EMAMECTIN BENZOATE: CONTROL OF THE HELIOTHINE COMPLEX AND IMPACT ON BENEFICIAL ARTHROPODS

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Abstract

Emamectin benzoate (MK-0244) is a semi-synthetic derivative of the natural product abamectin which is in the avermectin family of 16-membered macrocylic lactones. It has unprecedented potency against a broad spectrum of lepidopterous pests with LC_{90} values ranging between 0.001-0.02 *ug*/ml in ingestion-based foliar spray assays. Emamectin benzoate is more potent against tobacco budworm, *Heliothis virescens* (F.) than other new insecticides, such as fipronil, chlorfenapyr and tebufenozide. In the field, emamectin benzoate is very effective at controlling tobacco budworm and cotton bollworm, *Helicoverpa zea* (Boddie) at low use rates (0.0075-0.015 lb ai/a). The mode of action is similar to abamectin (i.e., GABA- and glutamate-gated chloride channel agonist) and is not cross resistant with any other compound currently used commercially. The first registrations for emamectin benzoate in the United States are anticipated in 1998 as Proclaim ™ on vegetable crops. Registration on cotton as Strategy ™ is expected in 2000 or 2001. An overview of the efficacy of emamectin benzoate against the Heliothine complex and the impact on beneficial arthropods is provided.

Introduction

Emamectin benzoate is a second generation avermectin insecticide being developed for use on cotton and other crops by Novartis Crop Protection, Inc. A review of its discovery, basic attributes and potential for control of lepidopterous pests was provided by White et al. (1997). Emamectin benzoate is a broad spectrum lepidoptericide that has excellent activity against cotton bollworm, *Helicoverpa zea* (Boddie), tobacco budworm, *Heliothis virescens* (F.), beet armyworm, *Spodoptera exigua* (Hubner), cabbage looper, *Tricoplusia ni* (Hubner), and many other species that attack cotton. It is being developed in the United States under the trade name Proclaim™ for vegetables and Strategy ™ for cotton. In this paper we report new data on the activity of emamectin benzoate against the Heliothine complex and its low impact on beneficial arthropods in cotton.

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Mode of Action

The mode of action of the avermectins has been reviewed by several authors (Arena, 1994; Fisher and Mrozik, 1984; Rohrer and Arena, 1995; Turner and Schaeffer, 1989). White et al. (1997) reported that most avermectins, including emamectin benzoate have a similar mode of action. In general in arthropods, the chloride ion flux produced by the opening of the channel into neuronal cells results in loss of cell function and disruption of nerve impulses. Consequently, arthropods are paralyzed irreversibly and stop feeding. Maximum mortality is achieved within several days. Although emamectin benzoate does not exhibit rapid knock down activity against lepidopterous pests, paralysis is rapid and feeding damage to plants is minimal because insects stop feeding shortly after ingestion. Arthropods are intoxicated by emamectin benzoate via contact and ingestion, however ingestion is considered to be the primary route whereby arthropods accumulate a lethal dose.

Activity Against the Heliothine Complex

A number of laboratory studies have been conducted to evaluate the potency of emamectin benzoate against cotton bollworm and tobacco budworm larvae. Dybas et al. (1989) reported that the LC_{90} of emamectin benzoate applied as a foliar spray against neonate larvae was 0.002 ppm for cotton bollworm and 0.003 ppm for tobacco budworm. Jansson et al. (1997) reported that emamectin benzoate was 12.5 to 20-fold more potent than lambda-cyhalothrin and 175-400 fold more potent than fenvalerate to tobacco budworm. More recent studies showed that emamectin benzoate was 2.0 to 3.5 orders of magnitude more potent to tobacco budworm than other new insecticides being developed for use in cotton including chlorfenapyr, fipronil and tebufenozide (White et al., 1997).

In a field-laboratory bioassay conducted at Louisiana State University during 1997, cotton bollworm and tobacco budworm were shown to be equally susceptible to emamectin benzoate at 2 and 4 days after treatment (Table 1). In that study, emamectin benzoate 5 SG was applied to cotton in the field at 0.0075 lb ai/a. One-day old larvae collected from the field were placed on treated terminal leaves and mortality was determined after 24 hrs.

In another field-laboratory bioassay also conducted at Louisiana State University during 1997, residual control of emamectin benzoate 5 SG was evaluated against tobacco budworm when it was applied to cotton with and without different surfactants. Sprays were applied in the field and treated terminal foliage was collected and taken to the laboratory. One-day old field collected tobacco budworm larvae were placed on the foliage and mortality was determined after 24 hrs. Results show that use of a surfactant significantly improved the activity of emamectin benzoate during the first day after application but not at later timings (Table 2). While the addition of a surfactant was important in improving initial activity of emamectin benzoate, the type of surfactant (e.g., Activator 90™ = non-ionic; Silwet™ = organosilicant; Dyne-Amic™ = oil + organosilicant) did not influence initial activity or residual activity. The results also show that the residual activity of emamectin benzoate against tobacco budworm was greatly decreased by four days after treatment. These data are consistent with results from vegetable crops where emamectin benzoate has shown very high levels of activity for up to 5-7 days after which time activity diminishes rapidly.

Excellent field efficacy of emamectin benzoate at low use rates (0.0075-0.015 lb ai/a) has been demonstrated against numerous lepidopterous pests in a variety of crops (Jansson and Lecrone, 1991; Jansson et al., 1996; Leibee et al., 1995). On cotton, White et al. (1997) reported that against cotton bollworm and tobacco budworm field performance with emamectin benzoate at 0.0075 lb ai/a was comparable to spinosad, chlorfenapyr and RH-2485. Field studies conducted across the cottonbelt during 1997 produced similar results, however higher rates of 0.01-0.0125 lb ai/a provided more consistent control of the Heliothine complex than the 0.0075 lb ai/a rate. In general, when the 0.0075 lb ai/a rate was tank-mixed with low rates of amitraz, lambda-cyhalothrin, profenofos or thiodicarb, control of the tobacco budworm and cotton bollworm was equal to that provided by higher rates of emamectin benzoate applied alone.

An excellent rate response with emamectin benzoate against tobacco budworm was demonstrated in a field-laboratory bioassay conducted at Louisiana State University during 1997. The results clearly showed that mortality of tobacco budworm larvae increased significantly when the rate of emamectin benzoate increased from 0.0075 lb ai/a to 0.01 lb ai/a (Table 3). There was little increase in mortality when rates were increased above 0.01 lb ai/a. In this study, plants were sprayed in the field. Terminal foliage was removed 2 hrs after application, taken to the laboratory where one-day old larvae of tobacco budworm were placed on the foliage and mortality was determined after 72 hrs. These data support the field observations which indicate that the field rate of emamectin benzoate, when applied alone, should be 0.01 lb ai/a instead of the lower rate.

Impact on Beneficial Arthropods

Emamectin benzoate has minimal impact on most beneficial arthropods (e.g., honey bees, parasitioids, predators), especially when exposure occurs beyond one day after application (Lasota and Dybas, 1991; Cox et al., unpublished; White et al., 1997). Foliar residues of emamectin benzoate were only slightly toxic (< 20% mortality) to most benefical insects, including honey bees, *Apis mellifera* (L.), within one day after application and often within a few hours after application (Cox et al., unpublished). The low toxicity was related to the short half-life of emamectin benzoate on foliage. Emamectin benzoate provided ecological selectivity (and in some cases physiological selectivity) to a wide range of beneficial arthropods. For this reason it is compatible with integrated pest management (IPM) programs in cotton.

Emamectin benzoate is very susceptible to photodegradation. The half-life on celery has been estimated to be 0.66 days (White et al., 1997). Despite the short half-life for emamectin benzoate in sunlight, low levels are taken up rapidly via translaminar movenment into foliage. Emamectin benzoate reservoirs in parenchyma tissue accounts for its long residual activity under field conditions (Jansson and Dybas, 1996).

In a field study conducted in Texas during 1997, emamectin benzoate 5 SG had no adverse effects on any of the beneficial arthropod species, i.e. big eyed bugs (*Geocoris* sp.), minute pirate bugs (*Orius* sp.), spiders, lady beetles, lacewing larvae (*Chrysoperla carnea* (Stephens)) and red imported fire ant (*Solenopsis invicta* (Buren)) measured in the trial (Table 4). In that trial, emamectin benzoate at multiple rates (0.0075-0.0125 lb ai/a) was applied one time to cotton plots 12 rows wide by 50 feet in length with four replicates. The insecticide applications were made in 10 gallons of water per acre. Plots were evaluated three days after they were sprayed. The "beat bucket" method was used to evaluate treatment differences. This entailed randomly selecting 20 plants from the center of the middle two rows of each plot and shaking them vigorously into a 5 gallon white plastic bucket. All insects present in the bucket were counted and recorded.

Similar results were obtained in a Mississippi study conducted druing 1997. In that study, emamectin benzoate 5 SG had no effects on the beneficial arthropods, i.e. big eyed bugs, minute pirate bugs, damsel bugs (*Nabis* sp.), green lace wings, and lady beetles (*Hippodamia convergens* (Guerin-Memeville)), evaluated (Table 5). Emamectin benzoate was applied at 0.01 lb ai/a to plots eight rows by 60 feet long replicated three times. One application was made and evaluations were made at various intervals after application. Three subsamples were made per plot with a drop cloth measuring one square meter.

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Table 1. Mortality (%) of cotton bollworm and tobacco budworm larvae exposed to cotton terminals treated with emamectin benzoate 5 SG at 0.0075 lb ai/a.

Treatment	2 DAT	4 DAT
Bollworm	98.3 a	85.0 a
Budworm	100.0 a	79.6 a
Bollworm Untreated	11.7 b	7.5 b
Budworm Untreated	6.7 b	0.0 b

a. Research conducted by Dr. B. R. Leonard, LSU Northeast Research Station (1997)
b. Means within columns followed by the same letter are not different (P=0.05, LSD)

Table 2. Residual activity (% mortality) of emamectin benzoate (MK-0244) 5 SG against tobacco budworm when applied with and without different surfactants.

Treatment	Rate(lb ai/a)	1 DAT	2 DAT	4 DAT
MK-0244	0.0075	50.8 b	83.3 b	18.6 a
MK-0244 + Activator 90	0.0075 + 0.25%	80.4 a	94.2 ab	13.7 ab
MK-0244 + Silwet L-77	0.0075 + 0.1%	83.9 a	90.8 ab	11.8 ab
MK-0244 + Dyne-Amic	0.0075 + 0.5%	92.8 a	96.7 a	11.7 ab
Spinosad + Activator 90	0.067 + 0.25%	58.9 b	66.3 c	21.7 a
Untreated		1.7 c	5.4 d	3.6 b

a. Research conducted by Dr. B. R. Leonard, LSU Northeast Research Station (1997)
b. Means within columns followed by the same letter are not different (P=0.05, LSD)

Table 3. Mortality (%) of tobacco budworm larvae exposed to cotton terminals treated with emamectin benzoate (MK-0244) 5 SG at different rates.

Treatment	Rate (lb ai/a)	0 HAT	72 HAT
MK-0244	0.005	5.0 a	48.0 b
MK-0244	0.0075	4.8 a	54.0 b
MK-0244	0.01	5.0 a	92.0 a
MK-0244	0.015	4.6 a	96.0 a
MK-0244	0.02	4.8 a	96.0 a
Spinosad 4 SC	0.075	4.4 a	82.0 a
Untreated		4.6 a	12.0 c

a. Hours after treatment (HAT)
b. Research conducted by Dr. B. R. Leonard, LSU Northeast Research Station (1997)
c. Means within columns followed by the same letter are not different (P=0.05, LSD)

Table 4. Effect of emamectin benzoate (MK-0244) 5 SG on beneficial arthropods in the Northern Texas Blacklands.

Treatment	Rate (lb ai/a)	No./20 Plants
MK-0244	0.0075	72.5 a
MK-0244	0.010	68.5 a
MK-0244	0.0125	59.0 a
Untreated		59.5 a

a. Research conducted by Drs. D. Reid and J. Swart, Texas A&M University and Texas Agricultural Extension Service, respectively (1997).
b. Means within columns followed by the same letter are not different (P=0.05, LSD).
c. Beneficials included big-eyed bugs, minute pirate bugs, spiders, lady beetles, green lacewing larvae and red imported fire ant.

Table 5. Effect of emamectin benzoate (MK-0244) 5 SG on beneficial arthropods in Mississippi.

		No. beneficials per 3 m^2 drop cloth samples			
Treatment	Rate (lb ai/a)	Pre-count	1 DAT	3 DAT	7 DAT
Dyne-Amic	0.25%	94.0 a	78.0 a	64.3 b	25.7 a
MK-0244 + Dyne-Amic	0.01+ 0.25%	93.3 a	71.7 a	66.3 b	39.7 b
Spinosad	0.067	87.0 a	65.7 a	57.0 ab	28.3 a
Untreated		124.7 a	92.0 a	48.0 a	31.0 ab

a. Research conducted by Dr. N. Ngo, Novartis Crop Protection, Inc..

b. Means within columns followed by the same letter are not different (P=0.05, LSD).

c. Beneficials included big-eyed bugs, minute pirate bugs, damsel bugs, green lacewings, and lady beetles.