Araneae communities associated with the chestnut tree canopy in north-eastern Portugal: the influence of soil management practices

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Abstract

Chestnut (*Castanea sativa* Mill.) is one of the economically important trees in the north of Portugal. Spiders, as generalist predators, are of potential importance for pest control, yet, their community composition in this crop is only poorly known. The objective of this work was to study the spider communities of the chestnut canopy under three different soil management practices in northeastern Portugal. Three chestnut groves under three different agricultural practices (grazed, tilled and untilled) were studied in 2008 and 2009. The Araneae communities were sampled using the beating technique and the individuals captured were identified to family and species when possible. To investigate the structure of spider community in each grove, abundance and family richness were calculated and compared between managements. In total, 4172 spiders were collected and, in both years, the three most abundant families were Araneidae, Philodromidae and Linyphiidae. In 2008, the grazed grove registered greater abundance of spiders followed by tilled and untilled but no significant differences were found among groves. However, in 2009 the tilled grove reached higher abundance of spiders, followed by grazed and untilled groves and significant differences were found between untilled and the other two groves. *Araniella*, *Oxyopes* and *Anyphaena* were the most abundant genera in the three groves. This study showed that soil management may influence the diversity of spiders, but effects were weak and not consistent between years. The reduction or absence of an adequate habitat for spiders under the tree canopy due to tillage may encourage a local migration to the canopy. However, based on the weak effects observed on spider abundance and potentially adverse effects on soils, tillage is not recommended as management practice in the chestnut grove.

Keywords

Araneidae, Philodromidae, Thomisidae, *Castanea sativa*, diversity, guilds, grazing, pest control, tilled, untilled.

Introduction

Chestnut (*Castanea sativa* Mill.) is a traditionally cultivated tree in the north of Portugal, due to its excellent adaptation to local soils (moderately deep and well drained sandy-loam soils) and its social and economical importance (Monteiro, 2000). The main pests described for this crop are tortricids (*Cydia* spp.) and curculionids (*Curculio* spp.) which action can cause losses up to 50% of the seed production (Assunção, 1997; Paparatti & Speranza, 2005; Aguin-Pombo *et al.*, 2008). Furthermore, other phytophagous species such as mites, aphids, psyllids and diaspidids are frequently found in chestnut crop (A. Bento, unpublished results). Despite those losses, chemical control is not feasible due to the lack of homologated products for the chestnut in Portugal (Oliveira, 2011) and this fact corroborates the need for the use of biological control agents against pests. Spiders are generalist predators, hunting mainly insects in all their instars and may provide a natural control of pests.

Several studies have shown the importance that spiders have in agroecosystems acting as natural enemies of pests. These predator-prey interactions were demonstrated by direct observations of hunting and feeding (e.g. Sunderland *et al.*, 1986; Ghavami, 2008; Monzó *et al.*, 2009; Oelbermann & Scheu, 2009), morphological measurements (e.g. Nentwig & Wissel, 1986), serological (e.g. Morris *et al.*, 1999; Nakamura & Nakamura, 1977) and molecular gut-content analysis (Greenstone & Shufran, 2003) and by studying the feeding behaviour and functional responses of spiders when fed with different prey items (Samu & Bíró, 1993; Harwood *et al.*, 2009). The potential and efficiency of spiders as biological control agents can be evaluated after a clear characterization of the spider community associated to each crop. For the chestnut, there is a need for information regarding the structure of the spider community that can also be affected by several management practices. According to Prieto-Benítez & Méndez (2011), the management of soil vegetation by using herbicides, cuttings, tillage and grazing negatively affected the diversity of spiders. Tillage and grazing are common practices in chestnut groves. The former aims at weed control and soil water conservation (Martins *et al*., 2005) leaving a bare soil surface. Usually, the effect of tillage on invertebrates depends on its intensity and frequency (Edwards, 1977) and Rodríguez *et al*. (2006) found lower abundance of Araneae in tilled than in untilled corn crops. On the other hand, grazing by livestock is a selective practice that, together with effects of trampling and defecating, may result in botanically rich and structurally diverse habitats (Dennis *et al*., 1998; Cole *et al*., 2010). Consequently, moderate grazing regimes can promote habitat heterogeneity that supports richer arthropod communities as it was showed for larger size carabids, predatory coleopteran larvae and lycosids (Blake *et al*., 1994; Cole *et al*., 2005). Changes in arthropod soil communities could also induce modifications in canopy communities, especially of those arthropods that climb the trunk, such as spiders. Therefore, the objective of this work was to study the spider communities of the chestnut canopy under different soil management practices in Trás-os-Montes region (northeastern Portugal).

Material and methods

Study sites

Field sites were located in three chestnut groves near Bragança (northeastern Portugal), Rossas (41º39'41"N 06º50'54"W), Oleiros 1 (41º50'60"N 06º49'52"W) and Oleiros 2 (41º50'50"N 06º49'49"W), during two crop seasons, 2008 and 2009. The sampling period took place between July and October and was selected accordingly with the phenology of the crop, i.e., chestnut is a deciduous tree with bud bursts usually occurring by the end of May - beginning of June. Rossas occupies an area of about 50 ha and the spontaneous herbaceous vegetation has been maintained and managed by sheep grazing where no tillage has been done for the last 20 years. Oleiros 1 occupies an area of about 2.5 ha and the natural vegetation has been maintained and cut once a year at the end of October (before harvest). Oleiros 2 occupies an area of 3 ha and soil has been ploughed two or three times a year to control weeds. In every grove, no phytosanitary treatments were done and they were not irrigated. In this work, Rossas is referred as grazed, Oleiros 1 as untilled and Oleiros 2 as tilled.

Sampling of Araneae

A central sampling area of 2 ha was established in every grove and the Araneae communities were sampled by using the beating technique on a fortnightly basis. Each branch was beaten twice over a rectangular cloth (0.6 m × 0.5 m) and five samples were collected per date and grove, being each sample compounds by 10 beating branches, one branch per tree.. On each sampling period, trees were selected randomly. The branches of a height range between 150 and 180 cm were randomly selected from a total number of 50 trees per grove. All captured individuals were frozen, sorted, counted, identified using a binocular stereomicroscope and preserved in ethanol 70% to avoid desiccation. The individuals were identified according to Nentwig *et al*. (2011), Roberts (1985; 1987), and Simon (1914-1937) and the nomenclatural system according to Platnick (2012). Juveniles were included in the data analysis.

Data analysis

Abundance data were evaluated for normality and homogeneity of variances with Kolmogorov-Smirnov test and Bartlett’s test, respectively and when necessary, the transformation log (x + 1) was used to normalize the data.

One way ANOVA was used to compare total abundance of Araneae and the abundance of the three most common families. Significance levels for all analyses were set at $P < 0.05$.

Family richness (S), Simpson’s diversity index (D) and evenness ($E_{1/D}$) were calculated for each grove. Simpson’s diversity index was calculated as 1/D, using the equation:

$$1/D = 1/\sum_{i=1}^{s} p_i^2 \qquad \text{eqn 1}$$

where p_i^2 is the proportion of individuals of the i^{th} family and S the total number of families. The minimum value of 1/D is 1 which is reached when the community has only a single species and the maximum is S, which is reached when a community has all species with equal abundance (Magurran, 2004). This index takes into account the number of species present as well as the abundance of each species and provides a good estimate of diversity at relatively small sample sizes and ranks assemblages consistently, i.e., an increase in the index will result in an increase in diversity. Evenness expresses the dominance and was calculated as

$$E_{1/D} = (1/D)/S \qquad \text{eqn 2}$$

$E_{1/D}$ is defined between 0 and 1, where 1 represents a community with perfect evenness, and decreases towards zero as the relative abundances of the species diverge from evenness (Magurran, 2004).

Community composition was investigated by plotting the rank-abundance curves of each grove, with the relative abundance of each family as its index of abundance. The relative abundance for the most common species is plotted first, followed by the next most common species until the array is completed by the rarest species (Magurran, 2004). Abundance was tested against the predicted distribution by geometric-, log-series- log-normal- and broken stick models. The difference between observed and expected values was tested by χ^2 test which gives the probability of fit between each distribution model and observed Araneae abundance.

Results

During the two sampling years, a total of 4172 spiders were collected, from which 44 were adults (1.05%) and 4128 immature (98.95%). In 2008, the grazed grove registered greater abundance of spiders followed by tilled and untilled (Table 1). The four most abundant families in the grazed grove were Araneidae (22.53%), Philodromidae (22.32%), Linyphiidae (13.37%) and Thomisidae (10.63%), while Philodromidae, Araneidae and Linyphiidae dominated the community in the other two groves where Thomisidae and Theridiidae were the fourth most common families in tilled and untilled groves, respectively. Despite these variations, no significant differences were found for total abundance of spiders in each grove ($F_{2,\ 112} = 0.92$, $P = 0.40$) in 2008. The genera *Araniella*, *Oxyopes* and *Anyphaena* were the most abundant in the three groves studied. The family Dictynidae occurred in increasing abundance from tilled to grazing management.

In 2009, the tilled grove featured a higher abundance of spiders, followed by grazed and untilled groves (Table 2). Philodromidae, Araneidae and Thomisidae were the three most abundant families in all the groves studied. However, the fourth most abundant family varied from Dictynidae in grazed, Theridiidae in untilled and Salticidae in tilled grove. Statistically significant differences for total abundance of spiders were found between untilled (442 individuals) and the other two groves (575, 582 individuals, respectively; $F_{2,\ 117} = 3.94$, $P = 0.02$). The genera *Araniella* and *Oxyopes* sp. were more abundant in the grazed grove.

In both years of study, Anyphaenidae were less abundant in the untilled grove while the abundance of this family was similar in the two other groves. The Uloboridae individuals were never present in the grazed grove.

In 2008, the diversity of spider families was greatest in the tilled grove with 13 families, followed by untilled with 11 and grazed groves with 10 families. On the contrary, in 2009, both grazed and untilled groves reached 12 families and the tilled groves 11 families.

The seasonal abundance of all collected individuals and of the most abundant families in each year of study is shown in Figure 1. In 2008, the peak of abundance occurred on the 17th of July in the grazed grove and three weeks later in the tilled and untilled groves. In 2009, the mean abundance for each sampling period was lower than that observed in 2008. The peak of abundance occurred on the 24th of August in the grazed and tilled groves and one month later in the untilled grove. In general, the peaks of abundance of the most abundant families occurred between the middle of July and the end of September. Statistically significant differences between untilled and tilled groves were found only for Thomisidae ($P = 0.02$).

The rank-abundance curves showed a good fit to the broken-stick model for the grazed grove in both years of study ($\chi^2 = 4.19$; $P = 0.94$ in 2008 and $\chi^2 = 9.67$; $P = 0.47$ in 2009) while the tilled grove obtained a good fit to the deterministic model of log-series distribution ($\chi^2= 10.20$; $P = 0.42$ in 2008 and $\chi^2 = 9.50$; $P = 0.49$ in 2009) (Fig. 2). However, data from the untilled grove followed different distribution models - in 2008 the rank-abundance curve fitted the broken-stick model ($\chi^2 = 11.46$; $P = 0.32$) while in 2009 it fitted the log-series model ($\chi^2 = 13.69$; $P = 0.19$).

Discussion

Over the two years study, 15 families of spiders were found in the chestnut tree canopy, 13 of them in 2008 and 14 in 2009, from which Philodromidae, Araneidae, Thomisidae, Lyniphiidae, Dictynidae and Theridiidae can be considered the most representative families in the canopy. In Japan, Nakamura and Nakamura (1977) found a total of 17 families of spiders in the canopy of the Japanese chestnut trees *Castanea crenata* Sieb. et Zucc. with some similarities with the communities found in Portugal. Namely, the families Philodromidae, Thomisidae and Lyniphiidae were also important in the Japanese chestnut canopy.

For every grove, the most abundant genus was *Araniella* spp. (among the identifiable individuals) and this can be related to their arboreal habits since they build small webs, usually very eccentric, at heights greater than 1.5 m (Jones, 2004). The dominance of *Araniella* in the canopy has a significant relevance in biocontrol context due to the high pest predation/killing rate that can be reached by spiders of this genus in agroecosystems (Kajak, 1978; Wyss *et al.*, 1995).

The presence of the other families is, despite variations in their relative abundances, in agreement with other works carried out in this region in crops such as cotton (Pérez-Guerrero *et al*., 2009), almond (Benhadi-Marín *et al*., 2011), olive (Cárdenas, 2008), and citrus (Barrientos *et al*., 2010).

As it was already found in citrus (Barrientos *et al*., 2010) and almond tree canopies (Benhadi-Marín *et al*., 2011), there was a high proportion of immature individuals relatively to adults. This can be explained either by the fact of taking complete nests when sampling or due to the dispersion of immature to new feeding places (Draney, 1997). The great number of unidentified immature specimens leads to an underestimation of the spider species richness for the habitat. To surpass this problem, metabarcoding seems to be a promising tool for assessing the biodiversity of arthropods in a more reliable and comprehensive way (Yu *et al.*, 2012).Apart from family richness, it is worth to notice the guild diversity in the chestnut tree canopy. According to the system proposed by Uetz *et al*. (1999), eight feeding/hunting strategies were present in the canopy of the chestnut that were by order of importance: (1) ambushers, (2) orb weavers, (3) space web builders, (4) wandering sheet/tangle weavers, (5) stalkers, (6) foliage runners, (7) ground runners and (8) sheet web builders. As predators, spiders can be useful biological control agents in agroecosystems. Previous studies showed that small linyphiids feed on aphids (Nyffeler & Sunderland, 2003) and theridiid on small insects (Pekár, 2000). On the other hand, philodromids and thomisids directly hunt bigger insects such as cicadelids (Wisniewska & Prokopy, 1997) and moths (Ramos & Lanfranco, 2010) and other web-weaving species preferentially feed on Diptera (Pekár *et al*., 2011). Therefore, the occurrence of diverse families with different hunting strategies and feeding preferences can contribute to the biocontrol of phytophagous agents that attack the chestnut tree, mainly *Cydia* spp. In Trás-os-Montes, the peak of adults of this pest occurs from the end of August to the middle of September; adults lay their eggs in the nearest leaves of the spiny cupules and the maximum of abundance of eggs occurs by the end of September and beginning of October. Shortly after egg hatching, larvae penetrate into the fruit, where they remain until pupation. Thus, and accordingly with the life cycle of this pest in the region, the period of vulnerability occurs from the end of August to the beginning of October, which is concordant with the peak of abundance of the most abundant spider families. This seasonal co-occurrence is an advantage and may favour natural predation of *Cydia* spp. by spiders.

In both years of the study, the lowest value of abundance of spiders was found in the untilled grove; but, only in 2009, statistically significant differences were found between the untilled grove and the other two groves. Several families contributed to this result, namely Philodromidae, Thomisidae, Araneidae, Oxyopidae and Dictynidae that were less abundant in the untilled grove. Thus, it seems that the vegetation on the ground is an important habitat for these groups. When soil coverage is removed by tillage or frequently disturbed by grazing, spiders tend to climb the trunk searching for a new habitat. Moreover, Philodromidae and Thomisidae are ambusher spiders and we suggest that the differences observed can be explained in terms of resource availability since a tilled soil represents a decrease of potential prey (e.g. cicadelids) and an increase of the risk of exposure to potential predators. In the case of Araneidae, they are orb-weavers and need to have an adequate vegetation structure to build their webs which can be more difficult in tilled or grazed groves. Oxyopidae usually appear in shrubs and weeds where they hunt during the day and use the upper part of the plant to make and guard their nests (Jones, 2004), thus, in the grazed grove, weeds are periodically removed and canopy becomes the only strata with appropriate resources. Something similar may happen with Dictynidae, which includes spider species that occupy ground level strata (e. g. *Lathys*, *Argenna* and *Altella*) or act as plant-dwellers (e. g. *Dictyna* and *Nigma*) appearing both on weeds, as well as higher up on shoot apices of shrubs or on trees foliage (Lissner, 2011).

The rank-abundance curves of the grazed grove in both years of the study and of the untilled grove in 2008 fitted the broken stick model. This model reflects uniform use of resources among species in the community where the coexistence of different species can be explained by the use of different niches. The availability of more vertical strata can promote a more even organization of the different taxa according to their habits, therefore, the different guilds appear distributed through the available space in order to reduce inter- and intraespecific competition resulting in a more diverse community (Tretzel, 1955; Uetz, 1977). On the other hand, the tilled crop fitted the logarithmic series. In this case, the chestnut canopy is the steadiest habitat where spiders can establish ecological relationships. According to this, in both years of study, Philodromidae, Thomisidae and Anyphaenidae were less abundant in the untilled crop canopies that in the tilled crop, suggesting that wandering/runner spiders were using lower strata when available. Despite these results, the usefulness of the rank abundance curves has been discussed. In particular, Beck & Chey (2006) pointed that this approach can be problematic when discriminating communities according to habitat type because several variables are potentially important in influencing community composition.

In conclusion, soil management can influence the abundance of spiders found in the canopy, but effects were rather weak (and not always significant). Tilling practices developed in this agroecosystem may result in a slight increase of spider abundance in the canopy. This fact could be beneficial for biocontrol, however the negative consequences of these practices concerning soil damage such as nutrient loss, fertility reduction and erosion, are possibly greater than the advantages resulting of any increase of natural enemy populations. Thus, concerning the effect of soil management practices in spider abundance, it would be preferable to maintain soil covered with vegetation (either controlled by grazing or superficially cut before harvest) in order to prevent soil erosion.

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Table 1. Guild at family level, total number of Araneae individuals (N), number of samples where the species occurred (*f*), occurrence (%), family richness, Simpson index (1/D) and evenness ($E_{1/D}$) of families in total samples collected in the chestnut tree canopy in the three types of agricultural practices studied in 2008.

Family / Species	**Guild**	**Tilled (n=39)**			**Non tilled (n=39)**			**Grazed (n=37)**		
		N	***f***	**O (%)**	**N**	***f***	**O (%)**	**N**	***f***	**O (%)**
Anyphaenidae	6									
Anyphaena numida Simon, 1897		2	2	5.13	3	3	7.69	5	4	10.81
Anyphaena spp.		23	15	38.46	6	4	10.26	16	10	27.03
Subtotal		25	17	43.59	9	7	17.95	21	14	37.84
Araneidae	2									
Araniella spp.		172	28	71.79	140	25	64.10	182	24	64.86
Mangora acalypha (Walckenaer, 1802)		4	3	7.69	0	0	0.00	1	1	2.70
Araneidae unid. immature		30	10	25.64	39	13	33.33	31	9	24.32
Subtotal		206	41	105.13	179	38	97.44	214	34	91.89
Clubionidae	6									
Clubiona sp.		1	1	2.56	1	1	2.56	0	0	0.00
Subtotal		1	1	2.56	1	1	2.56	0	0	0.00
Dictynidae	3									
Dictynidae unid. immature		45	20	51.28	57	23	58.97	95	24	64.86
Subtotal		45	20	51.28	57	23	58.97	95	24	64.86
Gnaphosidae	7									
Gnaphosidae unid. immature		1	1	2.56	1	1	2.56	1	1	2.70
Subtotal		1	1	2.56	1	1	2.56	1	1	2.70
Linyphiidae	4									
Meioneta fuscipalpa (C.L. Koch, 1836)		0	0	0.00	0	0	0.00	1	1	2.70
Meioneta rurestris (C.L. Koch, 1836)		3	3	7.69	0	0	0.00	0	0	0.00
Tenuiphantes tenuis (Blackwall, 1852)		2	2	5.13	0	0	0.00	0	0	0.00
Tenuiphantes sp.		0	0	0.00	1	1	2.56	0	0	0.00
Typhochrestus digitatus (O. P.-Cambridge, 1872)		0	0	0.00	2	1	2.56	0	0	0.00
Linyphiidae unid. immature		91	29	74.36	96	30	76.92	126	34	91.89
Subtotal		96	34	87.18	99	32	82.05	127	35	94.59
Miturgidae	6									
Cheiracanthium sp.		1	1	2.56	0	0	0.00	0	0	0.00
Subtotal		1	1	2.56	0	0	0.00	0	0	0.00
Oxyopidae	5									
Oxyopes spp.		34	18	46.15	8	7	17.95	44	16	43.24
Subtotal		34	18	46.15	8	7	17.95	44	16	43.24
Philodromidae	1									
Philodromus cespitum (Walckenaer,		1	1	2.56	0	0	0.00	0	0	0.00

1802)										
Philodromus praedatus O. P.-Cambridge, 1871		3	2	5.13	1	1	2.56	1	1	2.70
Philodromidae unid. immature		207	37	94.87	184	35	89.74	211	35	94.59
Subtotal		211	40	102.56	185	36	92.31	212	36	97.30
Salticidae	5									
Icius subinermis Simon, 1937		0	0	0.00	1	1	2.56	0	0	0.00
Macaroeris nidicolens (Walckenaer, 1802)		0	0	0.00	2	2	5.13	0	0	0.00
Salticidae unid. immature		15	13	33.33	21	13	33.33	16	11	29.73
Subtotal		15	13	33.33	24	16	41.03	16	11	29.73
Theridiidae	3									
Enoplogntha ovata (Clerck, 1757)		1	1	2.56	0	0	0.00	0	0	0.00
Theridion hannoniae Denis, 1944		0	0	0.00	0	0	0.00	1	1	2.70
Theridion sp. 1		1	1	2.56	0	0	0.00	0	0	0.00
Theridiidae unid. immature		42	19	48.72	81	23	58.97	59	18	48.65
Subtotal		44	21	53.85	81	23	58.97	60	19	51.35
Thomisidae	1									
Synema globosum (Fabricius, 1775)		10	9	23.08	3	3	7.69	4	4	10.81
Thomisus onustus Walckenaer, 1805		2	2	5.13	0	0	0.00	1	1	2.70
Thomisidae unid. immature		79	25	64.10	73	24	61.54	96	21	56.76
Subtotal		91	36	92.31	76	27	69.23	101	26	70.27
Uloboridae	2									
Uloborus sp.		2	2	5.13	0	0	0.00	0	0	0.00
Subtotal		2	2	5.13	0	0	0.00	0	0	0.00
Araneae unid. immature		64			67			59		
Total		836			787			950		
Richness - S (families)		13			11			10		
Simpson index - 1/D (families)		5.43			5.65			6.03		
Evenness - $E_{1/D}$ (families)		0.42			0.51			0.60		

Note - Codes for guilds: 1 - ambushers, 2 - orb weavers, 3 - space web builders, 4 - wandering sheet/tangle weavers, 5 - stalkers, 6 - foliage runners and 7 - ground runners.

Table 2. Guilds at the level of families, total number of Araneae (N), number of samples in which the species occurred (*ƒ*□ occurrence (O%), family richness (S), Simpson index (1/D) and evenness ($E_{1/D}$) of families in all the samples collected from the canopies of the chestnut trees in the three types of grove studied in 2009.

Family / Species	**Guilds**	**Tilled (n=39)**			**Non tilled (n=38)**			**Grazed (n=40)**		
		N	***ƒ***	**O (%)**	**N**	***ƒ***	**O (%)**	**N**	***ƒ***	**O (%)**
Anyphaenidae	6									
Anyphaena numida Simon, 1897		2	2	5.13	4	3	7.89	1	1	2.50
Anyphaena sp.		16	11	28.21	8	8	21.05	16	9	22.50
Subtotal		18	13	33.33	12	11	28.95	17	10	25.00
Araneidae	2									
Araneus diadematus Clerck, 1757		1	1	2.56	0	0	0.00	0	0	0.00
Araniella cucurbitina (Clerck, 1757)		1	1	2.56	2	2	5.26	0	0	0.00
Araniella sp.		0	0	0.00	48	14	36.84	82	33	82.50
Araneidae unid. immature		120	34	87.18	49	22	57.89	13	11	27.50
Subtotal		122	36	92.31	99	38	100.00	95	44	110.00
Clubionidae	6									
Clubiona sp.		1	1	2.56	4	3	7.89	2	2	5.00
Subtotal		1	1	2.56	4	3	7.89	2	2	5.00
Dictynidae	3									
Dictynidae unid. immature		32	21	53.85	22	14	36.84	50	21	52.50
Subtotal		32	21	53.85	22	14	36.84	50	21	52.50
Gnaphosidae	7									
Gnaphosidae unid. immature		0	0	0.00	0	0	0.00	1	1	2.50
Subtotal		0	0	0.00	0	0	0.00	1	1	2.50
Linyphiidae	4									
Linyphiidae unid. immature		26	20	51.28	23	15	39.47	18	16	40.00
Subtotal		26	20	51.28	23	15	39.47	18	16	40.00
Oxyopidae	5									
Oxyopes sp.		26	14	35.90	16	10	26.32	37	21	52.50
Subtotal		26	14	35.90	16	10	26.32	37	21	52.50
Philodromidae	1									
Philodromus buxi Simon, 1884		0	0	0.00	0	0	0.00	1	1	2.50
Philodromidae unid. immature		165	34	87.18	131	33	86.84	181	38	95.00
Subtotal		165	34	87.18	131	33	86.84	182	39	97.50
Salticidae	5									
Salticidae unid. immature		16	14	35.90	24	14	36.84	19	14	35.00
Subtotal		16	14	35.90	24	14	36.84	19	14	35.00
Sparassidae	6									
Sparassidae unid. immature		0	0	0.00	0	0	0.00	3	2	5.00
Subtotal		0	0	0.00	0	0	0.00	3	2	5.00

Theridiidae	3									
Parasteatoda tepidariorum (C.L. Koch, 1841)		1	1	2.56	0	0	0.00	0	0	0.00
Platnickina tincta (Walckenaer, 1802)		1	1	2.56	0	0	0.00	0	0	0.00
Theridiidae unid. immature		34	24	61.54	19	14	36.84	29	18	45.00
Subtotal		36	26	66.67	19	14	36.84	29	18	45.00
Thomisidae	1									
Thomisidae unid. immature		80	25	64.10	27	20	52.63	51	26	65.00
Subtotal		80	25	64.10	27	20	52.63	51	26	65.00
Titanoecidae	8									
Titanoecidae unid. immature		0	0	0.00	1	1	2.63	0	0	0.00
Subtotal		0	0	0.00	1	1	2.63	0	0	0.00
Uloboridae	2									
Uloboridae unid. immature		2	2	5.13	1	1	2.63	0	0	0.00
Subtotal		2	2	5.13	1	1	2.63	0	0	0.00
Araneae unid. immature		58			63			71		
Total		582			442			575		
S (families)		11			12			12		
1/D (families)		5.25			4.83			5.08		
$E_{1/D}$ (families)		0.48			0.40			0.42		

Note - Code for the guilds: 1 - ambushers, 2 - orb weavers, 3 - space web builders, 4 - wandering sheet/tangle weavers, 5 - stalkers, 6 - foliage runners, 7 - ground runners and 8 - sheet web builders.

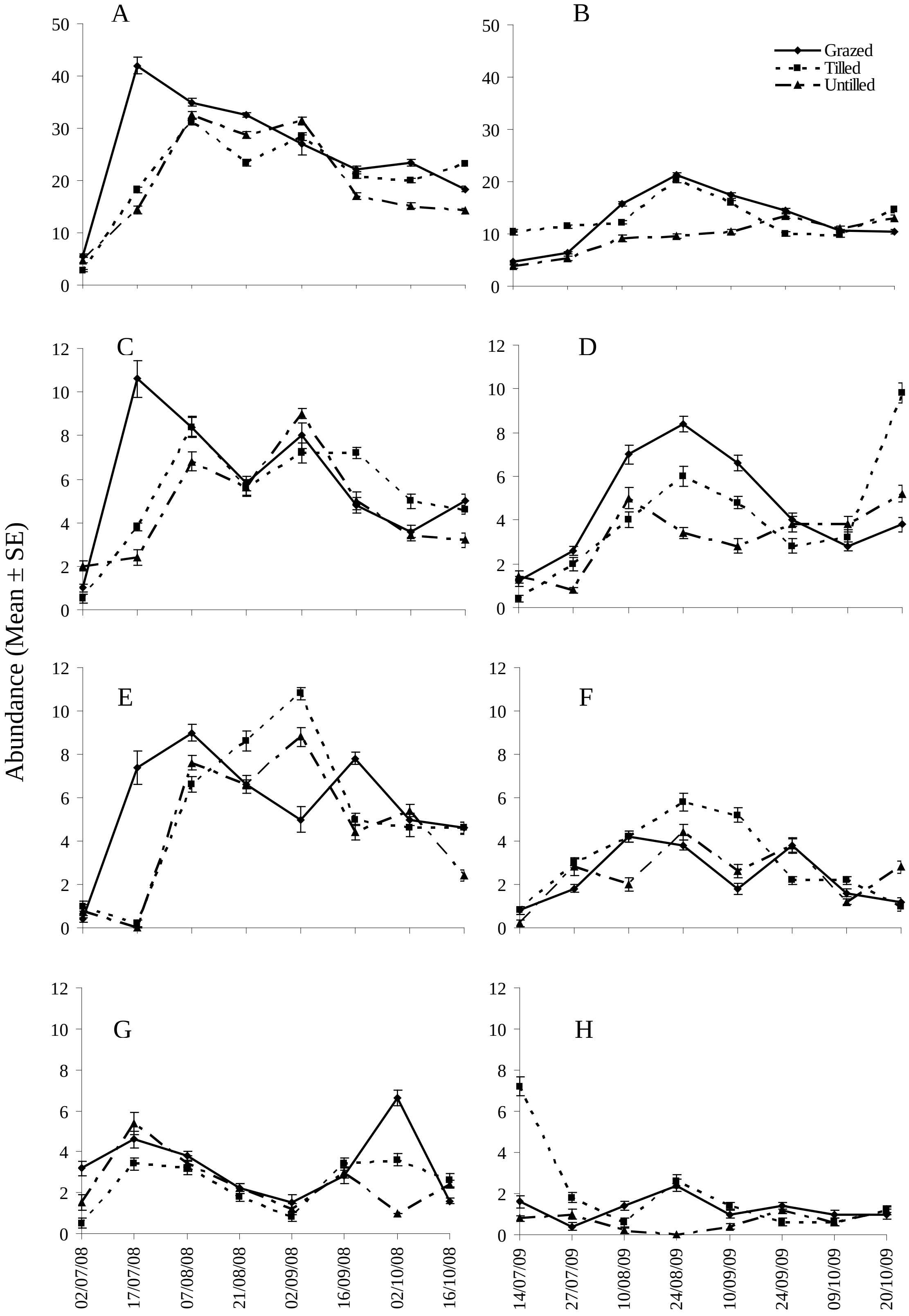

Figure 1. Seasonal trends in the abundance (mean ± standard error) of spiders in the two years of the study; n = 5. A, B: Total spiders; C, D: Philodromidae; E, F: Araneidae; G: Linyphiidae and H: Thomisidae.

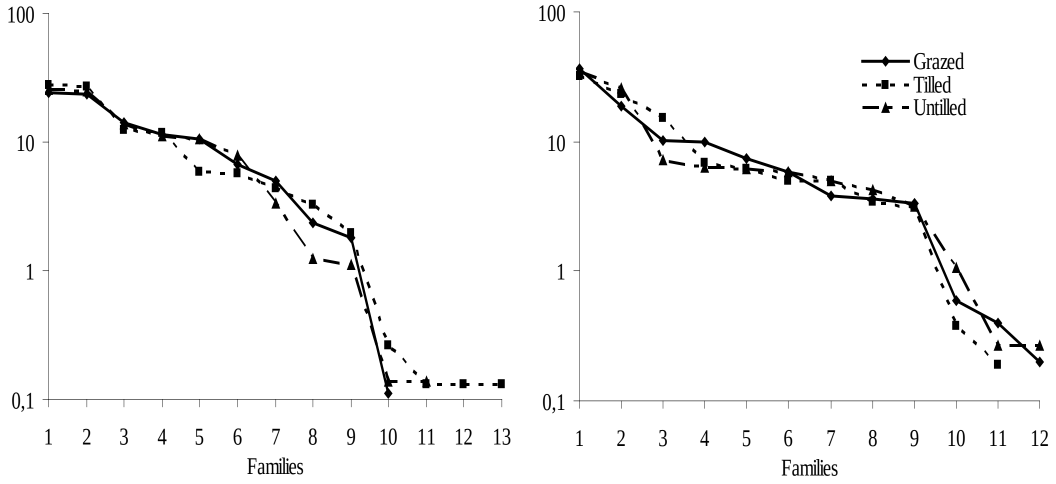

Figure 2. Rank-abundance curves of the families present in each type of chestnut grove in (A) 2008 and (B) 2009.