FIPRONIL: A MAJOR ADVANCE FOR THE CONTROL OF BOLL WEEVIL IN COLOMBIA.

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Abstract

Fipronil, discovered by Rhone-Poulenc scientists in 1987, is the first in a whole new class of foliar and soil insecticides called the phenyl pyrazoles. During the past eight years, fipronil has been evaluated on more than 250 insect pests on some 60 crops worldwide; the primary agricultural opportunities include cotton, rice, banana, corn, citrus, sugarcane, potato and sugar beet. The first commercial launch of fipronil was in Vietnam (rice pests) and Colombia (cotton boll weevil) in 1993. With more than five years of experience for boll weevil control in Colombia, two of them commercial, the significance of fipronil as a tool for boll weevil management is now clear. 65-70 g ai/Ha of fipronil (as Regent® 200 SC) provides superior and long residual control of boll weevil, Anthonomus grandis, (Boheman) generally reducing the number of applications required during a season by two or more compared to other commercial products. Fipronil rapidly breaks the weevil lifecycle, resulting in reduced fruit damage and significantly higher cotton yields. A secondary benefit from using fipronil for boll weevil control is suppression of other insect pests. Even at low application rates, fipronil applied alone has been shown to suppress Heliothis virescens, Spodoptera spp. and Alabama argillacea damage. When used in combination with an IGR or thiodicarb (as Larvin® 375), fipronil has clearly demonstrated superior Heliothis virescens and Alabama argillacea control compared to a mixture of endosulfan and IGRs. Low application rates, excellent yield responses and reduced number of applications make fipronil a highly economically favorable tool for boll weevil control compared to commonly used commercial products such as methyl parathion and endosulfan. Field and laboratory studies on beneficial insects have provided encouraging results, indicating that fipronil is softer on beneficial insects than methyl parathion and endosulfan. The benefits of fipronil for Anthonomus grandis control have also been demonstrated in Venezuela, Guatemala, Paraguay, Peru, Mexico and the USA, and against A. vestitus in Peru. Fipronil is now registered for boll weevil control in Venezuela, Guatemala, Paraguay and Puru; registration in the US is planned for the 1998 cotton season. The commercial success of fipronil in Colombia after only two years is a testament to its premium level of performance.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:990-994 (1996)
National Cotton Council, Memphis TN

Introduction

Fipronil is the first in a whole new class of insecticides called the phenyl pyrazoles (Colliot et al., 1992). Discovered by Rhone-Poulenc scientists in 1987 at its agricultural research facility in the UK, fipronil has a unique mode of action (Gant et al., 1990; Cole et al., 1993) and with low application rates (7.5 - 150 g ai/Ha) provides excellent control of a broad spectrum of agricultural and public health insect pests by seed treatment, soil, foliar and bait application. Low dose rates and novel mode of action make fipronil an excellent fit in IPM and IRM programs. Since its discovery, fipronil has been evaluated on more than 250 insect pests on some 60 crops worldwide. The primary agricultural opportunities for fipronil include cotton, rice, banana, corn, citrus, sugarcane, potato and sugar beet, and the first commercial launch of fipronil was in 1993 for the control of rice insects in Vietnam and for boll weevil control in Colombia. Considerable potential for fipronil in US cotton for the control of thrips (Frankliniella spp. and Thrips tabaci), tarnished plant bugs, (Lygus lineolaris) and boll weevil has been identified, (Burris et al., 1994). A US registration for control of tarnished plant bug, thrips and boll weevil is planned for the 1998 cotton season. Fipronil is now registered in more than 30 countries for the control of a wide range of agricultural and non-agricultural pests (trademarks: Regent®, Ascend®, Cosmos®, Presto®, Choice®). Fipronil is available as foliar applied formulations (50 SC, 200 SC, 300 EC, 800 WG, 12.5 and 25 UV), soil applied granule formulations (1 GR, 3 GR, 5 GR, 15 GR and 30 GR) and seed treatments (250 FS, 500 FS, 700 FS).

The cotton boll weevil is currently regarded as one of the most significant insect pests of cotton in Colombia. It is a native of Central America, having spread into Mexico and the US in the late 1800's. Other cotton pests in Colombia include: Thrips tabaci, Aphis gossypii, Tetranychus urticae, Heliothis virescens., Alabama argillacea, Pectinophora gossypiella, Sacatodes pyralis and Spodoptera spp. The broad distribution, high fertility and mobility, short generation time and limited effectiveness of biological control agents make boll weevil management a major challenge. Like all effective IPM programs, the integration of a series of methods and strategies based on a detailed knowledge of the biology and population dynamics of the target pest is critical. In Colombia, the boll weevil, whose principal host is cotton, has enormous reproductive capacity (5-6 generations in a single growing season) and has demonstrated an extraordinary ability to survive under adverse conditions. IPM in Colombia utilizes chemical control methods combined with:

<u>The use of early varieties</u>. There is a direct relationship between the potential number of insect generations and the growing period of the cotton plant. Those areas growing broad fiber varieties, with a growing period in excess of 160 days, tend to produce marginal cotton after they have been infested with boll weevil.

<u>Planting within a narrow time window of less than 30 days</u>. Weevils migrate from fields of more mature cotton, resulting in very high infestations on later sown cotton.

<u>Destruction of trash after harvest</u>. Leaving trash on the ground after harvest for a long period increases the proportion of weevils surviving into the following growing season. To reduce populations, trash should be destroyed immediately after harvest., allowing a minimum of 75 days fallow.

<u>The use and placement of trap crops</u>. Isolated plantings of trap crops are used to trap and concentrate emigrating weevils at the end of the season and immigrating weevils at the beginning of the following season. Trap crops are sprayed for weevil control at regular intervals (twice per week). Baiting trap crops with pheromone traps also increases their effectiveness.

<u>Regular scouting and localized applications of insecticides to control outbreaks</u>. Approximately 60,000 - 100,000 Ha of cotton are treated with ca. six application of insecticide for boll weevil control each growing season (Table 1.). Up until the introduction of fipronil, some 80% of all insecticides used for weevil control were methyl parathion and endosulfan; with the introduc-tion of fipronil, recent estimates suggest that this figure is now closer to 50%.

<u>Boll Weevil Control</u>

Studies between 1991 and 1995 have ranged from small plot artificial infestations of weevils on caged plants to large plot (>5 Ha) commercial-type trials utilising multiple aerial applications to mimic standard grower practices. The majority of studies have used the Regent® 200 SC formulation although more recently, studies have included the Regent® 800 WG formulation. More than fifty truals have been carried out in South America on boll weevil control, some ten of them in Colombia.

The first large plot field trials were conducted in 1991, comparing seven applications of the commercial standards with five applications of fipronil. The results of this trial are shown in Figure 1 and summarised in Table 2. By the end of the trial, plots treated with fipronil at 70 g ai/Ha showed 4.46 times less square damage when compared to endosulfan (525 g ai/Ha), and 3.36 times lower than methyl parathion (750 gai/Ha). Further trials in 1992 (Figure 2) and 1993 (Figure 3) confirmed that fipronil provided outstanding boll weevil control, superior to the commercial standards, reducing square and boll damage to very low levels within 10 - 20 days of the first application.

Field studies in 1992 and 1993 confirmed that the outstanding activity of fipronil could generally be attributed to its long residual control. In fields where adult weevils were released into cages at regular intervals after an application of fipronil at 60 g ai/Ha, 100% and 46 % residual mortality was observed at 24 hours and four days after application respectively (Table 3.). In a second field trial (unreplicated large plot), three days residual control of adult weevils was also demonstrated (Table 4). Fipronil was also shown to be relatively fast acting, with 100% adult weevil control observed some 5 hours after application (Table 5) and excellent residual activity at two days after treatment. The long residual control obtained with fipronil results in consistently higher cotton yields compared to commercial standards (Table 6). Studies have shown that although methyl parathion can provide ca. 90% adult weevil mortality within several hours of application, after less than one day, the newly emerging population of adults in unaffected, continuing to feed and eventially laying eggs.

To optimize insecticide performance, long residual control is essential to break the insect lifecycle by preventing the female from laying eggs. Climatic differences between the three main cotton growing areas in Colombia result in a wide variation in the pre-oviposition period (adult feeding stage, prior to copulation and oviposition) and the total development time. The pre-oviposition period ranges from three days in the Atlantic coastal region to seven days in the cooler Cauca valley. The recommended applications intervals used for insecticides with shorter persistence such as methyl parathion, endosulfan and monocrotophos has generally mimicked the pre-oviposition period; three days in the coastal region, five days in the Tolema area and seven days in the Cauca valley. Experiences with fipronil across all cotton growing regions of Colombia have clearly demonstrated that with fipronil's 2-3 days of residual activity, a considerably longer application interval is possible, with four (and occasionally three) applications being sufficient to break the weevil lifecycle (Table 7; Figures 1 and 2). Current recommendations for fipronil include:

• Commencing the application schedule when scouting shows that floral bud damage has reached 5%.
• Aerial application of fipronil (as regent 200 SC) at 65-70 g ai/Ha in 25 -40 litres of water per Ha.
• 3 - 5 applications per season using a five to nine days spray schedule, depending upon region.

<u>Secondary Benefits from the Use of Fipronil</u>

In boll weevil spray programs, even at low application rates, fipronil applied alone has been shown to suppress <u>Heliothis</u> spp, <u>Spodoptera</u> spp. and <u>Ala-bama</u> <u>argillacea</u> damage. When used in combination with IGRs (Merit) or thiodicarb (as Larvin® 375), fipronil has clearly demonstrated superior Helio-this spp control compared to a mixture of endosulfan and IGR (Table 8).

Boll Weevil Development Programs Outside of Colombia

The potential of fipronil for boll weevil control has also been demonstrated in Venezuela (Figure 5), Guatemala, Paraguay, Peru, Mexico and the USA, and against A. vestitus in Peru (Figure 6). The effective rate of fipronil against boll weevil in trials between 1993 and 1994 varied from 25 to 80 g a.i./ha, depending upon species, pest pressure, location, application method and timing Table 9). Typical control programs included 3-5 spray applications at 4-7 day intervals, the first application being timed using a spray threshold based on weevil counts or fruit damage assessments.

Impact on Beneficial Arthropods

Laboratory Studies

In laboratory tests in Colombia, fipronil, like almost all commonly used insecticides, did show some short term knockdown activity on several beneficial insects (Table 10). In longer term residual contact tests, fipronil showed only low to moderate toxicity to Hippodamia convergens, Chrysopa spp. and Apenteles flavipes. Although apparently as toxic to Trichogramma pretiosum in the laboratory as methyl parathion, in field studies currently in progress in Australia (targeted at Myrids and Heliothis spp. control), very low toxicity to Trichogramma spp. has so far been observed (Dick Bull, RP Rural Development, Pers. comm.). To complement the studies in Colombia, laboratory tests were also carried out in Brazil. Fipronil showed excellent selectivity against the coccinellids Cycloneda sanguinea and Scymnus sp. compared to both methyl parathion and endosulfan, although all three products showed toxicity to the earwig, Doru lineare (Figure 6).

Field Trials

In Colombia, whenever beneficial arthropod populations have been monitored in boll weevil efficacy trials, residual toxicity to beneficial arthropods appears to be moderate to low, with rapid recovery/reinvasion of the crop after some initial knockdown effect. In fact, in a 1995 trial in the Valledupar region of Colombia, no significant effect was observed on populations of Cycloneda sanguinea, scymnus spp. and Chrysopa spp. five days after application. Similar results were observed in field trials in Peru between 1993 and 1994 (Table 11). In Peru, fipronil (applied at 50 g ai/Ha) was non-toxic to Scymnus spp. but did causes some knockdown of Ceratocapsus dispersus and Orius spp.: however, populations recovered within seven days of the application. In a further large plot (360 m^2) replicated trial carried out in Peru in 1995, populations of predators and parasites were monitored 0, 5, 10, 15 and 20 days after a single backpack application of fipronil (as Regent® 200 SC) at 50 g ai/Ha. Fipronil had no effect on populations of parasitic diptera and hymenoptera, and on spiders. Some suppression of hemipterous predators (44% reduction at 5 days) was observed, with full recovery of the population by 10 days after treatment (DAT). Against predatory coloeptera, there was a 70% reduction at 5 DAT, but a gradual recovery of the population was observed. Some of the reduction in non-target coleoptera and hemiptera populations was considered to be due to the control or suppression of host insects such as aphids, Heliothis spp and Alabama argillacea. In field trials in Brazil, fipronil (as Regent® 800 WG) applied at 64 g a.i./ha and Regent 200 SC at 75g a.i./ha showed selectivity to Cycloneda sanguinea, Scymnus sp., Geocoris sp., Nabis sp., Doru lineare and spiders, with a moderate knockdown effect one day after treatment and low residual action at three days after treatment. Fipronil was significantly less toxic to beneficials than endosulfan or methyl parathion (Figure 7).

A large field program to further evaluate the effects of fipronil in cotton is ongoing in the USA. The results obtained so far are generally encouraging, with fipronil showing lower toxicity to many beneficial insects and mites than other commercial standards. In general, low toxicity to beneficial insects and mites has also been observed in other crops such as rice and citrus.

Acknowledgments

We would like to thank Alfredo Perez for supplying all the efficacy and beneficial data from Colombia. Thanks are also due to Dr. Valentin Lobaton of the Colombian Research Institite - ICA, and Jorge Mejia for providing the boll weevil lifecycle data. I would also like to acknowledge Manuel Arrieta for supplying the information for Table 6.

References

Burris, E., B. R. Leonard, S. H. Martin, C. A. White, J. B. Graves, R Shaw and W. P. Scott. 1995. Fipronil: Evaluation of Soil and Foliar Treatments for Control of Thrips, Plant Bugs and Boll Weevils. In 1995 proceedings Beltwide Cotton Production Research Conferences, National Cotton Council, Memphis , TN. pp 838 - 844

Colliot, F., K. A. Kukorowski, D. W. Hawkins and D. A. Roberts. 1992. Fipronil: A New Soil and Foliar Broad Spectrum Insecticide. Brighton Crop Protection Conference, Pests and Diseases, 1992. pp. 29 - 34

Cole, L. M., R. A. Nicholson, and J. E. Cassida. 1993. Action of Phenylpyrazole Insecticides at the GABA-Gated Chloride Channel, Pestic. Biochem. Physiol. **46**, 47

Gant, D. B., J. R. Bloomquist, H. M. Ayad, and A. E. Chalmers. 1990. A Comparison of Mammalian and Insect GABA Receptor Chloride Channels, Pest. Sci. **30**, 355

Table 1. Area treated with insecticide for boll weevil control in Colombia between 1992 and 1994.

Year	Area Planted (Ha)	Area Treated (Ha)	# Applications Per Season
1992	98,000	626,000	6.4
1993	70,000	433,000	6.2
1994	60,000	318,000	5.3

Table 2. Mean daily and maximum fruit damage following a boll weevil control program conducted at El Copey Departmento in 1991.

		% Fruit Damage		
Treatment	Dose g ai/Ha (# appl.)	0 DAT	Mean daily damage (1-21 DAT)	Maxi. damage recorded
Fipronil (as Regent 200 SC)	50 (5)	40.96	4.6	10.6
Fipronil (as Regent 200 SC)	70 (5)	43.87	2..3	8.82
Endosulfan	525 (7)	39.28	10.3	18.42
Methyl parathion	750 (7)	34.48	7.8	18.94
UTC	-	22.32	14.9	24.61

Table 3. Mortality of boll weevil adults exposed directly to a fipronil spray and then exposed to residial deposits some 6 hours to four days following application.

Adults Released On Crop:	% Control
Just prior to application	100
6 hours after application	100
24 hours after application	100
48 hours after application	90
72 hours after application	70
96 hours after application	46

Table 4. Number of live adult weevils per 100 flowers 72 hours after an application (HAA) of fipronil at 66 g ai/Ha.

		# adult weevils/100 flowers		
Treatment	Dose in g ai/Ha	0 HAA	72 HAA	% control 72 hours after application
Fipronil as Regent 200 SC	66	37	0	100

Table 5. Number of live adult weevils/100 flowers at 0, 5, 24 and 46 hours after application (HAA) of 70 g ai/Ha of fipronil.

		# adult weevils/100 flowers			
Treatment	Dose in g ai/Ha	0 HAA	5 HAA	24 HAA	48 HAA
Fipronil as Regent 200 SC	70	33.8	0	1.4	0

Table 6. The effect of fipronil on square/boll damage and cotton yields in large plot (20 ha) trials in Colombia in 1994 (location: Mata de Cana).

Treatments	# of applications during season	Yields (Kg/Ha)
Endosulfan + Methyl Parathion	6 1	2177
Fipronil + Methyl-Parathion	4 1	2644

Table 7. Variation in the development times of boll weevil according to location and recommended spray interval for fipronil (as Regent® 200 SC).

Region	Pre-oviposition period (days)	Egg to ovi-position (days)	Recommended application interval (days) for methyl parathion, endosulfan and monocrotophos	Recommended application interval (days) for fipronil as Regent® 200 SC
Coastal Region	3	13.8	3	5-6
Espinal Tolima	5-6	18.2	5	7-8
Cauca Valley	7	28.1	7	9-10

Table 8. The activity of mixtures of fipronil (Regent® 200 SC) and lufenuron (Match® 50 g/l), Thiodicarb (Larvin® 375) and fipronil (Regent® 200 SC), and endosulfan (Thiodan® 35) and lufenuron (Match® 50 g/l) for the control of Heliothis virescens. in Colombia (Location Medias Canas/ Aguachica), 1994. Plot size was 300 m^2. E = eggs, L = larvae

		# of Heliothis spp. eggs and larvae/100 terminals					
		0 DAT		2 DAT		3 DAT	
Treatment	Dose in mls. of formulated product	E	L	E	L	E	L
Fipronil + Lufenuron	66 + 40	30	34	10	3	2	3
Fipronil + Thiodicarb	66 + 562	57	45	4	2	2	2
Lufenuron + Endosulfan	40 + 500	34	41	21	13	9	16

Table 9. Effective field application rates of fipronil for boll weevil control in USA and South America; Commercial and development trials in the 1993 and 1994 seasons.

Country	Formulation	Effective Rates (g a.i./ha)
Colombia	Regent® 200 SC and 800 WG	65-70
Venezuela	Regent® 200 SC	75
Brazil	Regent® 800 WG	80
Peru (*A. vestitis*)	Regent® 200 SC	50
Guatemala	Regent® 200 SC	50-60
Paraguay	Regent® 200 SC	60-70
USA	Regent® 800 WG	30-75
Mexico	Regent® 800 WG	25-50

Table 10. Relative toxicity of fipronil and endosulfan to beneficial insects in direct and residual contact laboratory tests.
* low toxicity; **moderate toxicity; *** high toxicity

BENEFICIAL	Fipronil 60 g a.i./ha	Fipronil 70 g a.i./ha	Endosulfan 500 g a.i./ha
Hippodamia convergens.			
direct contact	*	*	***
residual contact	*	*	*
Chrysopa spp			
direct contact	***	***	***
residual contact	**	**	**
Trichogramma pretiosum			
direct contact	***	***	***
residual contact	**	***	***
Apanteles flavipes			
direct contact	***	***	***
residual contact	*	**	***

Table 11. Effect of 50 g ai/Ha of fipronil on populations of Scymnus spp., Ceratocapsus dispersus and Orius spp.

Species	Mortality
Scymnus spp.	little or no effect at 72 hrs
Ceratocapsus dispersus	Significant knockdown at 72 hours but the population had recovered by 7 days.
Orius spp.	Significant knockdown at 72 hours but the population had recovered by 7 days.

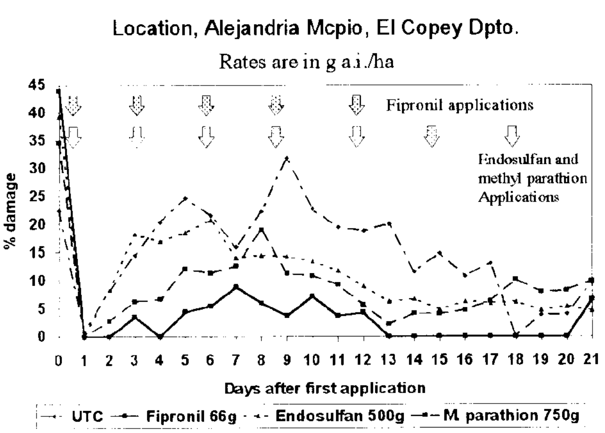

Figure 1. A comparison of the efficacy (measured as the percentage of damaged fruit) of fipronil, endosulfan and methyl parathion against boll weevil in a season long spray program; Colombia, 1991.

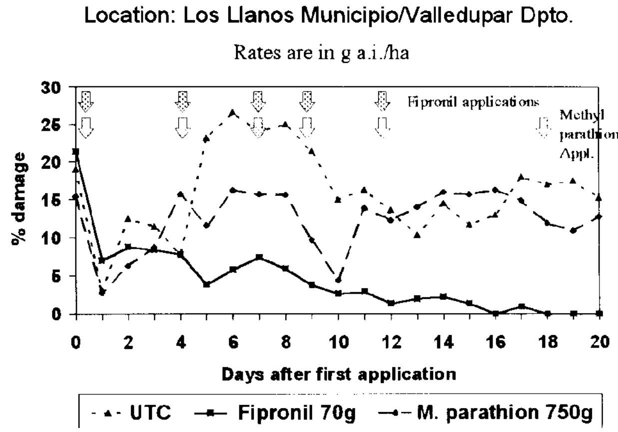

Figure 2. A comparison of the efficacy (measured as the percentage of damaged fruit) of fipronil and methyl parathion against boll weevil in a season long spray program; Colombia, 1992.

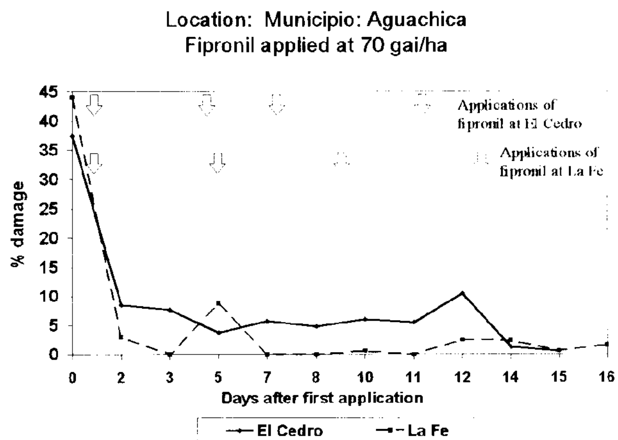

Figure 3. The efficacy (measured as the percentage of damaged fruit) of fipronil against boll weevil at two locations and spray regimes; Colombia, 1993.

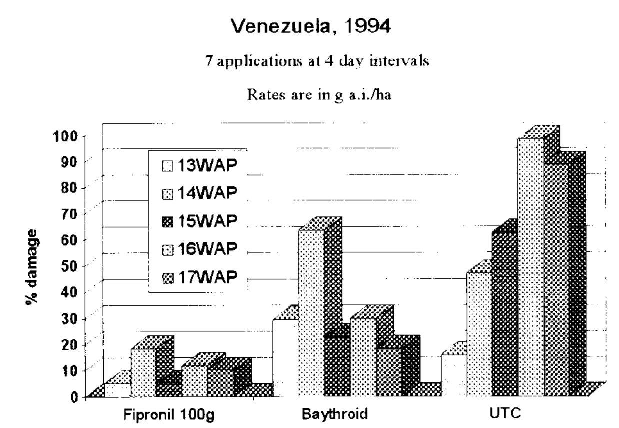

Figure 4. The activity of fipronil against boll weevil in Venezuela in a seven application spray program conducted in 1994. Efficacy was measured as the percentage of damaged squares and bolls. WAP = weeks after planting.

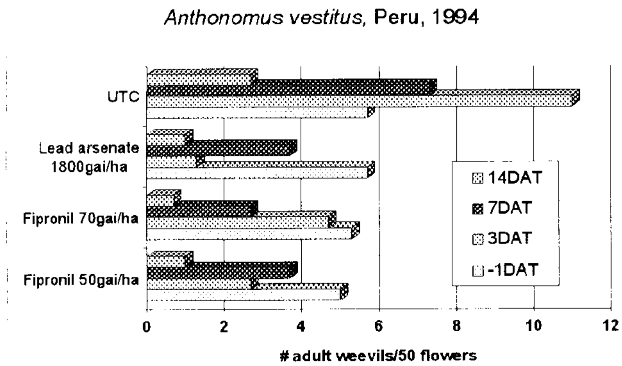

Figure 5. The activity of fipronil (50 and 70 g ai/Ha) and lead arsenate (1800 g ai/Ha) against Anthonomus vestitus in Peru in 1994. Efficacy was measured as the number of adult weevil per 50 flowers at one day before application and 3, 7 and 14 days after application.

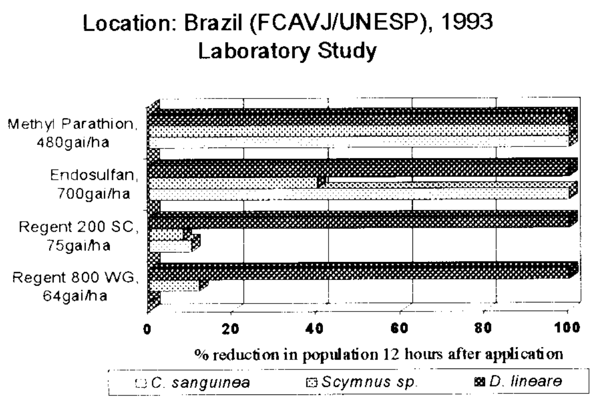

Figure 6. Laboratory studies on the toxicity of fipronil, methyl parathion and endosulfan to Coccinellids and earwigs; Brazil, 1993

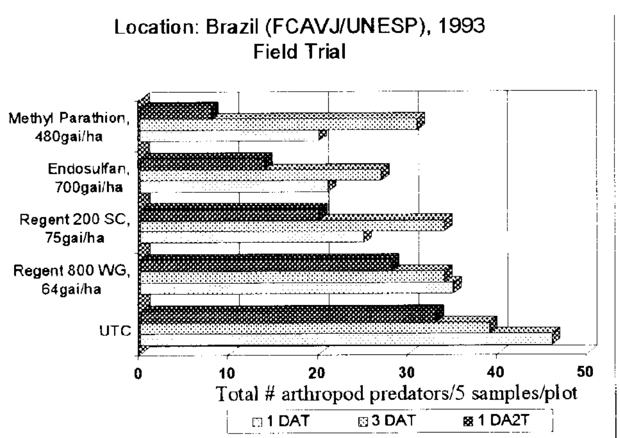

Figure 7. A comparison of the toxicity of fipronil, methyl parathion and endosulfan to arthropod predators (Cycloneda sanguinea, Scymnus sp., Geocoris sp., Nabis sp., Doru lineare and spiders) in the field; Brazil, 1993