SPIDERS OF SOYBEAN CROPS IN SANTA FE PROVINCE, ARGENTINA: INFLUENCE OF SURROUNDING SPONTANEOUS VEGETATION ON LOT COLONIZATION

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Received July 14, 2004 – Accepted October 4, 2004 – Distributed August 31, 2006

(With 2 figures)

ABSTRACT

Trials during two consecutive soybean cycles were performed in central Santa Fe in order to determine the main spider families present in the crop and to determine the influence of spontaneous margin flora on colonization towards the lot. Samplings were done by sweeping net and pitfall traps. It was concluded that:1. Oxyopidae was the most frequent family in the herbaceous layer of both the margins and the soybean crop, and Lycosidae in the lower layer; 2. Margin strips in a soybean lot contribute to the colonization of the crop by spiders of aerial habits and also promote re-colonization following pesticide applications, since they act as shelters. The influence on spiders of terrestrial habits was somewhat lower; 3. The distribution of the populations of spiders of terrestrial habits was homogeneous in a soybean crop seeded directly and these predators had a greater capacity to control pests at all points of the lot.

Keywords: spiders, soybean, colonization.

RESUMO

Aranhas no cultivo da soja no estado de Santa Fé, Argentina e a influência da vegetação espontânea ao redor sobre a colonização da parcela

Com o objetivo de determinar as principais famílias de aranhas presentes em cultivos de soja na zona central de Santa Fé e de determinar a influência da flora espontânea das bordas, na colonização, para o lote, realizaram-se, durante dois ciclos de cultivo de soja, amostragens mediante rede de arraste e armadilhas de queda. Concluiu-se que: 1) a família de aranhas mais freqüente no estrato herbáceo das bordas e do cultivo de soja foi Oxyopidae, enquanto no estrato inferior foi Lycosidae; 2) as faixas marginais do cultivo em um lote de soja contribuem na colonização das aranhas de hábitos aéreos, sendo também promotoras da recolonização posterior às aplicações de pesticidas, ao atuar como zona de refúgio. Uma menor incidência, foi encontrada na colonização das aranhas de hábitos terrestres e sua distribuição populacional foi homogênea em um cultivo de soja de semeadura direta, proporcionando maior capacidade para controlar as pragas em todos os pontos do lote.

Palavras-chave: aranhas, soja, colonização.

INTRODUCTION

Over the last decades, the loss of plant diversity due to the expansion of monoculture has resulted in the deterioration of environmental quality (Altieri, 1992a). Approximately 600 arthropod species are responsible for over 10% of the losses in agricultural production (Samways, 1997). These are controlled by agrochemical applications, which cause damage to both the health and the environment (Kaaya, 1994). Among several indirect effects, many beneficial arthropods, which may be accounted as the main cause of natural death of pest insects, are eliminated by the indiscriminate use of these products, which can reduce as much as three times the amount of natural enemies (Gamundi *et al.,* 2001). Integrated pest management (IPM), which was developed during the 1970´s as an alternative strategy in pest management, considers that biological control is the result of complex interactions at the community level. Biological control is one of the milestones of IPM and predators play an important role. At the beginning, the main interest was focused on specialist predators, capable of responding quickly to pest attacks. Little or no attention was paid to generalist predators, such as spiders. However, when the density of a pest population is too high, as is the case in monoculture conditions, spiders may restrict their diet, thus decreasing the pest population's exponential growth (Riechert & Gillespie, 1986; Minervino, 1996). Over the last 35 years, crop experiments have shown the capacity of spider's populations to reduce some pest insect populations and, therefore, causing damage to the crops (Ito *et al.*, 1962; Mansour & Whitcomb, 1986; Wise, 1993; Riechert & Lawrence, 1997; Greenstone, 1999). This new point of view has resulted in a remarkable increase in research trials focusing on spiders as agents in biological control strategies (Riechert & Lockley, 1984; Nyffeler & Benz, 1987; Young & Edwards, 1990; Sunderland & Greenstone, 1999).

Many predator insects behave as omnivorous, since they feed on species belonging to different trophic levels (Coll, 1996; Coll & Izraylevich, 1997; Coll *et al.*, 1997). These interactions may be favored or decreased by obtaining greater vegetation diversity (Altieri, 1992b), either by variation of species or by their spatial distribution and plant temporal disposition (Andow, 1991). The rational management of this vegetation regarded as a weed is one of the strategies that may promote diversity in agricultural systems. However, this is a subjective concept, since spontaneous vegetation can either decrease the action of phythofagous insects or provide alternative food sources and shelter to natural enemies of pests. *Brassicae* (Ellis, 1994; Mangan *et al.*, 1995; Idris & Grafius, 1996), *Asclepiadaceae* (Hawkeswood, 1994), *Asteraceae* (Starý, 1986), *Rosaceae* (Hemptinne & Desprest, 1986) and *Umbelliferae* (Salto *et al.*, 1991) are among the most studied taxa.

Spiders are more abundant in non cultured areas (Nyffeler & Benz, 1987; Desender *et al.*, 1989; Heidger & Nentwing, 1989), and even more so in complex vegetation structures (Samu *et al.*, 1999; Riechert, 1999), insecticide free (Withford *et al.*, 1987; Mansour, 1987; Minervino, 1996; Liljesthrom *et al.*, 2002). Moreover, they are highly susceptible to climatic conditions (Le Sar & Unzicker, 1978). Because of their resistance, spiders are the most abundant predators in terrestrial ecosystems (Rinaldi, 1998), reaching a maximum density of 100 individuals/m^2 (Nyffeler & Benz, 1987). At present, spiders are regarded as natural enemies (Sunderland & Greenstone, 1999) and, together with habitat diversification, should be considered for increasing sustainability in agricultural production. Future studies involving spiders should be oriented to quantitative estimations of abundance, observations on search strategies and diet, as well as studies on the quality of adjacent habitats (Uetz *et al.*, 1999).

In Argentina, there is little information regarding the role that spiders play as natural enemies in the soybean crop and their interaction with the surrounding vegetation. Minervino (1996) and Liljesthrom *et al.* (2002) studied the spider community in soybean crops in the Buenos Aires Province. The aims of the present work are to determine the main spider families in a soybean crop in central Santa Fe, determine the influence of spontaneous vegetation on the crop's margins, compare diversity in both habitats at different layers and analyze the colonization of spiders towards the soybean crop.

MATERIALS AND METHODS

Two trials were carried out over two consecutive years in the Castellanos Department (Santa Fe), on a 4 ha lot of second soybean (*Glycine max*, Merrill), cultivar A 8000, in mid December using direct seeding. A chemical fallow (4 l glyphosate + 200 cc cipermetrine) was applied prior to implantation and 200 cc cipermetrine was used for insect control. Two applications were made, the first by mid February and the second by mid March.

The spiders in the margins of the crops, hereafter called margin spiders, were sampled in a 2 m wide strip at the perimeter of the lot. Spontaneous flora, represented by annuals (*Chenopodium album* L.; *Amaranthus quitensis* Kunth., *Portulaca oleracea* L., *Carduus acanthoides* L., *C. thoermeri* Weinm. and *Digitaria sanguinalis* (L.) Scop.) and perennials (*Sorghum halepense* (L.) Pers., *Cynodon dactylon* (L.) Pers., *Sida rhombifolia* L., *Rumex crispus* L. and *Solanum sisymbrifolium* Lam., with predominance of *Cynodon dactylon* (L.) Pers. Species was left in this sampling area.

The spider community was sampled in both areas (crop and margins) at the plant and soil layers. In the first, sampling consisted of 20 sweeps performed at 20 sampling stations in the soybean crop and 5 in each margin, performed by means of a standard 37 cm diameter muslin sweep net, at a rate of 10 movements in each sampling point. Pitfall traps were used for the soil layer sampling. These traps consisted of 8 cm x 10 cm plastic containers, one fourth filled with ethylene glycol 30%, as a preserver. Forty traps were buried, at a rate of 5 equidistant traps in every margin; the remaining 20 traps were distributed in the same way within the crop (Liljesthrom *et al.*, 2002). All captured material was preserved in 70 % ethyl alcohol to be identified at the laboratory.

Field work started 15 days prior to seeding, and consisted of setting the soil traps and sweeps in the margin strips. After seeding, pitfall traps were set in the crop area and net sweeping started. Observations were performed every fifteen days until harvest by mid April. Samples were taxonomically identified to the level of a family using a 40x binocular magnifier. The Shannon-Weaver index (Minervino, 1996; Liljesthrom *et al.*, 2002) was used to compare spider diversity in the crop and margins:

$$H = -\sum_{i=1}^{S} Pi.\ln Pi \qquad (1)$$

where, *S* is the number of families in the community and *Pi* the relative abundance of each of the *i* families. The higher the number of families, the higher the index. Once *H* is obtained, the equity index "*J*" may be obtained:

$$J = H / H\max \qquad (2)$$

Hmax = ln *S* (maximum possible diversity at a given community), the values of *J* fluctuating between 0 and 1. Any family is strongly dominant when its value approaches 0; the richness value (*S*) represents the number of families present in the community. Colonization capacity was calculated by relating the total sampling units (total s.u.) and the number of sampling units where spiders were found (spider s.u.) (Minervino, 1996):

$$\%\text{ occupied area} = \frac{\text{spider s.u}}{\text{total s.u}} \qquad (3)$$

The software InfoStat (2004) was used to perform the statistical analysis and an ANOVA with LSD was done. Recorded densities were compared in two different ways according to the location in the field: 1. Plant and soil layers in the margin and seeded areas were compared to determine the influence the margins exert on the spider population of the soybean crop: 2. For the same analysis, the seeded area was divided into two, one next to the margins (intermediate zone) and the other in the center of the crop (central zone) to determine colonization advance.

RESULTS AND DISCUSSION

Spider families found in the soybean crop

Within the herbaceous layer, Oxyopidae was the most abundant family (62.3%), followed by Araneidae, Philodromidae, Thomisidae, Salticidae and Lycosidae, representing 16.9, 8.4, 3.8, 2.3 and 1.5%, respectively (Table 1). These results are not compatible with those reported by Minervino (1996) and Liljesthrom *et al.* (2002), who found Thomisidae to represent about 50%. The discrepancy might be due to: 1) a different sampling method; these authors placed plants in individual plastic bags and probably the results could have been masked because of the reduced size of the Oxyopidae individuals; 2) different seeding method; they used conventional seeding, which has destructive effects on the soil, whereas in the present work, soil conditions were not altered because of the direct seeding method; 3) different climatic conditions (mid-south Buenos Aires province vs. mid-west Santa Fé province).

Lycosydae was the most abundant family (86.9%) in the soil layer, followed by Theridiidae, Salticidae, Oxyopidae, Araneidae, Thomisidae and other families with values remarkably lower than the aforementioned family: 6.7; 2.0; 1.5; 1.0; 0.5 and 1.0%, respectively (Table 1). These results are compatible with Minervino (1996) and Liljesthrom *et al.* (2002), who found 84% Lycosidae, with Armendano (personal communication) regarding the capacity to adapt to different environments originated by different seeding methods and with Rinaldi (1998) regarding the resistance to adversities that spiders show.

Spider families found in the crop margins

Results for margins were similar to those of the crop (Table 1) and Oxyopidae was the most abundant family (42%) in the herbaceous layer, while Lycosidae was the most abundant (84%) in the soil layer coinciding with the information reported by Minervino (1996) and Liljesthrom *et al.* (2002). The similarity observed in the families making up the spider populations of both margin and crop communities could indicate that the colonization process, which takes place at the beginning of the crop development, would start in the adjacent areas.

The main difference when comparing margin and crop communities concerned the Oxyopidae family, representing 42 and 62.3%, respectively, while Thomisidae, a family of little importance in the crop (3.8%) represented up to 22.4% of the total margin community. These results could be related to a greater equilibrium in environmental factors, derived from the composition of the spontaneous flora in the margins, which would allow a greater diversity of the spider community, compared to that of the crop. The communities found in both areas represent less than one fourth of those cited for Argentina, which is compatible with Young & Edwards (1990).

Diversity, richness and equity indexes

Table 2 shows diversity (*H*), maximum diversity (*Hmax*), richness (*S*) and equity (*J*) in the margin strips and the crop. The values for the lower layer, prior to seeding and during soybean crop development, are higher in the margins than in the crop. Probably, the ecologic equilibrium found in the margin strips could be due to the variety of niches the spontaneous flora produces, which is compatible with Desender *et al.* (1989).

The same happens when the indexes for the herbaceous layers in the margins and crop are compared. Values of *H*, *Hmax*, *S* and *J* are higher and more stable in the margins during crop development, than in the crop itself. On the other hand, values in the herbaceous layer in the margins are lowest prior to seeding, *H, Hmax*, *S* and *J* being 0.54, 1.10, and 0.49, respectively. Oxyopidae is the dominant family in the spider community of margin strips prior to implantation. This could explain the low values of richness and diversity indexes, thus showing that margin strips have a higher richness, as well as a more regular distribution (Minervino, 1996 and Liljesthrom *et al.*, 2002).

The diversity found at the herbaceous layer of the crop (1.22), is in accordance with what was reported by Le Sar & Unzicker (1978) in a humid year. During years of drought, diversity was 0.7-0.8, thus reflecting the climatic effect on density.

TABLE 1
Spider families in herbaceous and soil layers in soybean crop and margins.

Family	Crop				Margins			
	Plants		Soil		Plants		Soil	
	Total	%	Total	%	Total	%	Total	%
Oxyopidae	81	61.8	3	1.5	90	42.0	9	3.8
Thomisidae	5	3.8	1	0.5	48	22.4	1	0.4
Anyphaenidae	11	8.4	2	1.0	24	11.2	2	0.9
Philodromidae	6	4.6	0	0.0	13	6.0	0	0.0
Salticidae	3	2.3	4	2.0	12	5.6	4	1.7
Lycosidae	2	1.5	167	82.7	1	0.5	196	83.8
Theridiidae	1	0.8	13	6.4	1	0.5	9	3.8
Araneidae	22	16.8	2	1.0	25	11.7	3	1.3
Otras	0	0.0	10	5.0	0	0.0	10	4.3

Colonization capacity

The colonization capacity of spiders of aerial habits grew higher reaching 55% by the second month after implantation and 100% by the third month (Fig. 1). These results coincide with those reported by Minervino (1996), who found values of 80% in the same period. During the emergence period, plants scarcely cover the soil and a high percentage of spiders are still in the margins; re-population of the lot started during this period. Insecticide applications were responsible for the decrease observed by the end of February and March, when the values were close to zero, and stayed low for the following 7 days, which is compatible with Minervino (1996), Gamundi *et al.* (2001), and Liljesthrom *et al.* (2002). Density started out with low values (0.3 spiders/m^2), reached the maximum (2.7 spiders/m^2) by mid March and ended at 1.2 spiders/m^2, with the mentioned insecticide-driven decrease, in accordance with Whitford *et al.* (1987) and Mansour (1987), who showed that agrochemical products produce negative effects.

There was a slight decreasing trend for spiders of terrestrial habits, with occupancy values of 80% at implantation and staying at approximately 70% for most of the period. These results could be attributed to the seeding method, as opposed to Minervino (1996), Liljesthrom *et al.* (2002) and Armendano (personal communication), who used the conventional system. There was a decrease by

TABLE 2
Shannon-Weaver diversity index (*H*), maximum diversity (*Hmax*), richness (*S*) and equity index (*J*) for different areas.

Area	*H*	*Hmax*	*S*	*J*
Crop				
Herbaceous layer	1.22	1.95	7	0.63
Soil	0.57	1.95	7	0.29
Margins prior to seeding				
Herbaceous layer	0.54	1.10	3	0.49
Soil	0.86	1.95	7	0.44
Margins during crop development				
Herbaceous layer	1.57	2.08	8	0.76
Soil	0.75	2.30	10	0.33

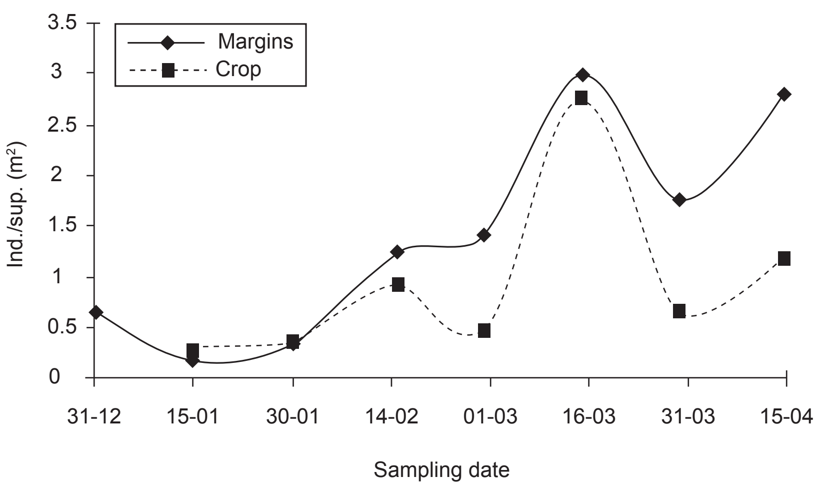

Fig. 1 — Variation on aerial habitat spider average in soybean crop and margins.

mid April, when heavy rain caused the loss of the contents in several traps.

The mean spider count in the margins fell before seeding, probably due to migration towards the lot by the end of February and March. Therefore, margins would act as shelter areas because of their greater diversity in ecological niches, which would exert a buffer action on chemical products (Nyffeler & Benz, 1987; Desender *et al.*, 1989; Heidger & Nentwing, 1989). Thus, they would favor lot re-colonization after harvest and colonization of the newly implanted crop (Minervino, 1996; Desender *et al.*, 1989; Liljesthrom *et al.*, 2002).

The trend for spiders of terrestrial habits also decreased in the margin strips. It started with 2.9 individuals before seeding and ended with 0.8, which might indicate a certain degree of migration towards the inner part of the lot (Fig. 2). In the crop, on the other hand, it started with 1.5, reaching the maximum (2.1) by the end of February and ended the cycle with 0.3 individuals. This decrease could be due to precipitation at the end of the crop cycle when light entrance increases to soil moisture and probably to the amount of antagonists this community presents (Le Sar & Unzicker, 1978). Three stages could be recognized in this trend: 1. Colonization, which would explain the low initial density values; 2. Community growth, favored by the abundance of food resources, and 3. A period of lower levels, due to competition for food resources and environmental changes. The results and their statistical analysis are presented in Table 3.

Spiders of aerial habits found in margins in the intermediate zone and central zone are compared in Table 4. Statistical differences were detected between the first two areas, mainly due to: 1. colonization from the margins to the center and 2. the central zone presenting better ecological conditions (more abundant food resources, better temperature, humidity and radiation equilibrium, among others). These conditions might have resulted in the migration towards the central

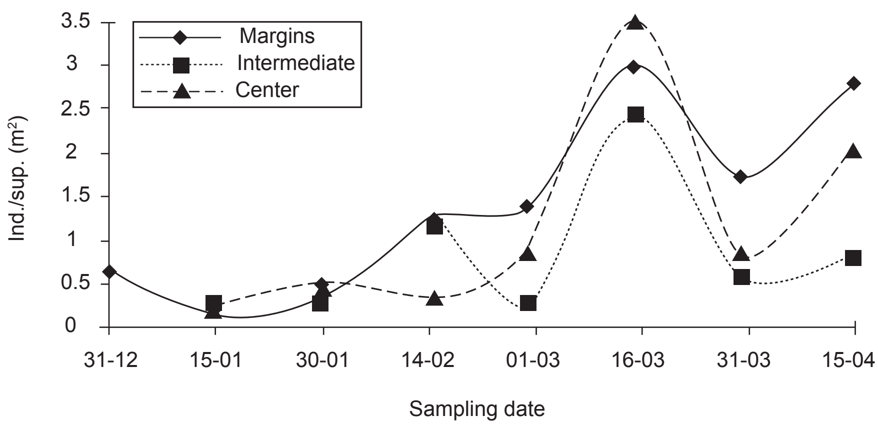

Fig. 2 — Variation on terrestrial habit spider average in the margins, intermediate and central zone of soybean crop.

TABLE 3
Average aerial spiders and spiders of terrestrial habits in soybean crop and margins.

	Aerial spiders	**Terrestrial spiders**
Location	**Individuals/m²**	**Individuals/m²**
Margins	1.5 a	1.7 a
Crop	0.9 b	1.6 a

Within the columns, the different letters indicate statistically significant differences (P < 0.05) (LSD test).

TABLE 4
Average aerial spiders and spiders of terrestrial habits in soybean crop margins, intermediate and central zone.

	Aerial spiders	Terrestrial spiders
Location	**Individuals/m^2**	**Individuals/m^2**
Crop margins	1.5 a	1.7 a
Intermediate zone	0.8 a	1.5 a
Central zone	1.2 ab	1.8 a

Within the columns, the different letters indicate statistically significant differences ($P < 0.05$) (LSD test).

zone. Areas where more individuals are found are characterized by better microclimatic conditions and/or resource availability (Minervino, 1996).

There were no significant differences among spiders of terrestrial habits, probably because of the few habitat modifications introduced by direct seeding. Therefore, the use of conservationist methods would provide ecological resources similar to those existing in the margins, thus showing that some culture practices could affect the density and organization of spider communities, especially those living in the lower layer of the crop. No differences were found when comparing the margins in the intermediate and the central zone. This would explain, once more, the influence of the seeding method on the distribution of spiders, which resulted in being homogeneous.

Margin strips should be a factor to consider for IPM (Riechert, 1999; Sunderland & Greenstone, 1999; Liljesthrom *et al.*, 2002). However, rational use of pesticides is necessary in order to preserve natural enemies because of the direct and indirect benefits for producers as a sustainable ecological equilibrium would be reached.

CONCLUSIONS

- The most frequent spider family in the herbaceous layer of margins of the soybean crop was Oxyopidae, while Lycosidae was the most frequent in the lower layer;
- Margin strips of soybean crops contribute to the colonization of spiders of aerial habits towards the crop. They also promote re-colonization following pesticide applications, since they act as shelter areas. Lower effects were observed on spiders of terrestrial habits; and
- The population distribution of spiders of terrestrial habits was homogeneous in a directly seeded crop, which produced an enhanced pest control capacity of these predators.

Acknowledgments — To the Universidad Nacional del Litoral for the funding in the program CAI+D'96 (Res. "C.S. Nº 105/88"), without which it would not have been possible to perform these trials.

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