

SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO
DIRECCIÓN DE NUEVAS CREACIONES

2020
Bogotá D.C.,

Abogado
JAIME EDUARDO DELGADO VILLEGAS

SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO

Nº. 09-054900- -00007-0000
Fecha: 2012-08-09 10:05:17 Dep. 2020 DIR.NUEVASCR
Tra. 11 PATENTEIYII Eve: 378 FASENACIONALI
Act. 519 TRASLADOINFORME Folios: 1

ASUNTO	Radicación	09 054 900
	Trámite	011
	Evento	378
	Actuación	519
	Oficio	E 14036
	Folios	15

Patente de Invención	☒	Patente de Modelo de Utilidad	☐
Vía Nacional	☐		
Vía PCT (Fase Nacional)	☒	Capítulo I	☒
		Capítulo II	☐
No. Solicitud Internacional	PCT/EP2007/009898		
Fecha de Presentación Internacional	16/Noviembre/2007		

Como resultado del Examen de Fondo realizado, con fundamento en el Artículo 45 de la Decisión 486 de la Comisión de la Comunidad Andina, se comunica:

1. Documentos estudiados

Descripción:	Folios 52 a 123	28/Mayo/2009
Reivindicaciones:	Folios 124 a 134	28/Mayo/2009
Prioridad:	DE 10 2006 056 544.4	29/Noviembre/2006

2. Análisis de la Prioridad

Se acepta la reivindicación de Prioridad porque esta solicitud fue presentada dentro del plazo establecido (Art. 9 D 486) y su contenido técnico corresponde con el de la prioridad reivindicada.

3. Objeto de la invención

Título de la solicitud: "Combinaciones de Principios Activos Insecticidas (Formononetina + Insecticidas)".

El problema planteado en esta solicitud es la necesidad de proveer composiciones de principios activos alternativas a las ya conocidas en el estado de la técnica.

Para resolver este problema técnico la solicitud en estudio proporciona composiciones de principios activos que contienen formononetina en combinación con insecticidas.

El objeto de la presente Solicitud se relaciona con la Clasificación Internacional de Patentes (CIP): A 01 N 43/16 // 51/00 // 47/02 // 43/22 // 43/56

4. Excepción a la Patentabilidad (Art 20 D 486 literal (c))

La reivindicación 17 enseña semillas que se trataron con una combinación de principios activos según una de las reivindicaciones 1 a 9, la cual no es patentable de acuerdo a lo siguiente:

Expediente 09 054 900 1er Art 45

Artículo 20.- No serán patentables:

c) las plantas, los animales y los procedimientos esencialmente biológicos para la producción de plantas o animales que no sean procedimientos no biológicos o microbiológicos.

5. Reivindicaciones relativas a un uso o a un segundo uso (Art 14 y 21 D 486)

El uso de las reivindicaciones 11, 14-16 no es patentable, de acuerdo con el Art 14.

La reivindicación 12 se refiere a un procedimiento para combatir plagas animales no deseadas, caracterizado porque se dejan actuar combinaciones de principios activos según una de las reivindicaciones 1 a 9 sobre los organismos nocivos y/o su hábitat. Es evidente que la llamada etapa: "se dejan actuar combinaciones de principios activos", es una forma de usar la combinación de principios activos según una de las reivindicaciones 1 a 9. Se le aclara al solicitante que un procedimiento donde su única etapa corresponde a una interacción por contacto donde actúa la combinación de los principios activos, dicha interacción corresponde a un uso. Por tal razón el procedimiento de la reivindicación 12 no es patentable, según el artículo citado.

La reivindicación 18 se refiere a un procedimiento para combatir plagas animales no deseadas, caracterizado porque se aplican combinaciones de principios activos según la reivindicación 1 sobre las plagas animales no deseadas y/o su hábitat y/o semillas. Es evidente que la llamada etapa: "se dejan actuar combinaciones de principios activos", es una forma de usar la combinación de principios activos según una de las reivindicaciones 1 a 9. Se le aclara al solicitante que un procedimiento donde su única etapa corresponde a una interacción por contacto donde actúa la combinación de los principios activos, dicha interacción corresponde a un uso. Por tal razón el procedimiento de la reivindicación 12 no es patentable, según el artículo citado.

6. De la Solicitud de Patente

Título

El título no corresponde con el objeto de la solicitud porque representa una generalización, por lo cual se sugiere al Solicitante hacer la corrección necesaria, guiándose de lo probado en los ejemplos de aplicación.

Reivindicaciones (Art 30 D 486, Art 22 PCT)

Las reivindicaciones 1-3, no se encuentran totalmente sustentadas en la capítulo descriptivo, si bien es cierto que se evidencio un efecto sinérgico en las dos combinaciones probadas, pero este resultado no evidencia que las otras posibles combinaciones que el solicitante desea reivindicar presenten el mismo sinergismo, sírvase modificar las reivindicaciones acordes a lo probado en los ejemplos de aplicación.

Las reivindicaciones 4, 6-9, no encuentran sustento en el capítulo descriptivo, puesto que no se encuentra sustentado formulaciones como las que indica en las respectivas reivindicaciones, se sugiere eliminar las reivindicaciones.

En la reivindicación 13, los términos "agentes tensioactivos y/o diluyentes", son muy generales e imprecisos, no permiten diferenciar la invención del estado de la técnica, se sugiere modificar los términos por el/los compuesto/s o estructuras químicas de los mismos probados en los ejemplos de la aplicación.

Las Reivindicaciones 11, 14-16 indican el uso que puede darse a las combinaciones de principios activos reivindicadas, el cual no es una característica técnica que defina a la invención. Se sugiere hacer la aclaración respectiva.

Descripción (Art 28 D 486)

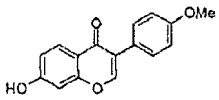
En la descripción (folio 121-122 o páginas de la solicitud 40-41) se menciona emplear marcas registradas, como Nemacur CS 240, Miconato FS 500, Imidacloprid FS 600, lo cual no es adecuado para que pueda ser reproducible la invención. Se sugiere que se establezca de manera inequívoca su estructura o características químicas.

7. Unidad de invención (Art 25 D 486)

Teniendo en cuenta que el objeto de invención está definido por la combinación de formononetina, junto con otros diferentes grupos activos seleccionados de una serie de insecticidas, después de una comparación con el estado del arte se encontró que la formononetina no se puede considerar el elemento unificador que relaciona las modalidades de la invención, puesto que la formononetina está divulgada en el documento D1 [Columna 10 Líneas 6-10], además se encuentra sugerido la combinación con herbicidas o pesticidas [Columna 8, Líneas 53-66]. Por lo tanto el concepto común no es inventivo y no se cumple el requisito de unidad de invención.

La Solicitud no cumple con el Requisito de Unidad de Invención porque se refiere a 23 Grupos Inventivos.

Los Grupos Inventivos están definidos por las siguientes características **esenciales**:

Grupo Inventivo	1er Principio Activo	2do Principio Activo
1	 (I) Formononetina o sus sales	Agonistas/antagonistas de receptores de acetilcolina (preferiblemente cloronicotinilos/neonicotinoides)
2		Inhibidores de la acetilcolinesterasa (AChE) (preferiblemente carbamatos y organofosfatos);
3		Moduladores de los canales de sodio/bloqueadores de los canales de sodio dependientes del voltaje (preferiblemente piretroides y oxadiazinas);
4		Moduladores de los receptores de acetilcolina (preferiblemente espinosinas);
5		Antagonistas de canales de cloruro controlados por GABA (preferiblemente ciclodienos organoclorados y fiproles);
6		Activadores de canales de cloruro (preferiblemente mectinas);
7		Miméticos de la hormona juvenil;
8		Agonistas/disruptores de ecdisona (preferiblemente diacilhidrazinas);
9		Inhibidores de la biosíntesis de quitina (preferiblemente benzoilureas);
10		Inhibidores de la fosforilación oxidativa, disruptores de ATP (preferiblemente organoestaños);
11		Desacopladores de la fosforilación oxidativa mediante interrupción del gradiente de protones H (preferiblemente pirroles y dinitrofenoles);
12		Inhibidores del transporte de electrones al sitio I (preferiblemente METI);
13		Inhibidores del transporte de electrones al sitio II;
14		Inhibidores del transporte de electrones al sitio III;
15		Disruptores microbianos de la membrana intestinal de insectos;
16		Inhibidores de la síntesis de grasas (preferiblemente ácidos tetrónicos y ácidos tetrámicos);
17		Carboxamidas;
18		Agonistas octopaminérgicos;
19		Inhibidores de la ATPasa estimulada con magnesio;
20		Ftalamidas
21		Análogos de la nereistoxina;
22		Productos biológicos, hormonas o feromonas;
23		Principios activos con mecanismos de acción desconocidos o no específicos (preferiblemente fumigantes, antinutritivos selectivos e inhibidores del crecimiento de ácaros).

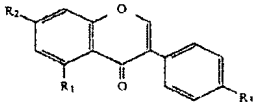
Se sugiere presentar las Solicitudes Divisionales que considere necesarias, ó limitar la solicitud inicial a una sola invención, eliminando de ella las otras invenciones.

8. Determinación del Estado de la Técnica

El Estado de la Técnica se determinó con base en la Fecha de Presentación de la Solicitud de Prioridad: 29/Noviembre/2006 y se encontraron los siguientes documentos que anticipan el objeto de esta solicitud:

Item	Documento	Título	Fecha de Publicación*
D1	US5002603	Method and compositions for stimulating vesicular-arbuscular mycorrhizal fungi	26/Marzo/1991
D2	Bisong Yue, Gerald E. Wilde, and Frank Arthur. Journal of Economic Entomology Vol 96, No2, Págs: 503-509. 2003	Evaluation of Thiamethoxam and Imidacloprid as Seed Treatments to Control European Corn Borer and Indianmeal Moth (Lepidoptera: Pyralidae) Larvae	2003
D3	Alan C. York and John W. Wilcut, Weed Science Vol. 41, No. 2, pp. 269-280 (Apr. - Jun., 1993)	Insecticides Do Not Affect Cotton (Gossypium hirsutum) Response to Imazaquin and Imazethapyr	1993

D1http://worldwide.espacenet.com/publicationDetails/biblio?DB=EPODOC&II=0&ND=3&adjacent=true&locale=en_EP&FT=D&date=19910326&CC=US&NR=5002603A&KC=A
divulga (abstract) un método y composiciones para estimular el crecimiento de los hongos vesiculares-arbusculares micorrizas solos o en presencia de un material vegetal utilizando compuestos



isoflavonoides de fórmula: donde los sustituyentes significan como se indica en el documento.

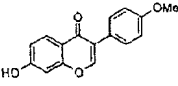
D2(ver folios anexos 204-211)
divulga la eficacia del tiametoxam y del imidacloprid en tratamientos de semillas contra larvas.

D3(ver folio anexo 269 [Solo la página 269])
divulga experimentos de campo y de invernadero donde se evaluaron las interacciones de los insecticidas aplicados (imazaquin y imazetapir) sobre el crecimiento y el desarrollo del algodón.

9. Examen de Patentabilidad (Art 14 D486)

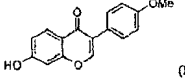
Novedad (Art 16 D486)

La reivindicación 1 consiste en Combinaciones de principios activos que comprenden



formononetina de fórmula (I) o sus sales ⁽ⁿ⁾ y al menos un principio activo que se selecciona de los siguientes grupos (2) a (24), como se ve en los folios 124-126 o paginas de solicitud 43-45.
Se le hará novedad al grupo inventivo 23

Comparación de las características técnicas **esenciales**, con las del Estado de la Técnica:

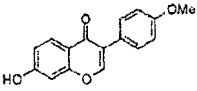
Características esenciales	D1
Combinaciones de principios activos que comprenden formononetina de fórmula (I) o sus sales 	Combinaciones que comprende isoflavonoides (formononetina [Columna 10 Líneas 6-10]) para estimular el crecimiento en plantas [Columna 1 Líneas 8-13]
Grupo Inventivo (23) Principios activos con mecanismos de acción desconocidos o no específicos (preferiblemente fumigantes, antinutritivos selectivos e inhibidores del crecimiento de ácaros).	Pueden ser mezclados con herbicidas o pesticidas, como Imazaquin [Columna 8, Líneas 53-66]

Las características **esenciales** de la composición de la reivindicación 1 habían sido divulgadas previamente en D1, el cual enseña combinaciones que comprende isoflavonoides (formonetina [Columna 10 Líneas 6-10]) para estimular el crecimiento en plantas [Columna 1 Líneas 8-13], que pueden ser mezclados con herbicidas como imazaquin [Columna 8, Líneas 53-66].

En consecuencia, la reivindicación 1 no es nueva, según lo divulgado en el documento D1.

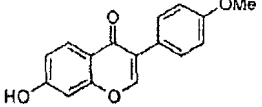
Nivel Inventivo (Art18 D486)

La reivindicación 1 consiste en Combinaciones de principios activos que comprenden

formononetina de fórmula (I) o sus sales  y al menos un principio activo que se selecciona de los siguientes grupos (2) a (24), como se ve en los folios 124-126 o paginas de solicitud 43-45.

Se le hará el nivel inventivo con el grupo inventivo 1.

Comparación de las características técnicas **esenciales**, con las del Estado de la Técnica:

Características esenciales	D1	D2
Combinaciones de principios activos que comprenden formononetina de fórmula (I) o sus sales  (I)	Combinaciones que comprende isoflavonoides (formonetina [Columna 10 Líneas 6-10]) para estimular el crecimiento en plantas [Columna 1 Líneas 8-13]	No menciona
Grupo Inventivo (1) Cloronicotinilos/neonicotinoides (preferiblemente acetamiprid, clotianidina, dinotefuran, imidacloprid, nitenpiram, nitiazina, tiacloprid, tiametoxam);	Pueden ser mezclados con herbicidas o pesticidas [Columna 8, Líneas 53-66]	Imidacloprid

El documento D1, considerado estado de la técnica cercano a la invención definida en la reivindicación 1, divulga combinaciones que comprende isoflavonoides (formonetina [Columna 10 Líneas 6-10]) para estimular el crecimiento en plantas [Columna 1 Líneas 8-13], que pueden ser mezclados con herbicidas como imazaquin [Columna 8, Líneas 53-66].

La diferencia entre la invención, definida en la reivindicación 1, y la composición del documento 1 es que no se muestra específica combinación de la formononetina con Cloronicotinilos/neonicotinoides mientras que en D1 se sugiere la combinación con herbicidas o pesticidas.

No existe evidencia que las diferencias en las composiciones de D1 y el las composiciones de la reivindicación 1 introduzcan un efecto técnico inesperado, que represente para la persona de nivel medio versada en la materia una mejor eficiencia contra insectos.

Por lo tanto, el Problema Técnico Objetivo que pretende resolver esta invención se puede formular así: “proporcionar composiciones de principios activos que contienen formononetina en combinación con insecticidas alternativas a las ya conocidas en el estado del arte”.

Sin embargo, en D1 ya se sugiere la combinación de la formononetina con
Expediente 09 054 900 1er Art 45

herbicidas o pesticidas [Columna 8, Líneas 53-66], y en D2 enseña el uso de imidacloprid, el cual se usa comúnmente para tratamiento sistémico para proteger semillas y plantas contra las lesiones por insectos (Folio Anexo 205 [Página 503]), y en D3 se menciona aplicación de herbicidas e insecticidas para el mismo cultivo es una práctica común (Folio anexo 212 [Página 269 Columna 2]).

En consecuencia, la persona del oficio medianamente versada en la materia, incluiría imidacloprid de D2 en la combinación de D1, y con lo sugerido en D1 y D3, llegando así al objeto de la reivindicación 1 de la solicitud. Por lo cual se considera obvia.

Puesto que las reivindicaciones dependientes 2-3, 5-6, 10 no mencionan características inventivas adicionales, tampoco pueden ser consideradas inventivas.

Conclusión:
Las reivindicaciones 1-3, 5-6, 10 cumplen el requisito de novedad (Art. 16), pero no cumplen con el requisito de nivel inventivo (Art. 18).

10. Conclusión

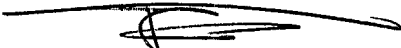
Los requisitos de Patentabilidad de la presente Solicitud están afectados así:

Ítem	Documento	Reivindicaciones afectadas	Requisito que afecta
D1	US5002603	1	Novedad
		1-3, 5-6, 10	Nivel Inventivo
D2	Bisong Yue, Gerald E. Wilde, and Frank Arthur. Journal of Economic Entomology Vol. 96, No 2, Págs: 503-509. 2003	1-3, 5-6, 10	Nivel Inventivo
D3	Alan C. York and John W. Wilcut, Weed Science Vol. 41, No. 2, Págs: 269-280 (Apr. - Jun., 1993)	1-3, 5-6, 10	Nivel Inventivo

En cumplimiento del artículo 45 de la Decisión 486 de la Comisión de la Comunidad Andina, se le indica que debe dar respuesta dentro del término de sesenta (60) días contados a partir de la fecha de notificación de la presente comunicación. En caso de no dar respuesta al presente requerimiento, o si a pesar de la respuesta subsistieran los impedimentos para la concesión, se denegará la patente.

Se invita al solicitante se sirva indicar, si así lo considera, su renuncia al término faltante y presentarla por escrito

Notifíquese el presente oficio conforme a lo dispuesto en el numeral 5.2, literal e), del capítulo quinto del título primero de la Circular Única No. 10 de 2001.


JOSÉ LUIS SALAZAR LÓPEZ
Director de Nuevas Creaciones (C)

El anterior requerimiento fue notificado por fijación en lista, de fecha _____
14 AGO. 2012

Elaborado por: Jhonattan Sánchez Sánchez *OK*
Revisado por: Jacqueline Alfonso Rozo

Evaluation of Thiamethoxam and Imidacloprid as Seed Treatments to Control European Corn Borer and Indianmeal Moth (Lepidoptera: Pyralidae) Larvae

Author(s): Bisong Yue, Gerald E. Wilde, and Frank Arthur

Source: Journal of Economic Entomology, 96(2):503-509. 2003.

Published By: Entomological Society of America

DOI: <http://dx.doi.org/10.1603/0022-0493-96.2.503>

URL: <http://www.bioone.org/doi/full/10.1603/0022-0493-96.2.503>

BioOne (www.bioone.org) is a nonprofit, online aggregation of core research in the biological, ecological, and environmental sciences. BioOne provides a sustainable online platform for over 170 journals and books published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Web site, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/page/terms_of_use.

Usage of BioOne content is strictly limited to personal, educational, and non-commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

Evaluation of Thiamethoxam and Imidacloprid as Seed Treatments to Control European Corn Borer and Indianmeal Moth (Lepidoptera: Pyralidae) Larvae

BISONG YUE,^{1,2} GERALD E. WILDE,¹ AND FRANK ARTHUR³

Department of Entomology, Kansas State University, Manhattan, KS 66506

J. Econ. Entomol. 96(2): 503-509 (2003)

ABSTRACT Efficacy of thiamethoxam (Cruiser) and imidacloprid (Gaucho) were evaluated as seed treatments for controlling European corn borer, *Ostrinia nubilalis* (Hübner) and Indianmeal moth, *Plodia interpunctella* (Hübner) larvae in stored grain. At ≈ 22 - 26°C , all fifth instar European corn borers died after two or 4 d of exposure to corn treated with 250 and 500 ppm thiamethoxam, respectively, while mortality of larvae exposed for two and 4 d on corn treated with 6.3-937.5 ppm imidacloprid did not exceed 48% at any concentration. At 29°C , all nondiapausing fifth instars were killed after 3, 4, and 6-d exposure to 400, 300 and 200-ppm thiamethoxam, respectively, while survival increased at successively lower concentrations of 100, 50, 25, and 12.5 ppm. At 29°C , the LC_{50} decreased from 85.9 to 7.2 ppm as the duration of exposure on treated corn increased from 2 to 6 d. All second and third instar Indianmeal moth larvae died after a 5 d exposure period to corn grain treated with thiamethoxam at 50 ppm or higher, but as the larvae aged, higher concentrations and longer exposure periods were required to give 100% mortality of each larval instar. Similar results were obtained when larval Indianmeal moths were exposed on corn treated with imidacloprid, or on sorghum treated with thiamethoxam. Mature wandering phase fifth instars were the most tolerant larval stage of the Indianmeal moth.

KEY WORDS thiamethoxam, imidacloprid, European corn borer, Indianmeal moth, *Plodia interpunctella*

SYSTEMIC INSECTICIDES FOR SEED treatments are being developed and used in the field for insect control on a variety of crops around the world. Cruiser is a trademark for thiamethoxam, a second-generation neonicotinoid insecticide developed by Syngenta Crop Protection Inc. (Greensboro, NC). It provides excellent control of a wide variety of commercially important insect pests on a variety of crops including barley, cotton, sorghum, wheat, canola, and corn through contact, stomach and systemic activity (Gobel et al. 1999, Maiefisch et al. 1999, Hofer and Brandl 1999, Zang et al. 1998, Lawson et al. 1999).

Imidacloprid (Gaucho) is commonly used as a systemic seed treatment to protect seeds and seedlings against injury by early season insects (Wilde et al. 1999, Graham 1998, Burd et al. 1996, Ahmand 1995, McKirdy and Jones 1996). Imidacloprid (Gaucho)

marketed by Gustafson Inc. (Dallas, TX), is effective in controlling many insects, including aphids, thrips, mites, wireworms, and true bugs (Bradley et al. 1998, Graham et al. 1995, Harvey et al. 1996), and is commonly used on several crops, including cotton, wheat, barley, sorghum, canola, corn, and sugar beets.

Although the effects of thiamethoxam and imidacloprid on pest insects on field crops are well documented, their effects on insects such as the European corn borer, *Ostrinia nubilalis* (Hübner) and Indianmeal moth, *Plodia interpunctella* (Hübner) present in or damaging stored grain have not been studied. The Indianmeal moth is an important pest of stored grain worldwide and its control in stored grain is an important concern of those storing grain for sale as food or seed (Arthur 1999). The European corn borer, while not considered a storage pest, may appear as a contaminant in grain stored for seed purposes and is thus a cause for concern by corn and sorghum hybrid seed producers (Wilde 1976). The objective of this study was to evaluate the efficacy of these two insecticides as seed treatment for controlling European corn borer, *Ostrinia nubilalis*, and Indianmeal moth, *Plodia interpunctella* in stored grain.

¹ E-mail: gwilde@oznet.ksu.edu.

² Department of Biology, Sichuan University, Chengdu, Sichuan 610064, China.

³ USDA Grain Marketing and Production Research Center, Manhattan, KS 66502.

Materials and Methods

The insecticides used in this study were thiamethoxam (Cruiser), a 47.8% 5 lbs/gallon (AI) product (600 mg/ml) supplied by Syngenta, and imidacloprid (Gaucho) 480 SL, a 40.7% (AI) 4 lbs per gallon product (480 mg/ml) supplied by Gustafson, Inc. The insects species and stages used for bioassays were fifth-instar European corn borer, obtained from French Agricultural Research Inc. (Lamberton, MN), and various stages of the Indianmeal moth, obtained from laboratory colonies reared as described by (Silhacek and Miller (1972).

Tests with European Corn Borer. The insecticides used in this study were thiamethoxam (Cruiser), a 47.8% 5 lbs/gallon (AI) product (600 mg/ml) supplied by Syngenta, and imidacloprid (Gaucho) 480 SL, a 40.7% (AI) 4 lbs per gallon product (480 mg/ml) supplied by Gustafson, Inc. Fifth-instar European corn borer, obtained from a commercial source (French Agricultural Research Inc. Lamberton, MN), were used for the bioassays. Initial tests were done by exposing fifth-instar European corn borers on corn treated with 0, 50, 250, and 500 ppm thiamethoxam and 0, 6.3, 62.5, 312.5, 625, and 937.5 ppm imidacloprid. Rates were chosen based on label rates and the results of preliminary observations and all tests were conducted at room temperature (≈ 22 – 25°C). The insecticides were formulated in water. The label spray rate for both products is 295.6 ml (10 ounces) of formulated spray per 45.4 kg (100 lbs) of corn. For our tests individual lots of 1.5 kg were treated, with 9.8 ml of spray. For each application rate of each insecticide, serial dilutions of the commercial insecticides were formulated in tap water to produce solutions giving the chosen ppm levels when sprayed at the rate of 9.8 ml/1.5 kg of corn. Applications were made by spreading the corn out in a thin layer onto a 0.6 by 0.3 m plywood sheet, and using a Badger model 100 artists' airbrush (Franklin Park, IL) to mist 9.8 ml of the insecticide in water on the corn. The untreated control lot was misted with water alone.

Each lot of 1.5-kg corn treated at the various concentrations was subdivided into five replicates of ≈ 235 g each, which were put into plastic containers (diameter 8.5 cm, height 6.0 cm), and the remainder discarded. Ten fifth instar European corn borers were put inside the containers, and the containers, each with a mesh cover, were put into a plastic cooler with ≈ 10 cm of water at the bottom to maintain a high humidity level. Insect mortality was assessed after 2, 4, and 6 d. The criterion of death was no movement of larvae when prodded with a camel's-hair brush.

In a second test, fifth instar European corn borers were exposed on corn treated with 0, 12.5, 25, 50, 100, 200, 300, and 400 ppm thiamethoxam. All concentrations were formulated in tap water from the 600 mg/ml EC product as described earlier, and each concentration was applied at the rate of 9.8 ml formulated spray per 1.5 kg of corn. The untreated control was sprayed with tap water. Each 1.5 lot of

each concentration from each replicate was subdivided into five replicates, each with 235 g of corn, and ten fifth instars added into each container as described earlier. The containers were then put inside a growth chamber at $29 \pm 1^{\circ}\text{C}$ and 50–70% RH with a photoperiod of 12:12 (L:D). Mortality was assessed after 2, 4, and 6 d.

Indianmeal Moth on Corn. Stock laboratory colonies of Indianmeal moth were maintained and reared as described by Silhacek and Miller (1972) at $\approx 27^{\circ}\text{C}$, 60% RH. Concentrations of thiamethoxam and imidacloprid used for the tests with Indianmeal moths were 0, 50, 100, 250, and 500 ppm, and 0, 62.5, 156.3, 312.5, 625, and 937 ppm for each insecticide, respectively. The individual concentrations of each insecticide were formulated as described earlier, and applied at the rate of 9.6 ml of spray per 1.5 kg of corn. The following instars were collected from the stock colony cultures, second instars, third instars, fourth instars, early fifth instars, and late fifth-instars (≈ 6 – S , 9–11, 12–13, 14–15, and 16–17 d-old, respectively, for each stage). The instars were exposed separately, depending on the availability of a particular stage. Each lot of 1.5 kg treated corn and the untreated lot of 1.5-kg corn was subdivided into five replicates, which were put into the plastic containers as described before. Each instar was treated separately, and 20 instars were put into each of five replicate containers, which were put inside a growth chamber set at $29 \pm 1^{\circ}\text{C}$, 50–70% RH and a photoperiod of 12:12 (L:D). A final set of mature fifth instars were held inside a plastic cooler, with water in the bottom, at room temperature of ≈ 22 – 25°C . Mortality of larvae held inside the chamber was assessed after 5, 10, and 15 d, while mortality of larvae held at room temperature was assessed after 6, 12, 24, and 38 d.

Indianmeal Moth on Sorghum. The response of Indianmeal moth larvae exposed on sorghum treated with thiamethoxam was also evaluated, using the same procedures as described for corn. Sorghum was treated and larvae were exposed as described for corn, except that all tests were conducted inside the growth chamber, and no tests were conducted at room temperature.

Statistical Analysis. Data for all studies were analyzed using the General Linear Models (GLM) and Means Procedures of the Statistical Analysis System (SAS Institute 2001). Because all observations at the various postexposure intervals were conducted on the same set of larvae, data were analyzed with days of exposure as a repeated measure. Means were separated using the Waller-Duncan k-ratio *t*-test option under the GLM Procedure of SAS ($P < 0.05$). Probit analysis susceptibility of fifth instar European corn borer to thiamethoxam was done using the POLO procedure (LeOra Software 1994).

Results

European Corn Borer on Corn. Concentration and ($F = 46.4$, $df = 5, 8$, $P < 0.01$) exposure interval ($F = 273.7$, $df = 2, 8$, $P < 0.01$) were significant for the tests

Table 1. Percent mortality (mean ± SEM) of 5th instar European corn borer exposed for 2, 4, and 6 d on corn treated with imidacloprid and thiamethoxam^a

Concentration (ppm)	Exposure (days)		
	2	4	6
imidacloprid			
0	1 ± 1.0c	5 ± 2.2d	35 ± 3.4b
6.25	8 ± 3.7bc	18 ± 7.3cd	52 ± 7.3ab
62.5	10 ± 4.4bc	34 ± 6.0ab	58 ± 8.0a
312.5	11 ± 3.1b	25 ± 2.7bc	49 ± 5.0ab
625.0	22 ± 4.9a	44 ± 8.7a	62 ± 7.3a
937.5	22 ± 2.0a	48 ± 8.6a	55 ± 8.6a
thiamethoxam			
0	2 ± 2.0c	6 ± 4.0c	30 ± 4.4c
50	30 ± 9.4b	68 ± 10.7d	82 ± 9.6b
250	92 ± 8.0a	100a	100a
500	100a	100a	100a

^a Means within columns followed by the same letter are not significantly different ($P \geq 0.05$, Waller-Duncan k-ration *t*-test, SAS Institute 2001).

with imidacloprid, with days of exposure as a repeated measure. Mortality of fifth instar European corn borer exposed on corn treated with imidacloprid at 6.2–937.5 ppm ranged from $6.0 \pm 2.4\%$ to $62.0 \pm 7.3\%$, depending on concentration and exposure interval (Table 1). Concentration and ($F = 375.2$, $df = 3, 8$, $P < 0.01$) exposure interval ($F = 71.7$, $d. f. = 2, 8$, $P < 0.01$) were also significant for the initial test with thiamethoxam. All larvae died within 2 d when exposed on corn treated with 500 ppm thiamethoxam, 92.0% and 100% of the larvae died after 2 d and 4 d, respectively, on corn treated with 250 ppm, and 30.0 and 68.0% died after two and 4 d of exposure on corn treated with 50 ppm (Table 1).

Concentration was also significant ($F = 737.6$, $d. f. = 8, 16$, $P < 0.01$) and exposure interval ($F = 262.2$,

$d. f. = 4, 16$, $P < 0.01$), with exposure interval as a repeated measure, for the additional evaluation with thiamethoxam. All larvae died after 3 d of exposure on corn treated with 400 ppm, after 4 d of exposure on corn treated with 300 ppm, or after 6 d of exposure on corn treated with 200 ppm (Table 2). The calculated LC_{50} decreased from 85.9 ppm at 2 d to 7.2 ppm at 6d, while the LC_{90} was 399.3 and 46.9 ppm at two and 6 d, respectively (Table 3). Thiamethoxam was equally effective in controlling diapausing fifth instar European corn borer larvae. All exposed were dead after 4 d of exposure in corn treated with 500 ppm or after 10 d of exposure in corn treated with 250 ppm. There were 10.0% of the diapausing larvae surviving after 10 d in grain treated with 50 ppm, compared with 71.3% survival in the untreated control.

Indianmeal Moth on Corn. For each larval stage, the analysis for concentration of imidacloprid and exposure, with exposure as a repeated measure, was significant ($F = 79.5$, $df = 4, 12$; $F = 597.7$, $df = 4, 12$; $F = 364$, $df = 4, 8$; $F = 542.7$, $df = 4, 8$ and $F = 124.1$, $df = 4, 16$ for second, third, fourth, early fifth, and mature fifth instars, respectively, $P < 0.01$). Exposure was also significant ($F = 25.1$, $df = 4, 16$; $F = 43.9$, $df = 3, 16$; $F = 243.5$, $df = 2, 16$; $F = 364.5$, $df = 4, 16$; and $F = 510.0$, $df = 4, 16$ for second, third, fourth, early fifth, and mature fifth instars, respectively, $P < 0.01$). All interactions were also significant at $P < 0.01$. As larvae aged, longer exposure intervals were required at each concentration to kill all exposed individuals (Table 4). Some mature fifth instars survived after 20 d when exposed at the lower concentrations, and this instar was the most tolerant larval stage of the Indianmeal moth exposed to imidacloprid.

For each larval stage, the analysis for concentration of thiamethoxam and exposure, with exposure as a repeated measure for the fourth and fifth instars, was

Table 2. Percent mortality (mean ± SEM) of 5th instar European corn borer exposed for 2, 3, 4, 5, and 6 d on corn treated with thiamethoxam^a

Concentration (ppm)	Exposure (days)				
	2	3	4	5	6
0	0 ± 0.0f	3 ± 1.6g	4 ± 1.6e	7 ± 3.0e	12 ± 3.2d
12.5	0 ± 0.0f	35 ± 2.5f	55 ± 4.9d	67 ± 5.1d	76 ± 3.4c
25	24 ± 2.7e	39 ± 2.5f	60 ± 6.3d	68 ± 2.4d	77 ± 5.5c
50	33 ± 3.0d	48 ± 3.2e	71 ± 1.6c	77 ± 1.6c	88 ± 1.3b
100	53 ± 2.0c	71 ± 2.7d	81 ± 4.4d	91 ± 1.6b	97 ± 1.6a
200	73 ± 2.1b	79 ± 1.3c	87 ± 2.1b	97 ± 1.6a	100a
300	85 ± 2.5a	87 ± 2.1b	100a	100a	100a
400	90 ± 1.0a	100a	100a	100a	100a

^a Means within columns followed by the same letter are not significantly different ($P \geq 0.05$, Waller-Duncan k-ration *t*-test, SAS Institute 2001).

Table 3. Toxicity of thiamethoxam to 5th instar European corn borer at 29°C

Days	LC_{50} (95% FL)	LC_{90} (95% FL)	Slope	H ²	df
2	85.90 (73.4–100.0)	399.3 (327.5–508.7)	1.92 ± 0.14	16.29	33
3	40.50 (31.8–49.6)	349.5 (266.3–495.7)	1.37 ± 0.13	19.02	33
4	15.70 (10.8–20.8)	157.3 (121.3–219.9)	1.28 ± 0.15	28.76	33
5	10.40 (6.7–14.4)	84.3 (66.4–113.5)	1.41 ± 0.18	17.21	33
6	7.22 (4.0–10.5)	46.9 (36.9–62.5)	1.58 ± 0.24	15.34	33

Table 4. Percent mortality (mean $\pm$ SEM) of Indianmeal moth larvae exposed for 5, 10, 15, and 20 d on untreated corn and corn treated with imidacloprid and held at 29°C^a

Concentration (ppm)	Exposure (days)				
	5	10	15	20	25
2nd instars					
0	20 $\pm$ 3.5b	26 $\pm$ 2.5c	26 $\pm$ 2.5c	32 $\pm$ 2.6d	
6.3	17 $\pm$ 3.4b	21 $\pm$ 6.0c	27 $\pm$ 6.2c	35 $\pm$ 4.6b	
62.5	81 $\pm$ 4.5a	92 $\pm$ 1.2b	95 $\pm$ 1.6a	100a	
156.3	96 $\pm$ 1.0a	100a			
312.5	100a	100a			
3rd instars					
0	15 $\pm$ 2.2c	19 $\pm$ 2.9b	20 $\pm$ 2.7b		
62.5	56 $\pm$ 5.0b	80 $\pm$ 3.1a	95 $\pm$ 2.7a		
156.3	100a	100a	100a		
312.5	100a	100a	100a		
625.0	100a	100a	100a		
4th instars					
0	8 $\pm$ 5.0c	16 $\pm$ 4.0c	22 $\pm$ 3.4b		
62.5	21 $\pm$ 1.8b	54 $\pm$ 3.3b	85 $\pm$ 3.5a		
156.3	37 $\pm$ 3.3b	78 $\pm$ 2.5ab	90 $\pm$ 3.2a		
312.5	64 $\pm$ 7.6a	91 $\pm$ 2.4a	97 $\pm$ 1.2a		
625.0	75 $\pm$ 6.0a	93 $\pm$ 2.5a	100 $\pm$ 0.0a		
early 5th instars					
0	1 $\pm$ 1.0c	9 $\pm$ 2.4c	17 $\pm$ 3.0c		
62.5	2 $\pm$ 1.2a	28 $\pm$ 3.7b	73 $\pm$ 3.4b		
156.3	20 $\pm$ 3.2b	49 $\pm$ 2.4b	94 $\pm$ 1.9a		
312.5	45 $\pm$ 3.5a	65 $\pm$ 2.7a	100a		
625.0	61 $\pm$ 4.0a	79 $\pm$ 2.4a	100a		
late 5th instars ^b					
0	1 $\pm$ 1.0b	2 $\pm$ 1.8b	29 $\pm$ 1.9b	33 $\pm$ 2.0b	
6.25	3 $\pm$ 2.0b	37 $\pm$ 1.2a	41 $\pm$ 4.6a	65 $\pm$ 3.2a	
62.5	1 $\pm$ 1.0b	41 $\pm$ 4.6a	65 $\pm$ 3.2a	77 $\pm$ 3.0a	
156.3	3 $\pm$ 1.2b	44 $\pm$ 2.4a	60 $\pm$ 3.5a	73 $\pm$ 5.8a	
312.5	49 $\pm$ 3.3a	45 $\pm$ 3.7a	56 $\pm$ 2.9a	78 $\pm$ 2.5a	

^a Means within columns followed by the same letter are not significantly different ($P \geq 0.05$, SAS) Waller-Duncan k-ratio t-test, SAS Institute 2001.
^b Mortality of late 5th instars after 25 d, at 0, 6.25, 62.5, 156.3, and 312.5 ppm of exposure was 33.3 $\pm$ 2, 75.5 $\pm$ 4.7, 85 $\pm$ 2.2, 84 $\pm$ 1.6 and 100.0%, respectively.

significant ($F = 140.6$, $df = 4, 23$; $F = 421.3$, $df = 4, 23$; $F = 64.4$, $df = 4, 8$; $F = 503.0$, $df = 4, 16$, and $F = 307.9$, $df = 4, 15$ for second, third, fourth, early fifth, and mature fifth instars, respectively, $P < 0.01$). Exposure interval was also significant (Table 5) ($F = 34.9$, $df = 2, 16$; $F = 2358.6$, $df = 4, 16$; and $F = 690.0$, $df = 4, 16$ for fourth, early fifth, and mature fifth instars, respectively, $P < 0.01$). All interactions were also significant at $P < 0.01$. As the Indianmeal moth larvae aged, they became less susceptible to thiamethoxam, and higher concentrations and longer exposure intervals were required to give 100% control (Table 6). Second and third instars were very susceptible and at least 98% of the exposed larvae died after 5 d on all concentrations. Mortality of fourth, early fifth, and mature fifth instars after 5 d of exposure on treated corn ranged from 64 $\pm$ 7.5–80 $\pm$ 5.5%, 1 $\pm$ 1–39 $\pm$ 4.0%, and 0–26 $\pm$ 2.4%, respectively. As the exposure interval increased, mortality increased, with 100% mortality occurring after 15, 20, and 25-d exposure of fourth, early fifth, and mature fifth instars, respectively.

Mature Fifth Instars Were Also the Most Tolerant of the Larval Stages Exposed to Thiamethoxam. When mature fifth instars were exposed on corn treated with

imidacloprid and held at room temperature of ≈ 22 –25°C, both concentration ($F = 84.1$, $df = 5, 24$, $P < 0.01$) and exposure were significant ($F = 367.5$, $df = 6, 24$, $P < 0.01$), with exposure as a repeated measure. Mortality generally increased with both concentration and exposure (Table 7), and after 38 d ranged from 90 $\pm$ 4.2–100% in the insecticide treatments. Similar results were obtained for fifth instars exposed on corn treated with thiamethoxam and held at room temperature of ≈ 22 –25°C. Both concentration ($F = 104.9$, $df = 4, 24$, $P < 0.01$) and exposure were significant ($F = 604.1$, $df = 6, 24$, $P < 0.01$), with exposure as a repeated measure. Mortality of mature fifth instars at all concentrations was low during the first 12 d of exposure, then gradually increased to 66 $\pm$ 5.1–100% after 38 d (Table 7).

Indianmeal Moth on Sorghum. For each larval stage exposed on sorghum, the analysis for concentration of imidacloprid and exposure, with exposure as a repeated measure, was significant ($F = 8.2$, $d. f. = 1, 23$) for second instars, $F = 3376.7$, $df = 4, 8$; $F = 593.6$, $df = 4, 12$; $F = 130.0$, $df = 4, 12$; and $F = 327.4$, $df = 4, 16$ for third, fourth, early fifth, and mature fifth instars, respectively, $P < 0.01$ for all stages). Days of exposure

Table 5. Percent mortality (mean $\pm$ SEM) of Indianmeal moth larvae exposed for 5, 10, and 15 d on untreated corn and corn treated with thiamethoxam and held at 29°C^a

Concentration (ppm)	Exposure (days)			
	5	10	15	20
3rd instars ^{b1}				
0	13 $\pm$ 3.7b			
50	99 $\pm$ 1.0a			
100	98 $\pm$ 1.2a			
250	100a			
500	100a			
4th instars				
0	12 $\pm$ 3.4b	16 $\pm$ 2.9b		
50	64 $\pm$ 7.5a	85 $\pm$ 2.7a		
100	71 $\pm$ 4.0a	98 $\pm$ 2.0a		
250	67 $\pm$ 4.4a	95 $\pm$ 1.2a		
500	80 $\pm$ 5.5a	100a		
early 5th instars				
0	0	26 $\pm$ 4.8b	26 $\pm$ 4.5b	
50	3 $\pm$ 1.2c	85 $\pm$ 2.2a	89 $\pm$ 2.9a	
100	1 $\pm$ 1.0c	94 $\pm$ 1.9a	100a	
250	15 $\pm$ 2.7b	96 $\pm$ 2.4a	100a	
500	39 $\pm$ 4.0a	100a	100a	
late 5th instars ^c				
0	0b	7 $\pm$ 2.0c	16 $\pm$ 2.9b	16 $\pm$ 2.9c
50	0b	21 $\pm$ 4.0d	45 $\pm$ 2.2a	77 $\pm$ 4.6b
100	2 $\pm$ 2.0b	17 $\pm$ 3.0b	52 $\pm$ 3.4a	85 $\pm$ 1.6b
250	8 $\pm$ 2.5b	28 $\pm$ 3.7a	53 $\pm$ 2.5a	96 $\pm$ 1.9a
500	26 $\pm$ 2.4a	45 $\pm$ 3.2a	64 $\pm$ 2.4a	94 $\pm$ 4.4a

^a Means within columns followed by the same letter are not significantly different (Waller-Duncan k-ratio *t*-test, SAS Institute 2001).
^{b1} All 2nd–3rd instars were dead after 5 d exposure on treated corn.
^c Mortality after 25 d at 0, 50, 100, 250, and 500 ppm was 16 $\pm$ 2.9, 89 $\pm$ 1.9, 96 $\pm$ 1.5, 100 and 100%, respectively.

Table 6. Percent mortality (mean $\pm$ SEM) of mature 5th instar Indianmeal moth exposed for 2 to 38 d on untreated corn and corn treated with imidacloprid and held at room temperature of about 22 to 25°C^a

Concentration (ppm)	Exposure (days)						
	2	4	6	12	14	32	38
0	0	0b	4 $\pm$ 1.6b	16 $\pm$ 1.6a	20 $\pm$ 1.2b	24 $\pm$ 2.7b	26 $\pm$ 1.6b
156.3	0	2 $\pm$ 1.3b	8 $\pm$ 2.5b	20 $\pm$ 2.1a	34 $\pm$ 1.6b	66 $\pm$ 2.7a	90 $\pm$ 4.2a
312.5	0	2 $\pm$ 1.3b	8 $\pm$ 2.5b	20 $\pm$ 2.1a	82 $\pm$ 2.9a	90 $\pm$ 4.2a	100a
625.0	0	8 $\pm$ 2.5ab	14 $\pm$ 1.6ab	26 $\pm$ 3.4a	78 $\pm$ 5.3a	94 $\pm$ 2.7a	100a
957.5	0	16 $\pm$ 1.6a	22 $\pm$ 2.4a	32 $\pm$ 2.3a	86 $\pm$ 2.7a	100a	100a

^a Means with columns followed by the same letter are not significantly different ($P \geq 0.05$, Waller-Duncan k-ratio *t*-test, SAS Institute 2001).

Table 7. Mortality (mean $\pm$ SEM) of mature 5th instar Indianmeal moth larvae exposed for 2 to 38 d on untreated corn and corn treated with thiamethoxam and held at room temperature of about 22 to 25°C^a

Concentration (ppm)	Exposure (days)						
	2	4	6	12	24	32	38
0	0	0	0	6 $\pm$ 2.4	18 $\pm$ 5.8	24 $\pm$ 4.0	36 $\pm$ 4.0
50	0	0	2 $\pm$ 2.0	16 $\pm$ 6.7	40 $\pm$ 10.9	62 $\pm$ 9.9	66 $\pm$ 5.1
100	0	0	4 $\pm$ 2.4	16 $\pm$ 4.0	38 $\pm$ 8.0	52 $\pm$ 4.9	88 $\pm$ 4.9
250	0	0	4 $\pm$ 2.4	12 $\pm$ 2.0	24 $\pm$ 5.2	92 $\pm$ 3.7	98 $\pm$ 2.0
500	0	0	2 $\pm$ 2.0	12 $\pm$ 3.7	74 $\pm$ 8.7	98 $\pm$ 2.0	100 $\pm$ 0.0

^a Means with columns followed by the same letter are not significantly different ($P > 0.05$, Waller-Duncan k-ratio *t*-test, SAS Institute 2001).

Table 8. Mortality (mean $\pm$ SEM) of Indianmeal moth larvae exposed for 5–30 d on untreated sorghum and sorghum treated with thiamethoxam^a

Concentration (ppm)	Exposure (days)				
	5	10	15	20	30
	2nd instar				
0	20 $\pm$ 2.2b				
50	97 $\pm$ 3.3a				
100	100a				
250	100a				
500	100a				
	3rd instar				
0	23 $\pm$ 3.0c	24 $\pm$ 2.4c			
50	86 $\pm$ 4.6b	94 $\pm$ 2.4b			
100	96 $\pm$ 1.9b	100a			
250	100a	100a			
500	100a	100a			
	4th instar				
0	19 $\pm$ 4.8c	23 $\pm$ 4.3c	24 $\pm$ 3.7d		
50	79 $\pm$ 1.8b	90 $\pm$ 1.6b	96 $\pm$ 1.8a		
100	82 $\pm$ 6.0b	98 $\pm$ 1.2a	99 $\pm$ 1.1a		
250	81 $\pm$ 6.1b	98 $\pm$ 2.0a	100a		
500	100a	100a	100a		
	early 5th instar				
0	10 $\pm$ 2.2b	13 $\pm$ 1.2d	19 $\pm$ 1.9d	19 $\pm$ 1.9c	
50	18 $\pm$ 4.6b	62 $\pm$ 3.7b	82 $\pm$ 1.2c	93 $\pm$ 1.2b	
100	20 $\pm$ 5.7b	79 $\pm$ 3.3b	92 $\pm$ 2.0c	99 $\pm$ 1.0b	
250	15 $\pm$ 5.7b	61 $\pm$ 4.0b	94 $\pm$ 3.6b	100a	
500	80 $\pm$ 6.7a	100a	100a	100a	
	late 5th instar				
0	13 $\pm$ 2.2b	13 $\pm$ 2.0d	24 $\pm$ 1.8d	24 $\pm$ 1.8d	24 $\pm$ 1.8c
50	14 $\pm$ 1.8b	18 $\pm$ 2.0c	78 $\pm$ 2.5c	84 $\pm$ 1.7c	84 $\pm$ 1.7b
100	17 $\pm$ 2.0b	25 $\pm$ 2.7bc	84 $\pm$ 1.8b	88 $\pm$ 1.2c	97 $\pm$ 1.2b
250	16 $\pm$ 1.8b	32 $\pm$ 4.6b	88 $\pm$ 1.2ab	93 $\pm$ 2.0b	100a
500	26 $\pm$ 2.9a	46 $\pm$ 6.4a	93 $\pm$ 3.3a	100a	100a

^a For each instar, means followed by the same letter are not significantly different ($P \geq 0.05$ Waller-Duncan k-ratio t -test, SAS Institute 2001).

was also significant ($F = 26.0$, $df = 1,4$; $F = 36.5$, $df = 2,8$; $F = 124$, $df = 3,12$, and $F = 704.8$, $df = 4,16$ for third, fourth, early fifth, and mature fifth instars, respectively, $P < 0.01$ for all instars). All interactions were also significant at $P < 0.01$. All second instars were killed when exposed on sorghum treated with thiamethoxam (Table 8). At each concentration, mortality generally decreased as larvae aged and increased with exposure interval, similar to results for Indianmeal moth exposed on corn. Although mortality of fifth instars was low for the first 10 d, a sharp increase in mortality occurred after 15 d at all tested doses. A mortality of 100% occurred after 20 and 25 d in the 500 and 250-ppm treatments, respectively, compared with mortalities of 84.0 and 97.0%, respectively, after 25 d in the 50 and 100-ppm treatments.

Discussion

As lepidopteran larvae develop, they often become more tolerant to insecticides. In our test, final instars of the Indianmeal moth were more difficult to kill compared with prior instars. Other tests with residual insecticides have shown that wandering-phase last-instar Indianmeal moth larvae are much more tolerant of insecticides than stored-product beetles. In tests where concrete was treated with the high and low

label rates of 20% cyfluthrin wettable powder (100 and 200 mg/m²), exposure intervals for 1–2 h would kill adults of the red flour beetle, *Tribolium castaneum* (Herbst), and the confused flour beetle, *T. confusum* (DuVal), for up to 12 wk after application (Arthur 1998a, b). However, when wandering-phase Indianmeal moths were exposed to the same concentration, there was little residual control and larvae were able to pupate and emerge as adults (Arthur 1999). In tests where cyfluthrin was applied directly to inshell peanuts, application rates of two and four ppm controlled adult red flour beetles, while application rates up to 22 ppm did not prevent adult emergence of Indianmeal moths exposed as wandering-phase larvae (Arthur 1995). Similar results have been obtained for other trials involving residual insecticides and residual exposures of Indianmeal moth and stored-product beetles (Arthur 1997). There are published reports of tests that imply equivalent control of Indianmeal moths and almond moths, *Cadra cautella* (Walker) and stored-product beetles, but in these tests the lepidopterans were exposed as eggs (Ardley 1976, Bengston et al. 1980, Bengston et al. 1987). Insecticidal applications that control coleopteran pests may not be effective against late-instar Indianmeal moths. Our results suggest that stored corn or sorghum grain treated with thiamethoxam or imidacloprid at rates commonly used

to control field crop pests should be well protected from the possibility of infestations by these two lepidopteran species.

Acknowledgments

This is Contribution No. 02-3-J from the Kansas Agricultural Experiment Station.

References Cited

- Almand, L. K. 1995. Gaucho® seed treatment for protection against early season insects. Proc. Beltwide Cotton Conf. Memphis, Tenn. 2: 1063-1065.
- Ardley, J. H. 1976. Synergised bioresmethrin as a potential grain protectant. J. Stored Prod. Res. 12: 253-259.
- Arthur, F. H. 1995. Susceptibility of fifth-instar Indianmeal moth and almond moth. (Lepidoptera: Pyralidae) to cyfluthrin residues on peanuts. J. Entomol. Sci. 30: 318-323.
- Arthur, F. H. 1997. Residual susceptibility of *Plodia interpunctella* to deltamethrin dust: effects of concentration and time of exposure. J. Stored Prod. Res. 33: 313-319.
- Arthur, F. H. 1998a. Residual studies with cyfluthrin wettable powder: toxicity toward red flour beetles (Coleoptera: Tenebrionidae) exposed for short intervals on treated concrete. J. Econ. Entomol. 91: 309-319.
- Arthur, F. H. 1998b. Residual toxicity of cyfluthrin wettable powder against *Tribolium confusum* exposed for short time intervals on concrete. J. Stored Prod. Res. 34: 19-24.
- Arthur, F. H. 1999. Residual susceptibility of fifth instar *Plodia interpunctella* to cyfluthrin wettable powder. J. Stored Prod. Res. 35: 99-105.
- Bengston, M., M. Connel, R.A.H. Davies, et al. 1980. Fenitrothion plus (1R)-Phenothrin, and pirimiphos-methyl plus carbaryl, as grain protectant combinations for wheat. Pesticide Sci. 11: 471-482.
- Bengston, M., J. M. Desmarchelier, B. Hayward, et al. 1987. Synergised cyfluthrin and cypermethrin as protectants of bulk wheat. Pesticide Sci. 17: 23-36.
- Bradley, J. R., Jr., A. L. Lambert, C.P.C. Suh, and J. Faircloth. 1998. Thrips management with Gaucho seed treatment in North Carolina cotton. Proc. Beltwide Cotton Conf. Memphis, Tenn. 2: 1183-1187.
- Burd, J. D., N. C. Elliott, and D. K. Reed. 1996. Effects of the aphicides 'Gaucho' and CGA-215944 on feeding behavior and tritrophic interactions of Russian wheat aphids. Southwest. Entomol. 21: 145-152.
- Gobel, T., L. Gsell, O. Huter, et al. 1999. Synthetic approaches towards CGA 293343: A novel broad-spectrum insecticide. Pesticide Sci. 55: 355-357.
- Graham, C. T., J. N. Jenkins and J. C. Jr. McCarty. 1995. Performance of Gaucho seed treatment insecticide against early season cotton insect pests. Proc. Beltwide Cotton Conf. Memphis, Tenn. 2: 917-918.
- Graham, C. T. 1998. Performance of Gaucho seed treatment across the mid-south and southeast. Proc. Beltwide Cotton Conf. Memphis, Tenn. 2: 1187-1188.
- Harvey, T. L., D. L. Seifers, and K. D. Kofoid. 1996. Effect of sorghum hybrid and imidacloprid seed treatment on infestations by corn leaf aphid and greenbug and the spread of sugarcane mosaic virus strain MDMV-B. J. Agric. Entomol. 13: 9-15.
- Hofer, D., and F. Brandl. 1999. Cruiser/Cruiser performance features of thiamethoxam as a seed treatment in worldwide cotton. Proc. Beltwide Cotton Conf. Memphis, Tenn. 2: 1101-1104.
- Lawson, D. S., D. M. Dunbar, S. M. White, and N. Ngo. 1999. Actara 25 WG: control of cotton pests with a new neonicotinoid insecticide, thiamethoxam. Proc. Beltwide Cotton Conf. Memphis, Tenn. 2: 1106-1109.
- LeOra Software. 1994. POLQ-PC probit and logic analysis. LeOra Software, Berkeley, CA.
- Maienfisch, P., L. Gsell, and A. Rindlischbacher. 1999. Synthesis and insecticidal activity of CGA 293343: A novel broad-spectrum insecticide. Pesticide Sci. 55: 351-354.
- McKirdy, S., and R. Jones. 1996. Use of imidacloprid and newer generation synthetic pyrethroids to control the spread of barley yellow dwarf luteovirus in cereals. Plant Disease 80: 895-901.
- SAS Institute. 2001. The SAS system for Windows, release 8.0. SAS Institute, Cary, NC.
- Silhacek, D. L., and G. L. Miller. 1972. Growth and development of the Indianmeal moth, *Plodia interpunctella*, under laboratory mass rearing conditions. Entomol. Soc. Am. Ann. 65: 1084-1087.
- Skopik, S., and M. Bowen. 1976. Insect Photoperiodism: an hourglass measures photoperiodic time in *Ostrinia nubilalis*. J. Comp. Physiol. 111: 249-259.
- Wilde, G. 1976. Fate of European corn borer larvae in stored shelled grain (Lepidoptera: Pyralidae). J. Kansas Entomol. Soc. 49: 557-561.
- Wilde, G., K. Roozeboom, M. Claassen, et al. 1999. Does the systemic insecticide imidacloprid (Gaucho) have a direct effect on yield of grain sorghum. J. Prod. Ag. 12: 382-389.
- Zang, L., V. Morton, and N. Ngo. 1998. Cruiser®: a new cotton insecticide seed treatment from Novartis Crop Protection, Inc. Proc. Beltwide Cotton Conf. Memphis, Tenn. 1998. 2: 1188-1190.

Received for publication 12 October 2001; accepted 8 October 2002.

Insecticides Do Not Affect Cotton (*Gossypium hirsutum*) Response to Imazaquin and Imazethapyr¹ALAN C. YORK and JOHN W. WILCUT²

Abstract. Field and greenhouse experiments evaluated interactions of soil-applied insecticides and imazaquin and imazethapyr on growth and development of cotton. Imazaquin and imazethapyr were applied PPI at 0 to 6 and 0 to 16 g ae ha⁻¹, respectively, in the greenhouse (plus a no-insecticide control), and 0 to 72 g ha⁻¹ in the field in combination with aldicarb, disulfoton, and phorate (without a no-insecticide control) applied in the seed furrow. Cotton shoot fresh weight in the greenhouse experiment decreased linearly as herbicide rates increased. Greater reductions in shoot fresh weight were noted with imazaquin than with imazethapyr. Compared with no insecticide, the methylcarbamate insecticide aldicarb and the organophosphate insecticides disulfoton and phorate did not affect cotton response to either herbicide. In the field, cotton injury increased while stand, yield, and maturity decreased as herbicide rates increased. Delayed maturity was due to a lower percentage of bolls produced on sympodia from main stem nodes four to nine. Imazaquin caused greater injury, greater reductions in stand, greater delays in maturity, and lower yields than did imazethapyr. Earlier maturity was noted with aldicarb-treated cotton. Compared with aldicarb, disulfoton and phorate did not alter cotton response to imazaquin or imazethapyr. Nomenclature: Aldicarb, 2-methyl-2-(methylthio)propionaldehyde *O*-(methylcarbamoyl)oxime; disulfoton, *O,O*-diethyl *S*-[2-(ethylthio)ethyl] phosphorodithioate; imazaquin, 2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-quinolinecarboxylic acid; imazethapyr, (±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid; phorate, *O,O*-diethyl *S*-[2-(ethylthio)-methyl phosphorodithioate; cotton, *Gossypium hirsutum* (L.) 'Deltapine 90', 'Stoneville Coker 304', 'Stoneville KC 380', and 'Stoneville McNair 235'. Additional index words: Pesticide interactions, maturity, plant mapping, fiber quality, aldicarb, disulfoton, phorate.

INTRODUCTION

Imazaquin, registered for use in soybean [*Glycine max* (L.) Merr.], and imazethapyr, registered for use in soybean and

peanut (*Arachis hypogaea* L.), are imidazolinone herbicides that control a broad spectrum of broadleaf weeds and certain monocot weeds (7, 16, 27, 36). Labels for both herbicides specify an 18-mo rotational restriction for cotton^{3,4}.

Cotton and corn (*Zea mays* L.) were injured when planted 1 yr after imazaquin application but yields usually were not reduced (19, 20, 22, 24, 26, 29). Cotton, which is more sensitive to imazaquin residues than is corn (20, 26), was injured when planted 2 yr after application (4).

Numerous field studies have examined the potential for imazaquin carryover while only a few such studies have been reported with imazethapyr. Most studies have shown a greater potential for corn injury from imazaquin than from imazethapyr carryover (11, 25). This may be because corn has greater tolerance of imazethapyr than of imazaquin (22). Injury and reduced yield were observed when sugarbeet (*Beta vulgaris* L.) was planted 2 yr after imazethapyr application while injury but no yield reduction was observed with sugarbeet planted 2 yr after imazaquin application (31). Similar degradation rates for imazaquin and imazethapyr have been reported under laboratory conditions (9, 13). Under field conditions, however, imazethapyr had a longer half-life than imazaquin (24).

Cotton acreage in North Carolina increased 400% between 1989 and 1991 (2). Smaller increases were noted in other southeastern states. Much of the new acreage was planted following soybean that had been treated with imazaquin, and cotton injury similar to that observed in Arkansas (4) sometimes was noted (personal observation by authors). Cotton and peanut are commonly grown in rotation. With imazethapyr registered for use in peanut, imazethapyr carryover to cotton also may be a problem.

Application of herbicides and insecticides to the same crop is a common practice. Crop tolerance of a herbicide may be reduced due to a synergistic interaction between the herbicide and an insecticide (17, 32). These interactions most commonly involve an organophosphate insecticide. Only a few cases of increased crop tolerance of a herbicide due to an antagonistic interaction with an insecticide have been reported. Most notable among these is the antagonism between phorate or disulfoton and clomazone [2-[(2-chlorophenyl)methyl]-4,4-dimethyl-3-isoxazolidinone] on cotton (37). Other examples of antagonism between herbicides and soil-applied organophosphate insecticides with cotton include fenamiphos [ethyl-3-methyl-4-(methylthio)phenyl (1-methylethyl)phosphoramidate] and lactofen [(±)-2-ethoxy-1-methyl-2-oxoethyl 5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoate] (12), and disulfoton or phorate and trifluralin [2,6-dinitro-*N,N*-dipropyl-4-(trifluoromethyl)benzenamine] (3).

A preliminary study (10) suggested soil-applied organophosphate insecticides might partially protect cotton

¹Received for publication May 13, 1992, and in revised form October 1, 1992.

²Prof., Dep. Crop Sci., North Carolina State Univ., Raleigh, NC 27695-7620, and Asst. Prof., Dep. Agron., Univ. Georgia, Coastal Plain Exp. Sta., Tifton, GA 31793-0748.

³Pursuit herbicide label, American Cyanamid Co., Wayne, NJ 07470.

⁴Soaper herbicide label, American Cyanamid Co., Wayne, NJ 07470.