CARBINETM: FIELD PERFORMANCE AGAINST TARNISHED PLANT BUG AND APHID IN MID-SOUTH COTTON DURING 2005 Henry R. Mitchell FMC Corporation Louisville, MS Joseph Reed FMC Corporation North Little Rock, AR Craig Heim FMC Corporation Philadelphia, PA

Abstract

Carbine TM, a new selective cotton insecticide for the control of *Lygus* species and aphids in cotton, is being codeveloped by Ishihara Sangyo Kaisha, Ltd. and FMC Corporation. The active ingredient, flonicamid (Code names: F1785, IKI-220), belongs to the pyridinecarboxamide class of chemistry. Carbine is not cross-resistant to any existing class of chemistry and thus, a valuable tool for resistance management. Carbine is also soft on beneficial arthropods and fits well in IPM programs. Field-test during 2005 confirmed earlier results demonstrating excellent activity against both nymph and adult plant bugs (*Lygus lineolaris* Palisot de Beavois and *L. hesperus* Knight) comparable to the neonicotinoid standards. Against cotton aphid (*Aphis gossypii* Glover), Carbine continues to exhibit excellent initial and extended residual activity generally superior to the older aphicides and equivalent to or better than the neonicotinoids. Research continues across the cotton belt to further define insect spectrum and best use recommendations with expected registration in time for the 2006 cotton season.

Introduction

Flonicamid (F1785, IKI-220) is a new and novel insecticide discovered by ISK Corporation. FMC Corporation obtained exclusive rights in 2001 to develop, market, and distribute flonicamid in North America and received USEPA registration in cotton in the fall of 2005. In North America, flonicamid will be sold in cotton under the trade name Carbine beginning in 2006. Flonicamid belongs to the class of chemistry, pyridinecarboxamide. It is highly specific for sucking pests with a novel mode of action and does not affect the target sites associated with any of the other known insecticide classes (Hancock, et. al. 2003; Hancock, 2004; Treacy, 2005). Flonicamid has also been shown to exhibit no cross-resistance with any existing chemistries thus making it an excellent choice for use in an insecticide resistance management program (Treacy, 2005). In addition, research has demonstrated that flonicamid, at maximum field use rates, has minimal to no impact on beneficial arthropods including honey bee (*Apis mellifera*), Pirate bugs (*Orius* spp.), Big-eyed bugs (*Geocoris* spp.), nabids (*Nabis* spp.), lacewings (*Chrysoperla* spp.) and predaceous mites (Treacy, 2005). Due to the minimal impact on beneficial arthropods, extreme selectivity to only pest species and lack of cross-resistance to other cotton pest management classes of chemistry, Carbine has tremendous potential to be utilized in an integrated pest management program.

FMC Corporation has conducted development activities with flonicamid in cotton since 2001. Research in 2002-2003 concentrated primarily on cotton aphid (*Aphis gossypii* Glover), with results showing excellent efficacy at 7 days after treatment and, depending on rate, residual control up to 21 days (Hancock, et. al. 2003; Parks and Norman, 2003; Hancock, 2004; Long, et. al. 2005; Treacy and Mize, 2005). Tarnished plant bug (*Lugus lineolaris* Palisot de Beavois) and western plant bug (*L. hesperus* Knight) activity was also demonstrated in trials conducted in 2003-2004 (Greene and Caps, 2003; Hancock, 2004; Treacy and Mize, 2005). The key objective of the 2005 FMC research program was to further substantiate the activity of flonicamid on the plant bug complex and aphid in cotton. These additional results will be presented here.

Materials and Methods

Field Trials – Aphids

Field trials were conducted on cotton aphid from 2001 to 2005 at various rates up to 0.088 lb ai/A. Trials were located across the cotton belt with contract research, university and FMC internal researchers. Field trials were planted to both Bt and non-Bt varieties of cotton in minimum and conventional tillage systems. All trials utilized

replicated experimental designs, typically a randomized complete block with a minimum of three replications. Application methods were generally those used in small plot research including CO^2 backpack and self-propelled spray equipment. Either hollow-cone or flat fan type nozzles, usually two per row, were used. Application volume ranged primarily between 8 and 15 gallons per acre. The majority of the trials employed a single application of the various insecticide treatments. Plot size varied among trials but usually was 2 to 6 rows x 50 to 100 feet in length. Cotton aphid field trials were initiated at local threshold levels or later. Post treatment cotton aphid evaluations were taken at approximately 3, 7, and 15 days after application to determine initial and residual efficacy of flonicamid in comparison to comparative standards. Untreated controls were utilized throughout. Assessments of insecticide efficacy were generally based on number of pest per unit area (square inch, leaf, terminal) and ranged for one to 10.

Field Trials – Plant Bugs

Field trials were conducted on tarnished plant bug from 2003 to 2005 at various rates up to 0.088 lb ai/A. Trial were located in key states across the cotton belt which demonstrated consistent and increasing yield and quality losses from this pest with the majority of work conducted in the states of AL, AR, LA, MS, and TN. Trials were conducted by either contract research or university researchers. Trials were planted to both Bt and non-Bt varieties of cotton in minimum and conventional tillage systems and typically conducted with a minimum of 4 replications in a randomized complete block design. Applications methods were generally those used in small plot research including backpack and self-propelled spray equipment using either hollow-cone or flat-fan nozzles that delivered an 8 to 15 gallon per acre spray volume. Plot size in 2004 was at least 10 rows x 200 feet in length to account for the mobile nature of plant bugs. 2005 trials utilized standard small plot parameters, generally 4 to 6 rows x 50 to 100 feet in length. Trials were initiated at local threshold levels. In most cases, trials received a minimum of two applications of each treatment at 7 to 10 day intervals. Post treatment evaluations were taken approximately 3, 7, and 10 days after each application. Plant bug assessments were made with varying methods, but generally were conducted using beat cloth or sweep net sampling techniques. Untreated controls were utilized throughout.

Results and Discussion

Flonicamid efficacy trials conducted by FMC internal research and through university and contract research from 2002-2005 have demonstrated the effectiveness against cotton aphid and various plant bug species. On cotton aphid, the research summary across the four years show that flonicamid at rates of 0.054 to 0.063 lb ai/a provide initial and residual control from 3 to 14 days after application that is comparable to the competitive standards thiamethoxam (0.047 lb ai/a) and acetamiprid (0.05 lb ai/a), and superior in performance when compared to imidicloprid (0.047 lb ai/a) (Table 1).

Flonicamid research on plant bug efficacy in cotton was a key objective in the 2004 and 2005 season. During the 2004 season, results demonstrated that flonicamid at 0.053 and 0.063 lb ai/a reduced plant bug nymph populations beginning at 7 days after the first application equivalent to that of thiamethoxam, acetamiprid, and acephate, and superior to that of imidacloprid. Evaluations following the second application demonstrated percent control levels from either rate of flonicamid comparable to that of thiamethoxam and acephate and superior to that of acetamiprid and imidacloprid against plant bug nymphs (Table 2). Plant bug adult data for the trials showed generally higher levels of control with both rates of flonicamid, superior at 7 days after the first and second application that the competitive standards (Table 3). Final lint yield comparisons among treatments clearly reflect the plant protection benefits provided by flonicamid in the management of plant bug infestations. When compared to the untreated check, followed by thiamethoxam, acephate, imidacloprid, and acetamiprid, respectively (Table 3).

Flonicamid research on plant bug efficacy in cotton during 2005 continued to support previous results. Results demonstrated that flonicamid at 0.072 lb ai/a provided plant bug nymph and adult control equivalent to the competitive standards including thiamethoxam (0.047-0.06 lb ai/a), imidacloprid (0.047 lb ai/a), acephate (0.5-0.75 lb ai/a), dicrotophos (0.375-0.5 lb ai/a), novaluron (0.058 lb ai/a), oxamyl (0.33-0.4 lb ai/a), dimethoate (0.4 lb ai/a), and acetamiprid (0.047-0.05 lb ai/a) (Tables 4, 5, and 6). Results also demonstrated excellent activity on cotton fleahopper with flonicamid at 0.072 lb ai/a providing control equal to that of acetamiprid (0.047 lb ai/a) and superior to that of thiamethoxam (0.047 lb ai/a), imidacloprid (0.047 lb ai/a) (Table 7).

Conclusions

Results presented here clearly demonstrate the significant potential flonicamid will provide as an effective pest management tool for cotton plant bug, fleahopper and aphid control. No only is flonicamid an effective pest management tool, it offers the additional benefits of exceptional safety and conservation of beneficial predators and parasites, minimal environmental and non-target impact, and an idea fit in an insecticide resistance management program due to the unique mode of action.

Acknowledgements

The author extends sincere appreciation to the university researchers participating in the Flonicamid Cotton Field Development Program across the southern regions of the US.

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Table 1. Efficacy of Flonicamid versus neonicotinoid insecticides against cotton aphid (Aphis gossypii) in cotton. ^a

| | | Percent Control ^b | | | | | |
|------------------------|---------|------------------------------|-----------|-----|------|-------|------|
| Treatment ^d | lb ai/a | 2-3 ° | $(n)^{e}$ | 5-7 | (n) | 10-14 | (n) |
| Flonicamid | 0.054 | 75 | (26) | 88 | (27) | 80 | (22) |
| Flonicamid | 0.063 | 85 | (19) | 96 | (23) | 95 | (30) |
| Thiamethoxam | 0.047 | 77 | (26) | 88 | (26) | 73 | (24) |
| Acetamiprid | 0.05 | 88 | (27) | 92 | (21) | 93 | (20) |
| Imidacloprid | 0.047 | 72 | (14) | 71 | (12) | 69 | (08) |

^a Data from replicated field trials conducted between 2002 and 2005 in North America contract, university and FMC research.

^b Percent control based on untreated.

^c Days after application.

^d Treatments applied at local threshold.

^e Number of observations in mean.

| | Percent Control ^b | | | | | | Seasonal | | |
|------------------------|------------------------------|---------|-------|-------|--------|-------|----------|--------|------|
| Treatment ^d | lb ai/a | 1dat1 c | 3dat1 | 7dat1 | 10dat1 | 3dat2 | 7dat2 | 10dat2 | Mean |
| Flonicamid | 0.053 | 57 | 69 | 59 | 61 | 77 | 62 | 67 | 65 |
| Flonicamid | 0.063 | 63 | 61 | 64 | 69 | 66 | 64 | 61 | 64 |
| Thiamethoxam | 0.047 | 36 | 66 | 62 | 46 | 64 | 66 | 65 | 58 |
| Acetamiprid | 0.05 | 42 | 64 | 64 | 40 | 60 | 50 | 50 | 53 |
| Imidacloprid | 0.047 | 42 | 50 | 56 | 44 | 51 | 47 | 38 | 47 |
| Acephate | 0.485 | 52 | 53 | 67 | 50 | 56 | 62 | 61 | 57 |
| Untreated ^e | | 14 | 17 | 20 | 21 | 23 | 19 | 14 | 18 |

Table 2. Efficacy of Flonicamid against Tarnished Plant Bug (Lygus lineolaris) nymphs in cotton. ^a

^a Data from 6 replicated field trials (AL, AR, GA, LA, MS, SC) following two applications conducted in 2004 by North America contract research.

^b Percent control based on untreated.

^c Days after treatment (dat) 1 or 2.

^d Treatments applied at local threshold.

^e Number of pest per 10 row feet.

Table 3. Efficacy of Flonicamid against Tarnished Plant Bug (Lygus lineolaris) adults in cotton ^a and yield. ^b

| | | Percent Control ^c | | | | | | | Seasona | lYield |
|------------------------|---------|------------------------------|-------|-------|--------|-------|-------|--------|---------|-------------|
| Treatment ^e | lb ai/a | 1dat1 ^d | 3dat1 | 7dat1 | 10dat1 | 3dat2 | 7dat2 | 10dat2 | Mean | (lint lb/a) |
| Flonicamid | 0.053 | 53 | 66 | 70 | 73 | 57 | 70 | 66 | 65 | 915 |
| Flonicamid | 0.063 | 55 | 86 | 73 | 80 | 60 | 71 | 71 | 71 | 937 |
| Thiamethoxam | 0.047 | 68 | 60 | 55 | 47 | 61 | 54 | 62 | 58 | 902 |
| Acetamiprid | 0.05 | 51 | 52 | 56 | 62 | 63 | 62 | 45 | 56 | 820 |
| Imidacloprid | 0.047 | 46 | 59 | 55 | 57 | 54 | 49 | 65 | 55 | 862 |
| Acephate | 0.485 | 74 | 71 | 62 | 58 | 61 | 65 | 58 | 64 | 881 |
| Untreated ^f | | 11 | 10 | 9 | 10 | 11 | 10 | 7 | 10 | 778 |

^a Data from 6 replicated field trials (AL, AR, GA, LA, MS, SC) following two applications conducted in 2004 by North America contract research.

^b Data from 5 replicated field trials (AL, AR, LA, MS, SC) following two applications conducted in 2004 by North America contract research.

^c Percent control based on untreated.

^d Days after treatment (dat) 1 or 2.

^e Treatments applied at local threshold.

^f Number of pest per 10 row feet.

| | Number of Plant Bugs / 15 Row Feet | | | | | | et |
|------------------------|------------------------------------|---------|---------------------|--------|---------|--------|--------|
| | | 3dat1 b | 3dat1 | 7dat1 | 7dat1 | 3dat2 | 3dat2 |
| Treatment ^c | lb ai/a | nymphs | ^d adults | nymphs | adults | nymphs | adults |
| Flonicamid | 0.072 | 2.0 bcd | 0.7 a | 1.7 b | 2.0 ab | 0.0 b | 0.7 a |
| Thiamethoxam | 0.047 | 4.7 bc | 1.5 a | 1.2 b | 0.5 bc | 0.7 b | 0.7 a |
| Imidacloprid | 0.047 | 1.7 cd | 2.2 a | 1.5 b | 1.2 abc | 0.7 b | 0.2 a |
| Acephate | 0.485 | 3.0 bcd | 1.5 a | 2.0 b | 1.0 abc | 1.5 b | 0.0 a |
| Novaluron | 0.058 | 4.2 bcd | 2.7 a | 0.7 b | 0.2 c | 0.5 b | 0.0 a |
| Dicrotophos | 0.5 | 1.0 d | 1.0 a | 1.5 b | 0.5 bc | 0.2 b | 0.0 a |
| Oxamyl | 0.4 | 2.0 bcd | 0.7 a | 0.2 b | 0.7 bc | 1.0 b | 0.2 a |
| Dimethoate | 0.5 | 1.3 d | 0.5 a | 0.7 b | 0.2 c | 1.2 b | 0.5 a |
| Acetamiprid | 0.05 | 5.0 b | 3.5 a | 1.7 b | 1.5 abc | 1.5 b | 0.0 a |
| Untreated | | 15.2 a | 3.7 a | 7.0 a | 2.5 a | 5.2 a | 1.0 a |
| | | | | | | | |

Table 4. Efficacy of Flonicamid against Tarnished Plant Bug (Lygus lineolaris) in cotton ^a

^a Data from 1 replicated field trials (Rohwer, AR) following two applications conducted in 2005.

^b Days after treatment (dat) 1 or 2.

^c Treatments applied at local threshold.

^d Means followed by the same letter do not significantly differ (P<0.05, LSD)

| Table 5. | Efficacy | v of Flonicamid agai | inst Tarnished P | Plant Bug (Lyg | pus lineolaris) in cotton ^a | |
|-----------|----------|----------------------|------------------|----------------|--|---|
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| | | Number of Plant Bugs / 10 Row Feet | | | | | |
|------------------------|---------|------------------------------------|--------------|--------------|--|--|--|
| | | <u>6dat1 ^b</u> | <u>6dat1</u> | <u>4dat2</u> | | | |
| Treatment ^c | lb ai/a | <u>nymphs^d</u> | adults | nymphs | | | |
| Flonicamid | 0.072 | 23.0 bc | 4.5 a | 10.5 b | | | |
| Imidacloprid | 0.047 | 29.2 bc | 2.5 a | 12.7 b | | | |
| Thiamethoxam | 0.06 | 17.0 c | 2.0 a | 7.0 b | | | |
| Acetamiprid | 0.048 | 26.2 bc | 3.7 a | 11.2 b | | | |
| Acephate | 0.75 | 22.7 bc | 2.7 a | 6.7 b | | | |
| Dicrotophos | 0.375 | 30.5 b | 2.7 a | 6.7 b | | | |
| Oxamyl | 0.33 | 33.2 ab | 3.5 a | 9.7 b | | | |
| Untreated | | 44.2 a | 3.0 a | 46.0 a | | | |

^a Data from 1 replicated field trials (Shellmound, MS) following two applications conducted in 2005.

^b Days after treatment (dat) 1 or 2.

^c Treatments applied at local threshold.

^d Means followed by the same letter do not significantly differ (P<0.05, LSD)

| | | <u>Number of Plant Bugs / 10 Row F</u> | eet |
|------------------------|---------|--|--------------|
| | | <u>4dat1 ^b</u> | <u>4dat2</u> |
| Treatment ^c | lb ai/a | nymphs ^d | nymphs |
| Flonicamid | 0.072 | 7.5 bc | 3.3 bc |
| Thiamethoxam | 0.05 | 3.0 d | 1.3 c |
| Imidacloprid | 0.047 | 8.8 ab | 2.5 bc |
| Acephate | 0.5 | 4.5 cd | 1.0 c |
| Novaluron | 0.058 | 5.3 bcd | 1.8 c |
| Dicrotophos | 0.5 | 1.5 d | 0.8 c |
| Oxamyl | 0.33 | 4.3 cd | 1.3 c |
| Untreated | | 12.3 a | 10.0 a |

Table 6. Efficacy of Flonicamid against Tarnished Plant Bug (Lygus lineolaris) in cotton ^a

^a Data from 1 replicated field trials (Lauderdale County, TN) following two applications conducted in 2005.

^b Days after treatment (dat) 1 or 2.

^c Treatments applied at local threshold.

^d Means followed by the same letter do not significantly differ (P<0.05, LSD)

 Table 7. Efficacy of Flonicamid against Cotton Fleahopper (Pseudatomoscelis seriatus) in cotton ^a

| | | Number of Fleahoppers / 10 Row Plants | | | | | | | |
|------------------------|---------|---------------------------------------|---------------------|--------|---------|---------|--------|-------------|--|
| | | 3dat1 b | 3dat1 | 7dat1 | 7dat1 | 7dat2 | 7dat2 | Yield | |
| Treatment ^c | lb ai/a | nymphs | ¹ adults | nymphs | adults | nymphs | adults | (lint lb/a) | |
| Flonicamid | 0.071 | 0.0 b | 0.2 a | 0.0 c | 2.7 abc | 0.0 d | 1.7 b | 549 | |
| Thiamethoxam | 0.047 | 0.0 b | 0.0 a | 3.0 bc | 4.3 ab | 3.7 bcd | 1.7 b | 601 | |
| Acetamiprid | 0.047 | 0.0 b | 0.0 a | 0.3 c | 0.0 c | 1.0 cd | 0.0 b | 555 | |
| Acephate | 0.5 | 0.0 b | 0.0 a | 2.3 bc | 3.3 abc | 8.3 b | 1.7 b | 544 | |
| Imidacloprid | 0.047 | 0.0 b | 0.0 a | 6.7 b | 2.7 abc | 5.0 bc | 2.3 b | 544 | |
| Untreated | | 0.7 a | 1.0 a | 15.0 a | 6.0 a | 14.3 a | 6.7 a | 450 | |

^a Data from 1 replicated field trials (Dallas, TX) following two applications conducted in 2005.

- ^b Days after treatment (dat) 1 or 2.
 ^c Treatments applied at local threshold.
 ^d Means followed by the same letter do not significantly differ (P<0.05, LSD)