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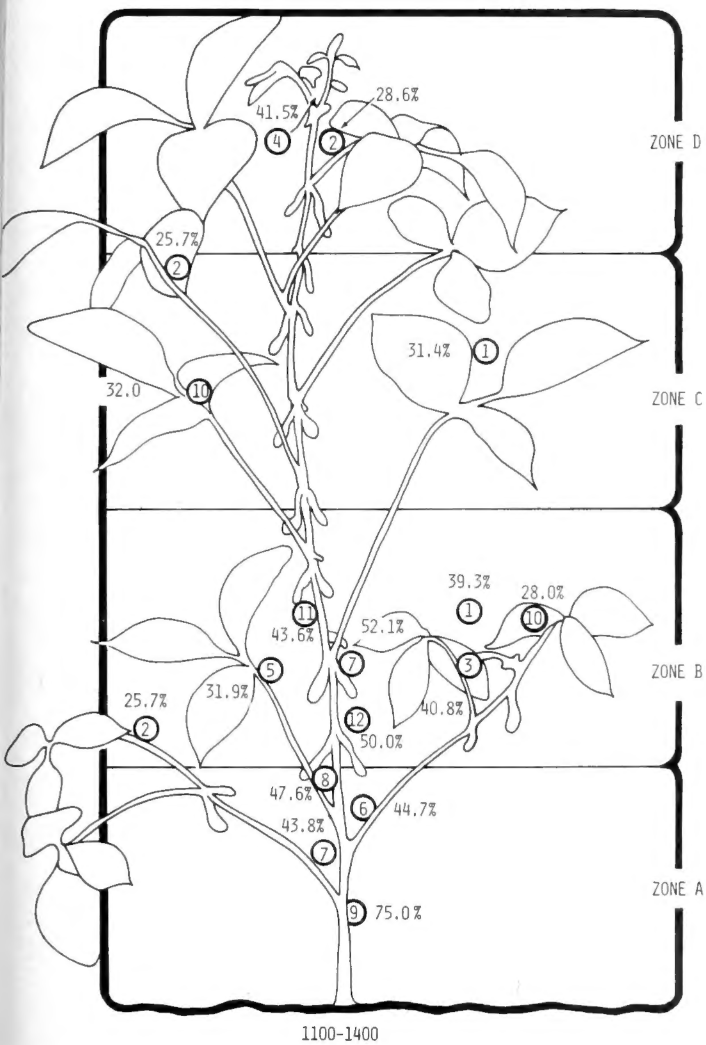
Charles D. LeSar and John D. Unzicker



Biological Notes No. 107

State of Illinois
Department of Registration and Education
Natural History Survey Division

Illinois Natural History Survey
Urbana, Illinois - July 1978

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Spiders are receiving considerable attention as potentially important predators of arthropod pests of agricultural crops because of increased interest in the development and use of integrated pest-management systems.

Studies concerning spiders in agricultural crops have been conducted by Chant (1956) and Dondale (1956 and 1958), apples; Putman (1967), peaches; Howell & Pienkowski (1971) and Yeargan & Dondale (1974), alfalfa; Fox & Dondale (1972), hayfields; and Muma (1975), citrus. However, there is a paucity of research on spiders in row crops. The few such studies that have been made are by Whitcomb et al. (1963) and Leigh & Hunter (1969), cotton; and Bailey & Chada (1968), grain sorghum. Investigations of arthropod populations in soybeans, including qualitative lists of spiders present during the growing season, have been carried out by Barry (1973), Neal (1974), and Deitz et al. (1976). However, reports quantifying spider populations, showing colonizing rates, and listing prey preferences of the dominant spider species in row crops are lacking. The data that will be presented here should help to fill the void of information on spiders in one of the most important row crops, soybeans.

The investigation was divided into two parts. The first deals with colonization times and rates, population densities, and species composition within the soybean field from the time the soybean plants appear above the ground in late May until they are harvested in the fall, usually in late September. In the second part determinations were made of the primary locations of the major spider species on the soybean plant and of the diurnal movements of spiders where possible. Sampling for information on species locations and diurnal movements was not begun until the soybean plant had reached maturity and colonization by the major spider species was relatively complete. These events occurred about the 2nd week of August, and sampling was continued until 15 September.

We would like to thank Drs. W. H. Luckmann, P. W. Price, and M. Kogan for their critical appraisals of this report and Dr. W. LaBerge, D. Webb, and J. Bouseman, who identified insect prey. Lloyd LeMere, Technical Illustrator, and Larry Farlow, Technical Photographer, both of the Illinois Natural History Survey, drew and photographed the illustrations. Robert M. Zewadski, Technical Editor of the Survey, edited the report for publication.

MATERIALS AND METHODS

Species Composition and Population Densities

Five different fields were sampled, two adjacent fields in 1975 and three widely separated fields in 1976. All were located in Tazewell and Champaign counties. Tazewell County, in west-central Illinois, and Champaign County, in east-central Illinois, are approximately 85 miles apart. All of the fields had been in corn-soybean rotation for several years. Each of them had some grassy or uncultivated areas adjacent on the south and/or west. No insecticides were applied to the soybeans during the growing season; however, preemergence herbicides were used. The summer prevailing wind is southwest with shifts to the west or northwest when thunderstorms occur. Large fields were selected (15–28 ha) to minimize the possibility of any unwanted encroachment of spiders from peripheral areas that would bias the colonization data.

A weekly series of 30 samples was taken in rows of each soybean field by means of a D-Vac suction machine, having a suction head 357 mm in diameter. Each sample therefore covered 357 mm along the row. This sampling method was selected after comparing quantitatively samples taken by D-Vac with samples taken by sweep net and by beat cloth into which the spiders are shaken or beaten from the vegetation. The sweep net yielded 34 percent fewer spiders and the beat cloth 19 percent fewer spiders than did the D-Vac method. Fig. 1 shows the correlation between the beat cloth and the D-Vac samples ($r = 0.864$), with the slope of the regression line indicating that the D-Vac retrieves about 1.2 more spiders than does the beat cloth from 5.25 m of soybean row. Papers by Dumas et al. (1964), Howell & Pienkowski (1971), and Shepard et al. (1974) give data on the limitations and timing of various sampling methods.

Transect samples taken in 1975 showed a much higher spider population (up to three times greater) during the early portions of the growing season in the first 20 peripheral rows (about 20 m wide) than

This paper is published by authority of the State of Illinois, IRS Ch. 127, Par. 58.12. It is a contribution to the Illinois Soybean Entomology Program supported by the Illinois Natural History Survey, the Illinois Agricultural Experiment Station, NSF-SC-0015, and the Illinois Soybean Program Operating Board. This paper is part of a thesis which was submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Entomology at the University of Illinois. Dr. Charles D. LeSar is an Associate Professor of Life Sciences at Illinois Central College, East Peoria. Dr. John D. Unzicker is an Associate Taxonomist, Section of Faunistic Surveys and Insect Identification, Illinois Natural History Survey.

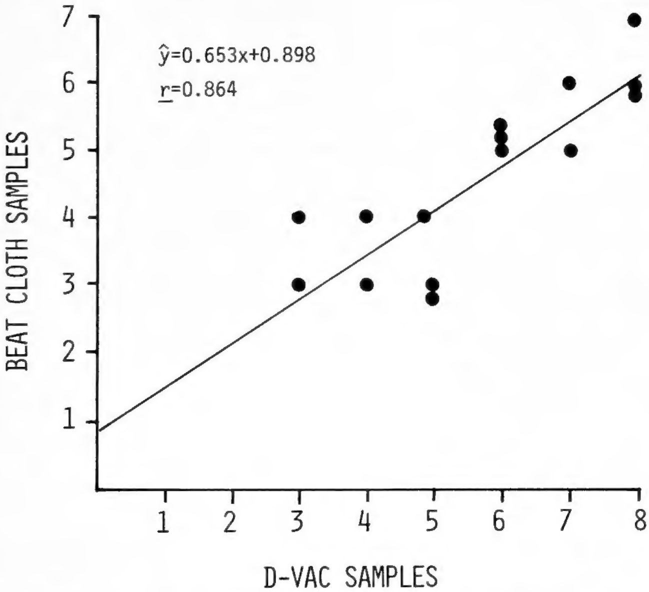

Fig. 1.—Correlation between the number of spiders collected by two sampling methods in Illinois soybean fields during 1975 and 1976.

in any other area of the fields. All samples for the study of population density and species composition were taken in random locations in the centers of fields, and these sites were noted so that no field was sampled more than once in a specific site.

The fields from which spider data were collected were planted from 15 to 20 May, the plants emerging from the ground during the last few days of May. The first spiders were collected in the experimental fields on 13 June 1975 and 15 June 1976, when the plants were about 2½ weeks old and stood 100–120 mm high.

To determine the differences between the spider-species composition in one field and that of another and to determine how much variation occurred in species composition from 1 year to the next, an analysis of species diversity was made.

According to Hurlbert (1971), species diversity is a function of the number of species present (species richness or abundance) and the frequency of occurrence of individuals of the various species (species evenness or equitability). We used two indices to analyze the diversity of spider communities in soybeans: H′ (Shannon & Weaver *in* Southwood 1971) and α (Margalef *in* Southwood 1971). Sorensen's (*in* Southwood 1971) quotient of similarity (QS) was used to compare species richness among different fields.

Species diversity, H′, was computed by this formula:

$$H' = -\sum_{i=1}^{S} p_i \log_e p_i$$

in which S is the number of species and p_i is the proportion of the total number of individuals represented by the species i, such that $p_i = N_i/N$.

The computation of α was based on the simplified form proposed by Margalef (*in* Southwood 1971):

$$\alpha = (S - 1)/\log_e N$$

in which S is the number of species in the sample and N is the number of individuals.

Sorensen's quotient of similarity was computed according to Southwood (1971):

$$QS = 2j/(a + b)$$

in which j is the number of species common to the two habitats, and a and b are the numbers of species in habitats A and B, respectively.

Vertical Distribution

The average soybean plant is approximately 1 m tall at maturity. We divided the plant into four vertical zones of about 250 mm each for stratified sampling. These zones, starting from the bottom of the plant, were designated A, B, C, and D. A portable D-Vac with a reducer cone measuring 220 mm in diameter was used to suck the spiders from each zone of the plant. The complex structure of the mature soybean plant makes it difficult to obtain representative samples from each zone of a single plant; therefore, the samples were collected from plants covering 15.75 m in a row. Four adjacent soybean rows were sampled in each of four daily time periods, one row for each of the vertical zones. This technique was necessary because sampling one zone of the plants could disturb the spider population on the remainder of the plants to the extent that normal stratification would not be present for subsequent samples. It should be noted that spiders may drift down from the upper zones as the lower ones are being sampled. Samples were taken during four times of day, 0800–1000, 1100–1400, 1600–1800, and 2000–2100 CDT, to determine whether spider species change positions on the plants during different time periods. Because heavy dew often prevented sampling, fewer samples were taken during the early morning and the evening hours than were taken at other times.

RESULTS AND DISCUSSION

Species Composition and Population Densities

The soybean field presents an unusual habitat. At the beginning of the growing season the field has a large area of soil without vegetation and with a very small resident population of arthropods, consisting mostly of ground-dwelling species. The soybeans create a temporary plant community with rapidly changing environmental conditions. The presence of plants gradually ameliorates the climate from that of a barren desertlike habitat with extreme exposure to the elements and little shelter for animals to that of a habitat in which most of the soil is shaded, humidity levels increase, and there is an abundance of food and shelter for the arthropod population.

Sampling the newly emerged soybean plant in early June indicates virtually no overwintering spider species that live primarily on the foliage. The field is essentially a monocultural island surrounded by hayfields, pastures, and fields planted in other crops. Therefore, the theory of island biogeography developed by Mac Arthur & Wilson (1967) provides, with modifications, the basis for this investigation in which the spider population is monitored to determine immigration into the soybean field. Price & Waldbauer (1975) have discussed crop islands in agricultural ecosystems and their possible roles in pest management. Price (1976) has recently written on insect colonization in soybeans, emphasizing the potential importance of island biogeography concepts as they apply to row crops.

Nearly all of the arthropods, especially those species found primarily on the foliage, find their way into the field during the growing season by migration. Migration is accomplished either by flight, in the case of most insects, or by ballooning, in the case of the majority of the spiders (Duffey 1962). The small sizes of most foliage-inhabiting spiders preclude their ability to disperse far enough into a field from the borders to colonize any area other than the edges except by ballooning. Thus, the arthropods that are found in the field as the soybean plants are becoming established in early June are there as a direct result of colonization from adjacent areas or of ballooning or flying greater distances. Over 4,100 spider specimens (from 30 weekly collections and from vertical sampling) representing 19 families and 77 species were collected from soybean foliage during two growing seasons (Table 1).

The data from three combinations of fields and/or years were analyzed and compared for species diversity. Table 2 shows α, H′, and QS values and the correlation of species diversity from one field to another and from 1975 to 1976. All values were obtained from counts of all spiders collected from each field throughout the entire growing seasons of 1975 and 1976.

A comparison of data from fields A and B of 1975 with data from all fields of 1976 shows that species diversity was higher in 1975, when a very wet growing

TABLE 1.—Spiders collected from soybean foliage in Illinois during 1975 and 1976.

Agelenidae
- *Agelenopsis kastoni* Chamberlin & Ivie
- *Agelenopsis* sp.
- *Cicurina pallida* Keyserling

Anyphaenidae
- *Anyphaena pectorosa* L. Koch
- *Aysha gracilis* (Hentz)
- *Oxysoma cubana* Banks
- *Wulfila saltabunda* (Hentz)

Araneidae
- *Acanthepeira stellata* (Walckenaer)
- *Araneus quttalatus* (Walckenaer)
- *Araniella displicata* (Hentz)
- *Argiope aurantia* Lucus
- *Argiope trifasciata* (Forskal)
- *Neoscona arabesca* (Walckenaer)

Clubionidae
- *Castianeira descripta* (Hentz)
- *Chiracanthium inclusum* (Hentz)
- *Chiracanthium mildei* Koch
- *Clubiona abbotii*[a] L. Koch

Dictynidae
- *Argenna obessa* Emerton

Gnathosidae
- *Drassylus depressus* (Emerton)
- *Gnathosa sericata* (Koch)
- *Sergiolus capulatus* (Walckenaer)
- *Zelotes laccus* (Barrows)

Hahniidae
- *Neoantistea agilis* (Keyserling)

Linyphiidae
- *Frontinella pyramitela* (Walckenaer)
- *Meioneta fabra* (Keyserling)
- *Meioneta micaria*[a] (Emerton)
- *Meioneta unimaculata* (Banks)
- *Microlinyphia pusilla*[a] Sundevall
- *Tennesseellum formicum* (Emerton)

Lycosidae
- *Pardosa milvina*[a] (Hentz)

Micryphantidae
- *Catabrithorax plumosus* (Emerton)
- *Ceratinops rugosa* (Emerton)
- *Ceratinopsis laticeps* (Emerton)
- *Ceratinopsis nigriceps* Emerton
- *Eperigone tridenta* (Emerton)
- *Eperigone trilobata* (Emerton)
- *Erigone atra* Blackwall
- *Erigone autumnalis* Emerton
- *Grammonota inornata* Emerton
- *Tapinocyba scopulifera* (Emerton)
- *Walckenaera vigilax* (Blackwall)

Mimetidae
- *Mimetus epeiroides*[a] Emerton

Oxyopidae
- *Oxyopes salticus*[a] Hentz
- *Oxyopes scalaris* Hentz

Philodromidae
- *Philodromus abbotii* Walckenaer
- *Philodromus aureolus*[a] (Olivier)
- *Philodromus washita* Banks

Pisauridae
- *Pisaurina brevipes* (Emerton)
- *Pisaurina mira* (Walckenaer)

Salticidae
- *Agassa cyanea* (Hentz)
- *Eris marginata* (Walckenaer)
- *Eris pineus* (Kaston)
- *Habronattus rutherfordi* (Gertsch & Mulaik)
- *Hentzia palmarum* (Hentz)
- *Metaphidippus galathea* (Walckenaer)
- *Metaphidippus protervus*[a] (Walckenaer)
- *Phidippus audax*[a] (Hentz)
- *Tutelina elegans* (Hentz)

Tetragnathidae
- *Mimognatha foxi* (McCook)
- *Tetragnatha laboriosa*[a] Hentz
- *Tetragnatha straminea* Emerton

Theridiidae
- *Paidisca unimaculatum* (Emerton)
- *Theridion albidium* Banks
- *Theridion frondeum* Hentz
- *Theridion neshamini*[a] Levi
- *Theridion rabuni* Chamberlin & Ivie
- *Theridula opulenta* (Walckenaer)

Thomisidae
- *Thanatus formicinnus* (Oliver)
- *Tibellus oblongus*[a] (Walckenaer)
- *Misumena calycina* (Linnaeus)
- *Misumenoides formocipes* (Walckenaer)
- *Misumenops asperatus*[a] (Hentz)
- *Xysticus auctificus* Keyserling
- *Xysticus elegans* Keyserling
- *Xysticus ferox* (Hentz)
- *Xysticus fraternus* Banks

Uloboridae
- *Uloborus glomosus* (Walckenaer)

[a] Denotes the most abundant species.

Table 2.—An analysis of species diversity and quotients of similarity for Illinois soybean fields sampled during 1975 and 1976. Data from fields A and B of 1975 were combined and compared with combined data from fields A and B of 1976 to compare species diversity from one year to the next.

Species Diversity

Field	Year	Number of Specimens	Species	Alpha	H′	QS
A & B	1975	785	74	10.95	1.17	
						0.54
A & B	1976	860	29	4.14	0.77	
A & B	1976	860	29	4.14	0.77	
						0.69
C	1976	326	23	3.80	0.69	
A	1975	402	57	9.34	1.17	
B	1975	383	48	7.90	1.11	
A	1976	503	24	3.70	0.80	
B	1976	357	24	3.91	0.68	
C	1976	326	23	3.80	0.69	

Quotients of Similarity

Field and Year	Field A 1975	Field B 1975	Field A 1976	Field B 1976	Field C 1976
A 1975	1.00				
B 1975	0.59	1.00			
A 1976	0.57	0.61	1.00		
B 1976	0.49	0.61	0.79	1.00	
C 1976	0.45	0.51	0.68	0.64	1.00

season suppressed the dominant species, causing a greater evenness of distribution among the remaining species in the population. In 1976, when a relatively dry summer allowed a build-up of the dominant species, *Tetragnatha laboriosa,* the species in the total sample became very uneven in their abundance, causing the diversity index (H′) to decline. Since α is more sensitive to the presence of rare species, the decline was greater in this value (63 percent) than it was in the H′ value (34 percent). Differences in species richness (2.5 times more species were collected in 1975 than were taken in 1976) also had significant effects on H′, α, and QS values.

A second analysis consisted of comparing fields A and B in Tazewell County with field C in Champaign County in 1976. The data indicate a greater similarity in spider populations between widely separated fields during one growing season (QS = 0.69) than that between fields that are close to one another but are sampled during two growing seasons (QS = 0.54).

The third analysis was a comparison of all fields sampled during both years. Fields A and B of 1975 had higher H′ and α values than had fields A, B, and C of 1976. Here again differences in species evenness are reflected in the discrepancies between α and H′ for fields A and B of 1976. The QS value for fields A and B of 1975 was relatively low even though the fields were close to one another. This fact suggests that differences in the adjacent habitats played an important role in species composition. Field A had brush and trees on the north, east, and west borders and an open area only on the south side, while field B, one-quarter mile to the east and south, had no brush or trees nearby. Field A of 1976 was one-half mile southeast of field B of 1975 but had much lower species-diversity values. The H′ and α values of field A of 1976 were similar to those of fields B and C of 1976, which were 15 and 90 miles away, respectively. Field B of 1976 and field C of 1976 had nearly identical H′ values. These two fields had very similar peripheral areas and soil types, suggesting that adjacent undisturbed areas have a great impact on the species diversity of spiders in soybean fields in a growing season.

Table 3 shows that among the earliest spider colonizers are members of the families Tetragnathidae, Salticidae, Oxyopidae, Thomisidae, and Theriidae.

Table 3.—Average abundances of the most frequently occurring spider species found per 10.5 m of row of soybeans throughout the growing seasons of 1975 and 1976.

Species	June 1–15 '75/'76	June 15–30 '75/'76	July 1–15 '75/'76	July 15–30 '75/'76	Aug. 1–15 '75/'76	Aug. 15–30 '75/'76	Sept. 1–15 '75/'76	Sept. 15–30 '75/'76
Tetragnatha laboriosa	2/1	3/3	6/3	5/7	3/12	5/25	18/61	20/26
Misumenops asperatus	0/0	0/0	0/1	1/1	2/2	4/3	3/4	1/3
Clubiona abbotii	0/0	0/0	0/0	1/1	3/1	2/2	4/3	2/2
Philodromus aureolus	0/0	0/0	0/1	0/1	2/2	2/3	2/3	0/2
Meioneta micaria	1/1	1/1	0/1	1/0	1/2	0/3	0/2	0/2
Phidippus audax	0/0	0/0	0/0	1/1	2/2	3/1	1/1	1/0
Metaphidippus protervus	0/0	1/1	0/2	1/1	3/1	1/2	1/1	2/2
Microlinyphia pusilla	0/0	0/0	0/0	1/0	2/2	3/4	2/7	2/3
Theridion neshamini	0/0	1/1	1/0	1/1	1/1	1/1	2/0	0/0
Pardosa milvina	0/0	0/0	2/0	1/1	1/1	2/1	2/1	4/0
Tibellus oblongus	1/0	0/0	1/0	1/2	2/1	0/1	1/2	0/0
Oxyopes salticus	0/0	1/0	1/1	0/1	1/2	1/1	1/2	0/0
Mimetus epeiroides	0/0	0/0	0/0	1/0	1/1	1/1	0/1	0/0

These early arrivals are exposed to the greatest environmental stress, and because colonization of the field by insects, which are their prey, is also still in its early stages (Price 1976), food sources are often discontinuous. Samples indicate that spiders are usually the first major predators to be found consistently in the soybean field. The data in Table 3 suggest that some spider species suffer extinction in soybean fields during the early part of the growing season, because heavy rains occur frequently and the small soybeans afford little protection. The lack of continuous food supplies affects small ballooning instars more than larger instars, because small individuals have had little opportunity to feed and build up energy reserves which would allow them to survive long periods between feedings (Miyashita 1968). Micryphantidae were found on the plants early in the season, but they are essentially ground spiders, which usually overwinter in the crop debris, and are only temporary inhabitants.

Cloudsley-Thompson (1962) suggests that plants are major modifiers of the macroclimate and that the structural complexity of the plant cover will determine, to a large degree, the microclimates experienced by arthropods. The spiders that arrive later in the growing season find a habitat greatly changed from the harsh environment encountered by the early colonizers. Therefore, the rate of successful colonization is controlled, in part, by the rate of plant growth. Those spiders that arrive later in the season find not only a more hospitable habitat, but also increased numbers of prey to feed upon (Carner et al. 1974; Price 1976).

Luczak (1963) used a grouping technique in which spider species that constituted more than 40 percent of the population were called dominants, those comprising 15–20 percent were classed as influents, and the remainder were classed as accessories. Only one species, *T. laboriosa,* reached the dominant level, and five species had sufficient numbers to be classed as influents.

The data show that of the 77 species of spiders found on the foliage of the soybean plant during some part of the growing season only 13 species were able to become firmly established. The criterion for establishment of a species was whether it was collected on a regular basis. If a species was collected only sporadically during the growing season and it made up less than 0.5 percent of the total population, it was considered an accessory which did not become successfully established. The 13 species considered established species made up more than 94 percent of the population and were collected, usually without interruption, over a major part of the growing season (Table 3). Fig. 2 shows the times of arrival in the field, the percentages of the population they represented, and their fluctuations in abundance

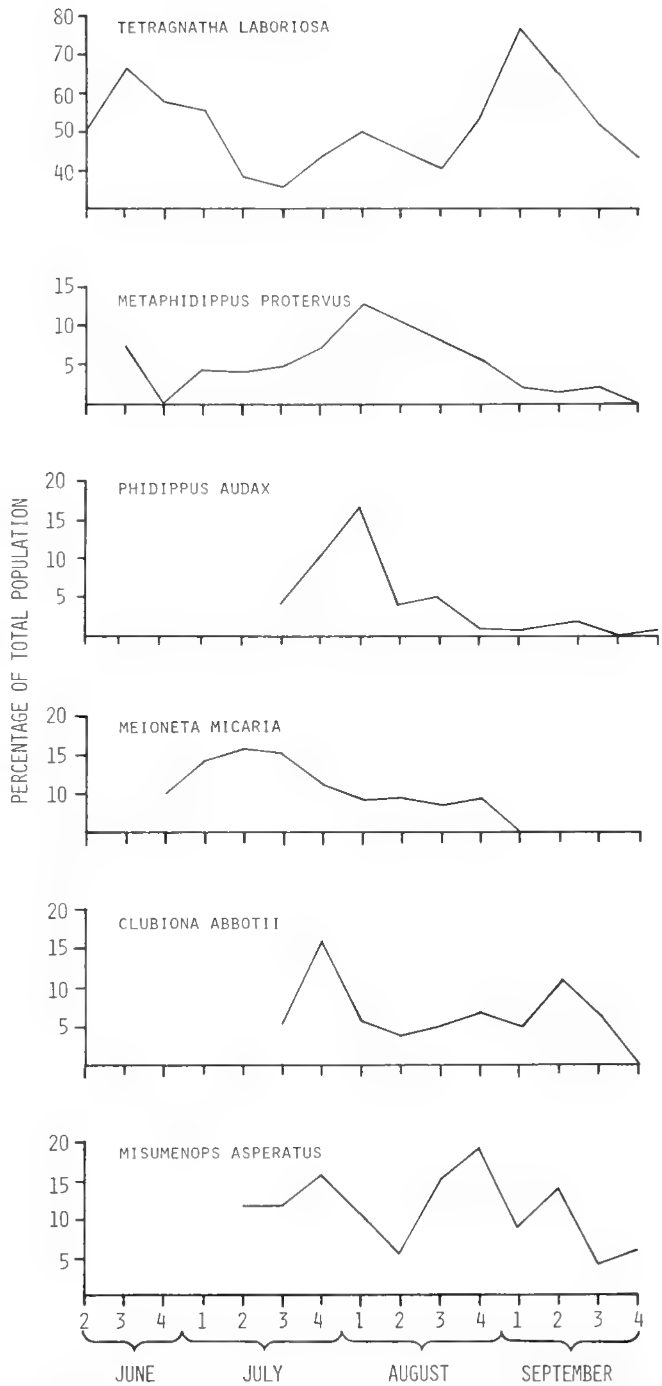

Fig. 2.—Times of colonization and population percentages of the six most common spider species found in Illinois soybeans during 1975 and 1976.

during the growing season in 1975 and 1976 of the six most common species.

The entire summer of 1975 was very rainy, and populations of the major web builder, *T. laboriosa,* were severely depressed (Table 3) as compared with its population densities in 1976, which had a considerably drier growing season. Data indicate that during August 1975 (rainfall was 47 percent above normal) *T. laboriosa* represented only 22 percent of the total population as compared with 46 percent of the total population in 1976, when August was much drier (about 50 percent below normal). August is the reproductive period for *T. laboriosa,* and the rain apparently interfered with the emerging young and their dispersal. Another web builder, *Microlinyphia pusilla,* made up only 2 percent of the total population in 1975, while it constituted 7 percent of the population in 1976. Fig. 3 compares spider population densities in different fields in 1975 and 1976 and illustrates the effect in 1975 of the above-normal rainfall on web builders. The major species of hunting spiders, including *Metaphidippus protervus, Phidippus audax, Clubiona abbotii, Philodromus aureolus,* and *Misumenops asperatus,* had populations considerably higher in 1975 than 1976, suggesting that heavy rainfall does not appreciably interfere with their establishment in soybean fields.

Only after 15 July, when the plants averaged 600–700 mm in height and there was an abundance of prey available (Shepard et al. 1974; Carner et al. 1974; Price 1976), was there a steady, uninterrupted increase in numbers of spider species. At that

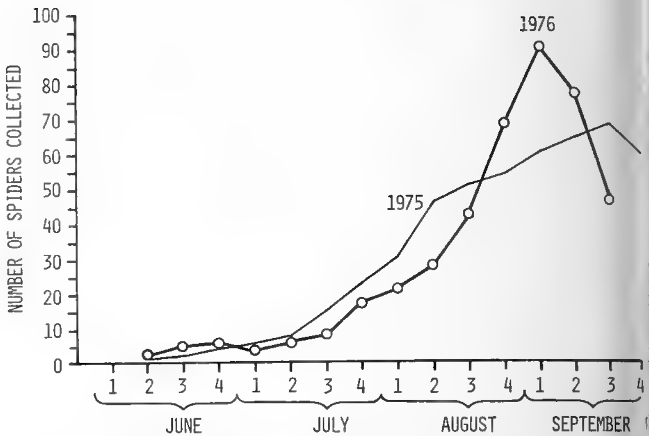

Fig. 3.—Mean numbers of spiders collected per 10.5 m of soybean row in Illinois during the growing seasons of 1975 and 1976.

time the foliage afforded protection from inclement weather and caused changes in soil temperature and humidity levels (Turnbull 1973). Maximum species numbers occurred during August (Fig. 4) at about the time of the maturation of the soybean plant in central Illinois. Maximum spider population densities occurred somewhat later in early September

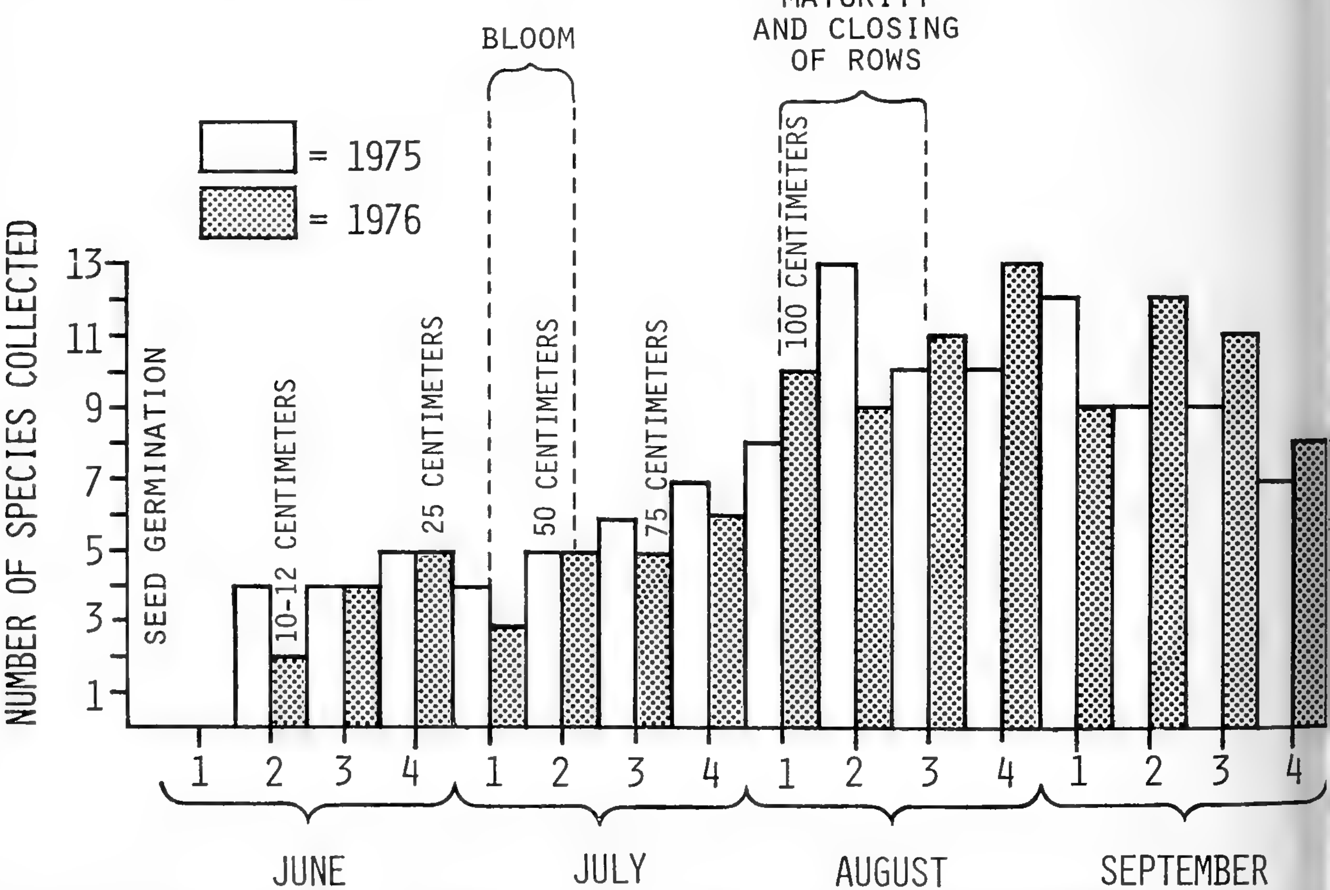

Fig. 4.—Average numbers of spider species collected weekly on soybeans in Illinois during the growing seasons of 1975 and 1976. Stages of development of the soybean plant are also shown.

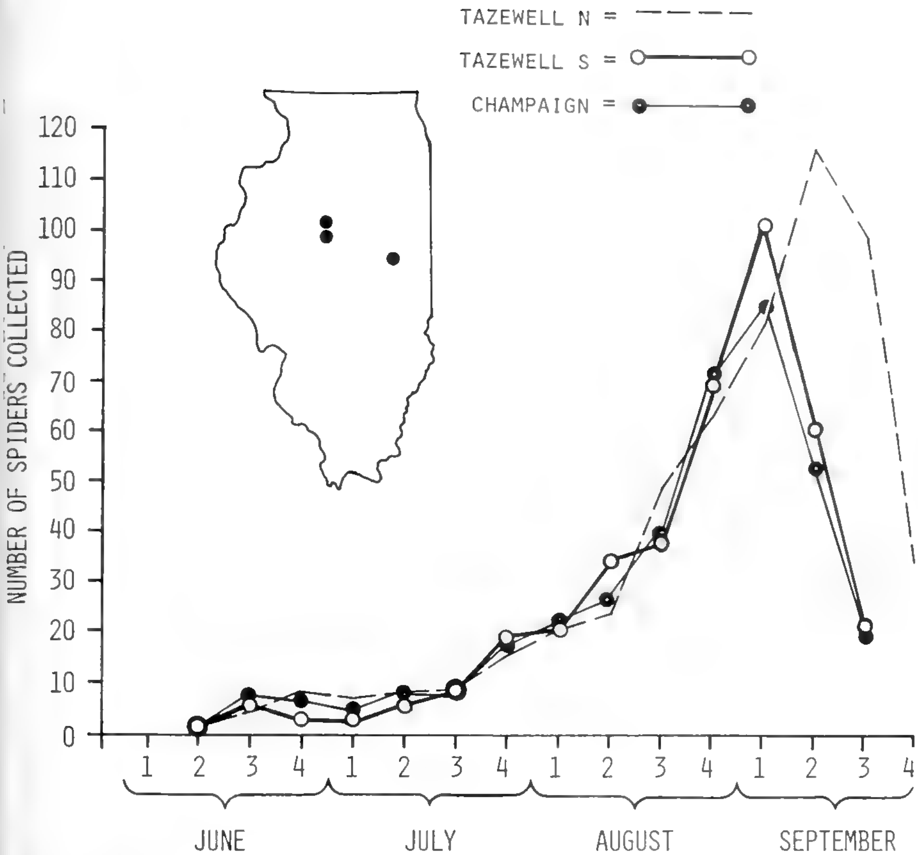

Fig. 5.—Mean numbers of foliage spiders collected per 10.5 m of row in three Illinois soybean fields during 1976.

(Fig. 3 and 5). Average abundances of the 13 spider species most commonly collected during the growing season are shown in Table 3.

Spider species numbers remained high through the remainder of August, but as the plants reached early senescence, a marked drop occurred in population densities. The major decrease in the population occurred by the time the soybean plant had undergone approximately 10–15 percent (estimated) defoliation and most of the leaves were yellow. Tugwell et al. (1973) indicated a declining population of many major insect species as the soybean is undergoing abscission and defoliation. Turnbull (1966) states that no evidence shows that a shortage of food in some areas caused spiders to leave those areas or that an abundance of food in other areas attracted spiders to those areas. Sampling of peripheral areas around the soybean fields confirmed Turnbull's finding, indicating that no significant amount of spider emigration occurred. This fact suggests that most insect species quickly emigrate to available plants still providing palatable food, leaving the majority of spiders behind. This series of events leaves little for spiders to feed upon and puts them in a situation similar to that of the early colonizers in the spring, little food and little protection as the plant begins to defoliate rapidly. Most evidence suggests that extinction for most of the spider population rapidly follows (Fig. 3 and 5), with some slight emigration to adjacent areas.

Vertical Distribution

The spiders that were collected from each vertical zone of the soybean plant during each of four daily

Table 4.—A two-way analysis of variance of the six most common spider species found on soybeans in Illinois during 1975 and 1976.

Source of Variation	Species											
	T. laboriosa		*M. asperatus*		*C. abbotii*		*P. aureolus*		*P. audax*		*M. protervus*	
	P	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*
Zone (Z)	0.002[b]	5.06	0.41ns	0.96	0.51ns	0.77	0.02[a]	3.20	0.0001[c]	8.24	0.01[a]	3.67
Time (T)	0.0001[c]	15.56	0.01[a]	3.79	0.02[a]	3.23	0.13ns	1.91	0.03[a]	3.10	0.008[b]	4.06
Z × T	0.24ns[d]	1.29	0.19ns	1.39	0.44ns	1.01	0.36ns	1.10	0.08ns	1.77	0.78ns	0.62

[a] $0.01 < P < 0.05$. [b] $P < 0.01$. [c] $P < 0.001$. [d] Not significant at the 0.05 level.

time periods were identified and counted. The number of spiders of each species found in each zone during each time period were then analyzed by using a two-way analysis of variance. This analysis determined whether the differences between zones and times of day were significant for the major species of spiders. The analysis was made on the six species most frequently collected during 1975 and 1976 (Table 4). Three of these species, *T. laboriosa, P. audax,* and *M. protervus,* had significant differences in location of the population between the different zones and during the different time periods of the day. Two of the remaining species, *C. abbotii* and *M. asperatus,* had significant differences in location of the population during the different time periods, while the remaining species, *P. aureolus,* had significant differences in population densities only among zones. *P. aureolus* was found mostly in the upper canopy, with 65 percent of its population located in zones C and D. An analysis of variance of the inter-

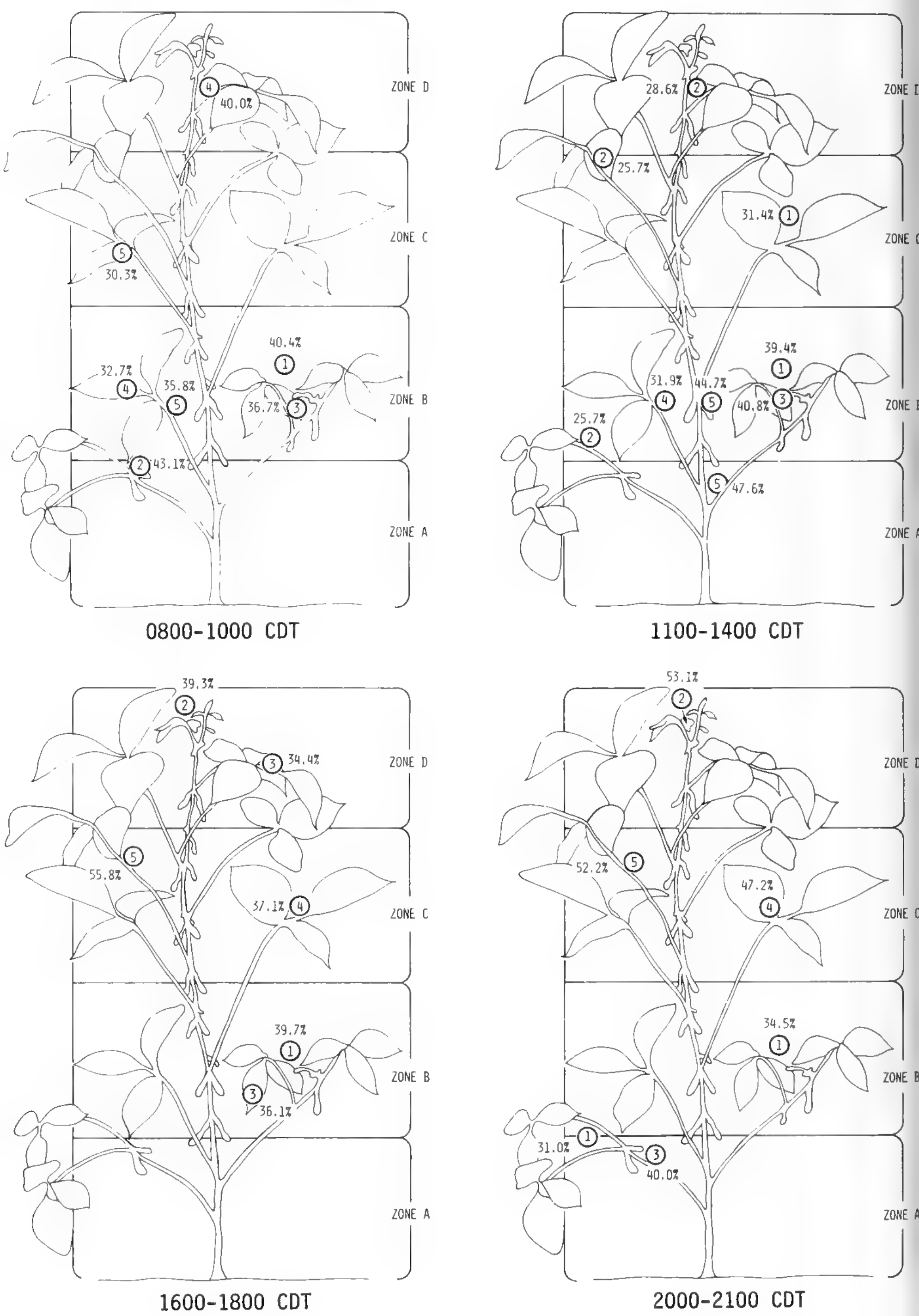

Fig. 6.—Locations of five frequently collected spider species that had significant changes in location on soybean plants during four times of the day in Illinois during 1975 and 1976. Each percentage value represents the percentage found in each plant zone of the total population of each species. The species are: 1. *Tetragnatha laboriosa,* 2. *Misumenops asperatus,* 3. *Clubiona abbotii,* 4. *Phidippus audax,* 5. *Metaphidippus protervus.*

action of zone × time indicated that no significant differences existed at any level for the six species, indicating that the two factors operate independently of each other. Locations of the spider species which had significant movements during four times of the day are recorded in Fig. 6.

Table 5 shows that about two-thirds of the entire spider population was located on the lower half of the soybean plant (zones A and B) regardless of the time of day (see also Fig. 7). These data suggest that prey abundance is probably greater on the lower portions of the plant during most of the day. Enders (1974) found that small insects on plants most often occur near the ground because individuals from higher up may fall and individuals from the detritus food chain climb up to the lower plant parts. *Mimetus epeiroides,* a major predator on spiders, was found almost exclusively on the lower half of the plant. Ninety-six percent of this species was located in zones A and B, suggesting that it feeds on spider prey that is most abundant in this region. Another member of the hunting guild, *Pardosa milvina,* is also prevalent in the lower canopy, about 68 percent of its total population being located in zone A. They are probably concentrated on the lower portion of the plant because they are primarily ground-dwelling spiders foraging for small prey on the soybean plant. Although adults were commonly collected in pitfall traps, every *P. milvina* specimen taken from the foliage was immature, suggesting that prey of the proper size and type was more abundant on the soybean plant than on the ground. Two other hunting species, *Tibellus oblongus* and *Oxyopes salticus,* did not show any marked zone or time preference.

The most noticeable changes in the locations of certain spider species were apparent reactions to heat and humidity stresses encountered by some species that were located in zone D most of the time. Nearly 50 percent of these individuals, mainly *M. protervus, P. audax,* and *T. laboriosa,* move to lower zones during the warmer portions of the day. It is interesting to note that the number of *M. asperatus* and *P. aureolus* individuals (both crab spiders) in the top portions of the plant increased during the same time when *M. protervus, P. audax,* and *T. laboriosa* individuals were moving downward. This upward movement is likely caused by the presence of prey that is preferred by these two species. An additional factor which appears to cause midday downward migration is the destruction of the web of *T. laboriosa* by the first substantial gusts of wind during the morning (C. D. LeSar unpublished data), causing them to seek shelter on a lower part of the plant where environmental conditions are more favorable. The other two web spinners that are commonly encountered, *M. pusilla* and *Theridion neshamini,* are not noticeably affected by wind because their webs have more protection, being positioned on the inner portions of the soybean plant. These two small spiders are mostly found on the lower portions of the canopy, with *M. pusilla* having 93 percent and *T. neshamini* 80 percent of their total populations in zones A and B.

TABLE 5.—Vertical distribution on soybean plants of all spiders collected from five fields in Illinois during 1975 and 1976. Zone A is at the bottom of the plant, and Zone D is at the top.

Time	Percentage of Spiders Collected in			
	Zone A	Zone B	Zone C	Zone D
0800–1000	35.7	32.7	21.9	9.7
1100–1400	38.4	32.8	21.9	6.9
1600–1800	35.5	33.6	20.6	10.3
2000–2100	39.3	26.0	20.3	14.4

FURTHER STUDIES

Although many ecologists believe that spiders do not serve a major role in the suppression of harmful insect populations in agricultural crops, we feel that far too little data have been gathered about the interactions of spiders with other arthropods in agricultural crops to draw even the most rudimentary conclusions about their potential impact as predators. Therefore, many important studies remain to be done. A number of researchers have found that in specialized circumstances some spiders can reduce harmful insect populations, but little has been published on their effects on the entire phytophagous insect complex. It is well known that spiders are indiscriminate feeders and that they feed on beneficial as well as pest insect species. Some researchers have suggested that spiders' feeding on major insect predators could negate the beneficial effects of their feeding on insect pests. However, data substantiating this point are not abundant, and additional investigations should be made to determine the validity of this theory.

With the exception of *T. laboriosa,* spiders that are found in soybeans, and presumably other agricultural crops, do not reproduce in the fields during the growing season. Therefore, there is no apparent way to increase the spider population to compensate for an increasing insect population during the growing season. Most spiders encountered in soybean fields have only one generation per year. The main reproductive strategies of the spiders are to lay eggs just before cold weather for overwintering as eggs or as spiderlings, which remain in a cocoon, or to overwinter as subadults which will mature and reproduce early in the next growing season. These subadults can take advantage of abundant prey populations for growth and development. In the fall these immatures usually hibernate until the next spring.

Since the life histories of most temperate-climate spiders span an entire year, from one growing season to another, they cannot respond numerically to fluctuations in prey density. However, there may be a

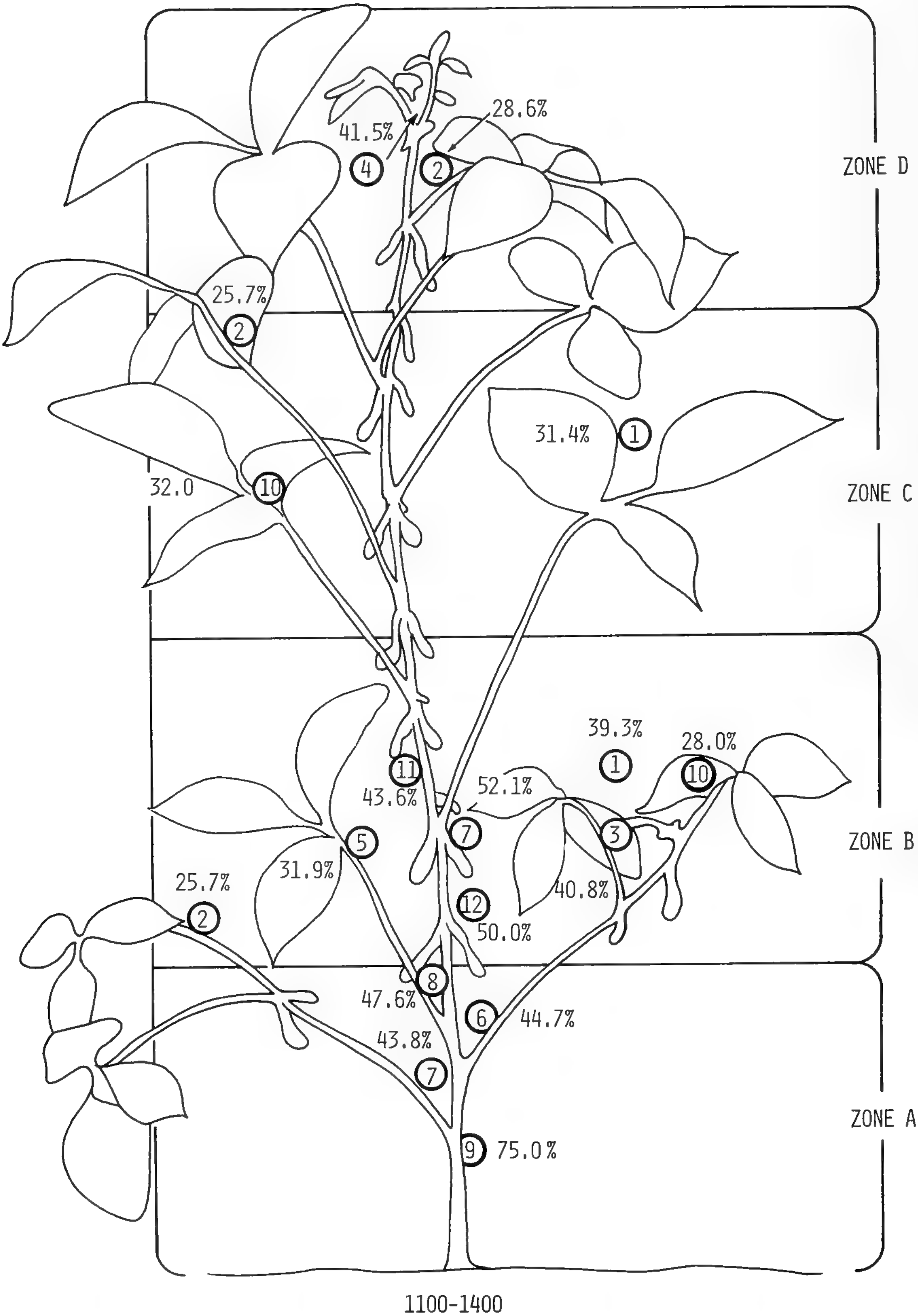

Fig. 7.—Locations of the 12 most abundant spider species on soybean plants during the 1100–1400 time period and the percentage found in each zone of the total population of each species. The species are: 1. *Tetragnatha laboriosa*, 2. *Misumenops asperatus*, 3. *Clubiona abbotii*, 4. *Philodromus aureolus*, 5. *Phidippus audax*, 6. *Metaphidippus protervus*, 7. *Microlinyphia pusilla*, 8. *Theridion neshamini*, 9. *Pardosa milvina*, 10. *Tibellus oblongus*, 11. *Oxyopes salticus*, 12. *Mimetus epeiroides*.

functional response to changes in prey density. Additional ballooning of individuals into a field could increase the spider population, but probably not significantly. One factor that could increase the control of harmful insects by spiders is a high rate of spider survival due to lessened competition for available food.

Therefore, any studies involving the use of spiders to control insect pests would have to develop our knowledge of spiders as natural control agents. In pest management we must fully understand this role and protect the spiders from outside disturbance, e.g., mowing or spraying.

One important aspect of spider ecology that should be researched to a greater depth is the determination of the species of spiders that are commonly found in major agricultural crops. Questions that should be asked are:

1) Do nearby agricultural crops have a species composition similar to that found on soybeans?
2) Are the major spider species in each crop present in approximately the same abundance, or are there major density variations in the commonly occurring species?
3) Are there any phytosociological limitations where individual species live?
4) Since major crops, such as corn, soybeans, alfalfa, and others, present very different environmental conditions during different times of the growing season, are any of the major spider species excluded as a result?
5) In row crops does the environment of narrow rows allow greater species diversity early in the growing season?

Therefore, we feel that continued research into spider species composition, species diversity, and population densities in different but adjacent field crops is a necessity before more detailed studies on the impact of spiders on pest insects can be made. Luczak (1966) postulates that a given environment will possess a specific association of spider forms; it would be useful to see if this is true.

Once a complete study of species diversity has been made, one can look at individual guilds or species to determine their particular roles as predators. The effect of inclement weather has already been demonstrated as a major problem for some species. There is some indication that web builders are more susceptible to inclement weather than are hunters. On the other hand, Howell & Pienkowski (1971) found that in alfalfa *T. laboriosa* was less affected by cutting and harvest than were most of the other spiders.

A study on the effects of rain and wind on both prey and predator would help to identify positively those spider species most susceptible to these weather conditions. Preliminary data suggest that heavy rain accompanied by moderate wind gusts causes many spiders to be knocked from the plant or otherwise affected to the degree that their population is suppressed or extirpated early in the growing season. An experiment which could demonstrate which spider species are most susceptible to rain and wind would be one in which potted alfalfa, soybeans, or corn were grown in a greenhouse. These plants would then have known populations of spiders established on them. Various combinations of artificial precipitation and wind gusts could establish to what degree inclement weather conditions affect spider populations. The spiders used should be species that are abundant on at least three major crops grown in one geographical area. Additional intensive sampling should also be done in the field with natural populations. Weather equipment, including rain gauges and anemometers, should be placed in soybean fields to monitor weather data. Intensive sampling of these fields would yield ample data to correlate population data before and after rainfall.

In addition, more information is needed to determine migration and dispersal patterns of the major spider species. Data indicate that significant migration occurs to soybean fields from peripheral areas that are uncultivated and relatively undisturbed. However, some questions still must be answered concerning the importance of these areas:

1) What proportion of the total spider population in a given field disperses or balloons from a nearby area?
2) What is the composition of the flora in these nearby areas, and do certain spiders prefer certain floral hosts or combinations?
3) Would the establishment of grass or legume strips enhance the colonization of adjacent row crops by spiders and perhaps by other beneficial entomophagous insects?
4) Could spider populations in these uncultivated strips be managed to increase colonization levels in soybean fields?

One of the major factors in whether spiders could become an important part of a pest-management program is our ability to exercise some degree of control over the potential colonization of row-crop fields. If we are to acquire this ability, data indicating the major factors affecting ballooning are needed. To gather such data a four-sided, fine-mesh screen, coated with an adhesive, could be placed at varying heights at the field margin and would determine the percentage of spiders ballooning from adjacent areas, local areas, and long-distance areas. Theoretically, the larger the local migration and dispersal, the more control one could exercise over a group of spider species. Since transect samples have already indicated a rather large movement of spiders into the edges of soybean fields early in the growing season, this fact suggests that some species colonize the soybean field by short balloon trips throughout the field, and the direction of movement is probably determined by the normal prevailing winds.

Once these basic ecological factors have been established, a group of spiders could be closely studied to observe their feeding habits during the various stages of their life cycles. Isolating a single species of spider to be used in a pest-management program probably would not be successful. Using a guild of hunting spiders, each species of which prefers a somewhat different vertical location on the soybean plant and has distinctive behavioral characteristics, seems more likely to meet with success. Four or five species feeding on a variety of phytophagous insect species would undoubtedly work better than one species which might be much more selective. Also, if one or two species encountered some sort of environmental difficulty and did not survive, the remaining species could fill in the niches vacated by the extirpated species. A number of feeding studies could be made in the laboratory to answer questions about the potential impact on insect pest species:

1) What are the rates of food consumption of each member of the guild?
2) What is the feeding efficiency of each species and of the male and female of each species?
3) Are all of the major species general feeders, or do they not prey on important insect pests because of size or other factors?
4) Can these species regulate insect pest populations or contribute significantly to their regulation?

When answers to these questions have been determined, field experiments can be conducted to correlate spider abundance with the volume of insect pests they consume, and we can calculate the real impact of spiders on other arthropods under normal field conditions.

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US ISSN 0073-490X (6254—2M—7-