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Organically Approved and Reduced Risk Pest Control Options for Fruiting Vegetable Production

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Field trials were conducted with pesticides approved (some very recently) by the United States Department of Agriculture for certified organic production in the United States for fruiting vegetables. The list includes copper octanoate (Cueva), clarified neem oil (Trilogy), *Gliocladium virens* (SoilGard), *Paecilomyces lilacinus* (Melocon), potassium salts of fatty acids (Des-X), *Bacillus thuringiensis* (Agree, Javelin, Deliver), and the nuclear polyhegrosis virus of *Helicoverpa* (Gemstar). Results from field trials have shown good activity controlling the common parasitic nematode, disease, insect, and mite pests encountered in Florida production systems using these products and following label directions.

Fruiting vegetables, including tomato (*Lycopersicon esculentum* L.), and pepper (*Capsicum annum* Mill.), continue to be very important crops in fresh market vegetable production in Florida and the southeastern United States. Fruiting vegetable production produced using pesticides approved for organic vegetable production represents a small portion of acres in the total production system in the United States at this time, but this market is expanding at a high rate. High demand for vegetables produced under approved organic conditions and corresponding high market prices have increased growers interest. Pest pressures can be particularly intense in Florida due to extended and over lapping growing seasons, and warm, wet and humid climate. This has been of particular concern in organic vegetable production especially in past years, when organically approved pesticide tools were few. This situation has changed dramatically in recent years as companies develop products appropriate for organic production.

In a 2008 survey (updated in 2010) there were approximately 132,776 USDA organically approved acres of vegetables (including potatoes) in the U.S. Florida accounted for 2,566 acres of this total, which places it as ranked number six in the United States (USDA, 2010). The total number of acres of organically grown tomatoes was estimated to be 8,818 acres with 870 acres of peppers. Growing any fresh market vegetable crop in Florida can be very challenging as far as adequately controlling insects, mites, diseases, nematodes, and weed pests (Olson et al., 2010; Pohronezny et al., 1996). High temperatures, humidity, and rainfall, as well as long and overlapping growing seasons, have made pest control difficult under the best of conditions. Growers hoping to produce reduced risk or organically approved produce have in the past found it difficult to control these pests with the limited number and variety of approved pest control pesticide alternatives available. However, this situation has seen dramatic change in the past few years. Major advances in the development effective and cost competitive products have been developed, labeled, and marketed by Certis USA and other companies for use in organically approved and reduced risk fruiting vegetable production.

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Materials and Methods

Copper octanoate (Cueva™) is a very effective and plant-safe copper formulation that is very effective against a wide range of common bacterial (bacterial leaf spot, bacterial speck) and fungal (early blight, late blight, powdery mildew, anthracnose, *Phytophthora capsici*) tomato and pepper pathogens. The active amount of metallic Cu in copper octanoate is 1.8% wt/vol, which is about one-fifth of the total metallic Cu content seen in standard Cu products. This unique fatty acid based formulation helps the Cu active ingredient to penetrate fungal or bacterial cells, and also helps in spreading the product on plant surfaces. The typical commercial use rate ranges from 0.5 to 2 gal per 100 gal finished spray, with the common use rate in tomatoes 2–3 qt/acre. Copper octanoate should be applied at least every 7 d or more often when diseases conditions are severe. Copper octanoate has no adverse effect on beneficial insects; very low phytotoxicity risk compared to other copper products, and has a 4-h re-entry interval (REI).

Clarified neem oil (Trilogy®) is a product that has activity on plant pathogenic fungi mites, and insects. It is used as a contact fungicide for protection of tomato against diseases such as early blight, late blight, powdery mildew and anthracnose. The recommended rate is from 0.5% to 1% vol/vol, with a typical commercial rate in tomatoes of 4 qt/acre. Clarified neem oil should be reapplied as a fungicide every 7–14 d, or more often if disease conditions are severe. The commercial use rate is normally 1% vol/vol, with a REI of 4 h and no preharvest interval. It is also has a minimum impact on beneficial insects.

Gliocladium virens strain GL-21 (SoilGard®) is a granular formulation containing spores of the fungus (also known as *Trichoderma virens*), and is a naturally occurring beneficial fungus derived from soil. It is a preventative fungicide used for control of "damping off" diseases that prevent establishment of healthy plants and decrease yield. The fungus in *Gliocladium virens* strain GL-21 directly attacks and kills pathogenic fungi, parasitizes any that survive, and prevents re-infestation by competitive exclusion. It is effective against a wide range of plant pathogens in tomatoes including *Phytophthora* (pepper blight), *Pythium, Rhizoctonia, Fusarium* (crown rot), *Sclerotium rolfsii* (white mold, southern

blight, southern stem blight), *Sclerotinia* spp. (white mold), and others. SoilGard can be applied in a flexible application regime for tomatoes, including a transplant drench while seedlings are in the greenhouse, chemigation, drench at plant, or soil incorporation pre plant. It has a 0-day preharvest interval and re-entry interval, and a signal word "Caution." The typical commercial use rate is 5 lb/acre.

Paecilomyces lilacinus strain 251 (Melocon WG®) is a granular formulation containing spores of this naturally-occurring beneficial fungus from soil. It is used as an inundative release bionematicide for control of plant parasitic nematodes that prevent establishment of healthy plants and decrease yield. *Paecilomyces lilacinus* strain 251 controls a wide range of plant parasitic nematode species, including root knot, sting, root lesion, stubby root, burrowing, reniform, and cyst. It attacks all life stages of the nematode (eggs, immatures, and adults). It has a 0-day preharvest interval, a 4-h REI, and a signal word "Caution." The common commercial use rate is 4 lb/acre.

Azadirachtin, which is the active ingredient in Neemix 4.5 ® and Neemazad 1% EC® is extracted from the neem tree *Azadirachta indica* A. Juss. seed (Schultz, 1992). Azadirachtin acts as a broad-spectrum insect growth regulator that inhibits normal insect development, disrupts insect reproductive ability, and deters insect feeding. They are very effective against many common tomato insects, including silver leaf whitefly, aphids, leaf miners, and thrips. Azadirachtin undergoes translaminar translocation upon foliar application. Typical commercial use rates are 4–8 oz/acre for Neemix, and 2–4 pt/acre for Neemazad.

Clarified neem tree oil (Trilogy®), referenced above as a fungicide, also acts as a miticide and insecticide. Clarified neem tree oil acts as a desiccant and toxicant against mites, and also repels and prevents host recognition by thrips and other insects. Because clarified neem tree oil is botanical oil, it also suffocates soft-bodied insects and spider mites with little risk of resistance. As a miticide/insecticide it is labeled at from 0.5% to 2% vol/vol.

The potassium salts of fatty acids (Des-X Insecticidal Soap®) act as a fast-acting, broad-spectrum insecticide/miticide, killing aphids, mites, whiteflies (and other soft-bodied insects) on contact. The potassium salts of fatty acids act by disrupting membrane and cellular function on contact, and is effective on all life stages. The effect of this insecticide on the waxy cuticle of insects can enhance the efficacy of other insecticides such as pyganic and spinosad. The potassium salts of fatty acids have a re-entry interval of 12 h and no preharvest interval. It is very safe for beneficial insects and the probability of insect resistance is low. The commercial use rate is 1% vol/vol.

The *Bacillus thuringiensis (B.t.)* based insecticides Agree WG® (*B.t. aizawai* strain) plus Javelin WG® and Deliver® (*B.t. kurstaki* strain) are highly specific insecticides, only affecting the larvae of the order *Lepidoptera* (moths and butterflies). The insecticidal activity of *Bacillus thuringiensis* results from the production of crystallized delta-endotoxins (Cry proteins) during sporulation, which have specific activity against various insect species including armyworms, tomato fruitworms, and tomato pinworms (VanFrankenhuyzer, 2009). The products must be ingested to be effective, and smaller larvae (1st and 2nd instars) are impacted to a greater effect compared to larger larvae. They are very safe to the user and the environment, and highly compatible with integrated pest management programs, as they are very safe for beneficial arthropods. They have a 4-h REI and no preharvest interval. Their unique mode of action means that cross resistance with other insecticides will be unlikely. *Bacillus thuringiensis* products are typically applied to fruiting vegetables at from 1 to 2 lb/acre.

The nuclear polyhedrosis virus of *Helicoverpa* sp. (Gemstar LC®) is a bioinsecticide that is specific for the larvae of the tomato fruitworm (corn earworm) *Helicoverpa zea,* and the tobacco budworm *Heliothis virescens,* and must be ingested by the larvae to be effective. The product is highly host specific, and is safe for beneficial insects and mammals. It has a 4-h REI and no preharvest interval, and its unique mode of action means that the resistance risk is low. Smaller larvae (1st and 2nd instars) are impacted to a greater effect compared to larger larvae. The commercial use rate in tomatoes is 4–10 oz/acre, and more frequent applications are generally more effective than increased rate.

All of these Certis USA products listed and discussed above are approved for fruiting vegetable organic production under the USDA National Organic Program (NOP) and are listed by the Organic Materials Review Institute (OMRI). All have favorable environmental profiles and are safe for users and non-target organisms.

The results outlined below are from trials conducted in small block replicated and randomized manner under normal growing conditions for the areas under consideration. Trials were conducted under commercially acceptable practices under pest pressures common to the crop and specific growing area and climate encountered during the trial timing. Normal commercially acceptable pest control techniques were employed. Tomato transplants were normally set into 50:50 methyl bromide : chloropicrin fumigated soil in polyethylene-mulched, raised beds unless otherwise specified (Fig. 6 provides results from a greenhouse trial). Transplants were irrigated and fertilized through drip tape. Treatments were arranged in a randomized complete-block design with (usually) four blocks, each in a separate bed. The plot size varied according to trial, but was large enough to conduct plant sampling and yields when required (usually 10 plant samples). Experimental products were usually applied to the foliage with a CO_2 backpack sprayer delivering 50–60 gal/acre at 50 psi through two disc-core hollow cone nozzles spaced 12 inches apart on the boom, or as tractor-mounted hydraulic sprays at 60–100 gal/acre at 200 psi. The products *Gliocladium virens* strain GL-21 and *Paecilomyces lilacinus* strain 251 were applied by injecting through drip tape irrigation systems. Applications were begun when pest pressure was indicated or seasonally when normal applications would have begun in commercial situations. The number of applications of products and intervals are indicated in the figures. Normal commercial fungicide programs (in the case of insecticide trials) or insecticide programs (in the case of fungicide trials) were applied as normally acceptable. All experimental plots received normal commercially acceptable herbicide applications. If yield was estimated, tomato fruit were harvested two to three times and marketable fruit counted and weighed to determine total yield. Plant disease ratings or insect counts were made periodically in each plot as needed.

Results and Discussion

Table 1 outlines target pests and shows the products, plant stage at start of application, and suggested commercial rates for several products approved for organic production in fruiting vegetables. The list includes many of the most prominent diseases found in Florida grown fruiting vegetables, including early blight, late blight, bacterial leaf spot, pepper blight, and southern blight. The most important plant pathogenic nematode found in

Table 1. Organic tomato pest management calendar.

Pest	Product	Stage at application	Rate/acre
Diseases			
Early blight, late blight, anthracnose, powdery mildew, other foliar leaf spots	Copper octanoate Clarified neem oil	Vegetative growth to harvest	2–3 qt 1%
Bacterial leaf spot, bacterial leaf speck	Copper octanoate	Vegetative growth to harvest	2–3 qt
Pepper blight, *Phytophthora capsici*	*Gliocladium virens* strain GL-21 Copper octanoate	Transplant to breaker fruit	5 lb 2–3 qt
Rhizoctonia, Pythium, Fusarium crown rot, Southern blight, *Sclerotinia* stem rot	*Gliocladium virens* strain GL-21	Transplant to breaker fruit	5 lb
Nematodes			
Root knot, stubby root nematodes	*Paecilomyces lilacinus* strain 251	Vegetative growth to breaker fruit	4 lb
Insects/mites			
Silver leaf whitefly	Clarified neem oil Potassium salts of fatty acids Azadirachtin	Vegetative growth to harvest	1 % 2 % 4–8 oz or 2–4 pt
Leafminers	Azadirachtin	Vegetative growth to harvest	4–8 oz or 2–4 pt
Thrips (western, flower, chili)	Clarified neem oil Azadirachtin	Vegetative growth to harvest	1% 4–8 oz or 2–4 pt
Two spotted spider mites	Clarified neem oil Potassium salts of fatty acids	Flowering to harvest	 2%
Aphids	Clarified neem oil Potassium salts of fatty acids Azadirachtin	Vegetative growth to breaker fruit	1% 2% 4–8 oz or 2–4 pt
Tomato fruitworm, armyworms	*Bacillus thuringiensis* Azadirachtin Nuclear polyhedrosis virus	Vegetative growth to harvest	1–2 lb 4–8 oz 4–10 oz
Tomato pinworm	*Bacillus thuringiensis* Azadirachtin	Vegetative growth to harvest	0.75–1 lb 4–8 oz

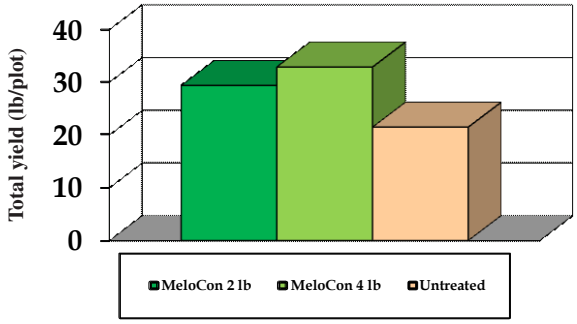

Fig. 1. *Paecilomyces lilacinus* strain 251 for root knot nematode in tomato, D. Seal, UFL, Homestead FL, 2008.

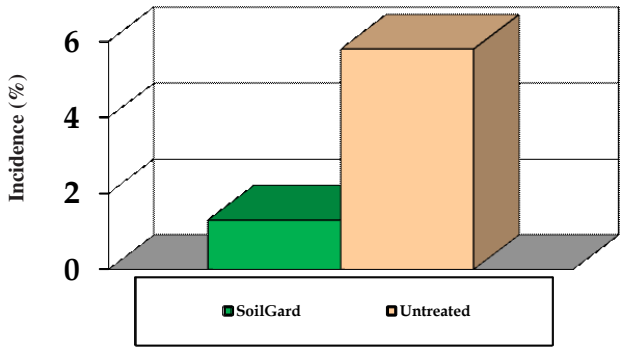

Fig. 2. *Gliocladium virens* strain GL-21 for southern blight incidence in tomato, Florida Ag Research, Dover, FL, 2009.

Florida grown fruiting vegetables is the root knot nematode, and is included on the list of targets. Important insect and mite pests included on the list on Table 1 include the silver leaf whitefly, leaf miners, thrips, and armyworms. Of course the list below was by no means inclusive of all of the important pests attacking fruiting vegetables in Florida (Olson et al., 2010), however, many other products exist on the market that are effective and approved for organic production and can be incorporated into programs as the need arises.

Figures 1–9 outline product development trials conducted in Florida with many of the products listed in Table 1. All of the trial results point out that these products can be incorporated into an organically approved IPM system to reduce plant damage, increase plant growth, and improve crop yield when used according to label directions and at the recommended rates. In a commercial setting growers were encourage to incorporate as many different control activities and products as possible, and to discourage the use of single products in any control scheme.

With these organically approved products from Certis USA (and others developed by other companies), southeastern U.S.

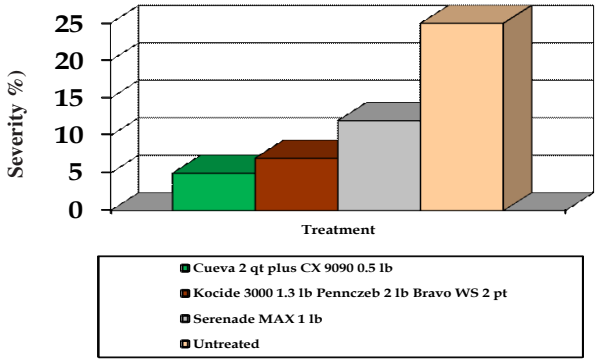

Fig. 3. Copper octanoate vs. bacterial leaf spot in tomato. P. Roberts, University of Florida, Immokalee, 2009.

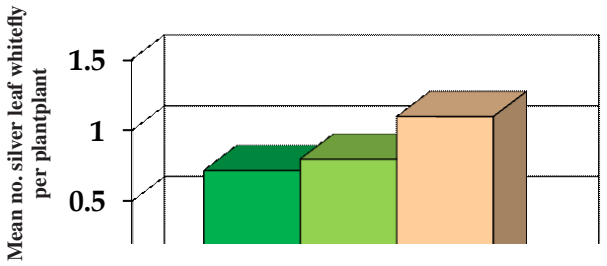

Fig. 4. Azadirachtin for silver leaf whitefly and reduction of TYLC incidence in tomato. D. Seal, University of Florida, Homestead, 2001. (All treatments except for UTC received 8 oz Admire at planting).

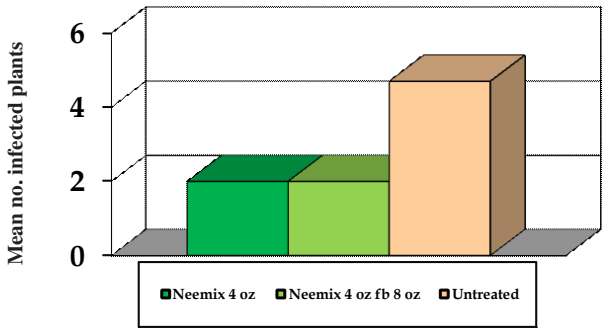

Fig. 5. Azadirachtin for silver leaf whitefly and reduction of TYLC incidence in tomato. D. Seal, University of Florida, Homestead, 2001.

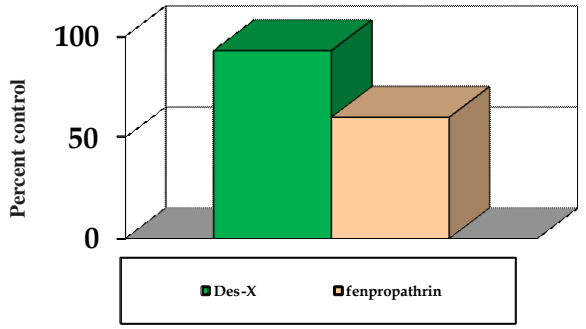

Fig. 6. Potassium salts of fatty acids for greenhouse whitefly control in greenhouse tomato, Neudorff County.

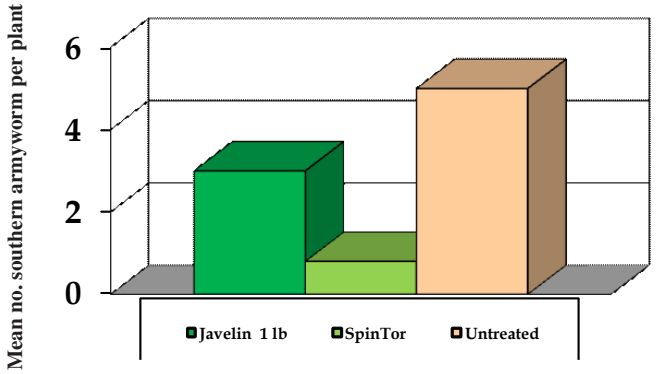

Fig. 7. *Bacillus thuringiensis* for southern armyworm in tomato. P. Stansly, University of Florida, Immokalee, 2000.

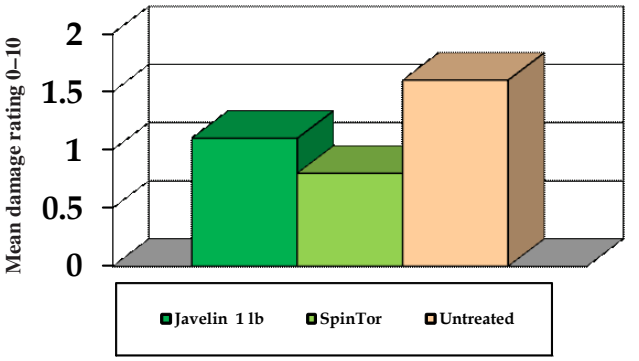

Fig. 8. *Bacillus thuringiensis* for southern armyworm in tomato. P. Stansly, University of Florida, Immokalee, 2000.

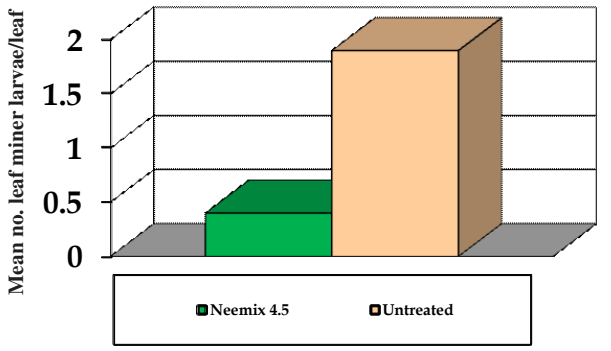

Fig. 9. Azadirachtin for vegetable leaf miner (in jalepeno pepper. B. Ahumada, Guasave, Sinaloa, Mexico, 2008.

fruiting vegetable growers now have an effective and extensive pest control arsenal for use in their production systems. One notable gap in the available product line for organic tomato and pepper production are efficacious and cost-effective herbicides. Weed control in organic vegetable production relies primarily on cultural activities, including tillage, mowing, mulches, cover crops, and flaming (William Curran, Penn State University, personal communication). Presently, products such as the organic salts of fatty acids, plant-derived oils such as terpenoid-based citrus oil,

clove, and thyme oils, natural acids such as acetic and citric, and natural plant-based non-synthetic surfactant extracts are being developed for commercial use in organic production. Naturally occurring plant parasitic fungi that target specific weed species are also being commercialized for future use.

The targeted and proper use of organically approved pesticide products makes the goal of achieving viable organic and reduced risk fruiting vegetable crop production increasingly likely in Florida, even with the challenge of the pest spectrum and intensity often encountered.

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