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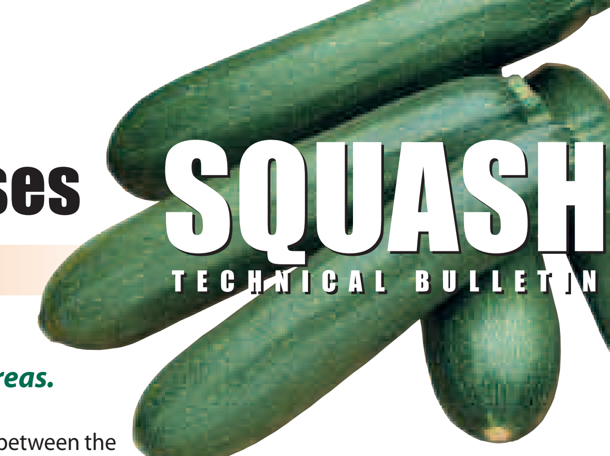
An Overview of Squash Viruses



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There are many different viruses that can cause disease, occasionally resulting in severe crop losses in squash production areas.

Many of these viruses are well known and have been well categorized, including identification of their vectors and the vectors' life cycles. However, some of the viruses, especially the geminiviruses, have only been identified fairly recently, and new strains of these viruses are being characterized on a seemingly continual basis. Squash viruses can be very difficult to identify based solely on host plant symptom expression because many of the symptoms caused by the different viruses are very similar. Knowing which virus (or viruses, because infections by multiple viruses can occur at the same time) is present, and the corresponding vector, are keys to a virus control strategy.

SYMPTOMS: Many squash viruses cause plant stunting due to shortening of the internodes and an overall reduced growth rate. Foliar symptoms include green or yellow mosaic or mottling, puckering, curling, and distortion of the leaves. Flowers may abort, or have pronounced abnormalities. In some cases, such as occurs with lettuce infectious yellow virus (LIYV), symptoms may develop primarily on older leaves. Fruit set may be reduced or eliminated, and fruits that set may not develop to normal size. Affected fruit may also develop distortions, blisters or discolorations and in some cases may not completely ripen. Generally, the younger the plant at the time of infection, the more pronounced the symptoms.

TRANSMISSION: Squash viruses can be transmitted in several ways. For example, zucchini yellow mosaic virus (ZYMV), watermelon mosaic virus (WMV), cucumber mosaic virus (CMV), and papaya ringspot virus (PRSV) are transmitted both by aphids and mechanically. Other viruses are transmitted differently. Squash mosaic virus (SqMV) is transmitted by beetles, melon necrotic spot virus (MNSV) by soil-borne fungi, squash leaf curl virus (SLCV) and LIYV by whiteflies, and beet curly top virus (BCTV) by leafhoppers. Acquisition of the virus by the vector may occur almost instantly or it may take many minutes. There may be a latent period of up to 12 hours or longer between the time the vector acquires the virus and is capable of transmitting it. Vectors may be capable of transmitting a virus for only very short periods of time or the virus (SqMV) may become persistent in the host vector, resulting in transmission for 3 weeks or more after acquisition.

HOST RANGE: Either commercial or volunteer crops, and weeds, can harbor squash viruses and serve as sources for additional infection. Some viruses that infect squash, such as CMV, have a very broad host range. CMV is distributed worldwide and can infect up to 800 plant species while other viruses such as SLCV infect a much more limited but diverse (beans and squash) set of species. Removing weeds or volunteers, or growing the commercial crop away from these other potential hosts or during a timeframe in which they do not grow, can help reduce the incidence of virus.

IDENTIFICATION: Determining the cause of symptoms associated with virus infection can be difficult because symptoms may vary depending on host genotype, plant age at the time of infection, and weather conditions. Therefore, it is frequently necessary to use some means of identification in addition to visual symptom expression. There are commercially available pre-prepared testing kits, known as ELISA (Enzyme Linked Immunosorbent Assay) that are rapid and provide a good preliminary diagnosis. However, it might be necessary to have a diagnosis performed or confirmed by a private or university lab, which might use techniques such as ELISA, electron microscopy, PCR (polymerase chain reaction) or host inoculations.

VIRUS CHARACTERISTICS: The virus particles themselves may be flexuous rods (ZYMV and WMV), isometric particles (SqMV), rigid rods, or other shapes. Some viruses that affect squash contain RNA while others contain DNA, and the genome may be divided into more than one component of equal or unequal size. It is these characteristics of the viruses that help determine how they will be transmitted, including which insect will be their vector.

CONTROL: Once the virus has been identified, a control strategy that includes insect suppression or eradication, sanitation, crop rotation, and adjusted planting schedules can be developed. In last few years, squash varieties that are resistant to some viruses have been developed. Examples include ROGERS' Noche and Contender, which have intermediate resistance to ZYMV and WMV (please see *Key to Resistance Abbreviations for Squash* on back page). These varieties can be effectively incorporated into a virus control strategy. However, it needs to be emphasized that resistant varieties will only provide resistance to the designated viruses, and not the whole assortment of squash viruses.

The diversity of insect vectors makes controlling viruses by controlling the vector difficult, especially if conditions are conducive for proliferation of these vectors. In some cases, the extent of virus infection can be limited by controlling the vector but in others (especially whitefly transmitted viruses), a limit in the rate of disease spread may be all that can be achieved. Weather and crop timing can be great influences on the insect vector populations and the subsequent amount of virus that develops. In the desert, aphids proliferate in the spring and early summer when temperatures are generally below 90-95˚F. The populations drop very quickly at higher temperatures. However, whiteflies develop and increase in number quickly at temperatures in excess of 90-95˚F. Therefore, viruses that are associated with each of these vectors also will be most common during the respective vector-favoring weather conditions. Crops that are planted late in the growing season are often at highest risk because the virus inoculum load, and insect vector populations, may have built up on earlier crops.

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Insecticide or mineral oil sprays can be used for controlling insect vectors. However, several other techniques can be used as well. One of these is known as mid-bedding, where seed is planted in V-shaped trenches between plant beds in the early spring, and the trenches are covered with plastic. The main benefit is increased soil temperatures to hasten plant development for early production, but a side benefit is a possible reduction in early aphid populations and associated viruses on the young plants. Reflective mulches, which are intended to disorient aphids, have been used with varying degrees of success for limiting aphid transmitted viruses. For the viruses that are transmitted mechanically as well as by insects, cultivation and other equipment should be cleaned and disinfected prior to being moved from infected to non-infected fields.

GEMINIVIRUSES (BEGOMOVIRUS): During the past 25 years geminiviruses (genus Begomovirus, family Geminiviridae), which are characterized by a bipartite single-stranded DNA genome, have become a severe problem on squash in desert regions where the whitefly vectors abound. There are at least three begomoviruses that have been identified to date on squash and the number continues to grow. The current list includes squash mild leaf curl virus (SMLCV) from California; squash leaf curl virus (SLCV) from Arizona, California, Texas, Mexico (Sinoloa and Sonora), Guatemala, Nicaragua, and Panama; and cucurbit leaf curl (crumple) virus (CuLCV) from Arizona, California, Texas, Northern Mexico (Coahuila), and others. Increased irrigation in desert areas has resulted in larger host plant and whitefly populations, and a corresponding increase in begomoviruses.

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SOURCES:
Zitter, T.A. et al. (eds.), 1996. Compendium of Cucurbit Diseases. APS Press, St. Paul, Minnesota.

Dr. Judy Brown, University of Arizona, and Dr. Robert Gilbertson, University of California-Davis, contributed information for this article. Eric Natwick, a University of California Entomology Cooperative Extension Advisor in Imperial County, also provided expertise.

Selected Syngenta Summer Squash Hybrids with Intermediate Resistance (IR)† to Powdery Mildew and Other Diseases

	POWDERY MILDEW	CUCUMBER MOSAIC	SQUASH LEAF CURL	WATERMELON MOSAIC	ZUCCHINI YELLOW MOSAIC
GREY ZUCCHINI					
Amatista	■				■
Topazio	■		■		■
MEDIUM GREEN ZUCCHINI					
CashFlow					■
Dividend		■		■	■
Payroll	■			■	■
MEDIUM-DARK GREEN ZUCCHINI					
Envy	■				■
DARK GREEN ZUCCHINI					
Noche				■	■
Contender				■	■
Equinox	■			■	■
YELLOW ZUCCHINI					
Golden Delight				■	■
YELLOW SQUASH (SEMI-CROOKNECK)					
Gold Star	■	■			
Sunglo	■				

†KEY TO RESISTANCE ABBREVIATIONS FOR SQUASH

CMV	Cucumber mosaic caused by *Cucumber mosaic virus*
Sf	Powdery mildew caused by *Sphaerotheca fuliginea*
SLCV	Squash leaf curl caused by *Squash leaf curl virus*
WMV	Watermelon mosaic caused by *Watermelon mosaic virus*
ZYMV	Zucchini yellows caused by *Zucchini yellow mosaic virus*
HR	**High Resistance:** describes plant varieties that highly restrict the growth and development of the specified pest or pathogen under normal pest or pathogen pressure when compared to susceptible varieties. Highly resistant varieties may, however, exhibit some symptoms or damage under heavy pest or pathogen pressure.
IR	**Intermediate Resistance:** describes plant varieties that restrict the growth and development of the specified pest or pathogen, but may exhibit a greater range of symptoms or damage compared to highly resistant varieties. Intermediately resistant varieties will still show less severe symptoms or damage than susceptible plant varieties when grown under similar environmental conditions and/or pest or pathogen pressure.

In cases where specific races or strains are not noted the variety is resistant to some, but not necessarily all known races or strains of the pathogen.

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Powdery Mildew in Summer Squash

In the drier areas of the Western United States and Mexico, powdery mildew epidemics often result in considerable losses to fields of summer squash. The disease is ubiquitous, however, and can also limit production of summer squash around the world. It frequently compromises yield by reducing the amount of leaves available for photosynthesis, accelerating senescence, and, ultimately, killing the infected plants.

CAUSES

Powdery mildew is caused by several fungi that affect cucurbits and other crops. Cucurbits are susceptible to powdery mildew caused by *Podosphaera xantii* (Castagne) U. Braun & S. Takam, formerly classified as *Sphaerotheca fuliginea* (Schlechtend.:Fr.) Pollaci. This pathogen has been widely confirmed in North, Central, and South America, and it is the recognized causal agent of powdery mildew in summer squash in those areas.

SYMPTOMS

Powdery mildew infections on summer squash appear as "white, talcum-like, powdery fungal growth"[1] that develops on the leaf blades, peduncles, and stems (also called growing points) of susceptible plants. The white structures visible to the naked eye are the mycelia (body) and conidia (reproductive structures) of the fungus. Usually, infection begins on the older leaves and then spreads to other parts of the plant.

INFECTION MECHANISM

Powdery mildew fungi are obligate parasites, which means they cannot survive unless they infect a living host. If their primary host is not present (e.g., due to crop rotation, etc.), the fungi may survive on alternative hosts such as weeds or other compatible crops.

Powdery mildew conidia, also known as spores or survival structures, are dispersed by the wind over long distances and remain viable for 7 to 8 days. An epidemic of powdery mildew usually begins when airborne spores land on the outer leaves of a plant. Each spore germinates and develops into a mycelium (fungal colony) which differentiates into new reproductive structures within 3 to 7 days. These will produce secondary inoculum that typically affect the rest of the plant. Additional infection cycles are then possible, with the new spores landing on such internal parts of the plant as stems and flowers.

CONDITIONS FOR DEVELOPMENT

Ideal conditions for powdery mildew epidemics are dense plant growth, low light intensity, dry weather during spore production and dispersal, and higher humidity during infection. Powdery mildew differs from many fungal diseases in that its spores do not require free moisture in order to germinate. Optimal temperatures for infection range from 50 to 90°F, and from 68 to 81°F for disease development. Disease development is arrested when temperatures are higher than 100°F. Thus, powdery mildew is a greater threat during the cool and dry months of the spring and fall, rather than the hot summer months. In addition, powdery mildew develops more easily on senescent leaves. Therefore, with the progressing of the plant age, and the increase of exposed senescent leaves to infection, powdery mildew may overcome genetic resistance of the plant.

CHEMICAL CONTROL

Fungicides can be used as a preventative measure or to delay the production of secondary inoculum on infected plants. Complete control of powdery mildew through fungicide applications is difficult on summer squash, however, because the fungicides often do not reach the lower side of the leaf blades or the more internal parts of the plant such as petioles and stems. Systemic fungicides are more effective, but powdery mildew has developed resistance to the active ingredients of some fungicides. The alternation of fungicides is usually desirable to help reduce the chances of the development of this resistance. However, during intense epidemics, biweekly applications are often required and make the technique non-economical.

GENETIC RESISTANCE TO POWDERY MILDEW IN SUMMER SQUASH

Plant breeders are developing summer squash with genetic resistance to powdery mildew. Currently recognized genes confer resistance at the intermediate level. Such resistance typically prevents a complete defoliation of the plants and the death of the main stem, and allows for a longer growing period and more harvests. However, powdery mildew resistant cultivars (cultivated varieties) are not wholly immune to this disease. During an epidemic, resistant cultivars will likely be infected and show some level of growth of mycelia from the primary inoculum. However, the development of the fungus (enlarged white spots) and its ability to sporulate can be limited and the plants will extend their production life.

The level of resistance of the main stem is more critical than the level of resistance of the leaves (See Disease Assessment Scale for Genetic Resistance). This is because the stem generates new leaves, as well as female and male flowers, thereby replacing diseased parts and providing new marketable fruit. Leaves can be easily protected with fungicide applications, while the stem will very rarely be reached by fungicide in a timely manner. On the basis of stem reaction, genetic resistance can be classified in five categories: 1 and 2 for "Susceptibility," 3 and 4 for "Intermediate Resistance," and 5 for "High Resistance." Examples of cultivars with intermediate resistance to powdery mildew include: Payroll, Envy, Equinox, Amatista, Topazio, Sunglo, and Gold Star (please see *Key to Resistance Abbreviations for Squash* on back page).

FIELD MANAGEMENT OF RESISTANT CULTIVARS

Genetic resistance provides the basis for successful management of powdery mildew in summer squash. Resistant cultivars benefit from weekly applications of fungicides that can reduce damage to leaves. Genetic resistance also allows for lower production costs due to less frequent fungicide applications and potentially higher yields due to the longer harvest period. When disease pressure is high, and environmental conditions are close to optimum for disease development, resistant cultivars may succumb to powdery mildew. Still, their life-span will most often be a few days to several weeks longer than susceptible cultivars and their production may be higher. The timely identification of powdery mildew hot spot development in a field, combined with the proper application of fungicides, will decrease the chances that the disease will cause serious damage to the crop.

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SOURCES:

[1] Zitter, T.A. et al. (eds.), 1996. Compendium of Cucurbit Diseases. APS Press, St. Paul, Minnesota.

Disease Assessment Scale for Genetic Resistance*

For squash, stem reaction provides a better basis than leaves for determining genetic resistance to powdery mildew because extensive leaf infection can occur on resistant varieties. The following assessment scale, which is based on disease development on the stem, provides a summary of the level of resistance that can occur in commercial cultivars:

Level 1: *The cultivar is susceptible to powdery mildew and production is fully lost. Stem and leaves are fully covered by secondary inoculum and the plants die.*

Level 2: *The cultivar is susceptible to powdery mildew and production is largely lost soon after the first symptoms become evident. Stem and leaves are partly covered in secondary inoculum, but the lesions are too extensive to allow further growth of the plant.*

Level 3: *The cultivar has a low level of resistance and can sustain fruit production for a slightly longer period of time, especially if fungicides are applied in a timely manner.*

The stem has several large areas covered by mycelia, but very little production of inoculum. The leaves may still show a susceptible reaction, but new leaves will be less affected than old ones.

Level 4: *The cultivar is resistant (intermediate level) to powdery mildew and fruit can be harvested longer, thus increasing total yield in comparison with susceptible cultivars. The stem shows some development of mycelia from primary inoculum, but there is very little or no production of secondary inoculum. The leaves may be affected slightly if treated with fungicides, or more heavily if not treated. New leaves are almost free of powdery mildew.*

Level 5: *The cultivar is fully resistant and yields as much as or more than a susceptible but disease-free cultivar. The stem, leaf blades, and petioles show very limited, if any, development of mycelia from primary inoculum and inhibit production of secondary inoculum.*

*Please see *Key to Resistance Abbreviations for Squash* on back page)