Pesticides are available that are effective against most of the life stages of most of the important insect pests of tomatoes and other vegetables; these pesticides can be less detrimental to certain natural enemies of these pests.

"Biorational" has only recently been proposed to describe those insecticides that are efficacious against the target pest but are less detrimental to natural enemies. The term at times has been used to describe only those products derived from natural sources, i.e. plant extracts, insect pathogens, etc. However, we choose to define a biorational pesticide as "any type of insecticide active against pest populations, but relatively innocuous to non-target organisms and therefore, non-disruptive to biological control." An insecticide can be "innocuous" by having low or no direct toxicity, or by having systemic or rapid translaminar activity or short field residual, thereby minimizing exposure of natural enemies to the insecticide.

Figure 1. Coverage is important when using oil on whitefly nymphs. Photograph by: James Castner.

OIL, SOAP AND NEEM

- **Oil** was also repellent to whitefly adults but reduced yields of tomato in the field when applied at a concentration higher than 2%. Studies showed that soap, neem and oil were all toxic to silverleaf whitefly nymphs, although coverage was particularly important for oil. Oil was relatively non-toxic to adults of two species of lacewings (*Chrysoperla rufilabris* and *Ceraochrysa cubana*) and to adults of a small lady beetle species (*Nephaspis oculatus*), and was moderately toxic to larvae of a major whitefly parasite species (*Encarsia pergandiella*) and to larvae of a non-trash bearing species of lacewing (*C. rufilabris*)). Oil was highly toxic to adults of the parasite species, to eggs of both lacewing species and, to a lesser extent, lady beetle eggs. Toxicity was again mitigated by coverage.

- **Soap** was highly toxic to whitefly adults but only when wet. Soap caused only slight effects on the parasite species and was moderately toxic to adults of both lacewing species and to larvae of the non-trash bearing lacewing species. Conversely, soap was highly toxic to young lady beetle larvae.

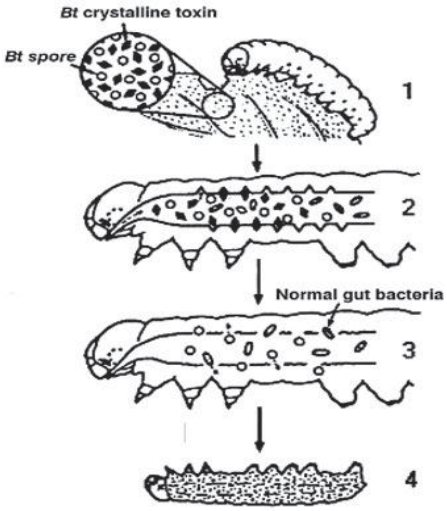
Figure 2. Soap is a highly effective agent to whitefly adults when wet. Photograph by: James Castner.

- **Neem** is reportedly an antifeedant to whitefly adults and is practically non-toxic to both species of lacewings and to the parasite. In general, trash bearing lacewing larvae were less susceptible to all three biorational pesticides than non-trash bearing larvae, even when considering the broad-spectrum pyrethroid bifenthrin.

- The potential of a **liquid dish detergent and a parafinnic oil (Ultrafine Oil™)** to cause phytotoxicity on tomato also was investigated. It was found that applications of 0.5% or more detergent applied twice weekly delayed production. Weekly applications were less damaging. On the other hand, no phytotoxic effect was seen on pepper from weekly applications of concentrations of oil up to 2% applied with or without mancozeb/maneb plus copper.

Prepared by: Drs. David Schuster and Phillip Stansly

The non- or low toxic effects of products based upon the bacterium, Bacillus thuringiensis, are documented for numerous species of natural enemies of numerous pests.



WHAT IS *Bt*?

- Bt is a bacterium that is pathogenic to larvae of certain insects, particularly lepidopterous insects, inducing mortality through infection.
- The resting stage, or endospore, of the bacterium contains endotoxins which are capable of paralyzing and lysing the insect gut, thereby causing mortality through starvation **(Figure 3)**.
- The endotoxins are not equally toxic to all species of Lepidoptera **(Table 1)**; therefore, wild strain selection, conjugation or recombinant DNA techniques have been used to develop *B. thuringiensis* products that have different arrays of endotoxins to alter or broaden the spectrum of activity of the product **(Table 2)**.
- In general, the products are effective against armyworm and fruitworm larvae.
- From the standpoint of resistance management, products with different arrays of endotoxins should be alternated; however, many products contain endotoxins in common **(Table 2)**.
- Rotate wild-type *B. thuringiensis* var. *kurstaki* products (i.e. Dipel, Javelin) with either wild-type *B. thuringiensis* var. *aizawai* products (i.e. XenTari) or with genetically modified *B. thuringiensis* products (i.e. Agree, Crymax, Lepinox, Mattch).

BACILLUS THURINGIENSIS (*Bt*) PRODUCTS:

Products for control of lepidopterous larvae are based upon two subspecies of *B. thuringiensis* var. *kurstaki* (i.e. Dipel™, Javelin™) and *aizawai* (i.e. XenTari™) or a combination of the two (i.e. Agree™).

As with insecticidal products, there is a time line of product evolution.

- First generation products: Based on wild-type isolates collected directly from nature (i.e. Dipel, Javelin, XenTari).
- Second generation products: Based upon conjugation of the two sub-species (i.e. Agree).
- Third generation products: Based upon the so-called *Psuedomonas*-based delivery system (insertion of *B. thuringiensis* genes into *Psuedomonas* bacteria for the purpose of increasing field persistence, i.e. Mattch™).
- Fourth generation products: Based upon new *B. thuringiensis* strains constructed using recombinant DNA technology (i.e. Crymax™, Lepinox™).

Figure 3. Products containing *Bacillus thuringiensis* var. *kurstaki* kill the caterpillar stage of a wide array of butterflies and moths. Diagram by: UF/IFAS.

Table 1. Relative toxicity of *Bacillus thuringiensis* endotoxins to larvae of selected species of Lepidoptera.

	Endotoxin					
Species	IA(a)	IA(b)	IA(c)	IC	ID	IIA
Diamondback Moth	+++	+++	++++	+++	++	-
Cabbage Looper	+++	+	++++	+++	++	++++
Beet Armyworm	-	+	-	++	+	-
Fall Armyworm	-	+	-	-	++	+
Fruitworm/Earworm	+	++	+++	-	+	++

++++ = LC_{50} <10 µg/175mm^2; +++ = LC_{50} 10-100 µg/175mm^2;
++ = LC_{50} 100-1,000 µg/175mm^2; + = LC_{50} 1,000-10,000 µg/175mm^2;
- = LC_{50} >10,000 µg/175mm^2

Table 2. Relative amounts (increasing number of "+s") of endotoxins present in selected *Bacillus thuringiensis* products. A "-" indicates the endotoxin was not present.

	Endotoxin					
Product	IA(a)	IA(b)	IA(c)	IC	ID	IIA
Dipel/Javelin	+	+	+	-	-	+
Mattch	-	+	-	+		-
Agree	+	+	+	+	+	-
XenTari	+	+	-	+	+	-
Crymax	-	-	+++	+	-	+
Lepinox			+	+*		+

Increasing numbers of "+s" indicate increasing relative concentration of the indicated endotoxin while a "-" indicates the endotoxin is not present.
*Hybrid

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It is always necessary to consider the entire pest complex when designing an IPM system for a particular crop because actions taken to control one pest may impact another pest or its natural enemies.

NEW INSECTICIDES:

A number of new insecticides in new chemical classes have recently become available or will likely become available in the near future **(Table 3)**. Unfortunately, little or nothing is known about the relative toxicity of these compounds to the natural enemies of interest to Florida vegetable growers; however, the biorational nature of the compounds can be predicted by the spectrum of activity and other characteristics of the compounds.

Nicotinoids:

- Highly systemic (i.e. they are distributed through the plant, primarily to new growth, when applied to the roots) and translaminar (i.e. readily absorbed into the leaf through the leaf surface).
- Soil-applied imidacloprid, thiamethoxam, and dinotefuran have provided control of the silverleaf whitefly for 8-12 weeks on tomato. Foliar applications of imidacloprid, thiamethoxam and dinotefuran controlled whitefly nymphs, but not as well as soil applications. Foliar applications of thiamethoxam and acetamiprid also controlled whitefly adults.
- Not only are soil applications of the nicotinoids more effective than foliar applications in controlling whitefly nymphs, the impact of soil applications on natural enemies would be expected to be less than that of foliar applications because most natural enemies would not be exposed directly to the compounds.

Table 3. New Insecticides in New Chemical Classes.

Chemical Action	Common Name	Trade Name	Target Pests
Systemics (nicotinoids)	Imidacloprid	Admire/Provado	whiteflies, aphids
	Thiamethoxam	Platinum/Actara	whiteflies, aphids
	Acetamiprid	Assail	whiteflies, aphids
Insect Growth Regulators	Pyriproxyfen	Knack	whiteflies, aphids
	Buprofezin	Applaud	whiteflies
	Tebufenozide	Confirm	leps
	Methoxyfenozide	Intrepid	leps
	Novaluron	Rimon	whiteflies, leps
Miscellaneous	Pymetrozine	Fulfill	aphids, whiteflies
	Spinosad	SpinTor	leps, leafminers
	Indoxacarb	Avaunt	leps
	Emamectin benzoate	Proclaim	leps, leafminers
	Rynaxypyr	Coragen	leps, leafminers, whiteflies
	Metaflumizone	Alverde	leps
	Spinetoram	Radiant	leps, thrips, leafminers
	Flubendiamide	Synapse	leps
	Pyridalyl	Tesoro	leps, thrips

Pymetrozine:

- Active against both nymphs and adults of aphids and whiteflies **(Figure 4)**.
- Has long residual activity because it is absorbed translaminarly and apparently is translocated to new foliage.
- Because the compound is translaminar and systemic and because it is highly specific to Homoptera (aphids and whiteflies), it should have minimal impact on natural enemies.

Pyriproxyfen and Buprofezin:

- Although both are insect growth regulators (IGRs) and both negatively impact development of immature life stages of whiteflies, they are in different chemical classes and affect whiteflies differently. Neither kills adults, but treated adults lay infertile eggs. Furthermore, eggs treated with pyriproxyfen fail to hatch while those treated with buprofezin tend to hatch normally. Pyriproxyfen interferes with the final molt of the whitefly from pupa to adult while buprofezin interferes with all nymphal molts.
- Both products are recommended for application to tomatoes as the effects of soil-applied imidacloprid diminishes.
- A threshold of 5 nymphs or pupae/10 leaflets has been established to time the applications.
- Because the IGRs affect development, control of whiteflies is not rapid. Although both of the IGRs would be expected to have minimal impact on natural enemies, pyriproxyfen has been shown to be highly toxic to pupae and moderately toxic to larvae of the whitefly parasite *Eretmocerous formosa*, but not to the whitefly parasites *E. pergandiella* and *E. transvena* . Buprofezin was toxic to larvae but not pupae of the whitefly parasite *E. tejanus* and was relatively non-toxic to larvae and adults of the parasite *E. mundus.*

Figure 4. New insecticides, such as pymetrozine are active against aphids and whiteflies. Photograph by: James Castner.

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The biorational nature of pesticides depends upon the time, pest and crop upon which they are used.

Figure 5. Tebufenozide, indoxacarb, spinosad and emamectin benzoate can control southern armyworm. Photograph by: Lyle Buss.

Tebufenozide, Methoxyfenozide and Novaluron:

- These IGRs affect development of the larval stages of the southern, beet and other species of armyworms. Novaluron also affects development of immature life stages of whiteflies.
- The controlling affect of the IGRs is not rapid.
- The IGRs would be expected to have minimal impact on natural enemies.

Other Miscellaneous Insecticides:

- Spinosad and spinetoram are in the same chemical class and provide control of armyworms, the tomato pinworm, thrips and have activity against leafminers.
- Indoxacarb, emamectin benzoate, rynaxypyr, metaflumizone, flubendiamide and pyridalyl all provide excellent control of larvae of several armyworm species **(Figure 5)**. The former two also provide control of the tomato pinworm. The activity of the remaining products against the tomato pinworm is not known at this time.
- Rynaxypyr also is active against leafminers and provides control of whitefly adults and nymphs when applied as either a soil drench or a foliar spray.
- Pyridalyl also is active against thrips.
- All of these new products have demonstrated minimal to very low toxicity to natural enemies.

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Figure 6. Reflective mulch is being used together with the reduced-risk insecticide, spinosad, that poses little threat to field workers or the environment. Photograph by: Eric Zamora.