

THE EFFECTS OF ORGANIC FARMING ON SURFACE-ACTIVE SPIDER (ARANEAE) ASSEMBLAGES IN WHEAT IN SOUTHERN ENGLAND, UK

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ABSTRACT. Spiders were sampled from organically farmed and conventionally farmed winter wheat fields at three sites in southern England, UK, using pitfall traps. A range of vegetation variables was also recorded from each field. We identified 56 species of spiders from 8609 individuals in our study samples. Most species caught belong to the Linyphiidae, with especially high captures of *Oedothorax* spp., *Erigone* spp., *Lepthyphantes tenuis* (Blackwall 1852), *Bathyphantes gracilis* (Blackwall 1841) and *Meioneta rustrestris* (C.L. Koch 1836). The Lycosidae were also well represented by *Pardosa* and *Trochosa* spp., although the samples were largely dominated by the presence of *Pardosa palustris* (Linnaeus 1758). More spiders, and more species of spiders, were captured from organic than from conventional fields. Principal Component Analyses suggested that the spider communities differed between the contrasting systems. Our results showed that more spiders, and a greater number of spider species, were captured with increasing abundance of understorey vegetation within the crop, both overall and within each farming system.

The intensification of arable agriculture over the last 50 years has been associated with substantial losses of biodiversity (Potts 1991; Gibbons et al. 1993; Firbank et al. 1994; Stewart et al. 1994). Several factors have been implicated, including loss of habitat (e.g., Moore 1962; Webb 1990), the direct and indirect effects of pesticides and herbicides (e.g., Newton & Wyllie 1992; Potts & Aebischer 1991), increased use of drainage and inorganic fertilizers (Fuller 1987), the loss and degradation of field boundary features (Barr et al. 1993) and changing patterns of cropping (Gibbons et al. 1993). Over the last ten years or so, there has been an increased awareness of environmental, health and amenity aspects of agriculture which, together with the need to reduce food surpluses within the European Union during the 1980s, has led to an increase in interest in low-input and organic agriculture. Such farming systems tend to be less productive in terms of yield per hectare than

high-input systems, but this can be outweighed by savings on inputs and by improved product quality and environmental benefits (Lampkin 1990; El Titi 1991; Jordan & Hutcheon 1995). For example, results from the Boxworth Project showed that reduction in pesticide use had a number of positive effects on the invertebrate fauna of arable fields (Grieg-Smith et al. 1991).

In this paper we present data on spider (Araneae) assemblages in cereal crops on three pairs of organic and conventional farms in southern England, UK. Spiders are increasingly studied in agroecosystems because they are recognized as a significant component of the polyphagous complex (Sunderland et al. 1986; Young & Edwards 1990). Spiders have been shown to be useful in controlling aphid increase (DeClercq & Pietraszko 1983) particularly in spring and early summer (Alderweireldt 1994; Sunderland et al. 1986) when aerial activity is at a peak (Bishop 1990; Bishop & Riechert 1990) and the initial population of aphids can be restrained.

The success of spiders as biocontrol agents depends on the type and duration of management practices within each field (Riechert & Lockley 1984). Annual plowing results in a

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reduced spider diversity (Haskins & Shaddy 1986); and pesticides, although not always seen as disruptive (Riechert & Lockley 1984), can decrease the spider population size for more than a month after application (Clausen 1990). However, not all agricultural practices exert a negative impact on spider communities. The introduction of legume species for pasture improvement using tillage practices, for example, can maintain the fields' spider communities because disturbance is kept to a minimum (Mangan & Byers 1989). Furthermore, irrigation of a crop once it has been established can increase the quality of habitat for lycosid spiders due to the larger plant canopy (Agnew & Smith 1989).

Organic farming systems are the extreme expression of low-input agriculture in the UK. Such systems could potentially sustain larger or more diverse spider communities than more intensive farming systems because of the absence of agrochemical use and the typically more complex crop rotations within the system. For example, Gluck & Ingrish (1990) showed that intensively farmed fields had fewer spider species, and lower activity of Lycosidae, than bio-dynamic fields. Our study aimed to characterize the spider communities of organic and conventional winter wheat fields in southern England, UK, and quantify any differences which might exist between the spider assemblages of the two systems. We discuss the implications of any differences for spider conservation in contrasting arable systems.

METHODS

The study was conducted on three pairs of organic and conventionally managed farms in southern England, UK. Two sites were in Gloucestershire (Broadfield, ST8895, and Harnhill, SP 0702) and one was in Oxfordshire (North Aston, SP4799). All fields were in winter wheat. Organic and conventional fields at any one site were located close together to minimize variations in soil type. Spiders were sampled in three organic and three conventional fields at each site, using pitfall trapping. Although experiments have shown that pitfall trap catches can be affected by a number of factors such as differing activity rates and habitat structure (Topping 1993; Topping & Sunderland 1992), pitfall trapping is nonetheless a valuable and widely used

method of investigating the activity of surface-dwelling invertebrates (e.g., Luff & Eyre 1988; Merrett & Snazell 1983), as long as the results are interpreted in terms of catch size and composition rather than mean densities.

Pitfall trapping was conducted at the end of May and the end of June in 1995. Twelve pitfall traps (plastic cups of 7 cm diameter, 8 cm deep) were placed in a grid formation in each of the 18 fields under study, with traps approximately 24 m apart. Each trap was set with a 70% ethylene glycol solution and was emptied after 10 days. No traps were lost or flooded. The samples were stored in a 70% ethanol solution during sorting and identification to species level. Nomenclature follows Roberts (1987). Voucher specimens from the study have been deposited at the University Museum, Parks Road, Oxford, UK (Organic Farming Collection).

Vegetation was sampled at the same time as each pitfall session. Quadrats, 0.5 m², were placed adjacent to each of the 216 pitfall traps. We recorded the number of crop stems, crop height, and percentage cover of non-crop grasses, non-woody broad-leaved species, leaf litter and bare ground within each quadrat. For the purposes of analysis, the sample units within individual fields were amalgamated to give a single data point for each field on each sample date.

Data analysis.—We used SAS software for all analyses (SAS Institute 1988). In the analysis for testing for organic versus conventional differences, simple two-way ANOVAs were used (SAS PROC GLM). Sites were treated as blocks, and the fields as replicates of the management systems within the sites.

Comparison of organic and conventional effects: The standard method of analysis for designs of this format, with a fixed effect (management system) replicated within a random effect (site) is a mixed model ANOVA using the interaction mean square as the denominator for the fixed effect. However, as McKone & Lively (1993) point out, this approach has low power in detecting a general treatment effect where few sites are sampled. Here, where we sampled only three sites, we adopted an alternative analysis suggested by these authors and applied an analysis with treatment nested within site. It should be noted that significant treatment effects in this

Table 1.—Total abundance of each species recorded from samples taken in May. Proportion of sample formed by each species from indicated field types and sites given in parentheses.

Species	Broadfield		Harnhill		North Aston	
	Conven- tional	Organic	Conven- tional	Organic	Conven- tional	Organic
Thomisidae						
<i>Xysticus cristatus</i> (Clerck 1757)	0 (0)	0 (0)	1 (0.00)	6 (0.01)	0 (0)	0 (0)
<i>Ozyptila praticola</i> (C.L.K. 1837)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.00)
Lycosidae						
<i>Pardosa palustris</i> (Linn. 1758)	2 (0.02)	16 (0.14)	115 (0.37)	167 (0.35)	32 (0.04)	5 (0.02)
<i>P. pullata</i> (Clerck 1757)	0 (0)	0 (0)	1 (0.00)	3 (0.01)	1 (0.00)	0 (0)
<i>P. prativaga</i> (L.K. 1870)	3 (0.03)	2 (0.02)	7 (0.02)	11 (0.02)	3 (0.00)	16 (0.05)
<i>P. amentata</i> (Clerck 1757)	3 (0.03)	1 (0.01)	1 (0.00)	1 (0.00)	0 (0.00)	0 (0)
<i>Trochosa rucicola</i> (Deg. 1778)	4 (0.04)	0 (0)	0 (0.00)	6 (0.01)	3 (0.00)	1 (0.00)
<i>T. terricola</i> Thor. 1856	0 (0)	1 (0.01)	0 (0.00)	0 (0)	0 (0)	0 (0)
Pisauridae						
<i>Pisaura mirabilis</i> (Clerck 1757)	0 (0)	0 (0)	0 (0)	1 (0.00)	0 (0)	0 (0)
Tetragnathidae						
<i>Pachygnatha clercki</i> Sund. 1823	0 (0)	0 (0)	0 (0)	0 (0.00)	0 (0)	10 (0.03)
<i>P. degeeri</i> Sund. 1830	2 (0.02)	3 (0.03)	22 (0.07)	18 (0.04)	13 (0.02)	0 (0)
Linyphiidae						
<i>Ceratinella brevipes</i> (West. 1851)	0 (0)	0 (0)	1 (0.00)	0 (0)	0 (0)	0 (0)
<i>Walckenaeria nudipalpis</i> (West. 1851)	0 (0)	0 (0)	1 (0.00)	1 (0.00)	0 (0)	4 (0.01)
<i>W. vigilax</i> (Bl. 1853)	0 (0)	0 (0)	6 (0.02)	2 (0.00)	1 (0.00)	0 (0)
<i>W. antica</i> (Wid. 1834)	0 (0)	0 (0)	0 (0.00)	1 (0.00)	0 (0.00)	0 (0)
<i>Dicymbium nigrum</i> (Bl. 1834)	0 (0)	0 (0)	0 (0.00)	1 (0.00)	0 (0)	1 (0.00)
<i>Dismodicus bifrons</i> (Bl. 1841)	0 (0)	1 (0.01)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Pocadicnemis juncea</i> L. & M. 1953	1 (0.01)	0 (0)	0 (0)	0 (0)	1 (0.00)	0 (0)
<i>Oedothorax fuscus</i> (Bl. 1834)	0 (0)	1 (0.01)	0 (0)	2 (0.00)	94 (0.11)	3 (0.01)
<i>O. retusus</i> (West. 1851)	1 (0.01)	1 (0.01)	6 (0.02)	2 (0.00)	4 (0.00)	7 (0.02)
<i>O. apicatus</i> (Bl. 1850)	0 (0)	0 (0)	11 (0.04)	17 (0.04)	5 (0.01)	1 (0.00)
<i>Troxochrus scabriculus</i> (West. 1851)	0 (0)	0 (0)	0 (0)	1 (0.00)	0 (0)	0 (0)
<i>Gongylidiellum vivum</i> (Camb. 1875)	1 (0.01)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Micrargus subaequalis</i> (West. 1851)	0 (0)	1 (0.01)	0 (0)	0 (0)	2 (0.00)	0 (0)
<i>Savigna frontata</i> (Bl. 1833)	5 (0.05)	1 (0.01)	5 (0.02)	2 (0.00)	2 (0.00)	6 (0.02)
<i>Diplocephalus latifrons</i> (Camb. 1863)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.00)
<i>Araeoncus humilis</i> (Bl. 1841)	0 (0)	0 (0)	0 (0)	2 (0.00)	0 (0)	0 (0)
<i>Milleriana inerrans</i> (Camb. 1885)	7 (0.07)	34 (0.29)	3 (0.01)	15 (0.03)	34 (0.04)	4 (0.01)
<i>Erigone dentipalpis</i> (Wid. 1834)	3 (0.03)	3 (0.03)	3 (0.01)	20 (0.04)	175 (0.21)	8 (0.03)

Table 1.—Continued.

Species	Broadfield		Harnhill		North Aston	
	Conventional	Organic	Conventional	Organic	Conventional	Organic
<i>E. atra</i> Bl. 1833	35 (0.35)	24 (0.21)	63 (0.20)	148 (0.31)	403 (0.48)	188 (0.63)
<i>E. promiscua</i> (Camb. 1872)	1 (0.01)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Halorates distinctus</i> (Sim. 1884)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.00)
<i>Porrhomma pygmaeum</i> (Bl. 1834)	1 (0.01)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>P. microphthalmum</i> (Camb. 1871)	1 (0.01)	4 (0.03)	3 (0.01)	4 (0.01)	1 (0.00)	3 (0.01)
<i>Meioneta rurestris</i> (C.L.K. 1836)	2 (0.02)	6 (0.05)	2 (0.01)	12 (0.03)	9 (0.01)	6 (0.02)
<i>Bathyphantes gracilis</i> (Bl. 1841)	5 (0.05)	4 (0.03)	22 (0.07)	17 (0.04)	22 (0.03)	11 (0.04)
<i>Diplostyla concolor</i> (Wid. 1834)	2 (0.02)	0 (0)	0 (0)	0 (0)	0 (0)	7 (0.02)
<i>Lepthyphantes tenuis</i> (Bl. 1852)	22 (0.22)	14 (0.12)	37 (0.12)	10 (0.02)	28 (0.03)	13 (0.04)
<i>Linyphia hortensis</i> Sund. 1830	0 (0)	0 (0)	0 (0)	1 (0.00)	0 (0)	0 (0)
<i>Neriene clathrata</i> (Sund. 1830)	0 (0)	0 (0)	0 (0)	1 (0.00)	0 (0)	0 (0)
<i>Allomenga scopigera</i> (Grube 1859)	0 (0)	0 (0)	1 (0.00)	0 (0.00)	0 (0)	0 (0)

analysis cannot be generalized to the wider population of sites.

Community analyses: To detect patterns in the species composition of the spider assemblages at each of the two sample dates, we used Principal Components Analysis (PCA) on the standardized species-sample matrices (SAS PROC FACTOR). PCA is a data reduction technique which allows patterns in a multivariate data set to be represented in a lower dimensional space (Pielou 1984). The method derives new axes (components) of variation in the data-set which summarize as much of the variation in the original data as possible. Hence the location of samples on biplots of their scores on these derived axes is related to their spider species composition. Samples with similar compositions appear closer together. Species abundances were $\log(x + 1)$ transformed to improve normality. Only species found in nine or more of the 18 samples in each analysis were included.

Vegetation variables: To relate the vegetation data to the size and composition of spider catches, the non-independence of samples within fields and fields within sites was first

eliminated from both variable sets using hierarchical regression. This generated residual values free of site and field co-variation. Simple correlation analysis was then used to estimate the degree of relationship between these residuals. This is exactly equivalent to Stearns' phylogenetic subtraction method for investigating relationships between life history characteristics independent of phylogeny (Harvey & Pagel 1991).

RESULTS

Spider assemblages.—We identified 56 species from 8609 individuals in our study samples (Tables 1, 2). Most species caught belong to the family Linyphiidae and are commonly recorded on agricultural land in the UK. (Alderweireldt 1994; Topping & Sunderland 1994), with high captures of *Oedothorax* spp., *Erigone* spp., *Lepthyphantes tenuis* (Blackwall 1852), *Bathyphantes gracilis* (Blackwall 1841) and *Meioneta rurestris* (C.L. Koch 1836). The Lycosidae were well represented by *Pardosa* and *Trochosa* spp., although the samples were largely dominated by the presence of *Pardosa palustris* (Linnaeus

Table 2.—Total abundance of each species recorded from samples taken in June. Proportion of sample formed by each species from indicated field types and sites given in parentheses.

Species	Broadfield		Harnhill		North Aston	
	Conven- tional	Organic	Conven- tional	Organic	Conven- tional	Organic
Clubionidae						
<i>Clubiona reclusa</i> Camb. 1863	0 (0)	1 (0.00)	0 (0)	0 (0)	0 (0)	0 (0)
<i>C. terrestris</i> West. 1851	0 (0)	1 (0.00)	0 (0)	0 (0)	0 (0)	0 (0)
Thomisidae						
<i>Xysticus cristatus</i> (Clerck 1757)	1 (0.00)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Tibellus oblongus</i> (Walck. 1802)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.00)	0 (0)
Lycosidae						
<i>Pardosa palustris</i> (Linn. 1758)	1 (0.00)	7 (0.02)	107 (0.08)	58 (0.07)	20 (0.01)	0 (0)
<i>P. pullata</i> (Clerck 1757)	1 (0.00)	2 (0.00)	0 (0)	0 (0)	1 (0)	0 (0)
<i>P. prativaga</i> (L.K. 1870)	1 (0.00)	1 (0.00)	1 (0.00)	0 (0)	0 (0)	2 (0.00)
<i>P. amentata</i> (Clerck 1757)	3 (0.01)	3 (0.01)	0 (0)	0 (0)	1 (0.00)	0 (0)
<i>Trochosa ruricola</i> (Deg. 1778)	1 (0.00)	0 (0)	2 (0.00)	0 (0)	2 (0.00)	0 (0)
<i>T. terricola</i> Thor. 1856	0 (0)	1 (0.00)	0 (0)	0 (0)	0 (0)	0 (0)
Pisauridae						
<i>Pisaura mirabilis</i> (Clerck 1757)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.00)
Agelenidae						
<i>Tetrix denticulata</i> (Oliv. 1789)	0 (0)	0 (0)	0 (0)	2 (0.00)	0 (0)	0 (0)
Theridiidae						
<i>Robertus neglectus</i> (Camb. 1871)	0 (0)	0 (0)	2 (0.00)	0 (0)	0 (0)	0 (0)
Tetragnathidae						
<i>Pachygnatha degeeri</i> Sund. 1830	1 (0.00)	0 (0)	6 (0.00)	0 (0)	7 (0.00)	0 (0)
Linyphiidae						
<i>Walckenaeria nudipalpis</i> (West. 1851)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (0.00)
<i>W. vigilax</i> (Bl. 1853)	2 (0.00)	1 (0.00)	7 (0.01)	23 (0.03)	2 (0.00)	0 (0)
<i>W. atrotibialis</i> (Camb. 1878)	0 (0)	0 (0)	2 (0.00)	0 (0)	1 (0.00)	0 (0)
<i>Oedothorax fuscus</i> (Bl. 1834)	53 (0.10)	86 (0.19)	48 (0.04)	66 (0.08)	478 (0.24)	25 (0.06)
<i>O. retusus</i> (West. 1851)	16 (0.03)	44 (0.10)	37 (0.03)	39 (0.05)	171 (0.09)	18 (0.04)
<i>O. apicatus</i> (Bl. 1850)	16 (0.03)	13 (0.03)	606 (0.47)	285 (0.34)	101 (0.05)	29 (0.07)
<i>Troxochrus scabriculus</i> (West. 1851)	0 (0)	0 (0)	0 (0)	2 (0.00)	0 (0)	0 (0)
<i>Gongyliidiellum vivum</i> (Camb. 1875)	1 (0.00)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Micrargus subaequalis</i> (West. 1851)	1 (0.00)	2 (0.00)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Erigonella hiemalis</i> (Bl. 1841)	1 (0.00)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Savigna frontata</i> (Bl. 1833)	2 (0.00)	0 (0)	2 (0.00)	0 (0)	8 (0.00)	1 (0.00)
<i>Diplocephalus cristatus</i> (Bl. 1833)	0 (0)	0 (0)	0 (0)	2 (0.00)	0 (0)	0 (0)

Table 2.—Continued.

Species	Broadfield		Harnhill		North Aston	
	Conven- tional	Organic	Conven- tional	Organic	Conven- tional	Organic
<i>Araeoncus humilis</i> (Bl. 1841)	0 (0)	0 (0)	1 (0.00)	0 (0)	0 (0)	0 (0)
<i>Milleriana inerrans</i> (Camb. 1885)	24 (0.05)	15 (0.03)	1 (0.00)	19 (0.02)	98 (0.05)	3 (0.01)
<i>Erigone dentipalpis</i> (Wid. 1834)	30 (0.06)	6 (0.01)	2 (0)	14 (0.02)	209 (0.10)	22 (0.05)
<i>E. atra</i> Bl. 1833	220 (0.42)	75 (0.16)	223 (0.17)	172 (0.2)	737 (0.37)	208 (0.50)
<i>E. longipalpis</i> (Sund. 1830)	0 (0)	0 (0)	0 (0)	0 (0)	3 (0.00)	0 (0)
<i>Leptorhoptrum robustum</i> (West. 1851)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.00)	0 (0)
<i>Porrhomma oblitum</i> (Camb. 1871)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.00)
<i>P. microphthalmum</i> (Camb. 1871)	0 (0)	1 (0.00)	0 (0)	0 (0)	2 (0.00)	3 (0.01)
<i>Agyneta subtilis</i> (Camb. 1863)	0 (0)	0 (0)	2 (0.00)	0 (0)	0 (0)	0 (0)
<i>A. decora</i> (Camb. 1871)	0 (0)	0 (0)	0 (0)	0 (0)	4 (0.00)	0 (0)
<i>Meioneta rurestris</i> (C.L.K. 1836)	82 (0.16)	107 (0.23)	84 (0.07)	121 (0.14)	60 (0.03)	14 (0.03)
<i>M. saxatilis</i> (Bl. 1844)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.00)	0 (0)
<i>Saaristoa abnormis</i> (Bl. 1841)	1 (0.00)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Bathyphantes gracilis</i> (Bl. 1841)	14 (0.03)	13 (0.03)	23 (0.02)	4 (0)	36 (0.02)	37 (0.09)
<i>Diplostyla concolor</i> (Wid. 1834)	1 (0.00)	1 (0.00)	0 (0)	0 (0)	1 (0.00)	0 (0)
<i>Leptyphantes tenuis</i> (Bl. 1852)	51 (0.10)	76 (0.17)	127 (0.10)	34 (0.04)	55 (0.03)	53 (0.13)

1758), a common predator in wheat fields (Nyffeler & Benz 1988). Three uncommon spider species were also captured during the study: *Robertus neglectus* (O.P.-Cambridge 1871) (Theridiidae), *Halorates distinctus* (Simon 1884) (Linyphiidae) and *Porrhomma oblitum* (O.P.-Cambridge 1871) (Linyphiidae). *H. distinctus* is associated with very damp environments, and the rare *P. oblitum* is thought to be subterranean, making small webs within the cracks in the soil (Roberts 1987).

Species restrictions.—When both sampling dates were combined, three species were captured only in organically farmed fields. These were *Diplocephalus cristatus* (Blackwall 1833) (Linyphiidae), *Tetrix denticulata* (Olivier 1789) (Agelenidae) and *Pachygnatha clercki* (Sundevall 1823) (Tetragnathidae). Five different species, *Agyneta subtilis* (O.P.-Cambridge 1863) (Linyphiidae), *Agyneta decora* (O.P.-Cambridge 1871) (Linyphiidae), *Gongyliidium vivum* (O.P.-Cambridge 1875)

(Linyphiidae), *Erigone longipalpis* (Sundevall 1830) (Linyphiidae) and *R. neglectus* were captured exclusively in conventionally farmed fields. However, none of these eight species was caught at more than one site.

Catch size.—In late May, more spiders were caught on all three organic farms than on all three conventional farms. In the nested analysis this was significant only for North Aston ($F_{(1, 12)} = 9.5, P < 0.01$; Fig. 1). In late June, spider catches were larger at all sites. As in May, significantly more spiders were caught on the organic fields than the conventional fields at North Aston ($F_{(1, 12)} = 25.9, P = 0.001$; Fig. 1). Spider catches were larger on conventional than organic fields in June at the two other sites, although this was non-significant (Fig. 1).

Catch composition.—More species of spider were captured on organic than on conventional fields in late May; this effect was significant for the North Aston site ($F_{(1, 12)} =$

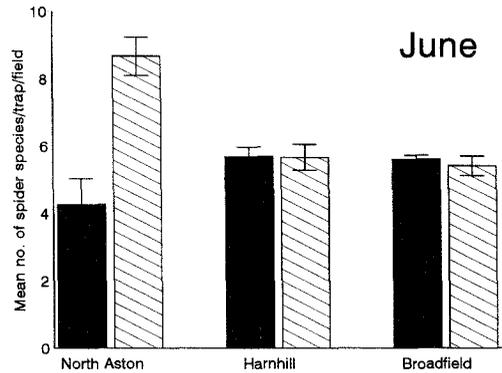
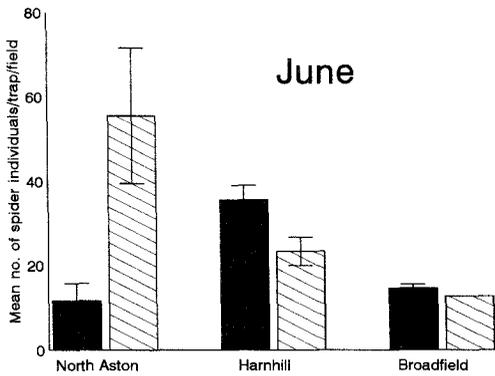
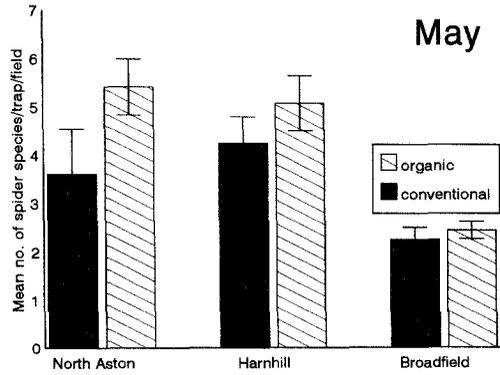
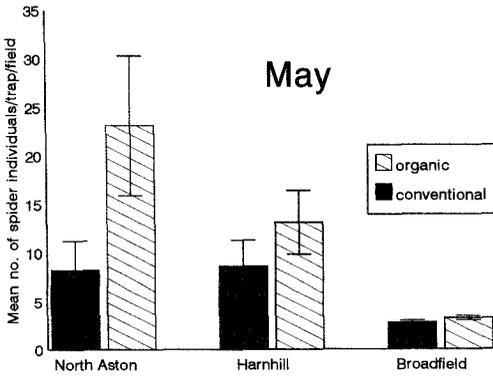


Figure 1.—Mean number of spider individuals caught per trap per field on organic and conventional fields at three sites in May and June.

Figure 2.—Mean number of spider species caught per trap per field on organic and conventional fields at three sites in May and June.

5.24, $P < 0.05$; Fig. 2). In June, significantly more species were again captured on organic fields at North Aston ($F_{(1, 12)} = 39.0, P < 0.001$), but catch composition was very similar between both systems at the other sites (Fig. 2).

Community results.—The Principal Components Analysis for the May sample summarized 47% of the overall variance in species abundance between the samples on the first two derived axes. A biplot of the location of the samples suggested that there were differences in the spider species composition both between sites and, within sites, between management systems (Fig. 3a). At the North Aston site the organic samples scored more highly on both axes, while at Harnhill organic samples were higher on the second axis alone. At Broadfield the organic samples scored highly on only the first axis. Inspection of the factor pattern for these axes revealed that the first

axis was principally related to the high capture of the species *P. palustris*, *B. gracilis*, *Pachygnatha degeeri* (Sundevall 1823) (Tetragnathidae), and *Oedothorax apicatus* (Blackwall 1850) (Linyphiidae) (loadings of 0.91, 0.54, 0.91 and 0.88, respectively). Highest loadings on the second axis were for *Erigone atra* (Blackwall 1833) (Linyphiidae), *Erigone dentipalpis* (Wider 1834) (Linyphiidae) and *Oedothorax fuscus* (Blackwall 1834) (Linyphiidae) (loadings of 0.76, 0.94 and 0.90, respectively).

The equivalent analysis for the June samples summarized 59% on the first two axes. In this sample round, the clearest resolution between sites and management systems was achieved with axes one and three (Fig. 3b). There was a tendency for organic samples from all sites to score higher on the first axis, and lower on the third, by comparison with

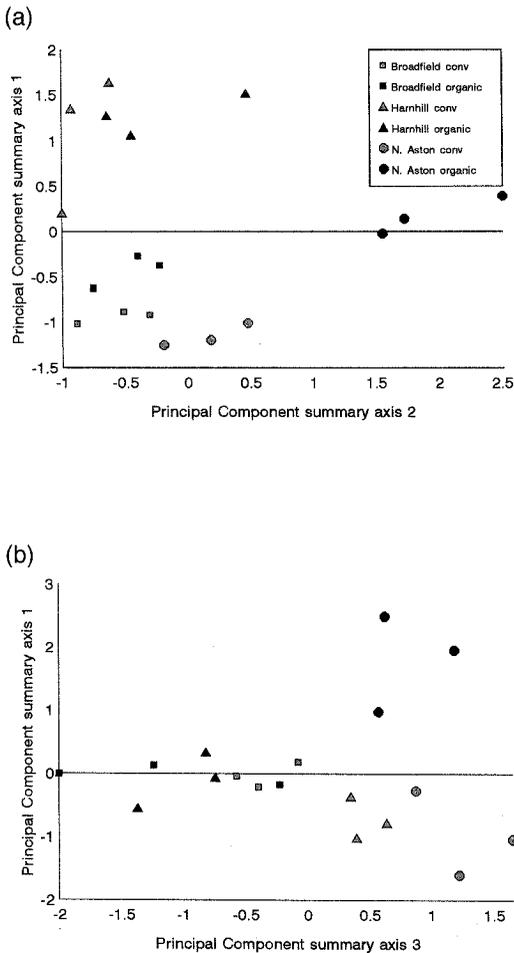


Figure 3.—Biplot showing location of organic and conventional fields with respect to first and second components derived from Principal Components Analysis applied to May sample (top graph), and first and third components derived from Principal Components Analysis applied to June sample (bottom graph).

samples from conventional fields. In this month, the species with highest loadings on the first axis were *E. atra*, *E. dentipalpis*, *Milleriana inerrans* (O.P.-Cambridge 1885) (Linyphiidae), *O. fuscus* and *Oedothorax retusus* (Westring 1851) (Linyphiidae) (0.59, 0.82, 0.95 and 0.78, respectively). Two species scored highly on the third: *M. rurestris* and *B. gracilis* (minus 0.67 and 0.87).

Relationship between vegetation data, spider abundance and spider species richness.—A number of vegetation variables differed significantly between organic and con-

ventional systems (Table 3). In both rounds, understory vegetation (both dicotyledonous and monocotyledonous species) was substantially more abundant on organic fields at two out of the three sites. Conventional fields had a higher crop density than organic fields. Crop height tended to be higher on organic than on conventional fields, although the North Aston site did not show this effect. There were no consistent patterns for the percentage cover of leaf litter and bare ground in either system.

In both months, there were significant positive relationships between the numbers of spiders caught and the percentage cover of dicotyledonous species and grasses within the crop. These relationships were significant both overall, and within each management system. Most other relationships were non-significant (Table 4), and the relationships with crop density can be explained as artifacts of the confounding effects of crop management.

In general, the patterns between the number of spider species caught and the vegetation data were similar to those for catch size. There was an inconsistent relationship between crop height and number of spider species caught, with a tendency for the relationship to be negative, particularly in the organic system (Table 5). As with catch size, the species richness of catches tended to be positively associated with the percentage cover of dicotyledonous and monocotyledonous species within the crop.

DISCUSSION

Arable ecosystems worldwide, whether high or low input, are characterized by a marked instability compared with natural communities. Their temporal and spatial structure militates against the persistence of populations of less mobile species, and major disruptions such as harvest (Topping & Sunderland 1994) and plowing (Haskins & Shaddy 1986) have negative effects on spider assemblages and are likely to exert the most over-riding effects. Our results showed, though, that contrasting arable farming systems can result in detectable differences in spider communities. Both the number of spiders captured and the species richness of spider samples were higher in organic than conventional winter wheat fields, significantly so at one site. Furthermore, our Principal Component Analyses suggested that spider communities as a whole differed between the con-

Table 3.—Mean values for vegetation variables on organic and conventional fields at each site in May and June (standard errors in parentheses). *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$, ns not significant. See text for details of analysis.

Variable	Broadfield			Harnhill			North Aston		
	Conventional	Organic	Signif.	Conventional	Organic	Signif.	Conventional	Organic	Signif.
May									
crop density	101.4 (4.60)	42.4 (5.47)	***	105.0 (3.91)	79.1 (14.64)	*	127.4 (6.44)	106.3 (6.31)	ns
crop height	74.4 (1.14)	94.8 (0.95)	***	71.5 (3.48)	79.7 (2.21)	ns	87.4 (3.14)	78.2 (3.91)	*
% dicots	6.1 (2.16)	1.1 (0.32)	ns	3.8 (1.25)	18.1 (6.28)	*	0.14 (0.14)	11.2 (4.88)	*
% monocots	0.8 (0.83)	1.9 (0.77)	ns	1.25 (0.64)	5.7 (2.37)	ns	0.9 (0.50)	6.8 (2.64)	*
% leaf litter	1.4 (0.37)	2.6 (0.91)	ns	5.8 (2.50)	5.7 (2.07)	ns	14.3 (2.05)	6.7 (1.44)	**
% bare	63.2 (1.69)	90.8 (1.97)	***	67.5 (0.96)	55.5 (6.17)	ns	55.4 (3.56)	59.3 (6.42)	ns
June									
crop density	100.0 (1.61)	60.6 (3.64)	*	115.1 (6.25)	89.0 (20.28)	ns	139.3 (13.49)	106.5 (3.71)	*
crop height	82.6 (1.30)	113.6 (3.46)	ns	78.1 (3.54)	96.8 (1.28)	ns	94.3 (2.82)	92.3 (1.3)	ns
% dicots	1.3 (0.24)	0.4 (0.03)	ns	0.9 (0.40)	10.3 (1.94)	ns	0.6 (0.56)	9.1 (4.09)	ns
% monocots	1.4 (1.39)	0.6 (0.56)	ns	0.6 (0.29)	1.8 (0.89)	ns	1.1 (0.45)	5.4 (3.22)	*
% leaf litter	3.5 (1.21)	2.1 (0.83)	ns	10.1 (0.89)	12.5 (0.00)	ns	10.9 (2.07)	9.3 (0.77)	ns
% bare	74.9 (1.96)	88.6 (1.08)	**	62.9 (1.97)	60.9 (0.19)	ns	52.7 (4.17)	60.6 (4.18)	ns

Table 4.—The relationship between spider abundance and vegetation variables in May and June. *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$. See text for details of analysis.

Variable	All sites		Organic		Conventional	
	<i>r</i>	<i>P</i>	<i>r</i>	<i>P</i>	<i>r</i>	<i>P</i>
May						
crop density	-0.26	***	-0.014	0.88	-0.055	0.57
crop height	-0.003	0.96	-0.087	0.373	-0.238	*
% dicots	0.279	***	0.147	0.127	0.201	*
% monocots	0.21	**	0.15	0.11	-0.001	0.99
% leaf litter	-0.303	***	-0.333	***	-0.142	0.142
% bare ground	-0.031	0.653	-0.191	*	-0.096	0.322
June						
crop density	-0.123	0.072	-0.003	0.969	0.028	0.774
crop height	-0.149	*	-0.400	***	-0.435	***
% dicots	0.255	***	0.221	*	0.222	*
% monocots	0.183	**	0.175	0.070	0.122	0.207
% leaf litter	-0.049	0.472	-0.081	0.403	-0.015	0.876
% bare ground	-0.147	*	-0.001	0.989	0.145	0.135

trasting management systems. While we could not interpret this difference in terms of the ecological characteristics of the species involved, these observations suggest that the habitat differences which are associated with these systems have a measurable impact on the spider communities.

Organic farming concentrates primarily on adjustments within the farm such as rotations and appropriate cultivations, rather than the use of inorganic fertilizers and pesticides, to achieve an acceptable level of output. It is ar-

gued that organic systems are more diverse, and therefore more stable, resulting in lower incidences of pest and disease problems, and increased biodiversity (Lampkin 1990). Many factors could thus contribute to our observed system effects. Our most consistent result was the increased abundance and species richness of spiders in our samples with increasing abundance of understory vegetation within the crop, both overall and within each system, within each sampling session. Web-building spiders are sensitive to changes in vegetation

Table 5.—The relationship between spider species richness and vegetation variables in May and June. *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$. See text for details of analysis.

Variable	All sites		Organic		Conventional	
	<i>r</i>	<i>P</i>	<i>r</i>	<i>P</i>	<i>r</i>	<i>P</i>
May						
crop density	-0.21	**	-0.077	0.423	-0.093	0.337
crop height	-0.023	0.741	-0.065	0.501	-0.179	0.064
% dicots	0.174	*	0.067	0.487	0.066	0.497
% monocots	0.058	0.394	-0.014	0.882	-0.066	0.499
% leaf litter	-0.19	**	-0.21	*	-0.09	0.310
% bare ground	0.062	0.364	-0.031	0.749	0.025	0.794
June						
crop density	-0.107	0.117	0.009	0.921	0.118	0.222
crop height	-0.092	0.176	-0.376	***	-0.396	***
% dicots	0.245	***	0.196	*	0.177	0.067
% monocots	0.199	*	0.149	ns	0.166	0.087
% leaf litter	-0.028	0.678	-0.052	0.594	0.001	0.991
% bare ground	0.115	0.090	0.016	0.872	0.029	0.767

density (Topping 1993), biomass (Rypstra & Carter 1995), structure (Asteraki et al. 1992; Alderweireldt 1994) and height (Smith et al. 1993). The linyphiine spiders, most notably *B. gracilis* and *L. tenuis*, always anchor their sheet webs to the surrounding vegetation and never on bare soil alone, unlike *M. rurestris* and *Erigone* spp. which use small depressions in the soil (Alderweireldt 1994). Understorey vegetation may assume increasing importance as senescence occurs in the lower leaves of the wheat stems (Sunderland et al. 1986) which is known to reduce overall spider abundance (Rypstra & Carter 1995). However, organic fields are not always weedier than conventional fields. Of our three sites, for example, one showed significantly lower abundances of understorey vegetation on the organic compared to the conventional fields. This often occurs when a cereal crop follows a ryegrass/clover sward in the organic rotation.

Apart from the benefit of increased plant structure to web spinners, the growth of understorey vegetation may offer polyphagous pests alternative food sources, and therefore benefit spiders indirectly (Rypstra & Carter 1995). Increased parasitism or predation of herbivorous pests may be partially responsible for a reduction of pest damage in weedy systems (e.g., Pavuk & Stinner 1992). Thus, a more complex community of predators, which includes spiders, could exert a significant controlling effect on prey species within the crop. We also recorded high numbers of spiders within our conventional fields, which may have been due to a temporary increase in spider abundance in response to high aphid densities.

Our data did not allow us to investigate the effects of agrochemical applications on the spider assemblages. Since spraying densities on conventional fields on the same farm were similar, and organic fields by definition had zero applications, agrochemical effects were entirely confounded with management system. However, various researchers have reported the declining abundance of predators with increased use of agrochemicals. In the Boxworth project, for example, the densities of Linyphiidae in areas receiving full pesticide inputs were approximately 47% those of levels in reduced-input areas (Grieg-Smith et al. 1991). Similar patterns were observed for

Staphylinidae and Coccinellidae (Coleoptera) (Vickerman 1991). In a study of twenty years of monitoring cereal fields in Sussex, Aebischer (1991) reported an overall annual decline rate of spiders of 4.1%, which effectively halved spider abundance over the study period, and agricultural intensification was cited as one likely explanation. Spiders in organic systems, while perhaps being subject to some aspects of intensification, such as spray drift from neighbouring land or poor water quality, should not suffer from major direct effects of pesticide use.

The spatial scale of land management changes is such that detecting significant effects of systems at the field scale can be very difficult. In the case of spiders which disperse by ballooning, which make up the greatest proportion of those inhabiting arable systems, the dominant landscape management is likely to exert the greatest influences on spider communities in an area. An organic farm is not isolated from these effects. That we were able to detect some differences in spider assemblages between the two systems, even under these circumstances, does suggest that the introduction of organic systems over wider areas may increase spider abundances disproportionately. However, a number of management strategies which are essential to organic farming can also be applied to conventional systems. Further studies are needed to understand whether effects similar to those of organic systems on arable species assemblages can be achieved under conventional systems if the management of the latter is modified appropriately.

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