HORIZONTAL AND VERTICAL DISTRIBUTION OF SPIDERS (ARANEAE) IN SUNFLOWERS

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ABSTRACT.   Sunflowers are an increasingly important crop plant in the Czech Republic. The spider fauna of this crop has not been investigated yet. The aim of this study was to monitor the spider fauna of sunflowers and to study the seasonal change in the spatial and vertical distribution of this fauna. For this purpose a small experimental area was used where spiders on each single leave of 50 sunflower plants were visually checked at monthly intervals from spring until autumn. The density of spiders increased during the season reaching a maximum of seven spiders/plant in the autumn shortly before harvest. The spatial distribution changed accordingly, being random in spring and early summer and normal or aggregated toward late summer. Two spider species, *Neottiura bimaculata* and *Theridion impressum* (Theridiidae), dominated (96% of all individuals) throughout the season. These two species exhibited a different microhabitat preference: *N. bimaculata* individuals were found particularly on the lower sunflower leaves, *T. impressum* preferred higher leaves. The density of the spiders (per leaf) was independent of the density of two dominant pest species, aphids and leafhoppers.

Keywords: Aphids, spatial distribution, agrobiocenosis, stratification, colonization

Although sunflowers are considered the second most important oilseed crop in the world (Cobia & Zimmer 1978), in the Czech Republic their importance was not recognized until recently when the current production had not been able to cover the need of our food industry (Jirátko et al. 1996). Since then the planted area has enlarged mainly in the southeastern part of the country where the warmer climate provides suitable conditions for a high production.

In its native region, i.e. North America, the sunflower has many pests (Charlet & Brewer 1998). Thus it thrives better in foreign countries because it has left a multitude of pests and diseases behind. This is particularly true for Europe. In the Czech Republic the sunflower plants are attacked by only a few pests: aphids, leafhoppers, moths and heteropterans (Jirátko et al. 1996).

The fauna of natural enemies of sunflower pests has been so far investigated only outside Europe. It was found to be composed of various heteropterans, lacewings, coccinellids, ants and parasitoids (Lynch & Garner 1980; Boica Junior et al. 1984; Men & Thakre 1998). Spiders were also among the most abundant and important predators (Seiler et al. 1987; Royer & Walgenbach 1991). For example, an araneid species, *Neoscona nautica* (L. Koch 1875), was found to prey on aphids and other pests on sunflower (Singla 1999).

As the fauna of predators occurring on sunflowers has not been investigated in Europe, the first aim of this study was to monitor spiders, particularly the change in their temporal and spatial distribution in a sunflower plot. Another aim was to observe the vertical distribution of the most abundant species of spiders on sunflowers. Very little attention has been paid to the stratification of spider fauna in agroecosystems (exceptions are He et al. 1995; Hao et al. 2000), obviously due to the intensive effort required for such investigation (Holland et al. 2004).

METHODS

The study was performed in Praha-Ruzyně, the Czech Republic (50°06′N, 14°15′E, faunistic grid no. 5951). The sunflowers were planted in April 2003 in rows 80 cm apart, at a distance of 30 cm from one seedling to another. The total area was about 2,000 m². In the middle of this area, an experimental plot (4 m × 7 m) including 50 plants was selected. The position (coordinates relative to the left lower corner of the plot) of each plant within the experimental plot was mapped.

The investigation began in late May when sunflower plants were 10 cm tall and termi-

Table 1.—List of spiders recorded species on the sunflowers during one season. Numbers are total records and the percentage from the total number.

Family/species	Number	%
Araneidae		
Aculepeira ceropegia (Walckenaer 1802)	11	0.70
Araneus sp.	1	0.06
Araniella sp.	4	0.20
Mangora acalypha (Walckenaer 1802)	1	0.06
Theridiidae		
Enoplognatha sp.	19	1.20
Neottiura bimaculata (Linnaeus 1767)	282	17.10
Theridion impressum L. Koch 1881	1301	79.20
Theridion varians Hahn 1833	2	0.11
Linyphiidae		
Microlinyphia pusilla (Sundevall 1830)	15	0.90
Thomisidae		
Xysticus sp.	6	0.40
Dictynidae		
Dictyna sp.	1	0.06
Total	1643	

nated in September shortly before harvest. Plants in the selected plot were examined at monthly intervals, i.e. altogether five times during the season. On each examination date every single leaf (upper and lower surface) of each of 50 plants was visually inspected to record the number of spiders present. The leaves were gently inspected not to disturb present spiders. The height of each plant was recorded on each date too. The spiders were not sampled, only visually inspected in order to record their change during the seasons. Further, on each date 25 plants were selected outside the experimental plot. On each plant one leaf was sampled in order to examine the number of spiders, aphids (unidentified), leafhoppers (unidentified) and other insects. All spiders were identified to species, if possible, or to a genus. Juvenile theridiid spiders were identified using Pekár (1999).

Statistical analyses were performed using STATISTICA (StatSoft). Distribution of spiders at each observation date was tested using Kolmogorov-Smirnov test (KST) for normality. Linear regression models (LM) were used to study the relationship between density and the season and the relationship between prey and spider densities. Since the data did not follow a normal distribution, log-transformation was used prior to analysis. Horizontal distribution of spiders in the study plot was studied using graphical spatial analysis. The analysis projects a three-dimensional dataset that includes two-dimensional coordinates of each plant and the spider density for each plant on a two-dimensional plane. The gradient of density is displayed as shades of gray with white color standing from 0 and black standing for the maximum density. The contours of density were modelled using distance weighted least-square method. Numbers represent means $\pm$ standard error throughout the text.

RESULTS

Horizontal distribution.—More than 1600 individual spiders were observed during the study (Table 1). The majority of spiders (99%) were represented by theridiids. Two spider species, *T. impressum* L. Koch 1881 and *Neottiura bimaculata* (Linnaeus 1767) (both Theridiidae), accounted for 98% of all spiders, with the former species making up 79% of the spider fauna. The density of spiders on sunflowers increased over the study season. On 28 May 2003, there were 0.27 ± 0.09 spiders per plant. On 25 June, the density increased to 1.49 ± 0.26 and on 23 July it was 1.12 ± 0.20 individuals/plant. On 20 August, the density further increased to 6.78 ± 0.68 and on
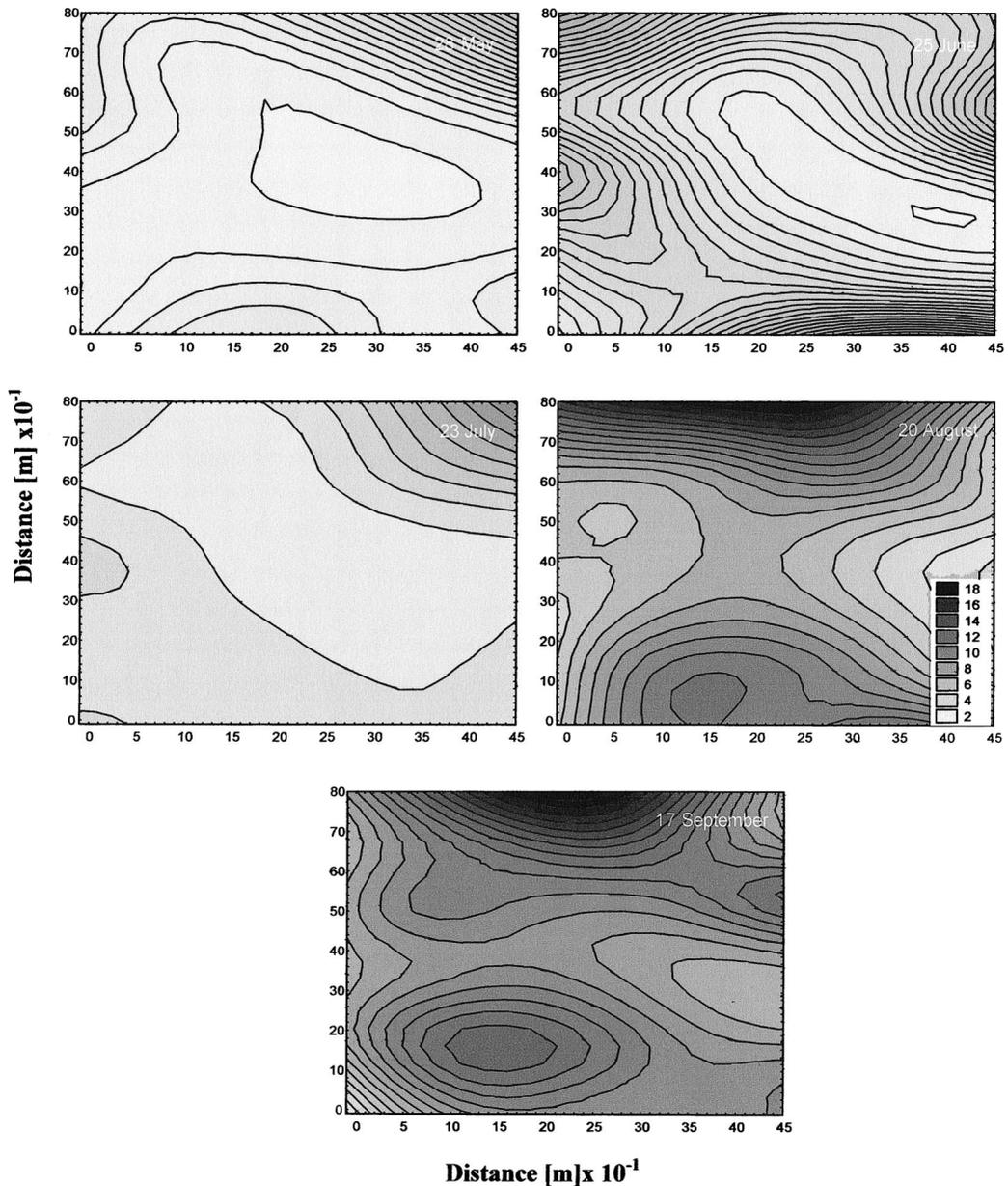
Figure 1.—Seasonal change in the spatial distribution of spiders on the sunflower plot. The graph represents the study plot. The shades of gray identify spider density (per plant) on individual plants: the darker the shade the higher number of individuals. Contours of densities were modelled using least-square method. Data from 50 plants in one 4 m × 7 m plot, inspected repeatedly.

17 September it was 6.98 ± 0.76 spiders per plant. The overall density thus increased following a linear model y = −0.48 + 0.07*× (LM, R^2 = 0.91, P < 0.04). The average increment was thus 3.5 spiders/plot/day.

Although the mean spider density of the entire plot increased during the season, detailed analysis of each individual plant revealed that there was a change of density within the plot. The highest increase (5.7 times on average) in the density was recorded from July–August, i.e. in the period following breeding when spider density increased on 88% of the plants. A less pronounced increase was found from
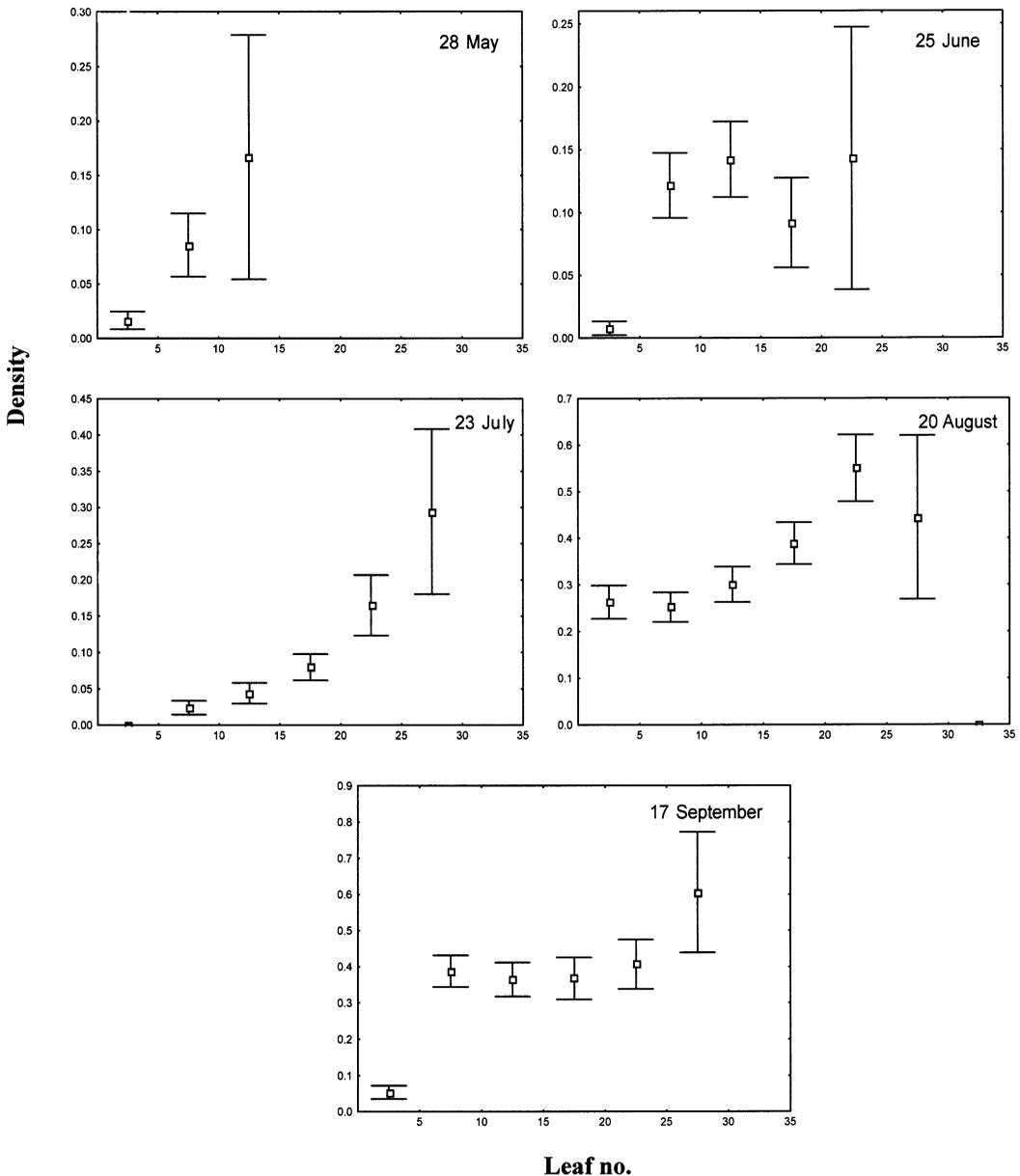
Density

Leaf no.

Figure 2.—Seasonal changes in the vertical distribution of spider density (mean ± SE) on sunflower plants. Leaves are numbered from the bottom to the top of the plants and grouped into height categories of 5 leaves.

May–June (1.2 times) when the spider density increased on 49% of the plants. From June–July the average density decreased (0.37 times) on 41% of the plants. Finally, from August–September the average density also decreased (0.2 times) on 53% of the plants.

The distribution of spiders changed during the season as follows (Fig. 1): in May, June and July the distribution was rather random (KST, $P < 0.01$). In August and September it approached a normal distribution (KST, $P > 0.10$). But the analysis of the spatial distribution showed that the distribution was in fact aggregated toward the end of season with two patches of high spider density on the margin of the study plot (Fig. 1).
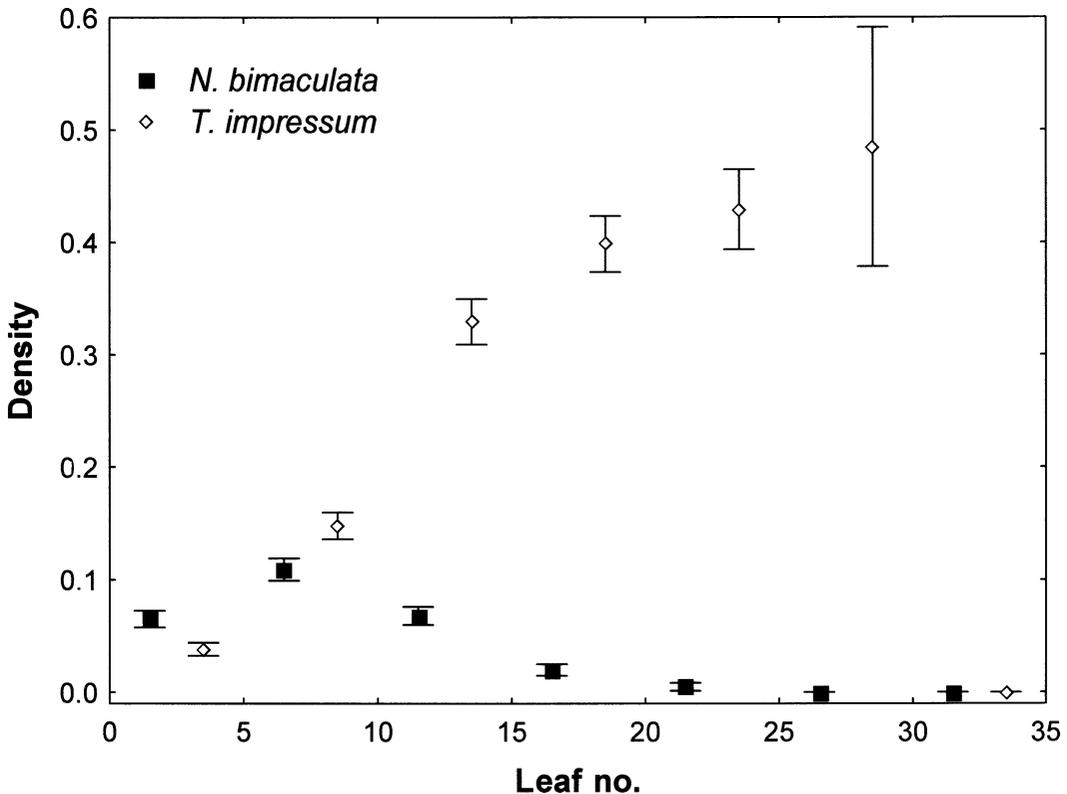
Figure 3.—Mean (± SE) density of *N. bimaculata* and *T. impressum* on sunflower leaves (numbered from the bottom to the top of the plants and grouped into height categories of 5 leaves). Data from July and August pooled.

Vertical distribution.—The stratification of spiders did not change dramatically during the season. Temporal analysis showed that the spiders were always more abundant on the upper leaves, except for the terminals, which formed the flower (Fig. 2). The distribution of the two most abundant species, *N. bimaculata* and *T. impressum*, differed. While *N. bimaculata* was mainly found in the lower parts of the plants, *T. impressum* dominated the upper parts (Fig. 3).

The vertical distribution of aphids on sunflower leaves is shown in Fig. 4. Unlike spiders, aphids were more abundant on lower than on upper leaves. The density of spiders (per leaf) was independent of the density of aphids and/or leafhoppers (LM, $P > 0.23$).

DISCUSSION

Observed composition of spiders on sunflowers was similar to the canopy fauna of corn, soybean or rape in Europe (e.g., Alderweireldt 1989; Nyffeler 1982), i.e., in all these studies it was dominated by theridiid spiders. Some differences were observed in comparison with other crops, which presumably result from the different plant structure. Large sunflower leaves do not provide suitable attachments for the webs of araneid spiders, which are therefore more abundant on structurally more complex plants, such as soybean or rape. In North America, the sunflower was dominated by other spider guilds: thomisid and salticid spiders (Seiler et al. 1987). This is because the spider fauna of agroecosystems in North America is different from that in Europe (Nyffeler & Sunderland 2003).

Increase of spider density with the development of crops was observed in many seasonal crops including sunflowers (Royer & Walgenbach 1991; Duffield & Reddy 1997). In this study it was caused by the influx of spiders, mainly theridiids, from neighboring habitats, which is taking place mainly in the spring (Blandenier & Fürst 1997). The new
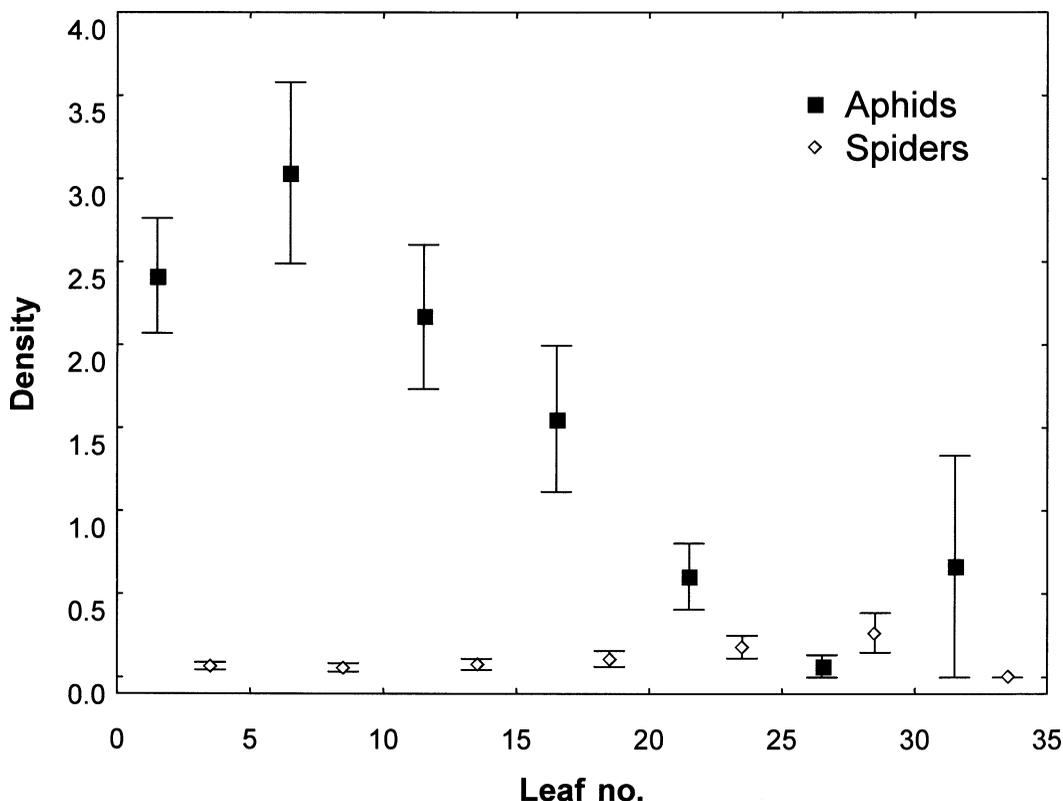
Figure 4.—Mean (± SE) density of spiders and aphids on sunflower leaves (numbered from the bottom to the top of the plants and grouped into height categories of 5 leaves). Data from July and August pooled.

individuals settled randomly in the plot, indicated by their random distribution. In June the spiders reached maturity and mated, followed by a decline in spider density resulting from the death of males. In July they reproduced (Pekár 1999) and the newborn spiderlings dispersed locally. As a result the distribution became aggregated. Such distribution has been rarely documented for spiders in agroecosystems (e.g., Yan 1988; Nyffeler & Breene 1992). Linyphiid spiders showed no evidence of spatial pattern (Thomas et al. 1990; Holland et al. 2004) probably because of their high dispersal ability. A change from random to aggregated distribution as observed in this study was found also by Cang et al. (1989). They recorded that a linyphiid spider *Hylyphantes graminicola* (Sundevall 1830) had a random distribution at low population densities but aggregated at higher population densities in cotton.

Spider densities vary not only temporally but also between different crops. In general,

the density is expected to be a function of plant size and complexity, thus smaller plants host fewer spiders than tall ones. In accordance with this, Liu et al. (2003) observed a maximum density of four spiders per cotton plant, whereas Zhang et al. (1997) found a maximum of six spiders per corn plant.

The two principal species of theridiid spiders seem to utilize different strata for their webs. Such dichotomous but syntopic web placement may be a result of competition or site preference. In an experimental work on the competition between two sympatric linyphiid spiders, Herberstein (1998) found that two species, *Frontinellina frutetorum* (C.L. Koch 1834) and *Neriene radiata* (Walckenaer 1842), compete for web space. As a result, they placed their webs in different strata when occurring syntopically. No web displacement was observed for the theridiid spiders. *Neottiura bimaculata* was never found in the upper strata even on plants where *T. impressum* was absent. Thus it is possible that these two spe-

cies have different microhabitat requirements and do not compete mutually for space. Similar preference for a certain stratum has also been observed in other spider species (e.g. Kim et al. 1989).

In total the number of spiders was higher in the upper than in the lower stratum in this study. In contrast to this, Liu et al. (2003) found that there were more spiders in the lower parts of cotton plants than in the upper parts. Similar results were obtained from a study on rice (Anwaru & Ibrahim 1995). But higher spider densities in the lower strata observed in these studies are due to the inclusion of epigeic spiders. Sunflower plants are not used as foraging sites by epigeic spiders as the leaves are high above the ground so it might be difficult for epigeic spiders to climb sunflower plants.

The number of aphids in this study was higher in the lower strata. Similarly, aphids on chili plants were more abundant in the lower than in higher strata (Idris & Mohamad 2002). Rarely has the distribution of predators in arable land been observed to be spatially dependent on their prey (Wang & Yan 1989). In a study of Holland et al. (2004) linyphiids showed no spatial association with aphids, though being their frequent prey. Pekár (2000) analyzed the diet of *T. impressum* on sunflower. He found it was composed mainly of aphids. Therefore it was expected that the spiders would be more abundant in the lower leaves where aphids were more abundant. But it was not, presumably due to counter effect of other factors, either biotic or abiotic.

ACKNOWLEDGMENTS

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