Crop losses caused by whitefly-transmitted agents could change the agriculture of the desert.

Jack Kelly Clark

Bemisia tabaci

Whitefly-transmitted disease complex of the Desert Southwest

James E. Duffus ☐ Robert A. Flock

Extremely large whitefly populations occurred during the summer and fall of 1981, inducing a series of viruslike disease epidemics on many important crops in California and Arizona desert production areas. Populations, mainly of sweetpotato whitefly, *Bemisia tabaci* (Genn.), exploded, attracting the attention of the national news media and causing losses amounting to a reported $100 million to growers and consumers.

Cotton yields were down significantly during the 1981 growing season and were also adversely affected by reduced grade due to sticky honeydew accumulations on the bolls. Damage worth $8 million to cantaloupe, watermelon, and other melons and squash in the late summer and fall of 1981 resulted in approval of a disaster loan program by the Farmers Home Administration. Lettuce plantings were virtually 100 percent affected with severe yellowing symptoms; yield losses estimated at 50 to 75 percent, when combined with a lower acreage planted, resulted in very low production and extremely high prices. Losses of sugarbeets, infected early in their growth cycle, were estimated at 20 to 30 percent.

The sweetpotato whitefly has occurred in California since the late 1920s but had never before attained such high populations and widespread distribution in the Southwest.

Disease agents transmitted by whiteflies are encountered mostly in tropical areas but occur also under subtropical and even temperate conditions, depending mainly on the species that serves as their vectors. *Bemisia tabaci* is the most important of the whitefly vector species and, although not as important as aphids on a worldwide basis, is responsible for the natural spread of economically important diseases in a band around the world between the 30° parallels south and north of the equator.

Some 30 or more diseases have been reported to be induced by the feeding of infectious whiteflies, including cotton leaf curl in Sudan and Nigeria, tobacco leaf curl in Java, India, and Africa, cassava mosaic in Africa, and legume diseases in the Western Hemisphere. It is probable that in many cases the diseases are caused by the same entity or by variants adapted to specific host plants.

Disease agents transmitted by whiteflies induce three major types of disease. One group induces color deviations of the variegation type on affected leaves. Another causes leaf-curl-type symptoms; mosaic symptoms are not evident, but infected plants show crinkling, vein etching, and leaf enations, or growths. The third group includes typical yellowing-type diseases, characterized by stunting of infected plants and accompanied by rolling, yellowing, reddening, vein-clearing, and brittleness of affected leaves.

Lettuce infectious yellows on greenhouse 'Bibb' lettuce, spread by the whitefly, can be confused with aphid-transmitted viruses.

An early objective in studying the whitefly-transmitted disease complex in the desert was to determine how many agents were responsible for the crop losses, how the agents were transmitted, and what were the common crop and weed hosts of the pathogens. With this information, the individual disease systems could be more systematically studied and control attempted through vector, host, or pathogen management.

Insect transmission studies conducted in our Salinas laboratory at the U.S. Agricultural Research Station indicate that the whitefly disease complex in the desert agricultural area is caused by at least three major agents. It should be noted, however, that field isolations from wild and cultivated plants have thus far concentrated on relatively few hosts, and still other whitefly-transmitted diseases may well play a role in the disease syndrome of desert plants. Each of the three major groups of whitefly-transmitted diseases is represented. The first, cotton leaf crumple, first observed in 1948 by Dickson and Laird in the Coachella and Imperial valleys, is of the leaf curl type. Leaves

Beds of 'Salinas' lettuce in a field of 'El Toro' are virtually 100 percent infected with lettuce infectious yellows virus. The disease severely reduced commercial lettuce yields in desert areas during the 1981-82 growing season.

Cotton leaf crumple was widespread in desert field cotton in 1981 and affected nearly all of the crop.

Squash leaf curl is characteristic of mosaic-type diseases. It severely damages squash, pumpkin, watermelon, and beans.

of infected cotton plants are puckered and appear warty on the upper leaf surface. Flower petals show similar puckering, especially on the margins. Young greenhouse and field-grown plants may be markedly stunted. The disease was widespread in desert cotton in 1981 and affected nearly all of the crop. A crumple disease of bean, with distortion of the pods, has been observed in greenhouse plants. Effects of the virus on cotton and bean yield reductions have not been determined.

The second disease, widespread in desert production areas, is squash leaf curl. This disease was first reported in 1981 by Flock and Mayhew but was recognized as early as 1977. Although termed "leaf curl," the disease is more characteristic of the infectious variegation or mosaic type of syndrome. Margins of infected squash leaves are curled and the veins thickened and distorted. Interveinal tissue becomes chlorotic or mottled with pronounced vein banding. The disease causes severe damage on squash, pumpkin, watermelon, and beans.

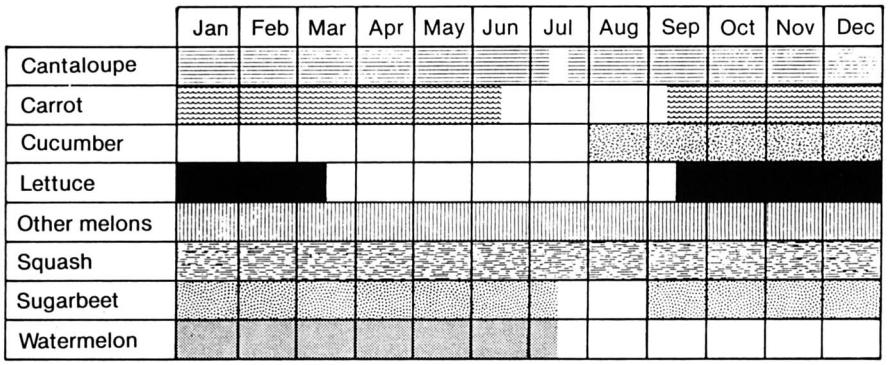
The third distinct disease is induced by the newly described lettuce infectious yellows virus. Interveinal yellowing or reddening and stunting of affected plants is characteristic of this virus on a wide range of commercial and weed hosts. Symptoms on most hosts are almost identical to those caused by aphid-transmitted viruses of the yellows complex and could readily be confused with them. This disease severely reduced lettuce yields (50 to 75 percent) in desert areas during the 1981-82 growing season and was responsible for large losses in sugarbeet production in the same areas.

Analysis of our early host-range laboratory data on some of the important crop, weed, and ornamental plants grown in the

Host range of the major whitefly-transmitted diseases of the southwestern desert

Hosts	Lettuce infectious yellows	Cotton leaf crumple	Squash leaf curl	Hosts	Lettuce infectious yellows	Cotton leaf crumple	Squash leaf curl
Crops				**Weeds and ornamentals**			
Alfalfa	–	–	–	*Anoda*	+*	–	–
Bean	–	+*	+*	*Beta* (wild beet)	+*	–	–
Cantaloupe	+*	–	–	*Capsella* (shepherd's purse)	+*	–	–
Carrot	+*	–	–	*Chenopodium* (goosefoot)	+*	–	–
Cotton	–	+	–	*Convolvolus* (morning-glory)	+*	–	–
Cucumber	+*	–	–	*Dichondra*	+*	–	–
Lettuce	+*	–	–	*Malva* (cheeseweed)	+*	+*	–
Melon	+*	–	–	*Physalis* (ground cherry)	+*	–	–
Okra	–	–	–	*Rumex* (dock)	+*	–	–
Safflower	+*	–	–	*Sonchus* (sowthistle)	+*	–	–
Squash	+*	–	+	*Tagetes* (marigold)	+*	–	–
Sugarbeet	+*	–	–	*Taraxacum* (dandelion)	+*	–	–
Sunflower	+*	–	–	*Trifolium* (clover)	+*	–	–
Tomato	–	–	–	*Zinnia*	+*	–	–
Watermelon	+*	–	+*				

*New hosts not previously reported.
+ = Positive recovery from inoculated plants.
– = No recovery from inoculated plants.



Growth period of crops susceptible to lettuce infectious yellows virus.

desert (see table) gives basic information that clearly distinguishes the diseases, clears up some misconceptions, and suggests possible control measures.

Early observations by field representatives and growers suggested that cotton played an important role in the disease cycle on lettuce and other crops. If this is so, our evidence indicates that cotton serves only as a source of whiteflies but not of viruses for the major crops except beans. The cotton crumple-leaf disease agent seems to have a very limited host range, including cotton, bean, and *Malva* (cheeseweed). Elimination of off-season (stub) cotton and reduction of cheeseweed would probably control this disease.

The squash leaf curl virus also has a limited host range: in studies thus far it has been recovered only from squash, watermelon, and bean. The agent under study in our laboratory does not infect melons, cotton, lettuce, or sugarbeets. A squash-, watermelon-, and bean-free period in desert growing areas would probably greatly reduce the incidence of squash leaf curl.

The lettuce infectious yellows virus appears to affect a wide range of crop and weed plants (see table and figure). It would be difficult at this stage of the research to design a simple crop management strategy that would eliminate or greatly reduce the incidence of this virus in wild species. However, a slight alteration in the growth cycles (planting and harvesting dates) of a few crops might affect the occurrence of two viruses. A two- to three-week period free of cantaloupe, other melons, and squash in July or August would greatly reduce the incidence of lettuce infectious yellows in the area and would probably greatly reduce squash leaf curl.

General control methods should be used until a better understanding of the infectious yellows virus, the diseases, and possible resistance can be studied. General strategies include reduction of whitefly populations, isolation of plantings from large acreages of infected plants, destruction of infected plantings immediately after harvest, and weed control in crops and along roadsides, ditches, and the like.

With the limited biological data on whitefly populations and basic information on reasons for seasonal variations, it is impossible to predict the economic impact of the disease complex on future crops. We do know, however, that reservoirs of whitefly-transmitted agents are widespread in southwestern desert plants and that losses caused by these agents could change the agriculture of the desert. Much additional host and biological information is needed to fully characterize the disease-inducing entities now known in the complex, and the possible role of additional diseases must be determined.

James E. Duffus is Research Plant Pathologist, U.S. Department of Agriculture, U.S. Agricultural Research Station, Salinas, California, and Robert A. Flock is Entomologist, Imperial County Agriculture Department, El Centro, California. *The authors gratefully acknowledge the cooperation of James M. Thompson, Wilber-Ellis Co., Glendale, Arizona.*