ENVIRONMENTAL FATE OF SPINOSAD

Wynetta S. Kollman, Ph.D.
Department of Pesticide Regulation
Environmental Monitoring Branch
P.O. Box 4015 Sacramento, California 95812-4015

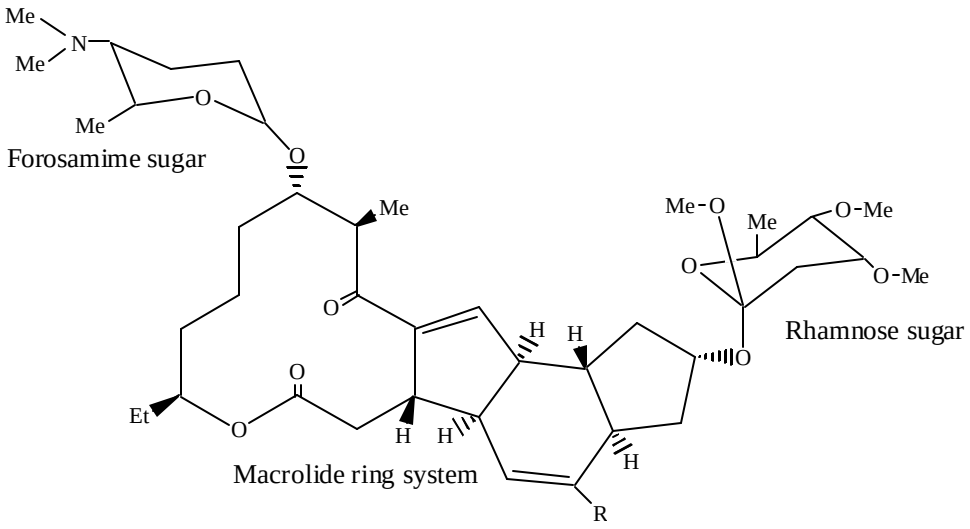


Figure 1. Spinosad: spinosyn A (R = H) + spinosyn D (R = CH_3)

Common Name:	spinosad: spinosyn A + spinosyn D	
Chemical Name:	spinosyn A	spinosyn D
	2-((6-deoxy-2,3,4-tri-*O* -methyl-a-L-mannopyranosyl)oxy)-13-(((5-dimethylamino)tetrahydro-6-methyl-2*H* -pyran-2-yl)oxy)-9-ethyl-2,3,3a,5a,5b,6,9,10,11,12,13,14,16a,16b-tetradecahydro-14-methyl-1*H* -as-indaceno(3,2-d)oxacyclododecin-7,15-dione	2-((6-deoxy-2,3,4-tri-*O* -methyl-a-L-mannopyranosyl)oxy)-13-(((5-dimethylamino)tetrahydro-6-methyl-2*H* -pyran-2-yl)oxy)-9-ethyl-2,3,3a,5a,5b,6,9,10,11,12,13,14,16a,16b-tetradecahydro-4,14-dimethyl-1*H* -as-indaceno(3,2-d)oxacyclododecin-7,15-dione
Trade Names:	Success® Naturalyte®, Tracer® Naturalyte®, XDE-105, NAF-144	
CAS Registry Number:	spinosyn A: 131929-60-7	spinosyn D: 131929-63-0
Molecular Formula:	spinosyn A: $C_{41}H_{65}NO_{16}$	spinosyn D: $C_{42}H_{67}NO_{16}$

- **Chemical Description**

Spinosad is a biologically derived insecticide produced via fermentation culture of the actinomycete *Saccharopolyspora spinosa*, a bacterial organism isolated from soil. It is composed of a mixture of two members of the chemical class of 12-membered macrocyclic lactones in a unique tetracyclic ring. Each component, designated spinosyn A and spinosyn D, is an unsaturated tetracyclic ester with two sugar derivatives (forosamine and rhamnose sugars) attached through ether linkages (Figure 1). Spinosyn A and D are identical in structure except for an additional methyl group on the core macrolide of spinosyn D. Commercial formulations contain a spinosyn A to spinosad D ratio of approximately 85:15. Technical grade spinosad is a light gray to white crystalline solid with an odor of slightly stale water. It is stable to metal and metal ions for 28 days, degrades under ultra-violet light, and is non-phytotoxic when used as directed. The fruit fly bait end-use product is a thick yellow brown liquid (at 20 ºC) with a sweet fruit odor. It is non-explosive, non-reactive toward monoammonium phosphate, zinc, and water, and reactive toward potassium permanganate. Spinosad is soluble in water, and soluble in common organic solvents such as acetone, acetonitrile, methanol, and toluene (British Crop Protection Council, 1997; Dow Agro Sciences, 1999; DPR, 2000; DPR, 1997; O'Neil, 2001; Saunders and Bret, 1997; Thomson, 1998). Additional physical and chemical properties are summarized in Table 1. Wildlife toxicity data are summarized in Table 2.

Table 1 Physical and chemical properties of spinosad (DPR, 1997; DPR, 1995a; DPR, 1995b).

Physical/Chemical Property	**Spinosyn A Value**	**Spinosyn D Value**
Melting Point	84 - 99.5 °C	161 - 170 °C
Vapor Pressure	2.4 x 10^{-10} mmHg at 25 °C	1.6 x 10^{-10} mmHg at 25 °C
Water Solubility	235 ppm at 25 °C, pH 7	0.332 ppm at 25 °C, pH 7
Octanol-water Partition Coefficient (K_{ow})	54.6	90
Henry's Law Constant (K_h)	9.82 x 10^{-10} atm-m^3/mol at 25 °C, pH 7	4.87 x 10^{-7} atm-m^3/mol at 25 °C, pH 7
Hydrolysis Half-life	>30 days at 25 °C, pH 7; 200 days at 25 °C, pH 9	>30 days at 25 °C, pH 7; 259 days at 25 °C, pH 9
Photolysis Half-life (aqueous)	0.96 day	0.84 day
Soil Adsorption Coefficient (K_{oc})	35,838 cm^3/g, averaged over different soil types	No data
Photolysis Half-life (soil)	8.68 days	9.44 days
Aerobic Soil Metabolism Half-life	17.3 days in silt loam soil	14.5 days in silt loam soil
Anaerobic Soil Metabolism Half-life	161 days	250 days

Table 2. Wildlife toxicity of spinosad (DPR, 1995a).

Species	Test	Toxicity
Bobwhite quail	5-day LD_{50}	>5253 ppm
Mallard duck	5-day LD_{50}	>5156 ppm
Rainbow trout	96-hour LC_{50}	30.0 ppm
Bluegill sunfish	96-hour LC_{50}	5.94 ppm
Carp	96-hour LC_{50}	5.0 ppm
Daphnia magna	96-hour LC_{50}	92.7 ppm
Grass shrimp	96-hour LC_{50}	>9.76 ppm
Sheepshead minnow	96-hour LC_{50}	7.87 ppm
Eastern oyster	EC_{50}	0.295 ppm
Green algae	EC_{50}	>105.5 ppm
Freshwater diatom	EC_{50}	0.107 ppm
Marine diatom	EC_{50}	0.227 ppm
Duckweed	EC_{50}	10.6 ppm

- **Regulation**

Spinosad is a product of bacterial fermentation. The U.S. Environmental Protection Agency (U.S. EPA) has classified it as a "reduced-risk" compound (U.S. EPA, undated). Because it is a naturally-derived, low-impact pesticide, spinosad labels carry the signal word "Caution", the lowest human hazard signal word assigned by the U.S. EPA. Products containing spinosad were first registered for use in California in 1996. Spinosad is not regulated as a restricted material. Criteria for a restricted material designation in California include posing a danger to public health, or a hazard to crops, domestic animals, farm workers, or the environment. Restricted materials are possessed and used by persons only under permit of the county agricultural commissioner.

While spinosad is a naturally-derived insecticide and a "reduced-risk" compound, the formulation registered for use in California in 1996 does not qualify as organic because it uses a synthetic chemical to retard spoilage. The registrant, Dow AgroSciences, recently received a federal registration for a new spinosad formulation without the spoilage retardant that qualified as an organic pesticide under federal and state guidelines. While not yet registered for use in California, this new spinosad product may be used to combat major pest infestations under Federal laws that allow temporary pesticide registrations ("Section 18" and "Section 24c"). The special registrations are time and/or site-specific.

A "Section 18" is an "emergency exemption registration" that usually must be approved by U.S.EPA and extends for up to one year. It may be renewed only if the emergency continues or reoccurs. A "Section 24c" is a "special local needs registration" that may be issued without prior approval by U.S.EPA. It has no automatic expiration date.

- **Applications Methods and Use Patterns**

Spinosad is a naturally occurring insecticide with stomach poison and contact activity. It activates the central nervous system of insects through interaction with the nicotinic acetylcholine receptors. Immediately after application, insect pests exhibit irreversible tremors, prostrate trembling, paralysis, and death. Spinosad is used on apples, citrus, cole crops, leafy, vegetables (fruiting and corm), cereal grains (wheat, barley, buckwheat, rye, oats, and triticale), almonds, pistachios, cotton, and ornamentals for the control of worms, caterpillars, peach twig borers, leafminers, beetles, and thrips. It is also used to control or suppress Red Imported Fire Ants (*Solenopis invicta*) in lawns and turf areas, as a public health insecticide, and to control or suppress multiple species of Tephritid fruit flies infesting specified tree, vine, and vegetable crops (British Crop Protection Council, 1997; Dow AgroSciences 2002, 2000; Salgado, 1998; Thomson, 1998; United Horticultural Supply, 2002). Spinosad is available in suspension, gel/paste/cream, flowable concentrate, solution/liquid (ready-to-use), aqueous concentrate, and granular/flake formulations with the signal word "Caution" on the product labels. As of December 11, 2002, there were twelve active registrations for products containing spinosad (DPR, 2002a).

Application Methods

Spinosad is applied to soil or foliage by aerial or calibrated power-operated ground spray equipment. It is also applied by chemigation through overhead sprinkler irrigation systems, such as center pivot, lateral move, end tow, side (wheel) roll, traveler, solid set, micro sprinkler, or hand move, that apply water uniformly.

Application rates for apples, pistachios, citrus, and apples range from 0.062 to 0.156 pound of active ingredient per acre. Respective application rates for cereal grains and field/row crops are 0.031 – 0.094 and 0.047 –0.156 pound of active ingredient per acre. Application rates for turf and ornamentals are 0.002 – 0.009 pound of active ingredient per 1,000 square feet and 0.0004 –0.0016 pound of active ingredient per gallon of water, respectively.

Use Patterns

Full pesticide use reporting in California was implemented by the Department of Pesticide Regulation (DPR) in 1990. All agricultural use must be reported monthly to the county agricultural commissioners. The county agricultural commissioners forward these data to DPR, which annually compiles and makes available a pesticide use report. Agricultural use is defined as including applications to parks, golf courses, cemeteries, rangeland, pastures, and rights-of-way (Food & Agr. Code, § 11408).

The annual pesticide use reports can be used to identify the counties where and the time of year a specific pesticide is most heavily used (DPR, 2002b). Table 3 summarizes spinosad use for reporting years 1998 through 2001 by county with the counties' population (based on the 2000 census). Figure 2 is a graphical representation of the data. These data indicate that, historically, more than 65 percent of spinosad use occurred in Monterey, Tulare, Fresno, Imperial, and Kern counties during this reporting period. The total population of these five counties constitutes about 7 percent of the total population

of California. Monterey County, which accounted for more than 18 percent of the total amount used during this reporting period, was the county where highest use occurred. Table 4 and Figure 3 summarize spinosad use by month for 1998 through 2001. These data indicate that the period of peak use occurs from May through October, with nearly 20 percent applied during the month of May.

Spinosad use by commodity or site for 1998 through 2001 is summarized in Table 5. Although used on a wide variety of commodities, the highest use for this period was on lettuce and oranges (Figure 4).

Table 3. Spinosad use by county from 1998 through 2001 (DPR 2002b).

	County	**Pounds Applied**			
County	**Population[a]**	**2001**	**2000**	**1999**	**1998**
Fresno	799,407	6,876	8,030	7,516	3,722
Imperial	142,361	5,559	4,307	6,104	4,948
Kern	661,645	4,641	5,121	4,659	2,324
Kings	129,461	1,418	622	170	203
Madera	123,109	843	763	344	420
Merced	210,554	351	687	768	566
Monterey	401,762	10,212	9,743	7,006	5,656
Orange	2,846,289	332	398	372	281
Riverside	1,545,387	2,997	2,324	1,846	1,540
San Benito	53,234	577	750	733	345
San Bernardino	1,709,434	179	190	107	56
San Diego	2,813,833	604	667	369	367
San Joaquin	563,598	52	131	148	160
San Luis Obispo	246,681	1,273	1,645	1,082	1,231
Santa Barbara	399,347	3,120	3,941	3,028	2,681
Santa Clara	1,682,585	685	456	373	245
Santa Cruz	255,602	502	517	354	307
Stanislaus	446,997	1,095	1,620	818	870
Sutter	78,930	346	125	51	59
Tulare	368,021	5,915	8,801	5,799	1,416
Ventura	753,197	2,630	3,844	2,397	2,039
All Others	17,640,214	835	760	630	280
Totals	33,871,648	51,040	55,442	44,673	29,717

[a]2000 census

Figure 2. Spinosad use by county from 1998 through 2001 (DPR, 2002b)

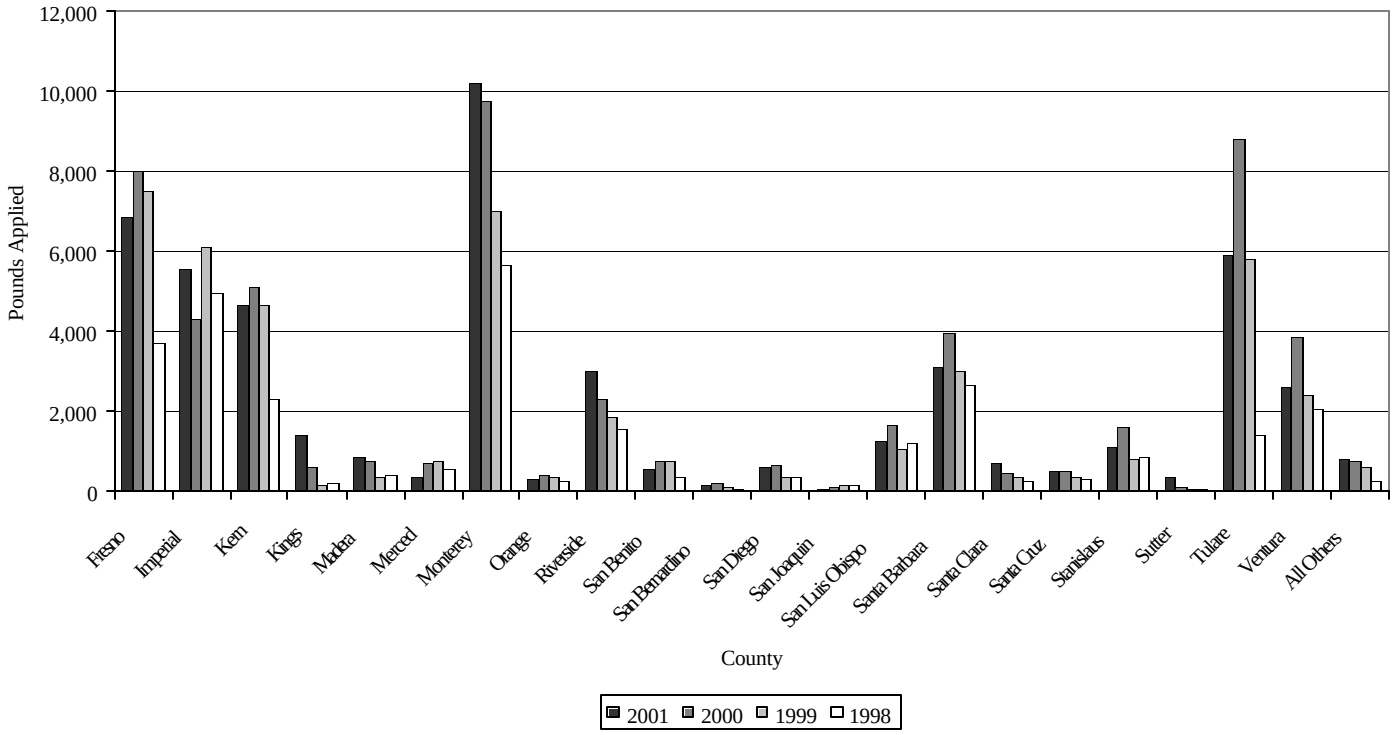


Table 4. Spinosad monthly use from 1998 through 2001 (DPR 2002b).

	Pounds Applied			
Month	**2001**	**2000**	**1999**	**1998**
January	1,435	1,646	1,680	1,084
February	1,124	1,106	1,461	609
March	1,770	1,537	862	595
April	2,780	3,656	1,239	569
May	11,401	14,382	6,323	3,551
June	5,005	5,296	4,543	2,208
July	4,651	5,085	3,972	3,278
August	5,591	5,159	4,827	2,854
September	7,437	7,188	7,680	4,612
October	5,630	6,136	6,785	5,709
November	3,042	2,541	3,325	2,958
December	1,174	1,710	1,874	1,690

Figure 3. Spinosad monthly use from 1998 through 2001 (DPR, 2002b)

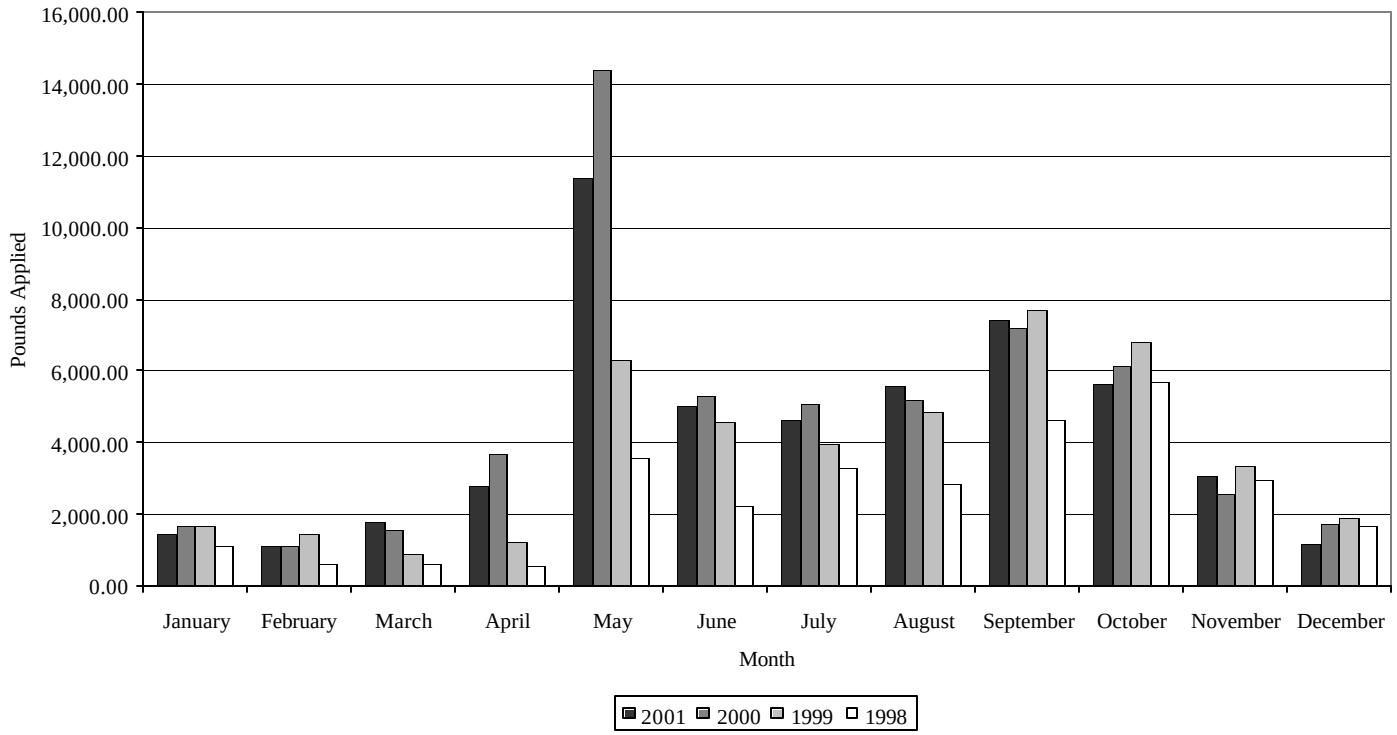


Table 5. Spinosad use by commodity/site from 1998 through 2001 (DPR, 2002b).

	Pounds Applied			
Commodity/Site	**2001**	**2000**	**1999**	**1998**
Almonds	1,813	3,863	4,413	3,121
Broccoli	3,600	6,358	5,607	4,897
Cabbage	1,081	1,411	1,087	1,047
Cauliflower	1,494	2,681	1,992	1,597
Celery	3,422	3,202	2,601	2,393
Cole Crops[a]	530	456	370	363
Field/Row Crops	2,635	1,414	374	255
Grenhouse/Nursery	1,602	1,568	1,032	638
Leafy Vegetables	757	723	464	421
Lettuce	13,634	11,056	12,673	9,391
Melons[b]	1,053	157	18	2
Nectarines	1,471	1,966	8	0
Oranges	8,016	10,667	8,180	2,577
Peaches	829	1,642	38	0
Peppers	2,241	1,883	1,475	907
Pistachio	1,248	284	0	0
Spinach	1,717	1,480	1,051	754
Tomatoes	1,677	2,338	2,541	1,123
Tree Fruits and Nuts[c]	2,087	2,126	540	132
Other[d]	129	145	93	74

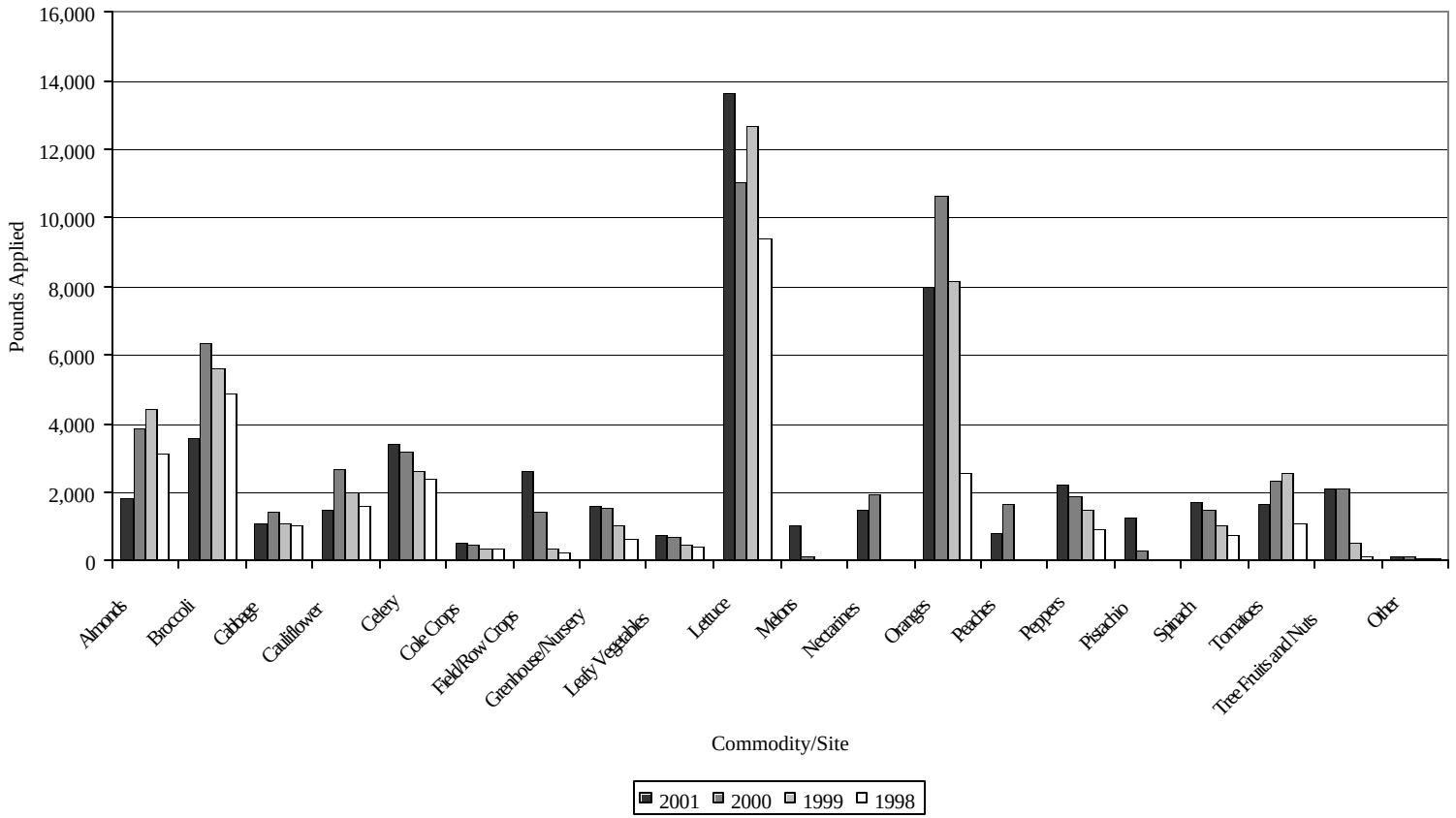
[a]Includes broccoli raab, brussel sprouts, chinese cabbage, and savoy cabbage.

[b]Cantaloupes, melons, and watermelons.

[c]Apples, apricots, cherry, citrus, pecans, plums, and walnut.

[d]Includes, landscape maintenance, rangeland, research commodities, rights of way, regulatory pest control, structural pest contol, and uncultivated agricultural areas.

Figure 4. Spinosad use by commodity/site from 1998 through 2001 (DPR, 2002b)



- **Environmental Fate**

The routes of spinosad dissipation and transformation in the environment include photodegradation and biotransformation on plant surfaces, abiotic hydrolysis, aqueous photolysis, photodegradation on soil, and biotransformation via soil microorganisms. Volatilization from plant or soil is not a mechanism of transport of spinosad in the environment.

Photolysis is the primary route of dissipation from plant surfaces. After initial photodegradation, residues are available for metabolism by plant biochemical processes. Abiotic hydrolysis is relatively unimportant compared to other dissipation routes. Spinosad does not degrade at a significant rate of hydrolysis under neutral conditions and slowly hydrolyzes under basic conditions. Aqueous photolysis is rapid in natural sunlight, and is the primary route of degradation in aquatic systems exposed to sunlight. In the soil environment, spinosad adsorbs strongly to soil particles and is unlikely to leach to great depths. It is photodegraded quickly on soil exposed to sunlight, but the degradation rate is decreased at longer exposure times. Spinosad is quickly metabolized by soil microorganisms under aerobic condition. Under anaerobic conditions, the degradation rate is slower.

Persistence and Metabolic Fate on Plant Surfaces

Several studies were conducted to investigate the dissipation and fate of spinosad applied to foliage. It was demonstrated that spinosyn A and D rapidly dissipated from plant surfaces and that photolysis was the predominant mechanism of dissipation (Table 6).

Table 6. Dissipation half-lives of spinosad from foliar surfaces.

Plant/Crop	Half-life (days) spinosyn A	Half-life (days) spinosyn D	Conditions	Reference
Mixed conifers	2.0	[1]ND	litter; full canopy	
	11.7	ND	litter; open canopy	Thompson et al., 2002
Apples	2.61	ND	leaves	DPR, 1995f
Cabbage	3.48	4.64	leaves	DPR, 1995f
Turnips	5.27	6.31	leaves	DPR,1995g

[1]No data

The proposed photodegradation/metabolism pathway for spinosyn A and D involves the initial formation of nonpolar photoproducts through N-demethylation of the forosamine sugar or O-demethylation of the rhamnose sugar. With further photodegradation, polar and non-extractable metabolites are formed that are subject to biochemical processes and incorporation into natural components of plants.

Persistence and Fate in the Aquatic Environment

A hydrolysis study of spinosad was conducted by incubating (^{14}C)-spinosyn A and D in sterile pH 5, 7, and 9 aqueous buffers (DPR, 1995b). Samples were incubated in the dark for up to 30 days at 25 ºC. Duplicate samples at each pH were removed at various times and analyzed for spinosyn A and D using reversed-phase high pressure liquid chromatography (HPLC). No significant hydrolysis occurred at pH 5 and 7 resulting in estimated half-lives of greater than the 30-day study length. Spinosyn A and D slowly hydrolyzed at pH 9 with respective half-lives of 200 and 259 days. Hydrolysis products identified were formed by the loss of the forosamine sugar and water with double bond formation in the macrolide ring system. Because natural water bodies and rain are generally not basic, spinosad will not hydrolyze in them or on moist plant surfaces (Saunders and Bret, 1997).

An aqueous photolysis study of 2.0 µg/mL solutions of (^{14}C)-spinosad A and D was conducted in pH 7 buffer (DPR, 1995b). Samples in Pyrex® test tubes were placed in stainless steel troughs maintained at 25 ºC by a constant temperature water bath, and exposed to natural sunlight in late June/early July. Sunlight intensity was normalized and measured with chemical actinometers. Duplicate samples were removed at 0, 3, 21, 24, 42, and 48 hours after study initiation and analyzed by reversed-phase HPLC. Spinosyn A and D photodegraded by first-order kinetics with respective half-lives of 0.96 and 0.84 day (corrected for slight degradation observed in the dark controls). The major photodegradate, formed by loss of the amino sugar and reduction of the 13, 12 double bond in the macrolide ring system, was identified as 13,14-dihydrospinosyn A.

Cleveland et al. (2002) investigated the dissipation and degradation of spinosad in outdoor aquatic microcosms. The microcosms were constructed from insulated stainless steel tanks (1.7 m x 0.58 m) with approximately 50 cm of water and 5 cm of clay loam sediment collected from a local pond. To simulate the direct overspray of a pond using a hand-sprayer, the microcosms were treated with 480 g/L suspension concentrate formulation of spinosad (the rate equivalent to a surface application of 0.089 lb spinosad/acre). Water samples down to the sediment layer were collected at 0, 1, 4, and 8 hours after treatment and at 1, 2, 4, 8, and 15 days after treatment. Sediment core samples were collected at 1, 2, 4, 8, 15, and 35 days after treatment. Water and sediment samples were analyzed by both reversed-phase HPLC and immunoassay analysis. Spinosyn A and D concentrations in the water column declined rapidly and reached the detection limit (0.5 ng/mL) by 8 days after treatment. The photodegradation curve fit first-order kinetics with a resultant half-life of 1.6 days for spinosyn A and D combined. The mean concentration of spinosad in the sediment samples remained constant at approximately 14 percent of the applied amount from 4 through 35 days after treatment. This indicated that once spinosad adsorbed to the soil, slower degradation under anaerobic dark conditions occurred. The majority of the spinosad applied rapidly photodegraded in the water column prior to adsorption to soil.

Persistence and Fate in Soil

A soil adsorption and desorption study was conducted with spinosyn A using five soils with varying percent organic matter and batch equilibrium methods (DPR, 1995c). The magnitude of the resultant soil adsorption coefficients (K_{oc}) indicated that spinosyn A has a strong tendency to favor the sorbed versus the dissolved state in soil (Table 7). The soil desorption coefficients were generally greater than the K_{oc} values, indicating that spinosyn A did not completely desorb from soil and reestablish equilibrium as predicted by the adsorption isotherm.

Table 7. Summary of spinosyn A soil adsorption coeffients (K_{oc}) and soil analysis data (DPR, 1995c).

Soil Type	K_{oc} (cm^3/g)	% Organic Matter	CEC[1]	pH
Sand	2,988	0.5	3.5	6.9
Loamy Sand	884	1.1	1.9	6
Sandy Loam	4,500	1.0	6.9	6.6
Silt Loam	145,350	0.4	12.0	7.5
Clay Loam	25,470	2.0	21.2	6.5

[1]Cation exchange capacity

The photodegradation of spinosad on soil has been investigated (DPR, 1995c). Samples of silt loam soil in 10 mL quartz flasks were treated with (^{14}C)-spinosyn A or D at the rate of 0.91 pound of active ingredient per acre. The flasks were placed in stainless steel troughs maintained at 25 ºC by a constant temperature water bath, and exposed late August through late September to natural sunlight for 30 days. Sunlight intensity was normalized and measured with chemical actinometers. Duplicate samples were removed at 0, 2, 18, 24, and 30 days after study initiation and analyzed by reversed-phase HPLC. Spinosyn A and D did not photodegrade by first-order kinetics. Examination of the degradation curve suggested that half or more of the spinosad was adsorbed to the interior of soil particles and not available for photodegradation. It was found that using a model where photodegradation proceeded by first-order kinetics on the portion of spinosad available for photodegradation resulted in respective spinosyn A and D half-lives of 8.68 and 9.44 days. A number of photoproducts were detected, but none exceeded 10 percent of the initial concentration. Two of the photoproducts were formed by mono-N-demethylation of the forosamine sugar of spinosyn A and D. Thompson et al. (2002) also examined spinosad photodegradation on exposed soils following application to a full canopy mixed conifer stand. Photodegradation proceeded following hyperbolic kinetics resulting in a spinosyn A half-life of 12.4 days. Quantifiable levels of the photoproduct formed by mono-N-demethylation of the forosamine sugar of spinosyn A were found. Spinosyn D degraded too rapidly for effective modeling of dissipation kinetics.

The aerobic soil metabolism of spinosyn A and D has been investigated (DPR, 1995c). Soil samples were placed in glass biometer flasks and treated with (^{14}C)-spinosyn A at the rate of 0.4 mg/kg or (^{14}C)-spinosyn D at the rate of 0.1 mg/kg. Water was added to achieve 75 percent of 0.33 bar moisture content, which was maintained during the study. The flasks were connected to a positive air flow manifold system, incubated in the dark

at 25 ºC, and sampled for analysis by reversed-phase HPLC at intervals for up to one year for spinosyn A or six months for spinosyn D. Spinosyn A and D biodegraded more rapidly at the beginning of the study than near the end due to decreased bioavailabity near the end of the study resulting from stronger soil adsorption. Half-lives calculated for spinosyn A in silt loam and sandy loam soils were 17.3 and 9.4 days, respectively. The half-life for spinosyn D in silt loam soil was 14.5 days. The two major metabolites detected were formed by mono-N-demethylation of the forosamine sugar of spinosyn A and D.

The anaerobic aquatic metabolism of spinosyn A and D was investigated using a water/soil system (DPR, 1995d). Biometer flasks containing pond sediment with associated surface water were made anaerobic and pre-incubated at 25 ºC for 30 days. The surface water in the flasks was then treated with (^{14}C)-spinosyn A or D at an initial concentration of 0.85 µg/mL. The flasks were anaerobically-incubated in the dark at 25 ºC, and sampled for analysis by reversed-phase HPLC at intervals for up to one year. Both spinosyn A and D moved rapidly to the sediment layer so that at 14 days after treatment less than 5 percent remained in the water column. Biodegradation of spinosyn A and D proceeded slowly with respective calculated half-lives of 161 and 250 days. The two major metabolites detected were formed by mono-N-demethylation of the forosamine sugar of spinosyn A and D.

A terrestrial field dissipation study was conducted in Wayside, MS and Fresno, CA to determine the dissipation rate of spinosyn A, the rate of formation and decline of degradates, and the leaching characteristics of spinosyn A and degradates under field conditions (DPR, 1995e). (^{14}C)-Spinosyn A (emulsifiable concentrate suspension in water) was applied to the soil surface using a hand sprayer pushed by guide wires above the plot. The respective application rates were 0.48 and 0.42 pound of active ingredient per acre in Wayside and Fresno. Soil sample cores (in 6-inch increments down to 36 inches) were collected for analysis by reversed-phase HPLC up to 10 months after application. At Wayside, spinosyn-A declined from an initial 0.45 pound per acre at time zero to 0.13 pound per acre one day after treatment. There were no detections at 8 days after treatment. At Fresno, spinosyn-A declined from an initial 0.33 pound per acre at time zero to 0.03 pound per acre one day after treatment. There were no detections at 5 days after treatment. Assuming first-order kinetics, respective dissipation half-lives for spinosyn A at Wayside and Fresno were 0.5 and 0.3 day. Degradation of spinosyn A under field conditions produced three major groups of degradates: mono, di, and tetra-hydroxylated derivatives of both spinosyn A and the degradate formed by mono-N-demethylation of the forosamine sugar of spinosyn A. Neither spinosyn-A nor the major degradation products leached below the top 6 inches of the soil profile.

Persistence and Fate in Air

Vapor pressure is an indicator of a chemical's volatility. Substances with vapor pressures less than 1.0×10^{-6} are considered to be nonvolatile. The respective vapor pressures of spinosyn A and D are 2.4 and 1.6×10^{-10} mmHg at 25 ºC (DPR, 1995a). Spinosad, therefore, is nonvolatile and would not volatilize from soil or plant surfaces or drift from application sites. Volatilization is not a mechanism of transport of spinosad in the environment.

- **References**

British Crop Protection Council. 1997. XDE-105 insecticide. Pages 1272-1273 *in* C. Tomlin, pesticide manual, 11th ed. Crop Protection Publications, Farnham, Surrey, U.K.

Cleveland, C.B., G.A. Bormett, D.G. Saunders, F.L. Powers, A.S. McGibbon, G.L. Reeves, L. Rutherford, and J.L. Balcer. 2002. Environmental fate of spinosad. 1. Dissipation and degradation in aqueous systems. J. Agric. Food Chem. 50(11):3244-3256.

Dow AgroSciences. 2002. Success® specimen label. Dow Agro Sciences LOC, Indianapolis, Indiana.

Dow AgroSciences. 2000. GF-120 Fruit Fly Bait specimen label. Dow Agro Sciences LOC, Indianapolis, Indiana.

Dow AgroSciences. 1999. Material safety data sheet. Dow Agro Sciences LOC, Indianapolis, Indiana.

DPR. 2002a. Pesticide label database. Department of Pesticide Regulation, Sacramento, California

DPR. 2002b. Pesticide use report database for 1998, 1999, 2000, and 2001. Department of Pesticide Regulation, Sacramento, California

DPR. 2000. Summary of physical /chemical properties. Volume No. 52050-121, Department of Pesticide Regulation, Sacramento, California.

DPR. 1997. Product identity and disclosure of ingredients. Volume No. 52050-069, Department of Pesticide Regulation, Sacramento, California.

DPR. 1995a. Summary of the environmental fate of spinosad. Volume No. 52050-001, Department of Pesticide Regulation, Sacramento, California.

DPR. 1995b. (1)Hydrolysis of XDE-105 Factors A and D in aqueous buffer; (2)Photolysis of XDE-105 Factors A and D in pH 7 buffer. Volume No. 52050-012, Department of Pesticide Regulation, Sacramento, California.

DPR. 1995c. (1)Photolysis of XDE-105 Factors A and D on soil; (2)The aerobic soil metabolism of (^{14}C)-XDE-105. Volume No. 52050-013, Department of Pesticide Regulation, Sacramento, California.

DPR. 1995d. (1)The anaerobic aquatic metabolism of (^{14}C)-XDE-105; (2)Soil adsorption and desorption of XDE-105 Factor A. Volume No. 52050-014, Department of Pesticide Regulation, Sacramento, California.

DPR. 1995e. Terrestrial field dissipation of ^{14}C spinosad factor A. Volume No. 52050-034, Department of Pesticide Regulation, Sacramento, California.

DPR. 1995f. (1)Nature of residue study in apple leaves using (^{14}C)-XDE-105 (Factor A and Factor D); (2)Nature of (^{14}C)-XDE-105 residues resulting from a single application of compound to cabbage. Volume No. 52050-047, Department of Pesticide Regulation, Sacramento, California.

DPR. 1995g. Nature of residue study in turnips using (^{14}C)-XDE-105 (Factor A and Factor D. Volume No. 52050-049, Department of Pesticide Regulation, Sacramento, California.

O'Neil, M.J. 2001. The Merck index, 13th ed. Merck & Co., Whitehouse Station, New Jersey.

Salgado V.L. 1998. Studies on the mode of action of spinosad: Insect symptoms and physiological correlates. Pestic. Biochem. Physiol. 60:1-102.

Saunders, D.G. and B.L. Bret. 1997. Fate of spinosad in the environment. Down to Earth 52(1):14-20.

Thompson, D.G., B.J. Harris, L.J. Lanteigne, T.M. Buscarini, and D.T. Chartrand. 2002. Fate of spinosad in litter and soils of a mixed conifer stand in the Acadian forest region of New Brunswick. J. Agric. Food Chem. 50(4):790-795.

Thomson, W.T. 1998. Agricultural chemicals, Book I: Insecticides, acaricides, and ovicides. Thomson Publications, Fresno, California.

United Horticultural Supply. 2002. Fire Ant Bait with Conserve® specimen label. United Horticultural Supply, Greeley, Colorado.

U.S. EPA. Undated. Pesticide Fact Sheet, Name of Chemical: Spinosad. Available at http://www.epa.gov/opprd001/factsheets/spinosad.pdf (verified 23 Dec. 2002).