Whitefly (*Bemisia tabaci*) Management Program for Ornamental Plants[1]

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Bemisia tabaci (Gennadius), commonly known as silverleaf whitefly, is a polyphagous pest and one of the most notorious invasive arthropods worldwide. It is known to feed on more than 900 plant species and vector over 100 plant-damaging viruses (Oliveira et al. 2001; Simmons et al. 2008). The pest status of *B. tabaci* is complicated because of their widely debated taxonomic status, previously identified as consisting of numerous "biotypes" (biotypes are groups of organisms sharing the same specific genetic makeup) but now considered as 24 or more discrete but morphologically indistinguishable species. Only a handful of countries have escaped the cosmopolitan distribution and subsequent establishment of the worst of these: *B. tabaci* Middle East-Asia Minor 1 (MEAM1) and Mediterranean (MED), also known as biotypes B and Q, respectively. MEAM1 (B-biotype) was first detected in Florida in 1986 in poinsettia greenhouses and quickly moved to the field, causing unprecedented losses to vegetable, field, and ornamental crops (Hoddle 2013). MEAM1 rapidly spread across the southern United States to Texas, Arizona, and California, where severe field outbreaks occurred during the early 1990s on melons, cotton, tomato, and other vegetable crops.

MED (Q-biotype) was first documented in the United States in 2004 (Dennehy et al. 2005) in Arizona, and in 2005 in Florida. Since then it has been reported from 26 states as a pest in greenhouses (McKenzie et al. 2012) but was not previously reported to have escaped protected culture (Dickey et al. 2013). However, there have been 53 positive confirmed detections of MED since April 2016 from 12 counties in Florida. Of the 53, 19 came from retail nurseries, 11 from wholesale nurseries, two from field locations, and the rest from outdoor residences in Palm Beach County. Considering its dispersal abilities (direct and indirect through transportation of infested materials), damage potential, and the wide range of host crops (vegetable or ornamental) grown in Florida, MED could cause serious economic impacts to Florida growers and consumers nationwide were populations to establish in various production areas. This is because of the reduced susceptibility of these whiteflies to a variety of insecticides, including some of the most widely used chemical classes (neonicotinoids and insect growth regulators) for whitefly control (Horowitz et al. 2004).

Considering the known economic impact of MEAM1 and the potential impact of MED on ornamental growers, we developed a management program for both species. The program does not require a pesticide application when the first whitefly adult is detected. Rather, it outlines steps to

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manage and maintain whitefly populations throughout the initial propagation and active growth stages at levels that will minimize numbers on the final plant material being shipped. This will also minimize selection for insecticide resistance irrespective of whitefly biotype while helping to achieve top-quality plant materials. Growers should apply pesticides when scouting reports identify population densities at levels where experience and/or Extension personnel indicate action should be taken. These densities would depend on many factors including the crop, source(s) of infestation, and environmental conditions.

Figure 1. Whitefly, *Bemisia tabaci* Gennadius, eggs and adults.
Credits: Lance S. Osborne, UF/IFAS

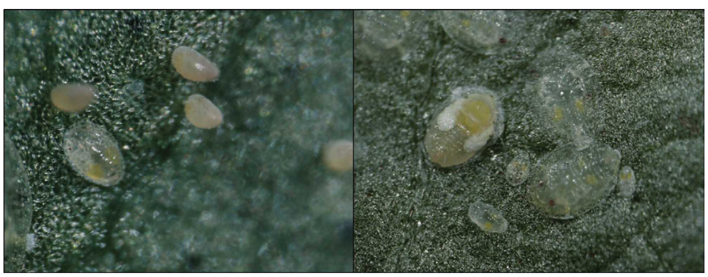

Figure 2. Whitefly, *Bemisia tabaci* Gennadius, immature stages.
Credits: Lance S. Osborne, UF/IFAS

Figure 3. Whitefly, *Bemisia tabaci* Gennadius, adult.
Credits: Lance S. Osborne, UF/IFAS

Hosts and Damage

Whiteflies feed on plant phloem by injecting enzymes and removing the sap, reducing the vigor of the plant, or, in cases of severe infestation, killing the host. Greenhouse-grown ornamentals such as poinsettia, hibiscus, ivy, gerbera daisy, lantana, verbena, garden chrysanthemum, salvia, and mandevilla are especially susceptible to whitefly damage. Honeydew secretions from the whitefly feeding promote the growth of sooty mold, which also significantly reduces plant quality. The most obvious whitefly feeding damage symptoms are stem blanching, chlorotic spots, leaf yellowing, and shedding. In many crops, the damage caused by *B. tabaci* is indirect, i.e., by transmitting disease-causing viruses. The following table compares biological characteristics of the three cryptic species of *B. tabaci* found in the United States and indicates that the invasive MEAM1 and MED are more destructive pests and have wider host ranges compared to the native New World (NW) species (A-biotype). Between the two invasive *B. tabaci*, species, MEAM1 has greater adaptability to different regions and ability to cause plant disorders, whereas MED has greater tolerance to insecticides than MEAM1.

Pest characteristics	Cryptic species		
	NW	MEAM1	MED
Host plant range	X*	XXXX	XXXX
Biotic potential	XX	XXXX	XX
Tomato Yellow Leaf Curl Vector	X	XXX	XX
Plant disorders	-	XXXX	X
Insecticide resistance	X	XX	XXXX
*The number of exes indicates the intensity/potential-for-impact of each of the whitefly species.			

Management Recommendations

There are three major goals of a successful whitefly management program 1) to help growers produce a high-quality, marketable crop for the consumer; 2) to preserve the effectiveness of the chemical tools used to manage whiteflies; and 3) to prevent the spread or distribution of difficult-to-control and possibly pesticide-resistant populations. If we do not maintain the viability of effective chemical tools, the wide host plant range of this pest will make it difficult for growers to produce and landscapers to obtain many popular ornamental species. Consequently, the wise use of chemicals through a scientifically based Integrated Pest Management (IPM) program is essential in today's global setting. It is important to consider that the MED whitefly is already resistant to a number of commonly used products. Non-judicious use of chemicals could also easily lead to increased MEAM1 resistance and make the existing problem worse. In response to the potential economic impacts of whitefly invasion, a consortium of entomologists from different organizations developed the Whitefly Management Program in 2006. The program provides guidance on best management practices, including scouting, sanitation, exclusion, biological control, and chemical control. Check with your local UF/IFAS Extension agent or specialist for the latest management recommendations targeting MEAM1 or MED whitefly.

The following subsections outline the steps of a whitefly IPM program that can effectively reduce growers' reliance on anti-whitefly chemicals and insecticides.

Detection/Scouting

Regular scouting is essential to detect whitefly incidence and avoid economic damage. Crops must be inspected at weekly intervals to find infestations early. Monitor whitefly population levels by trapping winged adults on sticky cards or inspecting leaves for the presence of adults and immatures. Strategically place yellow sticky cards throughout the greenhouse, especially near doors and among new plants to provide information about the presence and movement of whiteflies. Detect whiteflies on plants by randomly selecting 10 plants per 1,000 square feet of greenhouse space and thoroughly examining these plants on the underside of leaves for the presence of whitefly adults, nymphs, and eggs. Whitefly eggs are generally concentrated on upper new leaves of the host, and nymphs are usually found on the lower (old) leaves, so a good population estimation of whiteflies can be made by sampling leaves from different parts of the plants. A 10x hand lens may be needed to see eggs or small nymphs. Because the recommended management practices for the two biotypes may vary, it is important to determine the whitefly biotype before applying any chemical in the affected region. Density levels requiring treatments vary depending on factors including the crop, source of infestation, history of disease transmission, and environmental conditions.

Sanitation

Remove sources of infestation (weeds, old plant debris, and growing medium) from within and around the greenhouse or nursery that might carry over populations from one season to the next. While disposing affected plant materials, place debris into a sealed bag or container, and discard it in a safe place immediately. Because pests are often dispersed via transport of infested materials, be careful not to carry infested plant material or debris unsealed in an open truck/vehicle.

Exclusion

To prevent whiteflies from entering the greenhouse, seal or screen openings with appropriate screening material. Whiteflies are small, so screens with a hole size of 0.27 x 0.82 mm are required to exclude them. If possible, construct the facility so that workers enter through an anteroom.

Cultural Control

Grow plants so as to facilitate good pesticide coverage. If possible, try to have a crop-free period to break any cycling within the nursery, and install trap crops for diverting incoming whitefly populations.

Biological Control

Several biological agents are available for managing *B. tabaci* including predators (the mite *Amblyseius swirskii*, or the insects *Delphastus catalinae*, lacewing larvae), parasitoids (*Eretmocerus eremicus, Encarsia* spp.) or entomopathogenic fungi (*Beauveria bassiana, Isaria fumosorosea*). Before applying any biocontrol agents (BCA), it is important to check with commercial vendors of BCA for their compatibility with chemicals and environmental requirements such as temperature, humidity, and day length. BCAs may not control an existing high population of whiteflies before significant crop damage occurs, so early application of agents before high pest buildup is recommended. Use of generalist predators can provide control of *B. tabaci* along with other pests of ornamentals. In Florida, *B. tabaci* is effectively managed on ornamentals and vegetables grown in greenhouses with *Encarsia transvena*. In our recent greenhouse studies focused on integrated management of MED on salvia and mint crops, we observed the predatory mite *A. swirskii* and parasitic wasp *E. eremicus* to be very efficient in managing this pest, respectively. Consult with your local UF/IFAS Extension specialist about the suitable biocontrol agents available for a specific crop.

Figure 4. Predatory beetle, *Delphastus pallidus* adult.
Credits: Lance S. Osborne, UF/IFAS

Figure 5. Parasitic wasp, *Encarsia sophia* parasitized *B. tabaci* (on left), parasitoid emerging (on right).
Credits: Lance S. Osborne, UF/IFAS

Figure 6. Whitefly adult affected by entomopathogenic fungi *B. bassiana*.
Credits: Lance S. Osborne, UF/IFAS

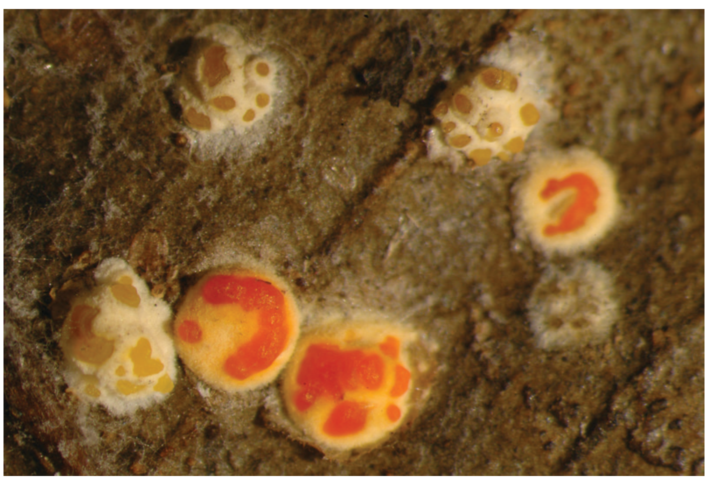

Figure 7. Whitefly scale infected by a species of *Achersonia* fungus
Credits: Lance S. Osborne, UF/IFAS

Chemical Control

If not selected correctly, chemicals can only provide a limited level of whitefly control. It is important to initiate application before the whitefly population increases to damage levels. Application timing should be based on residual activity of the pesticide instead of an established 5–7 days schedule. Many new insecticides have residual activity of greater than one week; check the product labels for specific reapplication intervals. However, it is highly recommended that no more than 2 to 3 applications be made during the entire growing season of compounds belonging to any single IRAC-Mode of Action Group and especially those in Group 4 to avoid undo selection for resistance (see tables). The insect growth regulators Talus and Distance should not be used more than twice during a crop cycle. Growers should also utilize non-selective products such as soaps, oils, and biological controls when possible. It is highly recommended that any whiteflies in the facility be tested periodically for biotype because more management tools are available for MEAM1 than MED. The contact information for the laboratory authorized to biotype whiteflies in Florida is presented below. Testing biotype is especially important if a product does not adequately control whiteflies. Select products based on the biotype of any whiteflies that are present. Follow all label guidelines for appropriate use sites, rates of application, reapplication intervals, reapplication intervals, and resistance management strategies.

Following are the steps and criteria for selecting among different whitefly management programs.

Start with the Line 1 in the "Key to Tables for Suggested Whitefly Applications," and then work your way through the key to the growth stage of your crop. Then refer to the tables (A–G) for suggested products, which are listed with recommended "yes" or "no" in the tables for each biotype based on current research. As you are developing your own personalized management plan, test products for crop safety on a small set of plants, and check label restrictions for number of total applications per crop.

Key to tables for suggested whitefly applications

1. Plants are *Bemisia tabaci* hosts

   a. Yes ……………….2

   b. No ……………….Done

2. Plants are cuttings in propagation being rooted

   a. Yes ………………..3

   b. No ………………..4

3. Rooting level during propagation

   a. Mist on, cuttings are newly stuck and not anchored ………………..Table A

b. Mist off, cuttings are anchored in the soil and able to withstand spray ………… applications ……………….Table B

4. Plants are rooted cuttings and ready for shipment

a. Yes ……………….Table F

b. No ……………….5

5. Plant development after transplanting

a. Root system is not well developed …………..Table C

b. Roots are well developed and penetrating the soil to the sides and bottom of the pots ………………6

6. Plants are actively growing finished plants or stock

a. Plants are more than two weeks from shipment or first cutting harvest ………Table D

b. Plants are two weeks from shipment or first cutting harvest ……………...Table E

c. Plants or cuttings are 2 to 3 days from shipment ………………Table F

Whitefly Resistance Management

There are multiple factors which can affect resistance development in a pest against a selected insecticide. The greater the number of whiteflies present when an insecticide application is made, the greater the chance that at least one individual might possess the ability to survive the treatment. The more frequently a given pesticide or mode of action is used, the greater the potential that a resistance problem will develop. In other words, selection for resistance in whiteflies against an insecticide can occur when their applications are made to successive generations of the pest. In addition, the longer the residual activity, the greater the selection pressure on a resident whitefly population. Therefore, limiting applications of products with similar modes of action will decrease the potential for resistance development. If the insecticide is properly applied and is not providing control, change to another material with a different mode of action because whitefly populations have the propensity to develop resistance. Scouting every week is critical to success by catching populations early and evaluating insecticide performance during production. While rotating insecticides it is important to consider that IRAC Class 9B exhibits cross resistance with IRAC Class 4.

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Laboratory Authorized to Determine Whitefly Biotype

For information about how to collect whitefly samples and preserve it for evaluation and directions for scheduling shipments, you can contact:

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Fort Pierce, FL 34945
Phone: 772-462-5917
Email: cindy.mckenzie@ars.usda.gov

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Table A. Cuttings are not anchored in soil.

Suggested products	IRAC class	MEAM1	MED
Foggers and aerosol generators	Manys	Yes	Yes

Table B. Cuttings able to withstand sprays.

Suggested products	IRAC Class	MEAM1	MED
Foggers	many	yes	yes
Avid (abamectin) + pyrethroid or acephate	6 + 3 or 1	yes	yes
Beauveria bassiana	n/a	yes	yes
PFR-97 (*Isaria fumosorosea*)	n/a	yes	yes

Table C. Root system is not well developed.

Suggested products	IRAC class	MEAM1	MED
Avid (abamectin)	6	Yes	Yes
Distance (pyriproxyfen)	7C	Yes	No
Endeavor (pymetrozine)	9B*	Yes	No
Enstar II (kinoprene)	7A	Yes	No
Sanmite (pyridaben)	21	Yes	Yes
Talus (buprofezin)	16	Yes	No
Tank mixes			
Avid + Talstar	6 + 3	Yes	Yes
Pyrethroids + acephate	3 + 1	Yes	No
Pyrethroids + azadirachtin	3 + 18	Yes	No

Table D. Plants are actively growing.

Select products based on the biotype of any whiteflies that are present. Rotating products during this production stage is essential. Where plants are tolerant, tank mix with horticultural oil to help minimize resistance development. Not all poinsettia cultivars are tolerant to Judo or Kontos during bract color development; it is recommended to apply these prior to bract formation and test on a small number of plants prior to spraying entire crop.

Suggested products for foliar applications on actively growing plants	IRAC class	MEAM1	MED
Avid + Pyrethroid	6 + 3	Yes	Yes
Beauveria bassiana	n/a	Yes	Yes
Bug Oil (tagetes oil)	n/a	-	Yes
Distance (pyriproxyfen)	7C	Yes	No
Enstar II (kinoprene)	7A	Yes	No
Horticultural oil	n/a	Yes	Yes
Insecticidal soap	n/a	Yes	Yes
Judo (spiromesifen)	23	Yes	Yes
Kontos (spirotetramat)	23	Yes	Yes
M-Pede	n/a	Yes	Yes
Orthene + pyrethroid	1 + 3	Yes	No
PFR-97	n/a	Yes	Yes
Rycar (pyrifluquinazon)	9B	Yes	Yes
Sanmite (pyridaben)	21	Yes	Yes
Talus (buprofezin)	16	Yes	No

Table E. Plants are two weeks from shipment or first cutting harvest.

Control of whiteflies is often challenging during this stage due to the difficulty of achieving adequate under leaf spray coverage, a lack of labeled products from multiple IRAC Classes, and concerns about phytotoxicity or residue on final product. Apply a drench or foliar application 14 days prior to shipment of finished plants or the initial harvest of cuttings from stock plants. If adequate spray coverage cannot be achieved, plants should be drenched. To reduce resistance development, do not use products listed in Table E that were applied prior to this growing stage. If multiple cutting harvests are taken from stock plants, rotate a neonicotinoid drench application (IRAC Group 4) with foliar applications of Judo and Sanmite, including other products as needed from Table D in different IRAC Classes.

Suggested products for plants or stock plants	IRAC class	MEAM1	MED
Soil drench or foliar applications			
Flagship (thiamethoxam)	4	Yes	Yes
Marathon (imidacloprid)	4	Yes	No
Safari (dinotefuran)	4	Yes	Yes
Soil drench			
Mainspring (cyantraniliprole)	28	Yes	Yes
Foliar applications			
PFR-97	n/a	Yes	Yes
Rycar (pyrifluquinazon)	9B	Yes	Yes
Sanmite (pyridaben)	21	Yes	Yes
TriStar (acetamiprid)	4	Yes	Yes

Table F. Plants or harvested cuttings are 2–3 days before shipping.

Make foliar applications 2–3 days before shipping finished plants or rooted cuttings or before each cutting harvest when shipping unrooted cuttings. To reduce resistance development, avoid applications of modes of action used in the previous growth stage (Table E for finished plants or stock, and Table B for rooted cuttings).

Suggested products for harvested cuttings	IRAC class	MEAM1	MED
Avid (abamectin)	6	Yes	Yes
Flagship (thiamethoxam)	4	Yes	Yes
Judo (spiromesifen)—targeting nymphs at this plant stage for unrooted cuttings or cultivars tested for crop safety	23	Yes	Yes
PFR-97	n/a	Yes	Yes
Safari (dinotefuran)	4	Yes	Yes
Sanmite (pyridaben)	21	Yes	Yes
TriStar (acetamiprid)—targeting adults at this plant stage	4	Yes	Yes

Table G-1. Insecticide efficacy for *Bemisia tabaci* MEAM1 and MED on Poinsettia.

Experiment	**Bethke 2005a**	**Bethke 2005b**	**Gilrein 2005**	**Oetting 2005a**	**Oetting 2005b***	**Gilrein 2006a**	**Gilrein 2006b***	**Oetting 2006b**	**Oetting 2007e**	**Oetting 2008e**	**Gilrein 2009a**	**Gilrein 2009b***
Initial Population Level of Untreated per leaf	n/a	n/a	2.1 to 2.4	2.3 to 6.5	2.6 to 7.0	15.2 to 22.3	57.4 to 75.2	2.7 to 8.3	6.4 to 37.2	3.1 to 5.1	31.2 to 43.2	65.0 to 88.1
DAT of assessment	21 DAT	24 DAT	21 DAT	21 DAT	21 DAT	17 DAT	20 DAT	22 DAT	21/28 DAT	22 DAT	21 DAT	20 DAT
Population Assessed	Adults		Immatures									
Population Counts per Leaf on Untreated	n/a	n/a	16.8	23.1	9.1	35.4	59.2	13.8	38.2	10.1	178.2	523.4
Aria 50SG (flonicamid)				-					- (++ 35 DAT)	-		
Avid 0.15EC (abamectin)		+					+			+		++
Distance 0.86EC (pyriproxyfen)		++	-	+								
DuraGuard (chlorpyrifos)		-										
Flagship 25WG, Meridian 25WG, (thiamethoxam)	-		-		+		+/-		- (+ 35 DAT)	+		
Judo 4F, Forbid 4F, (spiromesifen)		++	+	++		+			- (++ 35 DAT)	++		
Kontos (spirotetramat)									- (++ 35 DAT)	+	++	++
Marathon II 2F (imidacloprid)	-		-	+					- (++ 35 DAT)	+	+/-	
Ornazin (azadiractin)						-						
Orthene (acephate) + Tame (fenpropathrin)					+		+/-					
Pedestal (novaluron)								-				
Safari 20SG (dinotefuran)	++		+	++		+	- (++ 45 DAT)	++	++	+	++	++
Sanmite (pyridaben)		+								+		++
Talstar (bifenthrin)		-										
Talus (buprofezin)		-										
Tame (fenpropathrin)		-										
TriStar 30WSP (acetamiprid)	++							++				++

Experiment	Bethke 2005a	Bethke 2005b	Gilrein 2005	Oetting 2005a	Oetting 2005b*	Gilrein 2006a	Gilrein 2006b*	Oetting 2006b	Oetting 2007e	Oetting 2008e	Gilrein 2009a	Gilrein 2009b*
TriStar 70WSP (acetamiprid)					++				- (++ 35 DAT)	++	++	

This table is extracted from the IR-4 Whitefly Summary 2014 found at http://ir4.rutgers.edu/Ornamental/ornamentalSummaryReports.cfm. To review the entire table or individual experiments, download the full summary.
[1] Rating Scale: ++ = clearly statistically better than untreated and greater than 95% control; + = statistically better than untreated and between 85 and 95% control; +/- statistically better than untreated with control between 70 and 85%; - = statistically equivalent to untreated and/or efficacy less than 70%.
[2] Where more than one rate or application type for a product was included in the experiment and each performed statistically different, the better rating is provided in this table.

Table G-2. Summary of insecticide efficacy trials (2016) on potted mint or salvia plants.

Tested Products for Actively Growing Plants	IRAC Class	MED (effective)
	Foliar application	
Endeavor (pymetrozine)	9B	No
Rycar (pyrifluquinazon)	9B	Yes
	Soil drench	
Safari (dinotefuran)	4A	Yes
Mainspring (cyantraniliprole)	28	Yes

Note: There are three types of MED whitefly present in the United States; efficacy of an insecticide may vary depending upon the MED population. Mention of a commercial or proprietary product or chemical does not constitute a recommendation or warranty of the product by the authors. Products should be used according to label instructions, and safety equipment required on the label and by federal or state law should be employed. Users should avoid the use of chemicals under conditions that could lead to ground water contamination. Pesticide registrations may change, so it is the responsibility of the user to ascertain if a pesticide is registered by the appropriate local, state and federal agencies for an intended use. Trademarks and registered trademarks for mentioned products or chemicals belong to their respective owners.