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UTILITY OF SPINOSAD FOR INSECT CONTROL IN FLORIDA VEGETABLES

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Abstract. **Spinosad is a novel, naturally derived insect control product recently made available to Florida vegetable growers under the trade name SpinTor® Naturalyte® Insect Control (Trademarks of Dow AgroSciences). The mode of action of spinosad is unique and the product is active by both contact and ingestion. It is relatively low in mammalian and avian toxicity and is only slightly to moderately toxic to aquatic organisms. Chronic toxicology tests in mammals have shown that spinosad is not carcinogenic, teratogenic, mutagenic or neurotoxic. Spinosad has a short half-life in the field due to relatively rapid photodegradation and microbial degradation. Leaching potential is very low. Spinosad has high levels of activity against target pests, primarily Lepidoptera, Diptera and Thysanoptera, and relatively low levels of activity against beneficial insects. Thus, it is a very selective product with utility in integrated pest management programs. Vegetable crops for which spinosad is currently labeled include cole crops, fruiting vegetables and leafy vegetables. Additional labels are expected for cucurbits, legumes, sweet corn, potatoes and strawberries.**

Introduction

Spinosad is a novel, naturally derived insect control product recently made available to Florida vegetable growers under the trade name SpinTor® Naturalyte® Insect Control (Trademark of Dow AgroSciences). It is a mixture of the two most active naturally occurring components (spinosyns A and D) produced by the soil actinomycete bacterium *Saccharopolyspora spinosa* (Kirst et al., 1992). Structurally, these compounds are macrolides and contain a unique tetracyclic ring system to which two different sugars are attached. A unique mode of action coupled with a high degree of activity on targeted pests and low toxicity to non-target organisms make spinosad an excellent new tool for management of insect pests in vegetables. The purpose of this paper is to provide an overview of the activity of spinosad and relate this activity to utility in Florida vegetables.

Results

Physical and Chemical Properties. Spinosad is a light gray to white crystalline solid with an earthy odor similar to slightly stale water. It has a pH of 7.74 and is stable to metal and metal ions for 28 days. Table 1 summarizes other physical and chemical properties of spinosyns A and D (Anonymous, 1996).

Table 1. Physical and chemical properties of spinosyns A and D.

	Spinosyn A	Spinosyn D
Molecular Weight	731.98	746.00
Empirical Formula	$C_{42}H_{67}NO_{16}$	$C_{41}H_{65}NO_{16}$
Melting Point	84-99.5°C	161.5-170°C
Vapor Pressure	2.4×10^{-10}	1.6×10^{-10}
Solubility in Water at pH 5.0	290 ppm	29.000 ppm
Solubility in Water at pH 7.0	235 ppm	0.332 ppm
Solubility in Water at pH 9.0	16 ppm	0.053 ppm
Octanol/Water Partition Coefficient at pH 5.0	log P = 2.8	log P = 3.2
Octanol/Water Partition Coefficient at pH 7.0	log P = 4.0	log P = 4.5
Octanol/Water Partition Coefficient at pH 9.0	log P = 5.2	log P = 5.2

Toxicology. Table 2 summarizes acute mammalian, aquatic and avian toxicology (Anonymous, 1996). Spinosad is relatively low in toxicity to mammals and birds and is only slightly to moderately toxic to aquatic organisms. In addition, chronic toxicology tests in mammals have shown that spinosad is not carcinogenic, teratogenic mutagenic or neurotoxic.

Physiological and Biochemical Properties. Spinosad is active by both contact and ingestion. The mode of action of spinosad is characterized by excitation of the insect nervous system, leading to involuntary muscle contractions, prostration with tremors, and paralysis. These effects are consistent with the activation of nicotinic acetylcholine receptors by a mechanism that is clearly novel and unique among known insect

Table 2. Acute mammalian, aquatic and avian toxicity of spinosad.

Species	Test	Result	EPA Category
Mammalian			
Rat (male/female)	Acute oral LD_{50}	3738/>5000 mg/kg	Caution (IV)
Mouse	Acute oral LD_{50}	>5000 mg/kg	Caution (IV)
Rabbit	Acute dermal LD_{50}	>5000 mg/kg	Caution (IV)
Rat	Acute inhalation LC_{50}	>5 mg/kg	Caution (IV)
Rabbit	Eye irritation	slight, clearing in 2 days	Caution (IV)
Rabbit	Skin irritation	no irritation	Caution (IV)
Guineapig	Dermal sensitization	no sensitization	N.A.
Aquatic			
Daphnia	48 hr acute LC_{50}	92.7 mg/L	Slightly toxic
Grass shrimp	96 hr acute LC_{50}	>9 8 mg/L	Slightly toxic
Carp	96 hr acute LC_{50}	5.0 mg/L	Moderately toxic
Bluegill	96 hr acute LC_{50}	5.9 mg/L	Moderately toxic
Sheepshead minnow	96 hr acute LC_{50}	7.9 mg/L	Moderately toxic
Rainbow trout	96 hr acute LC_{50}	30.0 mg/L	Slightly toxic
Avian			
Bobwhite quail	Acute oral LD_{50}	>2,000 mg/kg	Practically non-toxic
Mallard duck	Acute oral LD_{50}	>2,000 mg/kg	Practically non-toxic
Bobwhite quail	5 day dietary LC_{50}	>5 000 mg/kg	Practically non-toxic
Mallard duck	5 day dietary LC_{50}	>5,000 mg/kg	Practically non-toxic

control products. Spinosad also has effects on GABA receptor function that may contribute further to its insect activity (Salgado et al., 1997). This mode of action is unique. Imidacloprid and other nicotinic receptor-based insecticides act at a different site than spinosad. Avermectin, although a natural product and a macrocyclic lactone, acts at a different site than spinosad. No other class of products affects the insect nervous system with the same mode of action and no cross resistance to spinosad has been demonstrated.

In the field, spinosad activity is characterized by relatively rapid cessation of feeding and paralysis of exposed insects. These insects typically remain on the plant and may appear to be alive for one to two days. For this reason, growers and scouts should wait a minimum of two to three days to evaluate control.

Spinosad is not highly systemic in plants although some translaminar movement in leaf tissue has been demonstrated. The addition of a penetrating surfactant may increase translaminar movement and activity on pests that mine leaves (Larson, 1997). No phytotoxicity has been demonstrated with this product.

Environmental Fate. The degradation of spinosad in the environment occurs through a combination of routes, primarily photodegradation and microbial degradation to its natural components of carbon, hydrogen and oxygen. The half-life of spinosad degraded by soil photolysis is 9-10 days. It is less than 1 day for aqueous photolysis and leaf surface photolysis results in a half-life of 1.6 to 16 days. The half-life of spinosad degraded by aerobic soil metabolism in the absence of light is 9-17 days. Hydrolysis does not contribute significantly to degradation as spinosad is relatively stable in water at a pH of 5-7 and has a half-life of at least 200 days at a pH of 9. Because of the low vapor pressure it is relatively non-volatile.

The leaching potential of spinosad is very low due to a moderate K^d (5-323), low to moderate water solubility and short residual in the environment. Thus, it does not pose a threat to groundwater when used properly and no buffer zones are required by the United States Environmental Protection Agency.

Spectrum of Activity. Spinosad has been tested extensively on vegetable pests in Florida and throughout the United States (Carson and Trumble, 1997; Eger et al, 1998; Fouche et al., 1998a, 1998b; Kerns, 1996; Linduska et al., 1998; McLeod, 1998; Palumbo, 1997; Palumbo and Reyes, 1998; Palumbo et al., 1998; Riley, 1998; Riley et al., 1997; Schuster, 1997a, 1997b, 1998; Stansly and Connor, 1996, 1998; Walgenbach and Palmer, 1997; Webb, 1998). Table 3 lists the vegetable insect pests against which spinosad has shown activity. In general, spinosad provides effective control of pests in the insect orders Lepidoptera, Diptera, Hymenoptera and Thysanoptera. It is also effective for some species of Coleoptera, Homoptera and Orthoptera and selected mites. Spinosad is not effective for control of most sucking insects, beetles and mites. Currently, there are no other registered products for use on vegetable crops that provide a combination of activity against lepidopterous larvae, thrips and dipterous leafminers.

Spinosad exhibits wide margins of safety to many beneficial insects and related organisms (Schoonover and Larson, 1995). Spinosad has relatively low activity against predaceous beetles, sucking insects, lacewings and mites. Table 4 summarizes the LC_{50} values for selected beneficials as compared to a pyrethroid, cypermethrin. Relative to cypermethrin, spinosad provides a 1000-fold margin of safety to many predaceous insects and mites.

Product Labeling. SpinTor is currently labeled on cole crops (broccoli, Chinese broccoli, broccoli raab, Brussels sprouts, cabbage, Chinese cabbage—bok choy and napa, cauliflower, cavalo, collards, kale, kohlrabi, mizuna, mustard greens, mustard spinach, Chinese mustard cabbage - gai choy, and rape greens), fruiting vegetables (eggplant, ground cherry, pepino, pepper, tomatillo, and tomato), leafy vegetables (including head and leaf lettuce, celery, arugula, chervil, edible chrysanthemum, corn salad, cress, dandelion, dock, endive, fennel, parsley, garden purslane, radicchio, rhubarb, spinach, and Swiss chard), apples and citrus. Crops for which additional labeling is being pursued include cucurbits, legumes, sweet corn, potatoes, and strawberries.

Restrictions on the use of SpinTor include a 1-day preharvest interval for most vegetables and a 4-hour reentry interval. Applicators must wear a long sleeved shirt and long pants, shoes and socks and waterproof gloves. Use rates range from 0.023 to 0.156 pounds of active ingredient per acre (1.5-10 ounces of product). The maximum amount of SpinTor allowed is 0.45 pounds of active ingredient (29 ounces of product) per acre per crop. For resistance management purposes, no more than three consecutive applications of SpinTor are allowed. Growers must then rotate to another class of insect control product for a 30-day period (cole crops) or a 21-day period (fruiting and leafy vegetables). Additionally, for control of leafminers, thrips and tomato pinworms, growers may not apply more than two consecutive applications of SpinTor before rotating to another class of insect control products. SpinTor may not be applied to seedling vegetables grown for transplant within a greenhouse or shade house.

Discussion

SpinTor is the first insect control product to offer growers a combination of unique mode of action, high levels of activity against targeted pests, large margins of safety for most beneficial insects, and low toxicity to non-target organisms. Because of the unique mode of action, spinosad fits well into insecticide resistance management programs. Selectivity for targeted pests makes this product very compatible with inte-

Table 3 Insect pests controlled by spinosad in field trials.

Common name	Scientific name	Common name	Scientific name
European corn borer	*Ostrinia nubilalis*	Fall armyworm	*Spodoptera frugiperda*
Tomato fruitworm	*Helicoverpa zea*	Beet armyworm	*Spodoptera exigua*
Cabbage looper	*Trichoplusia ni*	Colorado potato beetle	*Leptinotarsa decimlineata*
Diamondback moth	*Plutella xylostella*	Imported cabbageworm	*Pieris rapae*
Southern armyworm	*Spodoptera eridania*	Tomato pinworm	*Keiferia lycopersicella*
Leafminers	*Liriomyza* spp.	Tomato hornworm	*Manduca quinquemaculuta*
Melon thrips	*Thrips palmi*	Western flower thrips	*Frankliniella occidentalis*

Table 4. Toxicity of spinosad and cypermethrin to selected beneficial organisms.

Beneficial species	Spinosad LC_{50}	Cypermethrin LC_{50}
Honeybee, *Apis mellifera*	11.5 ppm	1.2 ppm
Whitefly parasitoid, *Encarsia formosa*	29.1 ppm	1.9 ppm
Minute pirate bug, *Orius insidiosus*	200 ppm	0.2 ppm
Lady beetle, *Hippodamia convergens*	>200 ppm	0.2 ppm
Lacewing, *Chrysopa rufilabris*	>200 ppm	<0.2 ppm
Predaceous mite, *Phytoseiulus persimilis*	>200 ppm	<0.2 ppm

grated pest management programs. Growers will find that spinosad has some of the least restrictive worker protection standards and use restrictions due to low mammalian and environmental toxicity. Thus, SpinTor provides vegetable growers with an effective and useful new tool for their insect management arsenal.

SpinTor has a unique mode of action, moderate residual, and is selective for pests and beneficials. However, it has a high level of activity against pests that have demonstrated the ability to develop resistance to other products. For this reason, pest resistance to spinosad and its rotation partners is a major concern of Dow AgroSciences. Growers are encouraged to follow resistance management restrictions on the product labels. Rotation of insect control products is strongly encouraged by Dow AgroSciences. Following these guidelines should ensure that Florida vegetable growers maintain SpinTor and other products as valuable tools for the management of insect pests.

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