Observation and Studies of Virus Yellows of Sugar Beet in California

C. W. BENNETT AND A. S. COSTA[1]

Virus yellows has been known for many years as a disease of sugar beet in Europe but it was not until 1951 that it was reported by Coons and Kotila (3)[2] to be present in the United States. In 1952 Coons (1) reported that the disease was present in all of the major sugar beet-producing states of the country.

Surveys in 1952 and again in 1953 indicate that virus yellows occurred in all of the areas in central California where sugar beets were grown, and the disease was found also near Oxnard and Riverside in the southern part of the state. It has not been found in the Imperial Valley or in the Hemet Valley where beets are grown as a seed crop.

In the Imperial Valley beets are planted in the fall and harvested the following spring. There is a period, roughly from July to September, during which few plants are available to serve as potential sources of infection for the fall planting. It is possible that even if the virus were introduced it would not persist through the summer in quantity sufficient to cause widespread infection in the commercial crop under present conditions of sugar beet culture employed in this area.

In the Hemet Valley the seed crop of beets is planted mainly in August and harvested the following June to July. But in this area many escaped beets grow throughout the year in waste places and often growth from stubble of the seed fields lives through the summer and could serve as a source of infection for the succeeding crop if the virus were present. In fact, many of the escaped and stubble plants are infected with beet mosaic and serve as sources for extensive mosaic spread to the fall plantings. The fact that virus yellows has not been found in this area probably indicates that it has not yet been introduced there.

Host Range and Symptoms

All varieties of sugar beet, table beet, and fodder beet which have been tested are susceptible to virus yellows. The disease occurs also on spinach and certain weed plants. In the Salinas Valley *Chenopodium album* (lambsquarters) in fields of sugar beet and spinach, has been found with a high percentage of the plants showing virus yellows. Occasionally, also, infected plants of *Chenopodium murale* (sowbane or nettleleaf goosefoot) occur in badly diseased beet fields.

Studies of the host range of the yellows virus under greenhouse conditions have indicated that the range of susceptible species is rather wide. All of the species of the genus *Beta* tested have shown signs of disease and some

[1] Principal Pathologist, Field Crops Research Branch, ARS, U. S. Dept. of Agriculture, Riverside, Calif., and Pathologist, Instituto Agronomico, Campinas, Brazil respectively.

[2] Numbers in parentheses refer to literature cited.

of them, notably *Beta macrocarpa*, appear to be even more susceptible to injury than sugar beet. The following plant species of the indicated families have been found susceptible to virus yellows under greenhouse conditions:

AMARANTHACEAE

Amaranthus albus
Amaranthus graecizans tumbleweed
Amaranthus palmeri
Amaranthus retroflexus pigweed
Celosia argentea coxcomb
Celosia sp.
Gomphrena globosa globe amaranth

AIZOACEAE

Tetragonia expansa New Zealand spinach

CARYOPHYLLACEAE

Stellaria media chickweed

CHENOPODIACEAE

Atriplex bracteosa
Atriplex canescens shad-scale
Atriplex elegans
Atriplex elegans var. *fasciculata*
Atriplex expansa fogweed
Atriplex patula var. *hastata* fat-hen
Atriplex hortensis
Atriplex rosea red-scale
Atriplex semibaccata Aust. saltbush
Beta lomatagona
Beta macrocarpa
Beta maritima
Beta patellaris
Beta patula
Beta procumbens
Beta trigyna
Beta vulgaris beet
Chenopodium album lambsquarters
Chenopodium amaranticolor
Chenopodium murale sowbane
Chenopodium leptophyllum
Chenopodium urbicum
Chenopodium watsonii
Cycloloma atriplicifolium
Monolepis nuttalliana
Salsola kali Russian thistle
Spinacia oleracea spinach
Suaeda fruticosa alkali blite

PLANTAGINACEAE

Plantago erecta

SOLANACEAE

Nicotiana clevelandii

Symptoms of virus yellows usually begin to appear in early May in fields of beets which are planted in December, January or February. First evidence of disease is usually a yellowing of older leaves in splotches, sectors or at the leaf tip. Yellowing may proceed on affected plants until all of the older leaves yellow, and become leathery and brittle. Lower leaves die prematurely. Usually, young leaves are normal and remain green until they approach maturity. However, at least one strain of yellows virus is known which is capable of producing distinct vein clearing in half-grown leaves under field conditions. This strain appears not to be widely distributed. Usually the plants recover from the yellowing to an appreciable degree by production of new leaves which show a lesser degree of yellowing. Fields that are very yellow in June may show much less evidence of the disease later in the season.

Symptoms of virus yellows differ appreciably in different species of plants under greenhouse conditions. On sugar beet they range from hardly perceptible yellowing on older leaves to severe yellowing and necrosis of older leaves and marked vein clearing of younger leaves. Plants of some species such as *Beta macrocarpa, Cyclolorna atriplicifolium,* and *Stellaria media* (chickweed), *Atriplex semibaccata* (Australian saltbush), and *Bassia hyssopifolia,* show no evidence of the disease although they may carry high concentrations of yellows virus. *Salsola kali* (Russian thistle) is dwarfed but otherwise shows no evidence of the disease. Infected plants of *Chenopodium amaranticolor* are dwarfed and show a distinct type of mottle which continues to be produced on new leaves as long as the plants grow vigorously. All strains of the virus appear to affect this species with about equal intensity.

Methods of Spread of Virus Yellows

Tests for Seed Transmission. Seeds of several varieties of diseased sugar beet plants were planted in the greenhouse and the seedlings were transferred to pots and watched for the appearance of symptoms of disease. None of more than 5,000 seedlings showed evidence of virus yellows. Also, several hundred seedlings from diseased plants of *Chenopodium amaranticolor, C. murale* (sowbane or nettle-leaf goosefoot) and *Tetragonia expansa* (New Zealand spinach), remained healthy under greenhouse conditions over extended periods. There is no evidence, therefore, that the type of virus yellows found in the United States is seed-transmitted and it may be assumed that new plantings of sugar beet are free of virus yellows until the disease is carried to them by aphids from other plants which have harbored the virus.

Transmission by Contact. Kassanis (4) reported transmission of virus yellows in England by rubbing juice from diseased plants over the surface of leaves of healthy plants. The first evidence of infection was small yellow or necrotic spots on the rubbed leaves. Often this was followed by production of typical symptoms on the noninoculated leaves and the plants became systemically infected. Extensive tests at Riverside, California, have given results similar to those obtained in England from inoculation of sugar beet plants with juice from diseased plants. However, infection has occurred in only a low percentage of the inoculated plants and it seems evident that sugar beet is very resistant to infection by inoculation with juice from diseased plants. This resistance is so great that it seems probable that transmission of the disease by contact or by any of the cultural operations employed in growing the crop is very rare, if it occurs at all.

Transmission by Aphids. The most important and probably the only agents of transmission of virus yellows are various species of aphids or plant lice. The disease has been transmitted experimentally by means of *Myzus persicae* (green peach aphid), *Aphis rumicis* (bean aphid), and *Macrosiphum solanifolit* (potato aphid). All of these aphids feed on sugar beet but the green peach aphid probably accounts for the greatest amount of spread of virus yellows. On beet, this aphid not only is usually more abundant but it appears also to be a more efficient agent of transmission than either of the other two species. Its relative ability to transmit virus

is indicated by results of tests in which green peach aphids and bean aphids were taken from the same diseased sugar beet leaf and caged singly on seedling sugar beets. In three tests, involving 40 aphids of each species in each test, the peach aphid infected 27, 27 and 19 plants, respectively, whereas the bean aphid infected only 2, 5 and 2 plants, respectively. Similar tests with the potato aphid indicate that it also is less efficient than the peach aphid as a vector of the yellows virus.

The green peach aphid is a highly efficient agent of transmission of the disease. It can pick up virus by feeding 5 to 10 minutes on infected plants and it can acquire a maximum charge of virus in feeding periods of from 6 to 12 hours. After virus is acquired this aphid can transmit it to healthy plants in a feeding period of 5 to 10 minutes. Aphids retain virus for periods of at least 24 to 48 hours after feeding on diseased plants. Thus, aphids not only pick up virus by feeding only a short time, but they also retain the virus long enough to enable winged forms to carry it considerable distances.

In California sugar beets remain alive and grow throughout the year. In nearly all sections where sugar beets are produced commercially, infected plants are available from which virus yellows may spread to new plantings. In all probability beets are the chief source of virus spread. Although a number of weed plants are known to be susceptible to infection, none of these is believed to be an important source of virus. In all instances in which weeds have been found infected extensively, evidence indicates that spread was from sugar beet or spinach to the weed host rather than in the reverse direction.

Beets which serve as sources of infection are of various kinds. The chief sources in California appear to be the following:

1. Some roots always are left in the field at harvest time. Many of these may sprout later and serve as sources of yellows spread. If the beet crop is followed by a noncultivated crop such as alfalfa these beet plants may serve as virus sources for several months.

2. In some areas beets are not harvested in the fall, particularly in wet seasons, but are carried through the winter and harvested the following spring. Such fields can be sources of widespread infestation of new winter and spring plantings in adjacent areas.

3. Fields of beets planted in December and January usually produce a certain number of bolters which mature seeds before harvest. Seeds from these plants fall to the ground and soon germinate if sufficient soil moisture is available. Numerous seedlings of this type, many infected with virus yellows, have been found in early December in cover crops which were planted after the beets were harvested.

4. Beets escape from cultivation and grow along ditch banks, fences, and other uncultivated places. Many of these become infected with virus yellows and may provide a plentiful supply of virus for infection of neighboring beet fields.

5. Wild perennial beets are prevalent in certain areas of central California. Many of these are infected and no doubt they are important sources of spread locally.

In certain parts of central California these sources of infection are so abundant that yellows spreads to entire fields when the plants are young and the fields, as a result, develop a uniform yellowing beginning in May or early June.

Control Measures

One of the most obvious control measures for virus yellows is elimination of sources of infection for new plantings. In those areas where sugar beets and closely related plants ordinarily donot live in the field through the period between harvest of one crop and planting of the next, elimination of sources of infection usually does not present a serious problem. In those areas in which beets grow throughout the year control by this method is more difficult and in many areas it is impractical under present methods of sugar beet production.

Sprays which drastically reduce aphid populations may reduce or delay infection but no evidence is available Avhich indicates that spraying for control of virus yellows is likely to be a profitable practice under most field conditions.

There is evidence of a range of resistance to virus yellows among varieties of sugar beet (2) . However, the range of resistance among commercial varieties does not appear to be a very wide one and, at the present time, this difference is not great enough to justify the planting of any particular variety on the basis of its resistance to virus yellows alone. Whether the success obtained in the breeding of sugar beet for resistance to curly top can be repeated for virus yellows, and varieties developed which will be highly resistant to this latter disease, remains to be determined. The fact, however, that there are some differences in resistance among sugar beet varieties lends support to the hope that plant breeders may eventually develop varieties with at least somewhat greater resistance than that possessed by varieties now available.

Summary

Virus yellows has been reported from nearly all of the principal sugar beet producing areas of the United States. During 1952 and 1953 it was found in all of the areas of California in which sugar beet is grown, except the Imperial and Hemet Valleys.

The disease attacks sugar beet, table beet, fodder beet and their close relatives. It also affects spinach and a number of noncultivated plants.

Virus yellows is spread by the green peach aphid *(Myzits persicae)*, the bean aphid *(Aphis rumicis)*, the potato aphid *(Macrosiphum solanifolii)*, and possibly other aphid species. The green peach aphid is believed to be by far the most important agent of spread because of its wide host range, prevalence, habits of feeding and migration, and its efficiency as a vector of the causal virus. There is no evidence that the disease is seed transmitted. It is difficult to transmit by juice inoculation and there is no reason to suspect that it is spread by contact in ordinary cultural operations.

Chief sources of field infection in California are: 1. Beets which are missed in harvesting and left to grow in the field. 2. Beets which are carried through the winter and harvested the following spring. 3. Seedlings from seeds which fall from bolters. 4. Escaped beets in non-cultivated and cultivated areas. 5. Wild beets.

No completely satisfactory control measures are available for areas where the disease is most prevalent. There is some hope, however, that it may be possible to increase the resistance of commercial varieties, to some degree at least, by selection and breeding.

Literature Cited

(1) COONS, G. H.
1952. Virus yellows of beet in the United States. Plant Dis. Reporter 36:356-363.

(2) COONS, G. H.
1953. Resistance of sugar beets to virus yellows. (Abst.) Phytopath. 43:405.

(3) COONS, G. H., and KOTILA, J. E.
1951. Virus yellows of sugar beet and tests for its occurrence in the United States. (Abst.) Phytopath. 41:559.

(4) KASSANIS, B.
1949. The transmission of sugar-beet yellows virus by mechanical inoculation. Ann. Appl. Biol. 36:270-272.