# A GENETICALLY-MODIFIED *BACILLUS THURINGIENSIS* PRODUCT EFFECTIVE FOR CONTROL OF THE FALL ARMYWORM (LEPIDOPTERA: NOCTUIDAE) ON CORN

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ABSTRACT

ECX9399, a variant of strain EG2348 (the active ingredient of the bioinsecticide Condor®) of *Bacillus thuringiensis* (Berliner) (Bt) subspecies *kurstaki* was developed by recombinant DNA technology by Ecogen Inc. This strain showed greater control of fall armyworm, *Spodoptera frugiperda* (J. E. Smith), infestations in whorl stage corn, *Zea mays* L., than other *Bt* products in field tests conducted in Georgia, Mississippi and Florida during 1993. Control by EC9399 was greatest in Mississippi, where a 4-day spray interval (total of 3 sprays) was used and least in Georgia, where a 7-day schedule (total of 3 sprays) was maintained. The new genetically-modified *Bt* product

had comparable efficacy (decrease in larval number on plants and reduced defoliation) to methomyl, which was used at commercial rates as a conventional insecticide standard at the 3 locations.

Key Words: Corn, *Bacillus thuringiensis*, *Spodoptera frugiperda*

RESUMEN

El ECX9399, una variante de la cepa EG2348 (ingrediente activo del bioinsecticida Condor*) de *Bacillus thuringiensis* (Berliner) (Bt) subespecie *kurstaki*, fue desarrollado por Ecogen Inc. mediante la tecnología de la recombinación del DNA. Esta cepa demostró mayor control de las infestaciones del gusano trozador, *Spodoptera frugiperda* (J. E. Smith), en el maíz, *Zea mays* L., en estado vegetativo que otros productos de Bt en pruebas de campo llevadas a cabo en Georgia, Mississippi y Florida durante 1993. El control con EC9399 fue mayor en Mississippi, donde fue utilizado un intervalo de aspersiones de cuatro días (3 aspersiones en total) y menor en Georgia, donde fue mantenido un programa de siete días (tres aspersiones en total). El nuevo producto de Bt genéticamente modificado tuvo una eficacia (disminución del número de larvas por planta y de la defoliación) comparable a la del methomyl, que fue empleado en concentraciones comerciales como un insecticida convencional estándar en los tres lugares.

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*Bacillus thuringiensis* (Berliner) (*Bt*) subspecies *kurstaki* products have generally exhibited moderate to low effectiveness for controlling the fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) (Gardner & Fuxa 1980; Krieg & Langenbruch 1981; Teague 1993). Recently, products derived from new *Bt* strains have been commercialized, including the EG2348 strain of *Bt* subspecies *kurstaki*, the active ingredient in the bioinsecticide Condor®. These products have shown improved toxicity for certain insects (Gawron-Burke & Baum 1991). EG2348 was developed by Ecogen Inc., (Langhorne, PA 19047) utilizing natural processes for transfer of plasmids with genes encoding for production of specified insecticidal crystal proteins (Gawron-Burke & Baum 1991). Recombinant DNA (*rDNA)* technology has made it possible to improve *Bt* strains (Carlton & Gawron-Burke 1993), and recently Ecogen produced a *rDNA* modified variant (ECX9399) of EG2348 that was more toxic to FAW in laboratory tests (T. Johnson, Ecogen, Inc., Langhorne PA, unpublished data). This study reports results of 1993 field trials in 3 locations with an oil flowable formulation of ECX9399 for FAW control in corn, *Zea mays* L.

## MATERIALS AND METHODS

Field experiments were conducted near Athens, GA, and Oktibbeha, MS, in August and near Groveland, FL, in November. A field corn cultivar (*DeKalb 689*) was used in GA, *Pioneer Tropical* corn was planted in MS, and *Silverqueen* sweetcorn was employed in FL. Plots at the 3 locations varied from 1 to 4 rows 6 to 12 m long. A randomized complete block experimental design was used with 4 or 5 replications.

Spray applications were made with $CO_2$ sprayers mounted with full-cone spray tips and calibrated at the rate of 80 to 120 liters per ha. Three applications were made in the GA (7-day intervals) and MS (4-day intervals) tests and 4 applications (4- to 6-day intervals) were made at the FL site. In each experiment, sprays were applied during the mid-whorl stage of plant development when moderate FAW infestations were

present in the fields (50% or more plants infested with small larvae). Test materials included Cutlass® WP (*Bt* subspecies *kurstaki*, strain EG2371), Condor® OF (*Bt* subspecies *kurstaki*, strain 2348, in an oil flowable formulation), ECX9399 OF (oil flowable formulation), and methomyl (Lannate® LV) (see Table 1 for rates).

Efficacy was determined at selected intervals during and following the spray applications by examining the plants in each plot for defoliation. In MS a visual estimate of defoliation was made, whereas, in GA and FL a 0 to 8 (GA) or 0 to 10 (FL) rating of defoliation and whorl injury was made, progressing from 0 to destruction of plants. Additionally, between 5 and 10 plants in each plot were examined for larvae at selected intervals during and after the spray period. They were categorized as small (<8 mm), intermediate (>8-12 mm) and large (>12 mm). To compare the data between locations, the defoliation estimates and larval counts were converted to percent control by determining the ratio of plant injury or larval counts in the treatment versus the untreated checks. Analysis of variance and Duncan's new multiple range test were conducted using a computer based statistical analysis system (SAS User's Guide: Statistics 1985).

## RESULTS

The FAW infestations at the 3 locations were moderate to heavy. The data in Table 1 demonstrate that the formulation of the genetically-modified *Bt* strain ECX9399 produced control comparable to the conventional standard methomyl. Control with *Bt* was best in MS, where a 4-day spray interval was used, and least in GA, which had a 7-day schedule. Larval numbers also were significantly reduced on corn treated with ECX9399, but were statistically different from methomyl and Condor® in GA. In the MS trial, larval populations were similar in ECX9399 and Condor® plots, and both were significantly less than in the methomyl treatment. In FL, larval populations were significantly less in ECX9399 than in Cutlass®, but not the methomyl treatment.

TABLE 1. EFFICACY OF SELECTED *BT* INSECTICIDAL PRODUCTS FOR FAW ON MID-WHORL STAGE CORN IN 3 LOCATIONS DURING 1993.

| | | % Control[1] | | | | | |
|---|---|---|---|---|---|---|---|
| | | GA[3] | | MS[3] | | FL[3] | |
| Insecticide | Rate[2] | Damage | Larvae | Damage | Larvae | Damage | Larvae |
| ECX9399 OF | 1.6 | 61.1a | 32a | 94.8a | 79.3a | 79.1a | 82.9a |
| Condor® OF | 1.6-1.07 | 32.8bc | 0a | 92.0a | 77.8a | -- | -- |
| Cutlass® WP | 1.13 | -- | -- | -- | -- | 44.9b | 27.1b |
| Methomyl | 1.13-0.5 | 55.6ab | 0a | 89.5a | 27.4b | 88.4a | 98.1a |

[1]Means followed by the same letter within a column are not significantly different in Duncan's new multiple range analysis ($P < 0.05$).

[2]Rates of ECX9399 OF and Condor® OF are presented as volume (in liters) of formulated product per ha, Cutlass® WP as weight (in kg) of formulated product per ha and methomyl (Lannate® LV) as weight (in kg) of active ingredient per ha. Condor® was used at a rate of 1.6 liter per ha in GA and 1.07 liter per ha in MS; methomyl was used at 1.13 kg per ha rate in FL and 0.5 kg per ha at GA and MS.

[3]Applications in GA were made on a 7-day schedule for 3 sprays, MS was every 4 days for 3 sprays and FL was every 4 or 6 days for 4 sprays.

The FL results were similar to those reported by Teague (1993) for Cutlass® and methomyl for FAW control on sweetcorn.

The results show that recombinant DNA technology can be used to improve the toxicity and specificity of *Bt* to insects such as the FAW. ECX9399 was superior to its parent strain, EG2348 (Condor®), in controlling FAW populations and damage in three locations. The fact that ECX9399 produced similar control as methomyl (one of the most efficacious materials available for FAW (All et al. 1986)) in the experiments accentuates the potential of genetically-improved *Bt* strains for insect management.

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