Saving Our Sugar Beets

by EUBANKS CARSNER and F. V. OWEN

ONLY 30 years ago curly top of sugar beets seemed an insurmountable barrier to progress of the beet-sugar industry in much of the West. One authority at that time even advised the abandonment of infested and susceptible areas. Had that been necessary, we would not have the sugar and sugar-beet seed now produced in a vast territory in 12 Western States, and their settlement and development would have been retarded.

But now, in retrospect, curly top appears to have been a blessing in disguise. The need to conquer it prompted much research, which led to the development of varieties adapted to American conditions and the establishment of a new industry, growing sugar-beet seed. The two results completed the integration of the American beet-sugar industry and made it independent of Europe.

The violent vicissitudes through which sugar-beet growing and the beet-sugar industry in the Western States passed before curly-top-resistant varieties were produced can be brought out best in the record of a representative region. Farmers in the Burley area of southern Idaho started growing sugar beets in 1912. Average yields were low at first but gradually improved with increasing experience, and the acreage was expanded because of the sugar shortage during the First World War. In 1919 came the first outbreak of curly top. From then until 1935 yields dropped recurringly to disastrous levels—in 1924, 1926, 1931, 1934. Areas in Arizona, California, Colorado, Nevada, New Mexico, Oregon, Texas, Utah, and Washington suffered in much the same way.

The deep dips in the curve of average yields in southern Idaho indicate only a part of the losses that curly top caused in those years. Average

yields of 5 to 6 tons an acre meant heavy losses to processors and the growers who carried their beets through harvest. Besides, a big acreage was plowed up. The average yield in 1934 was 4.88 tons an acre from 2,754 acres harvested—but in that season, of 21,389 acres planted to beets, 18,635 were abandoned. Contrast with this the record for 1941, a season in which damage from curly top also caused a conspicuous decline. It would have been a disastrous year if varieties of relatively high resistance had not been used. That year 22,005 acres were planted, 21,418 were harvested, and the average yield was 13.45 tons an acre.

The progress that has been made in the control of curly top through breeding resistant varieties can be indicated by results obtained in 1941 on experimental plots. Under the drastic disease conditions of that season a standard European variety once widely used in this country failed completely; U. S. 1, the first resistant variety to be released to growers, gave 6.31 tons to the acre, and the latest commercial variety, the second release of U. S. 22, yielded 16.61 tons. The test plots were purposely planted late to get more severe exposure to curly top. There was a good deal of curly-top damage that year in the commercial fields and, even with the resistant varieties now in use, curly-top losses of economic importance occur under some conditions. However, it can be stated with assurance that crop failures of sugar beets due to curly top need no longer be feared anywhere. It is not uncommon now to have the resistant varieties yield 25 and 30 tons an acre even when exposed to curly top, under conditions that cut the production of the old susceptible varieties to unprofitable levels.

Mass selection has been used to breed the varieties thus far released for commercial use. But the method involves much more than it did when breeding for curly-top resistance was started 29 years ago. We used to depend on naturally occurring epidemics to differentiate degrees of resistance. Now we regularly induce epidemics artificially in the breeding field regardless of the severity or mildness of the injury in the surrounding territory.

We introduce an abundance of the curly-top virus into the breeding field early in the spring. There are several ways to do it. In the first place, as many viruliferous leafhoppers (carriers of the curly-top virus) as possible are held over winter on hardy food plants, like annual mustards, spinach, and sugar beets, which are planted late in summer next to the field to be used for the sugar-beet plots the following spring. Leafhoppers held over in this way move into the young beets in the spring and inoculate beets here and there.

A second important measure is setting out in the field infected mother beets that have been carefully stored over winter. We usually also introduce virus into the experimental field by releasing viruliferous beet leafhoppers that are reared in insectaries. The newly infected young

plants or the transplanted, diseased mother beets serve as reservoirs of curly-top virus. From these reservoirs the spring-brood leafhoppers invading from natural breeding grounds in the desert obtain a supply of virus which they then pass on to the healthy beets they feed upon. The presence of an adequate source of virus in the experimental field at the time of the spring invasion accelerates the rate of development of the curly-top epidemic in the field because many of the invading leafhoppers carry no virus with them.

Planting the breeding plots late is another way we use to bring about severe epidemics. Beets generally are more susceptible to infection and injury when they are small. The leafhopper vector is more active under warm temperatures. And the curly-top virus multiplies more rapidly under relatively high temperatures when the beets are growing rapidly. Plants that withstand such severe epidemics give rise to highly resistant varieties.

But besides resistance to curly top, extensive areas, especially in California, require sugar beets that do not bolt and that resist downy mildew. Some varieties like that have been bred and are in wide use. Better adapted varieties are needed in several districts, however, and efforts are being directed toward producing them.

New Breeding Methods

Methods of breeding sugar beets, other than mass selection, have been investigated while that method was being used to produce and improve better kinds. The investigations open new vistas of progress.

We discovered lines of self-fertile beets that in their sexual reproduction would not follow the general pattern of cross-fertilization. The usefulness of these highly self-fertile beets for breeding purposes was increased when beets were discovered that produced no pollen themselves and hence needed pollen from other beets for their fertilization. These male-sterile plants can be fertilized by pollen from self-fertile beets, and so produce pedigreed hybrids. With the way thus open to produce self-fertile or inbred lines with characteristics that can be determined, the possibility has arisen that many desirable combinations of characters can be bred in pedigreed hybrids. Inbred lines must be produced and evaluated before desired combinations can be planned and developed.

An indication of the promising possibilities from pedigreed hybrids is afforded by the performance of one such hybrid that has been studied. S. L. 4108 was produced by crossing a vigorous inbred line with a male-sterile beet of fair quality and high resistance to curly top. Under conditions entirely free from curly top, S. L. 4108 yielded 513 pounds more sugar to the acre than the average of seven other leading mass-selected kinds. This excellence was due partly to high vigor and partly

to greater resistance to a parasitic disease that affects the petioles and roots. Under very severe exposure to curly top, S. L. 4108 proved as resistant as the most resistant variety now in commercial use.

We have another significant indication of the possibilities of pedigreed breeding. By studying the reaction between certain inbred lines of beets and the different strains of the curly-top virus, it was discovered that some of the inbred lines are immune to some of the virus strains. We hope that the same immunity will be found in hybrids made with these immune inbreds. None of the best commercial varieties now in use has such immunity.

Also possible is the production of varieties that have single-seeded, or unilocular, seedballs and kinds having bilocular seedballs. Inbred lines have been found with a high proportion of bilocular seedballs. These characteristics can be reproduced in pedigreed hybrids. Two-seeded seedballs would be inferior to single ones, but would be a big improvement over the mechanically segmented seed now generally used.

Certain inbred lines have shown a noticeably low bolting tendency. This fact brightens the prospect for breeding for general adaptation to conditions where nonbolting varieties are required, as with early fall and early winter plantings in California. Such plantings are necessary. In the Imperial Valley, for example, the summer heat is so intense that in this extensive, highly productive area sugar beets must be planted in the fall, grown through the winter, and harvested in the spring. The winters are cold enough, however, that varieties very low in bolting tendency are necessary. Varieties of higher bolting tendency were extensively planted there by mistake one year and in the spring the fields looked more like plantings for seed than for sugar production.

Greater uniformity in size and shape of beets and consequently better adaptation to harvesting machinery seems a likely possibility through pedigreed breeding.

Another approach to the control of curly top is unique, and perhaps has a point for many other farmers. It is through an ecological study of the vegetation in desert range lands where disturbances of the natural plant cover encourage weedy areas that serve as breeding grounds for the beet leafhopper. A large-scale disturbance of that kind occurred in several regions under the stimulus of high prices for food during the First World War. Later, many of the areas that had been under cultivation were abandoned and they were immediately invaded by annual mustards, Russian thistle, and other hosts of the beet leafhopper. Bad practices prolonged those objectionable early stages of the plant succession.

The factors in the restoration of the natural plant cover, plants like sagebrush and grasses on which the beet leafhopper does not breed, were sought in the investigation. We found that with adequate pro-

tection from destructive agencies—temporary farming and abandonment, fire, and excessive grazing—a grass cover will replace the leafhopper weed-hosts in 5 years. Cattle, incidentally, are not the only animals that may overgraze: The persistent, year-round feeding of large numbers of jack rabbits destroys more vegetation than we had realized. Large experimental plots in the desert, portions of old abandoned farms, protected from fire and the grazing of domestic animals, continued to produce crops of mustards and Russian thistle and consequently large numbers of beet leafhoppers—until jack rabbits were excluded. Then the desired change in plant cover began. Rodents sometimes thwart efforts to reseed the ranges with perennial grasses; such failures often are wrongly attributed to too little rain.

Good management of range land and farm land, besides helping to control curly top of sugar beets, by keeping the population of beet leafhoppers below dangerous levels, is highly important to several other commercial crops. Tomatoes and a good many varieties of beans, for example, would be produced in a number of areas if it were not for the frequent heavy invasion of beet leafhoppers and the consequent damage from curly top.

Establishing the Seed Industry

Sexual reproduction in sugar beets depends on two environmental factors of primary importance, prolonged low temperatures that permit only very slow growth, and long days or long daily periods of light exposure. Varieties vary genetically in these reproduction requirements. Only those high in bolting tendency gave good seed yields in the warmer areas first developed. And if they were repeatedly reproduced there, natural selection eliminated those individuals that did not go to seed and the bolting tendency of the resulting varieties increased to a degree unacceptable in fields of beets grown for sugar production.

Research overcame the difficulties. The factor of temperature required most attention. Early planting, proper fertilization, and right irrigation gave large growth of leaves in the fall to shade the soil and keep the beets comparatively cool through the winter. Deterioration of varieties in bolting tendency was avoided by growing the stock seed under climatic conditions of other regions that afforded complete reproduction. Such stock seed is used to produce only a single generation of commercial seed in the warmer areas.

The regions better adapted climatically were also found to reproduce satisfactorily the varieties so low in bolting tendency as to merit the designation "nonbolting varieties."

Thinning or spacing beets, a laborious, expensive operation in producing sugar, is undesirable in seed-growing areas where winter days

are often warm. Leaving the plants thick to shade the soil and each other helps reduce the temperature. The process of thermal induction of flowering goes forward slowly under favorable low temperatures, but under high temperatures it is rapidly reversed. Spacing may prove economically practicable in seed districts where daytime winter temperatures are seldom high enough to reverse the reproductive processes. Better light relations for photosynthesis and more economical use of nutrients and water in the soil result if there is not too much crowding.

Disease factors have been encountered in the seed-growing areas, too. Curly top in the interior regions, several fungus diseases, and one bacterial disease in the coastal regions have required attention. Breeding for resistance to all these diseases offers the best control.

The production of seed was firmly established in the United States as a result of the need for multiplying American varieties resistant to curly top. The foundation for the method of growing seed generally used in this country was laid some years before we had varieties that resist curly top. In Europe, the beets are grown one season, dug, stored over winter, and set out in the spring. Our method is much less laborious. The seed is planted in late summer or early fall, the plants allowed to grow slowly over winter in place, usually without thinning, and the seed harvested the following summer. The method permits mechanized operations that eliminate much of the hand labor required in the transplanting method.

Growing beet seed has benefited the agriculture of the areas where the industry has been established. The soil fertility has been improved as a result of research on the soil requirements for sugar-beet seed production and by the residual effect of fertilizers applied for the beet seed crop.

THE AUTHORS

Eubanks Carsner is a pathologist in the Bureau of Plant Industry, Soils, and Agricultural Engineering. He has been a field leader of sugar beet curly-top investigations since 1917.

F. V. Owen is a geneticist in the Bureau of Plant Industry, Soils, and Agricultural Engineering. He has had an important part in breeding sugar beets for curly-top resistance since 1930.

FOR FURTHER READING

Cook, W. C.: *The Beet Leafhopper,* U. S. D. A. Farmers' Bulletin 1886, 1941.

Owen, Forrest V., Abegg, Fred A., Murphy, Albert M., Tolman, Bion, Price, Charles, Larmer, Finley G., and Carsner, Eubanks: *Curly-top-resistant Sugar Beet Varieties in 1938,* U. S. D. A. Circular 513, 1939.

Tolman, Bion: *Sugar-beet Seed Production in Southern Utah, With Special Reference to Factors Affecting Yield and Reproductive Development,* U. S. D. A. Technical Bulletin 845, 1943.

Wallace, James M., and Murphy, Albert M.: *Studies on the Epidemiology of Curly Top in Southern Idaho, With Special Reference to Sugar Beets and Weed Hosts of the Vector Eutettix tenellus,* U. S. D. A. Technical Bulletin 624, 1938.