POPULATION DYNAMICS OF PESTS AND SOME OF THEIR PREDATORS IN SOYBEAN FIELD UNDER INFLUENCE OF HERBICIDAL APPLICATIONS OF TOXAPHENE[1]

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ABSTRACT - Population response of phytophagous arthropods and natural enemies to toxaphene, based on its use as a herbicide (two applications at the dose of 3.36 kg of a.i./ha) to control sicklepod, *Cassia obtusifolia*, was studied on soybean *Glycine max* (L.) Merrill, in a large field experiment of 0.04 ha parcels in a diversified agroecosystem at Madison Co., in North Florida, USA, during the 1980 crop reason. Only intensive toxaphene treatment appears to have affected population of *Spissistilus festinus* (Membracidae). Timing and intensity of sprays significantly decreased and increased the levels of the noctuid pests, *Anticarsia gemmatalis* and *Heliothis zea*, respectively. Populations of the predators *Nabis roseipennis* (Nabidae), and *Solenopsis invicta* (Formicidae) decreased while larvae of *Chrysopa rufilabris* (Chrysopidae) and *Labidura riparia* (Labiduridae) increased significantly following toxaphene applications. Populations of *L. riparia* augmented independently of the prey density of *A. gemmatalis;* however, nabids and geocorids showed a progressive and weak density dependent response to *A. gemmatalis*. Migratory activity of the predator *Calosoma alternans* was strongly associated with the presence of high levels of *A. gemmatalis* caterpillar populations.

Index terms: *Glycine max, Cassia obtusifolia,* natural enemies, *Anticarsia, Heliothis, Nabis, Chrysopa, Calosoma, Solenopsis.*

DINÂMICA POPULACIONAL DE PRAGAS E SEUS PREDADORES NA CULTURA DA SOJA SOB INFLUÊNCIA DE APLICAÇÕES DE TOXAFENO COMO HERBICIDA

RESUMO - As respostas populacionais de artrópodes fitófagos e inimigos naturais ao toxafeno, diante do seu uso como herbicida (duas aplicações na dose de 3,36 kg do i.a./ha) para combater o mato sicklepod, *Cassia obtusifolia*, foram estudadas na cultura da soja *Glycine max* (L.) Merrill, em parcelas experimentais de 0,4 ha num agroecosistema diversificado do município de Madison, norte da Flórida, USA, durante a safra de 1980. Somente o tratamento intensivo com toxafeno parece ter afetado populações de *Spissistilus festinus* (Membracidae). A época e a intensidade das pulverizações diminuíram e incrementaram significativamente os níveis das pragas de noctuídeos, *Anticarsia gemmatalis* e *Heliothis zea*, respectivamente. Populações dos predadores *Nabis roseipennis* (Nabidae), e *Solenopsis invicta* (Formicidae) diminuíram, enquanto *Chrysopa rufilabris* (Chrysopidae) e *Labidura riparia* (Labiduridae) incrementaram-se significativamente após as aplicações de toxafeno. Populações de *L. riparia* aumentaram independentemente da densidade da presa *A. gemmatalis;* entretanto, nabídeos e geocorídeos apresentaram uma dependência gradual e fraca em relação à densidade de lagartas de *A. gemmatalis*. A atividade migratória do predador *Calosoma alternans* (Carabidae) esteve fortemente condicionada à presença de altas populações de lagartas de *A. gemmatalis*.

Termos para indexação: *Glycine max, Cassia obtusifolia,* inimigos naturais, *Anticarsia, Heliothis, Nabis, Chrysopa, Calosoma, Solenopsis.*

INTRODUCTION

Sicklepod, *Cassia obtusifolia* L., is a serious weed pest in soybean; it is adapted to a wide range of conditions, able to germinate and emerge from deep within the soil, often escaping from most soil-applied herbicides (Teem et al. 1980) and is tolerant to most

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post-emergence herbicides in soybeans (Teem et al. 1977, Crowley et al. 1979, Currey et al. 1981). However, toxaphene, prior to its prohibition by the U.S. Environmental Protection Agency, was found to be a cheap effective herbicide at the rate of 3.36 kg of a.i./ha when broadcast to sicklepod in the cotyledonary stage. Toxaphene, primarely, has been for long time used on cotton arthropod populations in U.S.A.

By 1980 the extended permit for the insecticide toxaphene as a herbicide for control of sicklepod in Southeastern USA quickly became a polemic subject (Everest et al. 1980, Newsom 1980) since entomologists in the United States agreed, more than 10 years ago, to discontinue the use of most organochlorine insecticides in soybeans, because of its persistence in the environment and its detrimental effects to predatory and parasitic insects especially to ground-dwelling predators (Newsom 1980). Since that time both insecticidal and herbicidal uses of toxaphene have been of great concern. The Environmental Protection Agency of the United States Government issued notice to cancel most registered uses of toxaphene on 29 November 1982.

Research by Salleh (1980) at Quincy, Fl., indicated that toxaphene was very toxic to key predators in the aerial stratum of soybean, but when applied to the "soil" had no significant effect. Detrimental effects on ground dwelling predadors were not conclusive from this study. Huckaba et al. (1983) in Johnston Co., NC, during 1980-81, found that toxaphene applied to the "soil" (15 and 30 days after planting) did not reduce populations of predators at the aerial stratum and related late season outbreaks of *Heliothis zea* larvae to toxaphene treated plots where thrips larvae were reduced. While Isenhour et al. (1985) in research at several locations in Georgia, during 1981, found that pest resurgence due to toxaphene was limited and that a greater abundance of predators in soybeans with weeds appeared to be attributable to increases in habitat diversity provided by the weeds and soybeans and not to a reduction in predator numbers caused by toxaphene in the treated plots.

The objectives of the present investigations were to further examine the effects of toxaphene use in soybean on 1) phytophagous and predaceous arthropod populations in both aerial and soil surface strata, and 2) its effect on the induction of pest resurgence and secondary pest outbreaks.

The study reported here is a detailed examination of the effects of toxaphene in both pests and natural enemies in a soybean agroecosystem at North Florida, USA, during 1980.

MATERIAL AND METHODS

This study was performed in a field of soybean, *Glycine max* (L.) Merrill cv. "Bragg", surrounded by plantings of maturing corn, located in Madison Co., Fl., USA, from June to October, 1980. The plant stand averaged eighteen plants/row-m and the row spacing was 90 cm.

Treatments - Treatments were arranged in a randomized complet block design with three replications with each plot equal to 0.4 ha. Until July 28 there was only two treatments in the experiment: $T_1 = T_4$ and $T_2 = T_3 = T_5$, therefore there were treated and untreated plots with six replications each. Treatments T_1, T_2 and T_3 had two applications of toxaphene at 3.36 kg of a.i./ha each, plus 1,169 ml of Agri-Dex oil, spaced several days apart (ca. one week) during early, middle and late season, respectively. Treatment T_1 coincided with the normal use of toxaphene as a herbicide, T_2 was somewhat late for herbicidal use, while T_3 was very late, but coincided with the timing of insect control measures in the area. Treatment 4, T_4, was sprayed when any other plot was sprayed, and represented very intensive use of toxaphene for both weed and insect control. Treatment 5, T_5, did not receive experimental toxaphene applications but did receive the sprays applied by the farmer and represented the IPM (Integrated Pest Management) practices for the region. Applications of pesticide made by the farmer (T_5) were super-imposed upon experimental treatments on August 15 and September 1 with carbaryl and methomyl + methyl parathion, respectively (Table 1).

Sampling - Sistematic sampling was performed at approximately one week intervals for pitfal traps

TABLE 1. Chronology and frequencies of toxaphene applications to experimental plots.

Treatments[a]	Number of applications	July			August*		September*
T_1	2	02	10				
T_2	2			28	04		
T_3	2					18	08
T_4	6	02	10	28	04	18	08
T_5	0	-	-	-	-	-	-

[a] Note: $T_3 = T_5$ until August 18.

* Farmer sprayed entire field on August 15 and September 1 with carbaryl and methomyl + methyl paration, respectively, to control economically damaging level of Velvetbean caterpillar, *Anticarsia gemmatalis*.

and sweep-net sampling. Samples were collected by the same person on each date. Each plot was subsampled four times by each sampling method (Fig. 1). Pitfall traps were collected between 8:00 AM and 9:30 PM (EDT). Sweep-net samples were collected between 10:00 AM and 3:30 PM (EDT).

Pitfall traps - Each trap consisted of a glass jar (6 cm diam. x 9.5 cm depth; 437 ml capacity) buried in the soil so that the lip of the jar was even with the soil surface. The jars were situated within the soybean row. A trap cover constructed of sheet metal was placed over each jar which prevented insects from falling from the plantas and avoided water accumulation during rainfall. Each pitfall trap was provided with 75 ml of fixative solution composed of ethylene glycol to prevent evaporation and 15 ml of formaldahyde to preserve captured arthropods (37% formalin + 10 methyl alcohol). On each sampling date, jars containing trapped specimens were removed, the jars replaced and processed in the laboratory. Piftall-trap sampling were made from 08 July to 08 October.

Sweep-net sampling - Were taken with a standard muskin sweep-net (35 cm diam. x 70 cm depth) attached to a 1 - m long handle. Each plot subsample consisted of 25 sweeps (strokes) in a figure-eight pattern through the upper canopy of a single row of soybean. Subsample material was put into plastic bags for further processing in the laboratory. Sweep-net sampling was made from 08 July to 04 October.

Plant-shake sampling - A plastic sheet, 60 cm long and 91 cm wide, was placed on the soil surface between two rows. Soybean plants on either side of the sheet were shaken over the sheet 15 times to dislodge arthropods. The sheet was then quickly folded and the contents emptied into a plastic bag for later processing in the laboratory.

Arthropod classification - The insects were classified by species, by size and stage as follows: (a) Lepidopterous caterpillars and earwigs inmatures and adults: small (≤ 1.5 cm), medium (15 - 2.5 cm) and large (≥2.6 cm); (b) orthoptera, nabids, geocorids, hoppers and chrysopids: nymphs (N) and adults (A); and (c) ants, carabids, cicindellids, dolichopodids and mirids: adults only (A).

Damage evaluation - The girdle damage to soybean caused by the three-cornered alfalfa

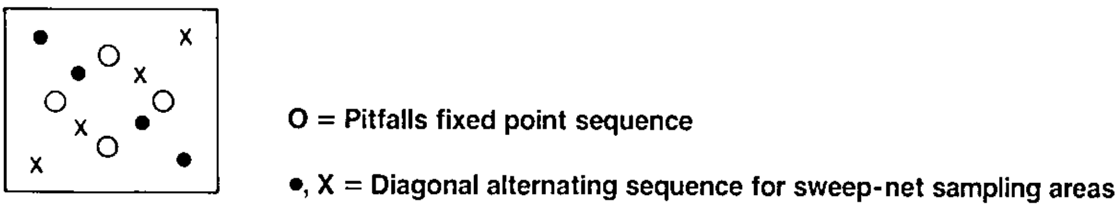

FIG. 1. Plot showing the general sampling allocation scheme.

hopper, *Spissistilus festinus* was evaluated on July/29.

Statistical analyses - Four subsamples per plot were pooled and constituted a sample. The arthropod population data were transformed by $\sqrt{x + 0.5}$ and subjected to analysis of variance (Pimentel-Gomes 1973, Little & Hills 1978). Comparisons among treatments means were made by using Duncan's multiple range test ($P < 0.05$). A regression analysis using Log_{10} number plus 1 transformation for *Labidura* and *Solenopsis* of toxaphene free treatments (T_5) and heavily treated plots (T_4), was made.

RESULTS AND DISCUSSION

The velvetbean caterpillar (VBC), *Anticarsia gemmatalis* Hübner, was the most abundant defoliator in our untreated experimental plots, reached economic damage levels around August 12 (full bloom-R^2 Soybean stage) and again on August 30 (R4) and triggered farmer control practices on the entire experiment, with carbaryl and methomyl + methyl parathion, respectively. The major secondary pest observed in óur plots was the corn earworm (CEW), *Heliothis zea* (Boddie) which attacks the leaves and seeds pods. The soybean looper (SL), *Pseudoplusia includens* (Walker) was the other secondary defoliating pest. The three-cornered alfalfa hopper (Δ CAH), *Spissistilus festinus* was a common insect. Stinkbug numbers were extremely low throughout the season.

The most abundant natural enimies in the aerial stratum captured in sweep-net sample were nabids (mainly *Nabis roseipennis*) and geocorids (mainly *Geocoris punctipes*). During the season, *N. roseipennis* was 6.3 times more abundant than *Tropiconabis capsiformis*, and *G. punctipes* was 3.4 times as prevalent as *G. uliginosus*. Nabis were on average 2.3 times more abundant than geocorids. *Spiders*, and *Orius insidiosus* were captured through most of the season, but their numbers were too low to allow meaningful comparisons. Dolichopodid flies and mirids (*Spanogonicus albofasciatus*) appeared in sufficient number to allow meaningful comparisons, and together with several coccinellids were found primarily in early season.

The most abundant natural enemies on the soil surface stratum, as measured by pitfall traps, were red imported fire ants, *Solenopsis invicta;* striped earwigs, *Labidura riparia;* and the carabid, *Calosoma alternans sayi*. Other carabids, found in low numbers, were *Tetragonoderus intersectus* Germar, *Apristus latens* Le Conte, *Anisodactylus merula* Germar and *Solenophorus palliatus* Fabricius. Many other carabids were captured but only sporadically. *Gryllus* spp. and tettigoniids were commom in pitfall traps. Cicindellids, primarily *C. puntulata,* and some dolichopodids were also common in the pitfall traps only during early season. Terrestrial spiders of the *Pardosa milvina* (Hentz) complex occurred, but in insufficient numbers to allow statistical analysis.

Effect of Toxaphene on Phytophagous Insects in the Aerial Stratum of Soybean

Timing of toxaphene applications had significant effects on VBC larval populations ($P < 0.05$) in treated plots throughout the season. This is best seen in the data in those plots (T_5) which did not receive pesticides until the farmer treatments on August 15 and September 1 (Table 2). Before late September in untreated check, T_5 consistently had the highest average number of VBC larvae, followed by T_1. The other treatments consistently had very low VBC numbers. On September 23, the T_1 treatment had significantly higher average VBC larval counts than did the check (T_5).

The nearer that toxaphene applications were made to the VBC larval outbreak (i.e., August 12), the greater were reductions in VBC populations. (Tables 1 and 2), whereas, when applied at the flowering - small pod crop phenological stages (i.e., before August 21 and 30) CEW outbreaks were induced. This can be observed in August 12 sample data for treatments T_2 and T_4, which were sprayed on

TABLE 2. Average number of small, medium, large and total velvetbean caterpillar (VBC, *Anticarsia gemmatalis*)/100 sweeps as influenced by toxaphene application at different times and frequencies in a soybean agroecosystem at Madison, Florida, during 1980.

VBC size	Treatment	Sampling date[a]						
		Aug.				Sept.		Oct.
		12*	21	27	30	*02	23	04
Small	T_1	66.0 b	0.0	29.7 b	127.3 b	0.3	25.3 a	11.0 a
	T_2	0.7 c	0.0	6.0 bc	8.7 d	0.3	2.0 c	4.7 ab
	T_3	188.0 a	0.0	6.7 c	33.3 c	0.0	0.7 c	0.0 b
	T_4	0.0 c	0.0	4.0 c	17.3 d	1.0	0.0 c	0.3 b
	T_5	176.7 a	0.0	83.3 a	180.7 a	0.0	9.3 b	11.0 a
	cv(%)[b]	(7.3)		(40.0)	(9.3)		(24.1)	(42.9)
Medium	T_1	23.0 b	0.0	0.3	23.7 b	0.0	13.3 a	10.0 a
	T_2	0.7 c	0.0	0.0	1.0 c	0.0	1.3 b	4.7 a
	T_3	79.0 a	0.0	0.0	0.0 c	0.0	1.0 b	0.0 b
	T_4	0.3 c	0.0	0.0	0.0 c	0.0	0.0 b	0.0 b
	T_5	71.7 a	0.0	0.7	38.0 a	0.0	3.0 b	9.0 a
	cv(%)	(15.7)			(23.4)		(37.7)	(27.4)
Large	T_1	23.3 b	0.0	0.0	22.0 a	0.0	8.3 a	15.3 a
	T_2	0.0 c	0.0	0.0	0.0 b	0.0	0.3 b	3.3 b
	T_3	73.3 a	0.0	0.0	0.0 b	0.0	0.0 b	0.0 c
	T_4	0.0 c	0.0	0.0	0.0 b	0.0	0.0 b	0.7 bc
	T_5	74.0 a	0.0	0.0	30.0 a	0.0	3.3 ab	13.0 a
	cv(%)	(16.8)			(34.0)		(46.0)	(22.8)
Total	T_1	112.3 b	0.0	30.0 b	173.0 b	0.3	46.9 a	36.3 a
	T_2	1.4 c	0.0	6.0 bc	9.7 d	0.3	3.6 c	12.7 b
	T_3	344.3 a	0.0	6.7 c	33.3 c	0.0	1.7 c	0.0 c
	T_4	0.3 c	0.0	4.0 c	17.3 cd	1.0	0.0 c	1.0 c
	T_5	322.4 a	0.0	84.0 a	248.7 a	0.0	15.6 b	33.0 a
	cv(%)	(9.8)		(40.0	(12.6)		(33.2)	(29.7)

[a] Treatment means followed by the same letter within each sampling date are not significantly different at the 5% probability level using the Duncan's multiple range test. Treatment means having no letters following them are not significantly different.

[b] cv(%) coefficient of variation.

* Farmer sprayed entire field on August 15 and September 1 with carbaryl and methomyl + methyl parathion, respectively. Note that $T_3 = T_5$ before August 18.

July 28 and August 4, respectively. The phenomenon of CEW induced outbreak was observed again in the T_3 and T_4 sample data on August 30, which had been sprayed on August 18 (Table 3).

The absence of *H. zea* in all treatments on August 21 is attributable to the carbaryl application on August 15, while the low numbers of *H. zea* in all treatments on September 2 are attributable to the application of methomyl + methyl parathion on September 1 (Table 3).

Buildups of *H. zea* larvae have been documented by previous researchers, for situations where broad spectrum insecticides, including methomyl and methyl parathion, have been used near peak bloom, or in cases where persistent insecticides were applied early in the crop season and the effects persisted until peak bloom (Hasse 1971, Morrison et al. 1979). This problem has been demonstrated to be intensified in an open canopy situation (Neal 1974, Bradley & Van Duyn 1980), when large moth flights occur simultaneously (Bradley & Van Duyn 1980), and when dispersal of adults from other infestation sources such as cotton, tobacco and corn occurs (Stinner et al. 1980). Huckaba et

TABLE 3. Average numbers of small, medium, large and total corn earworm larvae (CEW, *Heliothis zea*)/100 sweeps as influenced by toxaphene applications at different times and frequencies in a soybean agroecosystem at Madison, Florida, during 1980.

Size	Treatment	Sampling date[a]				
		Aug.				Sept.
		12*	21	27	30	*02
Small	T_1	22.7 b	0.0	2.0	5.3 b	0.0
	T_2	42.7 a	0.0	1.0	3.7 b	1.0
	T_3	16.3 b	0.0	0.0	24.3 a	0.3
	T_4	44.0 a	0.0	0.0	16.7 a	1.3
	T_5	17.0 b	0.0	2.3	4.3 b	0.7
	cv(%)[b]	(11.1)		(42.4)	(15.0)	(38.2)
Medium	T_1	8.7	0.0	0.0	0.7 a	0.3
	T_2	7.0	0.0	0.0	0.0 b	0.7
	T_3	5.0	0.0	0.0	0.0 b	0.0
	T_4	3.7	0.0	0.0	0.0 b	0.0
	T_5	3.7	0.0	0.0	1.0 a	0.3
	cv(%)	(25.6)			(15.2)	(34.6)
Large	T_1	3.0 ab	0.0	0.0	0.7	0.7 a
	T_2	0.3 c	0.0	0.0	0.0	0.0 b
	T_3	0.7 bc	0.0	0.0	0.3	0.0 b
	T_4	4.7 a	0.0	0.0	0.0	0.0 b
	T_5	2.0 abc	0.0	0.0	0.0	0.0 b
	cv(%)	(32.2)			(29.0)	(17.2)
Total	T_1	34.3 b	0.0	2.0	6.7 c	1.0
	T_2	50.0 a	0.0	1.0	3.7 c	1.7
	T_3	21.7 c	0.0	0.0	24.7 a	0.3
	T_4	52.3 a	0.0	0.0	16.7 b	1.3
	T_5	22.7 c	0.0	2.3	5.3 c	1.0
	cv(%)	(10.1)		(42.4)	(11.1)	(46.3)

[a] Treatment means followed by the same letter within each sampling date are not significantly different at the 5% probability level using the Duncan's multiple range test. Treatment means having no letters following them are not significantly different.

[b] cv(%) = coefficient of variation.

* Farmer sprayed entire field on August 15 and September 1 with carbaryl and methomyl + methyl parathion, respectively. Note that $T_3 = T_5$ before August 18.

al. (1983) related late season outbreaks of *H. zea* larvae to early applications of toxaphene to soybean plots where thrips larvae was reduced.

Although soybean looper larvae occured in very low numbers, their numbers tended to increase in treatments T_3 and T_4 late in the season (Table 4). Excessive use of wide spectrum insecticide has been related to increases in soybean looper on soybean (Hasse 1971, Neal 1974).

Populations of Δ CAH did not show

TABLE 4. Average numbers of small, medium, large and total soybean looper caterpilar larvae (SBL, *Pseudoplusia includens*)/100 sweeps as influenced by toxaphene applications at different times and frequencies in a soybean agroecosystem at Madison, Florida, during 1980.

Size	Treatment	Sampling date[a]			
		Aug.	Sept.		Oct.
		30	*02	23	04
Small	T_1	0.7	0.0	0.3	0.0
	T_2	1.0	0.0	2.0	0.7
	T_3	2.7	1.0	2.0	1.0
	T_4	0.7	1.0	4.0	0.3
	T_5	0.3	0.3	1.0	0.3
	cv(%)[b]	(44.3)	(36.6)	(49.2)	(35.4)
Medium	T_1	1.0 ab	0.0	0.0 b	0.3 ab
	T_2	0.7 ab	0.0	0.0 b	0.7 ab
	T_3	0.0 b	0.0	1.3 a	1.7 a
	T_4	0.3 ab	0.0	1.3 ab	1.0 ab
	T_5	1.3 a	0.3	0.0 b	0.0 b
	cv(%)	(28.2)	(18.0)	(31.1)	(31.1)
Large	T_1	1.0 a	0.0	0.3	0.7
	T_2	0.3 ab	0.7	1.0	1.3
	T_3	0.0 b	0.3	2.7	3.0
	T_4	0.0 b	0.0	0.3	4.0
	T_5	0.3 ab	1.0	0.7	0.0
	cv(%)	(24.2)	(41.0)	(40.4)	(51.6)
Total	T_1	2.7	0.0	0.7 b	1.0
	T_2	2.0	0.7	3.0 ab	1.3
	T_3	2.7	1.3	6.0 a	5.3
	T_4	1.0	1.0	5.7 ab	5.7
	T_5	2.0	1.7	1.7 ab	0.3
	cv(%)	(39.3)	(51.5)	(36.4)	(51.4)

[a] Treatment means followed by the same letter within each sampling date are not significantly different at the 5% probability level using the Duncan's multiple range test. Treatment means having no letters following them are not significantly different.

[b] cv(%) = coefficient of variation.

* Farmer sprayed entire field on August 15 and September 1 with carbaryl and methomyl + methyl parathion, respectively.

consistent significant differences among treatments for either adults (sweep-net-sample) or nymphs (plant-shake sampled). Significant differences in nymphal numbers were found between the heavy toxaphene treatment and the check in the plant-shake samples on Aug. 30, and in adult numbers among T_3 and T_1, T_2, check in the sweep-net samples on Aug. 21. Otherwise, the product appears to have little consistent effect upon the population of this insect. However, carbaryl and methomyl + methyl parathion sprays seemed to reduce population numbers in samples (Table 5). Significant differences were not observed in the number of gridled stems by Δ CAH in toxaphene treated plots on July 29 (treated plots = 2.9 girdled plants/1.20 m long x non treated plots = 2.7 girdled plant'1.20 m long). It can be noted that in July 29 sample, there was a large increase in population of Δ CAH, probably due to immigration.

Effects of Toxaphene on Predaceous Natural Enemies in the Aerial Stratum of Soybean

The clearest differences among treatments can be noted for nabid nymphs which are unable to disperse by flight. Throughout the season, the average numbers of nabids tended to follow the fluctuations of VBC larval

TABLE 5. Average numbers of nymphs, adults and total three-cornered alfalfa hopper (Δ CAH, *Spissistilus festinus*) as influenced by toxaphene applications at different times and frequencies in a soybean agroecosystem at Madison, Florida, during 1980.

Stage	Treatment	Sampling date[a]									
		July			Aug.				Sept.		Oct.
		08	15	29	12*	21	27	30	*02	23	04
Nymphs[b]	T_1				3.3	0.3	0.0	0.3	0.0	1.3	0.3
	T_2				2.3	0.0	1.0	0.3	0.0	0.3	0.7
	T_3				4.3	0.0	0.0	0.3	0.0	0.0	0.3
	T_4				1.3	0.0	0.3	0.3	0.0	1.3	2.0
	T_5				4.7	0.7	0.3	0.3	0.0	2.0	1.3
	cv(%)[d]				(27.8)						
Adults[b]	T_1				12.7 b	6.7 a	9.3	8.7	0.0	30.0	21.0
	T_2				26.7 a	5.7 a	4.0	4.0	0.0	22.3	22.0
	T_3				17.3 ab	1.0 b	6.7	9.7	0.0	20.7	26.7
	T_4				18.0 ab	3.3 ab	4.3	6.0	0.0	23.0	22.3
	T_5				15.7 ab	5.0 a	6.0	8.7	0.0	40.3	23.3
	cv(%)				(16.19)	(24.4)	(33.3)	(21.7)		(27.7)	(22.1)
Total[b]	T_1	4.0	2.8	144.7	16.0 b	7.0 a	9.3	9.0	0.0	31.3	21.3
	T_2				29.0 a	5.7 a	5.0	4.3	0.0	22.6	22.7
	T_3				21.6 ab	1.0 b	6.7	10.0	0.0	20.7	27.0
	T_4				19.3 ab	3.3 ab	4.6	6.3	0.0	24.3	24.3
	T_5	3.8	3.8	137.3	20.4 ab	5.7 a	6.3	9.0	0.0	42.3	24.6
	cv(%)	(18.8)	(40.4)	(3.3)	(13.7)	(24.9)	(30.0)	(20.2)		(29.2)	(23.0)
Nymphs[c]	T_1					2.0 a	5.7 ab	7.6 ab	0.0		
	T_2					2.3 a	5.0 ab	10.3 ab	0.0		
	T_3					1.0 a	3.7 b	10.3 ab	0.0		
	T_4					0.0 b	2.7 b	5.0 b	0.0		
	T_5					2.7 a	8.7 a	14.3 a	0.0		
	cv(%)					(19.9)	(19.6)	(17.8)			

[a] Treatment means followed by the same letter within each sampling date are not significantly different at the 5% probability level using the Duncan's multiple range test. Treatment means having no letters following them are not significantly different.

[b] Number of *S. festinus*/100 sweeps.

[c] Number of *S. festinus* nymphs/4 x 1,20 m long plant-shakes. No adults were captured by this method.

[d] cv(%) = coefficient of variation.

* Farmer sprayed entire field on August 15 and September 1 with carbaryl and methomyl + methyl parathion, respectively.

populations, except in treatment T_2 (see September 23 and October 4 data) where a relatively high nabid population occurred despite low VBC populations, relative to the T_1 and T_5 treatments (Tables 2 and 6). Sampling on August 21 indicated toxaphene treatments made to T_3 and T_4 on August 18 affected nabid nymphal populations significantly. At the same time, the other treatments (T_1, T_2 and T_5) were not sprayed and had about the same level of nabid nymphs. The August 21 sample occurred six days after the carbaryl application of August 15 (Table 6), and as carbaryl is known to be relatively non-toxic to nabids, the added toxaphene treatments to T_3 and T_4 likely caused the decline in nabid numbers.

The lack of prey in all treatments by August 27, no doubt, also contributed to the general decline in nabid numbers in all treatments. Numbers of small VBC larvae in treatments T_1 and T_5 rose significantly in

TABLE 6. Average number of nymphs, adults and total nabid[a]/100 sweeps as influenced by toxaphene applications at different times and frequencies in a soybean agroecosystem at Madison, Florida, during 1980.

Stage	Treatment	Sampling date[b]						
		Aug.				Sept.		Oct.
		12*	21	27	30	*02	23	04
Nymphs	T_1	2.0 b	6.7 a	0.0 b	6.0 a	0.0	14.0 a	3.0 a
	T_2	0.0 c	4.0 a	0.3 ab	1.3 b	0.0	15.7 a	3.0 a
	T_3	6.0 a	0.0 b	0.0 b	0.3 b	0.0	0.7 b	0.0 b
	T_4	0.0 c	0.0 b	0.0 b	0.3 b	0.0	0.0 b	0.7 b
	T_5	3.7 b	4.0 a	1.0 a	5.3 a	0.0	13.0 a	3.3 a
	cv(%)[c]	(16.8)	(34.0)	(25.7)	(36.1)		(24.8)	(29.2)
Adults	T_1	1.3	0.0	1.0 ab	2.7	0.0	2.0	3.7 a
	T_2	5.7	0.0	1.3 a	2.3	0.0	2.3	3.7 a
	T_3	4.3	0.0	0.0 b	2.0	0.0	1.3	0.7 b
	T_4	3.0	0.0	0.0 b	1.7	0.0	2.7	0.3 b
	T_5	3.0	0.0	0.3 ab	1.7	0.0	2.3	5.7 a
	cv(%)	(41.8)		(27.7)	(35.1)		(33.0)	(24.1)
Total	T_1	3.3	6.7 a	1.0	8.7 a	0.0	16.0 a	6.7 a
	T_2	5.7	4.0 a	1.6	3.6 ab	0.0	18.0 a	6.7 a
	T_3	10.3	0.0 b	0.0	2.3 b	0.0	2.0 b	0.7 b
	T_4	3.0	0.0 b	0.0	2.0 b	0.0	2.7 b	1.0 b
	T_5	6.7	4.0 a	1.3	7.0 ab	0.0	15.3 a	9.0 a
	cv(%)	(31.0)	(34.0)	(32.2)	(27.5)		(21.1)	(21.7)

[a] *Nabis roseipennis* Reuter was the most numerous nabid present throughout the sampling period.

[b] Treatment means followed by the same letter within each sampling date are not significantly different at the 5% probability level using the Duncan's multiple range test. Treatment means having no letters following them are not significantly different.

cv(%) = coefficient of variation.

* Farmer sprayed entire field on August 15 and September 1 with carbaryl and methomyl + methyl parathion, respectively.

relation to the other treatments after August 27 as did nabid nymphal populations (Table 2 and 6).

The application of methomyl plus methyl parathion on September 1 brought both VBC and nabid populations to undetectable levels in all treatments. On September 23 and October 4, the populations of nabids were significantly lower in the T_3 and T_4 treatments which had received a toxaphene application on September 8, while higher numbers of nabids and VBC were found in treatments T_1 and T_5 which received no applications of toxaphene. The high nabid numbers in T_2 which was also not treated with toxaphene were not significantly different from T_1 and T_5 Significantly lower VBC populations were found in T_2. A possible explanation for high numbers of nabids in treatment T_2 on September 23 and October 4 is that a minumum VBC larval population occurred and/or alternative prey species were present but not counted in our samples (Tables 2 and 6).

The direct toxic effect of toxaphene at 3.36 kg of a.i./ha on nabid nymphs in T_3 and T_4 on August 21 appears to be in agreement with results reported by Salleh (1980). By contrast, carbaryl at 0.44 kg of a.i./ha seemed to have a relatively minor effect on nabid populations as indicated by the August 21 samples, while the mixture methomyl (0.22 kg of a.i./ha) plus, methyl parathion (0.44 kg of a.i./ha) quickly reduced nabid populations (September 2 samples). These results are in accordance with data reported by Turnipseed (1972), Salleh (1980) and Gazzoni et al. (1981).

Similar trends to those observed for nabids occured with geocorid populations as measured by sweep-net samples. The differences among treatment means were significant only on August 12, September 23 and October 04. On August 12, treatments T_2 and T_4 had significantly lower populations of geocorid adults, but due to the length of time between the toxaphene application and the sampling date, no attempt was made here to assess the effect of toxaphene on geocorids. However, as was the case with the nabids, there appeared to be a density dependent response to VBC larval populations (see Tables 2 and 7).

Although the geocorid means for July 8 and 15 were higher for T_5 (no spray at all) than for T_1 (toxaphene sprayed early), no significant differencese were detected ($P < 0.05$) (Table 7).

The toxaphene treatments T_1, T_2 and T_4 applied prior to the carbaryl treatment resulted in significant increases of green lacewing larvae over the untreated areas (T_5). In addition, timing of the sprays appeared to be important as treatment T_1 (applied earlier than T_2) had significantly lower numbers of larvae than did treatments T_2 and T_4 (Table 8). No significant differences were found in larval or adult numbers among treatments on sampling dates after August 12.

The phenomenon of resistance in chrysopids to several pesticides has been reported by various investigators, both in the laboratory (Lingren & Ridgway 1967, Wilkinson et al. 1975) and field (Evelens et al. 1973, Van Steenwyk et al. 1975). Resistance to toxaphene, but not to carbaryl, in this *Chrysopa* species may account for increases in larval populations in the treated areas, but this should be confirmed through laboratory experimentation.

Numbers of dolichopodid and whitemarked fleahopper, were significantly lower in the treated plots in July 15 after the second spray of T_1, but not on July 8 (Table 9).

Effect of Toxaphene on Natural Enemies and Other Arthropods on the Soil Surface in Soybean

The earwig and fire ant data are considered together in this section because there appears to be an interesting interaction between them.

No *L. riparia* were captured on the first sampling date (July 8) (Table 10). However, those treatments that received early toxaphene applications soon developed significantly higher populations than did the untreated

TABLE 7. Average numbers of nymphs, adults and total geocorida[a]/100 sweeps as influenced by toxaphene applications at different times and frequencies in a soybean agroecosystem at Madison, Florida, during 1980.

Stage	Treat.	Sampling date[b]								
		July		Aug.				Sept.		Oct.
		08	15	12*	21	27	30	*02	23	04
Nymphs	T_1			0.0 b	0.3	0.0	0.3	0.0	3.7 a	1.0
	T_2			0.0 b	0.0	0.0	0.3	0.0	2.0 ab	1.3
	T_3			0.7 ab	0.0	0.0	0.0	0.0	1.0 ab	0.0
	T_4			0.3 ab	0.0	0.0	0.0	0.0	0.0 b	0.3
	T_5			1.3 a	0.3	0.0	1.7	0.0	4.0 a	1.7
	cv (%)			(28.5)	(21.1)		(37.8)		(38.5)	(36.5)
Adults	T_1			3.0 a	2.0	0.7	0.7	0.0	6.7	1.0
	T_2			1.0 bc	1.0	1.0	1.0	0.0	7.3	1.3
	T_3			3.3 a	0.0	0.7	3.0	0.0	3.7	0.0
	T_4			0.7 c	0.3	0.7	0.7	0.0	4.3	0.3
	T_5			2.3 ab	1.0	1.0	1.3	0.0	5.7	1.0
	cv (%)			(18.2)	(40.4)	(35.9)	(37.5)		(25.3)	(38.8)
Total	T_1	2.0	1.0	3.0 a	2.3	0.7	1.0	0.0	10.3	2.0 ab
	T_2			1.0 b	1.0	1.0	1.3	0.0	9.3	2.7 a
	T_3			4.0 a	0.0	0.7	3.0	0.0	4.7	0.0 b
	T_4			1.0 b	0.3	0.7	0.7	0.0	4.3	0.7 ab
	T_5	5.0	2.7	3.7 a	1.3	1.0	3.0	0.0	10.0	2.7 a
	cv (%)	(32.4)	(65.4)	(20.3)	(42.1)	(35.9)	(37.6)		(28.2)	(33.9)

[a] *Geocoris punctipes* (Say) was the most numerous geocorid present throughout the sampling period.

[b] Treatment means followed by the same letter within each sampling date are not significantly different at the 5% probability level using the Duncan's multiple range test. Treatment means having no letters following them are not significantly different.

[c] cv (%) = coefficient of variation.

* Farmer sprayed entire field on August 15 and September 1 with carbaryl and methomyl + methyl parathion, respectively.

check (T_5). All size classes of this earwig in all treatments showed increasing population trends, with the untreated plots (T_5) having the lowest rate of increase (Fig. 2). This would suggest that the colonization, survival and/or reproduction rates were higher in plots treated early in the season, and that VBC is not the only important prey for earwigs.

The general trends in the data are best seen for total *L. riparia* numbers Carbaryl and methomyl + methyl parathion treatments decreased earwig populations, but resurgence occurred rapidly (Fig. 3). This can best be seen in the T_1 data.

By contrast, as *L. riparia* populations increased, fire ant populations decreased. This can best be seen by comparing the respective trends as shown in Fig. 3.

TABLE 8. Average numbers of larvae, adults and total green lacewing (*Chrysopa rufilabris*)/100 sweeps as influenced by toxaphene applications at different times and frequencies in a soybean agroecosystem at Madison, Florida, during 1980.

Stage	Treat.	Sampling date[a] August 12*	Treat.	21	27
Larvae	T_1	1.7 b	T_1	0.7	1.7
	T_2	4.7 a	T_2	0.3	0.3
	T_3	0.3 c	T_3	0.3	0.3
	T_4	4.7 a	T_4	2.3	0.3
	T_5	0.3 c	T_5	0.3	0.3
	cv (%)[b]	(13.9)		(63.9)	(34.7)
Adults	T_1	0.0	T_1	0.3	0.0
	T_2	1.0	T_2	0.0	0.0
	T_3	0.3	T_3	0.0	0.0
	T_4	0.0	T_4	0.0	0.0
	T_5	0.0	T_5	0.3	0.0
	cv (%)	(32.4)			
Total	T_1	1.7 b	T_1	1.0	1.7
	T_2	5.7 a	T_2	0.3	0.3
	T_3	0.7 c	T_3	0.3	0.3
	T_4	4.7 a	T_4	2.3	0.3
	T_5	0.3 c	T_5	0.7	0.3
	cv (%)	(13.1)		(60.6)	(34.7)

[a] Treatment means followed by the same letter within each sampling date are not significantly different at the 5% probability level using the Duncan's multiple range test. Treatment means having no letters following them are not significantly different.

[b] cv (%) = coefficient of variation.

* Farmer sprayed entire field on August 15 and September 1 with carbaryl and methomyl + methyl parathion, respectively.

Almost without exception, the population levels of fire ant were higher in the untreated check than in any of the treatments, with the lowest numbers being found in treatment T_4 which received the earliest and largest quantities of toxaphene.

Late application of toxaphene (T_3) also had adverse effects on red imported fire ant populations during late season. The effects of carbaryl did not alter the trends (see the August 21 data), while the effects of the methomyl + methyl parathion are less clear.

Two factors might account for the differential trends of striped earwig and fire ant population numbers: The first is that fire ants are susceptible to toxaphene, while the striped earwig may have some degree of resistance. The second possibility is that fire ants and/or other natural enemies may restrict

TABLE 9. Average number of adults of dolichopodid and whitemarked fleahopper (*Spanogonicus albofasciatus*)/100 sweeps as influenced by toxaphene applications at different times and frequencies in a soybean agroecosystem at Madison, Florida, during 1980.

	Treatment	Sampling date[a] July 08	15
Dolichopodidae	T_1	5.7	0.3 b
	T_5	6.0	2.5 a
	cv (%)[b]	(33.8)	(22.0)
Whitemarked fleahopper	T_1	7.0	4.0 b
	T_5	9.0	18.0 a
	cv (%)	(24.8)	(25.7)

[a] Treatment means followed by the same letter within each sampling date are not significantly different at the 5% probability level using the Duncan's multiple range test. Treatment means having no letters following them ate not significantly different.

[b] cv (%) = coefficient of variation.

TABLE 10. Average numbers of small, medium and total striped earwig (*Lapidura riparia*)/4 pitfalls as influenced by toxaphene applications at different times and frequencies in a soybean agroecosystem at Madison, Florida, during 1980.

Size	Treatment	Sampling date[a]													
		July				August				September					October
		08	15	22	29	05	12*	21	27	*02	09	16	23	30	08
Small	T_1	0.0	0.8	3.7	3.0 a	9.3 a	30.0 a	15.0 a	9.7 ab	42.0 a	24.7 a	52.0 a	82.7 a	137.0	128.0 a
	T_2					0.0 b	0.7 c	5.3 ab	14.0 a	28.0 ab	9.0 bc	20.7 b	63.7 ab	110.7	151.3 a
	T_3					0.0 b	3.3 bc	2.0 b	2.3 b	6.7 c	10.0 bc	11.0 b	34.0 b	85.3	97.0 ab
	T_4					2.7 ab	8.3 b	8.3ab	12.0 a	18.3 b	15.0 ab	9.7 b	47.0 ab	74.7	80.3 ab
	T_5	0.0	0.2	0.2	0.7 b	0.0 b	2.0 bc	1.7 b	2.0 b	6.3 c	4.0 c	23.7 b	41.3 ab	70.3	29.7 b
	cv (%)[b]		(36.0)	(54.8)	(32.6)	(67.8)	(30.1)	(33.4)	(33.5)	(18.8)	(20.4)	(18.4)	(17.5)	(20.8)	(24.2)
Medium	T_1	0.0	0.5	1.3	0.2	1.7	6.7 a	5.3 a	3.0	14.7 a	12.3	6.7	13.3	42.3	18.7
	T_2					0.3	0.7 b	0.3 b	1.3	2.7 b	11.7	4.7	9.7	12.7	19.7
	T_3					0.3	1.0 b	1.3b	1.0	4.0 b	5.3	8.7	8.3	21.0	19.3
	T_4					0.3	1.3 b	2.3 ab	1.0	5.7 b	5.7	4.3	16.3	35.3	40.3
	T_5	0.0	0.2	0.3	0.2	0.0	1.0 b	0.3 b	0.7	3.7 b	4.3	8.3	7.7	21.7	25.0
	cv (%)		(39.5)	(62.0)	(29.1)	(38.8)	(42.1)	(42.0)	(51.0)	(26.7)	(25.5)	(32.9)	(27.8)	(29.2)	(23.3)
Large	T_1	0.0	2.8 a	3.0 a	2.3	3.0 a	6.0 a	5.0 ab	3.3	14.0 a	16.3	23.0 a	34.0 ab	55.0 ab	23.7
	T_2					1.3 ab	1.0 b	0.7 b	2.0	3.3 b	11.3	8.7 b	34.3 ab	29.3 b	20.3
	T_3					0.3 b	1.3 b	3.7 ab	3.3	3.3 b	8.3	20.7 a	25.7 ab	38.7 ab	28.0
	T_4					3.7 ab	3.3 ab	6.7 a	1.7	6.0 b	8.3	23.7 a	43.3 a	69.0 a	40.7
	T_5	0.0	0.3 b	0.0 b	0.7	1.0 ab	1.7 ab	2.7 ab	2.0	5.3 b	8.7	16.3 ab	17.0 b	32.0 b	34.3
	cv (%)		(19.2)	(20.5)	(41.9)	(31.7)	(34.8)	(35.0)	(30.6)	(17.0)	(21.8)	(18.6)	(22.6)	(21.2)	(21.4)
Total	T_1	0.0	4.2 a	8.0 a	5.5 a	14.0 a	42.7 a	25.3 a	16.0	70.7 a	53.3 a	82.0 a	130.0 a	234.0	170.7
	T_2					1.7 b	2.3 c	6.3 b	17.3	34.0 b	32.0 b	34.0 a	107.7 ab	152.7	191.3
	T_3					0.7 b	5.7 bc	7.0 b	6.7	14.0 c	23.7 b	37.0 b	68.0 ab	145.0	144.3
	T_4					6.7 a	12.7 b	17.3 ab	14.7	30.0 b	29.0 b	37.7 b	110.0 ab	179.0	161.3
	T_5	0.0	0.7 b	0.5 b	1.3 b	1.0 b	4.7 bc	4.7 b	4.7	15.3 c	17.0 b	48.3 b	66.0 b	124.7	89.0
	cv (%)		(20.4)	(48.6)	(26.9)	(32.4)	(28.7)	(29.7)	(30.8)	(14.3)	(14.5)	(12.7)	(16.9)	(18.4)	(18.5)

[a] Treatment means followed by the same letter within each sampling date are not significantly different at the 5% probability level using the Duncan's multiple range test. Treatment means having no letters following them are not significantly different.
following them are not significantly different.

[b] cv (%) = coefficient of variation.

* Farmer sprayed entire field on August 15 and September 1 with carbaryl and methomyl + methyl parathion, respectively.

striped earwig population growth by direct predation and competition for food. Both species are general predators, and it is unlikely that their populations even in unsprayed plots are dependent on only one prey species. The fire ant may include earwigs in its diet.

Toxaphene treatments applied at different times and frequencies, no doubt, influenced *L. riparia* numbers independently of VBC levels. For example, VBC larval populations were highest in untreated plots, while earwig numbers were lowest (Tables 2, 10 and Fig. 3). This fact may mean that VBC is not an important prey for earwigs. However, earwig numbers may be significantly influenced by fire ant predation or competition above certain population levels. The observed numbers and $\log_{10}$ (N + 1) densities of each are plotted against each other in Fig. 4, A and B, and show that there is a clear negative relationship. The correlations in Fig. 4B suggest a very strong negative effect on earwig induced by the presence of imported fire ants and illustrate the detrimental effects of toxaphene (T_4) on fire ant and striped earwig populations as compared to the toxaphene free treatment (T_5). The rate of decrease of fire ant populations was greatest where toxaphene was applied, and higher numbers of both co-occurred in a toxaphene free environment (Table 11).

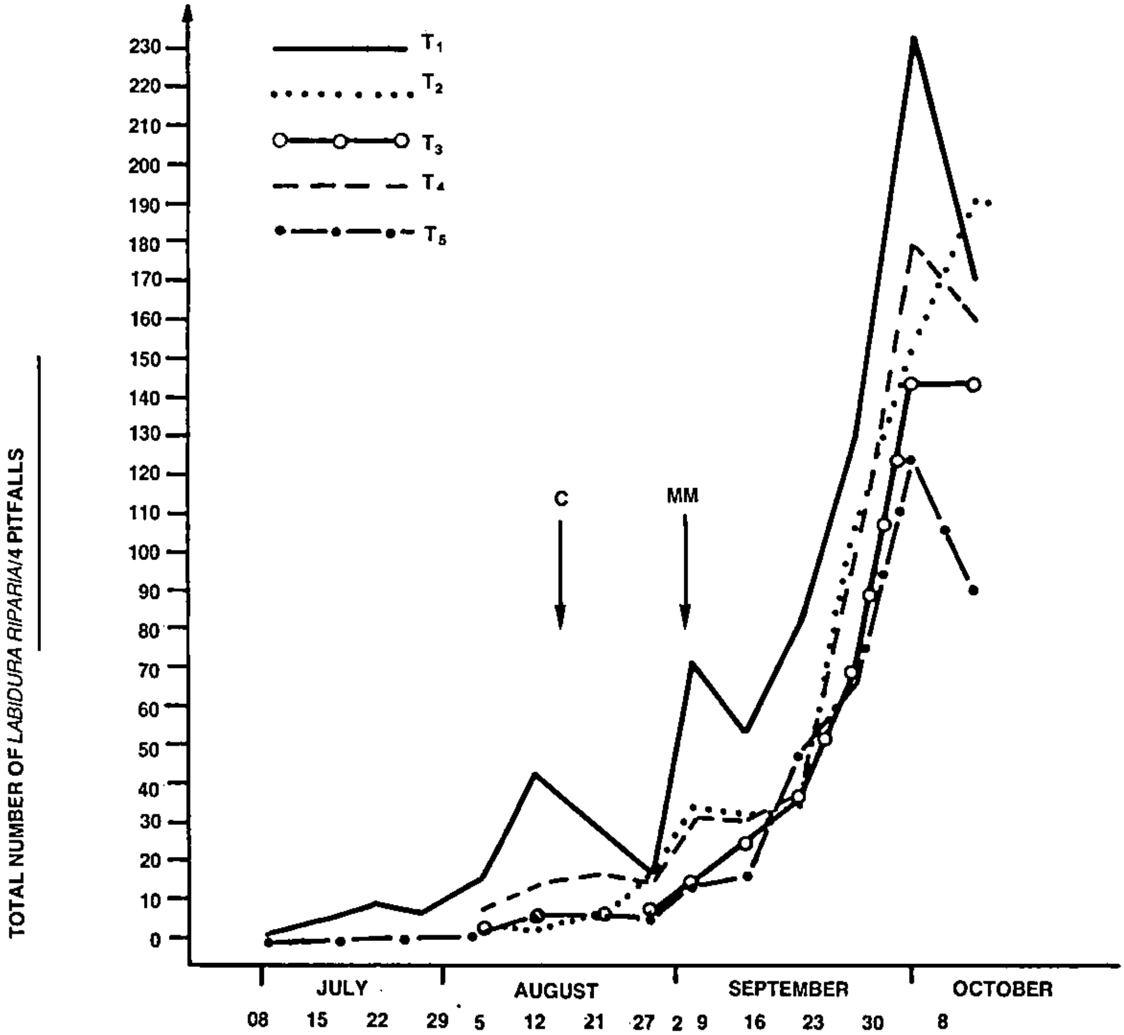

FIG. 2. Influence of timing and frequency of toxaphene applications on populations of the striped earwig (*Labidura riparia*) in a soybean agroecosystem at Madison, Florida, during 1980. C = carbaryl and MM = methomyl + methyl parathion.

This investigation further confirms that *L. riparia* populations increase in plots treated with toxaphene applied early in the season on late planted soybean. Such findings have also been reported for other pesticides: organochlorines [heptachlor, (Gross & Spink 1969)]; carbamates [carbaryl and carbofuran (Neal 1974 and Lema 1980, respectively)]; and carbamate + organophosphate [methomyl + methyl parathion (Price & Shepard 1977)]. The major argument used to explain the increase in *L. riparia* is the restraints imposed by the pesticide on competitors and its predators, especially fire ants (Gross & Spink 1969, Neal 1974, Price & Shepard 1977).

Calosoma responded in a density dependent manner to medium-large size VBC increases (Fig. 4). Gastal et al. (1975), and Price & Shepard (1978) reported that foraging activity of *Calosoma* within and among areas was

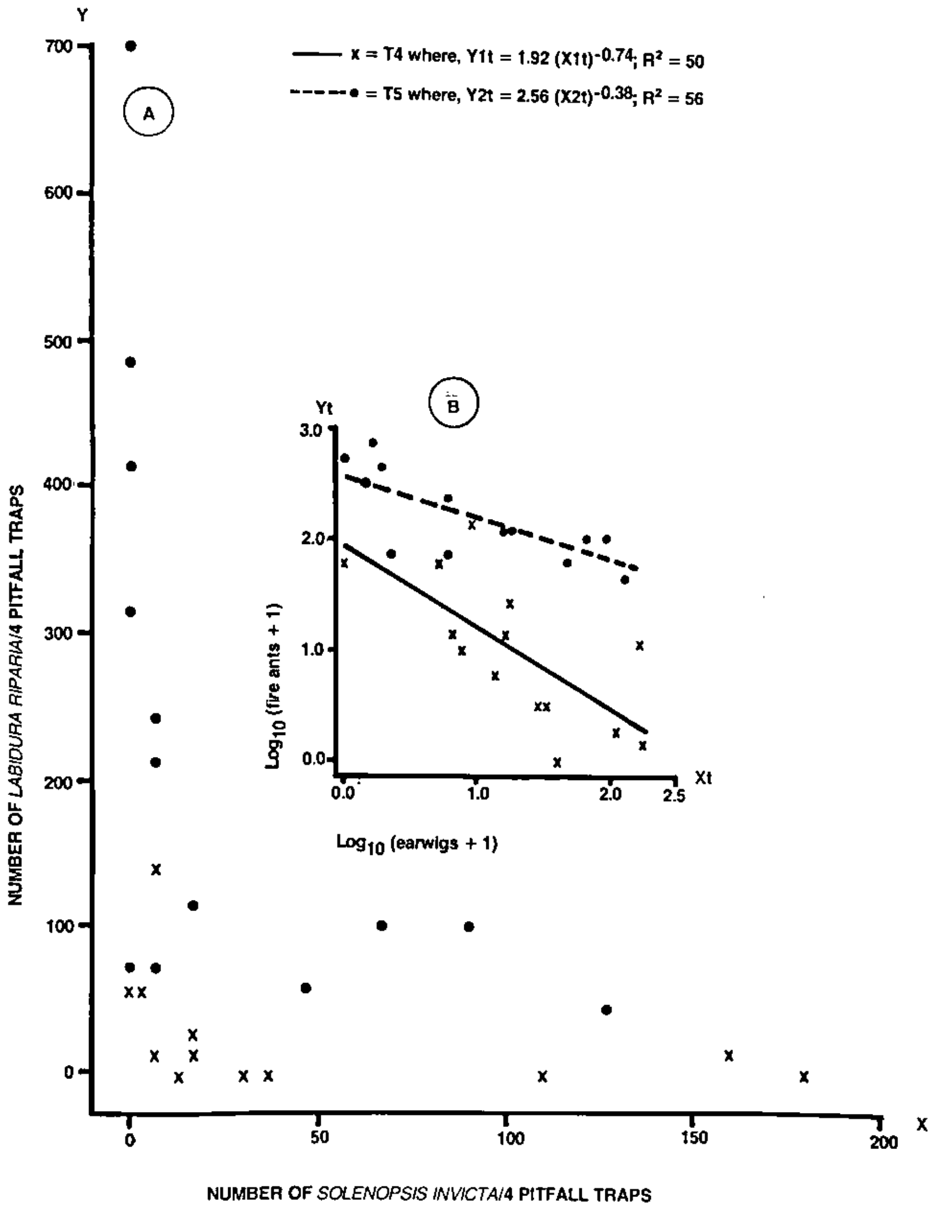

FIG. 3. Relationship betweem numbers of striped earwig and red imported fire ant per 4 pitfall traps in toxaphene free (T5) and heavily trated (T4) plots: A) observed number and B) $\log_{10}$ number plus l transformation.

directly related to the abundance of noctuid larvae. Since carbaryl and methomyl + methyl parathion sprays were applied between sampling dates, and the pitfall traps sampled carabids before the spray was applied, it is impossible to determine whether the decline in carabid populations was primarily in response to declining VBC populations and/or to the

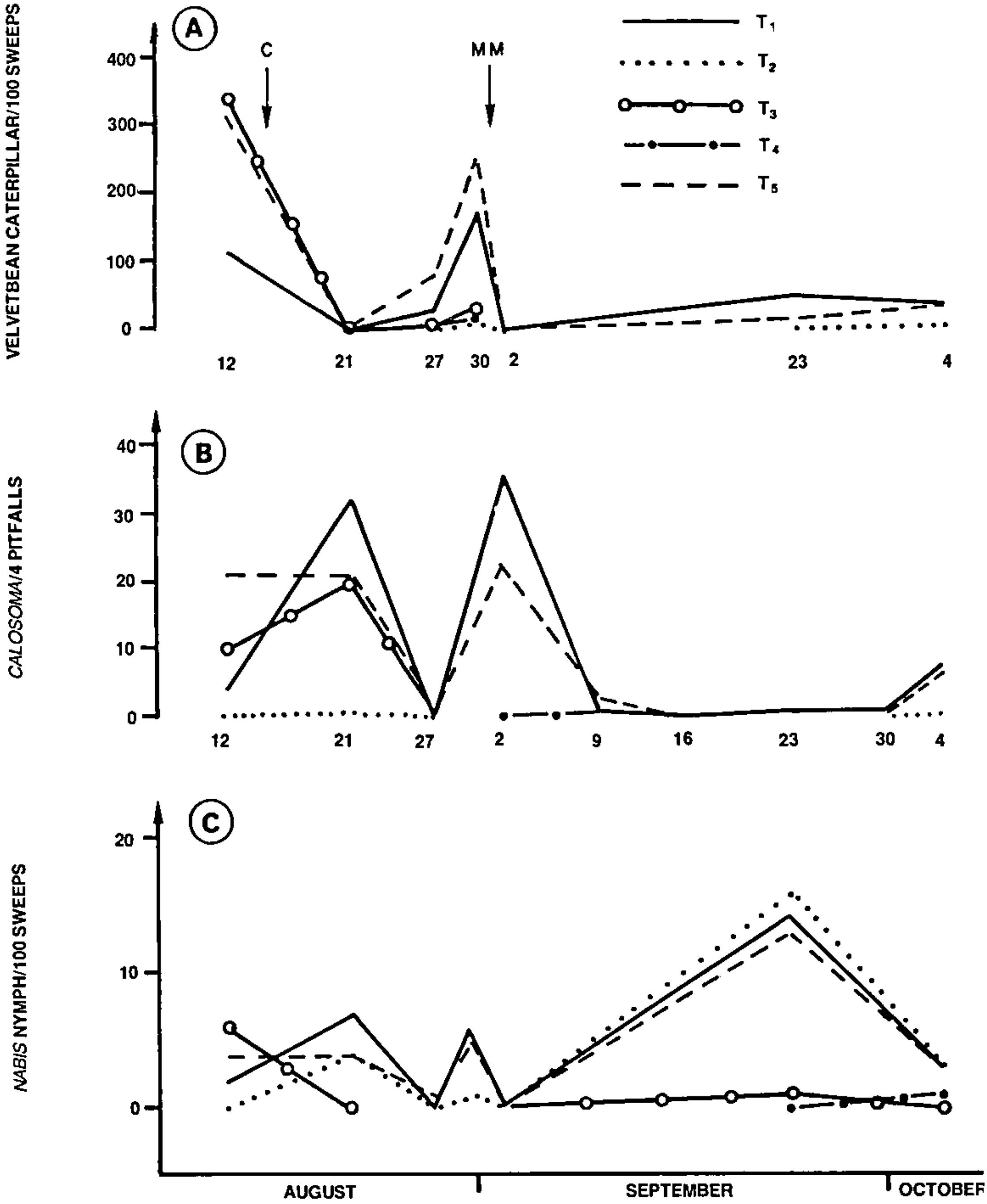

FIG. 4. Influence of timing and frequency of toxaphene applications on populations of A) velvetbean caterpillar (*Anticarsia gemmatalis*) and two generalist predators: B) a carabid (*Calosoma alternans*) and C) nabid (*Nabis roseipennis*) in a soybean agroecosystem at Madison, Florida, during 1980. C = carbaryl and MM = methomyl + methyl parathion.

TABLE 11. Average numbers of the red imported fire ants (*Solenopsis invicta*)/4 pitfalls as influenced by toxaphene applications at different times and frequencies in a soybean agroecosystem at Madison, Florida, during 1980.

	Sampling date[a]													
	July				August				September					October
Treat.	08	15	22	29	05	12*	21	27	*02	09	16	23	30	08
T_1	58.5 b	56.2 b	135.3	13.2 b	49.7 ab	27.7 b	16.0 b	20.3 ab	113.0 a	33.3 b	11.7 ab	39.7 ab	43.3 ab	46.3 abc
T_2					58.7 ab	42.0 b	101.0 ab	41.3 ab	20.7 b	66.0 ab	15.7 ab	99.0 a	32.3 ab	67.3 ab
T_3					334.7 ab	164.0 a	164.3 ab	31.0 ab	33.7 ab	117.3 a	56.0 a	17.3 ab	13.0 bc	24.7 bc
T_4					9.3 b	4.7 b	24.0 b	14.3 b	2.3 b	2.3 c	0.0 b	1.0 b	0.3 c	10.0 c
T_5	487.7 a	704.2 a	311.5	76.3 a	410.0 a	246.0 a	215.0 a	70.3 a	115.3 a	115.3 a	57.0 a	103.7 a	45.3 a	107.0 a
cv (%)[b]	(14.1)	(34.8)	(40.3)	(65.9)	(70.8)	(31.5)	(49.9)	(44.0)	(44.3)	(23.8)	(57.4)	(52.4)	(46.0)	(31.7)

[a] Treatment means followed by the same letter within each sampling date are not significantly different at the 5% probability level using the Duncan's multiple range test. Treatment means having no letters following them are not significantly different.

[b] cv (%) = coefficient of variation.

* Farmer sprayed entire field on August 15 and September 1 with carbaryl and methomyl + methyl parathion, respectively.

sprays. Dead *Calosoma* adults were found scattered about the field after the carbaryl application.

In general, more *Calosoma* were found in plots treated early with toxaphene (T_1-less defoliated plots, more sheltered sites) despite the fact that lower densities of VBC larvae (medium-large) occurred there than in the untreated plots (T_5) (Tables 2 and 12). The next highest densities of *Calosoma* were

TABLE 12. Average numbers of adults of a carabid (*Calosoma alternans*)/4 pitfalls as influenced by toxaphene applications at different times and frequencies in a soybean agroecosystem at Madison, Florida, during 1980.

	Sampling date[a]								
	August			September					October
Treat.	12*	21	27	*02	09	16	23	30	08
T_1	4.0 ab	31.7 a	0.03	36.3 a	1.0 b	0.0	1.0	1.0 b	7.7 a
T_2	0.0 b	0.3 c	0.0	0.0 c	0.0 b	0.3	0.3	0.03 b	1.3 ab
T_3	10.0 a	20.0 b	0.7	0.3 c	1.0 b	0.0	0.0	0.0 b	0.7 bc
T_4	0.3 ab	0.0 c	0.0	0.0 c	1.0 b	0.0	0.0	0.0 b	0.3 c
T_5	7.0 ab	21.0 ab	1.7	22.7 b	2.7 a	0.3	0.7	2.7 a	7.3 a
cv (%)[b]	(55.8)	(7.9)		(16.5)	(22.9)			(17.6)	(49.0)

[a] Treatment means followed by the same letter within each sampling date are not significantly different at the 5% probability level using the Duncan's multiple range test. Treatment means having no letters following them are not significantly different.

[b] cv (%) = coefficient of variation.

* Farmer sprayed entire field on August 15 and September 1 with carbaryl and methomyl + methyl parathion, respectively.

found in the check (more defoliated plots, less sheltered sites). It would be difficult to separate the direct effects of toxaphene on *C. alternans* from the effects on possible depletion of prey, because treatments T2 and T_4 had both few VBC and few carabids. It can, however, be said that carabid adults appeared to respond in a density dependent manner to VBC populations, a fact known from prior work (see above).

No significant differences in numbers of *C. punctulata* and dolichopodids were detected between treated and untreated plots in pittfall traps (Table 13).

Populations of the carabids *T. intersectus* and *A. latens* were significantly higher in toxaphene treated plots on July 22 and July 15, respectively. The numbers of carabids other than *C. alternans* and *T. intersectus* were too low on other datas for comparison of treatment effects. Average numbers for all carabidae except *C. alternans* were not significantly different in all datas except August 12 where heavy toxaphene spray had significantly lower level of these carabids in relation to the check (Table 14).

Late seasonal population fluctuations of *Gryllus* ssp. (mainly nymphs) and tettigoniids tended to be similar in pattern to those of VBC. Treatments T2, T3 and T_4 had lower levels of these insects than treatments T_1 and T_5. Therefore, the timing (mid-season, T2 - T3) and frequency (high, T_4) of spraying appears to have had the largest negative effects upon orthopteran populations (Tables 15 and 16).

TABLE 13. Average numbers of adults of dolichopodids and Cicindellids (*Cicindella punctulata*)/4 pitfalls as influenced by toxaphene applications in a soybean agroecosystem at Madison, Florida, during 1980.

	Treatment	Sampling date[a] July 05	15	22
Dolichopodids	T_1	3.3	10.7	12.3
	T_5	4.3	13.8	13.0
	cv (%)[b]	(55.3)	(25.2)	(10.9)
Cicindellids	T_1	0.5	2.7	
	T_5	1.3	4.7	
	cv (%)	(47.8)	(29.0)	

[a] Treatment means letters following them within each sampling date are not significantly different at the 5% probability level according the Duncan's multiple range test.

[b] cv (%) = coefficient of variation.

TABLE 14. Average numbers of adult carabids/4 pitfalls as influenced by toxaphene applications at different times and frequencies in a soybean agroecosystem at Madison, Florida, during 1980.

Treatment	Sampling dates and average numbers for *T. intersectus*[a] July 08	July 15	July 22	July 29	August 05	August 12*	August 21
T_1	3.2	5.3	3.5 a	0.5	0.3	2.7	1.3 ab
T_2					0.7	3.7	4.3 a
T_3					1.0	7.3	4.0 a
T_4					1.7	3.0	1.7 ab

TABLE 14. Continuing.

Treatment	July				August		
	08	15	22	29	05	12*	21
	Sampling dates and average numbers for *T. intersectus*[a]						
T_5	2.2	5.0	0.5 b	1.0	1.7	4.7	2.0 ab
cv(%)[b]	(34.1)	(39.7)	(36.6)	(49.7)	(34.5)	(35.4)	(32.5)
	Sampling dates and average numbers for *A. latens*						
T_1	0.5	4.0 a	2.0	0.0	0.7	0.7	1.7
T_2					0.0	0.0	0.7
T_3					1.0	0.0	0.3
T_4					0.0	0.3	0.3
T_5	0.2	1.3 b	0.8	0.0	0.0	0.3	0.3
cv(%)	(21.5)	(33.0)	(42.2)		(38.6)	(34.6)	(60.1)
	Sampling dates and average numbers for *A. merula*						
T_1	0.2	1.3	1.8	0.2	0.3	0.0	0.0
T_2					0.3	0.3	0.3
T_3					0.7	1.0	0.3
T_4					0.0	0.0	0.0
T_5	0.5	0.3	1.3	0.3	0.3	0.3	0.3
cv(%)	(34.0)	(46.0)	(20.1)	(12.5)	(20.1)	(45.5)	(31.9)
	Sampling dates and average numbers for *S. palliatus*						
T_1	0.5	0.3	0.0	0.0	0.0	0.0	0.3 b
T_2					0.0	0.0	0.3 b
T_3					0.0	0.0	0.7 ab
T_4					0.0	0.3	1.3 ab
T_5	0.3	0.3	0.0	0.7	0.0	0.3	3.3 a
cv(%)	(26.6)	(26.3)		(40.0)		(21.1)	(38.8)
	Sampling dates and average numbers for all Carabidae except *C. alternans*						
T_1	5.2	11.8	7.8	0.7	1.7	3.3 ab	3.7
T_2					1.7	4.0 ab	5.7
T_3					4.0	7.3 a	5.3
T_4					1.7	0.3 b	4.0
T_5	7.7	10.2	5.7	4.0	2.3	7.0 a	6.0
cv(%)	(33.0)	(28.0)	(20.9)	(55.2)	(28.4)	(42.5)	(28.0)

[a] Treatment means having no letters following them within each sampling date are not significantly different at the 5% probability level according to Duncan's multiple range test.

[b] cv(%) = coefficient of variation.

* Farmer sprayed entire field on August 15 and September 1 with carbaryl and methomyl + methyl parathion, respectively.

TABLE 15. Average numbers of nymphs, adults and total *Gryllus* spp./4 pitfalls as influenced by toxaphene applications at different times and frequencies in a soybean agroecosystem at Madison, Florida, during 1980.

Stage	Treat.	Sampling date[b]								
		August			September					Oct.
		12*	21	27	*02	09	16	23	30	08
Nymphs	T_1	0.7	0.7	0.0	38.3	0.7	0.7	14.3	5.0	72.0 a
	T_2	0.3	0.3	1.0	19.3	0.0	0.3	7.7	3.0	35.0 b
	T_3	0.7	0.3	0.0	16.0	1.7	0.3	6.3	4.7	35.0 b
	T_4	0.7	1.0	0.0	17.0	0.3	1.0	10.7	4.7	28.0 b
	T_5	0.7	1.3	0.7	46.7	1.0	1.7	18.0	8.7	70.3 a
	cv (%)	(30.8)	(36.6)	(36.7)	(28.9)	(34.3)	(51.1)	(32.6)	(37.9)	(17.8)
Adults	T_1	7.0	10.3	5.3	7.0	8.3	8.3	6.7 a	8.0	6.7
	T_2	10.0	18.7	4.3	4.0	14.0	7.0	5.3 a	7.0	4.7
	T_3	6.0	15.0	4.3	3.7	11.7	9.7	6.7 a	6.3	8.0
	T_4	7.3	22.7	5.0	5.3	13.7	5.3	2.7 b	4.7	8.7
	T_5	5.3	13.3	6.0	5.7	7.7	7.0	8.0 a	7.7	8.3
	cv (%)	(25.7)	(28.0)	(42.7)	(38.5)	(23.5)	(25.5)	(12.1)	(16.8)	(25.2)
Total	T_1	7.7	11.0	5.3	45.3	9.0	9.0	21.0	13.0	78.7 a
	T_2	10.3	19.0	5.3	23.3	14.0	7.3	13.0	10.0	39.7 b
	T_3	6.7	15.3	4.3	19.7	13.3	10.0	13.0	11.0	43.0 a
	T_4	8.0	23.7	5.0	22.3	14.0	6.3	13.3	9.3	36.7 b
	T_5	6.0	14.7	6.7	52.3	8.7	8.7	26.0	16.3	78.7 a
	cv (%)	(22.6)	(27.8)	(42.7)	(25.9)	(19.6)	(26.0)	(22.9)	(20.8)	(17.3)

[a] Treatment means letters following them within each sampling date are not significantly different at the 5% probability level according to Duncan's multiple range test.

[b] cv (%) = coefficient of variation.

* Farmer sprayed entire field on August 15 and September 1 with carbaryl and methomyl + methyl parathion, respectively.

TABLE 16. Average numbers of nymphs, adults and total tettigoniids/4 pitfalls as influenced by toxaphene applications at different times and frequencies in a soybean agroecosystem at Madison, Florida, during 1980.

Stage	Treat.	Sampling date[b]								
		August			September					Oct.
		12*	21	27	*02	09	16	23	30	08
Nymphs	T_1	1.7 ab	0.7	0.3	1.7 ab	0.7	0.7	1.7	0.7	12.7 a
	T_2	0.0 b	0.0	0.0	0.3 b	0.0	0.0	0.0	0.0	3.3 bc
	T_3	0.3 ab	2.3	0.0	0.3 b	0.0	0.0	0.3	0.7	0.3 c

TABLE 16. Continuing.

Stage	Treat.	Sampling date[b]								
		August.			September.					Oct.
		12*	21	27	*02	09	16	23	30	08
	T_4	0.0 b	0.0	0.0	0.3 b	0.0	0.0	0.0	0.0	0.0 c
	T_5	2.3 a	0.7	0.3	4.7 a	0.7	0.0	1.3	0.3	10.0 ab
	cv (%)[b]	(40.2)	(46.6)	(21.1)	(48.6)	(29.7)	(29.5)	(40.3)	(28.1)	(33.1)
Adults	T_1	2.3	1.0	0.3	8.3 ab	4.3 a	0.7	6.3	6.0 a	9.3
	T_2	2.0	1.0	0.3	9.0 ab	6.0 a	0.0	2.3	3.0 ab	11.0
	T_3	3.3	4.7	0.0	2.0 c	1.3 b	0.0	2.7	0.0 b	6.7
	T_4	0.3	0.7	0.0	3.7 bc	0.7 b	0.0	2.7	0.0 b	6.3
	T_5	1.0	3.7	0.0	12.0 a	4.7 a	0.0	7.3	5.0 a	14.7
	cv (%)	(41.2)	(41.6)	(21.1)	(25.4)	(20.8)	(29.5)	(59.4)	(46.9)	(27.2)
Total	T_1	4.0	1.7 b	0.7	10.0 ab	5.0 a	1.3	8.0	6.7 a	22.0 ab
	T_2	2.0	1.0 b	0.3	9.3 ab	6.0 a	0.0	2.3	3.0 abc	14.0 ab
	T_3	3.7	7.0 a	0.0	2.3 b	1.3 b	0.0	3.0	0.7 bc	7.0 b
	T_4	0.3	0.7 b	0.0	4.0 b	0.7 b	0.0	2.7	0.0 c	6.3 b
	T_5	3.3	4.3 ab	0.3	16.7 a	5.3 a	0.0	8.7	5.3 ab	24.7 a
	cv (%)	(38.1)	(43.2)	(26.1)	(29.0)	(23.7)	(45.6)	(60.6)	(42.7)	(29.4)

[a] Treatment means followed by the same letter within each sampling date are not significantly different at the 5% probability level using the Duncan's multiple range test. Treatment means having no letters following them are not significantly different.

[b] cv (%) = coefficient of variation.

* Farmer sprayed entire field on August 15 and September 1 with carbaryl and methomyl + methyl parathion, respectively.

CONCLUSIONS

These experimental results coupled with prior research information from the literature provide valuable insights for understanding arthropod pest-predator and predator-predator responses and interactions in late planted soybean agroecosystems characteristic of Northern Florida as influenced by the insecticide toxaphene.

1. The seasonal population dynamics of both phytophagous and predaceous arthropods in soybean were significantly influenced by timing of toxaphene applications.

2. Soybean field sprayed with toxaphene as a herbicide should be monitored on an individual basis, since timing and intensity of sprays can differentially decrease defoliating pests such as VBC but increase the pod borer CEW *Heliothis zea*. Timing of toxaphene applications can also influence the population levels of the most abundant noctuid predators. Populations of *Nabis roseipennis* and *Solenopsis invicta* were directly decreased and the carabid *Calosoma alternans* was indirectly

decreased. Also numbers of the striped earwig *Labidura riparia* and green lacewing *Chrysopa rufilabris* increased after toxaphene applications.

3. Toxaphene as well as similar pesticides should be used with caution when soybean is approaching the full-bloom stage because application of toxaphene may cause outbreaks of CEW. Separating pest resurgence due to decrease in predator populations from resurgence due to increased pest immigration is difficult.

4. The differences in VBC numbers among plots could have been due to early toxaphene applications or from differential late season immigration of VBC or a combination of the two.

5. Number of Δ CAH does not appear to be significantly affected in this experiment by toxaphene applications, except heavy sprays.

6. Populations of the striped earwig were shown to increase independently of VBC density whereas imported fire ant decreased independently of VBC density. This density independent response could have been due to the fact that both striped earwig and imported fire ant are generalist predators with many alternate prey.

7. Since striped earwig and imported fire ants are considered important predators of insect pests in soybean and other crops, but were found to vary independently of VBC density, it can be suggested that further investigations are needed to determine the impact to toxaphene effects, the food preference of these predators and direct predation on earwigs by the imported fire ant.

8. Outbreaks of both the pod boring pest (CEW) and predators (*Chrysopa rufilabris* and *Labidura riparia*) occurred. A resistance mechanism by these species is suggested. Further research to determine this mechanism is needed.

9. Nabids and geocorids showed a gradual and weak density dependent response to small sized VBC larvae while *Calosoma alternans* adults showed an abrupt density dependent response to medium and large sized VBC caterpillar.

Although significant influences of toxaphene on the most abundant predators of soybean pests were found, this does not preclude that toxaphene also may have influenced less natural enemies. Significant influences of toxaphene on less abundant predators is difficult to demonstrate statistically due to problems with sampling sparse populations.

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