CIR1443

UF UNIVERSITY of FLORIDA IFAS Extension

Strawberry Pest Management Strategic Plan (PMSP)[1]

Mark A. Mossler and O. Norman Nesheim[2]

APPENDIX

Table 1. Efficacy ratings for pest management tools against invertebrate pests in Florida strawberry.

Table 2. Toxicity of pest management tools to beneficials in Florida strawberry.

Table 3. Indications for disease management products used on Florida strawberries.

Executive Summary

Florida ranks second in the U.S. in the production of strawberry, providing 15 percent of the total U.S. crop, and 100 percent of the domestically-produced winter crop. Because of the great value of winter strawberries and the high competition on either end of the production window, this crop is highly integrated in all aspects, especially pest management. However, the loss of methyl bromide and greater restrictions on remaining fumigants are the largest IPM consideration for this production system. Secondary pests (such as thrips) and emerging pests (such as whitefly, aphids, and birds) do exist for Florida strawberry producers. Additionally, resistance issues (generally for miticides and fungicides but also noted for a herbicide) exist in this production system. PMSP members expressed confidence that these issues may well be addressed by a combination of research, education, and regulatory actions. A revision to the PMSP meeting held in late 2003 was done to address mainlymainly addressed fumigant use issues that affect strawberry, but also other topics which have changed since then. The following were placed on the ATo Do@ list.

Research

1. Examine efficacy of milbemectin on pest mites and thrips and toxicity to beneficial mites and beneficial thrips as well as phytotoxicity on current and potential Florida strawberry cultivars.

2. Conduct trials to identify cover crops that will reduce nematode populations.

3. Examine the possibility of using phage to manage angular leaf spot.

1. This document is CIR1443, one of a series of the Food Science and Human Nutrition Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date January 2004. Revised July 2007. Visit the EDIS Web Site at http://edis.ifas.ufl.edu.

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4. Examine the use of thiram as a bird feeding deterrent and devise new types of bird repellents.

Education

1. Educate growers/scouts with regard to whitefly identification and sanitation, especially on transplants.

2. Educate growers to the issue that in some cases (e.g. Roundup7) a brand name associated with an active ingredient (such as glyphosate) may have something Anew@ in it (such as diquat) which will influence the overall performance of the application and may/may not be used on strawberry.

Regulation

1. Determine if data exist that would allow a 2-day PHI for malathion and diazinon.

2. Refine planting window (currently 21 days) for dichloropropene, if possible.

3. Reduce the 110-day PHI for terbacil (Sinbar7) to 60 days.

4. Interact with registrant to facilitate state registration of clopyralid (Stinger7) in strawberry.

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Introduction

Florida ranks second in the U.S. in the production of strawberry, providing 15 percent of the total U.S. crop, and 100 percent of the domestically-produced winter crop. In 2004-2005, 179,000,000 pounds of fresh berries valued in excess of $196 million were produced on 7,300 acres ($26,850/acre). Over the last 10 years, Florida strawberry growers have increased their acreage 20 percent and their production volume 15 percent, while income has increased by 75 percent. Approximately 95 percent of Florida=s commercial strawberry production acreage is located in Hillsborough and Manatee counties with the remainder in several other counties in both north and south Florida. For this reason, a Pest Management Strategic Plan (PMSP) meeting for the Florida strawberry industry was conducted at the Farm Bureau office in Hillsborough County (Valrico), Florida. The revision to the plan was conducted by Extension specialists in 2007 to mainly address fumigant issues, but also weed control.

Because of the great value of the crop as well as the initial investment, it has historically been recommended that Florida strawberries be grown only on full-bed plastic mulch, and that a fumigant be applied to the bed as the plastic is laid over it. However, due to the restrictions on plant back with some of the fumigant and herbicide alternatives to methyl bromide, growers must now consider soil pest problems over a month before planting and make applications accordingly. Many producers are also now using or considering delivering fumigant in chemigation systems to reduce worker exposure. As of 2007, Methyl bromide, as of 2007, is only available only in a 50/50 mixture with chloropicrin, the latter whichand strawberry growers do not particularly favor the latter.

Several principal varieties are cultivated in Florida and these varieties can change yearly. To avoid re-introduction of mites, nematodes and other pathogens to the treated beds, growers are encouraged to use only the best quality transplants available. Transplants are set in late September through early November. Overhead irrigation is used to help establish plants and protect them from frost while drip irrigation is used after establishment. Following early vegetative growth, the cool nights and short days of winter stimulate the plant to produce flowers which, after pollination, develop into fruits ready for harvest in four to six weeks. This results in three or four crops of fruit from each plant (based on a 30-day cycle). Flowers are present on plants in production areas continuously from shortly after planting until the end of harvest, but there are typically two peak flowering periods each season, one in November or December, and the other in mid to late January. The average harvest period runs from late November through early April. Fruit are harvested by hand every two or three days throughout

the harvest season. Due to the frequency of harvest, preharvest intervals (PHIs) and restricted entry intervals (REIs) are important factors when growers select pesticides for use on strawberries. Pesticides are applied exclusively by ground application equipment. Florida=s warm, humid climate is ideal for the development of many insect and mite, nematode, disease, and weed pests. Additionally, birds have become a yearly problem for three out of the last four years(three out of the last four years) rather than a sporadic pest by consumption and damage of the strawberries. All of these pests were discussed at the Florida strawberry PMSP meeting.

Mites

Spider mites of the family Tetranychidae (especially the two spotted spider mite) are always the main mite pests, and cyclamen mites (family Tarsonemidae) are a sporadic mite problem. Transplants that arrive in Florida have been growing in northern fields (generally Canada or North Carolina) for months and have been exposed to various pest pressures. These producers try their best to provide pest-free plants, but many newer chemistries registered for field use on strawberry are not available to nurseries. Florida growers are encouraged by Extension specialists to monitor the transplants upon receipt for mites as well as aphids, immature whiteflies, and diseases. Once the condition of the transplants is understood, growers should decide to seek healthier transplants or prepare for pesticidal treatment after overhead watering/establishment ends.

The establishment period (approximately two weeks) when bareroot transplants are being irrigated overhead is the first period of pest management and Florida strawberry growers have very few chemical options because the irrigation water washes off the active ingredient. Consequently, any pest problems are often chemically unmanaged until the establishment period has ended. During this period, mites and lepidopteran larvae are the key arthropod pests. Lepidopteran larvae that were small upon arrival of the transplants are mature by the time establishment ends, and uncontrollable by B.t. sprays at that point. Consequently, mature larvae are often treated with methomyl, even though methomyl is not compatible with a predatory mite program. It is not hard to see that initial transplant pest pressures set the stage as tofor whether a grower can use a beneficial mite program, as well as for the entire mite/insect management program for the growing season. However, registration of spinosad on strawberry has provided growers with a product that is less toxic to predatory mites than methomyl at roughly the same cost per acre.

It was also noted by growers that weaker plants are infested by mites more quickly than stronger plants. The economic threshold for spider mites is presence of any life stage on five percent of the leaflets. In terms of chemical miticides, abamectin was being used (and possibly overused) just prior to the registration of bifenazate, hexythiazox, and etoxazole. Some growers were reporting resistance to abamectin.

These four active ingredients now make up the core of the spider mite chemical management system, although some growers not using predatory mites use bifenthrin and fenbutatin-oxide as miticides. Even though there appears to be many options for mite management, it should be noted that seasonal applications are limited to one for hexythiazox or etoxazole, two of bifenazate or fenbutatin-oxide, and four of abamectin.

Before the introduction of bifenazate, hexythiazox and etoxazole, when abamectin sensitivity was being questioned, Florida strawberry growers had an estimated 40 percent adoption of predatory mite programs. With the introduction of the new miticide chemistries, that rate has dropped to 25 percent, even though the two systems were roughly the same cost as reported by growers in attendance. Growers reported the desire to have Aclean plants@ rather than those with mites on them. Although predatory mite populations can withstand a few applications of certain insecticides (malathion, diazinon) over the season, one of the biggest impediments to the predatory mite program is that the liquid formulation of captan (used exclusively because the WP formulation leaves white residue) is toxic to predatory mites. Since captan is the backbone of the prophylactic fungicide program, it

is a certainty that predatory mites will be sprayed and may be reduced to non-efficacious levels by these sprays. Thiophanate-methyl was also reported by growers to be detrimental to predatory mites.

For strawberry miticides, there are no carbamate, organophosphate, carcinogen, PHI, or REI concerns with the currently registered materials. Acequinocyl, a miticide receiving reduced risk chemical classification status, has also been registered for use in strawberry (two applications per year).

Insects

The three lepidopteran larvae that were reported as pests in the crop profile (Spodoptera frugiperda, S. eridania, Helicoverpa zea) were confirmed by growers as the main Aworm@ problems, with Abudworm@ (H. zea) as the most damaging. These are mainly early season pests, and the ramifications of their presence during establishment have already been described. Mid- and late-season insect pests include thrips, aphids, and sap beetles. Sap beetles are a zero tolerance pest. Presence of larvae in a ripe strawberry can lead to rejection of the whole shipment.

For those growers employing predatory mites, B.t. and spinosad are the preferential materials for Aworm@ management so that predatory mite populations are conserved. For those using exclusive chemical control, methomyl, spinosad, and bifenthrin are often used. Growers expressed desire to transition away from methomyl, as its the restricted status carries licensing and recordkeeping regulations with regards to licensing and recordkeeping. Additionally, it was announced in 2007 that methomyl would be withdrawn from the strawberry market. Similarly, there are other insecticides which may be phytotoxic due to strawberry variety, temperature, or incompatibility with other active ingredients. These active ingredients are: carbaryl, dicofol, naled, propargite, oils (petroleum and neem), soaps, and sulfur. Perhaps the best example of this is for the incompatibility between petroleum oil and captan/sulfur. In this case, the user is cautioned not to use oil in combination with or immediately before or after spraying with captan or any product containing sulfur. Statements discouraging sulfur use within four weeks of an oil application are also common on oil products. Consequently, growers face these constraints when deciding choosing an insect spray program.

As strawberries begin to form on the plants, chemical cues radiate to surrounding natural areas. These cues attract adult sap beetles of mainlymainly from two different genera that deposit their eggs preferentially in rotting strawberries, although a few may be deposited in fresh strawberries. The most important steps to take to manage sap beetle problems are to pick all fruit as soon as they areit is mature and to not leave behind any fermenting fruit. In addition to giving pickers incentive (money) to pull the rotting fruits, the fruit should also be taken out of the field. The second best practice is to drop them into the row middles, where they decay too quickly for the beetles to complete their life cycle. The pressure from sap beetles is most intense during the last month of production, when picking is most intense. The five active ingredients used to control sap beetle are bifenthrin, diazinon, pyrethrins, carbaryl, and malathion. But bBifenthrin and pyrethrins can be hard on predatory mites, and there are potential phytotoxicity issues with carbaryl, so diazinon and malathion are used more than the others for sap beetle control. However, the PHI for diazinon is five days and the PHI for malathion is three days. Since the picking is done at two day intervals, growers expressed desire to have a PHI of two days for both diazinon and malathion.

During tThe last month of picking is also a time in Florida when oak and citrus blooms are concluding. Flower thrips move from these locations into the strawberry fields. However, it has also been noted that the beneficial six-spotted thrips is present in substantial numbers in Florida if the insecticidal spray program is not too Ahard.@ Consequently, an effort should be made to educate growers regarding the differences between these twobeneficial and pest thrips groups (beneficial or pest). When flower thrips do become problematic, spinosad, imidacloprid, or methomyl is used.

Aphids (strawberry and melon) have become more persistent in localized areas than they have been historically. The presence of aphids and their cast

skins and sugary excretions on fruit are is objectionable to consumers and reduce quality of the fruit. Although there are several aphid predators in Florida, the most effective is a parasitic wasp. As with the six-spotted thrips, Ahard@ chemical programs can reduce the level of parasitism and allow aphid populations to increase. Growers wishing to reduce aphids before naturally occurring predators and parasites have done so must rely on insecticides. A number of materials are efficacious on aphids, such as diazinon, malathion, methomyl, naled, azadirachtin, Beauveria bassiana, bifenthrin, and endosulfan.

A potential emerging insect problem is whitefly (usually greenhouse whitefly). The biggest concern for Florida strawberry growers is that plant material from California will harbor the inoculum for major outbreaks in Florida. Consequently, Florida growers utilizing material from California should be educated on how to scout transplants for all whitefly life stages.

For strawberry insecticides, there are no carcinogen or REI concerns with the currently registered materials. One concern in terms of IPM may be that there is only one efficacious compound (spinosad) for mature worms that will not drastically harm predatory mites. Methoxyfenozide and thiamethoxam have been recently registered on strawberry.

Nematodes

This arena of Florida strawberry pest management is in the greatest transition due to the phaseout of methyl bromide. Each year, the price of methyl bromide and chloropicrin content of the methyl bromide product increases. Currently, there is enough methyl bromide to last an estimated two years (2009). The only formulation available to growers in 2007 is one consisting of half methyl bromide and half chloropicrin and it currently sells for $4 per pound. Even at a reduced methyl bromide rate of 150 pounds per acre using virtually impenetrable film (VIF) mulches, the cost of fumigation would be approximately $1,200 per acre.

Florida strawberry growers have never particularly liked chloropicrin as a fumigant. As long as methyl bromide had beenwas the near exclusive constituent of the formulation, chloropicrin was not needed for soilborne pest and disease control. Generally, a higher weed pressure is observed as the percentage of chloropicrin increases in the fumigant mixture. Growers also believe that, with the 50/50 formulation, there will be a higher surviving percentage of nematodes after fumigation that will become unresolvable problems during the production season. Secondly, and probably as important as the loss of pest control activity, are the issues of worker complaints and the potential for off-site movement of a compound such as chloropicrin. Chloropicrin can be very unforgiving to workers who perform sloppy applications. The EPA is also proposing to implement requirements for substantial buffer zones surrounding fumigant treated fields. Consequently, research has more recently been directed towards pre-bed applications of fumigant, when workers are not around.

Of all combinations of methyl bromide alternatives for strawberry in Florida, the best available is Telone7 C-35 applied pre-bed at 22 to 35 gallons per treated acre, 3 to 5 weeks prior to transplanting. To avoid the use of half-face respirators, Telone7 C-35 must be injected to flat soil to a depth of at least 12 inches. With the use of VIF mulch, fumigant rates can be reduced by 25 to 40 percent from maximum labeled broadcast application rates. In addition to the Telone7 C-35, a mixture of oxyfluorfen and napropamide applied to the beds during mulch laying has proven most effective in weed control. Oxyfluorfen has a 30-day pre-plant interval before transplanting. For fields with high sting nematode populations, a late summer application of Telone7 is recommended.

Chemigation through drip irrigation is also a potential alternative which minimizes personal protective equipment and buffer requirements. Conducting the fumigation after the plastic is laid and irrigation is operational puts the majority of workers out of the field and the fumigant under the mulch. A major requirement of this is to have two drip tapes per bedded row to allow ample dispersion throughout the bed profile.

For strawberry nematicides, there are no carbamate, organophosphate, carcinogen, or REI concerns with the currently registered materials. Iodomethane (methyl iodide) is due to be registered for use in 2007.

Diseases

The key diseases reported by growers at the PMSP meeting were those listed in the crop profile, namely botrytis (gray mold) and Colletotrichum diseases (anthracnose, fruit rot, and crown rot). Other problematic and emerging diseases include angular leaf spot, powdery mildew, and Phytophthora diseases.

Botrytis attacks strawberry fruit in all stages of development in the field and in transportation. Years in which conditions are cool and wet during the major bloom period (mid-January to mid-February) provide exceptional disease pressure on Florida strawberries. Thankfully, several new chemistries have been introduced to help manage this fungus and growers reported utilizing all of them (boscalid, cyprodinil + fludioxonil, fenhexamid +/- captan, pyrimethanil). However, the backbone of the prophylactic fungus control program is the rotation and use of captan and thiram. This is illustrated by the 2004 NASS survey data, which reported an average of 15 applications of captan and 7 applications of thiram.

One of the characteristics of the newer materials for disease control are extensive label limitations. All of the new compounds mentioned above (as well as azoxystrobin and pyraclostrobin) have application limits per season. Azoxystrobin, pyraclostrobin, and fenhexamid are not to be used more than twice in a row without switching to an alternative mode of action. It is apparent that growers have a limited number of applications of the new and much costlier fungicides. They view these as supplements to the backbone spray program of captan and thiram.

There are three species of Colletotrichum fungus that affect Florida strawberry production, Colletotrichum fragariae, C. gloeosporioides, and C. acutatum. Fruit and root rot are generally caused by C. acutatum. Crown rot can be caused by the other two species. In fact, crown rot was the disease that led to the demise of the strawberry nursery industry in Florida. The strobilurin fungicides have shown to be most effective in managing anthracnose fruit rot prophylactically. However, there was consensus among meeting members that growers were uncertain as to the maximum number of applications that should be made since limitations are either prescribed on a season, crop, or yearly basis. Extension publications produced since the initial meeting have helped to clarify this issue.

Angular leaf spot is caused by the bacterium Xanthomonas fragariae. Transplants often arrive infected from the nursery. Cold, wet conditions (including overhead sprinkling for establishment or freeze protection) encourage disease outbreaks. Copper fungicides may negatively affect strawberry growth at full labeled rate, so growers use it sparingly at low rates.

Powdery mildew is a sporadic/emerging fungal problem. The disease is typically managed with fall applications of myclobutanil, triflumizole, or thiophanate-methyl. However, thiophanate-methyl cannot be used by those growers using predatory mites, and resistance to myclobutanil is suspected by members of the PMSP meeting. Consequently, some growers are going back to sulfur for management, and others are having success with potassium bicarbonate. Quinoxyfen has also been recently labeled and adopted for management of powdery mildew in strawberry.

Two Phytophthora species (P. cactorum and P. citricola) occasionally cause crown rot and leather rot in Florida strawberries. Subsequent to the fumigant application, mefenoxam is applied early to control this fungus and fosetyl-Al and potassium phosphite are used later in the season because those two materials can be sprayed on the foliage.

Field observations suggest that the causative agent of charcoal rot, Macrophomina phaseolina, may become a key disease after the loss of methyl bromide. This disease has been observed in portions of the strawberry field which did not receive sufficient or proper fumigation. It is a warm-season disease that may occur at either end of the Florida production season.

Other strawberry diseases are intermittent or incidentally controlled by applications intended to control target diseases. For strawberry fungicides, there are no IPM, PHI, or REI concerns with the currently registered materials. It appears that captan and thiram will remain labeled for strawberry foliar applications for the near future.

Weeds

Weed pressure has historically been one of the more difficult management aspects for Florida strawberry growers for several reasons. First, when methyl bromide is employed as the sterilant, the dormant weed seeds such as Carolina geranium and cut-leaf evening primrose are not inactivated. Since no treatment is capable of controlling weed emergence the entire strawberry season (six to seven months), these weeds become mid- to late-season problems that impact quality and harvest efficiency. The desired effect of methyl bromide is that it does control the majority of yellow and purple nutsedge, which are considered the worst weeds in this crop. Since the methyl bromide alternatives (except for methyl iodide) don=t control nutsedge, these species as well as the aforementioned late season weeds will be a problem in rows during some or most of the season.

Another consideration with respect to weeds is their ability to harbor spider mites. Soon after transplants are set, Carolina geranium seedlings appear. The potential for mite reinfestation is not great when the weed grows from transplant holes in the plastic mulch, because in that position miticide applications will kill resident mites on both the weeds and strawberry plants. However, this plant also grows in the row ends and field perimeter, and these areas are not treated. Consequently, spider mites can reinfest fields from these plants after miticide residues have decreased.

Herbicide research for strawberry has also lagged behind that of pepper and tomato due to the economic superiority of these two crops and the fact that some herbicides available to tomato and pepper growers are not and will not be available to strawberry growers. Results from solarization treatments were similar to those of the untreated control. Consequently, Florida strawberry growers have little experience with new herbicide alternatives.

Herbicide resistance has also been observed in Florida strawberry production. Goosegrass in the row middles has become resistant to paraquat, due to heavy reliance on this single herbicide. Growers also reported potential glyphosate damage to strawberry plants due to transmission from shallow roots present in treated row middles. In addition to nutsedge and resistant weeds, other problematic weeds include purslane, pusley, Carolina geranium, cut-leaf evening primrose, and eclipta. Dayflower is an emerging weed problem.

Weed pressure in Florida strawberry production comes from two locations, in-bed and the row middles. There are several herbicides which currently provide a degree of control in most cases for row middles. As noted, weeds in the bedded portion of the field, historically managed by methyl bromide application, are now considered the weakest point of methyl bromide alternatives. The following points list the issues with each of the in-bed herbicide options:

Napropamide (Devrinol7) appears to have reasonable early season efficacy for most weed species. Degradation leads to loss of weed control mid- to late-season with certain species more tolerant than others.

Oxyfluorfen (Goal7 2XL) appears to manage troublesome weeds such as Carolina geranium and cut-leaf evening primrose, but the use is through fallow bed labeling, which requires a 30-day post application fallow. This length of time is too long between bed formation and transplanting, as mentioned in the nematode section.

Like oxyfluorfen, newly registered flumioxazin (Chateau7) is supposed to be applied 30 days prior to bed formation.

Terbacil (Sinbar7) appears promising but there is a label restriction (110-day PHI) that make this product almost useless for the Florida strawberry growing system. The residue work has been done and Extension specialists are trying to work with IR-4 to refine this label with respect to the PHI (proposed 60-day).

Newly registered materials for row middles include aciflurofen, carfentrazone, and pendimethalin. The remaining herbicides available for Florida growers are non-selective or grass-killing postemergence herbicides. It is expected that the napropamide/oxyfluorfen combination will be the one adopted fully by Florida growers as the methyl bromide products begin to be lost, as it is the most proven tandem at this point.

One last consideration regarding herbicides (and especially Roundup7 products) is the addition of different active ingredients to established trade names. There is a new formulation of Roundup7 that offers weed control within 24 hours. This is accomplished by the addition of diquat to the glyphosate. Growers must be mindful that this type of addition has become more commonplace, and that they must examine the label to make sure the products they need do not also contain an active ingredient not allowed on strawberry. Other than the aforementioned, there are no IPM or REI concerns with the currently registered materials. Clopyralid is labeled nationally for strawberry, but is not registered in the State of Florida due to groundwater concerns.

Birds

Bird predation of strawberries used to be viewed as a sporadic event, but in three of the last four years, bird predation losses have been substantial. The species primarily associated with this phenomenon are American robin, cedar waxwing, and crows. It is estimated that these birds consume approximately 400,000 flats of strawberries (over $2 million in losses). An extension specialist that who works with vertebrate pests stated that the current technologies (propane cannon at a rate of one per ten acres or robin distress calls) have minimal effect, while twisted reflective ribbon (silver on one side/red on the other) may be slightly more effective. Additionally, audio devices are generally not acceptable since much of the growing area is now bordered by residential developments. Since the strawberry is a Anaked@ fruit, taste repellents such as methyl anthranilate (grape flavoring) and capsaicin (pepper) cannot be used. The specialist stressed that the most important aspect in trying to rid the field of birds is to try and scare them as soon as they start inhabiting the field. Flock presence draws in more birds.

One interesting potential for taste aversion that may well fit nicely into the current pest management program is the application of thiram when a flock first starts to land in the field. This fungicide is known to discourage other vertebrate pests from feeding, and some growers have applied it when birds were densely standing in the field, but did not report any particular positive effects.

Summary

Based on the input of the members of the Florida strawberry PMSP, the following items have been placed on the ATo Do@ list.

Research

1. Examine efficacy of milbemectin on pest mites and thrips and toxicity to beneficial mites and beneficial thrips as well as phytotoxicity on current and potential Florida strawberry cultivars.

2. Conduct trials to identify cover crops that will reduce nematode populations.

3. Examine the possibility of using phage to manage angular leaf spot.

4. Examine the use of thiram as a bird feeding deterrent and devise new types of bird repellents.

Education

1. Educate growers/scouts with regard to whitefly identification and sanitation, especially on transplants.

2. Educate growers to the issue that in some cases (e.g. Roundup7) a brand name associated with an active ingredient (such as glyphosate) may have something Anew@ in it (such as diquat) which will influence the overall performance of the application and may/may not be used on strawberry.

Regulation

1. Determine if residue data exist that would allow a 2-day PHI for malathion and diazinon.

2. Refine planting window (currently 21 days) for dichloropropene, if possible.

3. Reduce the 110-day PHI for terbacil (Sinbar7) to 60 days.

4. Interact with registrant to facilitate state registration of clopyralid (Stinger7) in strawberry.

Table 1. Efficacy ratings for pest management tools against invertebrate pests in Florida strawberry.

Pest Management Tools \ Pests	TSM	Other Mites	FT	SB	Aphids	FAW	SAW	CEW	TB	SMC	LCB	SLR	OLT	TPB	Whiteflies	Frujt flies	Mole Crickets	Ants	Slugs
Registered materials																			
Abamectin	G	G	F		F										F				
Acequinocyl	E																		
Azadirachtin	F		F	F	F	F	F	F	F	G		F	F		G	F			
Bacillus thuringiensis						G	G	G	G	G		G	G						
Beauveria bassiana	P		P	P	P	P	P	P	P	P		P	P		P			P	
Bifenazate	E																		
Bifenthrin	P		F	G	P	F	F	F	F			G						P	
Boric acid																			
Canola oil	...																		
Carbaryl																	P	F	
Chlorpyrifos	...																		
Diazinon	P	G	F	G	G														
Dicofol	P	G																	
Endosulfan		G	F		F	F		F	F						F				
Etoxazole	E																		
Fenbutatin-oxide	G																		
Fenpropathrin	P		F	G	F	F	F	F	F	G		G			F				
Hexythiazox	E																		
Imidacloprid			P		E										E				
Malathion	P		F	G	F	F	F	F				F			P	G			

Abbreviations:
TSM = two-spotted spider mite
FT = flower thrips
SB = sap beetles
FAW = fall armyworm
SAW = southern armyworm
CEW = corn earworm

Abbreviations:
TB = tobacco budworm
SMC = saltmarsh caterpillar
LCB = lesser cornstalk borer
SLR = strawberry leafroller
OLT = omnivorous leaftier
TPB = tarnished plant bug

Rating scale:
E = excellent;
G = good;
F = fair;
P = poor;

Rating scale:
? = research needed;
… = not used;
***** = used but not a stand alone management tool

Table 1. Efficacy ratings for pest management tools against invertebrate pests in Florida strawberry.

Pest Management Tools \ Pests	TSM	Other Mites	FT	SB	Aphids	FAW	SAW	CEW	TB	SMC	LCB	SLR	OLT	TPB	Whiteflies	Frujt flies	Mole Crickets	Ants	Slugs
Metaldehyde																			
Methoprene																		G	
Methoxyfenozide						G	G	G	G	G									
Naled	P		F		F														
Neem oil	...																		
Paraffinic oil	...																		
Insecticidal soap	...																		
Propargite	...																		
Pyrethrins + rotenone	P		F									G							
Pyrethrins + piperonyl butoxide			F	F	F	P	P	P	P	G		G	G		P	E	P	P	
Pyriproxyfen	E				F										E				
Spinosad			G			G	G	G				E	E						
Spiromesifen																			
Sulfur																			
Thiamethoxam					G										E				
New Chemistries - IR4 (▪ current IR-4 project)																			
▪ Fenpyroximate	E																		
▪ Milbemectin	G	?	?		G										F				

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Cultural/Non-chemical																			
Certified pest-free plants	EF	EG			F														
Crop rotation											F						F	F	
Removing ripe fruit from field				G															
Resistant varieties	EF																		
Sanitation	G	G		G											G	G			G
Traps																			
Weed control	G																		G
Biological controls																			
Beneficial mites	E	P	P																
Damsel bugs					P	P	P	P	P	P			P	P					
Big-eyed bugs	P				P														
Ground beetles						P	P	P	P	P			P	P					
Lacewings	P				P	P	P	P	P	P			P	P					
Ladybird beetles	F				F														
Minute pirate bugs	P	P	F			P	P	P	P	P		P	P		P				
Parasitic wasps				?	G	F	F	F	F	F		F	F		G				
Predatory midges	P				P														
Predatory thrips	F	?																	

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Pest Management Tools \ Pests	TSM	Other Mites	FT	SB	Aphids	FAW	SAW	CEW	TB	SMC	LCB	SLR	OLT	TPB	Whiteflies	Frujt flies	Mole Crickets	Ants	Slugs
Spiders	P		P			P	P	P	P	P		P	P						
Syrphid fly larvae	P				F														

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Table 2. Toxicity of pest management tools to beneficials in Florida strawberry.

Beneficial Insects/ Mites / Pest Management Tools	Beneficial mites	Big-eyed bugs	Damsel bugs	Ground beetles	Honeybees	Lacewings	Ladybird beetles	Minute pirate	Parasitic wasps	Predatory midges	Predatory thrips	Spiders	Syrphid fly larvae
Registered materials													
Abamectin	MH					MH	MH		MH				
Acequinocyl													
Azadirachtin	S					S	S		S				
Bacillus thuringiensis	S					S	S		S				
Beauveria bassiana	S					S	S		S				
Bifenazate	S					S	S		S				
Bifenthrin	H					H	H		H	H			
Boric acid													
Canola oil	S					S	S		S				
Carbaryl	S					H	H		H				
Chlorpyrifos	H					H	H		H				
Diazinon	M					H	?		H	H			
Dicofol	H					SM	?		M	H			
Endosulfan	H					H	H		M				
Etoxazole													
Fenbutatin-oxide	S					S	S		S				
Fenpropathrin	H					H	H		H				
Hexythiazox	S					S	S		S				
Imidacloprid	MH					M	?		H				
Malathion	M					H	H		H				

Toxicity scale:
S = slightly toxic
M = moderately toxic
H = highly toxic

Toxicity scale:
O = nontoxic
? = no data available

Table 2. Toxicity of pest management tools to beneficials in Florida strawberry.

Pest Management Tools / Beneficial Insects/ Mites	Beneficial mites	Big-eyed bugs	Damsel bugs	Ground beetles	Honeybees	Lacewings	Ladybird beetles	Minute pirate	Parasitic wasps	Predatory midges	Predatory thrips	Spiders	Syrphid fly larvae
Metaldehyde													
Methoprene													
Methoxyfenozide													
Naled	H					H	?		?				
Neem oil													
Paraffinic oil	M					S	S		S				
Insecticidal soap	H					H	?		M				
Propargite	MH					S	?		S				
Pyrethrins + rotenone													
Pyrethrins + piperonyl butoxide	MH					SM	?		MH				
Pyriproxyfen	S					S	H		S				
Spinosad	MH					MH	?		MH				
Spiromesifen													
Sulfur	SM					S	S		S				
Thiamethoxam	?					?	?		?				
New Chemistries - IR4 (■ current IR-4 project)													
■ Fenpyroximate	H					S	?		H				
■ Milbemectin	MH					MH	MH		MH				

Toxicity scale:
S = slightly toxic
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Table 3. Indications for disease management products used on Florida strawberries

Disease Management Product	Angular leaf spot	Anthracnose[a] crown rot	Anthracnose[a] fruit rot	Anthracnose[a] root rot[b]	Botrytis fruit rot	Phytophthora diseases	Powdery mildew	Misc. leaf spots
Azoxystrobin			X	X	S		X	
Captan		X	X		X			X
Captan + fenhexamid		X	X		X			X
Copper compounds	X							X
Cyprodinil + fludioxonil				X	X			
Fenhexamid					X			
Fosetyl-aluminum						X		
Hydrogen peroxide								
Iprodione					X			
Mefenoxam						X		
Myclobutanil							X	X
Potassium bicarbonate							X	
Potassium phosphite						X		
Pyraclostrobin			X		S		X	X
Pyraclostrobin + boscalid			X		X		X	X
Pyrimethanil					X			
Quinoxyfen							X	
Sulfur							X	
Thiophanate methyl		X			X		X	X
Thiram					X			
Triflumizole							X	

[a]Anthracnose diseases are caused by *Colletotrichum* species: *C. fragariae* and *C. gloeosporioides* (crown rot), *C. acutatum* (fruit rot, root rot)
[b]Anthracnose root rot is suppressed by dipping bare root runner plants in solutions or suspensions of the indicated products just before planting
X = used for control of indicated disease
S = for suppression only of indicated disease