Some Host and Vector Relationships of the Curly-Top Virus

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General Considerations)

The disease known as curly-top (Figure 1), as it occurs in North America is due to the virus *Ruga verrucosans* (Carsner and Bennett). It is known only in the western portion of the continental United States and is confined principally to the area west of the Rocky Mountains. There is only one known vector, *Circulifer tenelhis* (Baker). The virus has been occasionally transmitted experimentally from one plant to another in the greenhouse by dodder, *Cuscuta* sp., and rarely by means of puncture inoculations. It is, of course, readily transmitted by grafting **but** not by any of the usual contact or rubbing methods. The host plant range of the virus covers at least 25 families including such diverse economic crops as beets (Chenopodiaceae), tomatoes (Solanaceae), melons (Cucurbitaceae), beans (Leguminosae), flax (Linaceae), celery (Umbelliferae and buckwheat (Polygon aceae).

Figure 1. Sugar beet plants of SL 842 variety six weeks of age. Plants at left were inoculated with curly-top virus strain 3 when two weeks old. Pot at right has plant infected with virus strain 5 and healthy control.

Curly-top diseases have been reported from Argentina (1)[a] and from Brazil (2) but the vectors are different from that of North American curly-top and the host ranges are not the same. Oman reported (3) that a study of leafhoppers in two collections showed that *C. tenellus* existed in the Mediterranean area but in his book (4), a year later, he says, "The genus

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[2] Numbers in parentheses refer to literature cited.

Circulifer is primarily an Old World group centering around the Mediterranean region" and then, "In North America the single species *tenellus* (Baker) , commonly referred to as the genus Eutettix, is known to occur in Florida and certain of the West Indies, in addition to its wide range in western North America." There has been no report of plants infected with curly-top in the Mediterranean area.

Since infection, in nature, is completely dependent upon the presence of the vector the general distribution of the North American curly-top is limited to areas in which that insect normally occurs or into which it migrates. Annand and Davis report (5) good evidence of flights covering a distance of about 300 miles and Carter (6) suggests that they may easily be drawn into the upper air currents and thus carried for great distances. DeLong reported (7) *C. tenellus* from as far east as Florida but no plants infected by the curly-top virus have been reported in North America east of 91° W. Longitude and no proven cases of curly top east of 95° W.

Moisture (8) and low temperatures (5) have been reported as the most important factors limiting the natural habitat of the beet leafhopper. It is well known that these leafhoppers often migrate into the fog belt along the coast of California but they soon perish or move out. In areas where

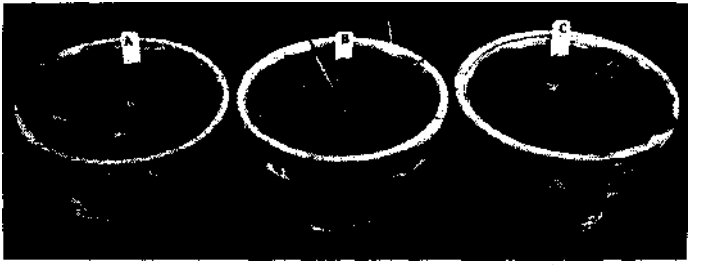

Figure 2. Plantain, *Plantago erecta* Morris, 33 days after inoculation with curly-top virus strains. Left, strain 1; middle, strain 2; right, strain 3.

the vector is normally present we have four major factors which determine the spread of the disease. These are abundance of the vector, favorable hosts for the vector, favorable hosts for the virus and prevalence of the virus. If these factors are favorable the relative prevalence of different strains of the virus is most important in determining the amount of injury which may result.

Hosts for the Vector

C. tenellus has many hosts but a very high portion of them are not favorable; that is, the leafhopper will not breed on them and will not feed on them long if better host plants are available. Tomatoes, beans and melons are often seriously injured by curly-top but these plants are not favorable hosts for the vector. The leafhoppers survive only on living host plants.

Hosts for the Virus

As indicated earlier, the curly-top virus has a vast number of hosts and the virus may be recovered quite readily from most of these plants. Australian

saltbush *(Atriplex semibaccata* Brown) is a fairly good host of *C. tenellus* but rarely, if ever, a host for the curly-top virus. Severin (9) reported experimental infection of this saltbush but I have never been able to recover curly-top virus from it either as it occurs in the field or after inoculation in the greenhouse. Several species of mustard *(Cruciferae)* are good hosts of the leafhopper and some are good hosts for the virus, while others are apparently immune. Tree tobacco *(Nicotiana glauca* Graham) is a perennial host normally showing no symptoms but in which some of the more virulent strains of curly top virus may live for several years. Russian thistle *(Salsola Kali* L. var. *tenufolia* Tausch.) is a good vrius host as well as an excellent host for the vector. Some California winter annuals such as *Plantago erecta* Morris, *Lepidium nitidum* Nutt. and *Erodiurn circutarium* L'Her. are good hosts for the vector and excellent hosts for the curly-top virus but greenhouse tests and field observations have shown (10) that, if infected while young, they may be rather unfavorable from the standpoint of actual quantity of virus produced and its dissemination. This is because the more virulent virus strains seriously dwarf and often kill such plants so that many leafhopper eggs fail to hatch and many virus sources are soon limited or destroyed (Figure 2). Young, susceptible sugar beet plants infected by the highly virulent strain of virus often react quite similarly but such plants receive water and cultural care which prolong their life and make them more serious as virus reservoirs.

Dead plants are not dangerous as curly-top virus sources because leafhoppers will no longer feed upon them.

Prevalence of the Virus

Assuming the presence of the virus in an area, its prevalence depends upon favorable virus hosts, favorable vector hosts and conditions which

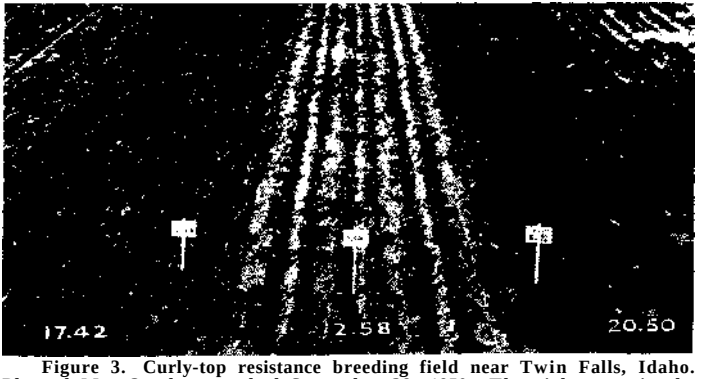

Figure 3. Curly-top resistance breeding field near Twin Falls, Idaho. Planted May 3, photographed September 28, 1950. The eight rows in the center are R & G Old Type, a European variety which has been widely used, and yielding 2.58 tons per acre in these plots. At left is SL 824, yielding 17.42 tons, and at right is SL 92, yielding 20.50 tons.

favor the movement and activity of the vector. Warm, dry weather, a rather open stand of host plants and disturbances such as those caused by cultivation favor spread of the virus locally. The harvesting, plowing up or destruction otherwise of a good host plant crop such as sugar beet may result in serious spread of the virus to crops in adjacent fields even though these crops are not good vector hosts. Various factors, including the extreme drying or death of winter and spring vector hosts, encourage dispersal over wider areas and migration for very long distances. No practical methods have been demonstrated for leafhopper control in the winter and spring breeding areas or in sugar beet fields except where they are being grown for seed by the overwintering-in-the-field method (11) so that we have little control over disease spread by means of dusting or spraying.

Both field (10) and greenhouse (12) studies have indicated that virus concentration is appreciably less in resistant sugar beets than in susceptible plants. Field collections of leafhoppers show that the virus load in vectors from resistant sugar beets is significantly lower than in those from susceptible sugar beet varieties growing in adjacent or nearby comparable fields. This is an important factor in the spread of the disease either in the fields concerned or to other crops in adjacent fields. The fact that there are significant differences is also strong evidence that the vectors are likely to move relatively short distances once they have settled on a favorable host and under favorable conditions.

Figure 4. Left, beet var. SL 842 30 days after inoculation with virus strain 1. Right, beet var. SL 68 30 days after inoculation with virus strain 1.

Age of plants at the time of invasion by virus-carrying vectors has also been found (13) to have a pronounced effect on the percent of infection and the amount of injury. The older plants are much more resistant to infection and to injury. They are quite likely to survive, recover to an appreciable extent and serve as both excellent reservoirs of the virus and hosts for the vector. Old, infected beets which are left in the field over winter are good sources of virus and encourage the rapid spread of curly-top.

Strains of the Curly-Top Virus

Various strains of the curly-top virus (14) (15) further complicate the already complex picture (Figures 1, 2, 4 and 5). A large number of plant species are susceptible to all known strains of the virus. Most varieties of sugar beets are susceptible to all strains but some of the most highly resistant ones are extremely resistant to one strain which is highly virulent on European sugar beet varieties and on many other hosts. The less virulent strains do not infect tomatoes, melons, Turkish tobacco or resistant bean varieties. In the spring it is quite usual to find that the less virulent virus strains are far more prevalent than the highly virulent strains. As mentioned earlier, the highly virulent strains cause extreme dwarfing and frequently death among the more favorable winter and spring host plants in California and it is felt that these strains are thus self-limiting to a great extent. The same species of host plants infected by the less virulent strains continue for a comparatively long time as good hosts for the vector and as reservoirs of the virus (Figure 2).

It has been found that infection by the less virulent strains of curly-top virus does not immunize the sugar beet against the more virulent strains (16) (18) so that the prevalence of the less virulent strains among the first plants infected does not in any way avert the rapid spread of the more virulent strains to them.

Great progress has been made in the development of sugar beet varieties which are resistant to infection and highly resistant to injury by this

Figure 5. Left, beet var. SL 842 six weeks after inoculation with virus strain 11. Right, beet var. SL 68 six weeks after inoculation with virus 11.

virus complex (Figure 3) (17) but other virus strains more virulent than any thus far encountered may be discovered or may arise as a result of mutations, so it is essential to be on the alert for such developments.

The possible danger from such newly discovered virus strains is strikingly evident when you compare Figures 4 and 5. Until late 1947 virus strain

1 (Figure 4) was the most virulent that we had recorded on beet variety SL 68, but the virus selection 11 (Figure 5) was recovered from leafhoppers and beet roots from commercial fields at that time. It is practically as virulent toward SL 68 as toward SL 842.

Discussion and Summary

The great number and variety of host plants for both virus and vector makes it quite probable that some good hosts exist in almost any agricultural region. In order to carry virus and vector throughout the year there need to be, within not too great distances, hosts which constitute a succession upon which they can maintain themselves.

The climatic limitations of the vector are extremely fortunate help in restricting the spread of the curly-top disease in North America. It might be quite serious if *C. tenellus* should develop mutations capable of thriving in the colder and more humid areas.

Infected, living plants might easily carry the virus to new locations but the virus, without the vector, would be eliminated at the death of the host plants in which it had been shipped.

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