tacking a particular crop. Now, with the increased emphasis on IPM, sustainable agriculture, environmental safety, and management of resistance, highly specific chemicals that affect only the target pest and are not harmful to other insects and animals in the environment are finding a place in vegetable production. By preserving beneficial insects, other pests not affected by the specific chemical may be kept at manageable levels by their natural enemies.

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EXPERIENCE WITH EMAMECTIN BENZOATE FOR CONTROL OF LEPIDOPTERA PEST SPECIES IN FLORIDA VEGETABLE PRODUCTION

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Additional index words. Insecticide, MK-244, PROCLAIM®, avermectin, vegetables.

Abstract. **Extensive testing with emamectin benzoate in Florida has demonstrated its excellent effectiveness for controlling Lepidoptera pest species on vegetable crops. Testing in Florida began in 1988 and has continued in each successive year. Beginning in 1995, the performance of emamectin benzoate has been evaluated in commercial cabbage, head lettuce, and celery fields in Florida and other states under an Environmental Protection Agency (EPA) approved experimental use permit (EUP). Results of research and EUP trials demonstrate control of all major economically important Lepidoptera species in commercial vegetable production. Results from recent trials conducted in Florida and best-use guidelines for emamectin benzoate are presented.**

Emamectin benzoate is a novel semi-synthetic insecticide that is derived from a natural fermentation product, avermectin B_1 (Dybas and Babu, 1988). Laboratory bioassays have demonstrated that it is highly toxic to a broad range of Lepidoptera pest species at very low concentrations (Dybas et al., 1988). The primary route of intoxication in Lepidoptera larvae is through ingestion; however, there is some contact activity.

The avermectins act by disrupting nerve impulses by a unique mode of action (Turner and Schaeffer, 1989). No cross-resistance between emamectin benzoate and any registered insecticide has been documented. Larvae characteristically stop feeding shortly after ingestion of emamectin benzoate and become irreversibly paralyzed. Maximum mortality usually occurs within four days after ingestion.

Emamectin benzoate penetrates the cuticle of plants through translaminar movement, which provides long residual activity against phytophagous insects. Residues that remain on plant surfaces rapidly photodegrade, which minimizes exposure to beneficial arthropods. The characteristics of long residual activity against phytophagous Lepidoptera species and short residual activity against predatory and parasitic species are compatible with integrated pest management programs (Jansson and Dybas, in press).

A 0.16 EC (1.9% emulsifiable concentrate) and a 5 SG (5% soluble granule) formulation of emamectin benzoate have been developed. Target crop groupings include: leafy vegetables (lettuce and celery); cole crops (cabbage, broccoli, cauliflower, and brussels sprouts); and fruiting vegetables (tomato and pepper). The field use rates will be from 0.0075 to 0.015 lb ai/acre.

In May 1995, the U.S. Environmental Protection Agency (EPA) granted an Experimental Use Permit (EUP) for emamectin benzoate. In May 1996, a section 18 emergency exemption to permit usage of emamectin benzoate (tradename: PROCLAIM® 5 SG) in Hawaii for control of diamondback moth larvae on cabbage was approved by the U.S. EPA.

Field research trials with emamectin benzoate have been conducted on cole crops and leafy vegetables throughout Florida since 1988 and on fruiting vegetables since 1989. Field trials have been conducted with both the 0.16 EC and 5 SG formulations, with full-season usage of emamectin benzoate, and with rotation with other insecticides. Application in field trials was by ground application equipment and by aircraft. Results from three of the most recent field trials conducted on cole crops, leafy vegetables, and fruiting vegetables are presented.

Materials and Methods

The efficacy of emamectin benzoate 0.16 EC (0.0075 lb ai/acre) applied weekly for the entire season (six applications) and every other week in rotation with *Bacillus thuringiensis* subsp. *aziawi* (Xentari®) (1.0 lb formulated product/

acre) for control of diamondback moth, *Plutella xylostella* (L.), on bok choi was compared with full-season applications of *B. thuringiensis* subsp. *aziawi* (1.0 lb formulated product) and a nontreated control in a field trial conducted at Loxahatchee, FL in 1995. Plots were one row by 25 feet and each treatment was replicated four times in a randomized complete block design. The efficacy of each treatment was evaluated by rating the diamondback moth feeding damage at harvest on an increasing scale from 1 to 10 with 1 equal to no damage and 10 equal to severe damage.

The efficacy of emamectin benzoate 0.16 EC (0.0075 lb ai/acre) applied full season (four applications) for control of beet armyworm, *Spodoptera exigua* (Hübner), on celery was compared with the efficacy of full-season applications of methomyl 1.8 L (0.45 lb ai/acre) and *B. thuringiensis* subsp. *aziawi* (1.0 lb formulated material/acre) and to a nontreated control at Zellwood, FL in 1994. Plots were two rows by 25 feet and each treatment was replicated four times in a randomized complete block design. The efficacy of each treatment was evaluated by assessing the yield (crates/acre) for each treatment.

The efficacy of emamectin benzoate 0.16 EC (0.01 lb ai/acre) applied full season (11 applications) for control of southern armyworm, *Spodoptera eridania* (Cramer), and tomato pinworm, *Keiferia lycopersicella* (Walsingham), on tomato was compared with full season applications of methomyl 1.8 L (0.45 lb ai/acre) and a nontreated control at Bradenton, FL in 1995. Plots were one row by 15 feet and each treatment was replicated four times in a randomized complete block design. Armyworm density was assessed by determining the percentage of fruit damaged by armyworms. Tomato pinworm density was assessed by counting the number of leafrolls found in a two-minute search.

For each trial, treatment differences were assessed using Fisher's protected least significant difference test (Steel and Torrie, 1980).

Results and Discussion

On bok choi in Loxahatchee, FL during 1995, emamectin benzoate applied full season and emamectin benzoate applied in rotation with *B. thuringiensis* subsp. *aziawi* resulted in very little feeding damage (Fig. 1). Compared with the treatments that included emamectin benzoate, there was significantly greater feeding damage where *B. thuringiensis* subsp. *aziawi* was applied alone for the full season. The mean level of damage where *B. thuringiensis* subsp. *aziawi* was applied full season would generally make this crop unmarketable. However, bok choi with this level of damage could be sold when there is a high market demand. There was significantly greater damage in the nontreated control than in the *B. thuringiensis* subsp. *aziawi* treatment. The results of this trial demonstrate that emamectin benzoate is very effective for controlling diamondback moth larvae on bok choi and that it can provide control even when rotated with a product that is less efficacious.

On celery in Zellwood, FL during 1994, emamectin benzoate applied full season for control of beet armyworm resulted in significantly higher crop yield than methomyl or *B. thuringiensis* subsp. *aziawi* applied full season (Fig. 2). Both methomyl and *B. thuringiensis* subsp. *aziawi* resulted in significantly greater yield compared with the nontreated control.

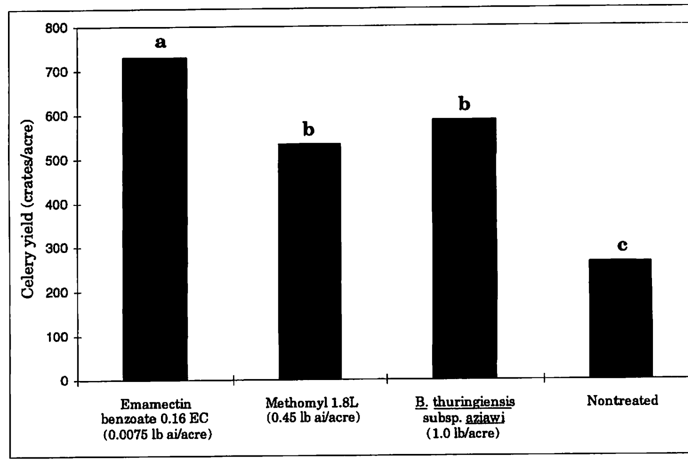

Figure 2. Mean harvest rating for celery treated with different insecticide programs to control beet armyworm larvae at Zellwood, FL in 1994. Four applications for insecticide treatments. Means with the same letter were not significantly different (p<0.05, Fisher's Protected LSD).

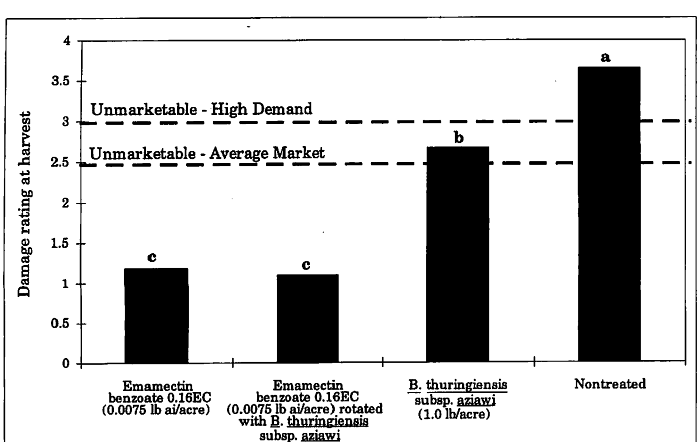

Figure 1. Mean harvest rating for bok choi treated with different insecticide programs to control diamondback moth larvae at Loxahatchee, FL in 1995. Six applications for insecticide treatments. Means with the same letter were not significantly different (p<0.05, Fisher's Protected LSD).

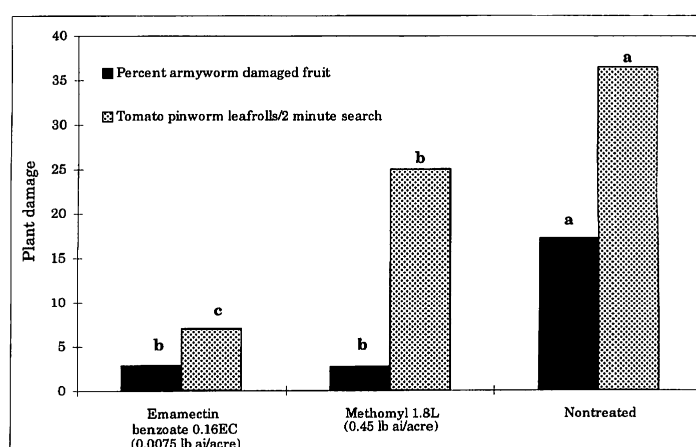

Figure 3. Mean leaf-roll and fruit damage ratings for tomato treated with different insecticide programs to control southern armyworm larvae and tomato pinworm larvae at Bradenton, FL in 1995. Eleven applications for insecticide treatments. Means with the same letter were not significantly different (p<0.05, Fisher's Protected LSD).

Table 1. Lepidoptera pest species controlled by emamectin benzoate.

Common name	Scientific name
	Cole crops
beet armyworm	*Spodptera exigua* (Hübner)
cabbage looper	*Trichoplusia ni* (Hübner)
cabbage webworm	*Hellula rogatalis* (Hulst)
corn earworm	*Helicoverpa zea* (Boddie)
cross-striped cabbageworm	*Evergestis rimosalis* (Guenée)
diamondback moth	*Plutella xylostella* (L.)
fall armyworm	*Spodoptera frugiperda* (J. E. Smith)
imported cabbageworm	*Pieris (=Artogeia) rapae* (L.)
southern armyworm	*Spodoptera eridania* (Cramer)
soybean looper	*Pseudoplusia includens* (Walker)
	Leafy vegetables
beet armyworm	*Spodptera exigua* (Hübner)
cabbage looper	*Trichoplusia ni* (Hübner)
corn earworm	*Helicoverpa zea* (Boddie)
fall armyworm	*Spodoptera frugiperda* (J. E. Smith)
southern armyworm	*Spodoptera eridania* (Cramer)
tobacco budworm	*Heliothis virescens* (F.)
	Fruiting vegetables
beet armyworm	*Spodptera exigua* (Hübner)
cabbage looper	*Trichoplusia ni* (Hübner)
fall armyworm	*Spodoptera frugiperda* (J. E. Smith)
southern armyworm	*Spodoptera eridania* (Cramer)
tobacco budworm	*Heliothis virescens* (F.)
tomato fruitworm	*Helicoverpa zea* (Boddie)
tobacco hornworm	*Manduca sexta* (L.)
tomato pinworm	*Keiferia lycopersicella* (Walsingham)
tomato hornworm	*Manduca quinquemaculata* (Haworth)
western yellowstriped armyworm	*Spodoptera praefica* (Grote)
yellowstriped armyworm	*Spodoptera ornithogalli* (Guenée)

The results of this trial demonstrate that emamectin benzoate can provide better control of beet armyworm compared with standard insecticides.

On tomato in Bradenton, FL during 1995, emamectin benzoate applied full season resulted in significantly fewer tomato pinworm leafrolls compared with methomyl (Fig. 3). Methomyl resulted in significantly fewer leafrolls compared with the nontreated control. Both emamectin benzoate and methomyl resulted in significantly fewer armyworm damaged fruit compared with the nontreated control. The results of this trial demonstrate that emamectin benzoate can provide control of multiple pest species on tomato.

The results of the trials presented here are consistent with those of other trials conducted in Florida and elsewhere. In trials conducted to date, emamectin benzoate has provided excellent control of a wide spectrum of Lepidoptera pest species on vegetables (Table 1). Across trials, control of Lepidoptera pest species was equal to or better than the standards methomyl, permethrin, methomyl applied in combination with permethrin, lambdacyhalothrin, *B. thuringiensis* subsp. *aziawi*, and *B. thuringiensis* subsp. *kurstaki* (Dipel®). Emamectin benzoate also controlled populations of Lepidoptera pest species that were resistant to other pesticides such as diamondback moth at Loxahatchee and beet armyworm at Zellwood. Under heavy population pressure, marketable yield was greater when emamectin benzoate was used compared with other insecticides.

The following best use guidelines are recommended based on results from trials conducted in Florida and elsewhere. Emamectin benzoate should be mixed with water and applied as a foliar spray; thorough coverage is essential for good insect control. Apply at a rate of 0.0075 lb ai/acre for low to moderate infestations and a rate of 0.015 lb ai/acre for severe infestations. Apply when larvae are first observed and repeat applications as necessary to maintain control. Apply with a non-ionic surfactant to improve the wetting of foliage and to smooth out spray deposits. Rotation with other products with different modes of action is strongly advised as part of a sound resistance management program.

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