INCIDENCE OF NATURAL CONTROL AGENTS OF THE VELVETBEAN CATERPILLAR AND RESPONSE OF ITS PREDATORS TO INSECTICIDE TREATMENTS IN BRAZILIAN SOYBEAN FIELDS[1]

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ABSTRACT - Larvae of the velvetbean caterpillar *Anticarsia gemmatalis* Hubner were collected from soybean (*Glycine max* (L.) Merrill) to determine their population levels and percentage of infection by the fungus, *Normuraea rileyi* (Farlow) Samson. Seasonal population levels of larvae and adults of the carabid predator, *Calosoma argentatus granulatum* (Perty) were determined by pitfall trap collections. The relationship between resurgence of *Anticarsia* and populations of *Calosoma*, geocorids, and nabids as influenced by insecticides was studied. Fungus attack began in February during the pod development stage when the third generation of *Anticarsia* larvae were reaching a peak and 100% of larvae observed on foliage were infected three weeks later. Activity of *Calosoma* coincided closely with population levels of the third generation of *Anticarsia*. Geocorid and nabid populations were severely affected by monocrotophos and methyl parathion treatments whereas diflubenzuron, a chitin inhibitor, had no apparent deleterious effect.

Index terms: *Calosoma argentatus granulatum*, chemical control, *Geocoris*, soybean insects, *Nabis*, natural enemies, *Nomuraea rileyi*.

INCIDÊNCIA DE INIMIGOS NATURAIS DA LAGARTA DA SOJA EM LAVOURAS DE SOJA, NO RIO GRANDE DO SUL, E SUA RESPOSTA AO TRATAMENTO COM INSETICIDAS

RESUMO - Lagartas de *Anticarsia gemmatalis* Hubner foram coletadas em soja (*Glycine max* (L.) Merrill) para determinar os níveis populacionais e a porcentagem de infecção pelo fungo *Nomuraea rileyi* (Farlow) Samson. Os níveis populacionais de larvas e adultos do predador *Calosoma argentatus granulatum* (Perty) foram determinados utilizando armadilhas de solo. Foi estudada a relação entre a ressurgência de *A. gemmatalis* e os níveis populacionais dos predadores *C. argentatus granulatum*, *Geocoris* spp. e *Nabis* spp. sob influência de inseticidas. A infestação pelo fungo *N. rileyi* começou em fevereiro, durante o estágio de desenvolvimento dos legumes quando a terceira geração de lagartas alcançou o seu pico. Três semanas mais tarde 100% das lagartas observadas sobre as folhas estavam infectadas pelo fungo. A atividade de *C. argentatus granulatum* coincidiu com o pico da terceira geração de *A. gemmatalis*. As populações de *Geocoris* spp. e *Nabis* spp. foram severamente afetadas com as aplicações de monocrotofos e metilparation, mas a aplicação de diflubenzuron, um inibidor da formação de quitina, aparentemente não provocou efeito deletério.

Termos para indexação: *Calasoma argentatus granulatum*, controle químico, *Geocoris* spp., insetos da soja, *Nabis* spp., inimigos naturais, *Nomuraea rileyi*.

INTRODUCTION

Soybean production in Brazil was increased dramatically during the past several years, primarily because of increased acreage rather than increased yields per hectare. Climatic conditions in Brazil favor insect pests which are one of the more important constraints to soybean production. The velvetbean caterpillar, *Anticarsia gemmatalis* Hubner (Noctuidae) and *Plusia nu* Guenee (Noctuidae) are the most common defoliators of soybeans in southern Brazil (Corseuil et al. 1974). *Anticarsia* is the most damaging. Most farmers use insecticides for control, averaging two applications per crop; many of the chemicals used are persistent and highly toxic to natural enemies.

Several predators are known to attack soybean pests in Brazil. Geocorids, nabids (Panizzi et al. 1977), and carabids (Costa Lima, 1952) are common predators in soybean fields. Ehler and van den Bosch (1974) report geocorids and nabids as predaceous on noctuid eggs and larvae in cotton. Geocorids and nabids are also abundant in soybean fields in the Southern United States

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where Turnipseed et al. (1975) studied the effect of insecticides on these predators of soybean pests.

The carabids *Calosoma argentinensis* C siki and *C. retusum* Fab. are mentioned by Costa Lima (1952) as predaceous on several noctuid species attacking soybeans. However, little is known about the biology, ecology, and effectiveness of *Calosoma* spp. as population regulating agents.

In 1973, we observed that a species of Calosoma was a voracious predator of the noctuid defoliators *Anticarsia* and *Plusia* spp. in soybean fields in Rio Grande do Sul. *Anticarsia* is the primary defoliator of soybeans and can cause complete defoliation when not controlled. The carabid predator was later identified as *Calosoma argentatus granulatum* (Perty)[4] and is common in soybean fields throughout much of Brazil. *Calosoma* was observed to be extremely active, rapidly moving from one plant to another and climbing to the uppermost branches in search of prey larvae. It was also observed to be feeding on *Anticarsia* pupae which were located just below the soil surface. The degree of control exerted by this predator has not been determined. Ellisor (1942) reported that carabid beetles of the genus *Calosoma* are predators as larvae as well as adults and feed primarily on lepidopterous larvae including *Anticarsia* but does not provide quantitative data. Clausen (1956, 1972) studied the control exerted by *C. syncophanta* on forest insects in the northeastern United States. He observed both the larvae and adults feeding on gypsy moth larvae and reported that a pair of adults are capable of consuming as many as 460 last instar gypsy moth larvae in their lifetime.

Diseases attacking soybean pests have also received little attention in Brazil. Puttler (1975) reported *Entomophthora* sp. and *Nomuraea rileyi* (Farlow) Samson attacking *Anticarsia* in Rio Grande do Sul with *Nomuraea* being most common. Correa & Smith (1975) in Paraná and Galileo et al. (1977) in Rio Grande do Sul, Brazil studied the seasonal occurrence of the disease on *Anticarsia*.

Naturally occurring epizootics of *Nomuraea* have been reported destroying populations of *Anticarsia* in the United States (Watson, 1916 and Allen et. al, 1971) and in Puerto Rico (Wolcott and Martorell, 1940). In addition to *Anticarsia*, *Nomuraea* attacks several additional lepidopterous pests occurring in soybean fields in the United States (Carner et al. 1975 and Puttler et al. 1976). Galileo et al. (1977) observed that *Anticarsia* larvae had a higher percentage infection of *Nomuraea* than *Plusia* sp. in Brasil. We have observed that *Anticarsia* populations can be almost completely decimated by *Nomuraea* within a week after the first infected *Anticarsia* are seen in the field. However, because the fungus often attacks after the soybean crop has been severely defoliated by *Anticarsia*, insecticidal applications are generally required (Heinrichs and da Silva 1975).

Basic studies concerning the seasonal occurrence of natural enemies and the effect of insecticides on predators of soybean pests are necessary for the development of an integrated approach to soybean insect control in Brazil. This study was conducted to (1) determine the seasonal occurrence of *Anticarsia* in relation to two of its regulating agents, *Calosoma argentatus granulatum* and *Nomuraea rileyi* and (2) assess the effect of various insecticides on *Anticarsia* and three predators, *Calosoma*, geocorids, and nabids.

MATERIALS AND METHODS

Two experiments were conducted during the crop year 1974-75 near Porto Alegre at the Agronomy Experiment Station, University of Rio Grande do Sul, Guaiba. In both experiments, the soybean variety Davis was planted on 28 October, 1974 at the rate of 21 viable seeds per meter and at a row width of 0.6 m. All other commonly recommended agronomic practices were followed.

The first experiment was designed to determine the relationship between the seasonal occurrence of *Anticarsia* and its pathogen, the fungus *Nomuraea*. Collections were made in untreated plots within an insecticide experiment and in additional untreated fields adjacent to and across a road from the insecticide experiment. Forty locations within a 3 hectare area were sampled weekly with a beat cloth from January 22 at flowering to April 24 at harvest. Living larvae

4 Determined by George Ball, Dept. of Entomology, University of Alberta, Canada.

of all instars and those killed by the fungus were counted in the field. Infected larvae generally remain on the leaves after death but can be easily removed with vigorous shaking of the plants. *Anticarsia* was the major lepidopterous species attacking the soybean plants during the sampling period but low populations of *Plusia* sp. and high populations of the stink bug, *Piezodorus guildinii* (Pentatomidae)[5] were also present, the latter being most abundant during pod filling.

In the second experiment, we tested the effect of insecticides on the population of *Anticarsia* and three predators, *Calosoma*, nabids, and geocorids and determined the seasonal occurrence of *Calosoma* in relation to *Anticarsia* populations. This insecticide experiment occupied 0.19 hectare. Plots consisted of 17 rows, 10.2 m in length (107 m^2/plot). Three rows on each side served as border rows. A two meter space with no soybeans served as a border at plot ends.

Insecticides were applied once as a foliar spray on January 29, 1975 at the flowering stage when plants were already 33% defoliated by *Anticarsia.* Insecticide was applied with a motorized mistblower delivering 393 liters of spray liquid/ hectare at the rate of 0.8 liter/minute. Treatments consisted of diflubenzuron 25 WP (a chitin inhibitor), monocrotophos 60 EC, methyl parathion 60 EC, carbaryl 85 WP, and chlordimeform 50 EC, all at 250 g active ingredient/hectare, and an untreated control. Treatments were replicated three times.

For the collection of *Calosoma*, three pitfall traps were placed in each replicate at the fourth, eighth, and twelfth rows. Traps were constructed by placing one plastic drinking cup (diameter of 7 cm and depth of 11 cm) within another. A saturated solution of picric acid, a non-repellent preservative (Southwood 1971) was placed in the inner cup. Traps were emptied weekly from January 15 (prior to flowering) to April 24, 1975 (at harvest) by removing the solution and *Calosoma* from the inner cup and refilling it with fresh picric acid. *Calosoma* were placed in alcohol and returned to the laboratory for counting.

Anticarsia larvae, geocorid,[6] and nabid[6] nymphs and adults were collected by shaking the plants over a 1 x 0.6 m beat cloth. Shepard et al. (1974) found the beat cloth to be the most efficient method estimating populations of soybean insects. A pre-spray count of the geocorids and nabids was conducted on January 29 followed by collections of the above plus *Anticarsia* on February 5, 19, and 26 and March 12 at seven, 21, 28, and 42 days after insecticidal application. Percent defoliation was also visually estimated on the same dates.

RESULTS AND DISCUSSION

Anticarsia is considered to have three generations in southern Brazil. We observed *Anticarsia* feeding on alfalfa and this host might serve as an overwintering site but this was not confirmed. Larvae first appear in extremely low numbers as early as December 11 but are difficult to find (Heinrichs and da Silva 1975). The second generation peaks about January 29 and the third about five weeks later on March 5 (Fig. 1). The *Anticarsia* larval population tripled within the one week period from January 22-29. Population of the third generation larvae increased dramatically from February 19 to March 5 and dropped rapidly thereafter. No live larvae were collected from the plants by March 19. The high incidence of natural control agents was deduced to be the major cause of the rapid decrease in the *Anticarsia* larval population as disease and predator incidence was high and few larvae had pupated.

Seasonal occurrence of Nomuraea.

Puttler et al. (1976) reported *Anticarsia* to have a low susceptibility to *Nomuraea* compared to other lepidopterous larvae attacking soybeans in the United States. However, in this experiment, we observed a high incidence of the fungus infected

[5] Identified by J. Grazia Vieira, Museu de Ciências Naturais, Fundação Zoobotânica do Rio Grande do Sul, C.P. 1.188, Porto Alegre, Brazil.

[6] Limited numbers were identified as *Geocoris punctipes* (Say) and *Nabis capsiformis* Germar by J.L. Hering, Systematic Entomology Laboratory, USDA, Beltsville, Maryland 20.705, U.S.A. Since other additional species may have been included in the collections, we hereafter refer to them as geocorids and nabids.

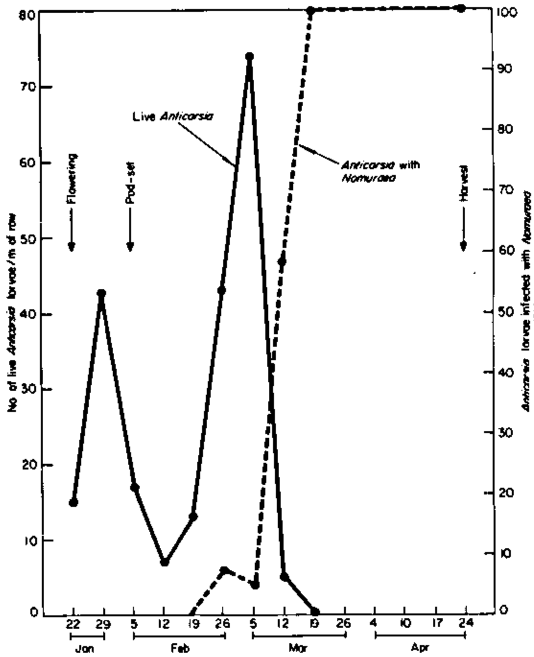

FIG. 1. Relationship between the seasonal occurrence of *Anticarsia gemmatalis* larvae and the fungal pathogen *Nomuraea rileyi* in a soybean field receiving no insecticide treatments. Data based on beat cloth counts. 1975. Guaiba, RS, Brazil.

Anticarsia larvae (Fig. 1). *Anticarsia* larvae were first observed to be infected on February 26 one week prior to reaching the peak *Anticarsia* population for the year. On March 19 three weeks after infection was first observed, 100% of the larvae taken from soybean plants were infected. Correa and Smith (1975) reported similar data from Parana, Brazil for the preceding crop year. The increase in *Nomuraea* incidence in our study corresponded to a decline in the *Anticarsia* larval population as previously reported by Carner et al. (1975) in the United States.

Larval infection developed after severe defoliation had already occurred. Observations by the authors in other fields in Rio Grande do Sul, however, indicate that this is not always the case and *Nomuraea* is capable of maintaining *Anticarsia* levels below the economic threshold under certain undetermined desirable conditions. *Nomuraea* is an effective biological control agent to *Anticarsia* when infection occurs sufficiently early, and even when infection occurs late it is partially responsible for the decrease in the number of larvae which pupate and emerge as moths the following spring.

Seasonal occurrence of Calosoma.

Maximum seasonal abundante of *Calosoma* collected in pitfall traps from three untreated plots within the insecticide experiment coincided closely with maximum numbers of *Anticarsia* larvae (Fig. 2). *Calosoma* adults were first collected on January 29 and were present in low numbers until the latter part of February. Pitfall trap catches of adults reached a peak on March 5. *Calosoma* larvae were first collected on February 12 with the peak trap population occurring on March 12. Date of maximum catch for the sum of larvae and adults was March 5 (Fig. 3). By April 10, no *Calosoma* were collected in traps from either the treated or untreated plots (Fig. 3). Cantelo et al. (1973) reported that, based on light trap catches, periods of maximum adult activity of *Calosoma alternans* (F.) coincided with the period when its prey, caterpillars and white grubs were most abundant.

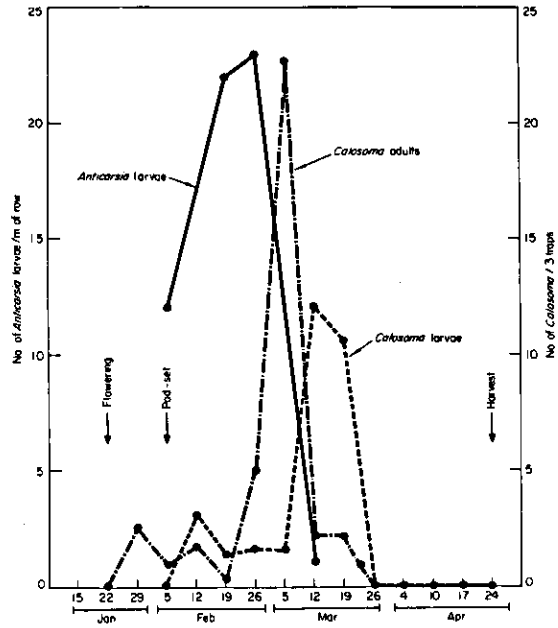

FIG. 2. Number of *Anticarsia gemmatalis* per meter row of soybeans and number of *Calosoma argentatus granulatum* larvae and adults collected in three pitfall traps in seven day periods in untreated control plots within an insecticide experiment. 1975. Guaiba, RS, Brazil.

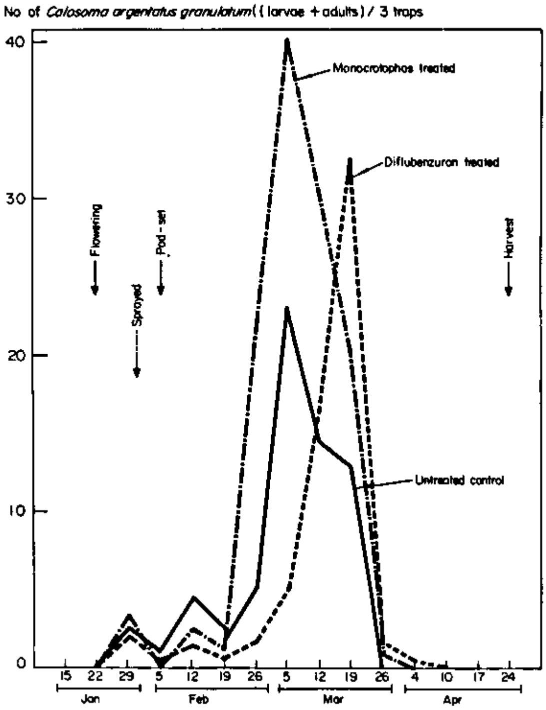

FIG. 3. Number of *Calosoma argentatus granulatum* larvae plus adults collected in three pitfall traps in seven day periods in soybean plots sprayed with monocrotophos and diflubenzuron at 250 g active ingredient per hectare and in an untreated control. 1975. Guaiba, RS, Brazil.

Insecticides and predator populations

Calosoma. The insecticides diflubenzuron, monocrotophos, methyl parathion, carbaryl, and chlordimeform were sprayed on January 29 the day when *Calosoma* adults were first collected (Fig. 2). Numbers of *Anticarsia* larvae and *Calosoma* were similar in the monocrotophos, methyl parathion, and carbaryl treated plots (Table 1). Chlordimeform treated plots were similar to the untreated control. Diflubenzuron provided control of *Anticarsia* to harvest as indicated by the low numbers collected.

The sum of *Calosoma* larvae and adults in the control, diflubenzuron and monocrotophos treatments as based on weekly collections is indicated in Fig. 3. In all treatments, low numbers were trapped on January 29, prior to the insecticide application. The number of *Calosoma* trapped increased rapidly beginning February 26.

TABLE 1. Number of *Anticarsia gemmatalis* and *Calosoma argentatus granulatum* collected in soybeans treated with insecticides. Guaiba, RS, 1975[1].

Treatment[2]	Before spraying (Jan. 29)	Date and Days After Spraying								Grain yield
		7 (Feb. 5)		21 (Feb. 19)		28 (Feb. 26)		42 (Mar. 12)		
	Calosoma[3]	Anticarsia[4]	Calosoma	Anticarsia	Calosoma	Anticarsia	Calosoma	Anticarsia	Calosoma	(kg/ha)
Diflubenzuron	2.0 a	0.5 c	0.3 b	3.6 d	0.7 a	2.5 c	1.2 c	0.1 c	16.3 a	1797 a
Monocrotophos	3.0 a	0.6 c	0.0 b	91.3 a	1.3 a	75.2 a	22.3 a	0.1 c	30.3 a	1267 b
Methyl parathion	1.0 a	2.6 b	0.7 ab	52.1 ab	1.3 a	65.4 a	18.0 a	0.4 bc	30.0 a	418 de
Carbaryl	2.3 a	1.5 bc	0.3 b	58.3 ab	2.3 a	61.7 a	11.7 ab	0.4 bc	22.0 a	718 cd
Chlordimeform	1.0 a	2.7 b	1.7 a	21.3 c	0.3 a	26.9 b	2.3 c	3.2 a	25.7 a	1161 bc
Control	2.7 a	21.1 a	1.0 ab	22.0 bc	2.3 a	24.2 b	5.3 bc	1.0 b	14.7 a	200 e

[1] In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.
[2] Insecticides were applied once on January 29 at the rate of 250 g active ingredient/ha.
[3] Number trapped in three pitfall traps over a seven-day period preceeding the collection date.
[4] Number of larvae per linear meter of row.

In the control and monocrotophos-treated plots, a peak was reached on March 5 whereas in the diflubenzuron plots, peak activity occurred on March 19.

Calosoma activity was greater in the diflubenzuron and monocrotophos treatments than in the control indicating no adverse effect of the one insecticide application at flowering on *Calosoma*. We have however, observed that an application of monocrotophos is extremely toxic to *Calosoma* and does decrease populations when applied after *Calosoma* activity is high. In this experiment, timing of insecticide application was such that the majority of the *Calosoma* escaped the insecticide treatment. The biology of *C. agentatus granulatum* has not been studied but our observation indicate that the majority of *Calosoma* adults had not yet emerged from the soil or were present in adjacent pastures at the time of insecticide application.

The abundance of *Calosoma* in treated plots seems generally related to the abundance of *Anticarsia* larvae in those treatments where *Anticarsia* resurgence occurred (Table 1). Monocrotophos, methyl parathion and carbaryl treated plots all had a three-fold increase in *Anticarsia* larvae over the control (Table 1) at 28 days after application and also had highest *Calosoma* catches. Although *Anticarsia* populations were extremely low in the diflubenzuron treatments, large numbers of *Calosoma* were trapped on March 19 (Fig. 3). By this date, diflubenzuron plots were the only ones providing agreeable habitat for *Calosoma* as they were only 29% defoliated whereas the control, monocrotophos and other treatments were almost completely defoliated (Figs. 4-6). There was an apparent movement of *Calosoma* to the diflubenzuron plots for a short period before *Calosoma* activity terminated on March 26 (Fig. 3).

Geocorids and nabids.

Although initial control of *Anticarsia* with monocrotophos as indicated at seven days after spraying was excellent (Fig. 6),

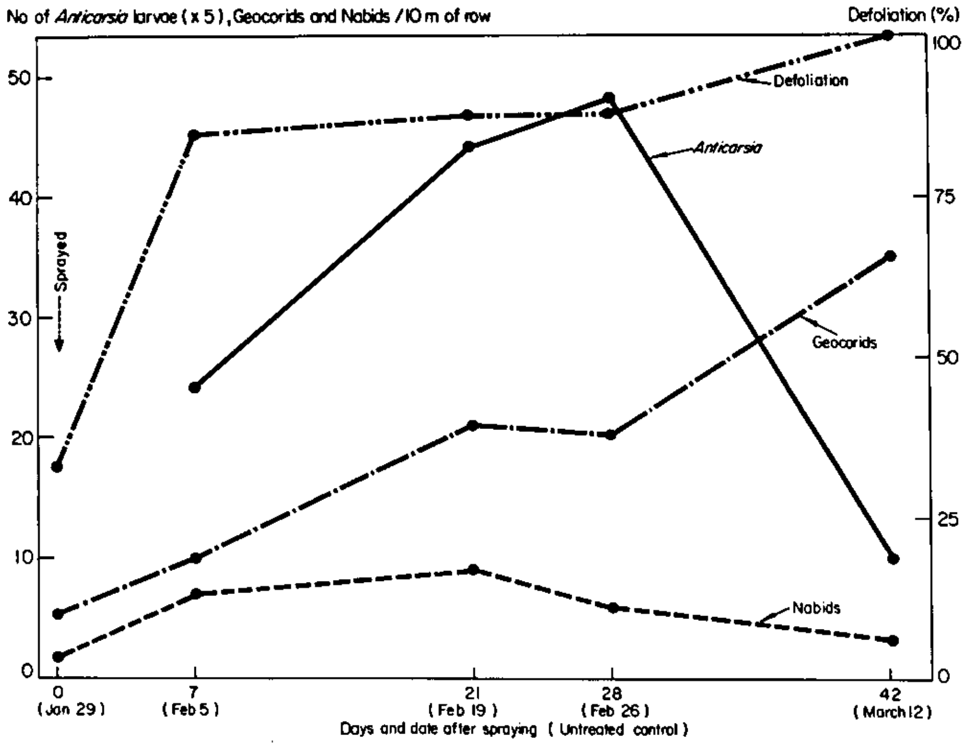

FIG. 4. Number of geocorid and nabid nymphs and adults and *Anticarsia gemmatalis* larvae per ten linear meter row of soybeans as collected in untreated plots. Defoliation readings based on visual estimates. 1975. Guaiba, RS, Brazil.

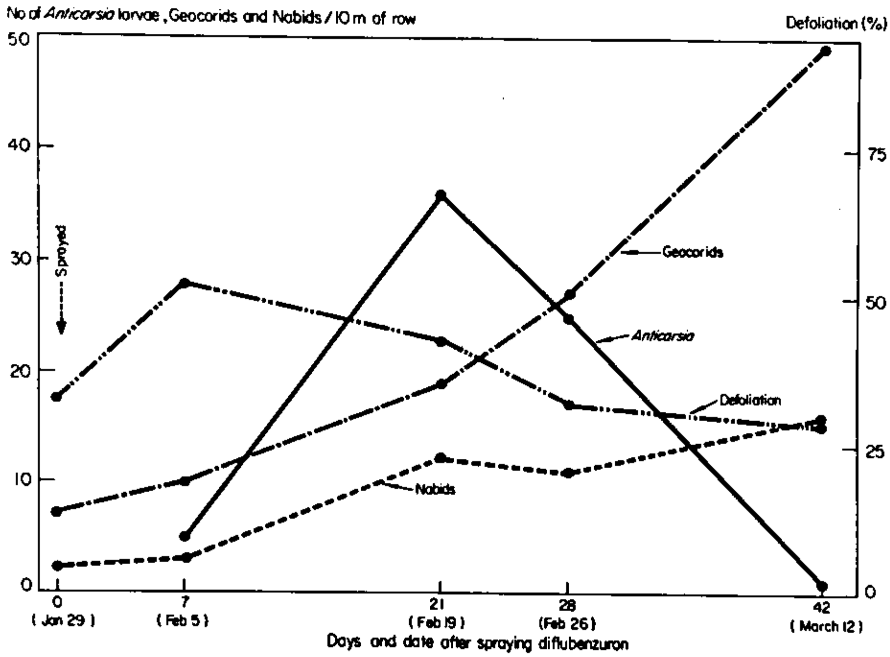

FIG. 5. Number of geocorid and nabid nymphs and adults and *Anticarsia gemmatalis* larvae per ten linear meter of row of soybeans as collected with a beat cloth after spraying once with diflubenzuron at 250 g active ingredient per hectare on January 29, 1975. Guaiba, RS, Brazil.

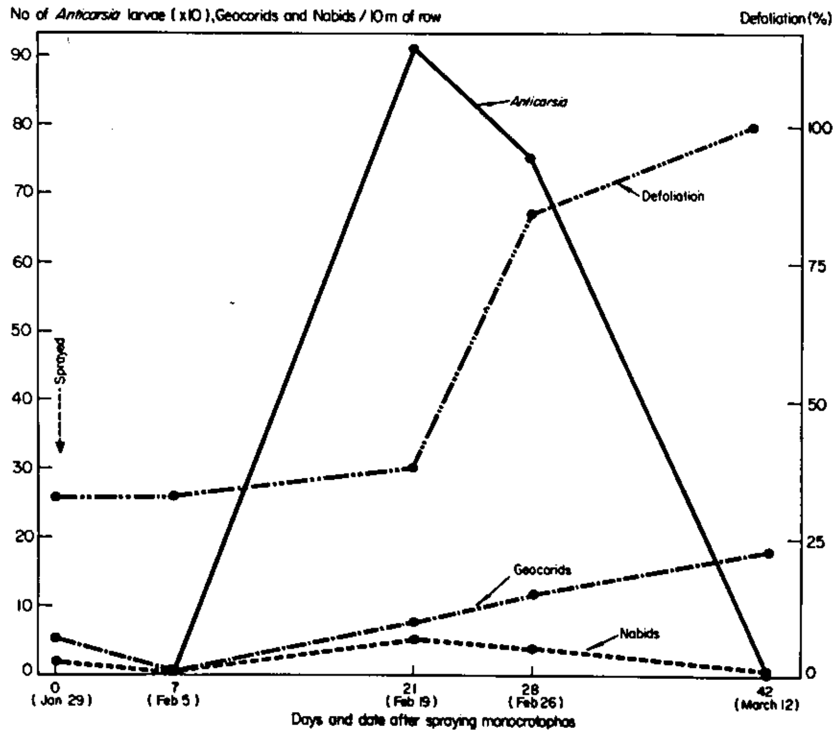

FIG. 6. Number of geocorid and nabid nymphs and adults and *Anticarsia gemmatalis* larvae per ten linear meter of row as collected with a beat cloth after spraying once with monocrotophos at 250 g active ingredient per hectare on January 29, 1975. Guaiba, RS, Brazil.

peak population of the next generation occurring 21 days after spraying was 3.8 times that of the peak population in the control plots which occurred 28 days after spraying (Fig. 4). The resurgence ratio was only slightly lower for methyl parathion and carbaryl. Chlordimeform did not cause a resurgence.

The cause of the *Anticarsia* resurgence in plots sprayed with monocrotophos, methyl parathion, and carbaryl was not determined. However, monocrotophos and methyl parathion had an adverse effect on geocorids and nabids. Geocorids and nabids were both more abundant in the untreated control and diflubenzuron plots than in monocrotophos plots (Figs. 4-6). On February 5, seven days after insecticide application, both the control (Fig. 4) and diflubenzuron (Fig. 5) had ten geocorids/10 meter of row while none were trapped in the monocrotophos plots (Fig. 6). The geocorid population gradually increased thereafter in all treatments reaching 35 and 49/10 meter of row in the control and diflubenzuron treatments respectively at 42 days after application and only 18 in the monocrotophos treatment (Figs. 4-6). Turnipseed et al. (1974) reported that geocorids and nabids decreased in plots treated with diflubenzuron (TH6040) but indicated it may have been the result of a reduction in the prey population.

The nabid population was lower than that of the geocorids but reacted similarly to the insecticide treatments (Figs. 4-6). Methyl parathion plots were similar to those of monocrotophos while the diflubenzuron, carbaryl, and chlordimeform sprays had little adverse effect.

Grain yields.

Grain yields (Table 1) were highest in the diflubenzuron treatment. Diflubenzuron has a long residual activity and one application provides season-long control of *Anticarsia* (Turnipseed et al. 1974). Defoliation rose slightly after spraying diflubenzuron because mortality is somewhat delayed (Fig. 5). The insecticide interferes with cuticle deposition and larvae must molt before they are killed (Mulder and Gijswift 1973). Defoliation dropped thereafter as new foliage was produced and the *Anticarsia* population remained low. Its safety to natural enemies and long residual activity makes diflubenzuron an excellent insecticide for control of *Anticarsia*.

CONCLUSION

The fungus *Nomuraea* and the carabid predator were important components in the biological control of *Anticarsia* in this study. Geocorids and nabids were abundant but their importance as predators feeding on *Anticarsia* was not determined. If these control agents can be manipulated to increase their effectiveness it may be possible to eliminate one or two insecticide applications from the two to three applications per crop now made by soybean producers in southern Brazil. Further studies could possibly identify cultural practices that would encourage earlier initial *Nomuraea* infection. Identification of selective insecticides such as diflubenzuron and application methods that allow the predators to survive are important components that need to be developed for the integrated control of *Anticarsia*.

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