Foreign Virus Diseases Potentially Dangerous to the Sugar Beet Industry in the United States

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Five virus diseases, curly top, mosaic, savoy, cucumber mosaic, and yellow vein are known on sugar beets in the United States. Of these, curly top, which occurs in western United States, is by far the most severe, but its destructiveness on sugar beets has been reduced greatly in recent years by the development and use of curly top resistant varieties. Beet mosaic occurs in all parts of the United States where sugar beets are grown. It has not caused serious reduction in yield of beets grown for sugar, but it has been shown (5)[2] to be capable of causing appreciable injury to beets grown for seed. Savoy appears to be limited largely to the middle western states. It produces severe injury on plants that are attacked, but fortunately it spreads slowly and few cases of high percentages of infection have been reported. A severe outbreak of cucumber mosaic on sugar beets occurred in the southern part of the San Joaquin Valley in California in 1940, resulting in the abandonment of some fields and in appreciable reduction in yield in other fields. The factors involved in this outbreak have not been determined. Under average conditions the disease is rarely found on sugar beets. Yellow vein is of very minor importance but small numbers of diseased plants are found in fields in Colorado and southern California during most seasons.

In addition to the diseases that already occur in the United States, there are at least three other virus diseases, each capable of causing considerable injury, that have not yet been introduced. These are ""sugar beet yellows" which occurs in Europe, "Argentine curly top" which occurs in northern Argentina, and "sugar beet yellow wilt" which occurs in the lower valleys of the Rio Negro and the Rio Colorado of Argentina. The introduction of any one of these diseases into the United States probably would increase the hazards encountered in the production of sugar beets.

Sugar Beet Yellows

The yellows disease of sugar beets has been reported from the British Isles, Belgium, the Netherlands, Germany, Denmark, and

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[2]Italic numbers in parentheses refer to literature cited.

northern France. Certain European writers *(8, 10)* have stated that the disease occurs or probably occurs also in the United* States. These conclusions are based on the fact that Townsend *(11)* mentioned leaf thickening as a symtom associated with beet mosaic and Robbins (.9) described vascular necrosis in plants affected with beet mosaic. Since beet mosaic does not cause leaf thickening or vascular necrosis, these European investigators concluded that both Townsend and Robbins were working with a mixture of virus diseases, one component of which was sugar beet yellows to which they attributed the observed leaf thickening and vascular necrosis. However, both Townsend and Robbins were working in areas where curly top occurs extensively and its is probable that the leaf thickening and vascular necrosis observed by them were due to curly top or some other factor rather than to yellows. As yet there is no evidence indicating that sugar beet yellows occurs in the United States.

Symptoms.—In the British Isles where yellows is reported *(6)* to have caused considerable loss to the sugar beet crop during the past few years, symptoms of the disease usually do not begin to appear until after the middle of the season. Single plants, groups of plants, or even whole fields begin to yellow. The yellowing occurs on the outer leaves. Even in advanced stages of attack the younger leaves usually remain green and free of signs of the disease. Yellowing begins with the production of chlorotic areas varying in color from pale, watery, or greenish yellow, to orange or even red in certain varieties of beets. The pattern of yellowing varies, but it begins often at the tip of the leaf, extending downward toward the petiole, sometimes avoiding the large veins and producing a type of interveinal mottle. Frequently the chlorotic areas become necrotic and are invaded by fungi. Yellowed leaves are thick and brittle and crackle when broken. Starch accumulates in the affected leaves and gummy deposits occur in the secondary phloem.

Symptoms of yellows are easily confused with yellowing due to too much or too little water, mineral deficiencies, and other nutritional or soil conditions. If infection occurs late in the season, yields are not greatly affected and the yellowing is mistaken often for normal ripening of the crop.

Host Range and Varietal Susceptibility.—Beet yellows has been reported on sugar beet, red garden beet, mangel-wurzel, spinach, and *Beta maritima* L. Apparently the host range of the disease has not, been investigated extensively, and it is possible that other kinds of plants may be susceptible. The relative susceptibility of many varieties of sugar beet has been tested in the British Isles. No variety has been found markedly superior to others in resistance, but small differences in susceptibility have been found which indicate that it

may be possible to breed varieties that will be more resistant to the disease than those now available.

Transmission.—Sugar beet yellows virus is not transmissible through seeds and it has not been transmitted by means of sap from diseased plants. Spread under field conditions takes place only through insects, chiefly the green peach aphid, *Myzus persicae* (Sulz.), and the bean aphid, *Aphis rumicis* TJ. Watson (72) has shown that the efficiency of *Myzus per.sicae* as an agent of transmission increases greatly with increased feeding on diseased plants. The virus is retained for a considerable period by the aphid and a single individual may infect several plants.

The virus overwinters in. the roots of escaped plants, in stecklings grown for seed production, and in roots of other susceptible crops where plants survive the winter. Aphids feeding on the new growth of such plants in the spring acquire the virus and carry it to neighboring beet fields.

Probable Results if Sugar Beet Yellows Were Introduced.—In the British Isles where best records are available on the damage sugar beet yellows is capable of causing to sugar beets, injury has varied considerably from year to year. During the war years injury apparently increased and in 1943 losses were severe. Factors most important in determining the amount of disease are aphid populations and migrations and the number of diseased plants of beets and other susceptible crops that survive the winter to serve as a source of spring inoculum. Losses vary with time of infection. Hull and Watson (6) estimate that when fields are 100 percent infected in July, reduction in yield of sugar amounts to about 50 percent; whereas, a 100 percent infection in mid-September results in a loss of only 15 to 20 percent in yield of sugar.

On the basis of the known requirements for the production of a severe attack of sugar beet yellows, it seems probable that in those areas of the United States where sugar beets do not readily survive the winter and where plants from the preceding crop would not serve as a source of infection little injury would result from yellows. However, in those areas where wild or escaped beets survive the winter or where plantings are made in th fall, this disease might become destructive. It is worthy of note that this latter area includes all of the locations in New Mexico, Arizona, California, Utah, and Oregon in which sugar beet seeds are produced. Furthermore, under the method of seed production employed in these areas, in which planting takes place in the fall and harvesting the following summer, the crop grown for seed would be subject to infection in the fall, the plants would carry the rivus through the winter, and spread would con-

tinue in the spring. In those areas where aphids are active throughout the year, probably some infection would occur even during the winter months.

In the California seed-producing areas living plants are available to harbor the virus throughout the year. Wild or escaped beets occur along irrigation ditches and roadsides, seedlings develop after harvest of the seed crops, and frequently growth from the stubble of the seed crop develops and lives through to the following year. Infected plants of these types would serve as excellent sources of infection for the plantings made in the fall for the seed crop of the following year. It is worthy of note that such material has harbored enough virus to produce very high percentages of mosaic in the seed crop during recent years. Since mosaic and yellows are spread by the same two species of aphids, it seems probable that conditions that result in a high percentage of infection by yellows if the latter virus should become established. It seems probable, therefore, that introduction of sugar beet yellows into the United States would result in considerable loss to the industry and that the disease might develop into a major problem in the sugar beet seed industry.

Argentine Curly Top

Argentine curly top was first described by Faweett *(4)* in 1925 in experimental, plots of sugar beets grown at the Estacion Experimental Agricola de Tucuman in the province of Tucuman, Argentina. There is evidence *(2)* that the disease occurs also in the Rio Negro Valley in central Argentina. Sugar beets have never been grown commercially in the province of Tucuman where the disease was first discovered, but European varieties appear to have been injured to an appreciable degree in the plots where the disease was first discovered. So far as known, conditions have not been favorable for serious spread of the disease in the Rio Negro Valley where sugar beets were grown commercially from 1929 to 1940. There is no report of the disease from the sugar beet producing area of Uruguay.

Symptoms.—Sugar beets may be attacked by Argentine curly top at any stage in their development. Soon after plants are infected the young leaves begin to curl, the veins become translucent, and the petioles are somewhat shorter than normal. Sometimes, especially in the earlier stages of the disease on rapidly growing plants, drops of sugary exudate that soon turn black appear on the diseased blades and petioles. In later stages, veins of mature leaves of the more susceptible varieties are swollen and irregular and often have protuberances and spiny outgrowths. Transverse sections of diseased petioles and roots often show dark areas in the veins due to necrosis of the phloem.

The first symptoms are the most severe and plants tend to recover from the more severe initial symptoms as they continue to grow. The more resistant varieties recover almost completely, even when infected in the seedling stage, and the more susceptible varieties improve markedly.

Symptoms produced by Argentine curly top are very similar to those produced by North American curly top. The chief difference between the two diseases lies in the greater tendency of plants affected by Argentine curly top to recover from the more severe effects of the disease. Because of this characteristic the Argentine curly top would be expected to have less effect on yield than North American curly top.

Host Range and Varietal Susceptibility.—Argentine curly top has been found occurring naturally on sugar beet, mangel-wurzel, and red table beet. It has been found also on petunia (X *Petunia hybrida* Vilm.) and a species of groundcherry and has been transmitted experimentally to chickweed *(Stellaria media* (L.) Cyr.) and zinnia *(Zinnia eleguns* Jacq.). Apparently it does not attack tomatoes or tobacco and limited inoculation tests have failed to produce infection on beans. The causal virus probably has weed host plants in Argentina from which the disease spreads to beets but these have not yet been determined.

Varieties of sugar beets tested under field conditions at Tucuman in the season of 1940-41 showed marked difference in susceptibility to the disease. Varieties S.L.[3] 842 and R. and G. Old Type, both known to be very susceptible to North American curly top, were found susceptible to Argentine curly top). Varieties U. S. II[3], U. S. 12, and S.L. 68, all restistant to North American curly top, were resistant also to Argentine curly top.

Transmission.—Argentine curly top is transmitted by a leaf hopper, *Agalliana ensigera* Oman, which appears to have been reported only from Argentina.

This leaf hopper thrives on sugar beets and closely related plants and may reach high population levels on these plants under field conditions. It acquires the curly-top virus by feeding on diseased plants; after the virus is acquired the insect retains it for long periods, probably for the remainder of its life, even though it may not again feed on a diseased plant. A single individual may produce infection

[5]Varieties released for commercial use by the Bureau of Plant Industry, Soils, and Agricultural Engineering are designated as "U. S." varieties. "S. L.." refers to varieties maintained at the U. S. Sugar Plant Field Laboratory at Salt Lake City, Utah.

on a number of different plants. The beet leafhopper, *Eutettix; tenellus* (Bak.), vector of North American curly-top virus, is unable to transmit the Argentine virus.

Probable Results if Argentine Curly Top Were Introduced.—Evidence indicates that it would be necessary to introduce both the causal virus and the insect vector in order for Argentine curly top to become established here, since neither the leaf hopper nor the virus now occurs in the United States. After introduction, the area over which the disease could spread would depend largely on the range of environmental conditions under which the leafhopper vector would be able to survive, assuming of course that there are no other insects able to transmit the disease. The amount of infection would depend largely on the leafhopper population and on the number and character of host plants of the virus from which the disease could spread to commercial plantings. Although the information on these points is limited, it may be sufficient to justify a certain amount of speculation.

The leafhopper vector, *Agalliana ensigera,* has been reported (7) from localities well distributed over northern and central Argentina. The range of climatic conditions in this area does not differ greatly from that encountered over the whole of the United States except that in Argentina there is no region of cold winters and high rainfall comparable to our northeastern and middle western states. It might be expected on the basis of the distribution of the insect in Argentina that it could survive in most of the western and southern parts of the United States. Thus Argentine curly top might be expected to spread over most of the area where North American curly top does not now occur or is found rarely. However, injury from this disease would be greatly minimized because varieties of sugar beet resistant to North American curly top are now grown over much of this area where sugar beets are produced and there is reason to believe that all or most of these varieties are resistant also to Argentine curly top.

Yellow Wilt

In recent years several atempts have been made to establish a beet sugar industry in Argentina. The most important of these occurred in the lower part of the Rio Negro where a factory was built and began operation in 1929. This part of Argentina has a fertile soil, an abundant supply of water for irrigation, and a favorable climate for sugar beets. It was found that beets thrived in the early part of the season but later many plants either turned yellow and ceased to develop normally or wilted and died because of a disease now known as yellow wilt. In 1937-38 and in 1938-39 the disease reached

apeak of severity in the plantings of the Rio Negro Valley and was responsible for an almost complete loss of the crop. It caused serious injury also in small plantings in the valley of the Rio Colorado about 90 miles to the north. In 1941, sugar beet growing in the Rio Negro Valley was abandoned because of the inroads of this disease, and the factory was dismantled and sold. The disease, so far as known, has not yet spread to any other beet-growing areas.

Symptoms.—Two rather distinct phases of yellow wilt have been described *(8)* on sugar beets in the Rio Negro Valley of Argentina. One is characterized by yellowing and stunting and the other by rapid wilting and death.

The disease does not begin to appear extensively in the field until the plants are well advanced and have roots an inch or more in diameter. Usually the most obvious symptoms on plants attacked early in the season consist of yellowing and stunting. Leaves have irregular edges, are rolled upward and inward, and are thick and brittle. Some of the outer leaves die; others appear scorched along the edges and between the larger veins and stand more nearly vertical than those of normal plants. Sometimes the vein pattern is clearly evident because of continuous or broken yellow lines along the medium-size veins. Frequently there is a tendency toward stimulation of growth of axillary buds, giving the plant a bunchy appearance. Roots become tough and woody and sometimes the tip portion dies and lateral roots develop. Successive crops of rootlets are produced and die, resulting in a tufted condition along the lines of sutures where rootlets are produced. Plants may live throughout the season but they grow very little after becoming diseased.

Plants attacked later in the season when temperatures are higher and transpiration rates greater often wilt rapidly and die. Frequently large vigorous plants begin to wilt about midday and by late afternoon the leaves droop markedly. During the night plants recover partially but the following day they usually wilt so much that the outer leaves lie flat on the ground. Often within a week all of the older leaves are scorched and dead. In some plants the small central leaves recover somewhat following the death of the larger leaves and produce some additional growth but such leaves are small, thick, folded, and greenish yellow, sometimes slightly tinged with purple. Roots wilt from the tip upward, shrink, and decay. Plants in stages intermediate between yellowing and wilting occur in most fields.

Usually by mid-season diseased fields have high percentages of the plants yellow, wilted, or dead (figure 1).

Figure 1.—Field of sugar beets in the valley of the Rio Negro in Argentina, showing damage produced by yellow wilt. Many plants are yellow and dwarfed, others are dead, and still others are badly wilted. A few plants are still healthy. Photographed February, 1941.

Host Range and Varietal Susceptibility.—In the valJey of the Rio Negro yellow wilt, has been important chiefly as a disease of the sugar beet, but it is capable of causing severe injury also to red table beets *(Beta vulgaris)* and to Swiss chard *(beta vulgaris* var. *cicla* L.). The causal virus probably is indigenous to this part of Argentina. It probably occurs in desert species of plants which may serve as the chief sources of spread of the disease to sugar beets.

There is no evidence that any variety of sugar bet has an appreciable amount of resistance 1o yellow wilt. In the season of 1938-39, Carlos Munck (3) tested 20 European varieties and 2 varieties from the United States (U S. 12 and U. S. 33) for resistance to this disease. Large percentages of all varieties were killed and there was no evidence that any one variety was superior to others. The test was repeated in the season of 1939-40 with results similar to those obtained the previous season. Extensive selections were made from plants surviving these tests in an effort to increase resistance. The progeny from these selections showed no greater resistance, however, than that possessed by the varieties from which the selections were made.

Transmission.—Yellow wilt is not transmissible by inoculation with juice from diseased plants. It has been transmitted by graft and by two species of dodder, *(Cuscuta subinclusa* D. & H. and by C. *campestris* Yuncker. Tinder field conditions in Argentina it ap-

pears to be spread by a leafhopper, *Atanus exitiosus* Beamer, which was described *(1)* as a new species from specimens collected in the Rio Negro Valley in 1941. Very little is known regarding the life history, distribution, and host plants of this insect, but it is known to be able to live and reproduce on sugar beets.

Probable Results if Yellow Wilt Were Introduced.—Of all the foreign virus diseases of sugar beet, yellow wilt probably constitutes the greatest potential threat to the sugar beet industry. To determine accurately the area over which the disease would spread in the United States and the amount of damage it likely would cause, a greater amount of information is needed regarding the host-plant and climatic requirements of the insect vector or vectors and on the number and distribution of susceptible non-cultivated and crop plants that would serve as sources of virus for spread to beet fields. The evidence now available indicates that certain areas in western United States where sugar beets are grown extensively would be most severely affected. The Rio Negro Valley of Argentina where this disease now occurs is a region of light rainfall and relatively low winter temperatures. Since *Atanus exitiosus,* the probable insect vector, thrives there it seems reasonable to expect that it would do well also in parts of the United States having a similar climate. Tt seems certain that in any area where the disease could become as destructive as it has been in Argentina its introduction would result in abandonment of the industry, at least until varieties more resistant than those now known could be found or developed. The threat is more serious because no appreciable resistance to the disease has been found in any of the many sugar beet varieties tested. Production of resistant varieties might require a long and complicated program of selection and breeding. It seems possible, therefore, that introduction of yellow[7] wilt into the United States might prove to be a major catastrophe to the sugar beet industry.

Summary

Three foreign virus diseases, each capable of causing appreciable injury to sugar beets, are known. These are "sugar beet yellows" in Europe, "Argentine curly top" in Argentina, and "yellow wilt" in the Rio Negro Valley of Argentina.

Sugar beet yellows in recent years has caused considerable loss to sugar beets in the British Isles. Probably in the United States it would cause injury in all areas where beet plants survive the winter to serve as a source of infection for the spring crop. This would include all of the acres where beet seeds are produced.

Argentine curly top in most respects is similar to North American curly top. However, it is spread by a different leafhopper vector, it

apparently is unable to attack tobacco and tomatoes, and infected beet plants tend to recover to a greater degree than from North American curly top. Certain varieties resistant to North American curly top are resistant also to Argentine curly top and it seems probable that the varieties that have been produced to resist attacks of North American curly top would provide a high degree of protection against Argentine curly top.

Yellow wilt probably is potentially the most dangerous of these three virus diseases. In the Rio Negro Valley it was extremely destructive over a period of about 10 years and was responsible for abandonment of the sugar beet industry in that region. Rather extensive areas in western United States have climatic conditions similar to those in the Rio Negro Valley. In these areas the disease might become very destructive. The threat is made more serious by the fact that rather extensive tests in Argentina have revealed no varieties of sugar beet resistant to this disease.

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