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DIAMOND™: A NEW BROAD SPECTRUM INSECTICIDE FOR COTTON

R. Tim Weiland
Crompton Corporation/Uniroyal Chemical Company
Middlebury, CT

Abstract

Diamond™, common name novaluron, is an insect growth regulator in the benzoylphenyl urea class of chemistry. It was recently registered in the U.S.A. as Pedestal™ for control of a variety of insect pests on container-grown ornamentals as a Reduced Risk pesticide. U.S.E.P.A. is currently reviewing Diamond after acceptance as an Organophosphate Replacement product for cotton and pome fruit. Completion of the review is scheduled between April and June 2004. Field-tests during 2002 and 2003 with cotton confirmed earlier results demonstrating activity on *Lygus* spp., Lepidoptera (e.g. *Heliocoverpa virescens*, *H. zea*, *Spodoptera exigua*, *Pseudoplusia includens* and *Trichoplusia ni*) and whitefly (*Bemisia* spp.). Research continues across the cottonbelt to further define rates and insect spectrum.

Introduction

Novaluron is a new generation Insect Growth Regulator (IGR) in the benzoylphenyl urea chemical class. It has broad-spectrum activity against numerous insect species of the orders Lepidoptera, Coleoptera, Hemiptera and Diptera (Ishaaya et al., 1996). The basic manufacturer of novaluron is Makhteshim Agan of North America (Makhteshim Chemical Works). Crompton Corporation is a Development and Marketing Partner. During the last quarter of 2001 it was registered in the U.S.A. for use on ornamentals as a reduced risk pesticide and currently is being marketed as Pedestal™. Early in 2002 U.S.E.P.A. granted novaluron Organophosphate Replacement registration status for cotton and pome fruit and initial sales as Diamond™ in these areas, including potatoes, is anticipated for 2004. Novaluron has very low acute and chronic toxicities to mammals, low toxicities to birds and fish, low impact on beneficial organisms and it quickly degrades in water. Additionally, it can be used as a replacement for carbamates and pyrethroids.

Several formulations of novaluron have been developed for the U.S.A. These include Diamond 0.83EC for use on field crops and vegetables, Diamond 7.5WG for use on pome fruits, and Pedestal (0.83SC) for use on ornamentals.

Novaluron acts on immature stages of numerous insect species of the orders Lepidoptera, Coleoptera, Hemiptera and Diptera by inhibiting chitin biosynthesis causing interference with cuticle formation (Ishaaya et al., 1996). In many species novaluron works by ingestion, however contact activity has been observed. High mortality of early instar larvae occurs when treated foliage is ingested or the chemical is absorbed into the immatures through contact. Novaluron also acts as an ovicide. Activity on cotton pests, including whiteflies, the Lepidopteran heliothines, foliage feeding Lepitopterans, and plant bugs has been published and shown to be equivalent to current standard products (Dalrymple and Hinkle, 2004; Greene and Capps, 2003; Schuster et al., 2003; Weiland and Whitehead, 2002, 2003). Ruberson and Fairbanks (2003) have determined Diamond has little effect on the predatory bug, *Orius insidiosus*. No cross-resistance has been determined with related benzoylphenyl compounds, pyriproxyfen and neonicotinoids (Ishaaya et al., 2003). Usage rates will depend on target species and ranges from 0.045 to 0.09 lbs ai (7 to 14 oz) per acre.

This paper presents additional results from trials conducted in 2002 and 2003.

Materials and Methods

Porterville, CA 2002

Diamond 0.83EC at 3, 6 and 12 oz/acre, Ambush at 6.4 oz/acre, and 3 oz/acre of Diamond with 3.2 oz/acre of Ambush were tested on cotton for beet armyworm and cabbage looper control. Acala Royal cotton was planted and test plots were10 feet wide by 40 feet long. Treatments were arranged in a randomized complete block (RCB) with 4 replications. The insecticides were applied on 4 and 11 September with a backpack sprayer delivering 35 gallons of water per acre. Larvae number in 30 net sweeps were determined at 3 and 7 days after the first application and 3, 7 and 14 days after the second application.

Florence, SC 2002

Insecticides tested for control of *Helicoverpa zea* were Diamond 0.83EC (7.5, 9 and 12 oz/acre), Tracer 4SC (2 oz/acre), Steward 1.25 SC (9.2 oz/acre), Denim 0.16EC (8 oz/acre) and Decis 1.5EC (2.1 oz/acre). These treatments were established on Stoneville FiberMax 989R cotton with plots 25.3 by 50 feet using a RCB experimental design with 4 replications. The insecticides were applied on 18 and 25 July, and the number of damaged bolls per 25 in a plot was determined at 4 days after the second application.

Fresno, CA 2003

In this study, 2nd instar *Lygus hesperus* nymphs and adults (hatched from eggs obtained at the USDA Laboratory, Sacramento, California) were cultured on green beans (*Phaseolus vulgaris*) at room temperature (~ 26°C). Beans were commercially available and washed with water prior to use. Twenty nymphs were placed in glass petri dishes (5.75 inches in diameter) with beans untreated or dipped in 400 ppm Diamond solution, and sealed with Parafilm®. The beans had been treated either just prior to nymph insertion or 1, 2 or 3 days before insertion of the nymphs. The number alive was monitored at 1, 2, 3 and 4 days after adding the nymphs. There were 4 replicates of each treatment. Potential effect on adults was also monitored on 4 replicates of each treatment (10 per dish) through 8 days where beans dipped just prior to adding the bugs were used.

In another experiment the effect of Diamond on nymph (20 per dish) and adult (10 per dish) feeding was investigated. Treated pods were dipped 3, 2 (nymphs only) and 1 day, or just prior to inserting the bugs. Two untreated and 2 treated (marked) pods were present in each dish; there were 4 replications. The number of feeding stings was recorded after 18 hours. Additionally, the percent of bugs present on pods from either treatment was assessed at 18 hours as an indication of potential repellency to Diamond.

Tift County, GA 2003

In this study, the effect of Diamond on the mean number of nymphs of a mixed population of *Nezara viridula* (Southern green stink bug), *Euschistus servus* (brown stink bug) and *Neurocolpus nubilus* (clouded plant bug) nymphs was investigated. Diamond was applied at 14 oz/acre and 10 oz/acre with either 1% COC or 0.125% Silwet; Steward at 11.3 oz/acre and Up-Cyde at 4 oz/acre were also evaluated. Diamond plots were sprayed 3, 18 and 31 July and 13 August; Steward was applied 25 and 31 July and 13 August. Cotton test plots were 4 rows by 40 feet. Treatments were made with a self-propelled sprayer delivering 10 gallons per acre; treatments were arranged in a RCB design with 4 replications. Nymph numbers per 12 feet of row were counted using a drop cloth on 21 August.

Soybean looper (*Pseudoplusia includens*) larvae were also counted on the drop cloth. Control chemicals included Denim at 8 oz/acre and Tracer at 2 oz/acre.

Senatobia, MS 2003

Insecticides evaluated in the first of two trials at this locale included Diamond 0.83EC (9 and 12 oz/acre) and Fury (0.025 lb ai/acre) for heliothine control. The second trial evaluated Diamond 0.83EC (9 and 12 oz/acre) and Centric (1 oz/acre) for *Bemisia tabaci* control. Both trials were planted with Stoneville 5303RR cotton. All treatments were made on 6 August using a HiBoy spray rig delivering 10 gallons of water per acre. Treatments were arranged in an RCB statistical design with 4 replications. Percent worm damaged fruit and number of whiteflies in 2-row feet were determined at 6 and 13 days after application.

Results

Porterville, CA 2002 (Tables 1,2)

Starting at 7 days after the first application and continuing through the sampling period, all treatments resulted in beet armyworm control (Table 1). Similarly, all treatments resulted in cabbage looper control starting at 3 days after the first application (Table 2). The lowest Diamond rate of 3 oz/acre was slower in control for both insects in contrast to the higher rates.

Florence, SC 2002 (Table 3)

The highest rates of Diamond (9 and 12 oz/acre) significantly reduced the number of square/small bolls damaged by *Helicoverpa zea* versus the untreated control. The 7.5 oz/acre rate of Diamond and other standards numerically reduced boll damage; however, control was not significantly different from damage found in the untreated plots.

Fresno CA 2003 (Tables 4,5,6,7)

The majority of *Lygus hesperus* nymphs died after 3 days of exposure to residues of Diamond on bean pods, regardless of when the pods were treated prior to introducing the nymphs (Table 4). Complete mortality occurred at 4 days. Significant mortality of the nymphs was seen as early as 24 hours exposure when the pods were treated just prior to introduction of the nymphs. Adult mortality was not affected through 8 days of exposure to Diamond residues (Table 5). After eighteen hours of exposure to either untreated or treated pods, nymphs showed no preference for feeding, indicating no repellency regardless of age of the Diamond residues prior to introduction of the nymphs (Table 6). However, adults avoided feeding on the Diamond treated pods. This was statistically significant ($P \leq 0.08$) on pods that were treated just prior to and 3 days prior to introduction of the adults. Notation of plant bugs on either untreated or treated pods at 18 hours after introduction showed only nymphs on pods with 3-day old residues and adults on pods treated just prior to introduction preferred avoiding the Diamond treated pods (Table 7). Otherwise the plant bugs showed no repellency to Diamond residues.

Many nymphs that died after contacting Diamond exhibited no molting abnormalities. However some nymphs were unable to shed their old exuviae and exhibited incomplete molting forms and rapid desiccation.

Tift County, GA 2003 (Tables 8, 9)

The % distribution of *Nezara viridula*, *Euschistus servus* and *Neurocolpus nubilus* in the bug population was 24, 9 and 67%, respectively, at evaluation (data not shown). Diamond 0.83EC at 14 oz/acre gave similar bug control to Diamond 0.83EC at 10 oz/acre with either oil or Silwet (Table 8). These treatments gave numerically better control of the bugs in contrast to Steward; however the control was not statistically different. Soybean loopers were controlled by all products, with Diamond 0.83EC at 10 oz/acre plus 1% oil giving statistically better control to Tracer (Table 9).

Senatobia, MS 2003 (Tables 10,11)

Both rates of Diamond (9 and 12 oz/acre) and Fury gave lower, but not significantly different control of heliothines at 6 days after application in contrast to the untreated control (Table 10). However, at 13 days after application, all treatments gave complete control of the heliothine complex. Diamond at 12 oz/acre gave equivalent control of whiteflies to Centric at 6 days after application, which were statistically better than Diamond at 9 oz/acre (Table 11). By 13 days all treatments exhibited similar control of this pest. Results on tarnished plant bugs (*Lygus lineolaris*) are presented in another paper (Dalrymple and Hinkle, 2004).

Concluding Remarks

Diamond exhibits a broad spectrum of activity on cotton pests, which includes plant bugs, stink bugs, the heliothine complex, foliage feeding Lepidopterans and whiteflies. The activity is equal to or more effective than standard control products. Since it affects chitin formation/deposition, only immatures stages of these pests are controlled, i.e. nymphs/larvae and eggs. A laboratory study with the plant bug, *Lygus hesperus*, indicated nymph mortality can occur with a few days of contact to residues of Diamond. There also was an indication that adults, more so than nymphs, prefer not feeding on tissue with residues of Diamond. How this extrapolates to field conditions is unclear. Applying Diamond throughout the period from 3 days prior to, up to the day of introducing the plant bugs, generally gave similar results.

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Table 1. Mean number of *Spodoptera exigua* larvae per 30 sweeps with an insect net during a 2-application period. (Porterville, CA 2002).

Treatment	Rate oz/A	Number per 30 sweeps				
		3 DAA1	7 DAA1	3 DAA2	7 DAA2	14 DAA2
Untreated		3.3a	3.5a	2.3a	2.0a	1.5a
Diamond 0.83EC	3	2.0a	1.3b	0.5b	0.0b	0.0b
Diamond 0.83EC	6	2.0a	0.8bc	0.0b	0.0b	0.0b
Diamond 0.83EC	12	1.5a	0.3bc	0.0b	0.0b	0.0b
Ambush	6.4	1.8a	0.3bc	0.0b	0.0b	0.0b
Diamond 0.83EC + Ambush	3 + 3.2	1.8a	0.0c	0.0b	0.0b	0.0b

Means within a column followed by the same letter do not significantly differ (P=0.05, Student - Newman - Keuls).
Application dates: 4 and 11 September.

Table 2. Mean number of *Trichoplusia ni* larvae per 30 sweeps with an insect net during a 2-application period. (Porterville, CA 2002).

Treatment	Rate oz/A	Number per 30 sweeps				
		3 DAA1	7 DAA1	3 DAA2	7 DAA2	14 DAA2
Untreated		6.5a	7.3a	5.5a	5.3a	3.5a
Diamond 0.83EC	3	2.8b	2.0b	1.3b	0.0b	0.0b
Diamond 0.83EC	6	4.0b	1.5b	0.5c	0.0b	0.0b
Diamond 0.83EC	12	2.5b	0.8b	0.0c	0.0b	0.0b
Ambush	6.4	3.0b	0.8b	0.0c	0.0b	0.0b
Diamond 0.83EC + Ambush	3 + 3.2	3.0b	0.8b	0.0c	0.0b	0.0b

Means within a column followed by the same letter do not significantly differ (P=0.05, Student - Newman – Keuls).
Application dates: 4 and 11 September.

Table 3. Mean number of *Helicoverpa zea* damaged bolls per 25 bolls at 4 days after the 2nd application (Florence, SC 2002).

Treatment	Rate (oz/A)	Damaged bolls/25
Untreated		6.2ab
Diamond 0.83EC	7.5	1.6b-d
Diamond 0.83EC	9	1.4cd
Diamond 0.83EC	12	1.2d
Tracer 4SC	2	3.7a-d
Steward 1.25 SC	9.2	3.7a-d
Denim 0.16EC	8	2.7a-d
Decis 1.5EC	2.1	3.0ad

Means within a column followed by the same letter do not significantly differ (P=0.05, Duncan's New MRT). Note that statistically analysis was done on square root transformations (x+0.5), however, original means are presented. Unregistered chemicals are omitted from above.
Application dates: 18 and 25 July.

Table 4. Percent *Lygus hesperus* nymphs alive at various days following exposure to residues of Diamond on bean pods treated 0 to 3 days prior to bug introduction. (Fresno, CA 2003).

Treatment	Percent alive after:							
	1 day	2 days	3 days	4 days	1 day	2 days	3 days	4 days
	Applied just prior to bug introduction				Applied 1 day prior to bug introduction			
Control	91.2a	88.8a	81.2a	77.5a	90.0a	88.8a	83.8a	80.0a
Diamond 0.83EC	70.0b	61.2b	2.5b	0.0b	70.0a	61.2b	6.2b	0.0b
	Applied 2 days prior to bug introduction				Applied 3 days prior to bug introduction			
Control	96.2a	95.0a	93.8a	82.5a	95.0a	95.0a	88.8a	83.8a
Diamond 0.83EC	95.0a	90.0a	1.2b	0.0b	93.8b	88.8b	1.2b	0.0b

Means within a column for a daily assessment followed by the same letter do not significantly differ (P=0.05, Student - Newman – Keuls).

Table 5. Percent *Lygus hesperus* adults alive at various days following exposure to residues of Diamond on bean pods treated just prior to bug introduction. (Fresno, CA 2003).

	Percent alive after:							
Treatment	**1 day**	**2 days**	**3 days**	**4 days**	**5 days**	**6 days**	**7 days**	**8 days**
Control	95.0a	90.0a	85.0a	80.0a	60.0a	52.5a	42.5a	42.5a
Diamond 0.83EC	95.0a	92.2a	77.5a	62.5a	52.5a	50.0a	37.5a	35.0a

Means within a column followed by the same letter do not significantly differ (P=0.05, Student - Newman – Keuls).

Table 6. Effect of Diamond on bean pod feeding by *Lygus hesperus* nymphs (n = 20) and adults (n = 10) at 18 hours following exposure to residues of Diamond on bean pods treated 0 to 3 days prior to bug introduction. *Lygus* had their choice of feeding on either treated or untreated pods. (Fresno, CA 2003).

	Average number of feeding stings on bean pods treated at respective days prior to bug introduction							
	0 days	**1 day**	**2 days**	**3 days**	**0 days***	**1 day**	**2 days**	**3 days**
Treatment	**Nymphs**				**Adults**			
Control	31.2a	44.2a	20.4a	27.9a	19.1a	nd	17.5a	17.8a
Diamond 0.83EC	31.2a	42.5a	19.2a	19.8b	11.8a	nd	13.2a	9.1b

* P=0.08

nd = not determined.

Means within a column for a daily assessment followed by the same letter do not significantly differ (P=0.05, Student - Newman – Keuls).

Table 7. Effect of Diamond on repellency by *Lygus hesperus* nymphs (n = 20) and adults (n = 10) at 18 hours following exposure on bean pods treated 0 to 3 days prior to bug introduction. *Lygus* had their choice of feeding on either treated or untreated pods and number of those on respective pods at that instance was recorded. (Fresno, CA 2003).

	% Lygus at 18 hours on bean pods treated at respective days prior to bug introduction							
	0 days	**1 day**	**2 days**	**3 days**	**0 days**	**1 day**	**2 days**	**3 days**
Treatment	**Nymphs**				**Adults**			
Control	25.6a	24.4a	23.7a	27.5a	47.5b	nd	35.0a	40.0a
Diamond 0.83EC	25.6a	17.5a	22.5a	20.0b	10.0a	nd	25.0a	40.0a

nd = not determined.

Means within a column for a daily assessment followed by the same letter do not significantly differ (P=0.05, Student - Newman – Keuls).

Table 8. Effect of Diamond on the mean number of nymphs of a mixed population of *Nezara viridula, Euschistus servus,* and *Neurocolpus nubilus* nymphs per 12 feet of row at 8 days after the last application. (Tift County, GA 2003).

Treatment	**Rate oz/A**	**Mean number per 12 feet 8 DAA (21 August, '03)**
Untreated		8.2a
Diamond 0.83EC + 1% oil	10	0.5c
Diamond 0.83EC + 0.125% Silwet	10	0.2c
Diamond 0.83EC	14	0.5c
Steward	11.3	2.8bc
Up-Cyde	4	0.5c

Means within a column followed by the same letter do not significantly differ (P=0.1, LSD). Note chemicals not labeled for bug control are omitted from the table.

Application dates: Diamond on 3, 18, 31 July and 13 August; Steward on 25, 31 July and 13 August.

Table 9. Effect of Diamond on the mean number of larvae of a population of *Pseudoplusia includens* in 12 feet of row at 8 days after the last application. (Tift County, GA 2003).

Treatment	Rate oz/A	Mean number per 12 feet 8 DAA (21 August, '03)
Untreated		5.5b
Diamond 0.83EC + 1% oil	10	0.2d
Diamond 0.83EC + 0.125% Silwet	10	1.0cd
Diamond 0.83EC	14	1.8cd
Denim	8	2.2cd
Steward	11.3	0.2d
Tracer	2	3.2bc

Means within a column followed by the same letter do not significantly differ (P=0.1, LSD). Note chemicals not labeled for loopers are omitted from the table.
Application dates: Diamond on 3, 18, 31 July and 13 August; others on 25, 31 July and 13 August.

Table 10. Percent worm damaged fruit by heliothines 6 and 13 days after application (Senatobia, MS 2003).

Treatment	Rate oz or lb/A	% worm damaged fruit 6 DAA	13 DAA
Untreated		12.5a	15.0a
Diamond 0.83EC	9 oz	5.0a	0.0b
Diamond 0.83EC	12 oz	2.5a	0.0b
Fury	0.025 lbai	7.5a	0.0b

Means within a column with the same letter do not significantly differ (P=0.05, Student-Newman-Keuls).
Application date: 6 August.

Table 11. Number of whiteflies (*Bemisia tabaci*) in 2-row feet at 6 and 13 days after application (Senatobia, MS 2003).

Treatment	Rate oz/A	Number per 2-row feet 6 DAA	13 DAA
Untreated		12.0a	10.5a
Diamond 0.83EC	9 oz	6.5b	3.5b
Diamond 0.83EC	12 oz	3.8c	2.3b
Centric	2	4.0c	2.8b

Means within a column with the same letter do not significantly differ (P=0.05, Student-Newman-Keuls).
Application date: 6 August.