Cucumber Mosaic in Seed Fields of Sugar Beet in the Salt River Valley of Arizona

C. W. Bennett, Harold K. Jewell, and Orin A. Hills[1]

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Introduction

It has been known for a number of years that sugar beet is a potential host of the cucumber mosaic virus and that the virus may produce severe damage to infected plants. Cucumber mosaic, however, is not found often in sugar beet fields and when it occurs the incidence of infection usually is very low. On rare occasions, in certain locations, high percentages of infection have been found in individual fields. The disease destroyed some fields and badly damaged others in the vicinity of Firebaugh and Mendota in California in 1940 as reported by Severin and Freitag (14)[2] and was present in a number of fields in the same area in 1941.

Strains of the cucumber mosaic virus capable of infecting sugar beet probably are widely distributed. Infected plants have been found in beet fields in most beet-producing areas in California and the disease has been reported from Oregon, Utah, and Kansas. Recently, Roland (12) reported a small amount of infection in one beet planting in Belgium.

In October 1956, Arnold A. Mast of the Western Seed Production Corporation of Phoenix, Arizona, called attention to an extensive infection with cucumber mosaic virus in a field being grown for seeds in the Salt River Valley. This appears to be the first year in which this disease had been found on sugar beets in that area. The disease was not observed in the 1955-56 crop. Since the fields of the 1955-56 crop were watched rather closely in connection with studies of virus yellows, it seems probable that if the disease was present the incidence of infection was very low.

The almost complete absence of cucumber mosaic in sugar beets under most conditions indicates that sporadic outbreaks of the disease in sugar beet is associated with a combination of factors and conditions that do not often occur. Efforts were made, therefore, to obtain information regarding the factors involved in the spread of cucumber mosaic in the seed fields in the Salt River Valley in 1956 and 1957 and to obtain further information on the type of virus involved and the damage produced.

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[1] Pathologist, Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture; Research Supervisor, Western Seed Production Corporation, Phoenix, Arizona; and Entomologist, Entomology Research Division, Agricultural Research Service, U. S. Department of Agriculture, respectively.

[2] Numbers in parentheses refer to literature cited.

Occurrence of the Disease

A survey of seed fields in the Salt River Valley in November 1956, revealed the fact that cucumber mosaic was present in 6 of 34 fields. Incidence of infection at this time ranged from 0.4 to 7.3 percent.

In the field that showed the greatest amount of infection, probably 20 percent of the plants on one side of the planting were diseased. On October 19, many of the infected plants were in early stages of disease development. Symptoms consisted of large chlorotic spots on many of the fully mature leaves and mottling and distortion of the younger leaves. Typical symptoms produced by the disease are shown in Figure 1, A, B and C.

During the inspection of the field, it was noted that large numbers of winged aphids were in flight and that as many as 10 aphids per minute were lighting on the shirts of the observers. It was found that these aphids were migrating from a field of grain sorghum adjacent to the beet field. Further inspection showed that the grain sorghum was heavily infested with a brown aphid, later determined to be the rusty plum aphid, *Hysteroneura setariae* (Thomas). Also present were relatively small numbers of the corn leaf aphid. *Rhopalosiphum maidis* (Fitch).

No evidence of mosaic mottling was found on plants of grain sorghum but a weed, identified as *Physalis wrightii* Gray, prevalent in the sorghum field and in adjacent areas, showed distinct mottling.

In a survey of seed-producing areas, there appeared to be an association between cucumber mosaic in beet and proximity of beet fields to grain sorghum plantings; at least, little or no mosaic was found in beet fields far removed from grain sorghum. Some beet fields growing close to sorghum plantings, showed very little infection. In general, such sorghum fields were relatively free of weeds. It appeared from these results that an association of grain sorghum and weed hosts of the virus in the immediate vicinity of the beet field, contributed to the production of a higher percentage of infection in beets.

Experimental Tests

Since there appeared to be a definite association between the occurrence of cucumber mosaic in beets and the growing of grain sorghum in the vicinity of beet fields, attempts were made to determine the plant source of the cucumber mosaic virus and the vector or vectors chiefly responsible for spread.

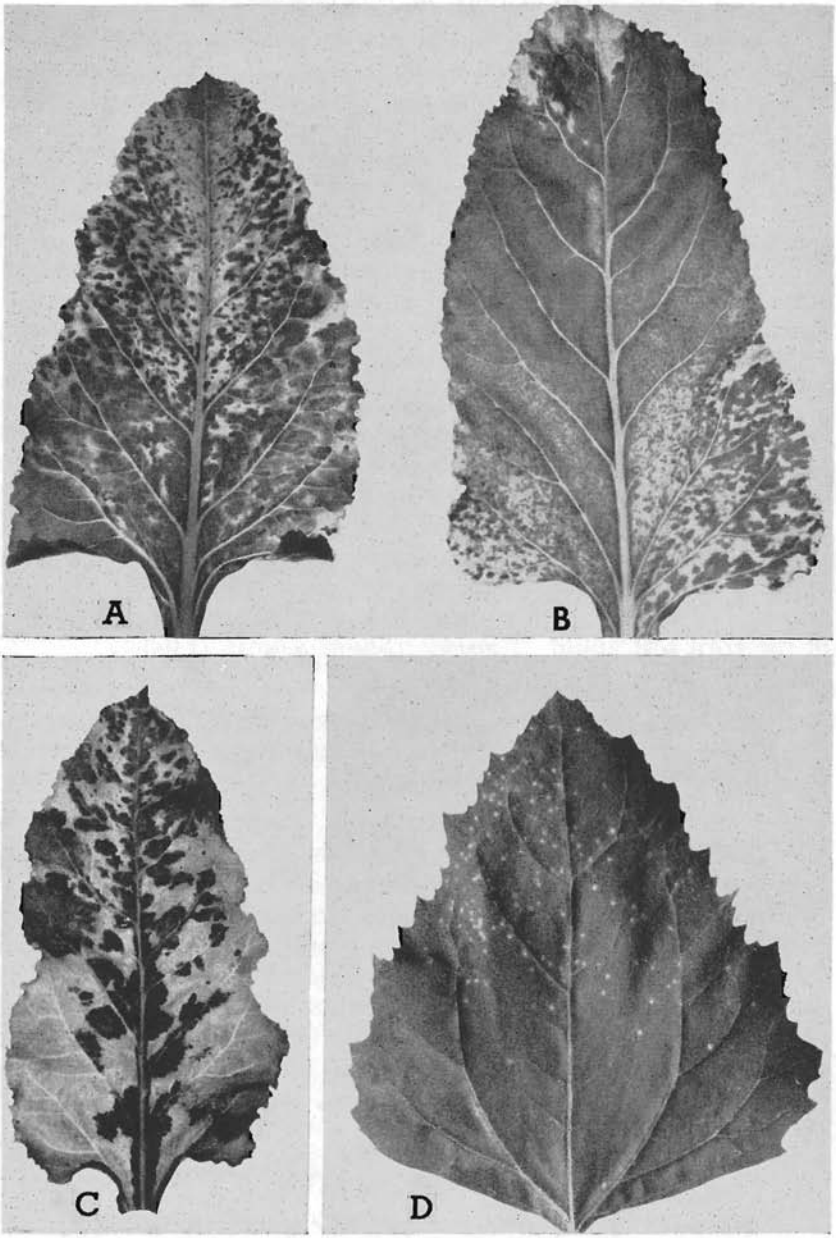

Figure 1.—Sugar beet leaves (A, B, and C) showing range of expression of symptoms of cucumber mosaic, and leaf of *Chenopodium amaranticolor* (D) showing local lesions produced following inoculation with juice from diseased beet plant. All leaves about natural size.

Test of Plants as Virus Sources

Plants of *Physalis wrightii* from the grain sorghum fields and from adjacent beet fields were collected and tested for presence of cucumber mosaic virus by making mechanical inoculation from these plants to sugar beet, Turkish tobacco, cucumber, and *Chenopodium amaranticolor* Coste & Reyn. Infection was readily obtained on all of these plants and symptoms were typical of those caused by cucumber mosaic virus. Large local chlorotic lesions were produced on inoculated leaves of sugar beet but systemic infection very rarely followed. Typical mottling and leaf distortion occurred on leaves of inoculated plants of tobacco and cucumber.

Inoculations of leaves of plants of *C. amaranticolor* was followed by the production of numerous local lesions, about 1 mm. in diameter, 3 days after inoculation. Lesions remained small and the virus apparently did not become systemic. Typical lesions on a leaf of *C. amaranticolor* are shown in Figure 1, D. These are similar to lesions produced by cucumber mosaic virus from other sources. This species appears to show promise for use as a local lesion test plant and may prove of value in work with cucumber mosaic virus.

Plants of *Physalis wrightii* were grown from seeds in the greenhouse and when they were about 10 cm. tall they were inoculated with virus recovered from naturally infected plants of *P. wrightii* and sugar beet. The plants proved to be susceptible to infection with virus from both sources and infection was obtained both by mechanical inoculation and use of the green peach aphid, *Myzus persicae* (Sulz.) Symptoms produced by virus from the two sources were indistinguishable. It is evident from these results that *Physalis wrightii* is a host of the cucumber mosaic virus and a potential reservoir of virus for infection of other plants, including sugar beet.

To determine whether grain sorghum may serve as a source of cucumber mosaic virus, seeds were collected from a field adjacent to one of the infested beet fields and planted in a greenhouse at Salinas, California. When the seedlings were about four cm. tall they were inoculated by allowing large numbers of green peach aphids to move onto them from infected sugar beet plants. Of 20 plants inoculated, none showed evidence of infection. These plants, and 20 others, were inoculated three times by mechanical means using juice from sugar beet and Turkish tobacco. No evidence of infection was obtained. Juice from these inoculated plants failed to produce local lesions on *C. amaranticolor*. It is assumed, therefore, that the type of grain

sorghum tested is extremely resistant or immune to infection with cucumber mosaic virus and that it was not a source of virus for other plants in the Salt River Valley.

Tests of Aphids

The aphid found to be most abundant at the time of spread of the cucumber mosaic virus in sugar beet was the rusty plum aphid shown by Ingram and Summers (8) to be a vector of sugarcane mosaic virus. Tests were made to determine whether this aphid is able to transmit the cucumber mosaic virus.

Aphids were transferred from colonies on plants of grain sorghum to beet plants with cucumber mosaic and allowed to feed for short periods after which they were transferred to seedling sugar beet plants. The results of these tests, presented in Table 1, show that the rusty plum aphid is able to transmit the cucumber mosaic virus. The insect feeds poorly on sugar beet and lives only one to three days when confined to this plant; however, the percentage of inoculated plants infected indicates that it may be an efficient vector.

Tests were made also with the corn leaf aphid, which occurred on grain sorghum in relatively small numbers in association with the rusty plum aphid. This aphid was shown to be a vector of cucmber mosaic virus by Dickson et al. (1) and the results shown in Table 1 indicate that it is a vector of the strain of virus isolated from sugar beet in the Salt River Valley.

Spread of the Disease

Several species of aphids, in addition to *Hysteroneura setariae* and *Rhopalosiphum maidis*, are known to transmit cucumber mosaic virus and may at times be involved in the spread of the virus to sugar beet. The following species have been listed as vectors:

Aphis fabae Scop., as *Aphis rumicis* L. (14)
Aphis gossypii Glov. (2, 9)
Macrosiphum pisi (Kelt.) (1)
Macrosiphum solanifolii (Ashm.) (6)
Myzus ascalonicus Doncaster (13)
Myzus circumflexus (Buck.) (7)
Myzus persicae (Sulz.) (5)
Myzus solani (Kltb.), as *Myzus pseudosolani* Theob. (7)
Rhopalosiphum maidis (Fitch), as *Aphis maidis* Fitch (1)

All of these species occur in western United States and may feed to some extent on sugar beet. *Myzus persicae* and *Aphis fabae* breed on sugar beet and are the two species most commonly

Table 1.—Transmission of Cucumber Mosaic Virus to Sugar Beet by Means of Aphids.

Species of Aphid Tested[1]	Plants Inoculated	Plants Infected	
	Number	Number	Percent
Aphis fabae	40	2	5.0
Hysteroneura setariae	20	14	70.0
Myzus persicae	48	9	18.7
Rhopalosiphum maidis	20	3	15.0

[1] Ten aphids or more were transferred from infected sugar beet plants to healthy sugar beet seedlings after short feeding periods on the diseased plants.

found on this plant. Both of these insects were tested to a limited extent in the transmission of the cucumber mosaic virus from Arizona. Each proved to be a vector, as shown in Table 1, but neither species was very effective in the transmission of the virus from beet to beet under the conditions of the tests.

Severin and Freitag (14) state that the bean aphid, *Aphis fabae,* rarely transmits cucumber mosaic virus. They attribute the 1940 outbreak of cucumber mosaic in the Firebaugh and Mendota area of California to large populations of green peach aphids, *Myzus persicae,* that developed on the neighboring foothills and plains and moved into the beet fields. Probably any vector that occurs in enormous number is potentially capable of transmitting considerable virus to beets where adequate virus sources are available. The vector, therefore, chiefly responsible for spread of cucumber mosaic virus to sugar beet may vary depending on conditions.

Most of the fall infection in the beet fields in Arizona in 1956 apparently took place over a relatively short period, probably from the middle of September through October, and probably resulted chiefly from the movement of the rusty plum aphid.

All seed fields in the Salt River Valley were inspected at regular intervals from November 1956 to June 1957, inclusive, and counts were made to determine the percentage of plants infected with cucumber mosaic and yellows. Before harvest time, cucumber mosaic was found in 14 of 34 fields. Average percentages of plants showing infection with cucumber mosaic and yellows on the dates indicated are shown in Figure 2. These results show that there was little increase in percentage of plants showing infection from November 1956 to June 1957, whereas there was a very rapid increase in yellows through April and May of 1957. The last counts June 1-15, 1957, showed 8.9 percent infection

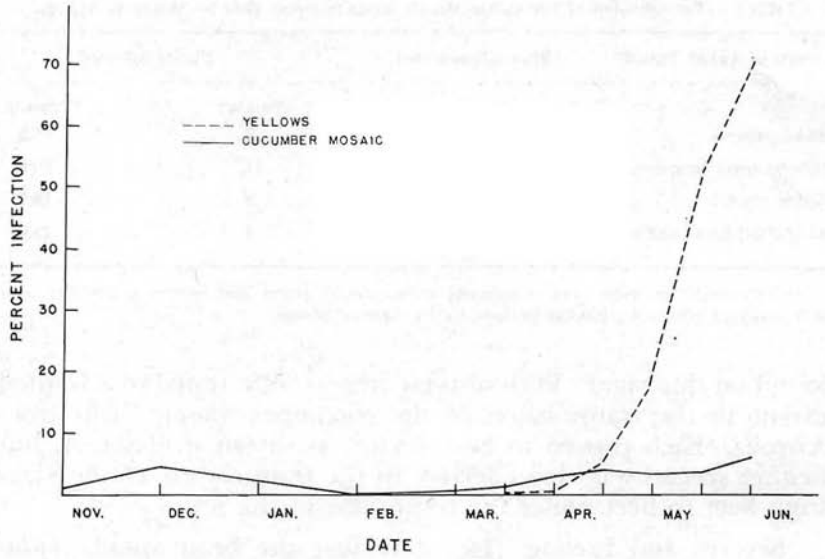

Figure 2.—Graph showing relative spread of cucumber mosaic and yellows in 14 seed fields of sugar beet in the Salt River Valley of Arizona in 1956-57.

with cucumber mosaic and 77.2 percent infection with yellows. The low counts of plants with cucumber mosaic in February are probably due to partial masking of symptoms and possibly to death of some of the affected plants.

The green peach aphid was the only aphid found in appreciable numbers in these fields in 1957, and it seems probable that virus spread that occurred during this time was the result of transmission by this insect. Therefore, since cucumber mosaic virus and yellows virus were spread by the same insect, evidence indicates that the ability of the green peach aphid to spread cucumber mosaic virus from beet to beet is far below its ability to spread yellows virus.

Tests of Seeds for Virus Transmission

Doolittle and Gilbert (3, 4) presented evidence that cucumber mosaic virus is transmitted occasionally through seeds of cucumber and through a low percentage of seeds of wild cucumber, *Echinocystis lobata* (Michx.) T. & G. Kendrick (11) showed that a form of the virus is transmissible through seeds of muskmelon. Tests were made, therefore, to determine whether the cucumber mosaic virus is transmissible through sugar beet seeds.

Seeds from mosaic infected field plants were harvested and planted in flats in the greenhouse and seedlings were observed

for the appearance of symptoms of mosaic. Five thousand one hundred and thirty-three seed balls were planted, from which 7634 seedlings were obtained. The seedlings were examined carefully when in about the 4-leaf stage and 51 seedlings that appeared to be slightly abnormal were transplanted and observed for an additional period of 2 months. All of the seedlings remained free of symptoms of cucumber mosaic. It seems unlikely, therefore, that cucumber mosaic virus is transmissible through beet seed.

Damage Produced by Cucumber Mosaic

There is a considerable range of susceptibility to injury by cucumber mosaic within varieties of sugar beet. A selection (SL. 54484+0) obtained from F. W. Owen and tested for susceptibility in the greenhouse in 1957, appears to have a high degree of resistance to systemic infection. Plants in about the 12-leaf stage were inoculated with cucumber mosaic virus by mechanical methods. Numerous chlorotic lesions appeared on the inoculated leaves. When the lesions were about four mm. in diameter large numbers of green peach aphids were placed on the plants and allowed to remain seven days after which they were destroyed by fumigation. Of 120 plants inoculated in this manner and held for seed production, none showed symptoms of systemic infection.

In the fields near Firebaugh and Mendota in California, in 1940, there was a wide range of severity on different plants apparently infected at about the same time. Some plants had leaves that were severely mottled and deformed and the plants were markedly dwarfed, whereas other plants had leaves that were mottled but not deformed and the plants showed very little dwarfing.

In fields in the Salt River Valley in 1956 there was a similar range of effects. Some plants were much more severely dwarfed than others.

In May 1957, plants in one field that showed a low percentage of cucumber mosaic and also a low percentage of infection with yellows and very little curly top, were selected, and diseased and healthy plants were staked. An attempt was made to pair diseased and healthy plants of about the same size and stage of development. Fifty pairs of plants were selected. The plants were harvested and the yield and germination of seeds of each plant were determined. Yields were combined at random so that there were five replicates each representing 8 to 10 plants. The results of this test are shown in Table 2.

Table 2.—Effect of Cucumber Mosaic on Production of Seeds by Beet Plants Selected in the Field.

Type of Plant[1]	Average Weight of Seeds per Plant			Average Weight of 100 Large Seeds	Average Germination of Large Seeds
	Large	Small	Total		
	Grams	Grams	Grams	Grams	Percent
Diseased	7.8	2.1	9.9	1.521	87.9
Mosaic-free	17.2	2.5	19.7	1.859	82.1
L.S.D. at 5%	2.79	2.79	1.76	.213	10.0
L.S.D. at 1%	3.91	3.91	2.47	.353	16.5

[1] Eight to 10 plants were included in each of 5 replications of diseased and mosaic-free plants.

The disease caused an average reduction of 49.8 percent in seed yield. The seeds from diseased plants were smaller than those from healthy plants but germination appeared not to be reduced. These results show conclusively that cucumber mosaic is capable of producing severe reductions in seed yield of infected plants. Since the plants selected in this test were among those least damaged by the disease it is evident that heavy losses could be produced if the disease spread to a high percentage of plants. The damage to the 1957 crop in the Salt River Valley, however, was low due to low incidence of infection and to the fact that stands of plants in the rows were higher than required for maximum yield and diseased plants, in many cases, were overshadowed by adjacent healthy plants.

Discussion and Conclusions

The characteristics of the disease on sugar beet in fields in the Salt River Valley and on plants to which the causal virus was transmitted in the greenhouse, are those commonly associated with so-called western cucumber mosaic. It is by no means certain, however, that a single strain of cucumber mosaic virus was involved. Very little is known with respect to the susceptibility of sugar beet to different strains of this virus.

The relatively rare occurrence of cucumber mosaic in sugar beet fields suggests that more factors are involved than are required for spread of yellows or beet mosaic. Extensive spread has been observed only where enormous populations of vectors moved into beet fields from adjoining areas where plants with cucumber mosaic were present to serve as virus sources. Little is known regarding the relative effectiveness of different vectors. Apparently the green peach aphid is capable of producing wide-

spread infection under favorable conditions (14). The rusty plum aphid appeared to be the most important vector involved in spread of the disease to beet in Arizona in 1956. Probably other species, if enormous populations were produced, would be effective in spreading the disease if virus sources were readily available. The usual populations of aphids found in and around beet fields, however, appear unable to produce appreciable infection in beets.

It seems probable from results of observations made in Arizona and in fields in California, that extensive spread of cucumber mosaic virus from beet to beet is unlikely to occur after the virus has been introduced into the beet field from outside sources. The reasons for this appear to be associated largely with the relationships of the virus to the beet plant, coupled with the fact that the virus is nonpersistent in its vectors.

Mechanical inoculation of sugar beet plants with juice from infected plants frequently results in large numbers of local chlorotic lesions on inoculated leaves but these lesions usually do not result in systemic infection. It is evident, therefore, that cucumber mosaic virus is able to invade parenchyma tissue extensively without entering the phloem through which it could pass to the growing point and produce systemic infection. Since the virus is nonpersistent in the vector and is soon lost by feeding, it seems probable that most of the virus carried by vectors is deposited in cells through which the stylets pass before reaching the vascular elements. Aphid feeding, therefore, would usually result only in localized infection. Under such conditions the efficiency of the vector in the production of systemic infection might be very low. This low efficiency probably accounts for the fact that cucumber mosaic in sugar beets has been associated invariably with enormous populations of aphids.

It seems probable that a high percentage of the infection with cucumber mosaic virus in sugar beets comes from sources outside the beet field. Keener (10) has suggested that sugar beets in turn may serve as sources of infection for other crops. This may be true under rare conditions, but in view of the evidence of lack of appreciable spread of the virus in sugar beets and the relatively rare occurrence of the disease in this crop, it would seem that the probability that cucumber mosaic virus, harbored by sugar beets, would often be a danger to other crops, is rather remote.

Where measures are needed for control of cucumber mosaic in sugar beet, use of cultural practices that tend to prevent the movement of large populations of vectors into beet fields from

outside virus sources, would seem to offer greatest promise. The type of outbreak that occurred in the 1956-57 crop in the Salt River Valley probably could be prevented either by planting sugar beet fields at a distance from grain sorghum or by keeping the grain sorghum fields free of weeds that harbor the cucumber mosaic virus.

Summary

Cucumber mosaic was found in 14 of 34 seed fields of sugar beet in the Salt River Valley of Arizona in the fall of 1956 and the spring of 1957. Infection in November ranged from a trace to 7.3 percent.

Infection appeared to be associated with the production of enormous numbers of winged individuals of the rusty plum aphid, *Hysteroneura setariae*, produced on grain sorghum. The aphids acquired cucumber mosaic virus from infected weeds, principally *Physalis wrightii*, growing in and around fields of grain sorghum. Spread of the virus in beets in the spring of 1957 was low despite the fact that large numbers of green peach aphids were present in some of the fields. Spread of yellows was rapid in all fields during April and May. Differential spread of the two viruses under similar conditions by the same vector probably is due to differences in the relationships of the two viruses to the vector and to the host. No evidence was obtained that the cucumber mosaic virus is seed-transmitted.

Damage to individual plants was severe. Reduction in yield of seeds of affected plants selected at blossoming time averaged 49.8 percent. Seeds were reduced in weight but germination was not affected. Total reduction in seed yield, however, even in fields most severely affected, probably was small due in part to the fact that the system of seed production used in the area provides many more plants than are required for maximum seed production.

Since there appears to be relatively little spread of virus from beet to beet after it is introduced into the field, cucumber mosaic probably could be controlled by adopting measures to avoid movement of large populations of winged vectors into beet fields from infected weed and crop plants.

Acknowledgment

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