

Recommendations for Management of Whiteflies, Whitefly-transmitted viruses, and Insecticide Resistance for Production of Cucurbit Crops in Florida¹

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Until recently, squash has been the only cucurbit crop seriously affected by the B biotype of the sweetpotato whitefly, *Bemisia tabaci* (Gennadius) (also known as the silverleaf whitefly, *B. argentifolii*), because of the silverleaf disorder induced by feeding of the immature stages (nymphs). However, three viruses transmitted by the whitefly have been identified in watermelon, muskmelon, and squash in Florida since 2004, making whitefly management a priority for most cucurbits.

Squash vein yellowing virus (SqVYV), an ipomovirus in the family *Potyviridae* (the same family that includes many of our aphid-transmitted viruses), was first identified from squash in Florida in 2005, but had been causing serious damage in watermelon crops as watermelon vine decline since at least 2003 (Adkins et al. 2007). Unlike aphids, which can acquire mosaic virus in a matter of seconds, just by “tasting” the plant, whiteflies must feed on the plant to acquire SqVYV and the longer they feed (up to about 8 hours), the more efficiently they are able to transmit the virus to a new plant. Whiteflies appear to retain the virus for less than a day after they move away from an infected plant, but SqVYV can still spread rapidly when whitefly populations

are high. Watermelon plants are killed by the virus (Figure 1) and fruit often have necrotic areas (Figure 2), especially just under the rind. Early symptoms on watermelon include yellowing and downward curling of the new growth and yellowing and collapse of petioles (Figure 3). Squash plants develop yellowing along all the leaf veins (Figure 4) and are stunted if infected early. Symptoms are more severe on yellow squash, including green streaks on the fruit, than on zucchini. Butternut squash, pumpkin, and calabaza are also affected (all *Cucurbita* species). Cucumber and muskmelon (*Cucumis* species) are not very susceptible to the virus. So far, the only weed hosts known are restricted to the cucurbit family: balsam apple, creeping cucumber, and smellmelon (Adkins et al. 2008, 2009).

Cucurbit leaf crumple virus (CuLCrV) was first recognized in 1998 in the Imperial Valley of California. CuLCrV was first found in northeast and north central Florida in 2006, but has now spread to other parts of the state. It is a begomovirus in the family *Geminiviridae*. Once acquired by the whitefly, CuLCrV may be transmitted for the rest

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Figure 1. Watermelon plants killed by infection with SqVYV.

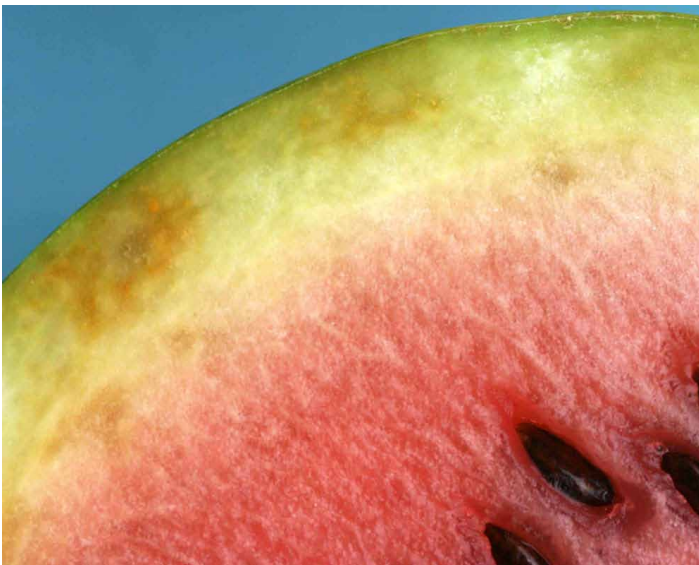


Figure 2. Effects of infection with SqVYV on watermelon fruit. Note necrotic (brown) areas of rind.

of its life. It appears to be more damaging to squash than to cantaloupe and watermelon. Infected squash and melon plants show leaf crumpling, curling, mottling, and a thickening of leaves. The fruit of yellow squash plants develop green streaks. In watermelon, yellowing of leaves and crumpling can occur (Figure 5), although in California, watermelon and cantaloupe appear to recover from infection with little effect on yield (Hagen et al. 2008). All cucurbits are susceptible except for acorn and butternut squash and a number of melons, such as Galia, honeydew, casaba, and golden crenshaw. Recently, CuLCrV has been found infecting green beans, balsam apple, and smellmelon in Florida (Adkins and Turechek 2008; Adkins et al. 2008, 2009). Other weed hosts have not yet been identified. See <http://edis.ifas.ufl.edu/in716> for other photographs of symptoms in squash, watermelon, and snap bean.

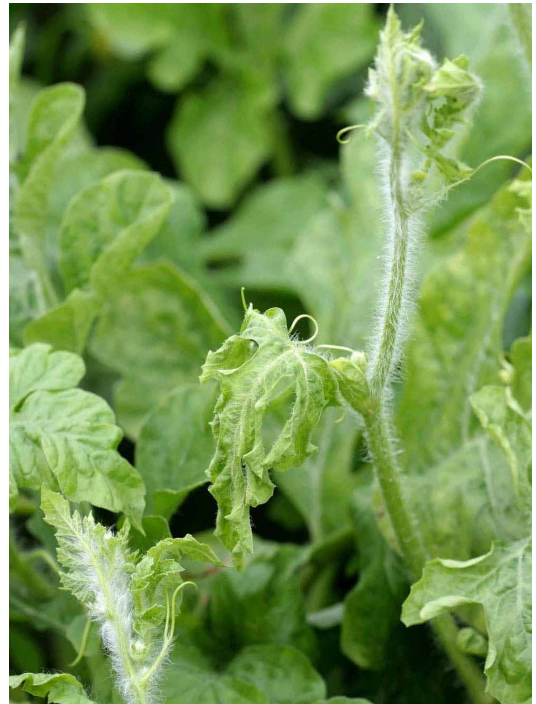


Figure 3. Early symptoms of infection with SqVYV in watermelon.



Figure 4. Vein yellowing symptoms on yellow summer squash in the greenhouse.

Cucurbit yellow stunting disorder virus (CYSDV) was originally reported from the Middle East and Spain. It was first found in the United States in Texas in 1999 and was widespread in the southwestern United States in the fall of 2006 (Brown et al. 2007, Kuo et al. 2007). CYSDV was found in Florida in 2007 (Polston et al. 2008). It is a crinivirus in the family *Closteroviridae*. It persists in the whitefly adult for up to 9 days, the longest time of any crinivirus (Wisler and Duffus 2001). It affects all cucurbit crops, causing reduced fruit size and sugar content. Symptoms resemble those of a nutritional deficiency or water stress; the most obvious



Figure 5. CuLCrV in watermelon.



Figure 6. CuYDV in watermelon.

symptoms are seen on older leaves. The first symptom is a yellow spotting of leaves (Figure 6). Then, leaves turn yellow between the leaf veins, which remain green -the opposite of what happens when squash are infected with SqVYV. Leaves roll downward and become brittle. It can take up to four weeks for symptoms to develop after infection, so it is easy to move the virus long distances in infected but symptomless transplants without realizing that the plants are infected. Recently, CuYDV has been found infecting melon in Florida (Adkins et al. 2009).

As of this writing, no cucurbit varieties resistant to these viruses are available. Managing the whitefly vector and weed hosts of the virus are the only options for reducing

losses at this time. Whiteflies must feed on plants to acquire enough virus to transmit it, and this feeding period offers some window of opportunity to interrupt the transmission cycle with insecticides. Reducing the overall population by controlling the immature stages of the whitefly should also contribute to reduced spread. Insect resistance to insecticides is a serious problem in whitefly management with a number of products no longer highly effective for killing adult whiteflies. Additional insecticides that kill adult whiteflies quickly are in development, but resistance management needs to be a primary concern, both for existing and new products, if we are to be able to manage whitefly-transmitted viruses without resistant varieties. Cultural controls, as outlined below, are essential for a strong resistance management program.

Most of the following management recommendations are taken directly from the recommendations for managing *Tomato yellow leaf curl virus* (TYLCV) and for delaying the development of resistance to insecticides in the whitefly vector (Schuster et al. 2007, <http://edis.ifas.ufl.edu/in695>). Those sections not relevant to cucurbits have been deleted and some information has been added. The recommendations for tomatoes have evolved over several years and continue to be revised. We envision a similar process for the recommendations for cucurbits.

Crop Hygiene

Field hygiene should be a high priority and should be included as an integral part of the overall strategy for managing whitefly populations, incidence of whitefly-transmitted viruses, and insecticide resistance. These practices will help delay the initial whitefly infestation and delay the introduction of viruses into the crop.

Establish a minimum two-month crop free period during the summer, preferably from mid-June through mid-August or longer.

- Delay planting new fall crops as long as possible and remove spring crops as early as possible to increase the summer crop-free period and avoid carryover of disease and pests to the fall crop.
- Try to eliminate, as much as is practical, any cucurbit weeds (balsam apple, creeping cucumber, citron) that could serve as a source of viruses and whiteflies for the crop.

Separate fall and winter cucurbit crops in time and space.

- Do not plant new crops near or adjacent to old, infested crops.
- If the cucurbit crop is to be a double crop, especially following tomatoes, the previous or primary crop should be thoroughly destroyed to reduce the initial whitefly population.

Destroy the crop and existing whiteflies quickly and thoroughly.

- Promptly and efficiently destroy all vegetable crops within 5 days of final harvest to maximally decrease whitefly numbers and sources of plant viruses.
- Use a contact desiccant (“burn down”) herbicide in conjunction with a heavy application of oil (not less than 3 % emulsion) and a non-ionic adjuvant to destroy crop plants and to quickly kill whiteflies.
- Time burn down sprays to avoid windy periods, especially when prevailing winds are blowing whiteflies toward adjacent plantings.
- Destroy crops block by block as harvest is completed rather than waiting and destroying the entire field at one time.

Other Cultural Control Practices

Use proper pre-planting cultural practices to avoid introducing whiteflies or viruses into crops.

- Grow and/or plant whitefly and virus-free transplants.
- Do not grow vegetable transplants and ornamental plants (i.e., hibiscus, poinsettia) at the same location, especially if bringing in plant materials from other areas of the US or outside the US.
- If this is not possible, isolate vegetable transplants and ornamental plants from each other.
- Do not work with or manipulate vegetable transplants and ornamental plants at the same time.
- Avoid yellow clothing or implements, which will attract whitefly adults.
- Cover all vents and other openings with whitefly resistant screening (0.25 x 0.8 mm openings or less for passive ventilation, less for forced air ventilation). Use double doors with positive pressure. Cover roofs with ultraviolet

light-absorbing films (UV-absorbing films), or UV-reflecting covers when feasible.

- Covering the ground outside the greenhouse or plant-house, particularly adjacent to greenhouse cooling pads, with UV-reflective mulch, can reduce entry of whiteflies, aphids, and thrips. See <http://edis.ifas.ufl.edu/in730> for this and other details of exclusion practices.
- If possible, do not purchase transplants produced in Texas, the southwestern US, or Mexico, where whitefly-transmitted viruses are common.
- Use UV-reflective (aluminum) mulch on plantings that are historically most susceptible to whitefly infestation. Reflective mulches with a black strip (not metalized) down the center to allow the soil to warm will be less likely to delay growth for crops grown in cooler months. The effects of the mulch will be lost when plants cover the mulch.
- No varieties resistant to the whitefly-transmitted viruses are available at this time.

Use proper post-planting practices.

- Removal of the earliest plants with symptoms may be of some value, especially for reducing the spread of viruses when whitefly populations are low.
- Manage weeds within crops to minimize interference with spraying and to eliminate weeds that can serve as whitefly and virus hosts.

Insecticidal Control Practices

- Use a proper whitefly insecticide program to delay development of resistance to insecticides, particularly neonicotinoid insecticides. Read and follow the label; many insecticides have limits on the number of applications that can be made in a growing season.
- **On transplants** in the production facility, apply a neonicotinoid **one time**, not more than seven days before planting. Do not use pymetrozine (Fulfill). It can be applied only twice during the season and currently is not approved for use on cucurbits in the planthouse.
- **Use soil applications of neonicotinoids** at planting for longer season crops, such as watermelon, so that there is less chance of affecting bees pollinating the crop. Research on effects of low levels of neonicotinoids in

pollen is being done, but we do not have specific recommendations yet.

- For best control, use a neonicotinoid as a soil drench at transplanting/seeding, preferably in the transplant/establishment water. Soil applications of neonicotinoids through the drip irrigation system are generally inefficient and wasteful of product and thus not recommended.
- In order to preserve the neonicotinoid-free period, do not use split applications of soil drenches of neonicotinoid insecticides (i.e., do not apply at transplanting and then again later).
- **If foliar applications of a neonicotinoid insecticide** (dinotefuran, acetamiprid, and thiamethoxam are labeled for this use on cucurbits) are used instead of soil drenches at transplanting, **foliar applications should be restricted to the period before flowering because of toxicity to bees.** Do not exceed the maximum active ingredient per season according to the label.

Follow scouting recommendations when using a foliar neonicotinoid insecticide program. Switch to non-neonicotinoid insecticide classes after flowering begins, and do not use any neonicotinoid class insecticides for the remaining cropping period. The use of insect growth regulators (buprofezin, novaluron, pyriproxyfen) to control nymphs is one effective option.

- Use selective rather than broad-spectrum control products when possible to conserve bees and natural enemies that enhance biological control. Bees are essential for production of cucurbit crops and insecticides that are toxic to them should be avoided during flowering or applied in the evening when bees are not foraging.
- Pymetrozine (Fulfill) has been shown to reduce virus transmission in greenhouse tomato studies. In greenhouse studies with cucurbits, pymetrozine reduced transmission of SqVYV effectively only if both the infected (source of virus) and uninfected plants were treated, so it will be of most value in preventing spread once this virus is present in the crop.
- Do not apply insecticides on weeds on field perimeters. These applications can kill insect natural enemies and interfere with biological control.
- Apply an effective insecticide to kill whitefly adults prior to any cultural manipulations, but apply when bees are not foraging.

Do unto your neighbor, as you would have them do unto you.

Look out for your neighbor's welfare.

This may be a strange or unwelcome concept in the highly competitive vegetable industry, but it is in your best interest to do just that. Growers need to remember that should the whiteflies develop full-blown resistance to insecticides, especially the neonicotinoids, it's not just the other guy who will be hurt—everybody will feel the pain!

Know what is going on in the neighbor's fields.

Growers should try to keep abreast of operations in upwind fields, especially harvesting and crop destruction, which both disturb the foliage and cause whitefly adults to fly. Many crops are hosts for whiteflies, and some of them can be infected by the same viruses that infect cucurbits (e.g., beans and CuLCrV).

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Table 1. Information for selecting insecticides for whitefly management programs (Schuster et al. 2007).

Common Name	Trade Name	Adult Rating	Nymph Rating	Bee Toxicity	Biotype B Resistance	Biotype Q Resistance	IRAC Classification	Comments
Pyrethroids	Many products	2	2	Highly toxic	?	Y	3	Reportedly less effective now than previously; most effective as tank mixes. Whitefly no longer on labels as a target pest for most pyrethroids
Endosulfan	Endosulfan, Thionex	3	2	Moderately toxic	?	?	2A	Reportedly less effective now than previously; more effective in tank mixes with pyrethroids and other products. This product will soon be phased out for safety reasons (EPA, June 2010)
Pymetrozine	Fulfill	2	1	Moderately toxic	N	Y*	9B	Reduces adult feeding and virus transmission
Buprofezin	Courier	1	4	Relatively non-toxic	N	Y	16	Insect growth regulator kills nymphs; acts slowly; causes sterility and reduced egg hatch
Novaluron	Rimon	1	4	Relatively non-toxic	N	Y	15	Insect growth regulator kills nymphs; acts slowly
Pyriproxyfen	Knack	1	4	Relatively non-toxic	N	Y	7C	Insect growth regulator kills nymphs; acts slowly; causes sterility and reduced egg hatch
Spiromesifen	Oberon	1	5	Relatively non-toxic	N	N	23	Effective against nymphs, kills adults slowly; induces sterility
Soap	M-Pede	1	2	Relatively non-toxic	N	N	N/A	Kills by contact; no residual; requires thorough coverage
Borate	Prev-Am	1	2	Relatively non-toxic	N	N	N/A	Kills by contact; requires thorough coverage; effects have been variable
Oil	Ultra-Fine Oil, JMS Stylet Oil, and others	1	2	Moderately toxic	N	N	N/A	Kills by contact; repels adults; requires thorough coverage, appears to help reduce spread of SqVYV
Neonicotinoids	Admire Pro, and generic imidacloprid products, Platinum, Actara, Venom, Assail, Belay	3	5	Highly toxic (foliar), Assail moderately toxic	T	Y	4A	Systemic when applied as soil drench. Actara and Assail used as foliar spray only.
Premixes	Voliam Flexi, Durivo	3	5	Highly toxic	T	T	4A/28	Mixture of thiamethoxam (Platinum) and chlorantraniliprole (Coragen) for use when both whiteflies and worms or leafminers are present or expected. Voliam Flexi is for foliar application and Durivo for soil.

Common Name	Trade Name	Adult Rating	Nymph Rating	Bee Toxicity	Biotype B Resistance	Biotype Q Resistance	IRAC Classification	Comments
Premixes	Vetica	1	4	Relatively non-toxic	N	Y	16/28	Mixture of buprofezin (Courier) and flubendiamide (Synapse). Use when both whiteflies and worms or leafminers are present
<i>Beauveria bassiana</i>	Mycotrol, BotaniGard, others	1	1	Relatively non-toxic	N	N	N/A	Fungal biocontrol agent; more effective in greenhouses
<i>Azadirachtin</i>	Azatin, Aza-Direct; Neemix, others	1	2	Moderately toxic	N	N	un	Antifeedant; more effective in greenhouse; some activity at higher rates

Rating Scale: 1=<30%; 2=30-50%; 3=50-70%; 4=70-90%; 5=90-100%
Bee toxicity: Highly toxic, kills upon contact as well as residues; Moderately toxic, kills if applied over bees; Relatively nontoxic, relatively few precautions necessary. Resistance Key: N = no; Y = yes; T = tolerance observed in Florida; ? = status unknown or not documented in Florida* Reported to be cross-resistant with neonicotinoids.