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SEASONAL DEVELOPMENT OF SOYBEAN ARTHROPOD COMMUNITIES IN EAST CENTRAL ILLINOIS

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ABSTRACT

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Numbers of individuals of arthropod species were sampled by direct observation at four sites in each of three different east central Illinois soybean fields at weekly intervals from plant emergence until harvest. Soybean plant development at each field was monitored throughout the season.

The number of species detected in a field was greater at the edge (site A) than in the middle (site D). Site A vs. site D differences in numbers of herbivore species were greater than for predator/parasitoid species. Habitat space development (i.e. plant growth) was correlated with the pattern of soybean field colonization by arthropods: a relatively constant number of species per habitat space existed throughout most of the season in all three fields. The mean number of species per habitat space was higher at site A than at site D for both herbivores and predators/parasitoids.

A windbreak at the edge of a field concentrated certain aerially dispersed herbivores at the leeward edge early in the season. Arthropod food webs during most of the season were very complex compared to early season trophic relationships. Suggestions for further study, including investigation of the effects of planting time, row-width, and interplanting on seasonal development of the soybean arthropod community are discussed.

INTRODUCTION

Relatively few studies dealing with arthropod colonization have been made. Price and Waldbauer (1975) emphasized the merit of regarding crops as islands available for colonization by arthropods. Price (1976) investigated the colonization of a soybean field with island biogeographical theory (cf. MacArthur and Wilson, 1963, 1967) as a conceptual basis.

A community approach to crop arthropod studies provides a solid basis for development of insect pest management systems. For example, such an approach necessitates chronological observations and analyses which permit viewing the studies as part of the group of theories and data on ecological succession and related areas (e.g. Odum, 1969; Root, 1975). Seasonal studies of the development of the arthropod community on a crop can also be helpful in determining the importance of natural control in an agro-ecosystem.

Major differences exist between the oceanic, subtropical islands studied by Simberloff and Wilson (1970) and the crop islands studied in temperate regions. Crop ecosystems contrast with oceanic islands in being available for colonization for a shorter time, continuous and rapid phenological change of the "islands", and frequent lack of a discrete source of colonizers. Despite these differences, important phenomena occur in crop ecosystems which can be investigated in the general context of island biogeographical theory: e.g. colonization curves, seasonal population dynamics, and number of species per habitat space throughout the season.

The primary purpose of this study was to investigate the specific patterns of colonization of soybean fields by arthropods and to determine if the theory of island biogeography could be applied to an annual crop.

STUDY AREAS AND METHODS

Three different soybean fields in east central Illinois (Champaign Co.) were studied, two in 1975 and the other in 1976. Prevailing winds during the soybean growing season are from the west or southwest (cf. Medler, 1962; Johnson, 1969). Therefore, the land adjacent to the west edge of each field was important and determined to a great extent which fields were chosen for the investigation. An 8 ha (20 acre) field of "Corsoy" soybeans 3 km east of Urbana was designated E20 and studied in 1975 (Fig. 1a). To the west of E20 was a 60 m × 130 m planting of pine trees with an average height of 12 m.

The other 1975 field, S40 (Fig. 1b), was a 16 ha (40 acre) field of "Williams" and "Wells" soybeans located 19 km south of Champaign. Adjacent on the west was a 2 ha (5 acre) alfalfa field separated from S40 by a blacktop road, 10 m wide. The alfalfa in the field was cut twice during the study, on 12 June (wk 4) and 26 July (wk 10). Certain insect pests have been found to migrate to soybean fields from recently cut alfalfa fields (Poston and Pedigo, 1975).

The TF field (Fig. 1c), studied in 1976, was a 13 ha (33 acre) field of "Williams" soybeans, 6 km northeast of Urbana. To the west of TF was Trelease Woods, a 24 ha (60 acre) tract of natural forest with an average height of 25 m.

Four different sites were sampled at each field, with site A at the west edge, sites B and C at intermediate distances from the edge, and site D in the middle of the field (Fig. 1). No insecticides were applied to any of the three fields during the studies.

Direct observation (DO) sampling of the arthropods present was performed at each site in each field once a week from plant emergence until harvest. Detailed description of DO sampling and comparison of the technique to another absolute method and to sweepnet sampling are given in

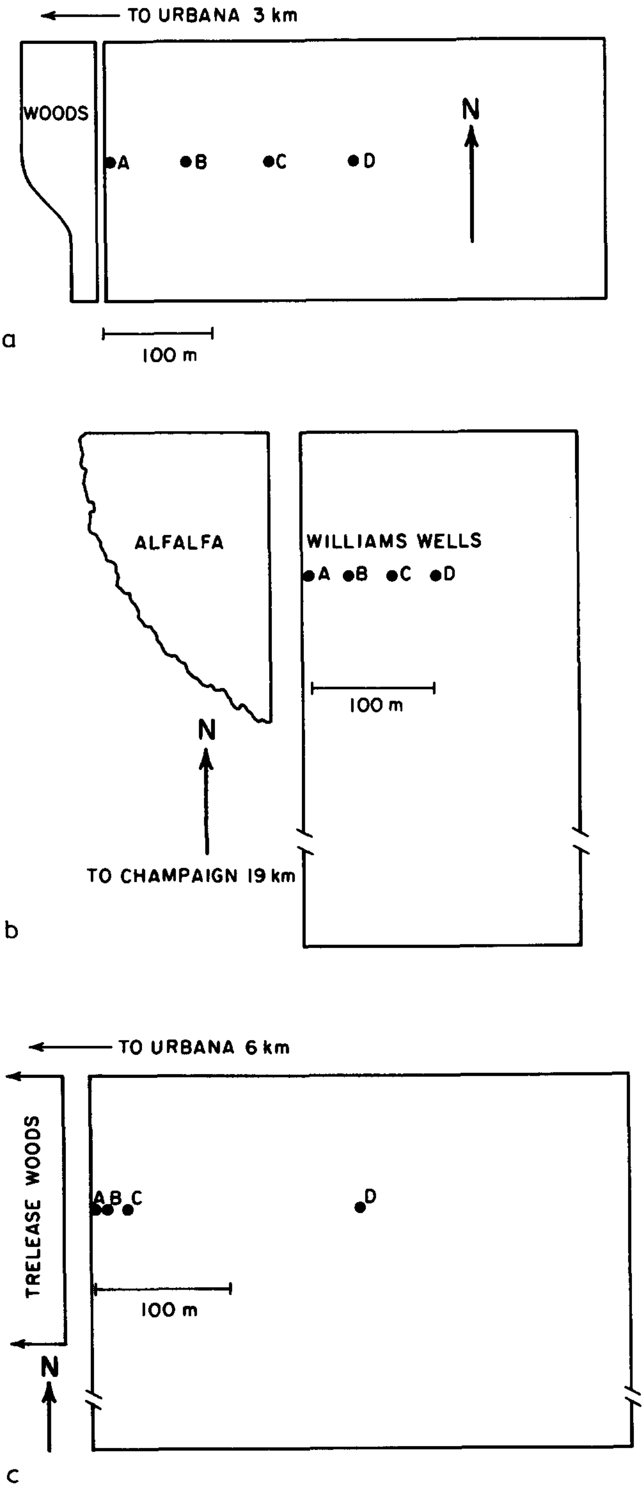

Fig. 1. Plans of soybean fields used in the study with sites A—D and adjacent areas to the west indicated. (a) E20 field, (b) S40 field, (c) TF field.

Mayse et al. (1977 a, b). The E20 season lasted for 16 wk, 28 May—8 September. At S40, sites A and B ("Williams") were sampled for 19 wk from 30 May—4 October, while sites C and D ("Wells") were sampled for 15 wk from 30 May—9 September. The 19 wk TF season lasted from 26 May—27 September.

Careful visual examination of the above-ground parts of 20 soybean plants randomly chosen from within a 1 m^2 area near a site marker constituted a DO sample for E20 and S40. During mid-June 1975, 40 plants were sampled per site. Comparing the number of species found on the first 20 plants with the number found on all 40 plants showed that doubling the sample size increased the number of species detected by only 15%. Data for the entire 1975 season showed that about 90% of all species detected by DO were recorded by the time the 15th plant had been examined. Thus at TF in 1976, a DO sample consisted of 15 plants per site.

DO sampling started at 7.30 a.m. and usually was completed by about 10.30 a.m. Even at peak arthropod abundances, sampling was completed before 12 noon. Cooler temperatures and heavy dew during early morning slowed down such active arthropods as the potato leafhopper *Empoasca fabae* (Harris). DO permitted sampling of such small arthropods as thrips, mites, *Chrysopa* eggs, *Orius* nymphs, and *Plathypena scabra* (F.) eggs.

The number of individuals of each arthropod species found on each plant was recorded. All observed instances of predation and parasitism were recorded. The general location of various arthropods on the plants was noted, e.g. in an unfurled trifoliolate, on the underside of a leaflet along the midrib, etc. No adult Diptera were recorded, although larvae of Syrphidae and eggs of Tachinidae were included in the study. Of all arthropods observed, adult Diptera were the only ones inadequately sampled by DO.

Specific identification of immatures of certain closely related species was not possible, but identification of large numbers of sampled arthropods by various specialists generally indicated the prevalence of one species or another among the problematic groups. For example, *Chrysopa carnea* Stephens was much more abundant than *C. rufilabris* Burmeister. *Nabis americoferus* Carayon was sampled much more frequently than *N. roseipennis* Reuter. Thus *Chrysopa* eggs and larvae were recorded as *C. carnea*, and all *Nabis* nymphs as *N. americoferus*.

Weekly measurements were made of soybean plant development at each field. Ten randomly chosen plants were cut at ground level and the following parameters were monitored. At E20 and S40, plant stage (Fehr et al., 1971), biomass, height, number of plants per m of row, and width of largest trifoliolate were recorded. At TF in 1976 two additional measurements were made: length and width of a typical trifoliolate, and mean number of trifoliolates present on the plants.

Habitat space values for E20 and S40 were calculated as an index of the mean number of trifoliolates times mean width of the largest trifoliolate per plant. Throughout the season the habitat space values reflected proportions of the maximum value derived, i.e. 1.0. For TF, habitat space was calculated as an index of mean area of a trifoliolate times mean number of trifoliolates present, i.e. an estimate of actual leaf area present on a plant. It was determined that if the length and width of a soybean trifoliolate ("Williams") are considered as the height and base of an isosceles triangle, the area of the trifoliolate calculated simply by $A = ½bh$ is slightly greater than, but within 10% of, the actual trifoliolate area as measured by a planimeter.

RESULTS AND DISCUSSION

Soybean plant development

Generally, soybean plants at the three fields showed growth patterns similar to those found at E20 (Fig. 2; Table I). Differences primarily resulted from different varieties being grown and differences in weather patterns. For example, the 1976 season had well below average precipitation resulting in delay of plant maturity at TF. Habitat space at E20 developed more rapidly than at S40 as "Corsoy" is a relatively early-maturing variety. Habitat space represents development of a crop island available for arthropod colonization and indicates that the resource base was changing continuously.

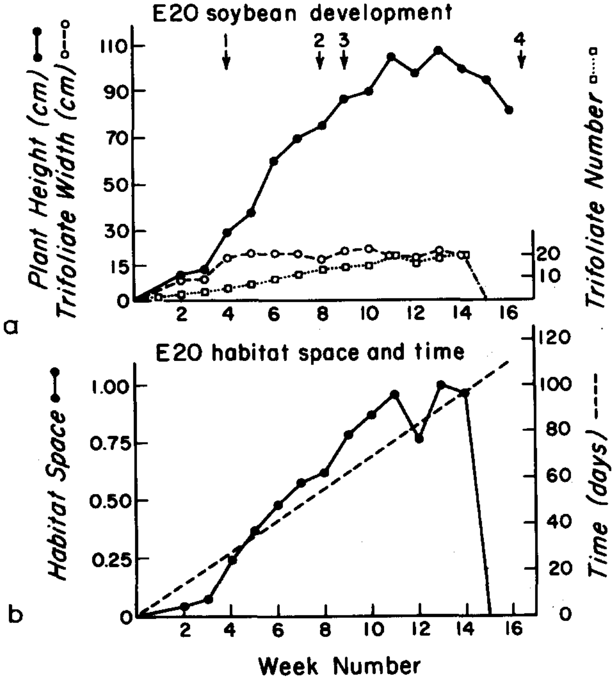

Fig. 2. Seasonal development of soybean plants at E20 field (a), and comparison of habitat space development to linear progression of time at E20 field (b). (1) time of first visible flowers, (2) longest pods 3—4 cm, (3) longest pods 4—5 cm, (4) harvest.

TABLE I

Seasonal development of soybean plants at the three fields

Field	Developmental stage*	Week number	Biomass (g) per plant	Fehr staging**	
				Vegetative	Reproductive
E20	1	4	1.2	V 4-5	R1
	2	8	13.1	V13	R4
	3	9	16.0	V14	R5
	4	16	24.0	V16	R8
S40	1(AB)	5	2.3	V 7	R1
	1(CD)	4	1.0	V 7	R1
	2(AB)	9	16.8	V14	R4
	2(CD)	8	12.2	V12	R4
	3(AB)	11	20.7	V19	R5
	3(CD)	10	22.1	V19	R5
	4(AB)	19	35.7	V21	R8
	4(CD)	15	31.3	V21	R8
TF	1	8	7.5	V10	R1
	2	11	24.7	V17	R4
	3	13	31.7	V18	R5
	4	19	40.6	V21	R8

*1 = first visible flowers
2 = longest pods 3—4 cm
3 = longest pods 4—5 cm
4 = harvest
**Fehr et al. (1971)

Numbers of arthropod species

Numbers of arthropod species detected at each site throughout the season at E20 (Fig. 3a) showed patterns similar to those at S40. At TF where the three edge sites were much closer together (Fig. 3b), observed patterns were somewhat different. Generally the numbers of species detected at site A were greater than at site D. Clearly the differences in location of sampling sites were reflected in the differences in patterns seen at E20 compared to TF (Fig. 3): sites B, C, and D showed more similar patterns at E20 than they did at TF.

Comparison of the numbers of herbivore species at sites A and D to the numbers of predator/parasitoid species at the two sites shown for TF (Fig. 4) was typical of all three fields. The site A vs. site D differences were greater for herbivores than for predators/parasitoids. Several factors may be involved in this phenomenon. For example, transient herbivore species which did not establish breeding populations in soybean were found much more frequently at the edge of the field than in the middle. Also, herbivore species colonizing

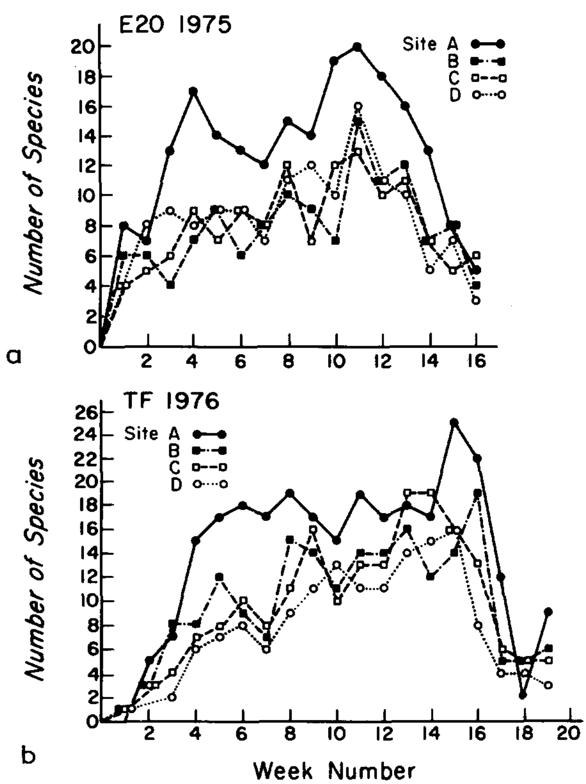

Fig. 3. Numbers of arthropod species detected throughout the season at each of four sites of E20 field (a) and TF field (b).

from the field's margin found abundant food at a site such as A and may have had little need to move further into the field until the location became overcrowded. However, predators and parasitoids move relatively large distances to find food items resulting in a more even distribution between sites A and D.

Phenological events such as soybean flowering, pod-set, and senescence were clearly important in the development of the soybean arthropod community. For example, numbers of certain herbivores, including *Empoasca fabae*, decreased rapidly when the plants reached physiological maturity. However, several predators and parasitoids, including the predatory red mite, remained abundant even when the plants had reached harvest maturity.

Numbers of arthropod species per habitat space

When numbers of arthropod species were considered in terms of habitat space available during the season, some interesting patterns emerged (Fig. 5; Table II). At S40, from wk 5 until harvest, a relatively constant number of

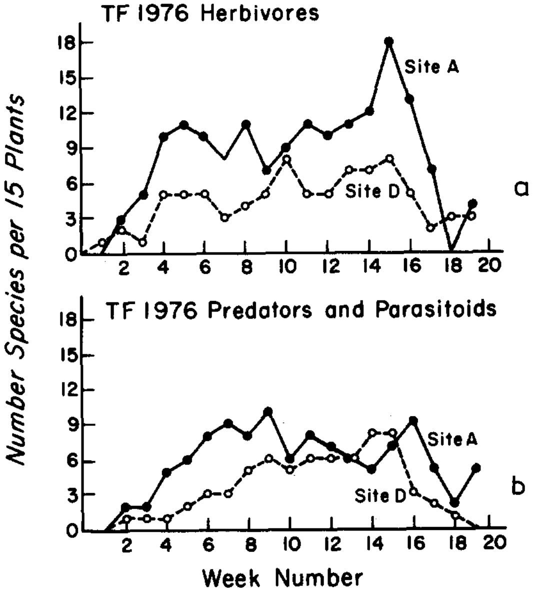

Fig. 4. Comparison of numbers of herbivore species (a) detected at sites A and D to numbers of predator/parasitoid species (b) at sites A and D of TF field.

TABLE II

Mean number of species per habitat space detected from first wk of relatively stable number* until end of season

	Herbivore species per habitat space		Predator/parasitoid species per habitat space	
Field	Site A	Site D	Site A	Site D
E20	13.6	8.4	9.3	6.2
S40	16.0	9.3	10.5	7.5
TF	16.0	7.7	10.9	7.2

*E20 and S40 — wk 5
TF — wk 7

species per habitat space was found for both herbivores and predators/parasitoids. Similar patterns were seen at E20 and TF. Such trends indicate that after wk 5 the development of habitat space in the fields was closely paralleled by development of the arthropod community in terms of number of species present. This relatively constant number of species per habitat space may be due to interactions among organisms, examined in the next section, or it may simply be due to species colonizing at a rate equivalent to the rate of habitat space increase.

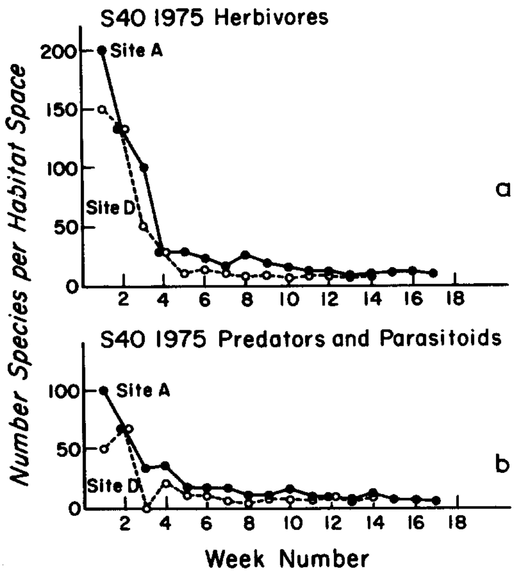

Fig. 5. Comparison of numbers of herbivore species per habitat space (a) detected at sites A and D to numbers of predator/parasitoid species (b) at sites A and D of S40 field. Habitat space is an index representing the total leaf area of a plant available for colonization and having a maximum value of 1.

The mean number of species per habitat space (Table II) for all three fields was higher at site A than at site D for both herbivores and predators/parasitoids. The location of site A at the edge of a field, adjacent to relatively complex vegetation, was probably an important factor in these trends.

Seasonal population trends

Wilson (1969) postulated that development of an equilibrium number of species involves a non-interactive phase before population densities make competitive exclusion and natural enemies factors in species extinction, followed by an interactive phase when population levels are high enough to make competitive exclusion important. Simberloff and Wilson (1970) tested the theory of island biogeography and found that the number of species which was reached during the non-interactive phase surpassed the equilibrium number later reached during the interactive phase.

Clearly, species abundances and interactions are essential in maintaining an equilibrium number. Both numbers of species and numbers of individuals along with their interactions were monitored throughout the season in the present studies to determine the pattern of development of the soybean arthropod community. The following sections describe seasonal patterns observed for the more important herbivores and predators/parasitoids.

Herbivores

Seasonal population trends for several relatively abundant arthropods were compared; numbers of individuals detected per wk were expressed as the mean of the preceding wk, the following wk, and the wk of the observation in order to damp large fluctuations from wk to wk. Thus the number for wk 2 = mean for wk 1, 2, 3, etc. Adults of *Sericothrips variabilis* (Beach) showed generally similar trends at all four sites at each field: early colonization and a broad population peak from about wk 8—12. However, numbers at TF site A were about four times greater than at site D throughout most of the season.

Population trends for *Empoasca fabae* at TF (Fig. 6) were generally representative of all three fields. Numbers of adults peaked early in the season at site A and then gradually decreased. Trends at site B were similar, but at TF site D a very late peak occurred. Numbers of *Empoasca* nymphs at E20 site A and S40 site A showed a high peak early followed by a later low peak. At E20 site D and S40 site D, numbers of nymphs showed a low peak early followed by a later high peak. However, numbers of nymphs were always low at TF site A and were low at site D early in the season, but later two high peaks were shown at site D.

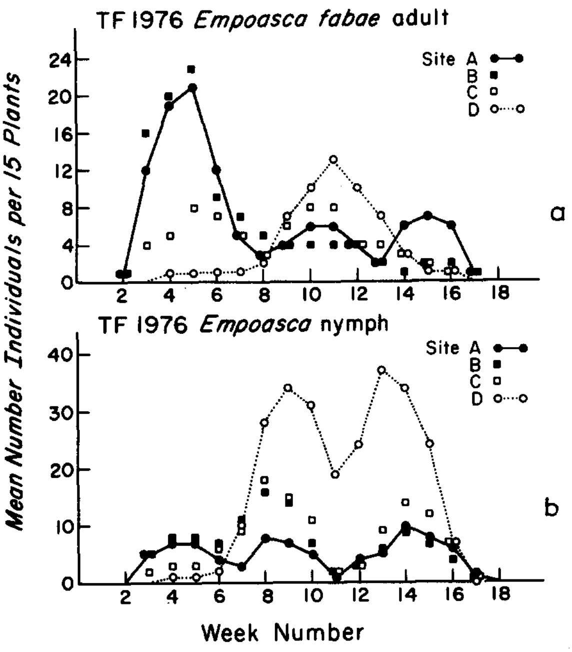

Fig. 6. Running average (wk 2 = $\bar{x}$ wk 1, 2, 3; wk 5 = $\bar{x}$ wk 4, 5, 6, etc.) of numbers of individuals of *Empoasca fabae* adults (a) and *Empoasca* nymphs (b) at four sites of TF field.

Both *E. fabae* (cf. Kieckhefer and Medler, 1966) and *S. variabilis* are primarily dispersed as aerial plankton. Wind patterns and the presence of windbreaks have been shown by Lewis (1965, 1967, 1969) to be very important in the distribution and movement of the arthropod component of aerial plankton. He found that such arthropods may be deposited and, in effect, concentrated at a distance of 1—6 H (H = height of windbreak) to the leeward of a windbreak. This type of pattern was shown by *S. variabilis* at E20 sites A and B (ca. 6 H), by *S. variablilis* at TF sites A, B, and C (ca. 1 H), and by *E. fabae* at TF sites A and B (1 H). At S40 where no windbreak was present, *S. variabilis* was not concentrated at the edge of the field.

It seems that many of the arthropods in the aerial plankton are herbivores, e.g. thrips, aphids, and leafhoppers. Windbreaks, either artificial or natural, could be used to concentrate pests into an area at the edge of a field allowing effective strip or spot spraying of non-persistent toxicants. This windbreak phenomenon occurs very early in the season before many of the important predators have colonized the field (cf. Fig. 4b, wk 1, 2, 3), so the probability of killing natural enemies while trying to control pests is reduced. Reducing numbers of *E. fabae* early in the season could be particularly significant since at this time females outnumber males four to one, and most of the colonizing females are gravid (Medler et al., 1966).

Adults of the bean leaf beetle *Cerotoma trifurcata* (Forster) (Kogan et al., 1974) and the Mexican bean beetle *Epilachna varivestis* Mulsant (Deitz et al., 1976) are active in the spring before soybean planting normally begins. Thus there is a strong tendency for early-planted soybeans to attract more colonizing adults than fields planted later. Damage by the three-cornered alfalfa hopper *Spissistilus festinus* (Say) also occurs largely on early plantings (Tugwell et al., 1973). Growers could create a trap crop by planting a few soybean rows early at field margins near suspected overwintering sites and/or windbreaks. Concentrations of the pests mentioned above along with herbivorous members of the aerial plankton colonizing these early rows could then be eliminated by application of non-persistent toxicants. Such trap cropping procedures have been successfully used by workers in Louisiana (e.g. Newsom et al., 1975).

Predators and parasitoids

No consistent patterns were seen at the three fields for the predatory red mite. Different sites showed high population peaks at various times in the season. For example, at TF the highest population levels were reached at site C (Fig. 7). These mites probably overwinter in the soil, and initial abundances at a site are reflected by the population levels reached later in the season. Prey density at a site may also be important. During the time when numbers of *Empoasca* nymphs at TF sites B and C were decreasing, numbers of predatory red mites were increasing (wk 9). Also, at TF site D where there were few red mites, *Empoasca* nymphs became very abundant later

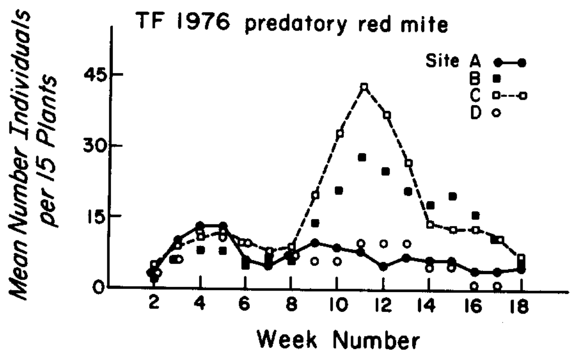

Fig. 7. Running average of numbers of individuals of predatory red mites at four sites of TF field.

in the season. Similar predator—prey correlations of this type were seen at E20 and S40. The general size class of prey items which the red mites fed upon suggests that young *Empoasca* nymphs were suitable prey.

Population trends for *Orius insidiosus* (Say) at E20 (Fig. 8) were typical for the three fields. Generally these predatory hemipterans were most abundant at site A. The lags between population peaks for *O. insidiosus* adults and nymphs appear to be related, representing two generations of *O. insidiosus* at E20 site A.

Numbers of spiders were always greatest at site A of each field: virtually no spiders were found at site D while there was an average of from three to four spiders per 20 plants at site A. Generally, spiders on the soybean plants were ca. 2—5 mm in length. LeSar (1977) mentioned that the majority of spiders which colonize soybean fields do so by "ballooning". Thus their concentration at the edge of the fields was probably due to the windbreak effect.

Chrysopa eggs were abundant at E20 and S40 (Fig. 9), reaching densities of almost 30 eggs per 20 plants. However, no consistent patterns in their distribution were seen. At E20, numbers were highest at site C and lowest at site A. All four sites showed very similar patterns to each other at S40. Trends shown in Fig. 9 indicate that *Chrysopa* eggs were most likely to be found towards the middle of the field, less likely at the edge, and least likely at site B.

Adults of parasitic Chalcidoidea were relatively abundant only at TF. An average of four chalcidoids per 15 plants was found at site A, while almost none were found at site D. Distribution of chalcidoids at TF appeared to show the windbreak effect. Lewis and Stephenson (1966) mentioned Mymaridae as one of the insect families influenced most by windbreaks. Such patterns also suggest the importance of alternate sources of adult food and/or the occurrence of alternate hosts near the field.

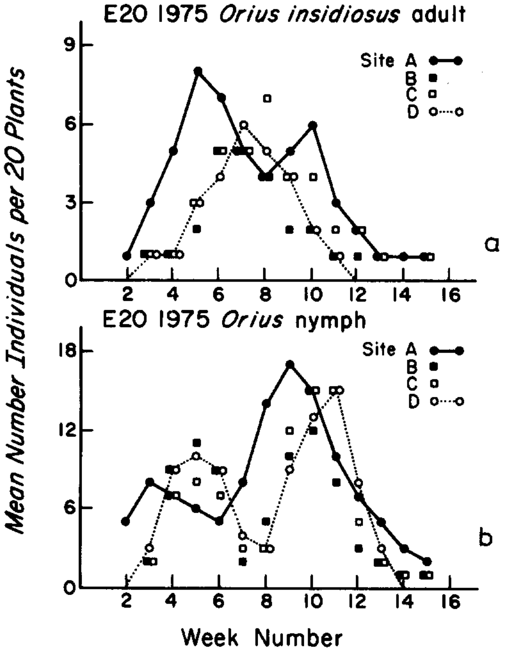

Fig. 8. Running average of numbers of individuals of *Orius insidiosus* adults (a) and *Orius* nymphs (b) at four sites of E20 field.

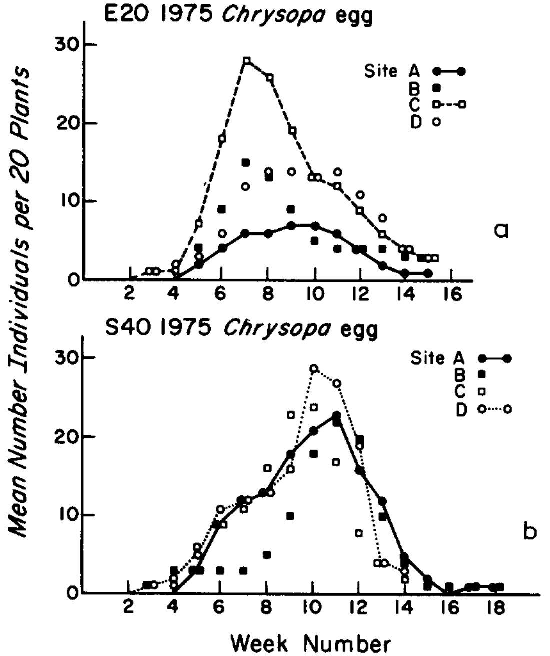

Fig. 9. Running average of numbers of *Chrysopa* eggs at four sites of E20 field (a) and S40 field (b).

Predator–prey interactions

All observations of arthropod predation in the fields were recorded (Table III). Most predators chose a variety of prey items, but general size classes of prey were well defined. Nymphs and adults of various thrips species were commonly observed prey items of several different predators.

Orius nymphs and thrips were usually found on undersides of leaves or near the growing tip of the plant. Predatory red mites were usually observed walking along stems, but were also found on undersides of leaves. Most of the spiders sampled in this study were usually found associated with a small web in the top third of the soybean plant.

Although few observations of predation on *Empoasca* nymphs were made, these insects are probably important prey for several predators. *Empoasca* nymphs were almost always found on undersides of leaves. Potential predators which were also frequently found there included *Orius* adults, *Nabis* nymphs, larvae of Syrphidae, *Aeolothrips* nymphs and adults, and predatory red mites. The general abundance of predators at TF site A and their relative scarcity at site D coincided with the high late-season peaks of *Empoasca* nymphs at site D and their relative scarcity at sites A, B, and C.

TABLE III

Instances of arthropod predation recorded during direct observation sampling

Field	Site	Date	Predator	Prey item
TF	C	5 July	predatory red mite	orange thrips nymph
TF	D	5 July	predatory red mite	orange thrips nymph
TF	NR	2 August	predatory red mite	orange thrips nymph
TF	NR	26 July	predatory red mite	*Aeolothrips fasciatus* adult
E20	C	30 June	predatory red mite	smaller predatory red mite
E20	NR	30 June	*Orius insidiosus* adult	orange thrips nymph
TF	NR	26 July	*Orius insidiosus* adult	orange thrips nymph
E20	NR	30 June	*Orius insidiosus* adult	*Sericothrips variabilis* adult
TF	NR	26 July	*Orius insidiosus* adult	*Colias* sp. larva
E20	NR	30 June	*Orius* nymph	orange thrips nymph
E20	NR	30 June	*Orius* nymph	*Sericothrips variabilis* adult
S40	D	29 July	*Orius* nymph	*Plathypena scabra* larva
S40	A	14 August	*Orius* nymph	*Orius* nymph
TF	B	19 July	*Aeolothrips* nymph	*Sericothrips variabilis* adult
TF	C	19 July	*Aeolothrips* nymph	*Sericothrips variabilis* adult
TF	NR	26 July	*Aeolothrips* nymph	orange thrips nymph
TF	B	19 July	thomisid spider	*Empoasca* nymph
TF	A	21 June	tetragnathid spider	black alate aphid (in web)
TF	D	23 August	tetragnathid spider	*Empoasca fabae* (in web)
TF	NR	2 August	*Nabis americoferus* adult	tortoise beetle larva
TF	B	29 August	*Nabis americoferus* adult	*Acrosternum nymph*
E20	C	30 June	*Nabis* nymph	*Empoasca fabae*
TF	B	19 July	Syrphidae larva	*Sericothrips variabilis* adult
TF	A	2 June	*Coleomegilla maculata* adult	black alate aphid

Larvae of Syrphidae were most abundant (ca. 2/20 plants) in the fields during wk 6—13, at times when very few aphids and no aphid "colonies" were found on the plants. Although many Syrphidae are aphidophagous, Schneider (1969) mentioned that in addition, psyllids, coccids, cicadas [sic], and aleurodids are rarely fed upon. One of us (MAM) observed a syrphid larva feeding upon a *Sericothrips variabilis* adult. Since no breeding populations of aphids were established in the fields, larvae of Syrphidae were preying on thrips and probably also on pseudococcids and aleurodids.

The complexity of the soybean arthropod food web increased considerably as the season progressed (Figs. 10 and 11). Early in the season only a few herbivores were present and even fewer natural enemies had colonized the fields. However, by wk 12, Lepidoptera larvae were common and a number of predators and parasitoids also occurred; trophic interactions had become complex by this time.

Some relatively uncommon arthropods have been omitted from the food webs shown in Figs. 10 and 11 for simplification, but the relative increase in complexity is apparent. For example, *Orius insidiosus* was observed to prey upon four different herbivores, and these hemipterans, along with *Nabis* and *Geocoris* have been known to also feed on plant material (Salas-Aguilav and Ehler, 1977; Stoner, 1970, 1972; Ridgway and Jones, 1968). Such com-

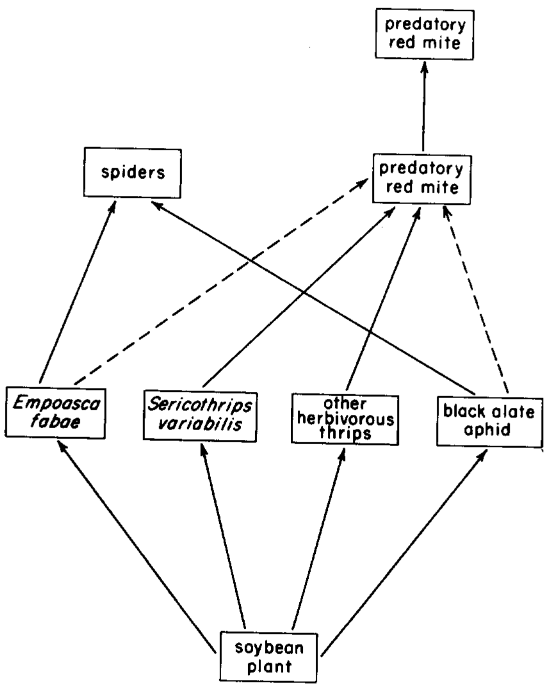

Fig. 10. Early season food web (ca. wk 3) in the soybean agro-ecosystem. Solid lines indicate observed interactions; broken lines indicate probable interactions.

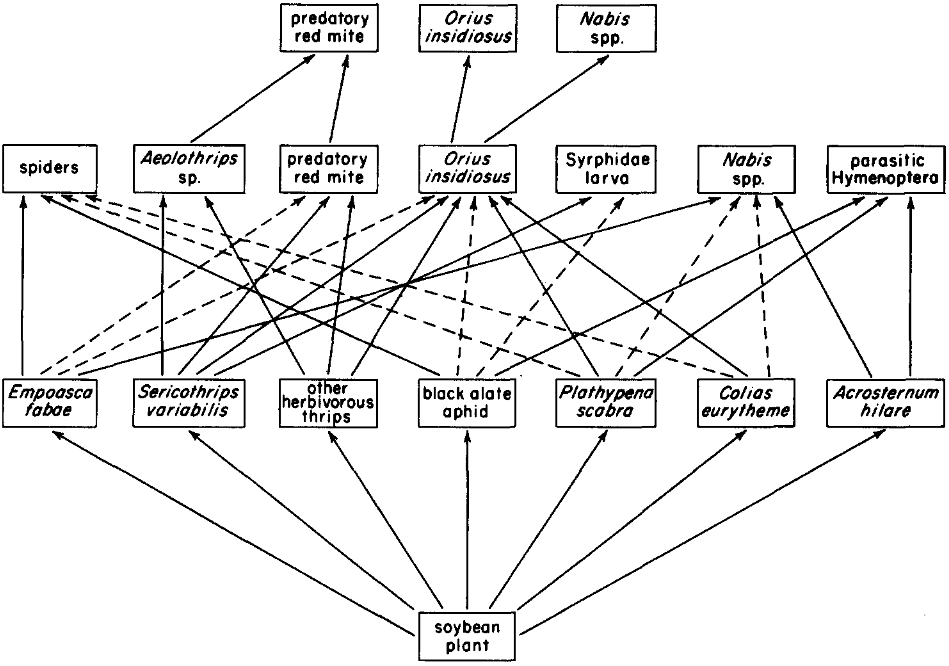

Fig. 11. Food web developed by wk 12 in the soybean agro-ecosystem. Solid lines indicate observed interactions; broken lines indicate probable interactions. *Orius* and *Nabis* have been reported to also feed on plant material (Salas-Aguilav and Ehler, 1977; Ridgway and Jones, 1968).

plex interactions among many species in the soybean arthropod community indicate that there is a delicate natural balance easily upset by outside interference (e.g. toxicant applications) which can result in pest outbreak situations.

Suggestions for further studies

The effect of planting time on development of the soybean arthropod community should be investigated. Patterns observed for colonization and population dynamics of various arthropods in this study relate to development of habitat space but probably also are dependent on planting time.

Further studies are needed to test the effect of different cropping systems (e.g. narrow rows, interplanting) on the early development and seasonal maintenance of the relatively constant number of arthropod species per habitat space. Manipulation of habitat space in simple ways can exert significant influences on the soybean arthropod community. For example, in a forthcoming paper one of the authors (MAM) will report in detail the findings of an experiment testing the effects of reduced soybean row-widths on population dynamics of herbivores and natural enemies: all predators and parasitoids showing significant differences among row-width treatments were favored by dense plantings, while the herbivore *Empoasca fabae* was favored by conventional row-width plantings.

Interplanting a reduced row-width soybean field with, e.g., red clover, would have two favorable effects on natural enemies. Reduced row-width plantings decrease the time of stress usually affecting predators and parasitoids early in the season before canopy closure when the natural enemies must operate in a more xeric environment (cf. Price, 1976). Also, interplanting with clover would add a rich source of pollen and nectar which predators and parasitoids could utilize. Increasing the plant diversity in a soybean agro-ecosystem could reduce the effects of fluctuations of populations of pests and beneficial insects by favoring establishment of a more diverse fauna. Of course, harvest practices would need modification to deal with an interplanted field, but the benefits of such cropping practices may well outweigh the detrimental effects, e.g. providing an alternate host plant for herbivores.

CONCLUSIONS

Several conclusions drawn from these results warrant consideration in designing a soybean insect pest management system.

Since different arthropods reach their highest population levels at various sites in a field, survey methods for estimating their numbers must involve several different areas in the field. Clearly, extrapolating to the whole field the findings at only one or two sampling sites could cause some problems.

Habitat space development was correlated with the pattern of soybean field colonization by arthropods. A relatively constant number of species per habitat space was found after the fifth wk at the three fields. This number may be due to interactions among organisms or may simply be due to species colonizing at a rate equivalent to the rate of habitat space increase.

A windbreak near a soybean field can produce a concentration of aerially dispersed arthropods, frequently herbivores, at the leeward edge of the field. Such a buildup of pests could allow effective use of non-persistent toxicants in a strip/spot spraying program at a time when many important predators have not yet colonized the field.

Time of planting can be manipulated so that such pests as *Cerotoma trifurcata*, *Epilachna varivestis*, and *Spissistilus festinus* are less likely to colonize a soybean field. An early trap crop of a few rows around a field's border could allow effective use of toxicants on the pests invading the field. Such an approach utilizes the concept of the host plant (crop) as an island available for arthropod colonization. Most of the early colonizers are herbivores.

Observations of predator—prey interactions made during direct observation sampling combined with data comparing seasonal population trends of herbivores and their predators and parasitoids can permit estimation of the importance of natural control at various areas in the field. Food webs during most of the season are very complex compared to early season trophic relationships.

Although predators and parasitoids affect the numbers of individuals of prey species, it was not demonstrated that natural enemies affect the number of arthropod species present. No evidence was detected of an interactive phase leading to species extinction as described by Wilson (1969) for oceanic islands. Additional studies are planned to determine the factors accounting for establishment of the relatively constant number of species per habitat space.

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