quality. Our problem is how to overcome diseases and insects. The diseases are commonly caused by fungi, viruses, and bacteria. Fungous diseases include late blight, early blight, and common scab. The worst of the virus diseases are mild mosaic, latent mosaic, rugose mosaic, leaf roll, net necrosis, yellow dwarf, and spindle tuber. Of the bacterial diseases, the most troublesome are ring rot, brown rot, and black leg.

Any one of them could eliminate the potato as a leading food crop of North America. We have control measures that allow us to grow even the most susceptible varieties, but the cost of the preventives and cures amounts to many millions of dollars a year, and they have by no means eliminated all losses. If a small fraction of the expense and effort now consumed in fighting disease had been put into the production of disease-resistant varieties, potato growing would be much more profitable.

State experiment stations and the Department organized the national potato-breeding program in 1929 and have distributed to growers 25 new varieties of potatoes. Some of them resist late blight, or virus diseases, or common scab. Much has been done, but there is much more to do.

Potato plants are propagated asexually and sexually. In commercial practice, the new crop is grown from tubers or pieces of tubers. That is a vegetative or asexual method of reproduction. A variety can be grown vegetatively for years without visible change, and any attempt to make a selection within it is usually futile. Occasionally bud mutations occur, and a few new potato varieties have been obtained by selecting bud sports. When such changes do occur they are for the most part of minor importance, because most of them have been color changes, for example, from red tubers to "splashed" or to white. Changes from white to red or
from white to russet have also been known to occur. Even though only a few varieties have come as the result of bud mutations, this is still a source of variation that the potato breeder cannot ignore. But because it is quite impractical to make much improvement by selecting tubers of a variety with the hope of getting something new, the plant breeder must use true seed and seedlings to get more variations and combinations of characters.

True seed is the result of the fusion of male and female gametes, or germ cells; that is the first step in sexual reproduction. The seed is found in the fruits or seed balls that grow on the potato vines and look very much like small tomatoes. A seed ball may contain 200 or more seeds which will produce plants that are quite different from each other. Most seedlings are undesirable from the commercial standpoint, but occasionally a new variety is produced that excels the old in one or more important characters. Many people who live in the South or where the climate is hot and dry have never seen a seed ball growing on a potato plant, and not a few are quite surprised when they first discover one. In cool, long-day climates, on the other hand, some sorts produce many seed balls.

The first potato-breeding work in this country started nearly 100 years ago, when late blight was destroying potato crops in many European countries and causing large losses in this country. Blight was the cause of the famine in Ireland in 1845, which, because of the failure of the potato crop, brought sickness and distress to many people and caused the death of at least a million persons. The cause of the disease was not known then, but many persons thought it was the result of a loss of vigor in the plants, brought about by growing the crop year after year from tubers. They also believed that the vigor could be restored and the disease eliminated by growing plants from true seed.

Acting upon this belief, a number of people in Europe and the United States began growing seedlings. As a result, many new varieties were produced. A few of them are among the best varieties we have today.

The blight problem remained unsolved, however, because the trouble was not a result of the loss of vigor but was due to a parasitic fungus that attacks the leaves and stems of the potato plants and often kills them before they have a chance to mature. Susceptible seedlings are just as severely attacked as the commonly grown susceptible varieties.

In 1910, when potato breeding was actively undertaken by the Department, resistance to late blight was still considered the most important character for which to work, but the project was just under way when the virus diseases took first place in the breeding work, and blight resistance was once more thrown into the background. It was not until 1932 that Department workers could again attend to the problem.

Varieties of potatoes showing different degrees of resistance to blight were introduced from foreign countries and used as parents of new seed-
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lings. A few seedlings with an intermediate type of resistance were produced by crossing two susceptible American varieties. A much larger proportion of intermediates was obtained when moderately resistant varieties, like Ekishirazu from Japan or President from Holland, were used as parents. Selections from the so-called \( W \) races, which were introduced from Germany, showed resistance to late blight, but were low in yield and market quality.

When some of them were crossed with American kinds and seedlings, a number of selections from the resulting family lines retained the blight resistance of their foreign parents and were much more desirable from the commercial standpoint. Several of the selections were in turn selfed, backcrossed, and outcrossed to various commercial varieties and promising seedlings. From this second series of progenies, selections have been made that are highly resistant to late blight. They have been subjected to blight epidemics by spraying them with blight spores in the field under conditions favorable for the spread of the disease, and many of them have escaped infection over a period of years. In the same tests, the Green Mountain, which was planted at frequent intervals throughout the field, was frequently killed by blight 30 to 40 days before it would mature normally.

In preliminary trials some of the blight-resistant selections have produced yields and dry-matter content of tubers equal to the best commercial varieties that are grown in Maine. Several of the most promising of these are being increased for distribution, and a limited amount of seed of two, B69-16 and B70-5, should be available soon.

Some of the seedlings that are resistant to late blight in the vines also show tuber resistance to rot caused by the late blight fungus. In the same family line some seedlings will be resistant, others susceptible. In a test for reaction to blight the tubers are covered with spores of the fungus and placed in a moist chamber and kept cool—conditions that favor rot.

While the Department, in cooperation with the Maine Agricultural Experiment Station, was producing blight-resistant varieties by using commercial types and foreign introductions closely related to our cultivated forms, Donald Reddick, of Cornell University, was attacking the problem by the use of species hybrids. It has been known for many years that some strains of \( Solanum demissum \) are immune to blight. This species is distantly related to our cultivated potatoes, however, and is deficient in almost all characters of economic importance. For one thing, it is almost nontuber-bearing in the ordinary potato-growing season in Maine. When crosses are made between it and cultivated varieties, some of the resulting progeny are immune to blight, but are still quite poor in other characters. Each cross to cultivated varieties shows some improvement, and, after four generations, Dr. Reddick has succeeded in combining the immunity to late blight of the species \( S. demissum \) with the desir-
able horticultural and culinary characteristics of the commercial varieties commonly grown in the Northeastern States.

Another fungous disease, common scab, causes losses in every section where potatoes are grown, and in some places its attacks have become so severe that potatoes can no longer be produced profitably. The organism causing this disease lives over in the soil and is carried also on the tubers. Soil treatments have been tried, but they are costly and not reliable. Treatments that will kill the organism on the seed potatoes have been recommended, but these are often of questionable value because if clean seed is planted in scabby ground the resulting crop of tubers will be scabby. In its effects on yields, scab is not so noticeable as late blight, but it affects the market quality and, hence, the value of the tubers.

In our program a comparatively large number of varieties and seedlings have been tested, and different degrees of resistance to scab have been found. Resistant varieties, such as Hindenburg, Jubel, and Ostragis, have been imported from Europe, but none of these is adapted to conditions in this country. They produce low yields of tubers and have poor market quality. Crosses have been made between these resistant types and American varieties and seedlings, and some of the resulting family lines have shown a high degree of resistance to scab, combined with other characters of commercial importance. None of them has reached the high standard of excellence for which we are striving, but they can be grown successfully in scabby soil where at present it is unprofitable to grow other commercial varieties. Four of these, Menominee, Ontario, Cayuga, and Seneca, have been distributed to growers for use in scabby lands.

As a group, the virus diseases are perhaps the most widespread and the most baffling. They occur in every potato-growing region of the United States, and it is probable that not a single field of the old varieties could be found entirely free from one or more of them. They are not new. Their effects have been observed by growers for many years, but for a long time it was thought that they were due to "running out" or "degeneracy" brought about by growing potatoes year after year from the same tuber stock—the same belief that was held concerning late blight. Not long ago it was discovered that degeneracy is due to virus infection and that insects spread the most common of the virus diseases.

Ways were soon devised to hold these diseases in check. Diseased plants are rogued out of the seed plots, and early harvesting is sometimes practiced in an effort to get away from late infections, because the insect vectors, especially aphids, are usually most plentiful during the latter part of the growing season. Seed-certification programs have been organized in the principal potato-growing States in an effort to provide growers with seed that will produce satisfactory yields.

In the earlier studies, it was observed that some varieties did not degenerate so quickly as others or, as we now say, some varieties are more
resistant to viruses than others. Knowing that such differences must be heritable, we have undertaken a rather extensive program to produce new varieties that resist the commoner virus diseases, mild mosaic, latent mosaic, rugose mosaic, leaf roll, and net necrosis. We have produced large numbers of seedling varieties that are immune to mild mosaic under field conditions, latent mosaic, and rugose mosaic.

It is doubtful whether any of the kinds we now have are immune to leaf roll, but some have been produced that under severe tests have not shown leaf roll for 4 or 5 years, although in some of the same tests more than 90 percent of the plants of the control varieties, Green Mountain and Chippewa, became infected with the virus in a single season. Current-season infection with the leaf roll virus frequently causes net necrosis in the tubers of such varieties as Green Mountain, and losses to growers are large. Many varieties have been produced, and some of them, like Katahdin and Chippewa, which are apparently immune to net necrosis, have been released to growers and have been increased rapidly.

A bacterial disease, ring rot, has recently come into prominence as a widespread menace to potato production. Sanitary measures and the insistence of State authorities that no seed be certified that has even a trace of ring rot in it have done much to keep this disease under control. However, outbreaks are frequent despite precautions.

Cooperating in the program of breeding for resistance to ring rot are the Maine, Michigan, and Wyoming Agricultural Experiment Stations. We have tested large numbers of varieties and seedlings and have found resistance in only a few lines. It is interesting to note, however, that resistance was obtained from widely separated sources. It was found in the varieties Friso and President from the Netherlands and in a number of seedling varieties produced in the United States.

The seedling U. S. D. A. 47102, tentatively called Teton, has shown a high degree of resistance in the tests in Maine and Wyoming. It has also produced high yields and has satisfactory market and cooking quality, compared with standard varieties grown under the same conditions. It is not immune to ring rot, but has shown only a small amount of the disease in tests over a period of years; control varieties, like Triumph and Green Mountain, usually show 80 to 100 percent infection in a year.

Since problems and objectives in the production of disease-resistant varieties of potatoes are not confined to a single State but involve large regions of the country, potato breeding was organized in 1929 as a national project. The work is conducted cooperatively by 35 State experiment stations and the Department. The practice under the program is to send seedlings produced by the Department or by any of the cooperating State experiment stations to other States for trial. After sufficient tests, if any seedling variety shows superiority to the standard varieties in at least one important character, such as yield, market quality, or resistance to a
disease that is difficult to control, it is named and released to growers. Since 1932 more than 25 varieties have been released. Several of these have increased rapidly in yearly production; others increased more slowly.

In some of the new varieties the important objective for which they were bred has been reached. Sebago, Empire, Placid, Virgil, Chenango, and Ashworth are resistant to late blight; Menominee, Ontario, Cayuga, and Seneca are resistant to common scab; Katahdin, Chippewa, Warba, Houma, Earlaire, Sebago, Red Warba, Mohawk and Menominee are resistant to one or more virus diseases; and Teton is resistant to ring rot.

How well the new varieties have been received by the growers is shown by the fact that in 1945 about 26 percent of all the certified seed in the United States consisted of varieties that have been released since 1932. None of these will meet the needs of the growers in all the cooperating States, and it is doubtful if such an ideal variety will soon be produced. However, a sectional demand existed for each one, and because of their disease resistance and other characters of economic importance they have been increased under severe competition and critical evaluation.

A beginning has been made, and the new varieties that have already been released have been a factor in increasing the yield of potatoes in the United States from a little more than 100 bushels an acre 25 years ago to about 150 bushels an acre in 1945. The results indicate much greater possibilities in breeding. We have available a large number of important characters that have not yet been combined in one variety, and each new combination should give us a new variety more valuable to some of the growers than any we now have. These characters include wide adaptation; early, medium, and late maturity; smooth, desirable shapes; shallow eyes; high yielding ability; and high dry-matter content. Besides, we have seedlings that resist one or more of the following diseases and insects: Mild mosaic, latent mosaic, rugose mosaic, leaf roll, net necrosis, yellow dwarf, late blight of the vines, tuber rot initiated by the late blight fungus, common scab, potato wart, brown rot, ring rot, hopperburn, flea beetle injury, and aphid injury.

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