If infestations are managed chemically, and the same pesticide, or class of pesticide, is used to manage the pest, resistance is likely to occur.

Florida growers produce tomato and bell pepper throughout the majority of the year. Continuous propagation of a certain type of plant eventually leads to pest infestations. If infestations are managed chemically, and the same pesticide, or class of pesticide, is used to manage the pest, resistance is likely to occur. The rate of resistance development depends on the genetics of the pest and the number of times the pest population is exposed to the pesticide.

WHAT IS RESISTANCE?

Resistance is a decrease in the sensitivity of a pest population to a toxicant (pesticide). The evidence of this occurrence is reduced mortality at application rates historically capable of killing the vast majority of the pest. Resistance can develop in two different ways that are not exclusive:

- The organism either limits the amount of toxicant that gets to the target site (by behavior, exclusion or metabolic inactivation).
- The target site itself has changed in a way that the toxicant no longer interacts with it, yet the target pathway still functions well enough for the pest population to thrive.

Figure 7. Bacterial spot is known to have resistance to copper fungicides. Photograph by: Ken Pernezny.

WHERE HAS RESISTANCE BEEN OBSERVED?

- **Arthropods** — Pyrethroid-resistant whitefly developed in the late 1980s, and this problem was not alleviated until new chemistry (imidacloprid, spinosad) supplanted the pyrethroids. Resistance monitoring is now being conducted for the neonicotinoids, so that resistant populations can be identified and managed.
- **Fungal** — Organisms such as *Phytophthora* spp. are known to have multiple biotypes that dictate management.
- **Bacterial** — Bacterial spot is a disease known to have resistance to copper fungicides; copper must be mixed with mancozeb/maneb to overcome this problem.
- **Weed pests** of tomato, and to a lesser degree pepper — Weeds such as American black nightshade and goosegrass have become resistant to paraquat due to the long-term use of this herbicide in row middles.

PESTICIDE MODE-OF-ACTION (MoA)

In order to address resistance, three action committees have been formed to categorize pesticide mode-of-action (MoA):

- Insecticide Resistance Action Committee (IRAC) — insecticides and miticides (See Appendix 5)
- Fungicide Resistance Action Committee (FRAC) — fungicides (See Appendix 6)
- Herbicide Resistance Action Committee (HRAC) — herbicides (See Appendix 7)

Herbicides (HRAC) Mode-of-Class for Tomatoes and Peppers

Herbicide	HRAC Mode-of-Action Class
Bensulide*	8
Carfentrazone	14
Clethodim	1
Clomazone*	13
DCPA	3
Diquat	22
Glyphosate	9
Halosulfuron	2
MCDS	no class
Metribuzin**	5

Herbicide	HRAC Mode-of-Action Class
Nepropamide	15
Oxyfluorfen	14
Paraquat	22
Pelargonic acid	no class
Rimsulfuron**	2
Sethoxydim	1
S-metolachlor	15
Trifloxysulfuron**	2
Trifluralin	3

* Bell pepper only
** Tomato only

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CHEMICAL CONTROL:
Pest Resistance

Managing Resistance:

Resistance is most effectively managed by switching to a different category of pesticide. Other methods (using more material, making more applications, using several categories of pesticide at once) are generally more expensive (more pesticide to buy, more fuel and time required for application) and less desirable (loss of beneficial insects, greater environmental load, increased loader/applicator exposure).

Although there are over two dozen categories for each of these groups, it is important to realize that a pesticide from each group may not be available to tomato or pepper growers. Pesticide manufacturers are starting to place the MoA category on pesticide labels. The EPA has recently released voluntary guidelines that suggest that this information should be placed in the upper right quadrant of the first page of the label. The category number should be in black, on white background, enclosed in a narrow black rectangular box. This labeling will make future pesticide selection easier with regard to resistance management.

SOME PESTICIDES DO NOT HAVE A TRUE MoA:

It should be noted that some pesticides do not have a true MoA. Insecticides such as petroleum oil, soaps and boric acid work by either smothering an insect or stripping the wax off the pest which then dies of dehydration. These materials can be used to break the cycle of resistance just as efficiently as switching to another category of pesticide. However, the application and timing of these materials is critical as they do not move within the plant. Fungicides may have several sites of activity such as the case for sulfur and the dithiocarbamates (maneb, mancozeb, etc.). These multi-site fungicides are useful for decreasing resistance due to this activity. Herbicides such as pelargonic acid and acetic acid (vinegar) work by stripping away protective wax cuticles of the plant causing death by desiccation much like the action of boric acid on insects.

Tomato and pepper growers should be aware of chemical management options available, keep records on pest response and consult with pest management professionals when questions arise. Managing resistance will ultimately be rewarded with reduced effort and associated costs of pest control.

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Fungicides (FRAC) Mode-of-Action Class for Tomatoes and Peppers:

Fungicide	FRAC Mode-of-Action Class
Acibenzolar-methyl*	P
Axoxystrobin	11
Bascalid	7
Chlorothalonil*	M4
Coppers	M1/M9
Cymoxanil	27
Dicloran*	14
Dimethomorph	15
Famoxadone	11
Fludioxonil**	12
Fosetyl-Al*	33
Mancozeb*	M2
Maneb	M2
Mefenoxam	4
Myclobutanil*	3
Pentachloronitrobenzene (PCNB)	14
Potassium bicarbonate	no class
Potassium phosphate	P
Propamocarb	28
Pyraclostrobin	11
Pyrimethanil*	9
Streptomycin	25
Sulfur	M1
Trifloxystrobin	11
Ziram*	M2
Zoxamide*	22

* Tomato only
** Seed treatment only