

Vegetation structure and spider behaviour: implications for brassica crops

EMMA M. SHAW, C. PHILIP WHEATER & A. MARK LANGAN

Manchester Metropolitan University, Department of Environmental & Geographical Sciences, Chester Street, Manchester M1 5GD, UK (E.shaw@mmu.ac.uk)

Abstract

Mark-release-recapture techniques were used to track movements of spiders out of simulated field margins and into a simulated crop area. The spiders, *Pardosa amentata* (Clerck, 1757), *Tenuiphantes tenuis* (previously *Lepthyphantes tenuis* Blackwall, 1852), *Erigone atra* (Blackwall, 1841) and *E. dentipalpis* (Wider, 1934) were used to examine these activities. *P. amentata* were recaptured at a higher rate than any of the Linyphiidae species. As the difference between the vegetation structure and density in the two habitat types decreased, *P. amentata* moved more readily out of the margin and into the simulated crop area. Implications for crop management are discussed.

Key words: margin, mark-release-recapture, *Pardosa*, Linyphiidae

INTRODUCTION

The disturbance encountered within agricultural systems means that non-crop areas, such as field margins and set-a-side land, provide potential refugia for beneficial predators in otherwise ephemeral ecosystems (e.g. Harwood et al. 1994; Kampichler et al. 2000). The type and quality of adjacent land may also affect predator distributions within the field, through the provision of overwintering sites from which immigration may occur (Maelfait & De Keer 1990; Bayram & Luff 1993; Harwood et al. 1994; Holland et al. 1999). Landscape and field margin architecture are important for enhancing populations of beneficial predators which re-invade fields after a major disturbance; the more diverse the architecture, the greater the diversity of potentially beneficial predators (Uetz 1991). Increased vegetation density and architectural complexity within the crop are also important in increasing the density of predators, such as spiders (Sunderland & Samu 2000). This change in

architecture can result from differences in mulching (Riechert & Bishop 1990), intercropping (Booij et al. 1997) and weed strip management (Lenke & Poehling 2002).

Movements between margins and fields may depend on the level of vegetation in both areas. Many spiders are highly mobile generalist predators that use both cursorial and aerial dispersal mechanisms (Suter 1999). Ballooning is highly effective in the colonisation of recently disturbed sites (Bishop 1990; Halley et al. 1996) and allows migration between unfavourable and favourable habitats within the landscape (Booij & Noorlander 1992). Spiders that probably rely heavily on cursorial dispersal, such as Lycosidae (Richter 1970), may be affected to a greater extent by the degree of vegetation cover and the severity of a boundary between the two areas. However, there is little evidence about the extent to which these factors affect spider dispersal.

This investigation aims to quantify the movements of some common agricultural spi-

ders, out of field margins and into more open areas, such as brassica crops. The vegetation around the simulated margin and crop was manipulated to produce differing boundaries around the ecotone. This was carried out to determine if dispersal into the simulated crop was influenced by the severity of the boundary between these two habitats. Mark-release-recapture was employed to allow the determination of directionality and timing of movements.

MATERIAL AND METHODS

Movements from the margin into the field were examined in agricultural grassland situated at York, UK, for 21 days, June 2001. Three plots (3×3 m) were marked out in a fenced off area in the corner of the field. Gutter traps (50 mm deep) were set, flush to the ground, around each of the three plots. The guttering was cut into sections (Fig. 1) to identify the area where marked spiders exited the plots. Each length of trap was sealed at both ends with gutter ends to ensure that no mixing of trap contents took place. Longitudinal traps (2

$\times 1.5$ m) were situated at both ends of the simulated margin and were employed to recapture spiders moving within the margin habitat. Lateral traps (2×3 m) were situated along both lengths of the simulated crop area to recapture spiders moving out of the margin and into the field. Sublateral traps (4×0.75 m) were employed between these two areas and recaptured spiders moving out of the margin but moving parallel to that margin. The vegetation in each plot was cut, using a strimmer, into a simulated margin 1.5 metre wide with 0.75 metre simulated crop area on either side (Fig. 2). Each of the three plots were cut to simulate a different level of vegetation cover within the crop area. The first plot simulated a hard boundary where there was no vegetation cover within the field area. The second plot simulated a soft boundary where the field area had moderate vegetation cover graduating to the higher vegetation of the central margin area, and the third plot simulated no boundary between the two areas where the density and structure of the vegetation was similar between both habitat types. The area directly

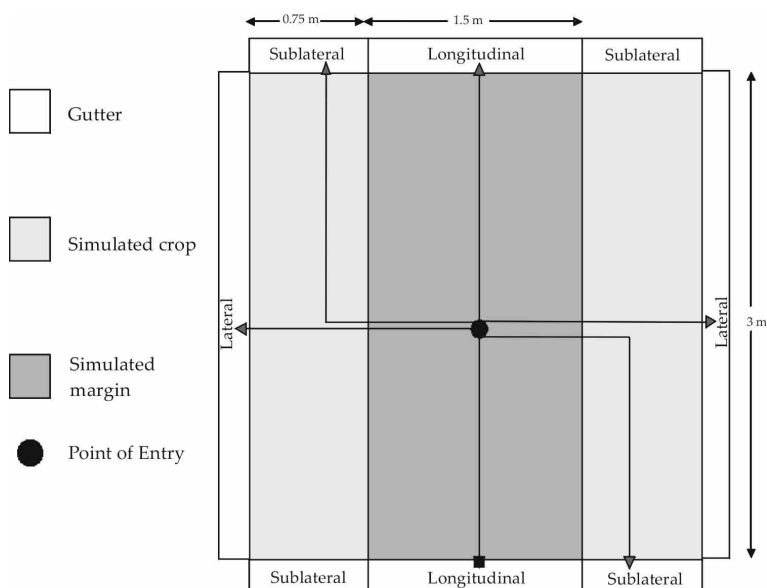


Fig. 1. Layout of the gutter trapping surrounding each experimental plot, showing the separation of traps that allowed direction of movement to be determined.

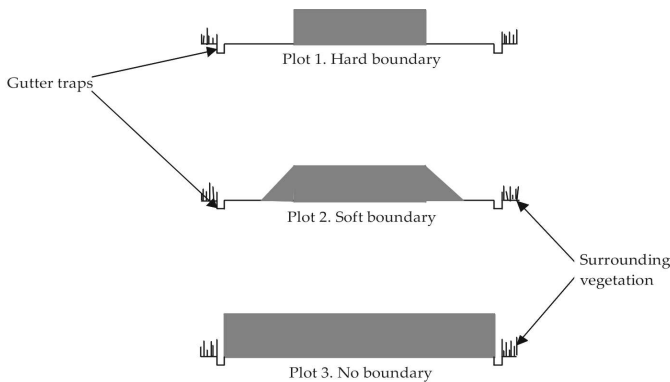


Fig. 2. A cross-sectional diagram of experimental plots showing their differing vegetation densities.

around the plots was also cut and all vegetation over-hanging the gutter traps was removed to minimise dispersal from the plots without encountering gutter traps. Traps were half filled with water and a small amount of detergent, which was maintained throughout the experiment.

Four common species of agricultural spiders were selected on their abundance in previous research (e.g. Alderweiltdt 1994; Thomas & Jepson 1997; Sunderland & Samu 2000). These were adult *Tenuiphantes tenuis* (transferred to this genus from *Lepthyphantes* by Saaristo & Tanasevitch 1996), *Erigone atra*, *E. dentipalpis* and *Pardosa amentata*. *E. atra* and *E. dentipalpis* have very similar life cycles, and habitat requirements (De Keer & Maelfait 1988) and were impossible to distinguish between in the field. Therefore, they were grouped together under the genus *Erigone* for the purpose of this study. Spiders were collected from the surrounding grasslands, using a modified G-Vac sampler (Bell et al. 2000). Each spider was anaesthetised using CO₂ and marked on the abdomen with a small spot of paint. Spiders were kept for 24 hours to minimise any effect of these processes had on their behaviour. Spiders were released on seven occasions throughout the 21 days and seven different colour cohorts were used sequentially to allow the time taken to leave the plots to be calculated. Each spider was released into the central point of entry (Fig. 1) and wherever possible the same sex ratio of each species

was placed in each plot. A total of 333 spiders were released evenly between the three plots. A total of 144 *Erigone*, 102 *T. tenuis* and 87 *P. amentata* were marked and released. For each site the marked spiders of each section of guttering were collected each day and their colour and position were recorded. At the end of the 21 day period the margin and the field area were sampled twice using the G-Vac to collect all the remaining marked spiders. The colour (release date), species, gender and gutter position for each marked spider was recorded. Chi squared analysis was performed, using StatView, to test if there was any directionality of dispersal associated with the severity of the boundary.

RESULTS

Of the 333 spiders released into the experimental plots, a total of 53 spiders were recaptured across the three plots, 19, 20 and 17 in the hard, soft and no boundary plots respectively, representing a 15.9% recapture rate overall (Fig. 3). More *P. amentata* (52.8%) were recaptured than either of the Linyphiidae (3.2%) species (Fig. 4). The remaining part of the results will concentrate on *P. amentata* only. A higher number of female *P. amentata* without egg sacs left the plots (80%) (Fig. 4) compared to the proportions recaptured of both *P. amentata* males (47.8%) and females with egg sacs (46.9%). However, a much lower number of females were released within the plots, 15 females without egg sacs compared

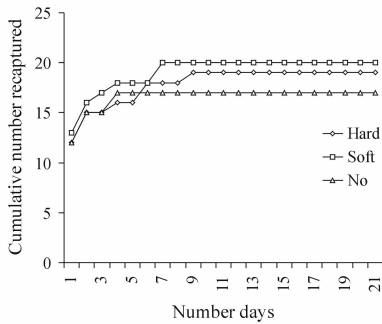


Fig. 3. Cumulative number of spiders recaptured in each plot over 21 days for hard, soft and no boundary plots.

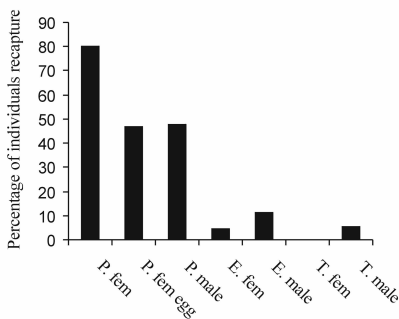


Fig. 4. Percentage of spiders recaptured within one day of release, for all three experimental plots. P. = *P. amentata*, E. = *E. atradentipalpis*, and T. = *T. tenuis*. Females (fem) and males are distinguished, along with females with egg sacs for *Pardosa* only.

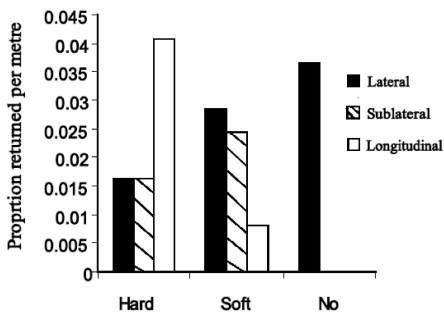


Fig. 5. The proportion of *P. amentata* returned per metre, in each experimental plot, separated into each area of gutter trap, one day after release.

to 49 females with egg sacs. Since 37 of the 56 were recaptured one day after release (Fig. 4), the remaining results concentrate on these.

When looking at each plot, taking into account all areas of the gutter traps together, numbers of spiders recaptured one day after release were very similar with 11 recaptured in the plots with hard and soft boundaries and 9 in the plot with no boundary. However, the number of *P. amentata* recaptured in each area of gutter trap differs according to the vegetation structure within the field area (Fig. 5). When the boundary was hard, significantly more spiders were recaptured in the longitudinal traps than in the lateral traps ($X^2 = 11.65$, $df = 4$, $P = 0.02$). Therefore, significantly more spiders remained within the margin when there was a hard boundary. As the severity of the boundary between the two habitats decreases, for example in the soft and no boundary plots, significantly more *P. amentata* were caught in the lateral traps, compared to the longitudinal traps ($X^2 = 11.65$, $df = 4$, $P = 0.02$).

The final G-Vac of each plot resulted in only low numbers of all spiders being caught, 3 individuals in the plot with the hard boundary, 2 in the soft boundary and 2 in the plot with no boundary. Of these 3 were caught in the margin and 4 were caught in the crop area.

DISCUSSION

Overall, significantly more *P. amentata* were recaptured than any of the other species released. This is probably due to their dispersal strategies. *P. amentata* dispersed cursorially and will, therefore, be more likely to encounter the gutter traps as they leave the plot. However, *T. tenuis* and *Erigone* disperse via ballooning (Bishop 1990), which is the most efficient dispersal at a landscape scale (Samu et al. 1999), they will therefore encounter the gutter traps at a much lower rate than *P. amentata*. This was confirmed as the final G-Vac sample produced only six Linyphiidae between all plots, leading to the assumption that those not present have dispersed via ballooning. This may have been an underestimation

of the actual number of Linyphiidae present at the end of the experiment. Although G-Vac sampling is known to be an efficient method for collecting spiders (Samu et al. 1997; Bell et al. 2000) the vegetation in the margins, and the field area in the no boundary plot, was quite dense possibly impeding the efficient collection of all individuals.

Pardosa display a high level of locomotory activity (Baatrup & Bayley 1993). The timing of the investigation coincided with a period in the phenology of *P. amentata* when numbers of males are reduced, and those that are still present are actively searching a mate (Edgar 1970). Females, before and after mating, are highly mobile as they actively hunt prey in preparation for egg sac production (Vlijm et al. 1963). Females with egg sacs have been shown to have some kind of site attachment (Vlijm et al. 1963), yet 80% of released females with egg sacs were recaptured within the experimental plots suggesting high levels of movement.

When considering each plot as a whole, there was very little difference in the numbers of total spiders, or the numbers of *P. amentata*, that were recaptured. However, on examination of exit location within each plot, more *P. amentata* exited the plot with a hard boundary via the longitudinal traps, and the plot with a soft boundary via the lateral traps. When there was a hard boundary significantly higher proportions of *P. amentata* were recaptured moving within the margin compared to moving into the simulated crop area. *P. amentata* are often found around the edges of crops (Sunderland 1987; Maelfait & De Keer 1990; Nyffeler & Breene 1992; Holland et al. 1999), or exclusively within non-crop features within the landscape (Lys & Nentwig 1993; Huusela-Veistola 1998). Micro-climatic conditions are found to be more stable in clumps of vegetation (Bossenbroek et al. 1977; Bayram & Luff 1993). The directionality of movements by females with eggs sacs may be related to pre-hatching brood care. Vlijm et al. (1963) observed females emerging in the heat of the

day, exposing their egg sacs to the sun but with their bodies in crevices in the soil. The edges of the margin, especially in the hard boundary plot, may have provided shelter for the females' body whilst allowing the egg sacs to be exposed to the sun. Once the sun's intensity decreased, females could then retreat into the vegetation where microclimatic temperatures would be more stable than in the open crop area, where there was no vegetation. The development of spiderlings is thought to be primarily dependent on temperature (Vlijm et al. 1963). The presence of prey and a suitable microclimate are thought to decrease dispersal (Honek 1997) therefore, ecotones, like the simulated margin may provide optimal conditions for *P. amentata*.

As the gradient between the two habitat types decreased, the proportion of spiders leaving the margins and entering the simulated crop area increased, potentially as a result of increases in vegetation density and structure. The probable similarity in the microclimates of the two areas may have also induced movement between them (Sunderland & Samu 2000). This was true of sites where the vegetation gradient either decreased slowly (plot 2; Fig. 2) or where the vegetation structure and density were similar (plot 3; Fig. 2).

Many spiders dispersed from the plots without being caught in the gutter traps. Linyphiidae species that left the plots probably did so via ballooning since some were found in adjacent fields. Many *P. amentata* were also missing from the plots without being caught within the gutter traps. In the first two plots predation may have been a factor in the removal of spiders as the reduced vegetation densities in the open areas may have made them more conspicuous to predators (such as birds), especially the females with egg sacs as they are easily seen from a distance. Mortality may have also played a part in reducing the numbers of individuals available to be recaptured. However throughout the experiment several of the marked *P. amentata* were found

outside the plots (pers. obs.). One individual was also found walking over the surface of the water within the gutter trap; this is a mode of dispersal often recorded in Lycosidae (Foelix 1996).

In conclusion, no effect on the dispersal of linyphiid spiders was detected in relation to habitat structure and vegetation density. The very low numbers of linyphiids recaptured in the gutter traps, and within the final G-Vac sampling has led to the assumption that the remaining individuals had left the plots via ballooning. The opposite was true of the epigaeic *P. amentata*. The results showed that a similarity in the structure of between vegetation and that within the crop area increases the movements of this spider into the crop area, where it could result in reduced insect pest populations. This has implications on the management of crops. The addition of an intercropping system may have similar results of increasing the movement of *Pardosa* spp. into crop areas, as could allowing weeds to grow within the crop. This could be particularly effective within brassica crops, since permitting weed growth, intercropping and undersowing have been found to increase the numbers of predators in crops (Kromp & Steinberger 1992). Intercropping cabbage crops with clover was found to significantly increase ground beetle populations (Booij et al. 1997) but this was found to be dependent on specific species requirements (Armstrong & McKinlay 1997). Intercropping Brussels sprouts was also found to significantly reduce densities of cabbage aphids (Vidal 1997). Allowing weeds to grow within cabbage crops has been found to effect a greater increase, in carabid species, than undersowing with clover (Armstrong & McKinlay 1994). In general we can speculate that allowing partial weediness can be a practice which makes the crop area more similar to the margin. Weed cover is less uniform than undersown clover plots providing a patchy environment that will accommodate species with differing requirements. For instance, weed cover would provide dense

vegetation along with more open areas, which would be beneficial for species such as *P. amentata* that appears to require some dense vegetation but also requires some degree of open space in which the basking and egg sac heating behaviour can take place.

ACKNOWLEDGEMENTS

The authors would like to thank Dr Andy Ramsey, Phil Shaw and Dr Philip Orton from Askham Bryan College, York for the use of their land and laboratory space and to Dr David Penney (University of Manchester) for comments on the manuscript and information on the taxonomy of *Lepthyphantes*, and Dr Michael Saaristo (University of Turku, Finland) for providing reprints of his work.

REFERENCES

- Alderweireldt, M. 1994. Day-Night Activity Rhythms of Spiders Occurring in Crop-Rotated Fields. *European Journal of Soil Biology* 30(2), 55-61.
- Armstrong, G. & McKinlay, R.G. 1997 The effect of undersowing cabbages with clover on the activity of carabid beetles. *Biological Agriculture & Horticulture* 15(1-4), 269-277.
- Baatrup, E. & Bayley M. 1993. Effects of the Pyrethroid Insecticide Cypermethrin on the Locomotor-Activity of the Wolf Spider *Pardosa amentata* - Quantitative-analysis employing computer-automated Video Tracking. *Ecotoxicology and Environmental Safety* 26(2), 138-152.
- Bayram, A. & Luff, M.L. 1993. Winter abundance and diversity of lycosids (Lycosidae, Araneae) and other spiders in grass tussocks in a field margin. *Pedobiologia* 37, 357-364.
- Bell, J.R., Wheeler, C.P., Henderson, R. & Cullen, W.R. 2000. Testing the efficiency of suction samplers (G-Vacs) on spiders: the effect of increasing nozzle size and suction time. In *European Arachnology* (S. Toft & N. Scharff eds.), pp. 285-290, Aarhus University Press, Aarhus.

- Bishop, L. 1990 Meteorological aspects of spider ballooning. *Environmental Entomology* 19 (5), 1381-1387.
- Booij, C.J.H. & Noorlander, J. 1992. Farming systems and insect predator. *Agriculture, Ecosystems & Environment* 40(1-4), 125-135.
- Booij, C.J.H., Noorlander, J. & Theunissen, J. 1997. Intercropping cabbage with clover: Effects on ground beetles. *Biological Agriculture & Horticulture* 15(1-4), 261-268.
- Bossenbroek, P.H., Kessler, A., Liem, A.S.N. & Vlijm, L. 1977. Plant growth-form as "shelter" for terrestrial animals. *Journal of Zoology, London* 182, 1-6.
- De Keer, R. & Malfait J.-P. 1988. Laboratory observations on the development and reproduction of *Erigone atra* Blackwall, 1833 (Araneae: Linyphiidae) *Bulletin of the British Arachnological Society* 7(8), 237-242.
- Edgar, W.D. 1970. Prey and feeding behaviour of adult females of the wolf spider *Pardosa amentata* (Clerck). *Netherlands Journal of Zoology* 20(4), 487-491.
- Foelix, R.F. 1996. *Biology of spiders*. 2nd edn. Oxford University Press, Oxford.
- Halley, J.M., Thomas, C.F.G. & Jepson, P.C. 1996. A model for the spatial dynamics of linyphiid spiders in farmland. *Journal of Applied Ecology* 33(3), 471-492.
- Hardwood, R.W.J., Wratten, S.D., Nowakowski, M. & Marshall, E.P.J. 1994. Wild-flower strips and winter/ summer populations of beneficial invertebrates on farmland. *IOBC/WPRS Bulletin* 17(4), 211-219.
- Holland, J.M., Perry, J.N. & Winder, L. 1999. The within field spatial and temporal distribution of arthropods in winter wheat. *Bulletin of Entomological Research* 89, 499-513.
- Honek, A. 1997. The effect of plant cover and weather on the activity density of ground surface arthropods in a fallow field. *Biological Agriculture and Horticulture* 15(1-4), 203-210.
- Huusela-Veistola, E. 1998. Effects of perennial grass strips on spiders (Araneae) in cereal fields and impact on pesticide side-effects. *Journal of Applied Entomology* 122, 575-583.
- Kampichler, C., Barthel, J. & Wieland, R. 2000. Species density of foliage-dwelling spiders in field margins: a simple, fuzzy rule-based model. *Ecological Modelling* 129, 87-99.
- Kromp, B. & Steinberger K.-H. 1992. Grassy field margins and arthropod diversity: a case study on ground beetles and spiders in east Austria (Coleoptera: Carabidae; Arachnida: Aranei, Opiliones). *Agriculture, Ecosystems and Environment* 40, 71-93.
- Lenke, A. & Poehling, H.-M. 2002. Sown weed strips in cereal fields: overwintering site and "source" habitat for *Oedothorax apicatus* (Blackwall) and *Erigone atra* (Blackwall) (Araneae: Erigonidae). *Agriculture, Ecosystems and Environment* 90, 67-80.
- Lys, J.A. & Nentwig W. 1992. Augmentation of Beneficial Arthropods by Strip-Management 4. Surface-Activity, Movements and Activity Density of Abundant Carabid Beetles in a Cereal Field. *Oecologia* 92(3), 373-382.
- Maelfait, J.-P. & De Keer, R. 1990. The border zone of an intensively grazed pasture as a corridor for spiders Araneae. *Biological Conservation* 54(3), 223-238.
- Nyffeler, M. & Breene R.G. 1992. Dominant insectivorous polyphagous predators in winter wheat: high colonisation power, spatial dispersion patterns, and probable importance of soil surface spiders. *Deutsch Entomologische Zeitschrift* 39(1-3), 177-188.
- Richter, C.J.J. 1970. Aerial dispersal in relation to habitat in eight wolf spider species (*Pardosa*, Araneae, Lycosidae) *Oecologia* 5, 200-214.
- Riechert, S.E. & Bishop, L. 1990. Prey control by an assemblage of generalist predators - spiders in garden test systems. *Ecology* 71 (4), 1441-1450.
- Samu, F., Németh, J. & Kiss, B. 1997. Assessment of the efficiency of a hand-held suc-

- tion device for sampling spiders: improved density estimation or oversampling? *Annals of Applied Biology* 130, 1-8.
- Samu, F., Sunderland, K.D. & Szinetár, Cs. 1999. Scale-dependent dispersal and distribution patterns of spiders in agricultural systems: A review. *Journal of Arachnology* 27(1), 325-332.
- Saaristo, M.I. & Tanasavitch, A.V. 1996. Redelimitation of the subfamily Micronetinae Hull, 1920 and the genus *Lepthphantes* Menge, 1866 with descriptions of some new genera. *Berichte. Naturwissenschaftlich-Medizinischer Verein in Innsbruck* 83, 163-186.
- Sunderland, K.D. 1987. A Review of Methods of Quantifying Invertebrate Predation Occurring in the Field. *Acta Phytopathologica et Entomologica Hungarica* 22(1-4), 13-34.
- Sunderland, K.D. & Samu, F. 2000. Effects of agricultural diversification on the abundance, distribution and pest control potential of spiders: a review. *Entomologia Experimentalis et Applicata* 95, 1-13.
- Suter, R.B. 1999. An aerial lottery: the physics of ballooning in a chaotic atmosphere. *The Journal of Arachnology* 27, 281-293.
- Thomas, C.F.G. & Jepson, P.C. 1997. Field-scale effects of farming practices on linyphiid spider populations in grass and cereals. *Entomologia Experimentalis et Applicata* 84(1), 59-69.
- Uetz, G.W. 1991. Habitat structure and spider foraging. In *Habitat Structure: the physical arrangements of objects in space*. (E.D. McCoy, S.A. Bell & H.R. Muskisky eds.) pp. 325-348, Chapman & Hall, London.
- Vidal, S. 1997. Factors influencing the population dynamics of *Brevicoryne brassicae* in undersown Brussels sprouts. *Biological Agriculture & Horticulture* 15(1-4), 285-295.
- Vlijm, L., Kessler, A. & Richter, C.J.J. 1963. The life history of *Pardosa amentata* (Cl.) (Araneae, Lycosidae). *Entomologische Berichten* 23, 75-80.