SPIDERS (ARANEAE) AS POLYPHAGOUS NATURAL ENEMIES IN ORCHARDS

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Proefschrift
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to my parents

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Propositions

1. Workers in the field of biological control should not try to make the spider fit the mold of the specialist predator or parasitoid.
   Riechert & Lockley (1984) Ann. Rev. Entomol. 29: 299-320.
   This Thesis

2. Single spider species cannot, but whole spider communities, as complexes of generalist predators can be effective in controlling pests.
   Wise (1995) Spiders in ecological webs. Cambridge University Press
   This Thesis

3. Careful use of pesticides in orchard IPM programs may result in development of more complex and abundant spider communities, thereby augmenting biological pest control.
   This Thesis

4. Cluster analysis and measurement of ecological similarity are two parts art and one part science, and ecological intuition is essential to successfully interpret the results.
   Krebs (1989) Ecological methodology. Harper & Row Publisher
   This Thesis

5. If you have an apple and I have an apple and we exchange these apples then you and I will still each have one apple. But if you have an idea and I have an idea and we exchange these ideas, then each of us will have two ideas.
   George Bernard Shaw

6. Observation not followed by speculation is like soup without salt.

7. Conservation of biodiversity is the key to IPM.

8. Handshaking is not usual in The Netherlands. The rule seems to be: Never touch the Dutch.

Propositions with the thesis "Spiders (Araneae) as polyphagous natural enemies in orchards"
by S. Bogya

Wageningen, April 27, 1999

CONTENTS

SUMMARY

Spiders (Araneae) occur in high abundance in all terrestrial ecosystems including agro-ecosystems. They are a very heterogeneous group of animals with different hunting tactics and therefore they play very different ecological roles. At family level these tactics are rather similar thus properties and behaviour found in different species of one family can be seen as characteristic for the whole family. Especially in orchards little is known about their role and probably it is undervalued. Therefore a comprehensive review (based on about 500 articles) of spiders as natural enemies of pest species of different crops was made resulting in information about the expected prey spectrum at family level. A qualitative evaluation of pest-spider relationship was carried out for a whole range of agro-ecosystems and the results are transposed to spider groups inhabiting the orchard ecosystems.

In a fundamental research project on integrated plant protection in orchards in Hungary (Apple Ecosystem Research) more than 2000 animal species were described for apple orchards. Until now the spiders were not studied in this project. The aim of this study is to describe the species richness and dominance order of spider communities inhabiting the canopy and the herbaceous-layer of apple and pear orchards in Hungary. Altogether 20283 individuals were collected belonging to 165 identifiable species. Considerable overlap has been observed between the spider fauna of apple and pear orchards.

Special attention is paid to the differences in spider fauna of orchards situated in different growing regions, because this knowledge can contribute to improve regional IPM programs. The great differences indicated that the composition of spider communities is basically determined by geographical locations. Although both the pesticide treatments and the different prey densities can significantly influence the densities of spiders, their effects on the composition of spider communities is limited.

The effect of conventional (based on broad-spectrum insecticides, e.g. OP's and pyrethroids) and integrated (based on selective chemicals, mainly IGR's) pest management systems on the canopy, herbaceous-layer and ground level inhabiting spider communities was investigated. The results lead to the conclusion that in case of applying integrated pest management there are possibilities to develop more complex spider communities. The negative effect of broad-spectrum compounds on spiders can be observed only on the canopy and to a lesser extent on the herbaceous-layer but not at the ground level. Regardless the pesticide treatments the composition of spider communities was similar.

The age of the orchards can significantly influence the spider density in the canopy through the prey density. In young (more vigorous) orchards, where the size of the canopy was smaller and the density of the pear lace bug (*Stephanitis pyri*) higher, significantly more complex hunting spider communities were present than in the same treated old orchards. This relationship was not observed in case of the guild web-building spiders. At the same time the diversity of the canopy inhabiting spider communities was higher in the old orchards, regardless of the chemical treatments.

The effect of the border of orchards on spider communities was investigated and it was found, that if selective insecticides were used the immigration into the orchards was significantly higher. While in case of applying broad-spectrum insecticides the canopy spider densities did not differ significantly between the outer rows and the interior rows of the orchards.

A considerable overlap exists between the spider communities of the canopy, the herbaceous-layer and the adjacent vegetation. Despite chemical treatments, exchange of individuals occurs and provides possibilities for re-colonization of spiders in the orchards from the herbaceous-layer and from the surroundings after pesticide treatments.

The most promising group of spiders in orchards is the clubionid spiders (Clubionidae) with as dominant species: *Clubiona pallidula*, *Clubiona phragmitis*, *Cheiracanthium mildei*. These spiders actively hunt on vegetation and never make a web for catching prey. Some species are winter-active, move and even hunt in winter. The low feeding rate in winter months at low temperature indicates that the winter-feeding will be of minor importance for natural pest control. In early spring when most of the other predators and parasitoids are not yet active, these spiders prey on pests that overwintered in the orchard like larvae of leafrollers (Tortricidae) and have a significant effect on suppression of pest populations.

Considerable predation by spiders was observed of the key pear pest, the pear suckers (*Cacopsylla spp.*) and of the pear lace bug (*Stephanitis pyri*) common in IPM orchards in the vegetative period. In the latter case it was observed that the clubionid spider *Ch. mildei* showed a positive numerical response to prey density in the field, indicating density dependent mortality resulting in a better natural control.

The predatory capacity of clubionid spiders was estimated to be 3.3 mg at 10 °C to 5.7 mg at 20 °C per day with a model based on digestion and egestion characteristics. This indicates a daily potential killing rate of 3-6 small (L_1-L_3) caterpillars of leafrollers depending on temperature. The size of the population in an untreated apple orchard was estimated to be 60.000 clubionids / ha (22 per tree) by mark-recapture method using double-release protocol in spring. These two findings indicate that spiders can be important in reduction of orchard pests, indeed.

The data provided in this thesis indicate that the role of spiders as natural control agents in orchards can be augmented. In orchards where Integrated Pest Management is applied, and where the use of broad-spectrum pesticides is minimized, an excellent possibility is available to develop more complex and abundant spider communities, which can contribute to a better suppression of pests.

SAMENVATTING

Spinnen (Araneae) komen in alle terrestrische en agro-ecosystemen in hoge dichtheden voor. Zij vormen een zeer heterogene groep dieren met diverse jaagtaktieken en daarom spelen zij naar gelang de familie een zeer verschillende ecologische rol. Op familieniveau zijn deze taktieken min of meer gelijk en daarom kunnen eigenschappen die in verschillende soorten van een familie worden aangetroffen als karakteristiek voor de gehele familie worden beschouwd. Vooral in boomgaarden is weinig bekend van hun rol en wordt daar waarschijnlijk ook ondergewaardeerd. Daarom is een uitgebreid overzicht (gebaseerd op ongeveer 500 artikelen) gemaakt van spinnen als natuurlijke vijanden van plagen, hetgeen resulteerde in een overzicht van het te verwachten prooispectrum per familie. Een kwalitatieve evaluatie van spin-plaag relaties is uitgevoerd voor een hele reeks van agro-ecosystemen en de resultaten daarvan zijn vertaald naar spingroepen die voorkomen in boomgaard ecosystemen.

In een fundamenteel opgezet onderzoeksproject betreffende geïntegreerde gewasbescherming in boomgaarden in Hongarije (Apple Ecosystem Research) werden meer dan 2000 diersoorten beschreven voor appelboomgaarden. Tot nu toe werden spinnen in dit project niet bestudeerd. Het doel van deze studie was het beschrijven van de soorten rijkdom en de volgorde van dominantie van spinnengemeenschappen die in de boom- en kruidlaag van appel- en peer boomgaarden in Hongarije voorkomen. Alles bij elkaar werden er 20283 individuen verzameld behorende bij 165 indentificeerbare soorten. Een aanzienlijke overlap tussen de spinnenfauna van appel- en peer boomgaarden is vastgesteld.

Speciale aandacht is gegeven aan de verschillen tussen de spinnenfauna van boomgaarden van verschillende groeiplaatsen, omdat deze kennis kan bijdragen tot de verbetering van regionale IPM programma's. De grote verschillen gaven aan dat de samenstelling van spinnengemeenschappen voornamenlijk geografisch wordt bepaald. Alhoewel bestijdingsmaatregelen en verschillende prooidichtheden in belangrijke mate de spinnen dichtheden beinvloeden zijn de effekten op de spinnengemeenschap beperkt.

Het effekt van conventionele (gebaseerd op breed werkende insecticiden, zoals bijv. organofosfaten en pyrethroïden) en geïntegreerde plaag bestrijdings systemen (gebaseerd op selektieve middelen, hoofdzakelijk IGR's) op zowel de in de boomlaag als in de kruidlaag levende spinnengemeenschappen is onderzocht. De resultaten leidden tot de conclusie dat in het geval van de toepassing van geintegreerde plaagbestrijding er mogelijkheden zijn om meer complexe spinnengemeenschappen te ontwikkelen. Het negatieve effekt van breedwerkende middelen op spinnen is slechts waargenomen in de boomlaag en in geringere mate in de kruidlaag maar niet op de bodemoppervlakte. Bestrijdingsmiddelen beïnvloeden de samenstelling van de spinnengemeenschappen niet.

De leeftijd van de boomgaard kan via de prooidichtheid een duidelijke invloed op de spinnendichtheid van de boomlaag hebben. In jonge (meer levenskrachtige) boomgaarden, waar de grootte van de boomlaag kleiner was en tegelijkertijd de dichtheid van een netwants (*Stephanitis pyri*) hoger, waren signifikant meer complexe jachtspinnen gemeenschappen aanwezig dan op dezelfde manier behandelde oude boomgaarden. Deze relatie werd niet waargenomen bij de groep der webspinnen. Tegelijkertijd was de diversiteit van de boomlaag bewonende spinnen gemeenschappen in de oude boomgaarden minder afhankelijk van de toegepaste chemische bestijding.

Het effekt van de randen van boomgaarden op spinnengemeenschappen is ook onderzocht, waarbij gevonden werd, dat wanner selectieve bestrijdingsmiddelen waren toegepast de immigratie in de boomgaarden signifikant hoger was. In het geval dat breedwerkende middelen waren toegepast was er geen signifikant verschil vast te stellen tussen de binnenste en de buitenste rijen van de boomgaarden

Er bestaat een hele duidelijke overlapping tussen de spinnengemeenschappen van de boomlaag en die van de kruidlaag en de aangrenzende vegetatie. Ondanks chemische bestrijding blijft de uitwisseling van individuen bestaan en biedt aldus de mogelijkheid voor rekolonisatie van spinnen in de boomgarden vanuit de kruidlaag en vanuit de omgeving na een behandeling met bestrijdingsmiddelen.

De meest veelbelovende groep spinnen in boomgaarden zijn de struikzakspinnen (Clubioniae), met als dominante soorten *Clubiona pallidula, Clubiona phragmitis* en *Cheiracanthium mildei*. Deze spinnen jagen aktief in de vegetatie en maken nooit een web om prooien te vangen. Sommige soorten zijn winteraktiefen bewegen en jagen zelfs in de winter. De lage voedselopname bij lage temperaturen gedurende de wintermaanden vormt een indicatie, dat de opname van voedsel gedurende de winter van betrekkelijk weinig belang is voor een natuurlijke plaagbestrijding. In het vroege voorjaar echter, wanneer de andere predatoren en parasitoïden nog niet aktief zijn, hebben deze spinnen een zeer sterk effekt op de onderdrukking van plaag populaties in boomgaarden zoals bijv. op de larven van bladrollers (Totricidae).

Aanzienlijke predatie door spinnen is waargenomen bij een van de sleutelplagen van de peer, nl. perenbladvlo (*Cacopsylla* spp.) en een netwants (*Stephanitis pyri*) die algemeen voorkomen gedurende de vegetatieve periode van IPM boomgaarden. In het laatste geval is waargenomen dat de Spoorspin *Ch. mildei* een positieve numerieke respons vertoonde ten opzichte van de prooidichtheid in het veld, hetgeen een aanwijzing is voor dichtheidsafhankelijk prooisterfte wat weer resulteert in een betere natuurlijke bestrijding.

De vraatcapaciteit van struikzakspinnen werd geschat op 3,3 mg bij 10 °C en 5,7 mg bij 20 °C door een model gebaseerd op verterings - en uitscheidingskarakteristieken. Dit komt neer op een dagelijkse potentiële doding van 3-6 kleine (L_1-L_3) rupsen van bladrollers afhankelijk van de temperatuur. Door middel van merk-terugvang proeven met een tweemalig loslaatprotocol werd de grootte van de spinnenpopulatie in een onbehandelde boomgaard geschat op 60000 struikzakspinnen / ha (22 per boom). Het bovenstaande geeft aan, dat spinnen een belangrijke bijdrage kunnen leveren in de vermindering van boomgaardplagen.

De data die in dit proefschrift worden aangeleverd geven aan, dat de rol van spinnen als natuurlijke bestrijders verbeterd kan worden. Boomgaarden waar geïntegreerde bestrijding wordt toegepast en waar dus het gebruik van breedwerkende middelen tot een minimum wordt beperkt, bieden dus een uitstekend uitgangspunt om hogere dichtheden en complexere spinnengemeenschappen te ontwikkelen, hetgeen kan bijdragen tot een betere plaagbestrijding.

ÖSSZEFOGLALÁS

A pókok (Araneae) valamennyi szárazföldi ökoszisztémában, így agrárterületeken is nagy egyedszámban fordulnak elô. Meglehetôsen heterogén csoport, különbözô vadászstratégiákkal, ezért az ökológia szerepük is különbözô. Családszinten azonban ezek a stratégiák hasonlóak, ezért az egy családba tartozó különbözô fajok tulajdonságai és viselkedése alapján általános képet kaphatunk az egész családról. Különösen gyümölcsültetvények esetében a pókok szerepérôl keveset tudunk és jelentôségük feltehetôleg alábecsült. Ezért egy a teljességre törekvô áttekintést készítettünk (közel 500 irodalom feldolgozásával) a pókokról mint a termesztett növények kártevôinek természetes ellenségeirôl, amely családszinten információt szolgáltat a pókok prédaspektrumáról. A kártevô-pók kölcsönhatást értékeltük az agro-ökoszisztémák teljes vertikumán és az eredményeket a gyümölcsösökben elôforduló pókcsoportokra vonatkoztattuk.

A hazai integrált növényvédelmi vizsgálatok alapját képezô alma ökoszisztéma kutatások során napjainkig több mint 2000 állatfaj jelenlétét sikerült kimutatni almagyümölcsösökbôl. A pókok azonban eddig nem kerültek feldolgozásra. Munkánk során célul tûztük ki az alma és körte ültetvények lombkorona és gyepszintjén élõ pókegyüttesek fajgazdagságának és dominanciaviszonyainak feltárását. Összesen 20283 pókegyet gyüjtöttünk, amelyek 165 fajba tartoztak. Jelentôs átfedést figyeltünk meg az alma és a körte ültetvények pókfaunája között.

Figyelmet fordítottunk a különbözõ termesztési körzetekbe telepített gyümölcsösök pókfaunájának eltéréseire, hiszen e regionális különbségek ismerete hozzájárulhat a helyi adottságok teljesebb kihasználásán alapuló regionális IPM programok kidolgozásához. A pókegyüttsek összetételében tapasztalt eltérések arra engedtek következtetni, hogy a pókegyüttesek szervezôdését alapvetôen a földrajzi elhelyezkedés határozza meg. Mind a növényvédelmi kezelések, mind a különbözô prédadenzitások jelentôsen befolyásolják a pókok egyedszámát, de a pókegyüttesek összetételére csak kis hatással vannak.

A hagyományos (széles hatásspektrumú inszekticideken, fôként foszforsavésztereken és piretroidokon alapuló) és integrált (szelektív inszekticideken, fôként IGR szeren alapuló) növényvédelmi technológiák hatását vizsgáltuk a lombkoronaszint, a gyepszint és a talajszint pókegyütteseire. Megállapítottuk, hogy integrált növényvédelem alkalmazása esetén lehetõség van nagyobb pókegyüttesek kialakulására. A széles hatásspektrumú szerek pókokra kedvezõtlen hatása a lombkoronaszinten és kisebb mértékben a gyepszinten is érvényesül, de a talajszinten már nem. A különbözõ kezelések ellenére az együttesek hasonlóan szervezõdtek.

A gyümölcsösök kora a prédadenzitáson keresztül jelentôsen befolyásolhatja a pókok egyedszámát. A fiatal (vitálisabb) ültetvényekben, ahol a lombkorona mérete kisebb és a körte csipkéspoloska (*Stephanitis pyri*) abundanciája nagyobb volt, szignifikánsan nagyobb vadász pókegyüttesek alakultak ki, mint az azonos módon kezelt öreg ültetvényekben. Hasonló összefüggést a hálószövô pókok nem mutattak. Ugyanakkor a lombkorona pókegyütteseinek diverzitása a kémiai kezelések ellenére az öreg ültetvényben volt nagyobb.

A gyümölcsösök szegélyének pókegyüttesekre kifejtett hatását vizsgálva megállapítottuk, hogy szelektív inszekticidek alkalmazása esetén a szegélyekrôl történô bevándorlás jelentôsen nagyobb. Míg a széles hatásspektrumú szerek használata esetén a szegélysorok pókdenzitása nem különbözött szignifikánsan a gyümölcsös belsejében levôkétôl.

Számottevô átfedést tapasztaltunk a lombkorona, a gyepszint és a környezô növényzet pókegyüttesei között. A növényvédôszeres kezelések ellenére a pókegyedek vándorolnak a habitatok között, amely lehetôséget teremt a pókegyüttesek permetezések utáni a gyepszintrôl és a környezetbôl történô rekolonializációjára.

A gyümölcsösökben növényvédelmi szempontból legperspektivikusabbnak tekinthetõk a kalitpókok (Clubionidae) domináns fajai a *Clubiona pallidula*, *Clubiona phragmitis*, *Cheiracanthium mildei*. Ezek a pókok fogóhálót nem készítve vadásznak a lombozaton. A fajok egy része télen is aktívan mozog, sõt táplálkozik. Megállapítottuk, hogy a téli táplálkozás mértéke elhanyagolható növényvédelmi jelentôségû. Viszont kora tavasszal, az áttelelô kártevôk pl. a sodrómolylárvák (Tortricidae) ellen olyan idôszakban hatékonyak, amikor még más predátorok és parazitoidok nincsenek jelen az ültetvényekben.

A vegetációs idõszakban a körte kulcskártevõje, a körtelevélbolhák (*Cacopsylla spp.*) és az IPM gyümölcsösök reaktivált kártevõje, a körte csipkéspoloska (*Stephanitis pyri*) esetében tapasztaltunk jelentõsebb fogyasztást. Ez utóbbi esetében a *Ch. mildei* szabadföldön prédadenzitásra mutatott pozitív numerikus válaszát is sikerült megfigyelni, amely denzitásfüggô mortalitást okozva hatékonyabb biológiai védekezést tesz lehetôvé.

A kalitpókok predátorkapacitását az emésztési karakterisztikákon alapuló számítógépes modell segítségével 10 °C-on 3.3 mg-ra, míg 20 °C-on 5.7 mg-ra becsültük, ami a hômérséklettôl függôen 3-6 (L_1-L_3) stádiumú sodrómolylárva elfogyasztását jelenti naponta. A populációnagyságot egy kezeletlen almásban tavasszal kétszeres jelölés-visszafogás módszerrel 60.000 pók / ha-ra (fánként 22-re) becsültük. Az eredmények alapján feltételezhetô, hogy a pókok valóban fontosak a gyümölcskártevôk gyérítésében.

Az értekezésben foglaltak alapján a pókok biológiai védekezésben betöltött szerepe növelhetô. Azokban a gyümölcsösökben, ahol integrált növényvédelmet alkalmaznak (ahol a széles hatásspektrumú szerek felhasználása korlátozott), ott kíváló lehetôség van nagyobb pókegyüttesek kialakulására, amelyek hozzájárulnak a kártevôk számottevô gyérítéséhez.

Chapter 1

General Introduction

1.1 Introduction

Apple and pear growing systems in Europe

Before World War I all apple orchards consisted of extensive cultivars on seedling rooted trees planted with wide spacing (10-15 m). The trees were high (5-12 m) and the yield was low especially by alternate bearing on approximately 70-100 trees/ha. These trees needed 7-8 years before first bearing and the top production was reached after 15 years, but they could live up to 80-100 years. All the cultural practices like picking, pruning and the pest and disease control were very labour intensive.

Just after World War II this system was replaced by spindle tree and hedge tree systems with traditional cultivars (Jonathan, Golden Delicious, Starking) on M4 rootstock, spacing at 7.5 x 4.5 m (300 trees/ha) and by later smaller, woolly apple aphid tolerant rootstocks (MM111; MM106) (4-500 trees/ha) and further by M26 and M9 rootstocks (up to 1200 trees/ha) in Eastern Europe. In Western Europe from the beginning of 1960's onward virusfree dwarfing rootstocks of type M9 became very popular and the growing system was changed further by smaller bushtype trees at densities of 600-800 trees/ha to 2-3000 trees/ha.

The advantages of using dwarfing rootstock are: the top harvest period was realized at younger age (5-6 years), handling the trees (pruning, picking, spraying) became easier and because of the better light conditions the quality of the fruit improved. However, mechanical tree support, in the form of tree stakes, advanced weed control, nutrition and water management are required in these closely spaced plantings. In the single row systems the integrated pest and disease management became easier (Gonda, 1995). These horticultural methods (intensive cultural practices, and use of specific rootstocks) are directed to keep the production between 30-40 tons of more than 95% top quality apples per hectare to prevent alternate bearing and decrease of quality.

Before IPM

The frequent application of broad-spectrum insecticides in 1950's seemed to be capable of controlling all the pest species in orchards. However, problems became soon apparent after the introduction. The number of treatments increased year by year, because resistance to pesticides developed rapidly and because of the lack of natural enemies for biological control. Already in the late 1950's scientists suggested to combine biotic mortality factors with chemicals (Stern, 1959). The famous book of Rachel Carson *Silent Spring* (1962) made that the public realized that health and environmental problems were associated with pesticides. In crop protection a new approach developed, based on the use of all appropriate pest management techniques, such as enhancing natural enemies, planting pest resistant cultivars, adopting cultural management and using selective pesticides only if economic thresholds are exceeded, nowadays called *integrated pest management* (IPM) (Gruys, 1982).

1.2 IPM in European orchards

History of IPM in Europe

The history of IPM in orchards started in Europe in 1965 with the foundation of the experimental orchard 'De Schuilenburg'. Implementation of the philosophy of IPM was hindered in most of Europe and not accepted by professional associations or by fruit growers for more than two decades. However, an enormous amount of information was collected and published about IPM techniques against the main orchard pests like spider mites, leafrollers and psyllids. Symposia on IPM in orchards were held regularly. This very slow implementation of IPM in 1970's and 1980's dramatically changed in 1988 when the AGRIOS IP (Integrated Production) program from the South Tyrol region of Italy was introduced. In the following year 14 IFP (Integrated Fruit Production) guidelines for pome fruit production were drown up in 9 European countries (Dickler et al., 1993).

At the first International ISHS Symposium for Integrated Fruit Production held in Wädenswil, Switzerland in 1989, the IOBC/WPRS working group 'Integrated Plant Production in Orchards' was commissioned to coordinate and harmonize the regional and national guidelines by formulating a basic document which defined Integrated Production/Integrated Farming, described the strategy and the standards for implementation and appraised the implementation procedure. This basic document has been published in OILB SROP Bulletin 14(3) 1991 and 16(1) 1993.

As a result of this process, nowadays IFP schemes are operating in nearly all fruit producing countries in western Europe accounting for approximately 35% (113.000 ha) of the total area of pome fruit production (322.000 ha). The area has increased by 40% in the last decade. IFP schemes have also been developed for several other major fruit producing areas of the world including South Africa, eastern Europe, USA, New Zealand and Argentina (Cross et al., 1996).

Philosophy of IPM

Application of IPM is based on the knowledge of a highly motivated and profit oriented manager, who understands how the crop system and its protection is working. His knowledge has to be continuously improved (journals, books, winter training etc.). Monitoring the pests and the diseases for decision making (damage threshold and economic injury level) is important. Finally different IPM techniques and tools can be used to manipulate pest populations such as biological control by natural enemies (protect/enhance/release predators and parasitoids), hostplant resistance (scab resistant varieties), different cultural methods (pruning, picking, pest monitoring), mechanical and physical control (e.g. remove fruit rot (*Monilinia spp.*) mummies at harvest) and chemical control by highly selective pesticides (IGR's, aphicides) minimizing hazards to the fruit, human health and the environment, while the end product, the fruit has high market value.

Overview of the most important apple and pear pests and the methods to control them in Europe

pest	bio-control agents and controlling methods	efficacy	references
Spider mites	Phytoseiids		
Panonychus ulmi	*Typhlodromus pyri*	****	Blommers, 1994
Tetranychus spp.	*Amblyseius andersoni*	***	Baudry & Favareille, 1997
rust mites	Phytoseiids		
Aculus schlechtendali	*Typhlodromus pyri*	****	Blommers, 1994
Eriophyes pyri			
Leafrollers			
codling moth	polyphagous predators and parasites	*	van der Geest & Evenhuis, 1991
Cydia pomonella	of eggs and pupae		
	granulosis virus (CpGv)	***	Helsen et al., 1992
	Bacillus thuringiensis	***	van der Geest & Evenhuis, 1991
	mating disruption	***	Blommers, 1992
	diflubenzuron, fenoxycarb	***	de Reede, 1985
summer fruit tortrix moth	*Colpoclypeus florus*	***	Helsen & Blommers, 1989
Adoxophyes orana	polyphagous predators	**	van der Geest & Evenhuis, 1991
	Nuclear polyhedrosis virus (AoNPV)	***	Blommers et al., 1987
	mating disruption	***	van Deventer & Blommers, 1992
	fenoxycarb	***	de Reede, 1985
dark fruit tree tortrix moth	fenoxycarb	***	de Reede, 1985
Pandemis heparana			
rose fruit tree tortrix moth	*Trichogramma embryophagum*	**	Maini & Mosti, 1988
Archips rosana	*Apanteles ater*	**	Harzer, 1990
	fenoxycarb	***	Balázs et al., 1996
large fruit tree tortrix moth	predators & parasitoids	**	van der Geest & Evenhuis, 1991
Archips podana	fenoxycarb	***	Balázs et al., 1996
eye-spotted budmoth	predators & parasitoids	**	van der Geest & Evenhuis, 1991
Spilonota ocellana	fenoxycarb	***	Balázs et al., 1996
green budmoth	predators & parasitoids	**	van der Geest & Evenhuis, 1991
Hedya nubiferana	fenoxycarb	***	Balázs et al., 1996
Leafminers			
spotted tentiform leafminer	*Holcothorax testaceipes*	***	Blommers et al., 1990
Phyllonorycter blancardella	diflubenzuron	***	Gruys, 1982
apple pygmy moth	*Chrysocharis prodice*	***	Gruys, 1975
Stigmella malella	diflubenzuron	***	Gruys, 1982
apple leafminer	predators & parasitoids	***	Blommers, 1994
Phyllonorycter corylifoliella	diflubenzuron	***	Gruys, 1982
pear leaf blister moth	predators & parasitoids	***	Balázs, 1992
Leucoptera malifoliella	diflubenzuron	***	Gruys, 1982
Other lepidopteran pests			
winter moth	predators & parasitoids	*	Pearsall & Walde, 1994
Operophtera brumata	diflubenzuron, BT	***	Blommers, 1994
noctuids	predators & parasitoids	**	MacLellan, 1979
Orthosia spp.	diflubenzuron, phosalone	***	Blommers, 1994
wood- and shoot-boring caterpillars			
leopard moth	lufenuron	***	Balázs et al., 1996
Zeuzera pyrina	mating disruption	**	Audemard et al., 1997
carpenter worm	lufenuron	***	Balázs et al., 1996
Cossus cossus			
apple clearwing moth	lufenuron	***	Balázs et al., 1996
Synanthedon myopaeformis	mating disruption	**	Blommers & Freriks, 1988
Phytophagous bugs			
green capsid bug	mineral oil	**	Gruys, 1982
Lygocoris pabulinus	fosalone, diazinon	***	Klein, 1996

pear lace bug			Jenser et al., 1997
Stephanitis pyri			
Phytophagous beetles			
apple blossom weevil	*Scambus pomorum*	**	Zijp & Blommers, 1992
Anthonomus pomorum	*Syrrhizus delusorius*	**	Zijp & Blommers, 1992
	fosalone, diazinon	***	Rizzolli & Paoli, 1995
leaf weevils	fosalone, diazinon	***	Gruys, 1982
Phyllobius spp.,			
Polydrosus spp.			
bark beetles	funnel pheromone traps	***	Balázs et al., 1996
Scolytus mali, S. rugulosus			
Xyleborus dispar			
chafers	funnel pheromone traps	***	Balázs et al., 1996
Melolontha melolontha	fosalone, diazinon	**	Balázs et al., 1996
Anomala vitis	entomoparasitic nematodes	**	Schmatz, 1998
scale insects			
San Jose scale	*Encarsia perniciosi*	****	Mani & Baroffio, 1997
Quadraspidiotus perniciosus	minaral oil, fenoxycarb	***	Rosen, 1990
mussel scale	predators	***	Karsemeijer, 1973
Lepidosaphes ulmi	minaral oil, fenoxycarb	***	Rosen, 1990
Sawflies			
apple sawfly	*Lathorestes ensator*	**	Zijp & Blommers, 1993
Hoplocampa testudinea	fosalone, imidacloprid, diazinon	***	Jenser et al., 1997
pear sawfly	fosalone, imidacloprid, diazinon	***	Jenser et al., 1997
Hoplocampa brevis			
Leaf midges			
apple leaf midge	*Platygaster demades*	****	Gruys, 1982
Dasineura mali	fosalone, diazinon	**	Molnár, 1988
pear leaf midge	fosalone, diazinon	**	Molnár, 1988
Dasineura pyri			
Aphids			
rosy apple aphid	predators & parasitoids	*	Minks & Harrewijn, 1988
Dysaphis plantaginea	imidacloprid, pymetrozine	***	Balázs et al., 1996
rosy leaf-curling aphid	predators & parasitoids	**	Minks & Harrewijn, 1988
Dysaphis devecta	imidacloprid, pymetrozine	***	Balázs et al., 1996
woolly apple aphid	*Forficula auricularia*	***	Stap et al., 1987
Eriosoma lanigerum	*Aphelinus mali*	***	Mueller et al., 1992
	Exochomus quadripustulatus	**	Mols, 1997
	Allothrombium fuliginosum	**	Potskhveriya, 1981
	pirimicarb	**	Balázs et al., 1996
green apple aphid	ladybirds, hoverflies, lacewings, earwigs	****	Minks & Harrewijn, 1988
Aphis pomi	parasitoids, *Entomophthora aphidis*	****	Minks & Harrewijn, 1988
	pirimicarb	***	Balázs et al., 1996
apple-grass aphid	predators & parasitoids	****	Minks & Harrewijn, 1988
Rhopalosiphum incertum	pirimicarb	***	Balázs et al., 1996
Psyllids			
pear suckers	*Anthocoris nemoralis*	****	van der Blom et al., 1985
Cacopsylla pyri	*Anthocoris nemorum*	**	Drukker et al., 1992
Cacopsylla pyricola	*Orius minutus*	**	
Cacopsylla pyrisuga	diflubenzuron, teflubenzuron, amitraz	***	Trapman & Blommers, 1992

****: complete control, no additional measures is needed
***: sufficient control, sometimes additional measures is needed
** considerable control, additional measures is needed
*: insufficient control, other measures is needed

Natural control in European apple and pear orchards

Mites

The spider mite control can be solved by the usage of the predatory mite *Typhlodromus pyri* in Western Europe. In Central and Southern Europe this predator is less effective, probably because of the high summer temperatures and is replaced by *Amblyseius andersoni.*

Leafrollers and leafminers

The natural control of these lepidopterous pests are essential, but implementation by growth regulators is necessary especially in Central and Southern Europe, where more generations develop than in Western Europe.

Aphids

Up till know biological control of most important aphid species (rosy apple aphid) by indigenous occurring natural enemies is not sufficient to keep this aphid each year under the economic injury level. For woolly apple aphid the effect of natural enemies is in many years effective but outbreaks may occur regularly especially relatively warm winters. Therefore some special aphicides (pirimicarb, pymetrozine) can be used for the implementation of the effectiveness of natural enemies of aphids.

Pear psyllids

The natural control of pear psyllids can be solved by pirate bugs (mainly anthocorids).

The package for IPM in European apple and pear orchards

Biological control of Fruit Tree Red Spider Mite with predatory mites No Pyrethroids and OP's because they kill predators and parasitoids Fungicides harmless for predatory mites (Captan) Aphicides (pirimicarb, pymetrozine) against aphids IGR's for lepidopterous pests (Insegar, Dimilin, Nomolt) IGR's and amitraz against pear suckers (Nomolt, Dimilin, Vertimec, Mitac) In case of emergency broad spectrum chemicals (fosalon, diazinon), timing of application and sometimes adaptation of dosage are important

1.3 IPM in Hungarian orchards

The ecological background to develop integrated pest management in apple and pear orchards has been studied in Hungary for 30 years. Arthropod communities were investigated in commercial, backyard and abandoned orchards as well as on wild growing apple and pear trees (Apple Ecosystem Research).

During the investigations on the natural enemies of pests the following parasitoids and predators have been found.

Parasitoids

Leafminers

Fifty-four parasitoid species could be reared from the larvae and pupae of leafminers. (Balázs, 1983; Balázs, 1984; Balázs, 1992). The populations of these parasitoids are associated with insect communities in the environment of the orchards. They are able to immigrate into the orchards and their population densities increase within a short period (2-3 years) after termination of used broad spectrum pesticides. The number of the parasitoids and their population densities depends on the type of the orchards and first of all on the intensity of application of pesticides. In commercial orchards 8-10 species of parasitoids can survive if the application of insecticides allows it (Balázs, 1986; Balázs, 1989a, 1989b).

Differences have been observed between the flight periods of the adults of the leafminers and their parasitoids depending on the species and weather conditions. Accordingly it is possible to choose the suitable moment to apply insecticides in order to save the parasitoids. The larvae of leafminers were parasitized for 30-40%, occasionally for 80% (Balázs, 1984; Jenser & Balázs, 1991a).

In the orchards treated with diflubenzuron, the population densities of leafminers decreased in a short time. A contradictory situation has been observed in case of leafrollers. Some species (*Adoxophyes orana, Archips podana, Pandemis heparana, P. ribeana*) increase in the orchards again, because they are not susceptible to diflubenzuron (Balázs, 1989b).

Leafrollers

Fifty parasitoid species have been reared from the larvae of leafrollers (Balázs et al., 1983; Balázs, 1986; Osman & Balázs, 1988). The rate of parasitism of larvae of leafrollers is in average between 10-20%, and seldom higher (27-30%) (Jenser & Balázs, 1991a).

About the effectiveness of *Trichogramma* species for control of leafrollers only a little information is available for the Hungarian orchards. Infestations of codling moth and leafrollers by *Trichogramma evanescens* Westwood race *semblidis* and *T. cacoecidae* March species have been reported (Bognár, 1961; Nagy, 1973). Other parasitoids of codling moth are reported by Bognár & Hassan, (1979).

Woolly apple aphid (WAA)

Populations of the WAA parasitoid *Aphelinus mali* Haldeman are able to survive in the colonies of *Eriosoma lanigerum* Hausmann living on the root or root collar of suckers in the orchards treated with organophosphorous and pyrethroid insecticides (Molnár, 1977; Jenser, 1983). Their regulating effect on the population dynamics of woolly apple aphid can be realised when selective insecticides are used (Jenser et al., 1992).

Pear psyllids

The parasitoid *Trechnites psyllae* Ruschke has been reared from the larvae of *Cacopsylla pyri* collected on wild pear trees and in treated orchards also in Hungary. It is a beneficial arthropod species which can be important in the regulation of pear sucker populations (Jenser, 1968; Jenser et al., 1992).

Predators

Hoverflies

Six hoverfly species (Syrphidae) were observed to be dominant in apple orchards infested by aphids (Visnyovszky In: Balázs & Mészáros, 1989).

Neuropterans

Twenty-eight Planipennia species were detected in different orchards. Among these some brown lacewings (Hemerobiidae) and green lacewings (Chrysopidae) were found very often in orchards (Szentkirályi, In: Mészáros et al., 1984).

Thysanopterans

Four predacious thysanopterans have been collected in orchards. Two species have been observed on pear trees infested by the pear sucker (*C. pyri*). *Haplothrips subtilissimus* has been observed sucking the eggs of *Archips podana* and pear psylla (*C. pyri*). *Scolothrips longicornis* often occurred on peach preying on *Tetranychus urticae* and in higher population density were on sour-cherry trees, where it was preying there on *T. wiennensis* (Jenser, 1992).

Predatory bugs

Six pirate bugs (Anthocoridae) and six damsel bugs (Nabidae) (together with other heteropterans in total 184 species) were found in orchards. The most frequent species was *Orius minutus*. These predatory bugs were present in low population densities in the investigated orchards (Rácz, 1986). The specimens of *Anthocoris nemoralis* were found in a large numbers in corrugated paper belts wrapped round the trunk in September of pear trees infested by pear suckers. The activity of *A. nemoralis* and *O. minutus* could be one of the factors which could regulate the population dynamics of some pest probably of *C. pyri* (Rácz, 1986; Rácz in Mészáros et al., 1984).

Predatory beetles

Three hundred and seventy species of Coleoptera were found in the canopy of apple trees (Markó et al., 1995). Seventy-eight ground beetles (Carabidae) and five rove beetles (Staphylinidae) occur on the ground layer of apple orchards (Lôvei, in Mészáros et al., 1984; Jenser et al., 1992).

Twenty-one species of ladybirds (Coccinellidae) were collected in different types of orchards, *Coccinella septempunctata* L., *Adalia bipunctata* L. *Propylea quatordecimpunctata* L. and *Stethorus punctillum* Weise being dominant. They sometimes immigrate to the orchards in great numbers (Lôvei, in Mészáros et al., 1984; Markó et al., 1995) From time to time *C. septempuntata* was observed preying on aphids, woolly apple aphid and on pear suckers (Kozár et al., 1979). *Stethorus punctillum* Weise has been observed to prey on tetranychid mites, but only in a few occasions they were found in high densities (Jenser, 1984; Molnár & Somogyi, 1988).

Earwigs

Two earwigs (Dermaptera) namely *Forficula auricularia* L. and *Labidura riparia* Pallas have been observed in orchards (Nagy in Mészáros et al., 1984).

Predatory mites

Some 30 species of predatory mites (Phytoseiidae) occur in orchards (Sz. Komlovszky & Jenser, 1987; 1988; Jenser, 1989; Jenser et al., 1992). In treated orchards only a few specimens have been found. *Typhlodromus pyri* Scheuten was collected only once in one abandoned orchard (Kropczynska & Jenser, 1968), consequently it is practically missing from the Hungarian orchards. Similar result was found by Sárospataki et al., (1991) in vineyards. After the use of selective insecticides the population density of a stigmaeid predacious mite, *Zetzellia mali* Ewing increased rapidly within 1-2 years. The populations of this species are able to influence the population dynamics of spider mites. The presence of Phytoseiid mites was observed only six years after the usage of IGR's (Jenser & Balázs, 1991a,b; Jenser, 1991; Molnár & Kerényi-Nemestóthy, 1991; Sz. Komlovszky & Jenser, 1987; 1992).

In total 1759 animal and 137 plant species were described from apple orchards in Hungary (Mészáros et al., 1984). This list ignores one predator group, the spiders. As a member of the Apple Ecosystem Research Team - co-ordinated by the Research Institute for Plant Protection - my research topic was to assess the role of spiders in controlling pest species in orchards. The present thesis is the result of a 5-year study in co-operation with the Department of Entomology of Wageningen Agricultural University in the Netherlands.

1.4 Spiders in biological and natural control

One of the best examples that spiders can play a fundamental role in suppression of pest species originates from studies in rice paddies in Asia. The wolf spider *Lycosa pseudoannulata* is the major factor in controlling homopteran rice pests such as the brown planthopper *Nilaparvata lugens*, the white backed planthopper *Sogatella furcifera* and the green rice leafhoppers *Nephotettix cinctipes* and *N. virescens* (Kiritani et al., 1972; Kenmore et al., 1984; Salim & Heinrichs, 1986). Jones (1981) reported that the Chinese used straw bundles as shelters for spiders to conserve their numbers during irrigation of rice paddies. This approach to spider conservation was associated with a 50-60% decline in pesticide use over a 3000 ha region in China. Mass rearing and release of this spider species is also possible (Thang et al., 1988).

In cotton ecosystems lynx spiders such as the stripped lynx spider (*Oxyopes salticus*) and the green lynx spider (*Peucetia viridans*) and the jumping spider, *Phidippus audax* have been observed preying on a wide variety of insect pests such as on the cotton fleahopper (*Pseudatomoscellis seriatus*) (Nyffeler et al., 1992a,b), on the tarnished plant bug (*Lygus lineolaris*) (Lockley & Young, 1988; Young, 1989) and on noctuids (*Alabama argillacea*; *Heliothis spp.*) (Nyffeler et al.,1987).

Chiverton (1986) and Riechert & Bishop (1990) provide the best experimental evidence for the importance of the spider assemblages in agro-ecosystems. Their experiments demonstrate clearly that spiders can limit pest numbers.

Studies of spider abundance and diets in agro-ecosystems (reviewed by Bogya & Mols, 1996) suggest that spiders contribute to the limitation of insect pests in field crops and orchards. A predator has the potential to regulate densities of its prey only if the mortality rate it inflicts is density dependent, which can occur if the predator displays a Holling type III functional response and / or a numerical response resulting increasing total response (Holling, 1966). Strong type III responses are probably not common among spiders (Wise, 1995), but especially the hunting spiders can show strong numerical responses, mainly aggregational (Corrigan & Bennett, 1987) and probably reproductive responses to prey density resulting the potential to regulate its prey even in the absence of a Holling type III functional response.

According to the present knowledge about spider behavior, population ecology and the importance of spiders in food webs lead to the hypothesis in general about the role of spiders as predators. The hypothesis assumes that spiders, *as a complex of generalist predators*, help to limit insect populations by inflicting substantial density-independent mortality (Wise, 1995).

1.5 Spiders in orchards

In orchard ecosystems Mansour and his colleagues have concluded that spiders especially the clubionid species *Cheiracanthium mildei* are important biocontrol agents (Mansour et al., 1977; 1980c,d; Mansour & Whitcomb, 1986). This species preys upon a wide range of insect pests (Mansour et al., 1977; 1980a,b,c,d) and was also regularly found on apple trees infested by the leafminer *Phyllonorycter blancardella* in a greenhouse experiment conducted by Corrigan & Bennett (1987). They suggest that *Ch. mildei* can detect the cryptic leafminer larva and attack it by biting through the lower surface of the mine. From a laboratory experiment Mansour et al. (1980b) concluded that *Ch. mildei* has s-shaped functional response to prey density, although their data clearly indicate a Holling type II response (Wise, 1995).

In addition to predation, the "disturbing effect" when young caterpillars fall down because of the movement of spiders and than are unable to walk back should be mentioned (Mansour et al., 1981); it is sometimes much more important than predation itself (Nakasuji et al., 1973a,b). Young spiders cause a lower predation and a higher disturbing effect than mature spiders (Mansour, et al., 1981).

The web-builder *Araniella* (*cucurbitina-opistographa*) *spp.* are common in apple orchards in Europe (Klein, 1988; Anchipanova & Shternbergs, 1987) and can be important as mortality factor of aphids as they catch winged migrants returning to the apple trees in autumn (Wyss, 1995 Wyss et al., 1995). The prey of these species also includes *Psylla mali* (Anchipanova & Shternbergs, 1987), *Anthonomus pomorum* (Tretyakov, 1984), mites (Chant, 1956) and lepidopteran pests (Sengonca & Klein, 1988).

Two reviews summarized the knowledge about spiders as biological control agents in agro-ecosystems and it was concluded that spiders can play a fundamental role here (Riechert & Lockley, 1984; Nyffeler & Benz, 1987). The last review was performed almost 10 years ago when the role of the foliage-dwelling spiders in orchard ecosystems was not well investigated. In the last decade many studies have been carried out especially on the behavior of spiders in agro-ecosystems and nowadays we are gaining more sight on the role of this group of animals as predators of pests of economic importance.

1.6 Outline of the thesis

First the knowledge about the role of spiders in agro-ecosystems is summarized, based on nearly 500 articles from the last 70 years (Chapter 2) with particular reference to orchards and to indicate what we can expect from spiders as beneficial agents in IPM management systems.

In the next section (Chapter 3) the results of faunistic and taxonomic work carried out in different strata (canopy, herbaceous layer, ground level) of several apple and pear orchards in the Carpathian Basin is presented.

Many apple and pear pests occur over wide areas, but in different abundance. Little is known of the spatial distribution of their natural enemies. If the spider fauna of different orchards differs considerably, than different prey-spider system will have developed. The knowledge about the regional differences is essential in the design of regional IPM programs. A comparison of spider communities inhabiting apple and pear orchards in different geographical scale (Holarctic, European, inter- and intraregional levels in Hungary) using literature data and own research can be found in Chapter 4.

In case of applying IPM, it is theoretically possible to augment spider communities in comparison with conventional control. The existing few studies (Olszak et al., 1992; Samu et al., 1997) did not give a detailed answer to this. The effect of an IPM system on foliage- and herbaceous layer inhabiting (Chapter 5) and on ground dwelling (Chapter 6) spider communities in orchards is compared with conventional control.

Finally, the potential role of the clubionid spiders (Clubionidae) as the most promising group of spiders (indicated by Bogya & Mols, 1996) with particular reference to their prey acceptance, winter-feeding, abundance and potential food intake is also discussed (Chapter 7).

The thesis is concluded with a summarizing discussion (Chapter 8) in which is stated that in applying integrated pest management systems (medium pesticide disturbance) there are possibilities to develop more complex and abundant spider communities, which can contribute to the suppression of orchard pests by adequate pest, disease and weed management and the management of the surroundings.

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Chapter 2

The Role of Spiders as Predators of Insect Pests with Particular Reference to Orchards: A review.*

Abstract. Spiders are well known predators of insects (including insect pests) but about their role as biological control agents in agro-ecosystems (particularly in orchards) little is known. In the last decade new information (especially of the behaviour of spiders in different agro-ecosystems) has become available and this increased expectations about spiders as beneficial organisms. Spiders are a very heterogeneous group of animals with different hunting tactics and therefore, they play a different ecological role. At family level these tactics are rather similar and one species of the group can be used as representative example for ecological studies for the whole family. On the other hand properties and behaviour found in different species of one family can be seen as characteristic for the whole family. A comprehensive review of spiders as natural enemies of pest species of different crops is given offering information about the expected prey spectrum per family.

A qualitative evaluation of pest-spider relationship has been carried out for a whole range of agro-ecosystems and the results are transposed to spider groups inhabiting the orchard ecosystem.

The effect of pesticides on spiders, both from laboratory and field experiments is discussed and it has been shown to be the most important factor influencing spider occurrence and abundance in the field. Thus the pest management system (conventional or IPM or ecological) determines to a great extent the role of spiders can play in controlling pest organisms.

Only from a few species that occurring in different ecosystems quantitative information of their searching and predatory potential is available resulting in functional and/or numerical response relationships to prey density. A list of method for further quantitative evaluation of spider impact on pest in getting insight in predation processes is presented.

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The last review of spiders as biological control agents was performed almost 10 years ago by Nyffeler & Benz, 1987. In the last decade an enormous amount of studies has been carried out especially on the behaviour of spiders in agro-ecosystems and nowadays we are gaining more sight on the role of this group of animals as predators of pests of economic importance. The aim of this review is to summarise the knowledge in this field, with particular reference to orchards and to indicate what can we expect from spiders as beneficial agents in IPM management systems.

2.1 Spiders as beneficial agents

Distribution and density

Spiders are one of the most common and ubiquitous groups of animals. The species total has been estimated to be about 50.000 of which 30.000 species have been identified properly. They are found in all terrestrial ecosystems, including agro-ecosystems (Turnbull, 1973). All of them are predacious organisms and feed almost exclusively on insects (Riechert & Lockley, 1984). In agro-ecosystems, spiders are a part of the beneficial fauna. In the canopy of apple orchards the proportion spiders of the beneficial fauna varied between 40% and 95% (Olszak et al., 1992b; Specht & Dondale, 1960) and on the ground level varies between 10% and 13% (Loomans, 1978; Zhao et al., 1993).

However, concerning their usefulness there are some exceptions. In some tropical ecosystems (e.g. coffee, citrus and mango) the so-called colonial spiders tie green topical leaves of branches together and thus create a micro-climate to live in. When the leaves of these nests are dried-out, the colony moves to another green branch. Damage caused is such that sometimes insecticidal control is needed (Stejskal, 1976).

In pome and stone fruit orchards more than 10% of hunting spiders (together with other arthropods e.g. ladybirds and predatory bugs) contaminated with the propagules of cytospora cankers and wood-rotting pathogens. Laboratory investigations suggest that contaminated orchard arthropods play an important role in distribution of diseases (Helton et al., 1988a;b).

The species richness and spider density are very variable; respectively varying between 52 species on guar to 308 species on cotton (Young & Edwards, 1990) and the density from 1 individual per m2 (Nyffeler et al., 1994a) to 1000 per m2 (Nyffeler, 1982). The species richness of agro-ecosystems is generally smaller than of natural habitats (Nyffeler, 1984). Olszak et al. (1992a) found 51 species of spiders in apple orchards while, 72 species were found in its surroundings. Turnbull (1973) computed the average spiders density as 130.8 individuals per m^2 called "overall mean value" (based on 34 literature data from world-wide). Since this work several authors found even 100 times lower population density in agro-ecosystems (Nyffeler et al., 1994a).

Investigations on the population density of foliage dwelling sac spiders (Clubionidae) by mark-recapture method in an IPM apple orchard in the Netherlands showed 6 individuals per m^2 (Bogya, 1995a).

Foraging behaviour

According to traditional foraging theory, spiders were considered to be predators of living, moving prey (Savory, 1928; Gertsch, 1949; Turnbull, 1973). More recent studies expanded this view since evidence was found that spiders utilise a much broader range of foraging strategies, including feeding on dead animals (Knost & Rovner, 1975; Williams et al., 1986), artificial diets (Peck & Whitcomb, 1968; Zhao & Zhao, 1983), plant components (Vité, 1953; Smith & Mommsen, 1984) and arthropod eggs (Whitcomb & Bell, 1964; Whitcomb, 1967; Nuessly, 1986). In most cases, the spiders were observed feeding on the eggs of Lepidoptera (families Noctuidae, Tortricidae, Lymantriidae, Pyralidae and Sphingidae), and to a lesser extent, on coleopteran eggs (family Curculionidae) (reviewed by Nyffeler et al., 1990)

Foraging strategies of spiders can be divided into two groups: web-building and wandering. Spiders are generalist predators (Riechert & Harp in Slansky & Rodrigez, 1987), this means they eat a wide variety of animals, and their sedentary foraging mode suggests that selection for habitat, not prey, should be the rule (Uetz, 1992). However, prey capture specialisation can be observed in bolas spiders, *Mastophora spp.* (Araneidae) which mimic the odour of sex pheromones emitted by female moths (noctuids) and in this way prey only on male moths (Stowe et al., 1987).

According to Nentwig (1986) a part of the hunting spiders are more or less specialised to specific types of prey. He mentioned 4 types such as ants; termites; spiders and hymenopterans.

The most important factor determining success of prey capture is the size of the prey. If prey size is between 50-80% of the spider size this will result in the highest prey capture. However some spiders with strong poison can catch bigger prey (e.g. flower inhabiting crab spiders or social hunting spiders) can catch 3-times bigger preys than themselves (Nentwig & Wissel, 1986).

The "ideal" predator described by Riechert & Lockley (1984) is highly specialised to its prey. Spiders fit poor into that model, but several other investigations and computer simulations indicate that generalist predators, especially spiders just like specialists can play an important role in agro-ecosystems (Whitcomb, 1987; Riechert, 1974, 1990; Provencher & Riechert, 1994). However, pest species form only a fraction of the diet of spiders (Nyffeler, 1983; Nyffeler et al., 1987a; 1987b; Nyffeler & Benz, 1979; 1988a) (varying between 0-100%). They can survive periods of food shortage by decreasing their metabolic rate or by switching to alternative prey. Wasteful killing (like a fox in a chicken-house) is also an important property of valuable predators.

The spider web is a very efficient trap for insects. Web-builders normally catch as much prey as in *ad libitum* conditions in laboratory, but hunting spiders ingest much less in the field than in laboratory. This is very important if we want to estimate the predatory potential of these spiders in the field (Nyffeler & Breene, 1990).

Eggs, immature and adult spiders can be found at the same time throughout the season (Schaefer in Nentwig, 1987), but most of them are mature in summer. A part of the spiders (so-called winter-active spiders) have no diapause, they are able to move, feed and even reproduce during winter (Schaefer, 1977; Aitchison in Nentwig, 1987). Down to -5 ?C they can feed mainly on springtails and on dipterans. The winter active wolf and crab spiders prey on aphids, leafhoppers, bugs, orthopterans, lepidopterans and coleopterans (Aitchison, 1984). Investigations on winter-active clubionids indicate that the consumption of pest species in winter months is too low to be of economic importance, but in early spring when all other predators and parasitoids are still in diapause preying on larvae of leafrollers may be of importance (Bogya, 1995a;b).

2.2 Review of spiders occurring in orchards and other ecosystems with particular reference to their role as natural enemies of pests

The first author that did write about the role of spiders in controlling pest species was Bilsing (1920) who presented a list of observed victims of spiders (including orchards pest). Klein (1936) observed the first time that spiders prey on fruit tree red spider mites in Palestine; Picket et al. (1946) mentioned the first time that spiders may be important predators in Canadian orchards; Chant (1956) presented a list of spiders preying on fruit tree red spider mites and bryobia mites in England and Le Roux (1960) concluded that spiders are the most important predators on apple in Canada.

Turnbull (1973) summarised the ecology of true spiders (Araneomorphae), but he ignored their role in agro-ecosystems. Since his review, considerable progress has been made in the field, and we are better able to evaluate the predatory potential of spiders at this time. The first authors who summarised the role of spiders as biological control agents were Riechert & Lockley (1984). They reviewed 174 articles and concluded that one spider species alone was unable to control pest species, but the whole spider community could do it. In contradiction to them Spiller (1986) stated that one spider species alone can be used better for biological control than several species together because of the competition between the species. They also concluded that "usage" of spiders in pest control is most promising in orchards because this agro-ecosystem is the least disrupted. They recommended spraying at noon to save the spider populations because most of them are inactive during that time. Nyffeler & Benz (1987) also summarised the role of spiders in natural pest control (reviewed 300 articles) and concluded that the foliage dwelling spiders play a less important role than ground dwelling spiders because of their lower densities.

From literature it can be concluded that the following families of spiders occur in European apple orchards: **Agelenidae, Anyphaenidae, Araneidae, Clubionidae, Dictynidae,**

Linyphiidae, Lycosidae, Oxyopidae, Philodromidae, Salticidae, Tetragnathidae, Theridiidae, Thomisidae.

They were recorded by Chant (1956) (**England**); Loomans (1978) and Langeslag (1978) (**The Netherlands**); Klein (1988) (**Germany**) and Olszak et al. (1992b) (**Poland**). Chant (1956) found 8 families of spiders in sprayed and 9 families of spiders in unsprayed orchards. The dominant families are Theridiidae and Linyphiidae. Loomans (1978) and Langeslag (1978) recorded 12 families of spiders from an experimental orchard. The dominant species in the canopy are *Theridion varians* Hahn (Theridiidae), *Araniella opistographa* Kulczynski (Araneidae), *Philodromus aureolus* (Philodromidae) and *Arelosimus vittatus*. In the ground level *Oedothorax fuscus*, *Centromerita bicolor*, *Centromerus sylvaticus*, *Lepthyphantes tenuis* and *Diplostyla concolor* (Linyphiidae) were dominant. Klein (1988) described 10 families. The dominant spiders are *Araniella opistographa* Kulczynski (Araneidae) and *Philodromus cespitum* Walckenaer (Philodromidae). Olszak et al. (1992b) reported 11 families. The dominant species are *Araniella cucurbitina* Clerck (Araneidae) and *Theridion varians* Hahn (Theridiidae).

In the following sections these families are described shortly with their dominant characteristics.

A comparison with species of the same family occurring on crops of economic importance outside of Europe is included. Especially their role as natural enemies of pests and their predatory behaviour is emphasised.

2.3 Families of spiders inhabiting in European orchards

Agelenidae (Funnel-web spiders)

General description There are 29 species in 9 genera in Central Europe (Heimer & Nentwig, 1991). The majority of species have the posterior spinners clearly longer than the anteriors. Males resemble females in general appearance but have a slimmer abdomen and, in most cases, relatively longer legs. These spiders spin a tubular retreat from which extends either a small collar of silk, or a small to large sheet, which may be slightly funnel-shaped. Courtship varies between genera. It may involve tapping on the female's web, seizing her fairly quickly and mating on the sheet; other species may mate away from the retreat/web and there may be considerable stroking, with the female entering a torpid state. The egg sac is made within the retreat, and males often remain with their mates, eventually dying of old age. The size of these spiders varies between 3-20mm (Roberts, 1995).

Hunting behaviour The spiders (diurnal hunters) run on the upper surface of the sheet to catch prey which has landed on it. Sometimes there is a superstructure of threads, and insects hitting this fall down on to the sheet. Prey is then dragged back into the retreat for consumption. (Intermediate behaviour between web-builders and hunting spiders). According to Nyffeler et al., (1994b) the prey of these spiders are lepidopterans, bees, orthopterans and beetles.

Habitat and distribution They occur in built up areas; on bushes and plants or in low base vegetation; in, on or under grass; amongst stones and stone walls. Generally widespread and common in the region.

Importance in crop protection

Species occurring in orchards Members of this family are reported from the **Netherlands** by Loomans (1978); from **Poland** by Olszak et al. (1992b); from **Canada** by Dondale (1956); from **Japan** by Hukusima (1961) and Okusima (1973); from **USA** by

McCaffrey & Horsburgh (1980) in apple orchards. This family represented by very few species with a small number of individuals in this habitat. It can thus be assumed that their presence on apple trees was accidental and was probably induced by wind movement from their habitats (Olszak et al., 1992b; McCaffrey & Horsburgh, 1980).

Species occurring in other agro-ecosystems Brignoli (1983) mentioned that egg sacs of *Agelena opulenta* L. were placed to mulberry trees infested by fall webworm (*Hyphantria cunea* Drury; Lep.: Arctiidae) in Japan and the spiders did manage to decrease the number of caterpillars under the economic threshold. *Agelenopsis emertoni* Chamberlin & Ivie and *A. pennsylvanica* C. L. Koch are commonly found in cotton fields in USA (Whitecomb et al., 1963). Members of this family preying on pest species are shown in Appendix A, Table 1.

Conclusion This family of spiders is not abundant in orchards and their hunting behaviour suggest that they probably are of minor importance in controlling pest species.

Anyphaenidae (anyphaenids)

General description A single member of the family Anyphaenidae, *Anyphaena accentuata* Walckenaer occurs in Central Europe (Heimer & Nentwig, 1991). The spider is distinctively marked and the tracheal spiracles are easily visible halfway between the spinners and the epigastric fold. The species lives and hunts on the leaves of trees and bushes. Males vibrate the abdomen on the surface of a leaf in order to attract the female's attention prior to mating. The female attaches the egg sac to a curled leaf and remains on guard with it in a flimsy silk cell. By this time, the abdomen of the female has become rather slim and the colour darkened to an almost uniform grey-brown. The size of this species varies between 4.5-7.5 mm (Roberts, 1995).

Hunting behaviour Similar to clubionids see there.

Habitat and distribution This species occurs on the leaves of trees and bushes. Generally locally abundant.

Importance in crop protection

Species occurring in orchards This species is reported from **Germany** by Klein (1988); from the **Netherlands** by Loomans (1978); and from **Poland** by Koslinka (1967) and Olszak et al. (1992b). Other members of this family are mentioned from **Canada** by Dondale (1956) and Specht & Dondale (1960); from **USA** by McCaffrey & Horsburgh (1980) in apple orchards and from USA by Mansour et al. (1982); from Mexico by Rodriguez Almaraz & Contreras Fernandez (1993) in citrus orchards. *Anyphaena pectorosa* L. Koch inhabiting on apple and prey on apple pests (aphids, planthoppers) (McCaffrey & Horsburgh, 1978) in USA. Other anyphaenids (*Aysha gracilis* Hentz) inhabiting citrus (Mansour et al., 1982) and pecan and prey on the blackmargined aphid (*Monellia caryella* Fitch.; Hom.: Aphididae) (Bumroongsook et al., 1992), the average daily consumption was 7.4 aphids in the field.

Species occurring in other agro-ecosystems This species (*A. gracilis* Hentz) also inhabiting on cotton and preys on many cotton pests (see Appendix A, Table 2).

Conclusion Only one and locally abundant species occurs in the region, but its hunting behaviour suggests that (where it is occurs) at least it contributes to reduction of pest species.

Araneidae (Araneids)

General description This family is represented by 46 species in Central Europe in 17 genera (Heimer & Nentwig, 1991). The small height of the clypeus, the lateral condyle on the chelicerae and the auxiliary foot claws are characteristics of this family. The males resemble females in patterns and markings, but have a much smaller abdomen. The carapace is sometimes rather narrow at the front and the front legs may be furnished with stout spines.

The species spin orb webs with a closed hub, the hole having been filled with a lattice of silk threads. A strong signal thread leads from the hub to a retreat amongst nearby vegetation or other structures, the spider waiting there and rushing down into the web in response to vibrations from ensnared prey.

Araneids generally have a number of strong teeth on the chelicerae and prey is chewed and mashed with digestive juices.

The result is an unrecognisable pellet of insect remains as opposed to the near-perfect, sucked-out husks left by theridiids and thomisids. Size small to medium large 3-15 mm (Roberts, 1995).

Hunting behaviour The hunting strategy of these spiders is ambushing for prey in the web. They generally prey on a wide variety of insects such as orthopterans, dipterans, hemipterans, and are able to feed on hard cuticled (e. g. beetles) and chemically protected (bees) insects. The lepidopterans do generally avoid the orb-webs (Nyffeler et al., 1994b).

Habitat and distribution They occur in built up areas; in and up trees; in forests; in webs between trees; on bushes and plants or in low base vegetation; in meadows; in, on or under grass. Generally common and widespread throughout Europe.

Importance in crop protection

Species occurring in orchards Members of this family are recorded from **England** by Chant (1956); from the **Netherlands** by Loomans (1978); from **Poland** by Koslinka (1967) and Olszak et al. (1992b); from **Australia** by Dondale (1966); from **Canada** by Dondale (1956); Specht & Dondale (1960); Hagley (1974); Dondale et al. (1979) and Bostanian et al. (1984); from **Japan** by Hukusima (1961) and Okuma (1973); from **USA** by McCaffrey & Horsburgh (1980) in apple orchards and From Japan by Nakao & Okuma (1958); from USA by Mansour et al. (1982) and from Mexico by Rodriguez Almaraz & Contreras Fernandez (1993) in citrus orchards. *Araniella cucurbitina* Clerck is widespread in this ecosystem in USSR (Anchipanova & Shternbergs, 1987; Tarabaev & Sheykin, 1990) in France (Naton, 1974) in England (Chant, 1956) and in Poland (Olszak et al., 1992b). Together with theridiids and micryphantids the main food source of these spiders in this habitat are the apple sucker (*Psylla mali* Schmidberger; Hom.: Psyllidae), the green apple aphid (*Aphis pomi* Deg.; Hom.: Aphididae) (Anchipanova & Shternbergs, 1987; Tretyakov, 1984), apple blossom weevil (*Anthonomus pomorum* L.; Col.: Curculionidae) (Tretyakov, 1984), fruit tree red spiders mite (*Panonychus ulmi* Koch) and the bryobia mite (*Bryobia praetiosa* Koch) (Chant, 1956). (The biology of this species is described by Bakken (1978) in Norway). An other closely related species *Araniella opistographa* Kulczynski was found as one of the most common species on apple in Germany (Klein, 1988; Sengonca et al., 1986), and investigated the prey spectrum of this species in the field by Sengonca & Klein, (1988) (Tortricidae, Geometridae, Aphididae, Psyllidae, Curculionidae). *Araniella displicata* Hentz is one of the dominant foliage dwelling species on apple in Canada (Dondale, 1958; Dondale et al., 1979) and reported as a predator of the mites *Tetranychus urticae* Koch and *Panonychus ulmi* Koch (Parent, 1967). *Araneus transmarinus* Keyserling was mentioned as natural enemy of the light brown apple moth (*Epiphyas postwittana* Walker; Lep.: Tortricidae) in Australia (Dondale, 1966; Danthanarayana, 1983) and another 8 araneids preying on this pest was reported by (Dondale, 1966). *Neoscona sp.* was the most frequently observed spider that preys on citrus psylla (*Trioza erytreae* Del Guercio; Hom.: Triozidae) in South Africa (Berg et al., 1987; Berg et al., 1992). *Neoscona arabesca* Walckenaer preys on pecan aphids (*Monellia caryella*) in USA (Liao et al., 1984; Bumroongsook et al., 1992). The aphid consumption was an average of 7.72 per day. *Argiope trifasciata* Forskäl occurs in citrus orchards (Muma, 1975) and takes adults of citrus weevil (*Diaprepes abbreviatus* L.) as prey (Mansour et al., 1982).

Species occurring in other agro-ecosystems Members of this family occurring in many agro-ecosystems e.g. cotton (Nyffeler et al., 1989), soybean (Culin & Yeargan, 1982) and rice (Kamal et al., 1992) and prey on many insect pests (see Appendix A, Table 3). The prey spectrum of *Argiope aurantia* Lucas is well investigated in cotton in USA by (Kagan, 1943; Nyffeler et al., 1987b). They obtained as a result that approx. 50% of the diet belonged to pest species (30% aphids and 17.9% orthopterans).

Conclusion The smaller species of this family regularly spin their webs in higher vegetation and their prey are smaller (<4mm, mainly dipterans and homopterans (Pasguet, 1984) Some of them are common and widely distributed in orchards (Klein, 1988; Olszak et al., 1992b). Their early appearance in spring and long activity period to late autumn makes these spiders probably an important group of natural enemies in orchards (Klein, 1988; Wyss, 1995). The large members of this family (e.g. *Argiope bruennichi* Scop.; *Araneus quadratus* Clerck; *A. diadematus* Clerck) spin strong orb-webs in lower vegetation (0-50) (Brown, 1981; Pasguet, 1984) and prey mainly on large insects (e. g. orthopterans), but aphids (Nyffeler & Benz, 1989) (especially the cereal aphid, *Rhopalosiphum padi* L.) are also an important part of the diet (Nyffeler & Benz, 1982; Nyffeler, 1983; Nyffeler & Benz, 1989). Sometimes these species catch honeybees (*Apis mellifera* L.; Hym.: Apiidae) too (Thakur & Sharma, 1984), but the rate of predation on this beneficial insect is rather low (approx. 1% of the diet) (Nyffeler & Breene, 1991). These spiders are sensitive to grazing, mowing (Gibson et al., 1992) and also spraying, because the spider web is an efficient collector of pesticides (Samu et al., 1992) and the orb-weavers are recycling their web every day.

Clubionidae (Sac spiders)

General description There are 37 species in Central Europe in two genera (Heimer & Nentwig, 1991): *Clubiona* (leaf-curling sac spiders) and *Cheiracanthium* (long-legged sac spiders). Their special characteristic is their 'black face' appearance. Clubionids have long legs with scopulae on the tarsi and tarsal claws (with help of this organ these spiders are able to run on the foliage very easily). The chelicerae are long and rather stout and black. Some species have chevron markings on the abdomen. The eyes are small almost of the same size, and situated in two transverse rows. In *Clubiona* usually the fourth pair of legs is the longest, while in *Cheiracanthium* the first pair of legs the longest. The carapace of *Clubiona* has fovea and *Cheiracanthium* has not.

Most members of this family construct tubular or flat sac of dense white silk, either opens at the end or closed, to be used as retreat. *Clubiona* makes a sac in rolled-up leaves, in folded blades of grass or under loose bark. *Cheiracanthium*, which is often found inside houses, makes a flattened, disc-shaped sac in the folds of curtains, behind and under the objects. The sacs are papery and shiny in appearance and very tough. The egg sac is similar but smaller. Size: small to medium large 3-15 mm (Roberts, 1995).

Hunting behaviour Clubionids are typical wandering spiders, rapid runners for short-distances with poor eyesight and hunt at night. Some wander on the soil surface and others (most of them) range over vegetation. Sac spiders are free-roaming, aggressive hunters, they catch their prey with great speed and agility, leaping on it and grabbing it with outstretched front legs.

Habitat These spiders occur under bark and stones; amongst low vegetation and leaf-litter; on bushes and trees; in marshy habitats and on sand dunes; in built up areas. Generally common and widespread in the region.

Importance in crop protection

Species occurring in orchards Members of this family are recorded from **England** by Chant (1956); from the **Netherlands** by Loomans (1978); from **Poland** by Koslinka (1967) and Olszak et al. (1992b); from **USSR** by Selivanov (1991); from **Australia** by Dondale (1966); from **Canada** by Dondale (1956); Specht & Dondale (1960); Hagley (1974) and Bostanian et al. (1984); from **Japan** by Hukusima (1961); Okuma (1973); Takeda et al. (1978); from **USA** by McCaffrey & Horsburgh (1980); in apple orchards and from USA by Mansour et al. (1982); from Japan by Nakao & Okuma (1958); from Mexico by Rodriguez Almaraz & Contreras Fernandez (1993) and from China by Yan & Wang (1987) in citrus orchards. One of the most important and widely distributed species of this family is *Cheiracanthium mildei* L. Koch. This spider preys upon a wide range of insect pest of several crops. Its prey are spotted tentiform leafminer *(Phylonorycter blancardella* F.; Lep.: Gracillariidae) in Canada (Corrigan & Bennett, 1987) and in Israel (Mansour et al., 1980a), codling moth (*Cydia pomonella* L. Lep.: Tortricidae), red and two spotted spidermites *Tetranychus cinnabarinus* Boisd. and *T. urticae* Koch (Acarina: Tetranychidae) Mediterranean fruit fly (*Ceratitis capitata* Wied.; Dip.: Trypetidae) aphids (Hom.: Aphididae) leopard moth (*Zeuzera pyrina* L.; Lep.: Cossidae) (Mansour et al., 1980a), Egyptian cotton leafworm (*Spodoptera littoralis* Boisduval; Lep.: Noctuidae) (Mansour et al., 1977; 1980b; 1980c; 1980d) and the giant looper (*Boarmia /Ascotis/ selenaria* Denis & Schiffermuller; Lep.: Geometridae) (Wysoki & Izhar, 1980. In addition to predation the "disturbing effect" may be mentioned (Mansour et al., 1981a) (young caterpillars fall down because of the movement of spiders and then are unable to walk back) being sometimes much more important than predation (Nakasuji et al., 1973a;b). Young spiders cause lower predation and a higher "disturbing effect" than mature spiders (Mansour et al., 1981a).

The effect of pesticides on this spider was carefully investigated by Mansour (1987a) and Hassan et al. (1994) in the standard of IOBC/WPRS and they found that the diflubenzuron caused 95-99 % mortality. Mansour et al. (1981b) investigated the toxicity of traditionally used insecticides on this species in Israel and they found that this spider is very sensitive to endosulfan and less sensitive to azinphosmethyl and cyhexatin. Mansour (1984) collected a malathion tolerant strain of this spider from citrus orchards (resistant factor 3.3), but this strain was sensitive to chlorpyrifos.

Sac spiders are predators of the polyphagous leafroller (*Epiphyas postvittana* Walker; Lep.: Tortricidae) on apple in Australia (Dondale, 1966; MacLellan, 1973). These spiders contain 20% of the spider fauna of the foliage of avocado in Israel and prey on the geometrid *Boarmia selenaria* (Mansour et al., 1985).

Clubiona johnsoni Gentseh and *Clubiona moesta* Banks reported as predators of the mites *Tetranychus urticae* and *Panonychus ulmi* in Canada (Parent, 1967). *Clubiona pallidula* and *Clubiona phragmitis* recorded as predators of leafrollers (Lep.: Tortricidae) (daily consumption 4.5 L_2 larvae in laboratory and 3.1 larvae in the field), pear suckers (*Cacopsylla pyricola* Förster and *C. pyri* L. Hom.: Psyllidae) (daily consumption 10-12 adults in laboratory) in the Netherlands (Bogya, 1995a; 1995b) and the pear lace bug (*Stephanitis pyri* F.; Hem.: Tingidae) in Hungary (Bogya & Markó, 1995a; 1995b). Sac spiders were thought to be the most important natural enemies of arthropod citrus pest too in USA (Carrol, 1980). *Clubiona sp.* was seen actively preying upon hairy-caterpillars of *Euproctis lunata* Wlk. and *Porthesia scintillans*

Wlk. (Lep.: Noctuidae) in damaging leaves and even fruits of *Zizyphus jujuba* L. in India (Battu, 1990). *Cheiracanthium lawrencei* Roewer reported as predator of citrus psylla (*T. erytreae*) in South Africa (Berg et al., 1992). *Trachelas volutus* Gertsch has been observed feeding on blackmargined aphid (*M. caryella*) on pecan (Liao et al., 1984; Bumroongsook et al., 1992). *Cheiracanthium inclusum* Hentz and *Clubiona reichlini* reported from citrus orchards by (Mansour et al., 1982; Yan & Wang, 1987; and Yan, 1988). Sac spiders (*Clubiona corrugata* and *Cl. japonicola*) are dominant in tea plantations too (Zhang, 1993) in China.

Species occurring in other agro-ecosystems This family of spiders occurring in many agro-ecosystems and prey on a wide variety of insect pests as shown in Appendix A, Table 4.

Conclusion Mansour & Whitecomb (1986) and Mansour (1987b) performed experiments to evaluate the predatory role of spiders (mainly clubionids) in different ecosystems (citrus and cotton). After removing spiders, the pests (*Ceroplastes floridensis* Comstock (Hom.: Coccidae) on citrus and *Spodoptera littoralis* Boisd. (Lep.: Noctuidae) on cotton) caused significantly higher damage compared to the control. In conventional apple orchards (treated with non-selective insecticides) the number specimens belonging to this family was reduced the smallest (25%) compared with the control (Olszak et al., 1992b). It can be concluded that these spiders potentially play a major role in orchards as nocturnal hunters of lepidopteran pests (see Fig.1.).

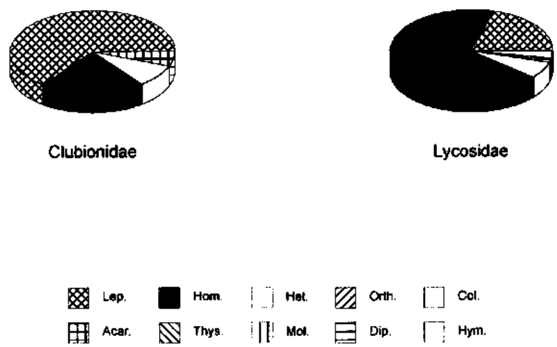


Fig.1. Prey composition of hunting spiders
Clubionidae: nocturnal hunters on foliage
Lycosidae: diurnal hunters at ground level

Dictynidae (Hackled-web spiders)

General description Twenty-one species in 8 genera occur in Central Europe (Heimer & Nentwig, 1991). The cribellate spiders in this family are less than 4 mm in length and have a calamistrum on metatarsus IV comprising a single row of bristles. The male vibrates his legs on the web and approaches to touch the female before mating; this takes place in the summer. Males have the inner margins of the chelicerae bowed outwards slightly and this allows grasping of the female chelicerae during mating. These size of these spiders are 2-4 mm (Roberts, 1995).

Hunting behaviour They spin a cribellate web in the heads of plants and on gorse bushes and heather and seem to prefer dry, dead vegetation or hard-leafed bushes. The dense weave of the cribellate web might well trap too much moisture if spun on rapidly transpiring leaves; this would encourage mould growth on the considerable number of prey remains and be a risk to the egg sacs.

The web is a permanent structure, which is added to daily, and it becomes dense near the centre, where the retreat is made. The prey of these spiders are generally small insects mainly aphids and bugs (Nyffeler et al., 1994b).

Habitat and distribution They occur often on dead plants and on foliage of low vegetation; on leaves of bushes and trees; in built up areas. Generally widespread throughout the region.

Importance in crop protection

Species occurring in orchards Members of this family are reported from **England** by Chant (1956); from the **Netherlands** by Loomans (1978); from **Poland** by Koslinka (1967) and Olszak et al. (1992b); from **Canada** by Dondale (1956); Specht & Dondale (1960); Hagley (1974); Dondale et al. (1979); Bostanian et al. (1984); from **Japan** by Hukusima (1961) and Okuma (1973); Takeda et al. (1978); from **USA** by McCaffrey & Horsburgh (1980) in apple orchards. But Specht & Dondale (1960) and Olszak et al. (1992b) mentioned that these spiders are probably not characteristic of orchards and their presence there was rather fortuitous. Hagley & Allen (1989) found that *Dictyna annulipes* Blackwall preys on the white apple leafhopper (*Typhlocyba pomaria* McAtee; Hom.: Cicadellidae), apple maggot (*Rhagoletis pomonella* Walsh), the green apple aphid (*Aphis pomi* DeGeer) and the spotted tentiform leafminer (*Phyllonorycter blancardella* Fabr.) on apple in Canada and an other species of this genus (*D. sublata* Hentz) feeds on apple inhabiting aphids (*Aphis sp., Dysaphis plantaginea* Passerini) (both alate and apterous forms were accepted) and thysanopterans (*Leptothrips mali* Fitch) in USA (McCaffrey & Horsburgh, 1978). Putman (1967) investigated the predators of fruit tree red spider mites *Panonychus ulmi* and 92% of the collected *Dictyna sublata* showed positive reactions by paper chromatography; Parent (1967) also mentioned that *Dictyna sp.* is a predator of *P. ulmi* and *T. urticae*. Dictynids are common in citrus orchards too (Mansour et al., 1982; Muma, 1975). Muma (1975) recorded that unidentified *Dictyna spp.* are natural enemies of whiteflies on citrus in USA. Temerak (1981) investigated the prey spectrum of the most common spiders (*Dictyna sp.*) on pomegranate in Egypt, and found that 54% of the diet was aphids and white flies.

Species occurring in other agro-ecosystems This family of spiders are not abundant in agro-ecosystems as shown in Appendix A, Table 5. Nyffeler et al. (1988) found that 71.6% of the diet of *Dictyna segregata* is aphids on cotton and potential predator of the bug (*Pseudatomoscelis seriatus* Reuter; Hem.: Miridae) too.

Conclusion Dictynids prefer other areas (e.g. dry vegetation) than agro-ecosystems. These spiders were observed feeding on many orchard pests but their size is too small to play an important role in controlling them.

Nuessly & Goeden (1983) observed that the spider *Dictyna reticulata* Gertsch and Ivie did feed on the larvae of *Coleophora parthenica* Meyrick (Lep.: Coleophoridae) which is an important biological control agent of the weed Russian thistle (*Salsola australis* R. Brown; Chenopodiaceae). This beneficial insect contained ±71% of the diet of the spider in USA.

Linyphiidae (Linyphiids, Money spiders)

General description This is the largest family of European spiders and contains well over four hundred species in over one hundred and twenty genera (Heimer & Nentwig, 1991). The majority are known as 'money spiders', this is undoubtedly the best known and most frequently used common name for a group of spiders. The name applies to fairly small, grey or black-bodied spiders with no pattern. The name does not apply to all members of the

Linyphiidae; those with patterns and markings are definitely excluded. The males of some species have ridges on the outer surface of the chelicerae and an opposing tooth on the inner side of the palpal femur. This is used in stridulation during courtship. Relatively little is known of the biology of most of these species. These spiders are rather small, the size varies between 2-7 mm (Roberts, 1985).

Hunting behaviour Most species make sheet webs, with no retreat, and run upside-down on the underside of the sheet. Generally abundant in fields and meadows. The sheet web catch selectively from the potential (available) food sources (Nentwig, 1980); the main victims are cereal aphids (12-40%), springtails, dipterans. Beetles and lepidopterans escape easily from the web (Nyffeler et al., 1994b), most of the predators avoid the web because of their sharper vision (Nentwig, 1980).

Habitat and distribution They occur on the bark of trees; on bushes and low vegetation; amongst adjacent leaf-litter and grass; under stones; on open ground. Generally widespread and fairly common in the region.

Importance in crop protection

Species occurring in orchards

Members of these family are reported from **England** by Chant (1956); from **the Netherlands** by Loomans (1978); from **Poland** by Koslinka (1967) and Olszak et al. (1992b); from **USSR** by Selivanov (1991); from **Canada** by Dondale (1956); Specht & Dondale (1960); Dondale et al. (1979); Bostanian et al. (1984); from **Japan** by Okuma (1973) and from **USA** by McCaffrey & Horsburgh (1980) in apple orchards and by (Mansour et al., 1982; Muma, 1975; Nakao & Okuma, 1958; Rodriguez Almaraz & Contreras Fernandez, 1993 and Yan & Wang, 1987) from citrus orchards. Selivanov (1991) found that 60.5% of the collected spiders belong to this family in apple orchards in USSR and the main food source the apple psyllid (*Cacopsylla mali*). Chant (1956) observed that *Entelecara acuminata* Wider, *Moebelia penicillata* Westring, *Erigonidium graminicolum* Sundevall, *Erigone dentipalpis* Wider and *Bathyphantes gracilis* Blackwall prey on the mites *P. ulmi* and *B. praetiosa*. *Ceraticelus sp., Ceratinopsis anglicana* Hentz and *Tennesseellum formicum* Emerton were observed preying on pecan aphid (*M. caryella*) in USA (Liao et al., 1984; Bumroongsook et al., 1992). Mansour et al. (1985) found that linyphiids are abundant (19% of the all spiders) on the ground level of avocado orchards in Israel and McMurtry & Johnson (1966) observed that unidentified linyphiids fed on the avocado brown mite *Oligonychus punicae* Hirst in USA.

Species occurring in other agro-ecosystems Linyphiids are the most common spiders in wheat fields (Carter et al., 1982; Nyffeler & Benz, 1979; 1988c). Their webs covered 0.3% in April and 30% in July of the surface of the soil (Carter et al., 1982). Considerable part of the diet (according to Sunderland et al. (1986) ±12%) are the cereal aphids *Sitobion avenae* F. (Carter et al., 1982; Nyffeler & Benz, 1988c; Sunderland, 1987) and *Rhopaloshiphum padi* L. (De Barro, 1992; Mansour & Heimbach, 1993; Nyffeler & Benz, 1988c; Sunderland, 1987); furthermore collembolans (Nyffeler & Benz, 1979; 1988c). Janssens & Clercq (1990) analysed the gut content of the aphid predators in the field by ELISA, and found that the most important predators are *Erigone atra* Blackwall and *Oedothorax apicatus* in Belgium. If the money spiders are removed from the field, the population of *R. padi* increased 2-6 times (Chiverton, 1986). Alderweireld (1994) was able to increase the number of linyphiids by making holes in the field.

According to Zhao (1984; 1993); Zhou & Xiang (1987); and Li et al. (1983) the spider, *Erigonidium graminicolum* Sund. is one of the dominant spiders on cotton and peanut fields in

China and preys on many cotton pests (see Appendix A, Table 6). Successfully mass-rearing of this spider was developed on artificial diet (Zhao & Zhao, 1983) against pests.

Conclusion It can be concluded that these spiders are very important in crop protection, but rather in arable fields not in orchards (Fig.2.).

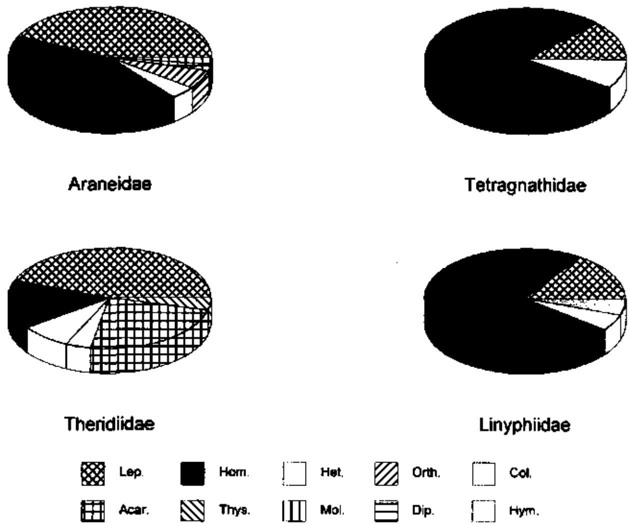


Fig.2. Prey composition of web-building spiders

Lycosidae (Wolf spiders)

General description The family Lycosidae is represented by 84 species in Central Europe in 10 genera (Heimer & Nentwig, 1991). The eye arrangement is very characteristic: front face of carapace with a row of four small, equal-sized anterior eyes and behind these a larger pair of posterior median and further back a pair of posterior lateral eyes of the same size. Although most species are brownish in overall coloration, many are attractively marked. Some parts of the markings and patterns are in the cuticle, this is frequently reinforced or modified by the dense, coloured hairs with which these spiders are clothed. In some cases, the pattern may be almost entirely due to light and dark hairs and this effect is largely lost when the spider is immersed in alcohol for preservation. The males of many species have their palps furnished with dense black hairs, and others have the first pair of legs conspicuously modified. Lycosids have good eyesight and having first located a female by her pheromones, the male waves the modified legs and palps about in front of her in a courtship display, prior to mating. The females of some genera excavate small burrows where they remain, with their egg sacs, until the spiderlings emerge. In the majority of these spiders the egg sac is attached to the spinners and carried around by the female. The egg sac in some species is spherical and white or beige in colour; in other species it is lenticular, with a pale seam, and brownish or green-blue in colour. The egg sac is periodically removed from the spinners, turned around and then reattached. Females frequently open the sac, introduce fluid from their mouthparts on to the developing eggs, and then reseal it with silk. Some species periodically dip the sac in water and most will orient themselves so that the bundle of developing eggs gets the optimum exposure to the warmth of the sun. Those living in burrows will periodically expose the egg sac near the entrance. When the spiderlings are ready to emerge, they rely on the female to open the egg sac for them. Once out, the spiderlings climb on to their mother's abdomen and are carried around by her for the first week or so (Roberts, 1995). The young spiders disperse by 'ballooning' (Greenstone, 1990) to prevent cannibalism. The size of these spiders is 4-20 mm.

Hunting behaviour They are all hunting spiders, mostly at ground level but occasionally on low vegetation. Some make silk-lined burrows in which they spend part of their time and *Aulonia* makes a flimsy sheet web with a tubular retreat. On warm sunny days, large number of lycosids may be seen running rapidly on the ground. This, together with their brown, furry appearance, has given rise to the common name of 'wolf spiders'. Many species, particularly of Trochosa, are also active at night (during the day they are sheltered in undergrowth) and some of them are typical 'sit-and wait' predators (Uetz, 1992; Stratton, 1985; Nyffeler et al., 1994b). In addition to their ability to run at speed, most species can also jump; this is most noticeably in the species such as *Pardosa nigriceps*, which hunts on low vegetation and is adapted to leaping from leaf to leaf (Roberts, 1995). The main prey of these spiders are collenbolans, aphids, orthopterans (Cherril & Begon, 1989), noctuids, other spiders and dipterans (Nyffeler et al., 1994b).

Habitat and distribution They occur on dry, sandy or stony ground and grassland; on low vegetation and bushes; in woodland; on mountains and in cultivated land. Generally common and widespread in the region.

Importance in crop protection

Species occurring in orchards Members of this family mentioned from **England** by Chant (1956); from the **Netherlands** by Loomans (1978); from **Poland** by Olszak et al. (1992b); from **Canada** by Dondale (1956); Specht & Dondale (1960); Hagley (1974); Bostanian et al. (1984) and from **Japan** by Okuma (1973); Takeda et al. (1978) in apple orchards and by Mansour et al. (1982); Muma (1975); Rodriguez Almaraz & Contreras Fernandez (1993) from citrus orchards. The spider *Trochosa terricola* Thorell preys on the apple maggot (*Rhagoletis pomonella* Walsh.; Dip.: Tephritidae) (Allen & Hagley, 1990), and on *Aphis pomi* (7.7 % of the collected spider was serologically positive) (Hagley & Allen, 1990) in Canada.

Species occurring in other agro-ecosystems One of the most important species of this family occurs in paddy fields (Reddy, 1991) is *Lycosa pseudoannulata* Boesenberg & Strand (Zhu & Zheng, 1984). This spider preys on a wide range of insect pests (Chen & Gao, 1992) (see Appendix A, Table 7.). But this species also preys on beneficial insects such as the predatory bug (*Cyrtorhinus lividipennis* Reuter; Hem.: Miridae) (Heong et al., 1989) in Philippine; the daily consumption in laboratory was 22 specimen of the prey. *Pardosa t-insignita* Boesenberg & Strand is the dominant spider (41% of the collected spiders) on ground level of groundnut (Li et al., 1983) and on cotton (Zhao, 1984) in China. *P. agrestis* Westring is one of the dominant spiders occurring in winter wheat fields in Europe (Nyffeler & Benz, 1982) and is able to cause 34-58% population reductions of the cereal aphid (*Rhopalosiphum padi* L.) (Mansour & Heimbach, 1993). Although half of its diet contains springtails (Nyffeler & Benz, 1979; 1988a). Another species, *P. ramulosa* is able to decrease by 84-96% of the population of the aster leafhopper (*Macrosteles fascifrons* Stal.; Hem.: Deltocephalidae) in paddy fields, compared with the control (Oraze & Grigarick, 1989).

Conclusion Wolf spiders are abundant in many agro-ecosystems (including orchards), but they are hunting only on the ground level and not much information exist about their predatory role in orchards. In other ecosystems they are one of the most important predators (Fig.1.).

Oxyopidae (lynx spiders)

General description Only one genus, *Oxyopes*, with 4 species occurs in the region (Heimer & Nentwig, 1991). The hexagonal arrangement of the eyes, and the long leg spines are the majority of this family. Courtship is visual recognition being followed by the male waving his palps and legs as he approaches, first to touch, and then to mate. Females place their rather flat-looking, discoid egg sacs near the top of low vegetation and stand guard over them. The size of these spiders is 4-10 mm (Roberts, 1995).

Hunting behaviour They are long legged, diurnal, hunting spiders, capable of running very rapidly on low vegetation and also jumping on their prey. Although their eyes are much smaller than those of the Salticidae and Lycosidae, their vision is obviously accurate enough to enable them to recognise potential prey.

Habitat and distribution They occur on low vegetation, bushes and the lower branches of trees. Generally widespread in the region.

Importance in crop protection

Species occurring in orchards Members of this family are recorded from the **Netherlands** by Loomans (1978); from **Canada** by Specht & Dondale (1960); from **Japan** by Hukusima (1961); Okuma (1973); and Takeda et al. (1978); from **USA** by McCaffrey & Horsburgh (1980); in apple orchards and by Mansour et al. (1982); Muma (1975); Nakao & Okuma (1958); Rodriguez Almaraz & Contreras Fernandez (1993) from citrus orchards. One of the most important species in this family the striped lynx spider, *Oxyopes salticus* Hentz occurs on several crops in USA (Whitecomb et al., 1963; Nyffeler et al., 1987a; Young & Edwards, 1990). This spider was common and represented 1.2-10.1% of the total spiders collected from apple orchards (McCaffrey & Horsburgh, 1980). This species together with the green lynx spider, *Peucetia viridans* Hentz as observed preying on pecan aphid (*M. caryella*) in USA (Bumroongsook et al., 1992). *Oxyopes elegans* showed positive reaction to anti-*Epiphyas postvittana* serum in Australia (Danthanarayana, 1983).

Species occurring in other agro-ecosystems Lynx spiders are abundant in many ecosystems and prey on a wide variety of insect pests (Kamal et al., 1992) as shown in Appendix A, Table 8.

Conclusions Only 4 species of lynx spiders occur in the region, but it can be concluded that their hunting behaviour (diurnal wandering spiders on vegetation) suggest that they at least contribute to reducing pest species in orchards (Fig.3.).

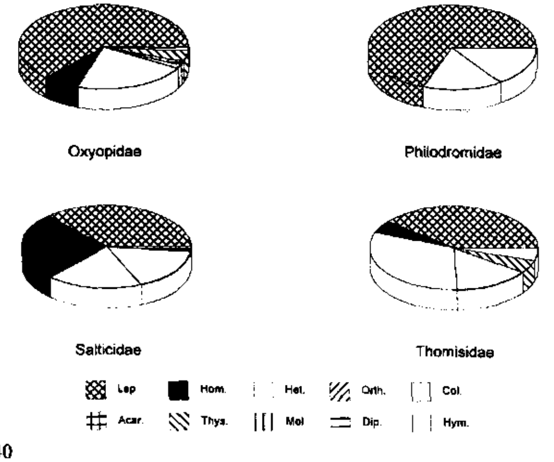


Fig.3. Prey composition of diurnal hunters on foliage

Philodromidae (Philodromids)

General description Twenty-four species occur in the region in three genera (Heimer & Nentwig, 1991). Formerly this family belonged to the family Thomisidae as subfamily Philodrominae. The appearance of these spiders is not crab-like, but the legs are fairly long. The abdomen is usually oval, quite elongate in some males. Claw tufts are present. The eyes are almost of the same size and positioned in two recurved rows. Courtship and mating appears to be very brief in this family. Egg sacs usually have a woolly or gauze-like exterior and females stand guard directly over them in foliage or on bark. The size of the species ranged between 3-10 mm (Roberts, 1995).

Hunting behaviour Most species are tree- or grass inhabiting and are wanderers. Philodromids do actively pursue their prey on vegetation, without making a web.

Habitat and distribution They occur on low vegetation, bushes and the lower branches of trees; on long grasses and at the ground level, sometimes in drier, sandy habitats.

Importance in crop protection

Species occurring in orchards Members of this family are recorded from the **Netherlands** by Loomans (1978); from **Poland** by Koslinka (1967) and Olszak et al. (1992b); from **Canada** by Dondale (1956); Specht & Dondale (1960); Hagley (1974); Dondale et al. (1979); Bostanian et al. (1984); from **Japan** by Hukusima (1961) and Okuma (1973); from **USA** by McCaffrey & Horsburgh (1980) in apple orchards and by Rodriguez Almaraz & Contreras Fernandez (1993) from citrus orchards. Philodromids are common in apple orchards (representing 7.5-29.6% of the total spiders collected (McCaffrey & Horsburgh, 1980)); *P. cespiticolis* Walckenaer, *P. praelustris* Keyserling and *P. rufus* Walckenaer recorded from Canada and USA (Dondale, 1958; Dondale et al., 1979; Specht & Dondale, 1960; Legner & Oatman, 1964; Bostanian et al., 1984; Arnoldi et al., 1991), *P. cespitum* (Klein, 1988; Klein & Sengonca, 1988) and *P. aureolus* (Sengonca et al., 1986) from Germany, *P. placidus* Banks from USA (McCaffrey & Horsburgh, 1978). These species prey on many apple pests *Aphis sp., Dysaphis plantaginea, Platynota flavedana* Clements (Hom.: Cicadellidae), *Tetranychus urticae, Panonychus ulmi, Lygus lineolaris,* and *Lygoris communis* (McCaffrey & Horsburgh, 1978; Parent, 1967; Putman, 1967; Putman & Herne, 1966; Sengonca & Klein, 1988; Arnoldi et al., 1991).

Species occurring in other agro-ecosystems Philodromids occur in other ecosystems too and prey on pest species as shown in Appendix A, Table 9. *P. aureolus* (Polesnyi, 1990) and *Philodromus sp.* (Mansour & Nentwig, 1988) are tolerant for 30 pesticides in Europe.

Conclusion Not much information exist on the predatory role of these spiders, but their predatory behaviour is suitable for crop protection (Fig.3). The pesticide tolerance is very valuable property too.

Salticidae (Jumping spiders)

General description Around 80 salticid species are recorded from Central Europe, in 23 genera (Heimer & Nentwig, 1991). The square-fronted carapace, with four large, forward-facing eyes, makes members of this family easily recognisable in the field, even though some are quite small spiders. Although popularly called 'jumping spiders' they are not alone in having this ability; members of the Lycosidae, Clubionidae, Oxyopidae and Agelenidae can also jump, and frequently do so in order to avoid capture or to get from one leaf to the next. Salticids use the third and/or fourth pairs of legs for jumping. Before leaping, the spider attaches a silk thread to the substrate and draws in the hind legs. Compared with fleas and grasshoppers, the salticids are very poor jumpers but some small species can achieve distances of over twenty times their own length. The eyes of salticids have a greater range of movement than our own, elaborate focusing, binocular vision and are probably sensitive to colour as well as to polarised light. The smaller eyes, further back on the carapace, are able to detect movement, but less detail; if something enters the rear or side field of vision the spider jumps around to focus the large front eyes upon it. Many species are clothed with coloured, shining or iridescent hairs, with the eyes attractively fringed, and males frequently have enlarged, coloured front legs and decorated palps. These find use, in conjunction with the great visual acuity, in elaborate courtship displays when legs and palps are waved semaphore-style as the male moves rhythmically about in front of the female. Females remain guarding their egg sacs within a silken cell, which the young spiderlings leave as soon as they are capable of an independent existence. The size of these spiders is 2-10 mm (Roberts, 1995).

Hunting behaviour The Salticidae are diurnal, wandering spiders, stalking prey which comes within their vision and finally leaping on to it (Forster, 1977). In warm, sunny weather they are extremely active creatures on vegetation. Rather polyphagous, but some species mimic ants and are specialised to prey on them (Nentwig, 1986).

Habitat and distribution They occur on the branches and trunks of trees; on low vegetation and in undergrowth, in built-up areas mainly on the walls and fences. Generally common and widespread throughout the region.

Importance in crop protection

Species occurring in orchards Members of this family mentioned from **England** by Chant (1956); from the **Netherlands** by Loomans (1978); from **Poland** by Koslinka (1967) and Olszak et al. (1992b); from **Australia** by Dondale (1966); from **Canada** by Dondale (1956); Specht & Dondale (1960); Hagley (1974); Dondale et al. (1979); Bostanian et al. (1984); from **Japan** by Hukusima (1961) and Okuma (1973); from **USA** by McCaffrey & Horsburgh (1980) in apple orchards and by Mansour et al. (1982); Muma (1975); Nakao & Okuma (1958); Rodriguez Almaraz & Contreras Fernandez (1993) from citrus orchards. *Phidippus audax* Hentz is one of the dominant spider in several crops in USA (Young & Edwards, 1990; Bumroongsook et al., 1992) including apple orchards (McCaffrey & Horsburgh, 1978). This species preys on *Aphis sp.* and on the rosy apple aphid (*Dysaphis plantaginea*) (McCaffrey & Horsburgh, 1978) in that habitat and on pecan aphid (Bumroongsook et al., 1992). *Paraphidipus marginatus* Walckenaer and *Metaphidipus profercus* Walckenaer were recorded as one of the dominant species from the foliage of apple trees from Canada (Dondale, 1958; Legner & Oatman, 1964) and these species prey on the mites, *T. urticae* and *P. ulmi* (Parent, 1967). *Metaphidippus galathea* Walckenaer is preying on the orchard pests eye-spotted bud worm (*Spilonota ocellana* Schiff.), Fall webworm (*Hyphantria cunea*) (Horner, 1972), *Aphis sp.*, *Dysaphis plantaginea*, *Leptothrips mali*, *Platynota flavidana* (Hom.: Cicadellidae) (McCaffrey & Horsburgh, 1978) blackmargined aphid (*M. caryella*) (Bumroongsook et al., 1992). *Salticus zebraneus* C. L. Koch was found as preying on pear psyllids (*Cacopsylla spp.*) (Angeli et al., 1994). 41% of the collected salticids showed positive precipitin reactions (fed on) the polyphagous leafroller (*Epiphyas postvittana*; Lep.: Tortricidae) in apple orchards in Australia (MacLellan, 1973). *Hentzia palmarum* Hentz common and abundant in apple orchards in Canada (Specht & Dondale, 1960) and preys on apple inhabiting aphids, *Aphis sp.* and *Dysaphis plantaginea* (McCaffrey & Horsburgh, 1978) and on pecan aphid (Bumroongsook et al., 1992).

Species occurring in other agro-ecosystems *Phidippus audax* is one of the most dominant spider in cotton fields (Whitecomb et al, 1987; Heiss et al., 1988) and it was reported to prey on cotton pests by many authors (see Appendix A, Table 10). But also preying on the curculionid (*Rhinocyllus conicus* Froelich; Col.: Curculionidae) which is a biological control agents against musk thistle (*Carduus nutans* L.; Asteraceae) (Dowd & Kok, 1981). Other salticids abundant in paddy fields (Togashi & Taka, 1988). *Paraphidipus marginatus* and *Metaphidipus profercus* were recorded from foliage of soybean from USA (Ferguson, et al., 1984).

Conclusion It can be concluded that jumping spiders are very important in crop protection (mainly outside of Europe), but the size of the European species are too small to play major role (Fig.3.).

Tetragnathidae (Tetragnathids)

General description This family is represented in Central Europe by 11 species in two genera (Heimer & Nentwig, 1991). Species of Tetragnatha are elongate spiders with long chelicerae and legs. Pachygnatha species are of more 'normal' proportions but have large chelicerae, which are elongate in males. All have relatively simple epigynes and male palpal organs, which are very similar in design and function. The maxillae are longer than broad in all species. The size of these spiders is varies between 3-11 mm (Roberts, 1995).

Hunting behaviour Most species spin orb webs with a small hole in the hub on vegetation, but older spiderlings and adults of Pachygnatha abandon web spinning and hunt at ground level. Generally preying on small soft-bodied insects such as aphids, planthoppers, dipterans (Nyffeler et al., 1994b).

Habitat and distribution They occur on low vegetation, bushes and trees sometimes on grasses and leaf-litter in damp habitats. Generally common and widespread in the Europe.

Importance in crop protection

Species occurring in orchards Members of this family are reported from **England** by Chant (1956); from **Poland** by Olszak et al. (1992b); from **Australia** by Dondale (1966); from **Canada** by Dondale (1956); Specht & Dondale (1960); Hagley (1974); Dondale et al. (1979); Bostanian et al. (1984); from **Japan** by Hukusima (1961); Okuma (1973) and Takeda et al. (1978); from **USA** by McCaffrey & Horsburgh (1980) in apple orchards and by Mansour et al. (1982); Muma (1975); Nakao & Okuma (1958); Rodriguez Almaraz & Contreras Fernandez (1993); Yan & Wang (1987) from citrus orchards. *Tetragnatha squamata* Karsch is recorded from the foliage of apple trees in Japan (Hukusima, 1961) and constituted 10% of the foliage-dwelling spider fauna. This species mentioned as predator of fall webworm (*Hyphantria cunea*) (Kunimi, 1983). *Tetragnatha versicolor* Walckenaer reported from apple orchards in USA by (Legner & Oatman, 1964) and this species preys on *T. urticae* and *P. ulmi* (Parent, 1967). *Tetragnatha extensa* L. reported as a predator of the mites, *P. ulmi* and *B. praetiosa* (Chant, 1956). *Tetragnatha quadridens* feeds on the light brown apple moth (*Epiphyas postvittana*) in Australia (Dondale, 1966). *T. laboriosa* Hentz preys on pecan aphid (Liao et al., 1984; Bumroongsook et al., 1992), the daily consumption in average of 19.35 aphids a day in the field.

Species occurring in other agro-ecosystems One of the most important species which is occurring on several crops in USA is *Tetragnatha laboriosa* (Young & Edwards, 1990; McIver & Belnavis, 1986; Provencher et al., 1988; Bumroongsook et al., 1992; Nyffeler et al., 1989; Heiss et al., 1988). This species is preying mainly on homopterans, hemipterans (Culin &

Yeargan, 1982; Nyffeler et al., 1989; LeSar & Unzicker, 1978) including pests (see Appendix A, Table 11). *Tetragnatha mandibulata* (Kamal et al., 1992) and *T. japonica* Boes et Str. (Kamal & Dyck, 1994) are recorded from paddy fields in Bangladesh. This family of spiders extremely sensitive to pesticides (Whitford et al., 1987)

Conclusion This family of spiders mainly feed on homopteran pests (Fig.2.), but their importance because of the high sensitivity to pesticides are rather minor.

Theridiidae (Comb-footed or cobweb spiders)

General description Seventy species represented in the region in 16 genera (Heimer & Nentwig, 1991). One of the majority the tarsal 'comb' of serrated bristles is not visible with a lens, and sometimes not even with a microscope and reduced or absent in males and small species. Another characteristic has an abdominal pattern, but some of the species are uniform greyish or black and resemble small members of the Linyphiidae. Members of this family exhibit great variety in shape and coloration. The legs have very few spines, and this is a useful character for separating theridiids with an abdominal pattern from the families Tetragnathidae, Araneidae and Linyphiidae. The size of these spiders varies between 1.5-14 mm (Roberts, 1995).

Hunting behaviour Many species of theridiids spin a considerable tangle of criss-cross threads higher up on vegetation which, with use, may develop into quite a dense structure centrally and usually incorporates a retreat for egg laying. The individual catching threads consist of a strand of silk loosely attached to the substrate (a leaf surface, bark etc.). The loosely attached end has a number of sticky droplets along it. Insects sticking to the droplets struggle, break the attachment of the thread, and find themselves hanging helplessly in the air. They are very polyphagous predators, but on places where ants are numerous, these form a large part of the diet. They often prey on aphids (Nyffeler et al., 1988) and beetles or cleptoparasites (Nyffeler et al., 1994b).

Habitat and distribution They occur on the foliage of shrubs and trees and on low vegetation, but frequently at ground level under stones. Generally common and widespread in the region.

Importance in crop protection

Species occurring in orchards Members of this family are mentioned from **England** by Chant (1956); from the **Netherlands** by Loomans (1978); from **Poland** by Koslinka (1967) and Olszak et al. (1992b); from **USSR** by Selivanov (1991); from **Canada** by Dondale (1956); Specht & Dondale (1960); Hagley (1974); Dondale et al. (1979); Bostanian et al. (1984); from **Japan** by Hukusima (1961) Okuma (1973) and Takeda et al. (1978); from **USA** by McCaffrey & Horsburgh (1980) in apple orchards. Theridiids are abundant in apple (Olszak et al., 1992b; Anchipanova & Shtembergs, 1987; Dondale et al., 1979; Bostanian et al., 1984; McCaffrey & Horsburgh, 1978; Selivanov, 1991), in citrus (Carrol, 1980; Mansour et al., 1982; Muma, 1975; Berg et al., 1987; Berg et al., 1992; Nakao & Okuma, 1958; Rodriguez Almaraz & Contreras Fernandez, 1993; Yan & Wang, 1987) in pecan (Liao et al., 1984; Mansour, 1993; Bumroongsook et al., 1992) and in avocado (Mansour et al., 1985) orchards too and feed on *Psylla mali, Aphis pomi* (Anchipanova & Shtembergs, 1987; Selivanov, 1991), *Dysaphis plantaginea*, *Leptothrips mali* Fitch (McCaffrey & Horsburgh, 1978) and *Epiphyas postvittana* (Lep.: Tortricidae) (MacLellan, 1973; Dondale, 1966), but very sensitive to pesticides (Olszak et al., 1992b).

Theridion octomaculatum (*Coleosoma maculatum*) is an important species occurring on several crops (Dong & Xu, 1984) including apple (Hukusima & Kondo, 1962a; Takeda et al., 1978) and preying on insect pests such as *Aphis gossypii* (Dong & Xu, 1984; Mao & Xia, 1983; Zhang, 1992) (it can consume an average of 21 aphids per day (Zhang, 1992)), pear aphids (*Toxoptera piricola* Matsumura) (Hukusima & Kondo, 1962a), apple leaf-curling aphids (*Myzus malisuctus* Matsumura) (Hukusima & Kondo, 1962a), larvae of noctuids (Dong & Xu, 1984). *Theridion pallens* Blackwall, *Theridion ovatum* Clerck and *Theridion varians* Hahn were reported as predators of the spidermites *P. ulmi* and *B. praetiosa* (Chant, 1956). *T. crispulum* Simon and *T. murarium* Emerton feed on pecan aphid (Bumroongsook et al., 1992).

Species occurring in other agro-ecosystems The cobweb spiders are abundantly represented in cotton fields in USA (Whitecomb et al., 1963; Heiss et al., 1988). The winter wheat field inhabiting cobweb spiders, particularly the *Theridion bimaculatum* L. (Sunderland et al., 1987) and *Achaearanea riparia* Blackw. are prey on cereal aphids and orthopterans (Nyffeler & Benz, 1988b) (Appendix A, Table 12.).

Conclusion This family of spiders is abundant in orchards and they are very polyphagous (Fig.2.), but because of the sensitivity to pesticides their importance is rather minor.

Thomisidae (Crab spiders)

General description Fourty-two species of the family Thomisidae are known from the region, in 12 genera (Heimer & Nentwig, 1991). The majority of species are rather crab-like in appearance, have the first two pairs of legs longer than the rest, and can walk sideways, as well as forwards and backwards. Thomisids have small chelicerae with no large teeth, and prey is sucked dry, rather than mashed up, leaving a perfectly formed husk. Some species have little ceremony before mating and the females usually stand guard over their egg sacs, but frequently die before the spiderlings emerge. The egg sacs themselves may be rather flat, silk structures fastened to vegetation, or may take the form of a woolly ball or papery sac, which is guarded on vegetation, on bark or at ground level under stones. The size of these spiders is 2-11 mm (Roberts, 1995).

Hunting behaviour Part of the species are typical 'sit-and-wait' predators; camouflaged in flowers, and ambush visiting insects, have venom which is highly toxic to insects such as bumble bees, which are much larger than the spiders themselves. When an insect approaches the flower, the spider opens wide the first two pairs of legs, and may also subtly realign itself with the prey. Only when the victim is definitely within grasp do the legs fold around, although there may be some almost imperceptible movement as it gets close and perhaps wanders away again. Once gripped, the prey is bitten and quickly dies from the poison. Others (*Xysticus*) are more active hunters, occurring on low vegetation or at ground level. Generally they prey on aphids (Pisarenko & Sumarokov, 1983), thysanopterans, beetles, hymenopterans and dipterans (Nyffeler et al., 1994b).

Habitat and distribution They occur in woodland; on bushes, lower branches of trees; on grasses and on flowers, especially white and yellow blooms. Generally common and widespread in the region.

Importance in crop protection

Species occurring in orchards Members of this family are recorded from **England** by Chant (1956); from the **Netherlands** by Loomans (1978); from **Poland** by Olszak et al. (1992b); from **Australia** by Dondale (1966); from **Canada** by Dondale (1956); Specht &

Dondale (1960); Hagley (1974); Dondale et al. (1979); Bostanian et al. (1984); from **Japan** by Hukusima (1961) and Okuma (1973); Takeda et al. (1978); from **USA** by McCaffrey & Horsburgh (1980); in apple orchards and by Mansour et al. (1982); Nakao & Okuma (1958); Rodriguez Almaraz & Contreras Fernandez (1993) from citrus orchards. *Misumenops tricuspidata* F. occurring on apple (11 % of the foliage-dwelling spider fauna) (Hukusima, 1961; Takeda et al., 1978) and cotton (Wu et al., 1981; Zhou & Xiang, 1987; Zhang, 1992) and recorded preying on pear psylla (Angeli et al., 1994), apple-inhabiting aphids such as pear aphids (*Toxoptera piricola*) and apple leaf-curling aphids (*Myzus malisuctus*) (Hukusima & Kondo, 1962a), fall webworm (*H. cunea*) (Kayashima, 1967; Kunimi, 1983) cotton aphid (*A. gossypii*) (Zhang, 1992) and on the American bollworm (*H. armigera*) (Wu et al., 1981). In the laboratory one *M. tricuspidatus* could consume 23-44 aphids a day (Zhang, 1992). Thomisids are abundant on apple in Australia too and 53% of the collected crab spiders fed on the light brown apple moth (*Epiphyas postvittana*) (MacLellan, 1973; Dondale, 1966). *Misumenops asperatus* Hentz, *Misumena vatia* Clerck and *Xysticus emertoni* Keyserling were reported as predators of red and two spotted spider mites (Parent, 1967). *Misumena vatia* was recorded by (Chant, 1956) as predator of the bryobia mite (*Bryobia praetiosa*) too. McCaffrey & Horsburgh (1978) mentioned that *Misumenops oblongus* Keyserling preys on apple aphids such as *Aphis sp.* and *Dysaphis plantaginea* and on pecan aphids (*M. caryella*) (Liao et al., 1984; Bumroongsook et al., 1992) in USA. An unidentified crab spider is mentioned as natural enemy of the green apple aphid (*Aphis pomi*) in USSR (Melnyik et al., 1976). *Diaea sp.* is recorded as natural enemy of apple-inhabiting leafrollers in New Zealand (Baker, 1983). The crab spider *Xysticus punctatus* Keyserling was observed feeding on the mirids, *Lygus lineolaris* Palisot de Beauvois and *Lygocoris communis* Knight on apple in Canada (Arnoldi et al., 1991). *Misumenops rubrodecorata* Millot was observed as predator of citrus psylla (*Trioza erytreae*) in citrus orchards managed under integrated control programmes in South Africa (Berg et al., 1987; 1992).

Species occurring in other agro-ecosystems Members of this family are abundant in many agro-ecosystems, and feed on many insect pests as shown in Appendix A, Table 13.

Conclusion Crab spiders are abundant in orchards and prey on many orchard pests. It can be concluded that this family of spiders probably are able to play an important role in this habitat (see Fig.3. too).

Conclusions

It can be concluded that:

- According to our criteria for measuring the usefulness of spiders (abundance; hunting tactics; diet) the following 10 families of spiders have importance in agriculture (**Araneidae; Clubionidae; Linyphiidae; Lycosidae; Oxyopidae; Philodromidae; Salticidae; Tetragnathidae; Theridiidae; Thomisidae**). Members of all of these occur in European orchards.

- Spiders prey on all kind of pest species (homopterans, heteropterans, orthopterans, thysanopterans, lepidopterans, coleopterans, hymenopterans, dipterans and mites).

- The orchard inhabiting spiders belonging to 4 different groups, but theoretically only 3 will possible play a role as predators of orchard pests (see Fig.4. too):

-foliage dwelling wandering spiders
(*Clubionidae; Oxyopidae; Philodromidae; Salticidae; Thomisidae*)

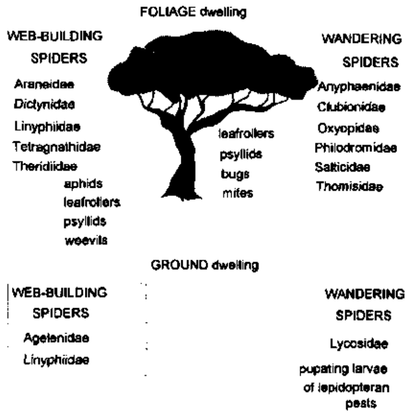
-foliage dwelling web-building spiders
(*Araneidae; Linyphiidae; Tetragnathidae; Theridiidae*)

-ground dwelling wandering spiders
(*Lycosidae*)

-[ground dwelling web-building spiders]

- The foliage dwelling wandering spiders feed mainly on caterpillars (larvae of lepidopteran pests), but also on homopterans, heteropterans and especially the young spiders on mites (Fig.1.,3.,4.).
- The foliage dwelling web-building spiders prey mainly on homopterans and lepidopterans (Fig.2.,4.).
- Almost no experimental data exist about the importance of ground dwelling spiders in orchards, but in other agro-ecosystems they are one of the most important predators (Fig.4.).

Fig.4. Spider-orchard pest interactions



2.4 The effect of chemical treatments on performance of spider communities

The pesticide application is the most important factor influencing spider communities in the field. This effect on performance of spider communities under different regimes of pesticides in different management systems (conventional versus IPM) is discussed.

Pesticide effect on spiders

Nowadays it is well-known that the spider fauna of sprayed and unsprayed fields differ completely (Chant, 1956; Hukusima & Kondo, 1962b). Insecticide treatments disturb (Basedow et al., 1985) and prevent normal build up of the population peaks (Mansour, 1987). Olszak et al. (1992b) found that some species, probably the most sensitive ones, disappeared from the treated orchard. The different spider groups react differently to pesticide treatments (e.g. the ratio of web-building and hunting spiders changed after the treatments). Many authors stated that hunting spiders are more sensitive to pesticides (Chant, 1956; Specht & Dondale, 1960; Legner

& Oatman, 1964; Bostanian et al., 1984), others (McCaffrey & Horsburgh, 1980; Olszak et al., 1992b) found opposite results. It can be concluded that in the time when the first group of authors investigated the effect of pesticides on spiders the pesticide usage was completely different from the second group of authors. Because the pesticide usage has been changed significantly since the 1970's. Earlier the chlorinated hydrocarbons (HCH), lime sulphur, lead arsenate, nicotine dominated which changed to organophosphates (OP's) and synthetic pyrethroids (SP's) in conventional systems and to insect growth regulators (IGR's) and "natural" pesticides (compounds of biological origin) in IPM systems.

The spider web is an efficient collector of the agrochemicals (Samu et al., 1992). The collecting rate depends on the droplet size (smaller droplets can easier be adsorbed). This observation agrees with Olszak et al. (1992b) who found that in sprayed orchards the family Theridiidae was most affected by chemicals. Especially the orb-weavers who recycle their web every day are generally very susceptible to insecticides (Whitford et al., 1987).

The effect of pesticides used in IPM on spiders has been investigated by laboratory and field spraying. Laboratory investigations on pesticide effect on spiders were performed by many authors. Mansour (in Hassan et al., 1994) tested the effect of diflubenzuron (IGR) on *Cheiracanthium mildei* and it was found that this insecticide caused 95-99% mortality in this species.

Field applications of *Bacillus thuringiensis* preparates showed that the concentration of a normal application (2%) was harmless to spiders although caused 71-72% mortality on larvae of *Heliothis armigera* (Umarov et al., 1975; Sklyarov, 1983; Shiryaeva & Savin, 1988) to which it was applied.

IGR's especially diflubenzuron in case of foliage application appeared to be harmless to the ground dwelling spider fauna (Winter, 1979; Martinat et al., 1993), but was harmful to the foliage dwelling spiders (Pan & Zhao, 1990; Wolfenbarger & Nemec, 1991).

The effect of three commercial pesticides fenvalerate (SP), endosulfan (HCH) and pyrazophos (OP), in Europe commonly used against cereal pests, on two dominant cereal field inhabiting spider species *Pardosa agrestis* and *Erigone atra* were evaluated by Mansour et al. (1992).

The effect of the pesticides has influenced by the substrate on which it was sprayed. Fenvalerate was more toxic than the other two pesticides and had a longer residual effect on all spiders when tested on moistened sand than on filter paper. Endosulfan had a high initial toxicity on sand, but was more toxic on filter paper for *Pardosa*. Pyrazophos was non-toxic to the spiders tested, regardless of the substrate. The some general conclusions can be drawn from the experiment of Mansour & Nentwig (1988) who determined the susceptibility of 4 spider species to 30 pesticides (16 insecticides, 4 acaricides, 1 herbicide and 9 fungicides). *Philodromus aureolus* (a hunting spider) from Germany was completely resistant to all the compounds tested (a similar result was found by Polesnyi, 1990) in Austria. While *Argyope argentata* (from Panama), *Linyphia triangularis* (from Germany) (both web-building spiders) and *Cheiracanthium mildei* (from Israel) (a wandering spider) showed medium to high susceptibility. The effects of insecticides varied widely from no mortality (mostly compounds of biological origin) and medium mortality (pyrethrins and organophosphorus and carbamate compounds) to high mortality (cyclo compounds). Most acaricides were highly toxic to spiders, whereas the herbicides and fungicides were not. These are probably the basic effects of pesticides, which will be modified by many factors in the field. From observations in the lab and field it can be concluded that the different factors which can modify the basic effect of pesticides in the field are:

The daily activity of spiders that influenced their reaction to pesticide treatments. Some of the pyrethroids and OP's (e.g. deltamethrin, DDVP) which are generally highly toxic to spiders have short (within 8 hours) contact toxicity. In case of normal pesticide application (in the morning) the nocturnal hunting spiders (e.g. Clubionidae) are sheltered (spending the daytime in silken chamber or under the loose bark etc.), and protected from insecticides. When the spiders become active again the insecticide is not toxic anymore. Olszak et al. (1992b) found that clubionid spiders were the least affected by pesticides, although the laboratory observations indicate that they are susceptible to these pesticides.
The habitat. The active ingredients of herbicides are generally non-toxic to spiders, but they destroy the habitat of spiders which can cause an indirect population decrease (Krause, 1987). On the other hand by diversification of the habitat by multi-cropping or mulching the number of ground dwelling spiders is augmented. It more or less protects spiders from the pesticides. (Koslinka, 1967; Altieri et al., 1985; Altieri & Schmidt, 1986; Nurindah, 1988; Riechert & Bishop, 1990).
The lack of prey. After insecticide treatments prey is dead or decreased in number which also influences the spider abundance (Krause, 1987).
Different soil types. The higher percentage of clay, silt or organic matter can decrease the effects of the pesticides on spiders (Heimbach et al., 1992). This effect is very obvious with organochlorines, less distinct with organophosphates and not present with pyrethroids. This might be due to the lipophilic character of the pesticides (Heimbach et al., 1995).
Temperature and humidity. High temperature and low air humidity can cause higher mortality (Everts, 1990; Everts et al., 1991).
Neurological disturbance. The walking speed of spiders' decreases by exposure to deltamethrin (Jagers op Akkerhuis, 1993) and this is followed by a higher predation by carabids (Everts et al., 1991).
Luczak (1979) and Mansour et al. (1983) stated that spiders are generally more tolerant to pesticides that most of the predators.

Conclusions

It can be concluded that:

- The effect of pesticides on the different groups of spiders has changed in the course of years by the change of pesticides.
- The spiders are generally more tolerant to pesticides than most of the other predators.
- Chlorinated hydrocarbons (esp. used before the 70's) are highly toxic to spiders.
- Both organophosphates and pyrethroids are toxic to spiders but this effect in some extends can be modified in the field.
- IGRs are also moderately toxic to spiders.
- Natural insecticides (e.g. *Bt* preparates) are non-toxic to spiders.

2.5 The predatory potential of orchard inhabiting spiders

It can be concluded that most of the literature mentioned in 1.1 concerns qualitative observations or laboratory investigations on prey consumption by spiders. These data cannot be applied directly to field situations (Nyffeler, 1982). (Hunting spiders feed much less in the field than in the laboratory (Nyffeler & Breene, 1990). In this chapter the possibilities for evaluation of usefulness of spiders is discussed.

Theoretical background

A predator has the potential to regulate a prey population only if the predator responds to increases in prey density by inflicting a higher mortality percentage (Wise, 1993). Whether or not a population of predators causes such density dependent mortality depends upon the nature of the functional and numerical responses, which concept was introduced by Solomon (1949) and developed further by Holling (1959a; 1959b; 1961; 1965; 1966). The functional response is defined as the change in the rate at which an individual predator captures prey as prey density changes. The numerical response is the change in population density of predators as a function of changing prey density. Together these components of a predator's response to changes in prey density comprise the total response, which is expressed as a fraction of the prey population consumed.

Holling (1959a;b) defined three basic types of functional responses:

Type I shows a linear rise in the number of prey captured until a plateau is reached. (Animals having an automatic prey capture mechanism e.g. filter feeders, web-building spiders.) (Nakamura, 1977)

Type II is a saturation curve. This is the most common pattern of functional response seen in invertebrate predators (Nakamura, 1977).

Type III is an S-shaped or sigmoid curve, observed mainly in vertebrate predators (Nakamura, 1977).

Most of the spiders have Type II. response, but Nakamura, (1977) found Type III responses by wolf spiders and Haynes & Sisojevic (1966) by a crab spider.

A predator has a potential to regulate its prey even in the absence of a Type III functional response if it exhibits a numerical response. Spiders show both aggregational and reproductive numerical responses to increases in prey densities in nature. Spiders have been shown to aggregate in habitats with higher prey densities, and temporal increases in prey density within a particular habitat can be correlated with increases in rates of spider reproduction (Reddy, 1991).

How spiders can be evaluated?

An overview of the methods, which can be useful for evaluation of spiders, is given, divided into field and laboratory methods.

Methods in the field

1. Introduction and augmentation

The introduction of new spider species to the field has not been performed extensively until now, because they are too generalist predators. The existing species can be mass-reared and released to control pest species. Wang & Zhou (1984) in China and Thang et al. (1990) in the Philippines developed a method to mass-rear the wolf spider, *Lycosa pseudoannulata* to control rice pests. In China 200.000 spiders were released to paddy fields. Zhao & Zhao (1983) did manage to rear the spider, *Erigonidium graminicolum* on artificial diet.

Several methods exist to increase the number of spiders. They can be divided into indirect and direct methods. The most important indirect methods are habitat management, intercropping, improving edge effect, mulching and using corrugated cardboard belts as overwintering place described (Mansour et al., 1983; Whitcomb, 1987; Altieri et al., 1985; Altier & Schmidt, 1986; Desender et al., 1989; Fye, 1985; Makarov & Tarabaev, 1990; Mangan

& Byers, 1989; Mizell & Schiffhauer, 1987; Riechert & Bishop, 1990). Direct methods are releasing alternative foods (e.g. Drosophila flies) (Kobayashi, 1975), placing egg sacs of spiders in to crops (Brignoli, 1983) or releasing mass-rear spiders. Some of these techniques can be useful in orchards too.

2. Removal of natural enemies

A.) Specific small-scale inclusion and exclusion techniques (cages, barriers or hand removal)
These techniques in small-scale level based on specific prey-predator relationships. Clark & Grant (1968) were the first to demonstrate experimentally that spiders can have a strong stabilising influence on prey. They located four 13 m^2 areas 'chosen for structural uniformity in a beech-maple forest. They removed as many spiders as possible from one area, which was enclosed with a sheet-metal fence, by sieving litter over a one-week period. Another fenced area in which litter was sieved but spiders were not removed served as a control. Two open areas served as controls to assess the effect of enclosing the plots. One of these open controls was undisturbed and litter was sieved in the other. Plots were sampled by taking ten 0.09 m^2 samples from each area on several sampling days over a 10-week period. Each plot had been sampled once before the week of the perturbation. Over the course of the study the average number of spiders per sample in the removal plot was approximately half the number in the three control plots. Numbers of springtails, a major prey of spiders, were highest in the removal plot.

Mansour et al. (1985) and Mansour & Whitecomb (1986) performed experiments to evaluate the role of spiders in controlling pest species (based also on removal) and they obtained as result that on branches where spiders were removed the pests caused significantly higher damage compared with the control.

B.) Non-specific large-scale removal of natural enemies (by insecticides)
The controlling effect of natural enemies can be investigated by removal of them with insecticides or acaricides (spiders). These techniques are not very specific, but can be used to get indications on the total role of natural enemies. See fruit tree red spider mite problem (Chant, 1966; Rabbinge, 1976).

3. Prey enrichment

Kobayashi (1975) increased the number of spiders in paddy fields by releasing fruit flies (*Drosophila*) and the number of rice pests decreased. But the correlation between the number of spiders and the number of released fruit flies was not strong.

4. Direct observation

One of the best examples that spiders are able to influence pest densities comes from studies of rice paddies. The wolf spider *Lycosa pseudoannulata* is the dominant spider in rice fields and has been studied by many authors (see Appendix A, Table 7.). The diet of this lycosid consists primarily of two major pests of rice, the green rice leafhopper (GRL) and the brown planthopper (BPH). Estimated rates of predation by *L. pseudoannulata* upon these pests ranged from a few percent to 100%. The high mortality rates make it reasonable to predict that wolf spiders depress homopteran populations. Kenmore et al. (1984) sprayed one rice field with insecticide and left another field 500 m away, as a control. Densities of BPH were 800-times higher on the sprayed field; densities of spiders and veliid bugs (also predators of BPH) were lower in the treated field. Jones (1981) reported that Chinese have used straw bundles as shelters for spiders to conserve their numbers during irrigation of rice paddies. This approach to spider conservation was associated with a 50-60% decline in pesticide use in 1977 over a 3000 ha region of Hunan Province.

5. Determination of prey-predator relationships

A.) Gut analysis of predators (electrophoresis, monoclonal antibodies, ELISA)
The gut analysis of spiders by serological methods has been performed by many authors (e.g. Angeli et al., 1994; Chen & Gao, 1992; Cherril & Begon, 1989; Sunderland et al., 1987). They got evidence that pest species constitute a part of the spiders' diet.

B.) P^{32}-radiolabelling technique
The predator complex of a given pest species can be investigated by this method. The existing results show that spider constituted a large part of the predators occurring in agro-ecosystems (e.g. Clark & Glick, 1961; McDaniel et al., 1981; Gravena & Sterling, 1983)

6. Interaction with other beneficial agents

Generalist predators especially spiders prey on other beneficial organisms such as ladybirds, lacewings, other spiders etc. Most of the existing literature about spider predation on beneficial insects are laboratory observations (e.g. McCaffrey & Horsburgh, 1978; Sengonca & Klein, 1988; Heong et al., 1989), but some other field observations definitely indicate that spider sometimes feed on beneficials too (Krämer, 1961; Temerak, 1981; Nuessly & Goeden, 1983; Nyffeler & Benz, 1988b). According to Nyffeler et al., (1994b) this may help to survive periods of food shortage. On the other hand, Ghorpade, (1979) reported that ladybirds (*Menochilus sexmaculatus* F., *Micraspis cardoni* Weise, *Jauravia dorsalis* Weise) preyed on the spider *Sparassus lamarcki* Latr. too.

Green lacewings have a special escape strategy (described by Masters & Eisner, 1990) from orb webs (escaping rate 90%).

Methods in the laboratory

1. Determination of prey acceptance

These experiments have been carried out by many authors (see Tables in Appendix A) to determine which pest species are acceptable as food by spiders in given agro-ecosystems. In most of the cases the daily consumption in laboratory at constant temperatures is also given. But these data can not be applied directly to the field situation. Success ratio experiments in relation to hunger give more information about the real situation.

2. Assessment of potential feeding capacity (max. gut content, ingestion and digestion rates etc.)

To assess the potential role of spiders information is needed about the potential food consumption. This may be assessed by measuring the meal size, the relative rate of gut emptying, assimilation and respiration rate (Bogya & Mols in press).

3. Reproduction experiments with a specific pest as prey

To assess the nutritional value of a given pest species for spiders or in other words to determine whether the given pest species is essential food for spiders may be difficult to investigate. Many investigations show that spiders on monodiet did not reach adulthood (e.g. Uetz et al., 1992).

4. Prey preference experiments

The aim of these experiments to rank potential prey types in order. It offers information on the chance that a pest has to be killed by a predator when other prey is also available. (Provencher & Coderre, 1987; Heong et al., 1990; Toft, 1995).

5. Searching and predatory behaviour

It gives information on the performance of a spider to different densities and distribution of the prey (leads to assess most of functional response curves).
The complete searching and predatory behaviour as has been described by Mols (1987; 1988; 1993) for a carabid is lacking for spiders.

6. Simulation models can show potentials for biological control

Simulation models as a combined result of the laboratory and field experiments may be used to evaluate theoretically the role of spiders. Good models are lacking.

Conclusions

It can be concluded that:

- The correct evaluation of spiders as biological control agents can be obtained by following the above-mentioned list. Some of the mentioned experiments alone (e.g. laboratory prey consumption experiments) are not enough to take a decision.
- The number of spiders in the field can be augmented by several methods (e.g. inter-cropping, mulching, habitat management).
- Experiments and observations indicate that spiders are a part of the predator complex of pest species on many crops.
- But quantitative data (about searching and predatory behaviour; potential and actual feeding capacity) concerning their predatory potential are hardly available.

2.6 Discussion

Spiders are polyphagous predators, but most of the cases they show high preference to types of prey. There are many advantages of this hunting behaviour. They are preying on a wide variety of insect pests and in case of low level of pest densities they can switch to alternative prey. The disadvantage of this hunting behaviour is that only a fraction of their diet consists of pest species, which is very variable. Other beneficial organisms seem to be less important for spiders as prey than phytophagous insects. In orchard ecosystems probably the foliage dwelling wandering spiders are the most important in crop protectional point of view. Their hunting behaviour suggests that maybe they are important as predators of many pest species. The web-building spiders mainly specialised to catch flying insects, this behaviour is also suitable for plant protection. The ground dwelling spiders play less important role in controlling pest species in orchards, because most of the orchard pests are living in the canopy of fruit trees.

It can be concluded that spiders because of their high abundance, their constant presence and their predatory capacity belong to the most important predators of many pest species. Although their impact on pest insects are strongly depends on the pesticide usage. In addition to the pesticide usage, other cultural methods (e.g. inter-cropping, irrigation) can augment the number of spiders in agro-ecosystems. The establishment of suitable overwintering places (e.g. treebands, hedge around the orchards) is also very important. In IPM (or organic) management systems, where the pesticide use is low (together with the cultural methods), spiders have a considerable impact on the reduction of number of pest organisms. However still many more carefully controlled field experiments are needed to test this hypothesis.

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Chapter 3

Species Composition of Spider (Araneae) Communities in Apple and Pear Orchards in the Carpathian Basin*

Abstract. The species richness and composition of spider communities were investigated in the canopy, herbaceous-layer and at ground level when differently treated with pesticide and in abandoned apple and pear orchards in the Carpathian Basin. Furthermore attention was paid to the bark-inhabiting spider fauna. Altogether 20283 individuals were collected belonging to 21 families; 165 spider species have been identified to species level and further nine spider taxa were determined up to generic level. More than 20 % of the Hungarian spider fauna was represented in the orchards. In the canopies, 103 species were found in apple orchards and 70 species in pear orchards. The similarity (Jaccard index) between apple and pear in the canopy is 45%. The species richness in each orchard varied between 22 and 56 species. In the herbaceous layer, 66 species were found in apple orchards and 43 species in pear orchards.

Most of the species belonged to the families Araneidae, Salticidae, Thomisidae, Theridiidae. Species of hunting spiders were represented by 55 %, web-building spiders by 45 % of the entire fauna.

The canopy and the herbaceous layer inhabiting fauna overlapped. Out of the 76 herbaceous-layer inhabiting species, 59 occurred also in the canopy. The similarity (Jaccard index) in species composition between the canopy and the herbaceous-layer is 45%.

The most widely occurring species in orchard canopies in decreasing order were: *Philodromus cespitum, Theridion impressum, Theridion pinastri, Oxyopes heterophthalmus, Araniella opistographa*; on the bark: *Philodromus cespitum, Xysticus spp. (lanio, cristatus), Drassodes lapidosus, Theridion pinastri, Clubiona marmorata*; in the herbaceous-layer: *Xysticus spp. (cristatus, ulmi), Oxyopes heterophthalmus, Pisaura mirabilis, Mangora acalypha, Araneus diadematus*; on the ground-level: *Xysticus kochi, Titanoeca schineri, Pardosa agrestis, Alopecosa sulzeri, Harpactea rubicunda*. This species could play a role in the natural control of orchard pests in IPM systems in the Carpathian Basin.

Three species collected in the canopy of apple and pear orchards, *Enoplognatha latimana, Philodromus longipalpis* and *Euophrys monticola* were not recorded from Hungary until the present study.

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3.1 Introduction

The ecological bases of integrated pest management in orchards have been investigated for 30 years in Hungary. As part of a greater project (Apple Ecosystem Research), faunistic studies have been carried out to describe the species composition of apple orchards in Hungary since 1976. Mészáros et al. (1984) examined apple orchards in five localities, while Markó et al. (1995) investigated the coleopteran communities in apple and pear orchards in three localities. Altogether more than 2000 animal species were recorded. In latter project, the spiders were not studied until now.

Other studies reported 28 species from the canopy and herbaceous-layer of an apple orchard (Samu et al., 1997) and 28 species from the ground level of another apple orchard (Samu & Lõvei, 1995) in Hungary.

Spiders were reported from orchard ecosystems by many authors (reviewed by Bogya & Mols, 1996), but comprehensive spider fauna lists are rare. The existing lists focus mainly on the foliage-dwelling spiders only. From Europe Loomans (1978) (The Netherlands), Klein (1988) (Germany), Olszak et al. (1992) (Poland) and Angeli et al., (1996) (Italy) presented a list of spiders occurring in the canopy of apple orchards. Outside of Europe, Hukusima (1961) (Japan), Dondale et al., (1979) (Canada) and McCaffrey & Horsburgh (1980) (USA) recorded spider lists from apple orchards. The overwintering spiders in and under the bark of apple trees were investigated by Koslinka (1967) and Loomans (1978). Little is known about the ground-dwelling spider fauna of apple and pear orchards; Zhao et al. (1993) and Samu and Lövei (1995) published some data.

Our aim was (1) to make a thorough faunistic study of spiders occurring in apple and pear orchards, (2) to describe the biodiversity of the spider communities of orchards differently treated with pesticides and in abandoned orchards and (3) to determine the most widely occurring species.

3.2 Material and methods

The investigations took place in six Hungarian and one Romanian (Transylvania) orchards, which are located in woodland areas of medium height mountains, agricultural lowland environments and regularly flooded forest areas. The samples were collected at the following localities: Nagykovácsi (Lat. 47° 30' N, Long. 19° E; UTM: CT47) (abandoned, one apple and two pear plots), Sárospatak (Lat. 48° 20' N, Long. 21° 30' E; UTM: EU45) (conventional, one apple and one pear plot), Tura (Lat. 47° 40' N, Long. 19° 30' E; UTM: CT97) (conventional, one apple and one pear plot), Szigetcsép (Lat. 47° 20' N, Long. 19° E; UTM: CT43) (conventional, one apple and one pear plots), Kecskemét (Lat. 46° 40' N, Long. 20° E; UTM: DS09) (abandoned, one apple plot), Szarkás (Lat. 46° 40' N, Long. 20° E; UTM: DS09) (apple, two conventional and three IPM plots) and Beresztelke / Breaza (Transylvania, Romania) (Lat. 46° 40' N, Long. 24° 40' E; UTM: LM18) (apple, one conventional, one IPM, one untreated, one abandoned plot).

The beating method was carried out to collect spiders from the canopy by using Winkler-type umbrella (d=0.7m). Each orchard (except Beresztelke) was investigated by tapping 600 whole trees (100 in spring, 100 in summer and 100 in autumn) for two years. Additionally in Nagykovácsi and Szigetcsép samples were taken from April till October 12 times annually by beating 10 trees every time for three years. In Beresztelke the sample taking were performed 12 times by beating 10 trees in each plot in 1995.

Trapping on the bark (Nagy and Szentkirályi, 1982) was executed to investigate the bark inhabiting spider fauna in Nagykovácsi in 1978-82. Five-five traps, which collected the spiders going upwards, were placed around the trunk of apple trees in treated and untreated plots. Three additional traps, which collected the spiders going downwards, were placed in the untreated plot. The traps were emptied weekly through the vegetation period.

Corrugated cardboard bands were used to monitor the overwintering spiders on the trunk. The traps were placed around the trunk at about 20-25 cm height from the ground in autumn before the leaf fall and were collected 2-2.5 months later, after the first frost. Ten bands were placed in each plot of the investigated orchards (except at Beresztelke).

Sweep netting was applied to collect spiders from the herbaceous-layer by using a triangular-shaped sweep net (0.3m wide). Each orchard (except at Beresztelke) has been investigated by making 5x100 sweep net samples on three occasions (one in the spring, one in the summer and one in the autumn) for two years. Additionally in Nagykovácsi and Szigetcsép samples were taken 12 times annually by making 3x33 sweep net samples for three years.

Pitfall trapping was performed to collect ground-dwelling spiders in Szarkás in 1992-95. Forty pitfall traps (0.08m in diameter, halfway filled with ethylene glycol 30% solution) were used and emptied weekly.

Additionally, hand picking was done in Nyírbogdány (in Szabolcs-Szatmár-Bereg County). The collected spiders were stored in 75% ethanol.

Table 1. in Appendix B shows the characteristics of every investigated orchards.

The collected spider individuals were identified to the lowest taxonomic level possible. Juveniles were identified mostly to generic level. Juveniles of the genus *Philodromus* were separated into three species groups as *Philodromus* (*aureolus*) which contains the species *Ph. aureolus*, *Ph. cespitum*, *Ph. praedatus*, *Ph. longipalpis*. *Philodromus* (*margaritatus*) which contains *Ph. margaritatus* and *Ph. emarginatus*. Finally *Philodromus* (*rufus*) which contains *Ph. rufus* and *Ph. albidus*. Juveniles of *Philodromus dispar* were identified until species level. Juveniles of *Enoplognatha ovata* and *Enoplognatha latimana* were considered as *Enoplognatha* (*ovata-latimana*). Similarly juveniles of *Araniella cucurbitina* and *Araniella opistographa* were considered as *Araniella* (*cucurbitina-opistographa*). *Theridion* (*mystaceum*) contains the juveniles of the species *Th. mystaceum*. Juveniles of the family Linyphiidae were separated into two subfamilies as Linyphiinae spp. and Erigoninae spp. Females of *Trochosa terricola* or *Trochosa ruricola* were indicated as *Trochosa sp.* The spiders were placed in the collection of S. Bogya.

The most widely occurring species were considered either by investigating the number of localities and years they occurred. The frequency of occurrence in different orchards and years was calculated and the species, which were found with a frequency of more than 60%, are listed.

For the calculations of the similarities in species composition between different strata and plants the Jaccard index was used (Krebs, 1989).

3.3 Results and Discussion

Based on a comparison of our results with those of other faunistic studies, it can be concluded that the family composition of the spider communities is rather similar. Members of the family Theridiidae, Linyphiidae, Araneidae, Thomisidae, Philodromidae and Salticidae dominate. However, members of the family Linyphiidae are more numerous in Western Europe, than in Central or South Europe, while the family Salticidae shows an opposite trend. The ratios of web-building and hunting spiders are about 30-40% and 60-70%, respectively.

Table 2 - 6. in Appendix B show the composition of spider communities based on the collection methods used and treatments in the different strata (canopy, herbaceous-layer, ground level) of apple and pear orchards. Altogether 165 species and further 9 taxa were identified from the 20283 individuals collected. This number represents more than 20 % of the total Hungarian spider fauna. The bibliographic check list of the Hungarian spider fauna contains 714 spider species (Samu & Szinetár, 1999), three species presented here are new to that list: *Enoplognatha latimana* Hippa & Oksala, 1982; *Philodromus longipalpis*, Simon, 1870; *Euophrys monticola* Kulczynski, 1884. The followings rare species were found which were reported only once from Hungary until the present study: *Diaea pictilis* Banks, 1896 (one male /01.06.81./, two male /23.05.97./ in Nagykovácsi) (Szinetár, 1995); *Tmarus stellio* Simon, 1875 (one female in Kecskemét /19.07.96/ and one male /15.07.82./ in Nagykovácsi) (Chyzer & Kulczynski, 1918); *Sitticus distinguendus* Simon, 1868 (one female and one male /30.09.82./ in Nagykovácsi) (Chyzer & Kulczynski, 1918). Further rare species were *Alopecosa fabrilis* Clerck, 1757 (one male /02.11.93/ in Szarkás) and *Theridion suaveolens* Simon, 1879 (one female /29.07.80./ in Nagykovácsi).

Most of the *Philodromus* (*aureolus*) belonged to the species *Ph. cespitum*, only a few other members of the group were found. From the group *Philodromus* (*rufus*), only the species *Ph. rufus* was found. Most of the *Araniella* (*cucurbitina-opistographa*) belonged to *Araniella opistographa*. From the group *Enoplognatha* (*ovata-latimana*) only *E. latimana* was found within the boundary of Hungary. Only one adult *Theridion sisyphium* was found from the group *Theridion* (*sisyphium-impressum*), the others were identified as *Th. impressum*.

One hundred and three species belonging to 16 families and 64 genera were found in the canopy of apple trees, while 70 species belonging to 13 families and 50 genera were found in the canopy of pear trees. The majority of the species in the canopy belonged to the families Theridiidae, Araneidae, Salticidae, and Thomisidae. The most widespread species in decreasing order were: *Philodromus cespitum, Theridion impressum, Theridion pinastri, Oxyopes spp., Araniella opistographa*. The ratio in number of species of the two main guilds, web-building and hunting spiders in case of apple trees was 45:55%, while in case of pear trees was 43:57% of the entire canopy fauna. In the investigated orchards the total number of species in the canopy varied between 22 and 56 in apple and 22 and 52 in pear orchards. The Jaccard similarity between apple and pear canopy spider communities was 45%.

Previous faunistic studies in Hungary registered three additional species that were not found by us: *Silometopus reussi* Thorell, 1871; *Yllenus vittatus* Thorell, 1875; *Salticus quagga* Miller, 1971, from the canopy and herbaceous-layer (Samu et al., 1997).

Between the species list of canopy and herb-layer inhabiting spiders considerable overlap was found. The similarity in species composition between the canopy and the herb-layer was 45%. Out of the 76 herb-layer inhabiting species 59 occurred in the canopy too.

Forty-six species belonging to 14 families and 32 genera were found overwintering in the corrugated paper belt traps. The most widely occurring species in decreasing order were: *Clubiona spp. Cheiracanthium mildei, Philodromus* (*aureolus*), *Philodromus* (*margaritatus*), *Misumenops tricuspidatus*. Few of them, mainly clubionid species (*Clubiona phragmitis, Cl. genevensis, Cl. pseudoneglecta, Segestria bavarica, Lathys humilis*), were found only with this method. In our work, species from the families Theridiidae, Clubionidae, Thomisidae and Philodromidae overwintered under the bark of the apple and pear trees. However, species from the families Araneidae and Salticidae overwinter outside of the tree. Previous studies revealed that species of the families Dictynidae, Linyphiidae and Theridiidae dominated in Poland (Koslinka, 1967) while Theridiidae, Philodromidae, Dictynidae and Clubionidae dominated in The Netherlands (Loomans, 1978) on the trees during the winter.

Fifty-seven species belonging to 13 families and 41 genera were found in the bark traps. An additional species *Pardosa palustris* Linnaeus, 1758 was found by hand picking from the trunk in an apple orchard in Nyírbogdány. The most common species were: *Philodromus* (*aureolus*), *Xysticus spp., Drassodes spp., Theridion pinastri, Clubiona spp.* The species composition was similar to both the canopy and herbaceous-layer which indicates close relationship between the canopy and the herbaceous-layer through the entire vegetative period. However, some typical ground dwelling spiders as Lycosidae, Gnaphosidae and Agelenidae occurred frequently on the trunk of the trees.

In the herbaceous-layer of apple orchards there were 66 species belonging to 15 families and 47 genera, while in case of pear orchards 43 species belonging to 12 families and 38 genera were found. The majority of the species in the herbaceous-layer belonged to the families Theridiidae, Araneidae, Salticidae and Thomisidae. The most widespread species in the herbaceous-layer were: *Xysticus spp., Oxyopes spp., Pisaura mirabilis, Mangora acalypha, Araneus diadematus*. The ratio of the two guilds, web-building and hunting spiders in case of apple trees was 59:41%, while in case of pear trees was 42:58% of the entire herbaceous-layer inhabiting fauna. In the investigated orchards the total number of species in the herbaceous-layer varied between 13 and 36 in apple and 12 and 34 in pear orchards. The similarity between apple and pear herbaceous-layer inhabiting spider communities was 35%.

Forty species belonging to 12 families and 26 genera were found on the ground-level. The most frequently occurred species were *Xysticus kochi, Titanoeca schineri, Pardosa agrestis, Alopecosa sulzeri, Harpactea rubicunda.*

Previous faunistic study in Hungary reported 17 additional species that were not found by us: *Enoplognatha thoracica* Hahn, 1833; *Robertus lividus* Blackwall, 1836; *Diplostyla concolor* Wider, 1834; *Alopecosa accentuata* Latreille, 1817; *Alopecosa pulverulenta* Clerck, 1757; *Alopecosa trabalis* Clerck, 1757; *Pardosa agricola* Thorell, 1856; *Pardosa hortensis* Thorell, 1872; *Pardosa monticola* Clerck, 1757; *Pardosa paludicola* Clerck, 1757; *Pardosa prativaga* L. Koch, 1870; *Pardosa pullata* Clerck, 1757; *Pardosa riparia* C. L. Koch, 1833; *Trochosa ruricola* Degeer, 1778; *Coelotes longispinus* Kulczynski, 1897; *Agroeca cuprea* Menge, 1873; *Drassyllus villicus* Thorell, 1875 from the ground level (Samu & Lõvei, 1995). As these two studies sampled only two different orchards further research is needed to complete the list of ground dwelling spiders of apple and pear orchards.

Studies of abandoned and commercial orchards were undertaken in different regions and with different sampling efforts, but it was obvious that there were more species and individuals in the unsprayed than in any of the commercial orchards studied. However, in same cases (e.g. in Szigetcsép), because of the diverse surroundings in contradiction to the commercial treatments the species richness of spider communities could be rather high. There were markedly more species and individuals of theridiid spiders in the untreated orchards. Simultaneously pirate spiders (*Ero spp.*) that prey on theridiids were found only in the untreated orchards too. Some species, mainly hunting spiders (e.g. *Philodromus (aureolus), Misumenops tricuspidatus, Xysticus spp. Salticus zebraneus*) were common and widespread independently from the treatments.

In previous studies Szentkirályi and Kozár (1991) found 54 species of natural enemies in apple orchards, while Markó et al. (1995) found 74 predaceous beetles in the canopies of apple and pear orchards in Hungary. Present study describing the faunistical composition of Araneae communities occurring in apple and pear orchards in the Carpathian Basin refer to high diversity (165 spider species) of this predator group. It can be concluded that spiders are important potential natural control agents, which could play an important role in orchard integrated pest management systems in the future. Further research is needed to describe the theoretical and practical background of protection and application of spider communities in these agro-ecosystems.

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Chapter 4

Comparison of Pome Fruit Orchard Inhabiting Spider Communities at Different Geographical Scales*

Abstract. The composition of pome fruit orchard inhabiting spider communities was investigated at different geographical scales (Holarctic, European, inter- and intraregional levels within Hungary) using previous faunistic studies and data collected in Hungary between 1995-97. Samples in Hungary were taken from the canopy and herb layer of apple and pear orchards in five markedly different fruit growing regions by beating and sweep-netting methods.

The family composition of canopy spider communities of apple orchards at **Holarctic level** was determined by latitudes, while the genus composition by the main zoogeographical regions. At **European level** both the genus and species composition changed along a North-South gradient.

At **interregional level**, both the foliage- and grass-dwelling spider communities showed considerable differences in species composition and dominance order in apple and pear orchards in Hungary. However, the regional differences in the grass-layer were smaller than in the canopy.

At **intraregional level,** in differently treated apple and pear orchards both the foliage-and grass-dwelling spider communities showed moderate differences.

Although the spider communities inhabiting the canopy and the herbaceous-layer distinguished unambiguously, the overlaps were still significant.

We concluded that the composition of spider communities is basically determined by geographical locations. Although both the pesticide treatments and the different prey densities can significantly influence the densities of spiders, their effects on the composition of spider communities comparing with the effect of regionality is moderate.

These scale-specific differences can be essential in the development of prey-predator systems in orchards and also in the design of integrated pest management (IPM) programs for apple and pear.

*: This chapter has been submitted as: Bogya, S., Markó, V. & Szinetár, Cs. Agricultural and Forest Entomology

4.1 Introduction

Natural control of phytophagous insects and mites by their predators and parasitoids is a key element of integrated pest management (IPM) in orchards (Blommers, 1994). Experiments in The Netherlands have shown that over half of 24 arthropod species damaging to apple orchards can be controlled fully or substantially by natural enemies (Gruys, 1982).

The major pests of apple like woolly apple aphid, other aphids, San Jose scale, codling moth, leafrollers and mites are widespread through out the apple growing areas of the world and their distributions and population dynamics are generally well known. This is in striking contrast with our relatively poor knowledge about their natural enemies.

Many studies have indicated that spiders are important predators and occur everywhere in apple growing areas (reviewed by Bogya & Mols, 1996). Some studies showed that the abundance of spiders is strongly influenced by the insecticide treatments (e.g. Olszak et al., 1992b). At the same time, the studies did not deal with the question what determines the abundance and the dominance order of spiders within spider communities as a function of treatment and location. The prey spectrum of the spider species belonging to various genera and families can be very distinct, and therefore the ecological role they play as predators in orchard ecosystems may be different (Bogya & Mols, 1996).

Spiders are reported from pome fruit orchards in many studies (reviewed by Bogya & Mols, 1996), but more or less complete faunal lists of orchard-inhabiting spiders are rare. Faunistical studies considered complete have been carried out by Loomans (1978) (The

Netherlands - NL), Klein (1988) (Germany - D), Olszak et al. (1992b) (Poland - PL), Angeli et al. (1996) (Italy - I) and Bogya et al. (1999) (Hungary - H) in Europe. In addition the following studies from outside of Europe are considered to be complete: Hukusima (1961) (Japan - J), Dondale et al. (1979) (Canada - CND) and McCaffrey & Horsburgh (1980) (USA).

The aim of this study is to investigate: (i) the geographical differences of the canopy and herb layer inhabiting spider communities in pome fruit orchards at different scales; (ii) the interaction between the spider communities of the canopy and the herb layer; and (iii) the influence of different prey items and treatments on spider communities. This information can be used to improve the scale-specific crop protection in orchards.

4.2 Material and methods

The fieldwork took place in five markedly different fruit growing regions in Hungary between 1995-97. The canopy and the herb layers were sampled by the beating method and by sweep netting respectively in two orchards in each region, in every region with the same effort. Apple and pear orchards were sampled in four regions with different management regimes, while different managed and abandoned apple orchards were investigated in the fifth region (Kecskemét). In the latter case, data from the two neighbouring plots (one IPM and the other conventionally treated) of the treated orchard were pooled. The characteristics of the orchards and the regions are shown in Appendix B, Table 1.

Spiders from the canopy were collecting using the beating method with a Winkler-type umbrella (d=0.7m). Each orchard has been investigated by beating the canopy of 600 whole trees (100 in spring, 100 in summer and 100 in autumn) for two years. The collected spider individuals were identified to the lowest taxonomic level possible. Juveniles were identified mostly to generic level. The specimens were identified by the authors.

Sweep netting using a triangular-shaped sweep net (0.3m wide) was performed to collect spiders from the herb layer. Each orchard has been investigated by doing 5x100 sweeps at three occasions (one in spring, one in summer and one in autumn) for two years.

For the comparison of spider communities of different locations, in Holarctic and on a European level, the results of the faunistic studies mentioned in the introduction were used as follows. The family and the genus composition were computed as a proportion of the total species. The data were pooled when more than one orchard was investigated. Those orchards are situated at the following latitude: NL: 52°, PL: 52°, D: 51°, CDN: 50°, H: 47°, I: 46°, USA: 40°, J: 40°. Within Hungary the regions were compared using the species composition and dominance order. For the validation of our results about the effect of pesticide treatments on spider composition in orchards data of Olszak et al. (1992 a,b) were taken into account and analysed.

The analysis of the data was performed by the program Syntax 5.1 using multivariate data analysis methods, namely classification (hierarchical) and ordination (non-metric and metric multidimensional scaling) methods simultaneously. Both the cluster analysis and the PCoA (principal coordinates analysis) were based on the Horn index (Krebs, 1989). As the PCoA method gave similar result to the non-metric ordination, the latter is not discussed in this paper.

4.3 Results

At the Holarctic level, the family composition of pome fruit orchard inhabiting spider communities in the canopy level (Appendix C, Table 1.) shows high similarity (Horn index) with a value above 0.8 as can be seen in Fig. 1. The orchards situated above the line of latitude 50° are more similar to each other than those of below 50°. Similar tendency can be seen in case of functional groups of spiders. Hunting spiders comprised 14% - 30% in northern orchards (above 50°) and 44% - 58% in southern orchards (below 50°) (Appendix C, Table 1.).

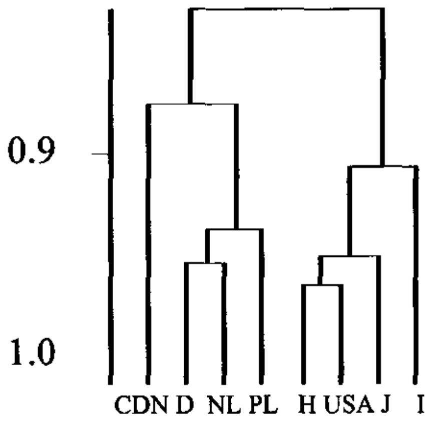

Fig. 1. Comparison of the family composition of canopy spider communities in apple orchards in different Holarctic regions; Hierarchical classification based on Horn index, nearest neighbour method. (CDN: Canada, D: Germany, NL: The Netherlands, PL: Poland, H: Hungary, USA: United States, J: Japan, I: Italy)

In the case of genus composition unambiguous separation of the Nearctic (America and Canada), East Palearctic (Japan) and West Palearctic (Europe) areas is possible. Within Europe the orchards can be distinguished according to the line of latitude again. Thus the genus composition of the canopy spider communities of German and Dutch apple orchards are the most similar, followed by Polish orchards. The genus composition of Hungarian and Italian canopy spider communities differ markedly from the latter three geographical regions (Fig. 2.). The comparison of species composition of canopy spider communities showed similar results but at lower similarity level.

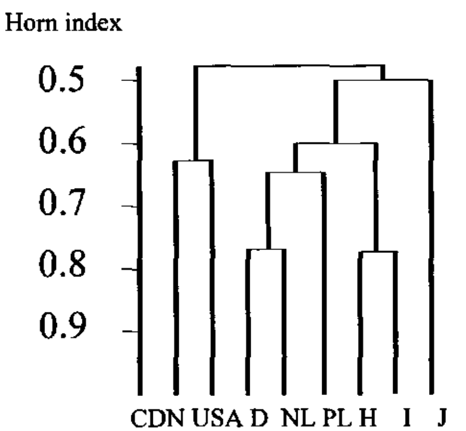

Fig. 2. Comparison of the genus composition of canopy spider communities in apple orchards in different Holarctic regions; Hierarchical classification based on Horn index, nearest neighbour method. (CDN: Canada, D: Germany, NL: The Netherlands, PL: Poland, H: Hungary, USA: United States, J: Japan, I: Italy)

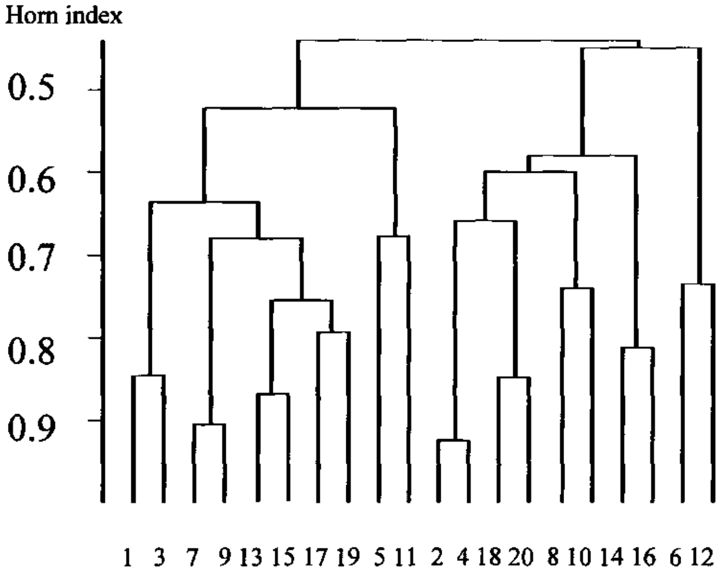

Fig. 3. Interregional comparison of spider communities inhabiting the herbaceous-layer and the canopy of apple and pear orchards in Hungary; Hierarchical classification based on Horn index, nearest neighbour method. (Nk: Nagykovácsi, Ke1: Kecskemét - abandoned orchard, Ke2: Kecskemét - treated orchard Sp: Sárospatak, SzCs: Szigetcsép, Tu: Tura; s.n.: sweep netting, b.m.: beating method)

1: Nk apple s.n.	6: Ke1 apple b.m.	11: Ke2 apple s.n.	16: SzCs pear b.m.
2: Nk apple b.m.	7: Sp apple s.n.	12: Ke2 apple b.m.	17: Tu apple s.n.
3: Nk pear s.n.	8: Sp apple b.m.	13: SzCs apple s.n.	18: Tu apple b.m.
4: Nk pear b.m.	9: Sp pear s.n.	14: SzCs apple b.m.	19: Tu pear s.n.
5: Ke1: apple s.n.	10: Sp pear b.m.	15: SzCs pear s.n.	20: Tu pear b.m.

The comparison of the canopy spider communities in orchards with different surroundings on a regional level results in separation of orchards at a similarity level of 0.45 and 0.63 (Fig. 3, 4). In spite of the fact that similar habitats (apple and pear orchards) were investigated in every region the differences are quite high. It can be seen that the role of the regional differences in the development of species composition and dominance order is significant (Appendix C, Table 2). This indicates that predator complexes of pests can be different in the case of frequent species in orchards situated in different habitats (Appendix C, Table 2). The highest separation was detected between orchards with sandy and clay soil (Fig. 3, 4).

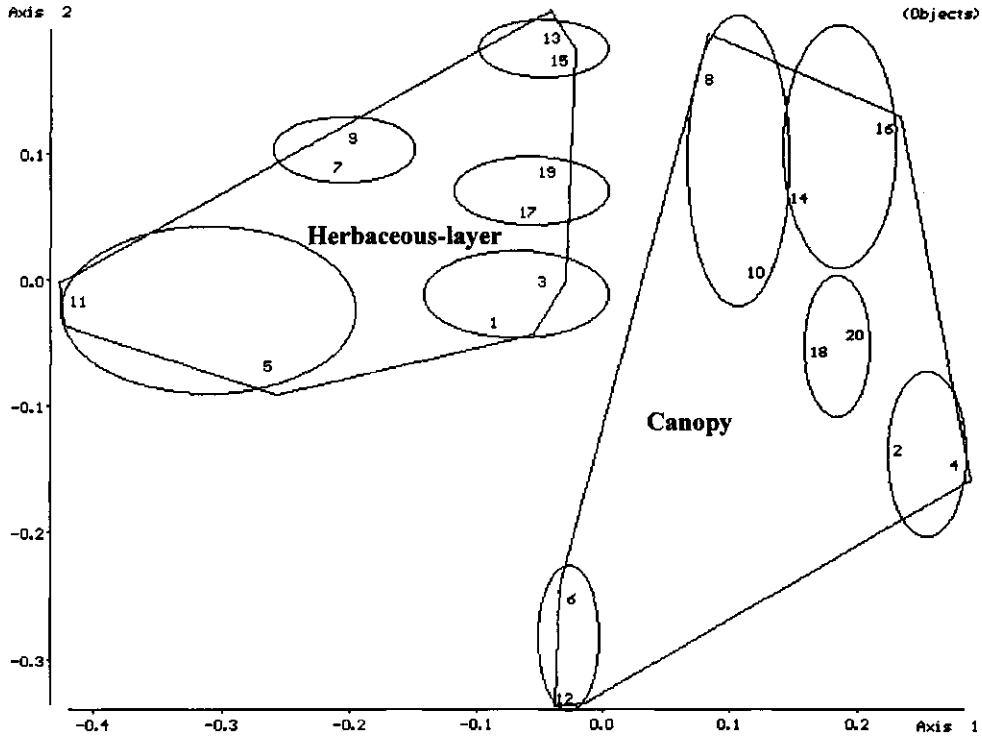

Fig. 4. Interregional comparison of spider communities inhabiting the herbaceous-layer and the canopy of apple and pear orchards in Hungary; PCoA analysis based on Horn index. The numbers represents the different layers of the investigated orchards, see legend of Fig. 3. Within the spider communities collected from the same layers - linked with straight line -, the orchards situated in the same region are linked with ellipses.

The herb layer inhabiting spider communities show the same patterns than the canopy inhabiting spider communities. The separation among the different regions were between similarity levels 0.53 and 0.76 (Fig. 3, 4). This indicates that the differences in the herbaceous-layer inhabiting spider communities were smaller than in the canopy.

Data originating from the canopy and herbaceous-layer shows that the canopy spider communities separate markedly (45% similarity). Although the overlap between the canopy and the herbaceous-layer is still considerable (Fig. 3, 4).

When comparing the apple and pear orchards it can be seen that the similarity is rather high within the region, between 0.74 and 0.92 in the canopy. Similar results were obtained for the herb layer where the similarity was between 0.78 and 0.91 (Fig. 3, 4).

Treated and untreated orchards were compared only in the region of Kecskemét, in Hungary. The absence of treatments did not significantly influence the species composition and dominance order in both layers (Fig. 3, 4). To verify these results, the data of Olszak et al. (1992a, b) from one locality in Poland were analysed. Cluster analysis revealed that the treatments had a moderate effect on the species composition and dominance order. The differently treated plots of apple orchards and their surrounding shrub vegetation separated at a similarity level of 0.85 (Fig. 5). The level of this similarity is higher than the interregional similarities in Hungary (Fig. 3).

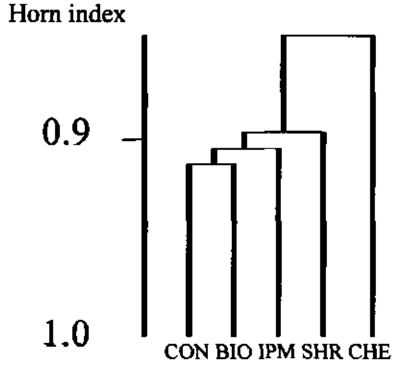

Fig. 5. Comparison of spider communities in differently treated plots of a Polish apple orchard and its surroundings according to data of Olszak et al. (1992b); Hierarchical classification based on Horn index, nearest neighbour method. (CON: untreated control, BIO: biological plot, IPM: integrated plot, CHE: chemical plot, SHR: adjacent shrub vegetation).

The dominant species (Appendix C, Table 2) in most places in the canopy are: *Philodromus* (*aureolus*), *Theridion* (*sisyphium-impressum*), *Xysticus spp.*, *Araniella* (*cucurbitina-opistographa*). However, every orchard has its own characteristic composition. In Kecskemét, where the soil is sandy and the climate is very dry *Oxyopes heterophthalmus* and *Cheiracanthium mildei* are dominant. Whereas *Larinioides spp.* were dominant in Szigetcsép, where the orchards were close to the Danube. The orchards in Nagykovácsi are surrounded by an oak forest which has a very rich spider fauna especially in the family Theridiidae, Linyphiidae and Thomisidae. In Tura large jumping spiders *Carrhotus xanthogramma* and *Marpissa muscosa* were common. In Sárospatak *Xysticus* (*ulmi-lanio*) individuals were frequent.

The dominant species in the herbaceous-layer were mainly wandering spiders: *Mangora acalypha*, *Xysticus spp.*, *Araniella* (*cucurbitina-opistographa*), *Misumenops tricuspidatus*, *Pisaura mirabilis*. *Oxyopes heterophthalamus* was dominant in Kecskemét.

Some species e.g. most of the members of the family Theridiidae, large orb-weavers (*Argiope lobata*, *Araneus diadematus*) were abundant only in untreated orchards. Others like *Philodromus* (*aureolus*), *Theridion* (*sisyphium-impressum*), *Misumenops tricuspidatus*, *Araniella* (*cucurbitina-opistographa*), *Xysticus spp. Salticus zebraneus* were common and widespread independently from the treatments.

4.4 Discussion

Our comparison of spider faunistic data of pome fruit orchards of some areas in the Northern Hemisphere leads to the conclusion, that orchards as spider habitats situated above the line of latitude 50° are more similar to each other than those of below 50°. This is probably caused by the higher proportion of money spiders (Linyphiidae) and the lower proportion of jumping spiders (Salticidae) in the northern orchards. Although, the main zoogeographical regions separated on the generic and species levels.

According to our results in Hungary, regional differences can significantly influence the species composition of spider communities in the canopy and to a lesser extent in the herb layer. Kozár (1992) investigated the insect communities in the canopy and herbaceous-layer of orchards and found that the species composition of insect communities of orchards situated in different regions differs considerably. However, the influence of regional differences in the predatory arthropods guild was smaller than in the phytophagous and tourist guilds. Markó et al. (1995) shows the importance of regional differences in species composition of beetle communities inhabiting the canopy of apple orchards.

Analysing the quantitative data leads to the conclusion that the different surroundings of orchards not only influenced the species composition of spider communities, but also determined which species became dominant and subdominant. What is the origin of these differences? It is evident that the prey composition may differ between regions. Brown & Adler (1989) showed that the species composition and dominance order in phytophagous arthropod communities of apple orchards in three states of USA differed significantly. Although the prey composition was not investigated in our study, we assume that the prey composition was different on the different host plants (apple and pear) within the region too. In pear orchards the density of pear suckers (*Cacopsylla spp.* mainly *C. pyri*) often exceeded the damage threshold. Despite of the different available prey species, the apple and pear orchards as well as the treated and untreated apple orchards within each region were more similar to each other than any of the other orchards situated in other region. Our results support the idea that in spite of the different prey composition, the dominance order in spider communities was determined basically by the main regional differences like surrounding vegetation, soil, climate and so on. The explanation can be twofold: firstly it is possible that functionally similar phytophagous arthropods can be abundant in the different orchards within a region, secondly because of the same surroundings similar prey items immigrate into the orchards. Some spider species e.g. *Cheiracanthium mildei* can show positive aggregational numerical response to its prey density (Chapter 5). At the same time, the possible positive numerical response of some spider species did not result such a big change of the dominance order than caused by regionality in the investigated 10 orchards. Further conclusion is that the treatments can significantly influence the abundance of spiders, but to a lesser extent the dominance order within the community. Probably the surrounding of the orchards have spider community with a certain composition and those species can colonise the orchards after chemical treatments. The effect of the different insecticide treatments on spiders was investigated by Olszak et al. (1992a, b) in neighbouring plots of an apple orchard and its surroundings. The conclusion being that, in spite of the different treatments, the similarity of spider communities was high and there was a considerable overlap in spider community composition between the orchard plots and their adjacent shrub vegetation (Olszak et al., 1992a, b).Their result also showed that the different insecticide treatments modify the dominance order in spider communities, to a lesser extent. Similar results were obtained by Bogya & Markó (1999) when spider communities of apple orchards under conventional and integrated pest management systems were compared.

The present study indicated that the spider communities in the canopy and in the herb layer differ considerably. However, the overlap in composition between the two layers is still significant, some species e.g. *Philodromus* (*aureolus*) *spp., Oxyopes spp. Xysticus spp.* occur both in the canopy and in the herb layer. Others like *Araniella spp.* occur in the canopy, but overwinter in the herbaceous-layer and prey on "tourists" (Wyss et al., 1995). Therefore, we expect that manipulation of the herbaceous-layer would influence the spider communities in the canopy.

In conclusion, the spider communities show remarkable scale-dependent regional differences. In the future if the IPM techniques give free play for spiders as natural control agents in orchard ecosystems, these differences should be taken into account in the design of regional IPM programs.

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Chapter 5

Effect of Pest Management Systems on Foliage- and Grass-dwelling Spider Communities in an Apple Orchard in Hungary

Abstract. Spider communities (Araneae) inhabiting the canopy, the herbaceous layer and the borders, as well as the populations overwintering on the tree trunks of different aged IPM and conventional apple orchards were investigated in Hungary.

The abundance and the species richness of the entire spider communities in the IPM plots were significantly higher than in the conventional plots, probably caused by the lower toxicity of pesticides used and the higher prey densities. In the case of abundance, similar tendencies were observed in the web-building and hunting spider guilds.

The age of the plantations can significantly influence the spider density in the canopy through the prey density. In young plantations, where the size of the canopy was smaller and the density of the pear lace bug (*Stephanitis pyri* L.) higher, significantly higher hunting spider communities were present than in the same treated old plantations. This relationship was not observed in case of the guild of web building spiders. The diversity of the canopy inhabiting spider communities was higher in the old plots, regardless of the treatments.

The effect of the border of the orchard on spider communities was investigated and it was found that when selective insecticides were used, the immigration of spiders into the orchards was increased significantly. When broad-spectrum insecticides were applied the spider densities in the canopy did not differ between the outer rows and the interior rows of the orchards.

The effect of the treatments and orchard age, both on the abundance and the species richness on the overwintering spider communities on the trunk showed the same result as in case of the canopy spiders. Namely significantly higher spider communities were found in the IPM plots and in the young plantation than the conventionally treated plots and in the old plantation.

The broad-spectrum insecticides reduced the abundance and the species richness of spider communities in the herbaceous layer of the conventionally treated plot. At the same time, the spider communities of the herbaceous layer of the IPM plot did not differ significantly from the adjacent herbaceous plants.

A significant overlap exists between the spider communities of the canopy and the herbaceous layer. Despite chemical treatments, immigration from the herbaceous layer into the canopy occurs.

The effect of the chemical treatments on the dominant species is discussed. There were no significant differences in abundance of one of the dominant species *Oxyopes heterophthalmus* Latreille, between the differently treated plots. However, the other dominant species *Cheiracanthium mildei* L. Koch showed higher abundance in the IPM plots.

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5.1 Introduction

Spiders are polyphagous predators, which occur in all terrestrial ecosystems. In agro-ecosystems they can play a fundamental role as predators of pests of economic importance because of their high density (Thornbull, 1973). For orchard ecosystems several faunistic studies have been carried out in Europe (Chant, 1956; Loomans, 1978; Klein, 1988; Olszak et al., 1992b; Bogya et al., 1999), which indicate that a relatively large number (50-70) of spider species occurs in orchards. Moreover, all studies agree that the species richness and the density of spider communities in untreated orchards are significantly higher than in treated orchards (Chant, 1956; Specht & Dondale, 1960; Legner & Oatman, 1964; Mansour et al., 1980). Integrated pest management (IPM) programmes, where the amount of acaricides used against mite pests is considerably reduced (Blommers, 1994), provide a possibility for establishment of high density spider communities. However, according to several studies, the spider densities did not increase in case of applying the moderately toxic pesticides widely used in IPM (e.g. diflubenzuron, fenoxycarb) compared to usage of broad-spectrum insecticides (organophosphates, pyrethroids) (Olszak et al., 1992b; Samu et al., 1997). According to laboratory investigation, organophosphates, pyrethroids and diflubenzuron are generally toxic to spiders (Mansour in Hassan et al., 1994). However, some species (e.g. *Philodromus aureolus*) show some tolerance to pesticides (Mansour & Nentwig, 1988; Polesnyi, 1990).

Very few studies were carried out on the numerical response of spiders to prey density indicating ability to prey suppression. According to Chiverton (1986) the decreased prey density did not result in a decreased density of spiders, but in some other cases spiders showed an aggregational numerical response to prey density, thus the spider density increased with increasing prey density (Kobayashi, 1975; Corrigan & Bennett, 1987).

In addition to the effects of pesticides and prey density, the immigration from the surroundings of the orchard and from the herbaceous layer could also be an important factor in the composition of spider communities in the canopy. In the surroundings of the orchards the spider communities both at the ground level (Bogya & Markó, 1999) and in the shrub layer (Olszak et al., 1992a) are higher in abundance and more diverse than in the orchard, but there is a considerable overlap with the spider fauna of the orchards. However, in case of orchard ecosystems there is little evidence that spiders can immigrate from the surroundings into the orchards. Wyss et al. (1995) investigated the relationship between the canopy and the herbaceous layer. They could increase the density of spider communities in the canopy by manipulating the herbaceous layer, and so reduce the amount of aphids there. In the rows, where the herbaceous layer was manipulated, the suitable overwintering places and the higher prey density composed by indifferent insects coming from the herbaceous layer could cause the higher spider communities in the canopy. Samu et al. (1997) stated, however, that the relationship between the canopy and the herbaceous layer is limited because of the different family composition of spiders and that there is little evidence that adding herbs to the herbaceous layer would increase the abundance of spiders in the canopy.

In the present study the following questions were asked: (i) What is the effect of conventional control (based on broad spectrum insecticides) versus integrated pest management (based on selective insecticides) on the composition of spider communities in the canopy of apple trees and in the herbaceous layer? (ii) Does the age of the orchards influence the composition and density of spider communities? (iii) How is the species composition of overwintering spider populations in the orchards? (iv) Do spiders immigrate from the surroundings of the orchard into the differently treated plots? Finally, (v) what kind of relationship exists in spider community composition between the canopy and the herbaceous layer?

5.2 Material and methods

Experimental plots

The investigation took place in an experimental apple orchard of the Research Institute for Fruit Growing and Ornamentals in Kecskemét-Szarkás (about 70 km south from Budapest) in Hungary in 1995. The soil of this orchard was sandy, and surrounded by a locust tree forest (*Robinia pseudo-acacia* L.), agricultural and rural fields. The area is in the driest part of Hungary with an average annual rainfall of ± 550mm.

The orchard contained two closely situated differently aged plantations and was not irrigated. The "old plantation" was planted in 1962 with cultivars of 'Jonathan' and 'Starking' on rootstock M4; the planting space was set at 5x4 m. This plantation was divided into two parts. One 6 ha sized plot (OldCON) and one of 5 ha (OldIPM) have been receiving conventional management systems (based on broad-spectrum insecticides) and integrated pest management systems (based on selective insecticides), respectively, since 1986. The "young plantation" was planted in 1981 with cultivars of 'Idared', 'Mollies Delicious' and 'Jonagold' on rootstock M4; the planting space was 6x4 m. This plantation was also divided into two plots. One 2 ha sized conventionally treated plot (YoungCON) and another 2 ha sized plot (YoungIPM), where an integrated pest management program was executed, respectively, since 1992. All the treatments in the different plots were applied at the same time (Appendix D, Table 1).

Sampling methods

1. A beating method was chosen to collect spiders from the canopy. A Winkler-type beating umbrella (diameter 0.7 m, depth 0.8 m) and beating stick (covered with plastic, 1.2 m long) were used. Five times two whole randomly chosen individual trees were tapped in each plot with intervals of two weeks from April until October, 14 times in sequence. Subsamples were taken as gradient from the outer rows to the interior rows of the plots in the old plantation.
2. In addition to the beating method, corrugated cardboard treebands were used to sample the overwintering spider communities in the orchard. Thirty treebands were placed at about 0.3 m height around the trunk in each plot before the leaf fall (September). Ten bands were removed from each plot after two, four and six weeks.
3. Sweep netting was performed to collect spiders from the herbaceous layer. A triangular shaped sweep net (0.3 m wide) was used. Three times 33 sweeps were made in both the young conventional (YoungCON) and integrated (YoungIPM) plots and in their adjacent field vegetation within 10 m from the outer row (EDGE) as well. These samples were taken at the same times as the beating method.

Community comparison

The spider communities were characterised by their density and species richness.
Rényi diversity ordering (Rényi, 1961) was chosen for calculating the diversity:

$$H\alpha = \frac{\log \sum_{i=1}^{S} pi^{\alpha}}{1-\alpha} \qquad \text{where } \alpha \neq 1$$

p_i = proportion of total sample belonging to *i*th species
α = scale parameter

When the scale parameter (α) is zero, the function gives the logarithm of the species richness, when it is equal (or very close) to one it gives the value of the Shannon-Wiener function and when it approaches infinity (α>5) the function gives the logarithm of the invert of the Berger-Parker (1970) diversity (Tóthmérész, 1995). This method covers the entire range of the diversity from indices sensitive to the rare species (low α parameters) till indices sensitive to the dominant species (high α values). The program Divord 1.90 was used for this calculation.

The similarity of spider communities between differently treated and aged plots was compared using Horn index (C_H) (Krebs, 1989). Hierarchical clustering (nearest neighbour method) was used to compare the effect of treatments on different layers and the edge of the orchard, with help of the program Syntax 5.1.

Statistics and analysis.

The statistical analysis was performed by the package Ministat 2.4 as follows. Two-way ANOVA was used to compare the effects of treatments (conventional versus IPM) and plantation age (young versus old) on abundance and species richness of the total canopy spider communities, different guilds and the abundance of the dominant species. The same method was used for the overwintering spider communities on trunks for the comparison of the effects of treatments and age of plantations for total number of spider individuals, density of the dominant spider, *Cheiracanthium mildei* L. Koch and for its potential prey *Stephanitis pyri* L. A t-test was used for the comparison of abundance, species richness and diversity indices of the grass-dwelling spider communities within the orchard versus the adjacent field vegetation.

To calculate the correlation between the densities of the overwintering pear lace bug, *St. pyri* and the yellow sac spider, *Ch. mildei* the treeband data were used. To minimise the standard deviation the material from two neighbouring bands was pooled.

The Horn index was used for the comparison of the canopy, herbaceous layer and ground level inhabiting spider communities. The source of the data for this comparison in addition to the data presented in this study was Bogya & Markó (1999).

5.3 Results

Spider communities in the canopy

During the observation period (April-October) a total of 295 spiders were collected belonging to 35 species in 13 families (Appendix D, Table 2). In the course of the vegetative period two peaks were found, a small one in spring and a large one in autumn (Fig. 1).

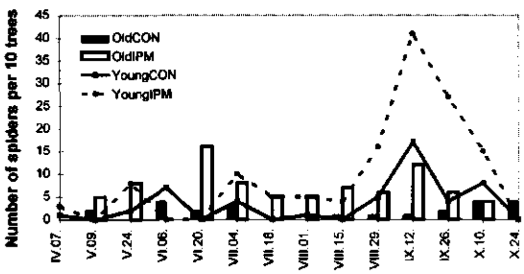

Fig. 1. Occurrence of spiders in the canopy of differently treated apple orchards (Kecskemét-Szarkás, beating method, April-October, 1995)

Comparison of treatments

The abundance of spiders in the IPM plots was significantly higher than in the conventional plots both in the young and in the old plantations (Appendix D, Table 2 and 3). This effect was similar for the two main guilds, the "web-builders" and "hunters" (Appendix D, Table 3 and 4).

The species richness in the young plantation was one and a half time and in the old plantation two times higher in the IPM plots than in the conventionally sprayed plots. The differences were significant (Appendix D, Table 3 and 4).

The diversity of spider communities of same aged, but differently treated plots did not differ significantly anywhere in the entire range of the diversity scale parameter used (Fig. 2, Appendix D, Table 3 and 5).

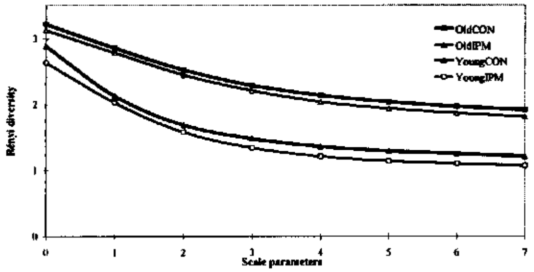

Fig. 2. Diversity ordering of foliage-dwelling spider communities in different aged (young, old) and differently treated (conventional, IPM) apple orchards (Kecskemét-Szarkás, 1995, Hungary)

The hierarchical clustering showed that the different treatments (conventional versus IPM) did not result in a separation of the different plots (Fig. 3). This leads to the conclusion that the chemical treatments did not affect the composition of canopy spider communities.

The dominant species were *Oxyopes heterophthalmus* Latreille (22%), followed by *Cheiracanthium mildei* L Koch (19%). The subdominant species were: *Xysticus spp.*, *Eris nidicolens* Walckenaer and *Carrhotus xanthogramma* Latreille. There were no significant differences in abundance of *O. heterophthalamus* between the differently treated plots (Appendix D, Table 2 and 3). However, a significantly higher abundance of *Ch. mildei* was found in the IPM plots (Appendix D, Table 2 and 3). In case of the subdominant species there was a tendency of a higher abundance in the IPM plots.

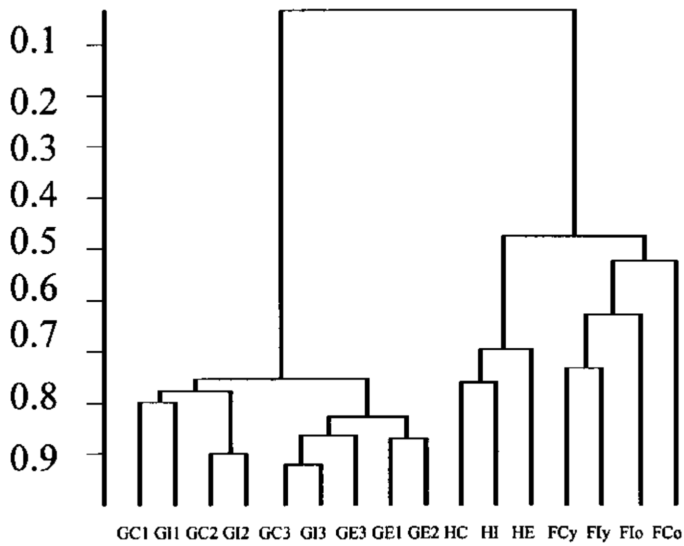

Fig. 3. Comparison of spider communities inhabiting different layers of differently treated apple orchards and their adjacent fields. Hierarchical clustering based on Horn index, nearest neighbour method, Kecskemét - Szarkás (1992 - 1995)

G: ground level (pitfall trapping), H: herbaceous layer (sweep netting), F: foliage/canopy (beating method);
C: conventionally treated, I: IPM, E: adjacent field of the orchard;
1: 1992, 2: 1993, 3: 1994. y: young plantation, o: old plantation

Comparison of differently aged plantations

There is a tendency that in plots which differ in age, but that received the same treatments, spider communities in the young plantation were higher in abundance, in spite of the smaller size of the canopy (Appendix D, Table 3 and 4). Species richness did not differ significantly between similarly treated young and old plots (Table 3 and 4). The Rényi diversity index indicates more diverse spider communities in the old plantations, both in the conventional and the IPM plots (Fig. 2, Appendix D, Table 3, 5).

The age of the plantations has a different influence on the abundance of the different guilds and species (Appendix D, Table 3 and 4). In case of the web-builders, higher abundance was found in the old plantation, but the difference is not significant. The guild of wanderers (hunters), however, shows the same tendency as the spider communities as a whole: there was a significantly higher abundance in the young plantation. The major reason for this is that the two most dominant species are both hunters (*O. heterophthalmus* and *C. mildei*) (Appendix D, Table 3 and 4).

Effect of the border

The effect of the orchard border on spider community composition and abundance was investigated in the old plantation. In the plot treated with broad-spectrum insecticides there was no difference between the outer rows and the interior rows in abundance and species richness of spider communities. In the IPM plot, however, there were twice as many individuals and species in the outer rows than in the interior rows (Fig. 4. and 5.). Here the diversity indices show a more diverse spider fauna in the outer rows: $\alpha(1)_{outerrow}$=2.91; $\alpha(1)_{interiorrow}$=2.20; $\alpha(3)_{outerrow}$=2.59; $\alpha(3)_{interiorrow}$=1.9; $\alpha(7)_{outerrow}$=2.35; $\alpha(7)_{interiorrow}$=1.69, but the differences are significant only in case of low α values ($t_{\alpha 1}$= 4.42 **, $t_{\alpha 3}$= 2.04 *, $t_{\alpha 7}$= 1.54 n.s.). The similarity indices showed low to medium similarity: C_H=0.39.

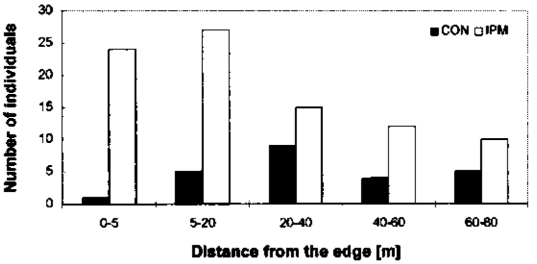

Fig. 4. Changes in abundance of spiders collected along transect from the border to the centre of differently treated apple orchards (Kecskemét-Szarkás, beating method, April-October 1995)

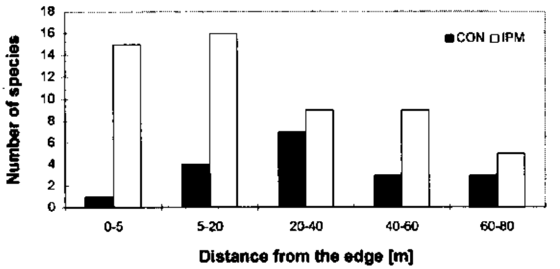

Fig. 5. Changes in species richness of spiders collected along transect from the border to the centre of differently treated apple orchards (Kecskemét-Szarkás, beating method, April-October, 1995)

Overwintering spider communities on the trunk

From the treebands 180 spiders belonging to 14 species in 8 families were collected (Appendix D, Table 2).

Comparison of the treatments

The numbers of individuals and species were significantly higher in the IPM plots both in the young and old plantations. The diversity indices did not show differences. The dominant species in all plots was the *Cheiracanthium mildei*, (with a dominance of more than 50%), and this species occurred in significantly higher numbers in the IPM plots (Appendix D, Table 6 and 7).

Comparison of the differently aged plantations

Both the numbers of individuals and species were significantly higher in the young plantation (Appendix D, Table 6 and 7).

In case of *Ch. mildei* the abundance was higher in the young plantation similarly to the entire spider community. The most frequent potential prey overwintering in the treebands in the orchard was the pear lace bug (*Stephanitis pyri*). Under laboratory conditions *Ch. mildei* preyed on this tingid. In the IPM plots more *St.pyri* overwintered than in the conventional plots. In addition the density of *St pyri* was higher in the young plantation (Appendix D, Table 6 and 7). This density pattern agreed with the pattern of *Ch. mildei*. The relationship between the prey and spider densities within the plots indicated that the density of *Ch. mildei* was determined by the density of *St. pyri* in the treebands in the young IPM plot (Fig. 6).

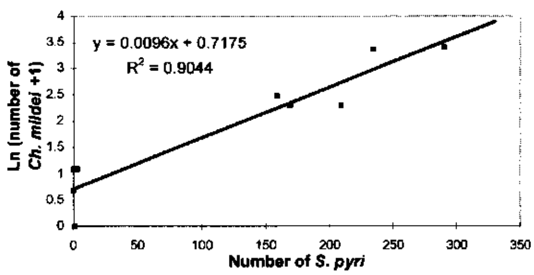

Fig. 6. Relationship between the numbers of overwintering *Stephanitis pyri* and *Cheiracanthium mildei* in the treebands in the young IPM plot (Kecskemét-Szarkás, 1995)

Spider communities in the herbaceous layer

In the herbaceous layer 234 spiders were collected belonging to 20 species in 8 families (Appendix D, Table 2). In the course of the vegetative period the spiders occurred permanently in this stratum (Fig. 7.).

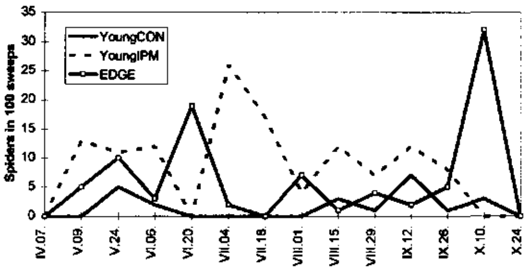

Fig. 7. Seasonal occurrence of spiders in the herbaceous layer of a differently treated apple orchard and its surroundings (Kecskemét-Szarkás, sweep netting, 1995)

The abundance and the species richness were significantly higher (abundance: $t_{IPM/CON}=4.51^*$; $t_{EDGE/CON}=4.15^*$ $t_{EDGE/IPM}=1.19$; species richness $t_{IPM/CON}=3.13^*$; $t_{EDGE/CON}=3.78^*$; $t_{EDGE/IPM}=2.53+$) in the adjacent field and in the IPM plot than in the orchard treated with broad-spectrum insecticides (Appendix D, Table 8.). The Rényi diversity index of herbaceous layer inhabiting spider communities in the conventional and IPM plots differed significantly in the whole range of the scale parameter. While between the IPM plot and the adjacent field of the orchard a significant difference was observed only in case of rare species (Appendix D, Table 8, 9, Fig. 8). The similarity of the spider communities of the differently treated plots ranged between 0.69 and 0.77 (Fig. 3.).

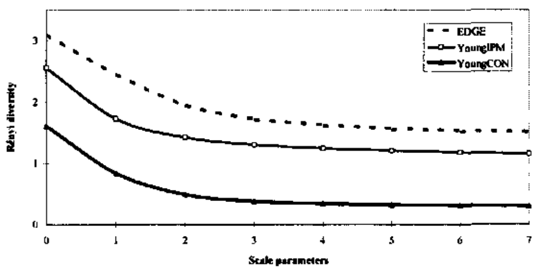

Fig. 8. Diversity ordering of herbaceous layer inhabiting spider communities in apple orchards and their surroundings (Kecskemét-Szarkás, 1995, Hungary)

The dominant species were *Oxyopes heterophthalmus* in both habitats, and in the adjacent field *Xysticus spp.*. The density of *O. heterophthalmus* was significantly higher in the IPM plot ($t_{CON/IPM}=4.24^*$; $t_{EDGE/IPM}=3.47^*$) and the other two plots did not differ from each other ($t_{CON/EDGE}=1.46$). In case of *Xysticus spp.* the abundance was higher in the IPM plot and the edge than in conventional plot ($t_{CON/IPM}=2.95^*$; $t_{CON/EDGE}=7.27^{**}$), the density was not different between the IPM plot and the adjacent field ($t_{IPM/EDGE}=1.04$). The samples in the herbaceous layer were dominated by juvenile spiders, notably *O. heterophthalmus* ($D_{juv}=0.87$) and *Xysticus spp.* ($D_{juv}=0.86$).

Comparison of the layers

Comparing the spider communities between the three strata (canopy, herbaceous layer, ground level) leads to the conclusion that the similarity between the canopy and the herbaceous layer inhabiting spider communities was only 51%, but there is still a large overlap (Fig. 3). The dominant species in both strata is *Oxyopes heterophthalmus*. Twenty species were found in the herbaceous layer, and 12 of these occurred also in the canopy. The similarity between the canopy and the ground level - calculated by using the pitfall trap data from the three previous years - is rather low, the similarity indices in all surveyed years showed a value below 3% (C_H1992=0.62%; C_H1993=0.65%; C_H1994=2.62%). The similarity between the ground level and the herbaceous layer is also low (C_H1992=4.18%; C_H1993=5.93%; C_H1994=7.54). The spider community from the ground level seems separated from the other two strata (Fig. 3).

The overwintering spiders on the trunk are originating first of all from the canopy and resemble the fauna of the canopy (*Cheiracanthium mildei, Philodromus spp.*), and secondly species that facultatively live on the bark (*Drassodes spp.; Scotophaeus spp.; Aphantaulax spp.*). The bark-living species can be collected by beating method also in small abundance, but not with sweep netting and pitfall trapping (Appendix D, Table 2). The similarity between the canopy and the overwintering spider fauna on the trunk is weak to medium (C_H=40%), which means that the canopy spiders (*Oxyopes heterophthalmus, Xysticus spp.*) partly overwintering in other places for example in the grass- or at the ground layer.

5.4 Discussion

Two population peaks can be seen in the canopy of apple orchards, a small one in springtime and a larger one in autumn. Previous studies have shown the same result from several European and American orchards (Klein, 1988 (Germany); Olszak et al., 1992b (Poland); Dondale, 1958; Specht & Dondale, 1960; Bostanian et al., 1984 (Canada); McCaffrey & Horsburgh, 1980 (USA)). This pattern basically originates from the seasonal change in abundance. Similar tendencies were found in treated and in untreated orchards. The increasing abundance of spiders in the second half of the vegetation period is largely the result of increased numbers of juveniles. These juveniles may originate from the progeny of the individuals that survived the chemical treatments and/or from immigrating individuals from the surroundings of the orchard.

All three methods of collection, beating, sweep netting and treebands yielded significantly more individuals and species in the IPM plots. However, the diversity and similarity indices did not show significant differences, which means that the different treatments (conventional and IPM) had the same effect on the entire spider communities and only had a small amount of influence on the structure of the communities. Previous studies demonstrated that increasing pesticide use can result in a dramatic decrease of spider numbers in the canopy (Hagley, 1974; McCaffrey & Horsburgh, 1980; Mansour et al., 1980; Bostanian et al, 1984). The major factors responsible for this are the direct effect of the broad-spectrum insecticides and the lack of prey after the treatments. The abundance of spider communities did not differ significantly in case of the application of integrated pest management system based on selective insecticides (diflubenzuron, fenoxycarb) and the conventional management system based on broad-spectrum insecticides (Olszak et al., 1992b; Samu et al., 1997). Olszak et al. (1992b) supposed that their results could be strongly influenced by the prey density. In our experimental orchard leafminers, leafrollers, codling moth and phytophagous mites occurred in higher densities in the conventional plots, while aphids and pear lace bug occurred in higher abundance in the IPM plots (Jenser et al. 1997).

Both the investigations by the beating method and the treebands showed higher spider densities in the young plantation. When spider communities were split up in guilds, the same tendency was found only in case of hunting spiders. The web-building spiders showed an opposite result. According to the study of Sengonca et al. (1986) the web-builder, *Araniella opistographa* was more frequently found in orchards with small canopy size while the wanderer, *Philodromus aureolus* was more abundant on standard sized apple trees. However, our results disagree with these observations, but fit quite well to the observed densities of the pear lace bug in the different aged plantations. It is likely that the positive aggregational numerical response of the hunting spiders to the higher density of the *Stephanitis pyri* in the young plantation resulted the differences in spider communities between the young and the old plantations. The abundance of *Ch. mildei* fits quite well to the abundance of *St. pyri* between the different plots. Within the young IPM plot the overwintering number of *Ch. mildei* in different trees correlated with the number of overwintering *St. pyri*. The pear lace bug, similar to *Ch. mildei* occurred in higher abundance in the second half of the vegetative period (Jenser et al., 1997). In laboratory experiments (Bogya unpubl.) *Ch. mildei* accepted *St. pyri* as prey. To summarise the above mentioned facts, both between the plots and within the plots, *Ch. mildei* showed a strong aggregational numerical response to the density of *St. pyri*. This agrees well with the results of Corrigan & Bennett (1987), where *Ch. mildei* actively sought out infested trees by *Phyllonorycter blancardella*. Also a direct numerical relationship was observed between *Cheiracanthium mordax* and larvae of *Heliothis spp.* in cotton (Bishop & Blood, 1981). For web-builders a positive numerical response was not observed, which can be explained by the different prey spectrum and lower moving activity of those spiders.

A close relationship exists between the spider fauna of the canopy and the herbaceous layer. During the vegetative period the indices showed 52-74% similarity, which means that we can expect much exchange between both layers. In case of the difference in abundance between the conventional and IPM plots, the herbaceous layer inhabiting species (*O. heterophthalmus* and *Xysticus spp.*) were smaller in number than the other foliage-dwelling species (*Ch. mildei, E. nidicolens, C. xanthogramma*). This probably is caused by immigration from the herbaceous layer after the treatments. Further relationships between these two strata are that during the vegetative period indifferent organisms as alternative prey can immigrate from the herbaceous layer to the canopy and at the end of the season the canopy spiders partly overwinter in the herbaceous layer. Manipulation of the herbaceous layer could influence the spider fauna of the canopy. The present results fit quite well to the results of Wyss (1995), Wyss et al. (1995) and Altieri & Schmidt (1986).

The present study took place in the experimental orchard where Samu et al. (1997) obtained partly similar results in the previous year (1994). In that investigation the spider fauna of the canopy and the herbaceous layer also overlapped. The observed differences in family composition between the present study and their results is probably caused by the different sampling methods used and, furthermore, by the effect of different years. In that work, the investigation of spider communities inhabiting the herbaceous layer was limited to the flowering herbs, and that is why the dominant spider was a flower-inhabiting crab spider, *Thomisus onustus*. The investigation of canopy spiders was performed by beating the top of the shoots above a $0.5m^2$ sheet. Probably these facts resulted in the differences in fauna composition of the herbaceous layer and the lack of *Cheiracanthium mildei* from the canopy fauna. Further differences maybe that in case of the comparison of the canopy and herbaceous layer Samu et al. (1997) neglected the juveniles, while the spider communities is normally dominated by juveniles.

Spiders may immigrate from the surroundings to the orchards, but only when integrated pest management is applied. The spider fauna of the adjacent vegetation is richer and more diverse than the orchard fauna and in case of the dominant species significant overlapping can be seen. (Olszak et al., 1992b; Bogya & Markó, 1999). One of the reasons that larger spider communities could develop in the IPM plots is probably the possibility for recolonization after the treatments. In the IPM plots both in the canopy and in the herbaceous layer, the diversity was higher in the outer rows (canopy level) and in the adjacent field of the orchard (herbaceous layer) than inside the orchard, but differences were significant only in case of low α values. This means that some species can colonise only the border of the orchard.

In conclusion, the main factors determining the composition of spider communities in the canopy are (a) direct toxicity of pesticides, (b) variation in prey density due to pesticides and (c) age of plantations, (d) the numerical response of spiders to prey density and (e) immigration of spiders from the herbaceous layer and from the surrounding of the orchards.

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Chapter 6

Effect of Pest Management Systems on Ground-dwelling Spider Communities in an Apple Orchard in Hungary*

Abstract. Ground dwelling spider communities in differently treated plots of a Hungarian apple orchard were investigated by pitfall trapping. The samples were taken weekly from April to November over 3 years as part of a study to compare the effects of integrated pest management based on selective insecticides, with conventional control utilising broad-spectrum compounds. Attention was also paid to the effects of boundaries and of different weed patterns on the spider communities.

No significant differences were found between the conventional and IPM plots in species richness and composition, density and diversity of epigeic spider communities. The density in the IPM plots was moderately higher in only one year. Greater spider densities were observed in the tree rows where the weed coverage was higher than in the alleys where mechanical weed control was applied. However, community structures did not differ significantly.

Near the edge of the orchard, the density and species richness of epigeic spiders were higher and the community structure differed slightly from that of the orchard habitats.

The spiders showed one population peak in springtime in all habitats, but this was more extended in the edge. The collections included 1147 individuals representing 37 species, with *Xysticus kochi* Thorell, *Pardosa agrestis* Westring and *Titanoeca schineri* L. Koch being the most dominant species. Their population dynamics, sex ratio and habitat preferences are also discussed.

*: This chapter has been submitted as: Bogya, S. & Markó, V. Agriculture, Ecosystems & Environment (in press)

6.1 Introduction

Beneficial organisms, selective chemicals and other techniques are essential components of integrated pest management. Orchard IPM often involves the use of polyphagous natural enemies such as ladybirds, predatory bugs, earwigs and spiders (Blommers, 1994). However, generalist natural enemies, such as spiders, cannot control a given pest species when an outbreak has developed (in contrast to specialists), but their role in preventing outbreaks may be substantial (Riechert and Lockley, 1984).

The results of many studies have increased expectations that spiders can play an important role in the suppression of orchard pests. Spiders have different hunting tactics and may therefore act as predators of different pests (reviewed by Bogya & Mols, 1996).

Little attention has been paid to ground-dwelling spiders in orchards, despite their high density (Zhao et al., 1993; Holstein & Funke, 1995) and diversity (Samu & Lövei, 1995). The two major factors influencing the development of the ground-dwelling spider communities could be the effect of pesticide treatments and the weed cover.

Little is known about the side effects of pesticides on epigeic spiders in orchards, where, in contrast to arable crops, these effects should be less as treatments are directed to the canopy and not to the ground (Altieri & Schmidt, 1986; Bogya & Mols, 1996).

Spider abundance is correlated with the specific vegetation characteristics, suggesting that the availability of habitats is important for spider colonisation and establishment (Rypstra & Carter, 1995). Increased weed coverage can result in higher numbers of epigeic spiders in the field (Frank & Nentwig, 1995), and can also leads to higher densities of foliage inhabiting spider communities. This suggests that there are interactions between the communities in canopy and the ground cover (Altieri & Schmidt, 1986; Wyss, 1995; Wyss et al., 1995).

An additional factor could be the boundary's effect. In arable ecosystems, these pesticide-free areas can conserve spider populations and thus represent an important source of immigration (Alderweireldt, 1989; Kromp & Steinberger, 1992; Tóth et al., 1996). Surrounding vegetation and hedges around the orchards are important reservoirs of other beneficial arthropods (e.g. Olszak et al., 1992).

The aim of this study was to investigate the impact of pesticide treatments and weed cover on epigeic spider communities in an apple orchard and the extent of interactions between inside and outside the orchard epigeic spider communities.

6.2 Material and methods

The study was carried out in an apple orchard at Kecskemét-Szarkás, about 70 km south of Budapest in Hungary in 1992-94. The orchard was located in a typical Hungarian fruit-growing region, with sandy soil. The planting consisted of the cultivars 'Jonathan', 'Jonagold', 'Idared' and 'Mollies Delicious', all on rootstocks M4, planted in 1981 at distances of 6 x 4 m. It was surrounded by a locust tree (*Robinia pseudo-acacia* L.) forest, agricultural fields and ruderal areas and was not irrigated.

The previously conventionally treated orchard was divided into three parts, each of 2 ha. One part was treated conventionally (CON) with broad-spectrum insecticides and acaricides. In the other two (IPM/1 and IPM/2) an integrated pest management program was executed with selective insecticides (Appendix E, Table 1). In one of the IPM plots (IPM/2), flowering ornamentals were sown in each year, but because of the dry conditions seed germination was too poor to have any effect on arboreal or epigeic arthropods. Therefore the IPM/2 plot is treated here as a replicate of IPM/1. More details about pesticide treatments and the plant species sown can be found in Jenser et al. (1997). The alleys, between tree rows, were mechanically cultivated six or seven times during the vegetative period, while chemical weed control was applied under the trees within rows once a year with glyphosate or glyphosinat-ammonium in the IPM plots. In addition, pendimetalin and diuron were applied in the conventional plot. The weed density and the number of weed species were higher in the tree rows than in the alleys during the entire vegetative period. All pesticide treatments were carried out at the same time.

Covered pitfall traps (300 cm^3 in size, 8 cm in diameter) half-filled with 30% ethylene glycol in water were used to collect spiders from April until October. The traps were emptied weekly, the contents were washed with tap water through a paper tissue and stored in 75% ethyl alcohol. Ten traps were used in each plot (CON, IPM/1 and IPM/2), five traps were placed between tree rows and five within the rows. Another five traps were placed near the edge of the orchards (EDGE), among the locust trees where weed coverage was nearly 100%.

The adult spiders were identified to species, and the juveniles were counted and identified as far as possible, usually to genus. For the different calculations, all the juveniles were included.

The spider communities were characterised by their density, species richness, diversity and evenness. Four diversity indices were calculated: Berger-Parker Dominance Index (BP) and Shannon-Wiener function (H) (Southwood, 1978), which are sensitive to density changes of the dominant and rare species, respectively, and Q-diversity (Q) (Kempton and Taylor, 1976) and α-diversity (α) (Williams in Fisher et al., 1943), which are sensitive to species of medium dominance. Evenness was measured from the Shannon - Wiener function (Margalef, 1958). The Jaccard - index (C_j) was used to investigate the degree of similarity in species composition while the Morisita - Horn index (C_{MH}) was used to assess uniformity in species composition and dominance (Southwood, 1978; Krebs, 1989).

The statistical procedure was performed by Ministat 2.4 as follows: The three years' total catch of each trap was used for the comparison of abundance, species richness and diversity. The effect of management type (CON versus IPM) and the intra-orchard habitat (alley versus tree row) were analysed by two-way ANOVA. Additionally, the effect of management type on abundance was analysed by comparing the annual data with one-way ANOVA. The effect of intra-orchard habitat on abundance was analysed by one-way comparison of related samples (One-sample t test, Wilcoxon test), where the three years total catches of each trap were used and paired respectively. The comparison of spider communities between the orchard habitats and borders was performed by one-way ANOVA (where the population variances were equal) or by more robust were this was not of the case (Welch test, James test, Brown-Forsythe test). Abundance of the three dominant species in the different plots and habitats was compared in the same way.

The similarity indices for the experimental units: groups of five traps in the rows, in the alleys and in the borders were calculated annually. The same statistical methods were applied (one-way ANOVA or robust tests as in the previous case) to test whether the similarity indices calculated between the intra-orchard units differed from those calculated for the orchard units and the borders.

6.3 Results

During the study, 1147 individuals and 37 species of epigeic spiders were collected; 14 species in CON, 16 in IPM/1, 13 in IPM/2 and 27 in EDGE, respectively (Appendix E, Table 2). Two families dominated: Lycosidae 38.5% and Thomisidae 35.8%.
The seasonal occurrence of spiders shows one population peak in springtime, regardless of the treatments. The peak is lower but broader in the orchard border (Fig. 1).

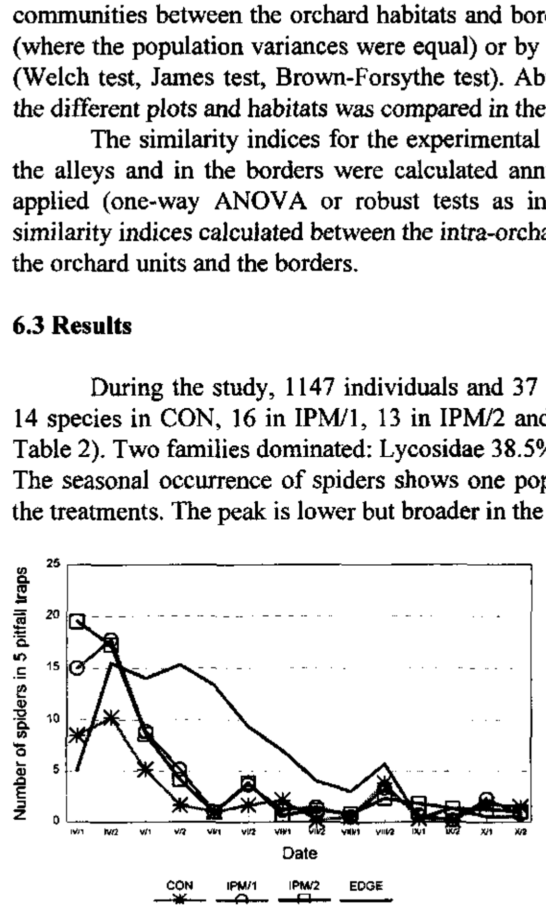

Fig. 1. The seasonal occurrence of spiders in conventional and IPM treated orchard plots and in the orchard borders (Kecskemét-Szarkás, pitfall trapping, 1992-94)
The date expressed as the 1st and the 2nd part of the moth

Effect of management programs on spider community composition

Abundance

Comparison of the annual data by one - way ANOVA did not show a significant treatment effect on the abundance of spiders in 1992 and 1993 (F_{1992}=1.09; F_{1993}=0.20). The number of specimens was moderately higher in the IPM plots in the following year (1994)

(Tukey - Kramer pairwise comparison; $T_{CON/IPM1} = 3.62+$; $T_{CON/IPM2} = 3.66+$; $T_{IPM1/IPM2} = 0.04$). This difference in abundance was most obvious in spring in 1994, and also contributed to the difference between treatments over the three years (Fig. 1).

When the three years' data were pooled and analysed in the same way, no significant treatment effect was found (F=1.68) (Appendix E, Tables 3, 4).

Species richness and diversity

The species richness, the BP index, the H diversity, the evenness, the α and the Q diversity were analysed (2 - way ANOVA) and no significant differences (p>0.05) were observed between treatments (Appendix E, Tables 3, 4, 5).

Similarity

The Jaccard index and the Morisita - Horn index showed low and medium-high similarity, respectively, between the differently treated plots. The similarity indices between the two IPM plots were not significantly higher than those between the IPM and the conventional plots (Fig. 2).

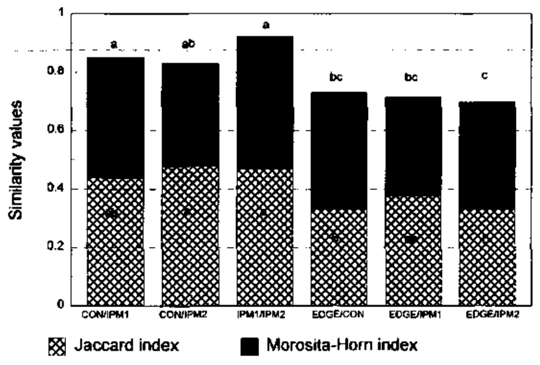

Fig. 2. Similarity of spider communities in conventional and IPM treated orchard plots and in the orchard borders (Kecskemét-Szarkás, pitfall trapping, 1992-94)
Values marked by the same letter do not differ at 10% level of significance
Tukey - Kramer pairwise comparison (pmin<0.10), means of annually compared data

Community composition in tree rows and alleys

Abundance

The abundance of ground-dwelling spiders was significantly higher (2 - way ANOVA) in the tree rows (p<0.01), where the weed density was higher (Appendix E, Tables 3, 4). A similar result was obtained by the other statistical procedure (one-way comparison of related samples: one-sample t test (t=3.96**), Wilcoxon test R+=6.5, R-=98.5**))

Species richness and diversity

The number of species, the BP index, the H diversity, the evenness, the α and the Q diversity were analysed (2 - way ANOVA) and no significant differences were observed (Appendix E, Tables 3, 4, 5).

Similarity

The similarities between the tree rows and alleys were moderate (Jaccard index ± SD): 0.56 (0.15); 0.40 (0.17); 0.68 (0.13) and medium - high (Morisita-Horn index ± SD): 0.83 (0.05); 0.73 (0.08); 0.88 (0.05) in the CON; IPM/1 and IPM/2, respectively. This suggests that there were no differences between the two habitats.

Comparison of orchard and border spider community composition

Abundance

The abundance of the border spider fauna was significantly higher than that of the orchard (in both the alleys and the tree rows) ($p<0.01$) (Appendix E, Tables 3, 6)

Species richness and diversity

The number of species was significantly higher in the border than in the orchard ($F = 5.14^{**}$) (Appendix E, Table 6). The BP index, the H-, the α- and the Q- diversity do not show significant differences. However, all indices show a trend towards higher diversity in the border (Appendix E, Table 3).

Similarity

Both the Jaccard and the Morisita - Horn indices showed differences in the similarity of the spider fauna in the orchard and its border ($p<0.01$) C_j: Welch's modified t test 4.43**; C_{MH}: Two-sample t test 5.84**. The similarities between the differently treated orchard units were significantly higher than between the units and the border (Fig. 2).

Dominant species

The three most abundant species were *Xysticus kochi* Thorell, *Pardosa agrestis* Westring and *Titanoeca schineri* L. Koch followed by *Alopecosa sulzeri* Pavesi and *Harpactea rubicunda* C. L. Koch. They represented 34.3%, 21%, 14.6%, 14% and 4.6% of the catch, respectively.

Xysticus kochi

X. kochi showed one population peak in April-May (Fig. 3). The proportion of males in the pitfall trap catches was more than 90 %. No differences were found with regard to treatment or habitat preference, or between the orchard and the border (Appendix E, Tables 3, 7).

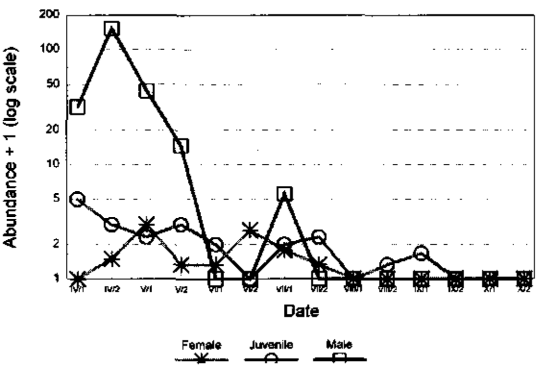

Fig. 3. The seasonal occurrence of *Xysticus kochi*, mean annual catch* (Kecskemét-Szarkás, pitfall trapping, 1992-94)

The date expressed as the 1st and the 2nd part of the moth

*: total catch of 35 traps divided by 3 years

Pardosa agrestis

The males of this species showed a large population peak in spring (April-May) and a smaller one in autumn (October) (Fig. 4). It seems that *P. agrestis* has at least two generations a year in Hungary. The sex ratio of adults in the pitfall trap catches differed from the two previous species, in that only 35% were males, and more than 60% of captures were juveniles. No significant differences were found with regard to treatment (F = 0.75) (Appendix E, Tables 3, 7). However, significant differences were observed both in habitat preference (F = 4.67*) and between the orchard and borders (F = 4.34**) (Appendix E, Tables 3, 6, 7). It appears that *P. agrestis* prefers those habitats where the weed coverage is greater.

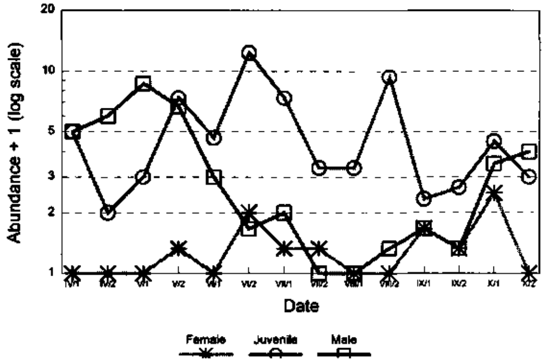

Fig. 4. The seasonal occurrence of *Pardosa agrestis*, mean annual catch* (Kecskemét-Szarkás, pitfall trapping, 1992-94)

The date expressed as the 1st and the 2nd part of the moth

*: total catch of 35 traps divided by 3 years

Titanoeca schineri

T. schineri also showed one population peak in early spring (April) (Fig. 5). The proportion of males in the pitfall trap catches was also more than 90 %. No significant differences were found with regard to treatment (Appendix E, Tables 3, 7) or between the orchard and the border, but in case of the habitat preference (tree row-alley) significant differences were found (F = 8.96**) (Appendix E, Tables 3, 7). This suggests that *T. schineri* prefers tree row habitats where the weed density is greater than in the alleys.

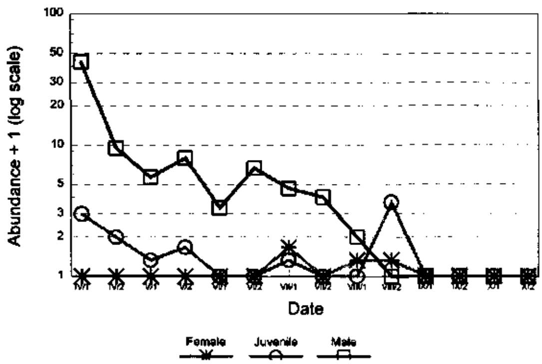

Fig. 5. The seasonal occurrence of *Titanoeca schineri*, mean annual catch* (Kecskemét-Szarkás, pitfall trapping, 1992-94)

The date expressed as the 1st and the 2nd part of the moth

*: total catch of 35 traps divided by 3 years

6.4 Discussion

Pitfall trapping has been criticised as a sampling method in ecological studies, because the catch can be influenced by factors other than abundance (Topping & Sunderland, 1992). Problems include differing trappability of species differing activity patterns, variable capture rates of males and females, and effects of habitat structure. Nevertheless, pitfall trapping is extensively used to study ground-dwelling arthropods (including spiders) because pitfall traps are inexpensive, easily monitored and trap large numbers of a wide range of species. Sampling is continuous and therefore not prone to the problems of spot sampling in time. Additionally, the results of pitfall trapping often show strong correlation at the community level to those desired from other observations.

This study failed to indicate differences between epigeic spider communities in IPM and conventional plots. Though this is in accord with what Olszak et al. (1992) and Samu et al. (1997) have found in the case of foliage inhabiting spiders, the causes could be somewhat different. In laboratory investigations, organophosphorous insecticides (Brown et al., 1983) and diflubenzuron (Mansour in Hassan et al., 1994) are harmful for spiders, but although the OP's are generally also toxic in the field (Powell et al., 1985), diflubenzuron (Kuijpers, 1992) and fenoxycarb (Schoemans, 1995) are not. Pirimicarb is harmless for spiders both in the laboratory (Brown et al., 1983; Dinter & Poehling, 1995) and in the field (Powell et al., 1985).

In addition many factors can modify the direct effect of pesticides in field investigations (Bogya & Mols, 1996). In orchards, where the treatments are directed to the canopy, the effect of pesticides on ground-dwelling spiders could be limited. The adsorption effect of the soil and the weeds could reduce the toxicity of pesticides (Wehling & Heimbach, 1991; Luff & Rushton, 1989). However, although diflubenzuron showed some toxicity in laboratory experiments it was non-toxic for spiders in field experiments at the ground level (Winter, 1979; Wehling & Heimbach, 1991). The relatively low density and diversity of phytophagous prey in the IPM plot because of indirect effect of pesticides, could be the reason for the similar densities of spiders in IPM and CON plots (Olszak et al., 1992). In the present investigations, the a combination of these factors could have led to the similarities in community structure and abundance between the conventional and IPM plots.

Greater spider densities were observed within the orchard in sites where the weed density was higher. It seems that this is general phenomenon in spiders, mentioned in many studies (Frank & Nentwig, 1995). However, some species prefer microhabitats with low weed cover (Alderweireldt, 1989). In the present work, weed density did not play an important role in habitat distribution of the dominant species, *Xysticus kochi*.

Abundance and species richness were higher on the border than within the orchard, but the species composition and dominance were similar. This indicates that spiders could immigrate from the border into the orchard. However, trends in the differently treated plots were more similar to each other than to the borders. The diversity indices of spider communities in the borders were always higher than those of the different units of the orchard, although the differences were not significant. This suggests that only a fraction of the spider fauna occurring outside can colonise the disturbed habitats of the ground level of orchards.

The epigeic spider fauna of another apple orchard surrounded by an oak forest was investigated by Samu & Lövei (1995) in Hungary. Among the dominant and subdominant species found in the present investigation, several also occurred in that apple orchard. The species composition and the dominance structure were different in case of these two apple orchards, which emphasises the role of different factors, especially the different surroundings on the organisation of epigeic spider communities.

The crab spider *Xysticus kochi* (Thomisidae) is common and widespread both in natural and agricultural lands in Europe (Nyffeler and Breene, 1990; Jedlickova, 1988). It occurs in low vegetation and at ground level. *X. kochi* becomes adult in spring (Jedlickova, 1988), which agrees with present results. This species is reported as a predator of Colorado potato beetles (*Leptinotarsa decemlineata*) (Gusev & Sorokin, 1976) and cereal leaf beetles (*Oulema spp.*) (Szabolcs & Horváth, 1991). The crab spiders are generally typical "sit-and-wait" predators, and only the males are active when searching for females. This could explain the high proportion of males in the pitfall trap catches. The chemical treatments and different habitats have limited negative effect on this species, probably because of the high moving activity of males.

The second species, *Pardosa agrestis* (Lycosidae) occurs very generally in Europe, especially in heliophil and xerophil sites, in agricultural areas (Nyffeler & Breene, 1992; Tóth et al., 1996). This species was reported as an important predator of the cereal aphid, *Rhopalosiphum padi* (Nyffeler & Benz, 1982; Mansour & Heimbach, 1993). However, the major components in the spider's diet are springtails and dipterans (Nyffeler & Benz, 1988). Wolf spiders are active wanderers at ground level, which is why high number of juveniles were caught by the pitfall traps. In the edge of the orchard, where no pesticide applications were used, significantly more *P. agrestis* were found. This agrees with laboratory studies of the effect of pesticide residues on *P. agrestis* (Mansour et al., 1992). Another possible explanation is that in these studies *P. agrestis* always showed preference for those habitats where the weed density was higher.

Not much is known about the other species *Titanoeca schineri* (Titanoecidae), which is a cribellate spider living under stones and logs, amongst leaf-litter and in low vegetation. It matures in spring and the males are more active than the females or the juveniles. The chemical treatments did not affect this species. However, *T. schineri* seemed to more abundant in tree rows, where the weed density was higher.

To summarise, it can be concluded that there were no differences between the effects of pest management systems on epigeic spider communities. However, the abundance of ground-dwelling spider communities could be enhanced by increasing the ground cower density in the orchards.

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Chapter 7

Clubionid Spiders (Araneae: Clubionidae) as Biological Control Agents in Apple and Pear Orchards*

Abstract. Prey acceptance and prey consumption experiments were performed with dominant orchard inhabiting clubionid spiders (*Clubiona pallidula* Clerck and *Clubiona phragmitis* C.L. Koch). Considerable predation was found on larvae of leafrollers (Tortricidae) (with a daily predation rate of 2.3±0.9 (mean ± SD) larvae/spider) and on pear suckers (*Cacopsylla spp.*) (with a daily predation rate of 11.7±1.8 (mean ± SD) adults/spider) in autumn at 15 °C. A low feeding rate at 5 °C to simulate winter conditions would have indicated that winter feeding had only a minor effect on pest reduction, but in early spring predation rapidly increased. The foraging behaviour of spiders was monitored using a video camera and it was observed that the two sac spider species are nocturnal and active only for the first half of the night. The spiders spent the daytime in a sac-like chamber made of silk. The population size of clubionid spiders was estimated by the mark-recapture method (using a double-release protocol) to be 60.000 individuals per hectare in an untreated apple orchard. Potential daily food consumption was estimated with a model based on egestion and digestion characteristics and ranged between 3.3 mg at 10 °C to 5.7 mg at 20 °C. This indicated a potential daily killing rate of 3-6 small (L_1-L_3) caterpillars of leafrollers, depending on temperature.

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7.1 Introduction

Clubionid spiders (Clubionidae) are typical foliage-dwelling wandering spiders, which are rapid runners for short-distances with poor eyesight. They forage at night without making a web. They are generally occurring and widespread in Europe (Roberst, 1995) including agro-ecosystems (Bogya & Mols, 1996). Many authors have reported that members of this family occur in orchards (reviewed by Bogya & Mols, 1996).

One of the most important and widely distributed species of this family is *Cheiracanthium mildei* L. Koch. This spider preys upon a wide a range of insect pests in several crops. In orchards it preys on the spotted tentiform leafminer (*Phyllonorycter blancardella* F.) in Canada (Corrigan & Bennett, 1987) and in Israel on codling moth (*Cydia pomonella* L.), red and two spotted spider mites (*Tetranychus cinnabarinus* Boisduval and T. *urticae* Koch), Mediterranean fruit fly (*Ceratitis capitata* Wied.), aphids (Aphididae) and leopard moth (*Zeuzera pyrina* L.) (Mansour et al., 1980a), on Egyptian cotton leafworm (*Spodoptera littoralis* Boisduval) (Mansour et al., 1977; 1980b,c,d) and the giant-looper (*Boarmia* (*Ascotis*) *selenaria* Denis et Schiffermuller) (Wysoki & Izhar, 1980). In addition to predation there is a "disturbing effect" when young caterpillars are disloged by foraging spiders and are unable to walk back may be (Mansour et al., 1981). This is sometimes much more important than predation itself (Nakasuji et al., 1973a,b). Young spiders have a lower predation rate and a higher "disturbing effect" than mature spiders (Mansour, et al., 1981). *Ch. mildei* can shows Holling II functional (Mansour et al., 1980b) and aggregational numerical (Corrigan & Bennett, 1987; and see Chapter 5 too) responses to prey density.

Another *Cheiracanthium* species (*Ch. lawrencei* Roewer) was reported as a predator of the citrus psylla (*Trioza erytreae* Del Guercio) in South Africa (Berg et al., 1992). Members of the *Clubiona* genus (*Cl. johnsoni* Gentseh and *Cl. moesta* Banks) were also recorded as predators of the mites *Tetranychus urticae* and *Panonychus ulmi* in apple orchards in Canada (Parent, 1967). An unidentified *Clubiona* species was seen actively preying upon hairy-caterpillars of the noctuids, *Euproctis lunata* Wlk. and *Porthesia scintillans* Wlk. on damaged leaves and fruits of *Zizyphus jujuba* L. in India (Battu, 1990).

Mansour & Whitcomb (1986) and Mansour (1987) performed experiments to evaluate the predatory role of spiders, mainly clubionids, in different ecosystems (citrus and cotton). After removing spiders, the pests (*Ceroplastes floridensis* Comstock, Hom.: Coccidae on citrus and *Spodoptera littoralis*, Lep.: Noctuidae on cotton) caused significantly more damage compared to the control. In apple orchards treated with non-selective insecticides the number of individuals belonging to the family Clubionidae was strongly reduced (25%) when compared with the control (Olszak et al., 1992). These spiders can potentially play a major role in orchards as nocturnal predators of lepidopteran pests (Marc, 1993; Bogya & Mols, 1996; Marc & Canard, 1997).

Some species of clubionids are winter-active, have no diapause and are able to move, feed and even reproduce during winter (Schaeffer, 1977; Aitchison in Nentwig, 1987). They can feed at temperatures as show as -5°C and they forage mainly on springtails and dipterans. At the same time of year, winter-active wolf and crab spiders prey on aphids, leafhoppers, bugs, orthopterans, lepidopterans and coleopterans (Aitchison, 1984). Information about suppression of overwintering pests in orchards by winter-active clubionid spiders is lacking.

The population size of wolf spiders was earlier estimated with a mark-recapture method in a paddy field (Kawahara & Kiritani, 1975) and in agricultural fields (Samu & Sárospataki, 1995; Samu & Kiss, 1997), and for fishing spiders in a pond (Zimmermann & Spence, 1992). Such a method has not yet been used to estimate the population density of clubionid spiders.

To quantify the role of clubionid spiders in orchards, information is needed on their searching and feeding behaviour. Until now the role of these spiders in orchards has only been evaluated qualitatively (see above). We wanted to investigate whether it is possible to get more insight into the feeding potential of these predators by using the method that was successfully used to measure the potential food intake of the carabid beetle *Pterostichus coerulescens* L. (Mols, 1988).

Factors that influence the feeding behaviour of predators can be divided into intrinsic and extrinsic factors. The intrinsic factors, originating from the physiological state of the predator, comprise the 'motivation' of the animal. This 'motivational' state may be the result of the states of different organs like the filling of the gut, the size of the ovaries, the fat body and the concentration of carbohydrates and amino acids in the haemolymph. The rates of change of these internal states are influenced by extrinsic factors such as food quality, temperature, day length (inducing reproductive activity or diapause) and sometimes humidity (Mols, 1988).

This paper mainly focuses on (i) the acceptance of different prey species; (ii) the role of clubionid spiders as predators of orchard pests especially in winter and spring; (iii) the size of the spider population in untreated apple orchards and finally (iv) the amount of prey that can be potentially ingested by clubionid spiders.

7.2 Material and methods

The spiders were collected at the experimental orchard "De Schuilenburg" and 10 other commercial apple orchards in The Netherlands by means of treebands (corrugated cardboard bands) in 1993-94. After capture they were stored in an outdoor insectary and fed twice a week until the start of the experiments with young (L_1-L_3) caterpillars of the leafroller *Adoxophyes orana* originating from a laboratory rearing (t=20 °C, R.H. = ±70-75%). Subadult spiders (1-2 moultings before adult) were used for all experiments. At the start of the experiments subadult spiders could not be identified. Therefore, similar sized and coloured spiders were selected. The spiders were identified when they had reached adulthood after the experiments.

All feeding experiments were done in the same way in the laboratory. Moist filter paper was used as a substrate to prevent desiccation (R.H. = ±95%). Then, one spider individual and *ad libitum* prey items were placed in a Petri dish (d = 9 cm). The experiments were carried out in climate rooms at constant temperatures. The day length was set at 18/6 (L:D). Before the experiments the spiders were starved for a week at the experimental temperatures.

Prey acceptance. The experiments were carried out at a constant temperature of 15 °C and 5 spiders were used in each experiment. Several pest species and beneficial organisms (such as larvae of leafrollers (L_2 instar), various species of apple-inhabiting aphids (adult apterous form), woolly apple aphids (adult), apple blossom weevils (adult), pear suckers (adult), ladybirds (adult), staphylinid beetles (adult), lacewings (adult), and larvae of hoverflies) were tested to determine their acceptability to clubionids.

Activity of spiders. The walking activity of clubionid spiders was investigated during winter and spring 1993-94 by using treebands. Twenty treebands (60 x 10 cm) were placed around the trunk of apple trees and fixed with wire. The bands were collected and investigated weekly. Each week, bands were placed in new trees. The experiment was performed from the beginning of October util the end of April on cultivar 'Jonagold'. During this period the daily maximum and minimum temperature were also recorded.

Feeding of spiders. During winter and early spring the spiders were fed (in a way described earlier in this section) at a constant temperature of 15 °C. The winter-feeding was also investigated at a low temperature (5 °C). The day-length was set at 12/12 (L:D).

Foraging behaviour. Foraging behaviour was investigated by video camera in an temperature uncontrolled chamber containing 20 spiders. Observations were made for 24 hours by time-lapse recording. The day-length was set at 14/10 (L:D). The temperature in the chamber varied between 19-21 °C, and was measured by thermograph. Night observations were made by placing a ring of IR LED's between the camera and the spiders.

Population estimation. The size of spider populations was estimated in an untreated plot of the apple orchard by a mark-recapture method, using a double release protocol in April-May, 1994. The distance between trees in the plot was 3 x 1.25 m, (= 2667 trees per ha). Spiders were collected from 100 trees with 700 treebands from the plot (7 treebands/tree). Out of the 700, 400 treebands were small (15 x 5 cm) and placed around the shoots, 200 were medium-sized (30 x 10 cm) and were placed around branches and 100 were large (60 x 10 cm) and placed around the trunk. The bands were collected after one week and the spiders were removed and marked. Marking was done by cutting the tarsus and the metatarsus of the second right leg of the spiders. Hundred spiders were released at foliage in a block of 100 trees (one spider/tree) at sunset. During the following day the 700 treebands were replaced in the same way. One week later the bands were collected and the number of marked spiders counted. The experiment was repeated by releasing the spiders with marks on the second left leg. A week later, the bands were collected again and the number of marked spiders collected was counted.

Population estimates, and their variance, were calculated by using Lincoln Index, modified for low recapture rate by Bailey (1952):

$$N = [n(a+1)/r]-1 \qquad \text{var } N = [(a-r+1)(a+1)n(n-r)]/r^2(r+1)$$

Where N: estimate of the number of individuals in the population
a: total number of released individuals
n: total number captured individuals
r: recaptured, marked individuals

Food intake. To enable estimating of daily potential consumption at variable field temperatures, the ingestion, gut emptying and respiration rate of these spiders were measured at a range of constant temperatures.

Food contents of the gut is reduced by assimilation of food into the haemolymph and by defaecation, can be described in general by an exponential decay function (Fransz, 1974; Mols, 1988). The general equation of this process is:

$$A_1 = A_0 \, e^{-rt}$$

Where A_0 and A_1 are the food contents of the gut before and after the time period 't', respectively. The relative rate of gut emptying 'r' is independent of the amount of food in the gut and mainly determined by temperature and food quality. By using the same type of food, the food quality can be assumed to be the same for all the spiders. Knowing the assimilation efficiency, the relative rate of gut emptying can be derived by measuring the decline in weight after satiation, which is the combined result of faeces excretion (FP), respiration (RESPIR) and sometimes dehydration. When the gut is empty the decline in weight equals the weight loss caused by respiration, because, from that moment onwards the predator stops producing faecal pellets. The amount of food assimilated is the weight gain of the spider at the moment that the weight loss after feeding equals the respiration rate plus the weight used for respiration during the starvation after feeding (Mols, 1988).
In Fig. 1. the process of ingestion and egestion is shown.

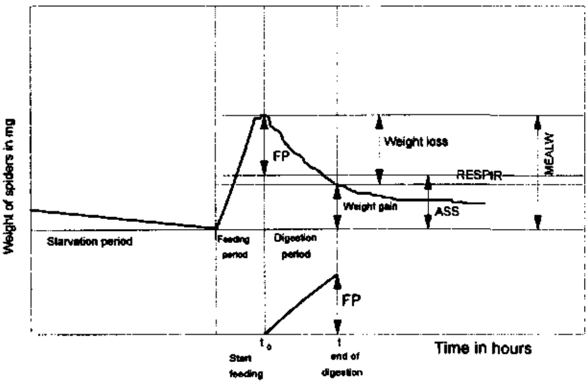

Fig.1. A schematic representation of the changes in weight of the spiders caused by digestion and faeces production during and after ingestion of a prey (after Mols, 1993)
FP: faecal production (quantity of faeces produced)
ASS: assimilation (quantity of food assimilated from the gut into the haemolymph)
MEALW: meal weight (quantity of food ingested)

The assimilation efficiency (EFF) is defined as:
EFF=ASS / MEALW
FP=weight loss - RESPIR
ASS=weight gain + RESPIR
MEALW=FP + ASS
The daily potential food intake was investigated by a gravimetric method in a laboratory experiment with 20 spiders at 10 °C and with 15 spiders at 15 °C and is at 20 °C. The spiders were starved for a week at the experimental temperature. The weight of spiders was measured using a microbalance before and after the starvation period. They were placed into a gelatin capsule and weighed. The weight of the capsule was subtracted. After starvation each spider was given 6 L_2-instar caterpillars of *Adoxophyes orana* and was allowed to feed for 2 hours in the dark. After the feeding period the remaining food was removed and the predators were weighed again. Firstly the weighing was repeated twice with an interval of 1.5 hours and subsequently with two hours intervals resulting in a total of seven weighings during the first day. The following day two additional measurements were made. For each temperature the experiment was repeated three times with the same animals. The few specimens have been moulted during the experiment were not included in the calculations.

7.3 Results and Discussion

From Dutch apple orchards a total of 529 identifiable clubionid spider individuals belonging to 8 species were collected. Ninety percent of the individuals belonged to the two species, *Clubiona pallidula* Clerck (295 indiv.) and *Clubiona phragmitis* C. L. Koch (170 indiv.). The other species were: *Clubiona lutescens* Westring (33 indiv.), *Clubiona reclusa* O.P. Cambridge (14 indiv.), *Clubiona stagnatilis* Kulczynski (9 indiv.), *Clubiona comta* C.L. Koch (4 indiv.), *Clubiona terrestris* Westring (3 indiv.) and *Clubiona neglecta* O.P. Cambridge (1 indiv.).

Prey acceptance. Considerable daily predation was observed in the case of larvae of leafrollers (Tortricidae) (2.3±0.9) (mean ± SD) and pear suckers (*Cacopsylla spp.*) (11.6±1.8) (mean ± SD), while moderate predation was observed on aphids (*Rhopalosiphum incertum*) (2.3±0.8) (mean ± SD). The apple blossom weevil (*Anthonomus pomorum*) and the woolly apple aphid (*Eriosoma lanigerum*) were not accepted by clubionid spiders. None of the four species of beneficial insects (*Propylea quatordecimpunctata* L.; *Tachyporus hypnorum* Fabr.; *Chrysoperla carnea* Stephens s.l.; larvae of hoverflies) investigated were accepted.

Activity of spiders. During autumn, winter and spring a total of 221 sac spiders were collected by the treebands. The activity of the population (expressed as the number of spiders collected in treebands) was highest in late autumn. A strong correlation was found between the activity of spiders and the daily minimum temperature in winter (Fig. 2). Regression analysis indicated that the threshold temperature for spider activity is 1.5 °C (R^2=0.87).

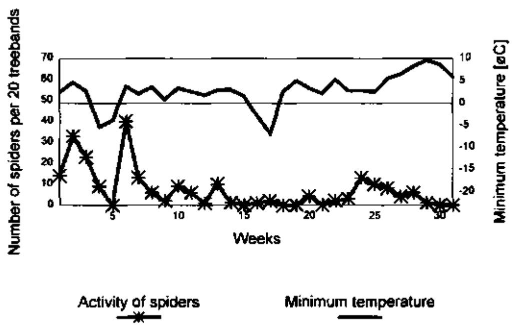

Fig.2. Activity of spiders in relation to temperature, 04.11.1993 – 02.06.1994 (31 weeks)
(De Schuilenburg, 1993-94)

Feeding of spiders. During the course of winter and spring, feeding experiments showed that the daily predation rate strongly decreased in the winter months, but rapidly increased again in February (Fig. 3). The low feeding rate in winter months at low temperature indicates that winter-feeding will be of minor importance for prey reduction, but that feeding in early spring becomes important (Fig. 4). The results lead to the conclusion that winter-active spiders such as clubionids can be important in the suppression of overwintering pests such as larvae of leafrollers in early spring, when most of the other natural enemies are still inactive.

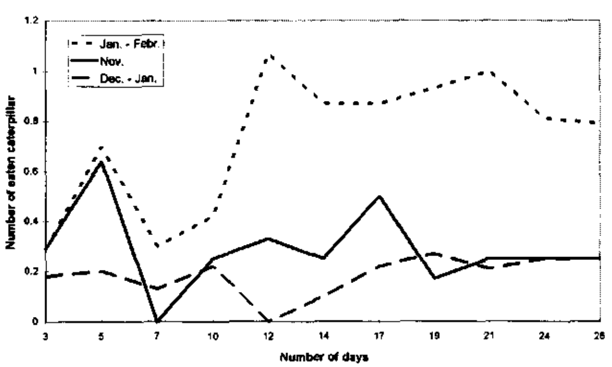

Fig.3. Feeding activity of *Clubiona pallidula* in the course of winter in the laboratory at 15 °C
(De Schuilenburg, 1993-94)

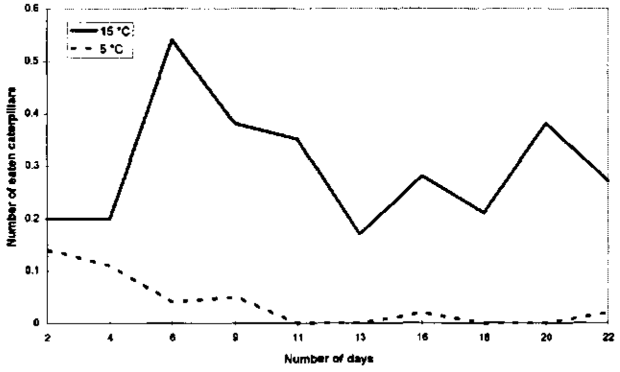

Fig.4. Winter-feeding of clubionid spiders at different temperatures in the laboratory
(De Schuilenburg, 1993-94)

Hunting behaviour. According to the observations by video camera the daily predation rate in spring (May) was 4.6±0.7 SD L_2 instar caterpillars. The spiders were active only in the first half of the dark period. The spiders spent the daytime in a sac-like chamber made of silk. The time taken to consume one caterpillar was 50±30 SD minutes (N= 78). The reaction distance at which the predator reacts to the prey was measured and found to be 7±3 mm (N= 69).

Population estimation. For the first release 100 spiders were collected, marked and released. The second sample contained 93 captured individuals, out of which 4 were marked. For the second release the 93 captured individuals were marked and re-released, and in the second sample, 3 out of 68 were marked.

	released (a)	captured (n)	recaptured (r)	spiders/tree (N)	SD
1st release	100 spiders	93 spiders	4 spiders	23	10
2nd release	93 spiders	68 spiders	3 spiders	21	10
Average				22	10

The results led to the conclusion that there were 22±10 clubionid spider individuals on one apple tree, which is equivalent to about 60.000 spiders per ha.

Food intake. The general pattern of change in weight of spiders is shown in Fig. 5. It starts with a decrease caused by respiration and digestion when the spiders come from storage conditions. Thereafter, an increase of weight caused by ingestion was followed by a steep decrease, caused mainly by gut emptying. This is repeated three times in sequence.

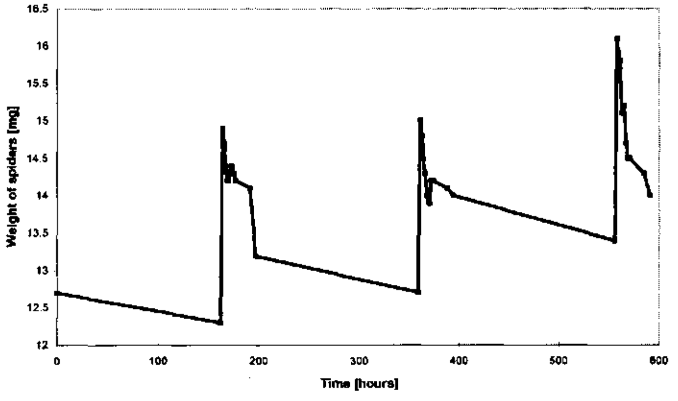

Fig.5. Change in weight of spiders caused by ingestion, egestion and respiration, for three replicates in sequence (De Schuilenburg, 1993-94)

The digestion characteristics for the two spider species are given in Table 1.

	Clubiona pallidula			*Clubiona phragmitis*		
	Average	Standard error	N	Average	Standard error	N
10 °C						
RESPIR	0.096	0.0093	32	0.072	0.012	13
RRGE	1.93	0.114	26	1.98	0.169	8
ASS%	29.4	5.7	17	33	3.6	8
Meal size	2.39	0.15	34	2.2	0.251	15
15 °C						
RESPIR	0.11	0.0085	26	0.11	0.022	11
RRGE	2.33	0.067	17	2.2	0.063	6
ASS%	31.6	3.8	12	32.6	4.6	5
Meal size	2.52	0.18	26	2.47	0.375	10
20 °C						
RESPIR	0.168	0.001	21	0.144	0.001	11
RRGE	3.77	0.232	18	2.69	0.197	9
ASS%	37.4	4.2	13	44	9.3	5
Meal size	2.66	0.36	20	2.49	0.302	11

Table 1. The measured and calculated digestion characteristics of the two clubionid spider species

The decrease does not follow a smooth exponential decay but shows some fluctuations. This can be explained by the drinking behaviour of the spiders. In the first two experiments it was difficult to keep humidity at such a high level that dehydration was prevented. Adding water during the observation resulted in drinking by some of the spiders causing a sudden increase of body weight. In the last experiment the Petri dishes with the spiders were incubated at a controlled humidity regime above a salt solution and this prevented drinking behaviour. This made calculation of egestion parameters easier and more reliable.

Respiration. Weight loss caused by respiration was measured over the starvation periods (Fig. 6.). Respiration increases significantly with temperature. At 10 and 15 °C the respiration values for the two species do not differ significantly, but at 20 °C a significant difference is observed.

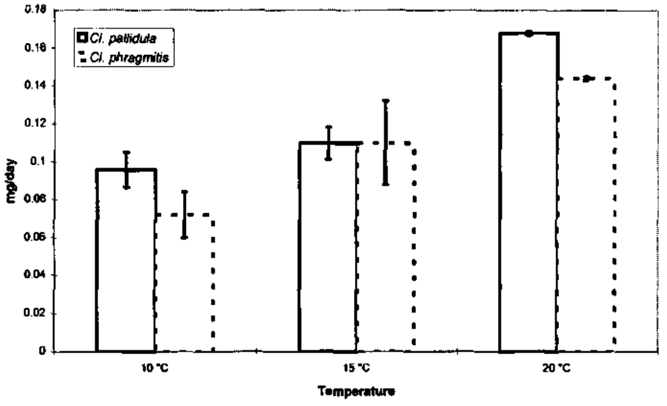

Fig.6. Respiration rate (±SE) of clubionid spiders at different constant temperatures (De Schuilenburg, 1993-94)

Meal size. The meal size (MEALW) of the two clubionid species did not differ significantly (Student's t-test, $P<0.05$) for all temperatures (Fig. 7.). Meal size was approximately 2.5 mg. Weight increase was sometimes influenced by drinking behaviour, but spiders that drank were not included in the analysis.

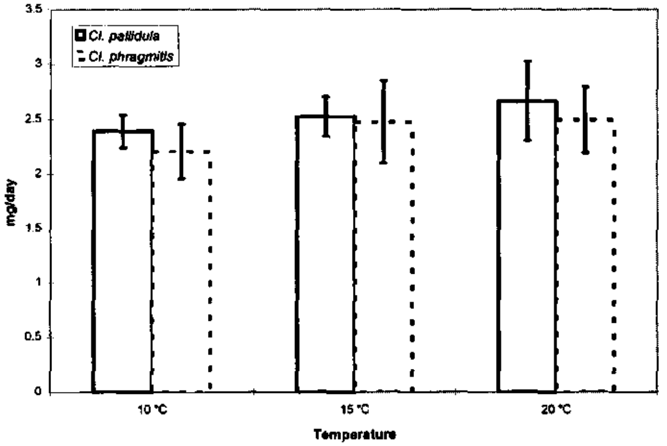

Fig.7. The meal size (±SE) of clubionid spiders at different constant temperatures (De Schuilenburg, 1993-94)

Assimilation. For both species assimilation efficiency shows a large variation and a tendency to increase with temperature, but this tendency is not significant (Fig. 8.). Average assimilation efficiency (EFF) is approximately 35%.

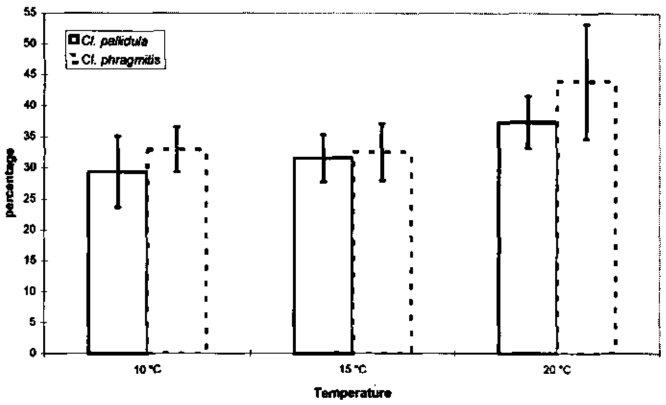

Fig.8. Assimilation efficiency (±SE) of clubionid spiders at different constant temperatures
(De Schuilenburg, 1993-94)

Relative rate of gut emptying. For the two spider species relative rate of gut emptying (RRGE) shows a positive relationship with temperature (Fig. 9.). In *Clubiona phragmitis* the relationship is weak, but the species *C. pallidula* shows a strong positive relationship with temperature.

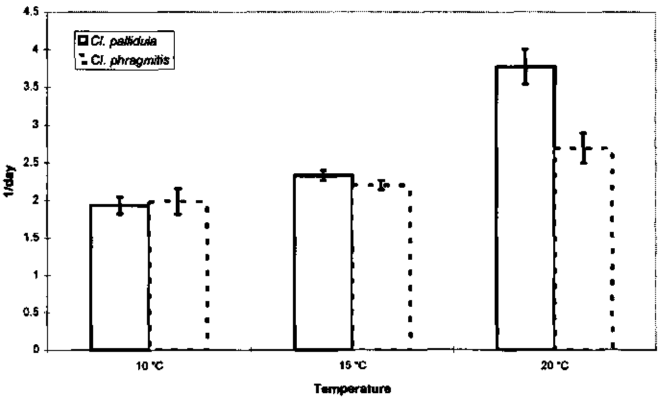

Fig.9. Relative rate of gut emptying (±SE) of clubionid spiders at different constant temperatures
(De Schuilenburg, 1993-94)

A problem for the proper calculation of weight loss characteristics was caused by the drinking behaviour of the spiders. Drinking resulted in fluctuations in weight. This is probably a normal behaviour of this type of spider because they have a thin cuticle and therefore are sensitive to desiccation. It makes the use of gravimetric methods for assessing respiration and RRGE rather cumbersome. Although humidity fluctuations occurred, they could be damped partly by putting the spiders under very high humidity. The general process of gut emptying could be described by an exponential decay. A similar process was found in the cockroaches *Periplaneta americana* L. (Davey & Treherne, 1963) and *Leucophaea maderae* Jam. (Engelmann, 1968), the blowfly *Phorbia regina* L. (Gelperin, 1966), the preying mantis *Hierodula crassa* F. (Holling, 1966), the predatory mites *Amblyseius potentillae* Chant (Rabbinge, 1976), *Phytoseiulus persimilis* Athias-Henriot (Sabelis, 1981) and the wolf spider *Lycosa pseudoannulata* Clerck (Nakamura, 1968). The value that Nakamura (1972) obtained for RRGE in *Pardosa laura* was 5.46/day at 25 °C. This is higher than the present results, but the temperature was also higher. In the carabid beetle *Pterostichus coerulescens* L. the RRGE depends both on reproductive state, temperature and diel rhythm (Mols, 1988). In reproductive beetles the average RRGE ranged from 0.7/day at 12 °C to 3.3/day at 27 °C. In non-reproductive beetles the values were half of these. The values for the Clubionidae are higher than for carabid beetles, but these spiders are active at low temperatures. For *P. coerulescens* the threshold of activity is 8 °C while clubionids are walking at temperatures above 1.5 °C and even feed around 0 °C.

The size of meal needed to satiate these spiders offers a good estimate of gut capacity. A meal weight of 2.5 mg is about 20 % of the fresh body weight of these clubionids. For the wolf spider *L. pseudoannulata* the equivalent figure is about 34% of the body weight (Nakamura, 1968).

The respiration or metabolic rate is generally estimated by oxygen consumption or carbon dioxide production. As we assessed respiration by fresh weight it is difficult to compare the present result to those in the literature. Fresh weight loss measured in the spider *Lycosa lenta* Hentz was 0.0055 mg/mg body weight/day (Anderson, 1974). As the clubionids have an average weight of about 12.5 mg the respiration was calculated to be 0.0052 mg/mg body weight/day, which is similar to the value for *Lycosa lenta*. Other arthropods, such as the mantis *Paratenodera angustipennin*, may show values that are two to three times higher (Matsura, 1981). Respiration depends also on the duration of the starvation period. Spiders are able to reduce respiration and thus survive long periods without food (Anderson, 1974).

At 20 °C carabids of about 40-60 mg utilize about 0.6 mg fresh weight per day, which isequivalent to 0.012 mg/mg body weight/day (Mols, 1988). This value is twice as high as found for the clubionid spiders. Assimilation efficiency of spiders is lower than carabids (average of about 35% for spiders and 50% for carabids), because spiders ingest only liquid food containing more water.

Potential food consumption can be calculated with help of a computer model (Mols, 1993) using ingestion and egestion parameters, gut capacity and a feeding threshold. The feeding threshold is the percentage of gut already occupied by food, which was determined by measuring the time interval between prey captures. By using the formula for gut emptying, the threshold appeared to be between 80-90% which compares with 40% for a carabid (Mols, 1988). Estimated daily food consumption rates for the two species are given in Table 2. The two spider species can consume about the same amount of food each day, varying between 3.3 mg at 10 °C and 5.7 mg at 20 °C.

Temperature	*Cl. pallidula*	*Cl. phragmitis*
	consumption	consumption
10 °C	3.3	3.4
15 °C	4.0	3.6
20 °C	5.7	5.0

Table 2. Estimated daily potential food consumption (mg) by the two clubionid spider species, using RRGE, meal size (2.5 mg), ingestion rate (2.5 mg/h) and an ingestion threshold of 85%

One L_2 caterpillar of the leafroller, *Adoxophyes orana*, weighs about 2 (± 0.2 SD) mg (N =100). If the spiders ingest only liquid food, half of it will be consumed. This indicates a potential daily killing rate of 3-6 small caterpillars, depending on temperature. This agrees rather well with preliminary observations done in the laboratory. Only the small L_1-L_3 stages of leafroller caterpillars were accepted by the spiders. Helsen & Blommers (1989) investigated the mortality of leafrollers in an apple orchard during the larval development and found that 80% of the caterpillars died before the 4th instar. Several factors may have been responsible for this mortality and spiders could play an important part of it.

The density of spiders was estimated to be approximately 22±10 clubionids/tree and this number may be important in reduction of leafrollers in orchards. As a consequence of the surplus in the density comparing with the 1-2 leafrollers/tree found by Helsen & Blommers (1989), the spiders have a choise to switch from one prey to another. These estimates only indicate potential food consumption and whether this potential will be realized will depend on prey density and searching efficiency. Nevertheless, the high abundance and predatory capacity of these spiders suggest that clubionids can be important in reduction of orchard pests.

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Chapter 8

Summarizing Discussion

8.1 Study approach

Spiders are occurring very generally in all terrestrial ecosystems including agro-ecosystems. Besides being abundant, their constant presence and their polyphagous feeding behaviour makes this group of arthropods important natural enemies of agricultural pests (Riechert & Lockley, 1984). However, little is known about the role that spiders can play in agro-ecosystems, particularly in orchards and their role is probably undervalued.

In case of orchard ecosystems, spiders are abundant and prey on a wide range of pests in outside of Europe (Dondale, 1956; 1958; 1966; Dondale et al., 1979; Hagley, 1974; Legner & Oatman, 1964; McCaffrey & Horsburg, 1978; 1980). Mansour and his colleagues concluded that spiders could be good candidates for natural control in orchards (Mansour et al., 1980a; b; 1985; Mansour & Whitecomb, 1986; Mansour, 1993). At the same time, little is known about their role in European orchards (Chant, 1956; Klein, 1988; Sengonca & Klein, 1988). Besides some faunistic work by Loomans (1978) and Angeli et al. (1996), Langeslag (1978) and Olszak et al. (1992) investigated the spider communities in apple orchards under different regimes of pesticides, resulting in the conclusion that the spider densities are strongly influenced by pesticide application. Investigations on the role of spiders in agriculture have recently been started in Hungary and for orchards only few data are available (Samu & Lôvei, 1995; Samu et al., 1997).

This thesis provides the basic ecological background of spiders as polyphagous predators in orchards for integrated pest management. The fundamental aims of this thesis were (1) to summarise the knowledge about the role of spiders as predators in orchards, (2) to assess the spider fauna of apple and pear orchards in Hungary and (3) to describe the effect of regional differences and the different management systems on the complexity of spider communities in orchards. Attention was also paid (4) to synzoological studies of the spider fauna occurring in the different strata (canopy, herbaceous-layer, and ground level) of the orchards and (5) to the relationship between the different habitats within the orchard and between the orchard and its surroundings. Further, the thesis provides more insight (6) in the potential role of a particular group of spiders (Clubionidae) in natural control of orchards.

In short, the thesis describes the basic *structure* of spider communities in different orchards and it gives information on the *function* of some spider species in natural pest control.

8.2 Research findings

Review of the arachnological investigations in agriculture with particular reference to orchards

Two earlier reviews were performed to summarise the knowledge about spiders as biocontrol agents (Riechert & Lockley, 1984; Nyffeler & Benz, 1987). Knowledge in this field expanded enormously in the last decade, especially with regard to the behaviour of spiders in different agro-ecosystems. The present knowledge stresses the idea that the role of spiders in agro-ecosystems is undervalued. In addition, particularly in orchard ecosystems the data are controversial. Spiders are a very heterogeneous group of animals with different hunting tactics and therefore, they play different ecological roles. At family level these tactics are rather similar, thus properties and behaviour found in different species of one family can be seen as characteristic for the whole family. Furthermore, one species of the group can be used as representative example for ecological studies for the whole family. A comprehensive review of about 500 papers on the subject appeared in the last 70 years was prepared with particular reference to the prey spectrum of the different spider families and the effect of chemical treatments on the spider communities. In addition, the predatory potential of spiders is discussed and related to orchard ecosystems (Bogya & Mols, 1996).

Faunistic assessment of spider communities in orchards

The species composition of spider communities in European apple and pear orchards were investigated by several authors (Loomans, 1978; Klein, 1988; Olszak et al., 1992; Angeli et al., 1996). They found that a small number of spider species are superdominant in the canopy of orchards. These are *Theridion varians* and *Araniella opistographa* in the Netherlands; *Philodromus cespitum* and *Araniella opistographa* in Germany; *Araniella cucurbitina* and *Theridion varians* in Poland and *Philodromus cespitum*, *Dictyna pusilla* and *P. albidus* in Italy (Loomans, 1978; Klein, 1988; Olszak et al., 1992; Angeli et al., 1996, respectively). However, this information is limited as only the spider fauna of one orchard was considered, or if more orchards were involved it did not give a comprehensive description of the spider community. Other layers such as the herbaceous-layer or the ground level rarely have been investigated. The species *Oedothorax fuscus* is dominant at the ground level of an apple orchard in the Netherlands (Loomans, 1978). In the Hungarian Apple Ecosystem Research, the spiders have not yet been identified (Mészáros et al., 1984) and in pear orchards there were no faunistic investigation until now.

In the present work altogether 165 species and a further 9 taxa were identified from the 20283 individuals collected, belonging to 21 families of spiders in Hungarian apple and pear orchards.

One hundred and three species belonging to 16 families and 64 genera were found in the canopy of apple trees, while 70 species belonging to 13 families and 50 genera were found in the canopy of pear trees. The most widespread species in decreasing order were: *Philodromus cespitum*, *Theridion impressum*, *Theridion pinastri*, *Oxyopes heterophthalmus*, *Araniella opistographa*.

Fifty-seven species belonging to 13 families and 41 genera were found in the bark traps. The most common species were: *Philodromus* (*aureolus*), *Xysticus spp*., *Drassodes spp*. *Theridion pinastri*, *Clubiona spp*. The species composition was similar to both the canopy and the herbaceous-layer, which indicates a close relationship between the canopy and the herbaceous-layer through the entire vegetative period. Besides some facultative bark-living species, typical ground-dwelling spiders as Lycosidae, Gnaphosidae and Agelenidae occurred frequently on the trunk of the trees.

Forty-six species belonging to 14 families and 32 genera were found overwintering in the corrugated paper belt traps. The most widely occurring species in decreasing order were: *Clubiona spp*., *Cheiracanthium mildei*, *Philodromus* (*aureolus*), *Philodromus* (*margaritatus*), *Misumenops tricuspidatus*. Few of them, mainly clubionid species (*Clubiona phragmitis*, *Cl. genevensis*, *Cl. pseudoneglecta*) and the *Segestria bavarica*, *Lathys humilis* were found only with this method.

In the herbaceous-layer of the apple orchards there were 66 species belonging to 15 families and 47 genera, while in case of pear orchards 43 species belonging to 12 families and 38 genera were found. The most widespread species in the herbaceous-layer were: *Xysticus spp*., *Oxyopes heterophthalmus*, *Pisaura mirabilis*, *Mangora acalypha*, *Araneus diadematus*.

Forty species belonging to 12 families and 26 genera were found at the ground level. The most frequently occurred species were *Xysticus kochi*, *Titanoeca schineri*, *Pardosa agrestis*, *Alopecosa sulzeri*, *Harpactea rubicunda*.

This investigation took place in one orchard only and is thus not a comprehensive description of the general epigeic spider fauna of Hungarian orchards. A previous faunistic study in Hungary reported 17 additional species that were not found by us (Samu & Lôvei, 1995). A comparison of the spider communities of each strata lead to the conclusion that the similarity between the canopy and the herbaceous-layer is rather high (more than 50%), while the ground level is separated from both the canopy and the herbaceous-layer (similarity of 3% and 8%, respectively).

Regional differences of spider communities at different geographical scales

The most important apple and pear pests are widespread and common throughout the growing areas, but the density of these herbivores can be different depending on the surroundings of the orchards. Little is known about the spatial distribution of their natural enemies. If the spider fauna of orchards situated in different growing regions differs significantly, than there are possibilities to develop different prey-predator systems, thus knowledge about the regional differences can be important in the design of regional IPM programs.

The composition of spider communities inhabiting pome fruit orchards was investigated at different geographical scales (Holarctic, European, inter- and intra-regional levels within Hungary). Besides the present study, previous faunistic data were used also. The family composition of canopy spider communities of apple orchards at Holarctic level was determined by latitudes, the genus composition by the main zoogeographical regions. At a European level both the genus and species composition changed along a North-South gradient. At interregional level (between growing regions in Hungary), both the foliage- and grass-dwelling spider communities showed considerable differences in species composition and dominance order in apple and pear orchards. However, the regional differences in the herbaceous-layer were smaller than in the canopy. At intraregional level (within growing regions in Hungary), in case of differently treated apple and pear orchards both the foliage and the herbaceous layer inhabiting spider communities showed moderate differences. Although the spider communities inhabiting the canopy and the herbaceous layer differed unambiguously, the overlaps were still significant.

The results lead to the conclusion that the organisation of spider communities is basically determined by geographical locations. Both, the pesticide treatments and the different prey densities, can significantly influence the densities of spiders, but their effects on the composition of spider communities is limited. The scale-specific differences can be essential in the development of pest-spider systems in orchards and also in the design of integrated pest management programs for apple and pear.

Composition of spider communities in differently treated apple orchards

Applying integrated pest management in orchards by using reduced insecticide and acaricide regimes, theoretically provides possibilities for establishment of spider communities that are higher in abundance. However, the few existing studies (Olszak et al., 1992; Samu et al., 1997) did not give a proper answer to the effect of IPM on spiders communities. In this research project:

a) a) No significant differences were found between the conventional and IPM plots in species richness and composition, density and diversity of epigeic spider communities.

Greater spider densities were observed in the treerows where the weed coverage was higher than in the alleys where mechanical weed control kept the weed density lower. However, community structures did not differ significantly. Near the edge of the orchard, the density and species richness of epigeic spiders were higher and the community structure differed slightly from that of the orchard habitats, but the overlap was still significant.

b) The broad-spectrum insecticides reduced the abundance and the species richness of the spider communities in the herbaceous-layer of the conventionally treated plot compared with the IPM plot. The density and the species richness of spider communities did, however, not differ between the IPM plot and the edge of the orchards.

c) Similar results were obtained in the canopy. The abundance and the species richness of the entire spider communities in the IPM plots were significantly higher than in the conventional plots, probably caused by the lower toxicity of pesticides used and the higher prey density. A similar tendency of abundance was observed in both guilds of web-building and hunting spiders. At the same time, the species diversity indices did not show differences. A considerable boundary effect was found only in the IPM plot. Both the species richness and the density of spider communities were higher in the edge rows than in the centre of the orchards, suggesting that immigration of spiders into the orchards is significant. This effect was not observed when broad-spectrum insecticides were applied.

d) Besides the chemical treatments, the age of the plantations can also significantly influence the spider density in the canopy through the prey density. In the young orchards, where the size of the canopy was smaller, but the density of the pear lace bug (*Stephanitis pyri*) higher, significantly more complex and abundant hunting spider communities developed than in the same treated old plantations. A similar aggregational numerical response was not observed in the guild of web-builders. The diversity of the canopy inhabiting spider communities regardless of the treatments was higher in the old plots.

e) According to the investigations in 10 different orchards situated in 5 markedly different growing regions, the differences in spider communities between the canopy and the herbaceous-layer were prominent, but the overlap between those two habitats is still considerable. According to the detailed investigations performed in the conventional and IPM plots, the similarity between the canopy and the herbaceous-layer, both in the species composition and in the presence of dominant species, is significant. At the same time, the epigeic spider communities differ from these two strata.

Based on the results of experiments with integrated pest management, there are possibilities to develop spider communities higher in abundance and species richness. Undesirable effects of broad-spectrum insecticides on spiders were found for the canopy and to a lesser extent for the herbaceous-layer, but not at the ground level. Despite the different treatments, the communities are composed similarly.

Studies on the dominant species occurring in orchards

In the synzoological investigations numerous data related to the frequently occurring species about the seasonal occurrence, habitat preference, and insecticide tolerance became available. Little is known about the autecological characteristics of most of the species occurring in apple and pear orchards.

The Mediterranean species, *Cheiracanthium mildei* (Clubionidae) has recently been introduced in Hungary (Szinetár, 1992). It frequently occurs in the canopy of apple trees in the Lowland area of Hungary, where the soil is sandy and therefore easily warms up. This species is a key predator in orchards in Israel (Mansour, 1980a), because it is capable to locate prey items and shows functional (Mansour, 1980b) and numerical responses (Corrigan

& Bennett, 1987) to prey density. This may also make it an important spider species in the suppression of orchard pests in Hungary. Besides *Ch. mildei* another 12 species (*Theridion impressum*; *Araniella opistographa*; *Clubiona pallidula*; *Philodromus cespitum*; *Misumenops tricuspidatus*; *Xysticus ulmi*; *Xysticus lanio*; *Ballus chalybeius*; *Carrhotus xanthogramma*; *Eris nidicolens*; *Salticus zebraneus*; *Heliophanus spp.*) can be considered as potentially important polyphagous predators in orchards.

Some species (*Ch. mildei*; *Clubiona pallidula*) occur only in the canopy of the orchards, and can, therefore, be easily eliminated by pesticide treatments. Others (e.g. *Misumenops tricuspidatus*, *Philodromus cespitum*, *Xysticus spp.*) can be found in several strata and can easily recolonize after pesticide applications. From studies in treated and untreated orchards it can also be concluded that some species (e.g. the majority of the family Theridiidae) occur only in untreated orchards, while others (*Philodromus cespitum*; *Misumenops tricuspidatus*; *Salticus zebraneus*) can occur in various orchards regardless the treatments.

Functional studies on the dominant clubionid spiders (Clubionidae) occurring in orchards

Clubionid spiders can play an important role in controlling orchard pests (Mansour et al., 1980a; b; 1985; Mansour & Whitecomb, 1986; Mansour, 1993). Autecological investigations were carried out with three clubionid species: *Clubiona pallidula* and *Clubiona phragmitis* (these are common in orchards in The Netherlands) and with *Cheiracanthium mildei* (which frequently occurs in apple orchards in the Lowland of Hungary, where the soil is sandy).

The results lead to the conclusion that the winter-feeding is of minor importance because of low temperatures, but in early spring predation will become significant. The winter-active clubionid spiders can be important factors in the suppression of overwintering pests like larvae (L_2-L_3 stage) of leafrollers (Tortricidae) especially by feeding in early spring when most of the other natural enemies are still inactive. In case of *Cl. pallidula* and *Cl. phragmitis* considerable predation was found on larvae of leafrollers and on pear suckers (*Cacopsylla spp.*) in the laboratory. *Ch. mildei* preyed on the pear lace bug (*Stephanitis pyri*) in the laboratory and showed a strong correlation with the infested trees in the field.

The size of the population of clubionid spiders was estimated to be 60.000 individuals per hectare (22 per tree) in an untreated apple orchard by mark-recapture method.

To quantify the role of clubionid spiders as predators in orchards, information is needed on the potential food intake of the predator. This can be estimated by using digestion and egestion characteristics. The capacity of the gut, relative rate of gut emptying, the rates of assimilation and respiration were measured and estimated for the species *Cl. pallidula* and *Cl. phragmitis* at three different constant temperatures by a gravimetric method. There were slight differences between the two species. The capacity of the gut was 2.5 mg, the relative rate of gut emptying was 1.9-3.7/day, assimilation efficiency was 35% and the rate of respiration was 0.07-0.17 mg/day depending on the temperature. The potential daily food consumption was estimated with a simple computer model and ranged between 3.3 mg at 10 °C to 5.7 mg at 20 °C, which indicates a potential daily killing rate of 3-6 small (L_1-L_3) caterpillars of leafrollers depending on temperature.

8.3 Implementation of orchard IPM

The current orchard IPM programs are based on the presence of certain natural enemies and on the availability of selective chemicals. The improvement of natural and biological control is essential in IPM systems (Blommers, 1994). Since the amount of acaricides used against phytophagous mites is considerably reduced, it provides possibilities for the related group of spiders to establish more complex communities at higher densities, which can contribute to the suppression of orchard pests.

Pesticide effect on spiders

Considering the pesticide treatments, the basic structure of the spider communities are the same in the differently treated plots, only the abundance is lower when broad-spectrum chemicals were applied (Chapter 5). In the course of the vegetative period two population peaks of canopy spiders can be seen in spring and in autumn. Therefore the application of dormant sprays in spring (Jenser et al., 1997) and the preharvest sprayings in autumn can considerably affect the spiders. This should be avoided in the design of IPM programs. The application of the acaricide amitraz (Mitac) - widely used also against pear psyllids in IPM orchards - should be prevented due to the harmful effect on spiders (Jenser et al., 1997).

Spider species for natural control

Spider species occurring in orchards in high abundance and candidates for natural control are: (*Philodromus (cespitum) spp.*; *Theridion (impressum, varians) spp.*; *Araniella (cucurbitina-opistographa) spp.*; *Clubiona (pallidula, phragmitis) spp.*; *Xysticus (ulmi, lanio, kochi) spp.*; *Salticus (zebraneus) spp. Misumenops tricuspidatus*). These species can contribute to the suppression of orchard pests in Europe.

The role of the regionality

Knowledge about the regional spider fauna can be essential for the improvement of the local IPM programs due to the considerable differences between regions in species composition and dominance order of spider communities. An example is the yellow sac spider (*Cheiracanthium mildei*) which can occur in high densities only in the orchards with sandy soil in the Lowland of Hungary. This characteristic species of this region should be taken into account as potential biocontrol agent in orchard IPM.

Augmentation of spiders for natural control in orchards

The main factors influencing the composition of spider communities in orchards are the relationship between the canopy and the herbaceous-layer, the higher weed density, the border effect and the positive numerical response of spiders to prey density. The close relationship between the canopy and the herbaceous-layer emphasised that adding more herbs would increase the spider densities both in the herbaceous-layer and in the canopy (Altieri & Schmidt, 1986; Wyss, 1995; Wyss et al., 1995). The pesticide-free adjacent vegetation can be an important source for recolonization after chemical treatments (Olszak et al., 1992), but the immigration of spiders into the orchards is significant only if integrated pest management is applied. Many spiders can hibernate under the loose bark of alder trees (*Alnus glutinosa* (L.) Gaertn), which form the hedge around the orchards (Bogya, 1995). This can contribute to augmentation of the spiders in orchards. Spiders, especially the hunting spiders (e.g. Clubionidae) show a positive numerical response to prey density (Corrigan & Bennett, 1987). An increased pest density and the available non-pest preys as alternative food source can augment also the number of spiders in orchard IPM systems, but in untreated orchards the number of spiders are still more abundant (Jenser et al., 1997).

The most promising group of spiders (Clubionidae) for natural control in orchards

Clubionid spiders, especially the winter-active species (*Clubiona pallidula* and *Clubiona phragmitis*), can play an important role in the suppression of overwintering pests like larvae of leafrollers (Tortricidae) in early spring when other natural enemies are still inactive.

In the natural control of the pear lace bug (*Stephanitis pyri*) as resurged pest of apple and pear orchards, the role of the yellow sac spider (*Cheiracanthium mildei*) in the orchards with sandy soil in Hungary can be important in the second half of the vegetation period.

The pear suckers (*Cacopsylla spp.*) are the key pests of pear. In the natural control of pear suckers some wandering spiders (Clubionidae, Thomisidae, Philodromidae, Salticidae) can be important in the first half of the vegetative period in relation to the pesticide regime applied (Jenser et al., 1997).

The data provided in this thesis indicate that the role of spiders as natural control agents in orchards can be augmented. In orchards where Integrated Pest Management is applied, and where the use of broad-spectrum pesticides is minimized, an excellent possibility is available to develop more complex and abundant spider communities, which can contribute to a better suppression of pests.

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APPENDICES

Appendix A

Table 1. Agelenidae as predators of pests occurring in other ecosystems

Spiders	Common name	Scientific name	Taxon	Crops	Authors	Countries	Daily consumption
Agelena limbata Thorel	black pine bast scale	Matsucoccus thunbergianae Miller & Park	Hom.: Margarodidae	pine forest	Kim, 1993	Korea	
"	fall webworm	Hyphantria cunea Drury	Lep.: Arctiidae	-	Kunimi, 1983	Japan	
"	"	"	Lep.: Arctiidae	-	Kayashima, 1967	Japan	
Agelena opulenta L.	"	"	Lep.: Arctiidae	mulberry	Brignoli, 1983	Japan	
indet. Agelenidae	planthoppers	Magicicada spp.	Hom.: Cicadellidae	-	Smith et al., 1987	USA	

Table 2. Anyphaenidae as predators of pests occurring in other ecosystems

Spiders	Common name	Scientific name	Taxon	Crops	Authors	Countries	Daily consumption
Anyphaena pacifica Banks	Douglas-fir tussock moth	Orgyia pseudotsugata McDunnough	Lep.: Limantriidae	pine forest	Swezey et al., 1991	USA	
"	"	"	Lep.: Limantriidae	pine forest	Mason & Torgersen, 1983	USA	
"	white fir sawfly	Neodiprion abietis Harris	Hym.: Diprionidae	pine forest	Swezey et al., 1991	USA	
Aysha gracilis Hentz	cotton aphid	Aphis gossypii Glov.	Hom.: Aphididae	cotton	Whitecomb et al., 1963	USA	
"	cotton fleahopper	Pseudatomoscellis seriatus Reuter	Hem.: Miridae	cotton	Kagan, 1943	USA	
"	"	"	Hem.: Miridae	woolly croton	Breene et al., 1988	USA	
"	cotton leafworm	Alabama argillacea Hubner	Lep.: Noctuidae	cotton	Gravena & Sterling, 1983	USA	
"	tobacco budworm	Heliothis virescens F.	Lep.: Noctuidae	cotton	McDaniel et al., 1981	USA	
"	fall webworm	Hyphantria cunea Drury	Lep.: Arctiidae	-	Warren et al., 1967	USA	
Aysha velox Becker	sugarcane rootstalk borer	Diaprepes abbreviatus L.	Col.: Curculionidae	citrus	Richman et al., 1983	USA	

Appendix A

Table 3. Araneidae as predators of pests occurring in other ecosystems

Spiders	Common name	Scientific name	Taxon	Crops	Authors	Countries	Daily consumption
Araneus bituberculatus Walckenaer	fall webworm	Hyphantria cunea Drury	Lep.: Arctiidae	Morus alba L.	Groppali et al., 1993	Italy	
Araneus cucurbitinus Clerck	buckthorn - potato aphid	Aphis nasturtii Kalt.	Hom.: Aphididae	potato	Galecka, 1966	Poland	
Araneus diadematus Clerck	cherry blackfly	Myzus cerasi F.	Hom.: Aphididae	-	Nyffeler, 1983	Switzerland	
"		Myzus lythri Schr.	Hom.: Aphididae	-	Nyffeler, 1983	Switzerland	
"	Bird cherry - Oat aphid	Rhopalosiphum padi L.	Hom.: Aphididae	-	Nyffeler, 1983	Switzerland	
"	"	"	Hom.: Aphididae	grassland	Nyffeler & Benz, 1982	Switzerland	
"	thistle aphid	Brachycaudus cardui L.	Hom.: Aphididae	-	Nyffeler, 1983	Switzerland	
"	mealy cabbige aphid	Brevicoryne brassicae L.	Hom.: Aphididae	-	Nyffeler, 1983	Switzerland	
"	black bean aphid	Aphis fabae Scop.	Hom.: Aphididae	grassland	Nyffeler & Benz, 1982	Switzerland	
"	ceanothus leafminer	Tischeria immaculata Braun	Lep.: Tischeridae	Ceanothus griseus Yankee Point	Fasoranti, 1984	USA	
"	pine moth	Dendrolimus pini L.	Lep.: Lasiocampidae	pine forest	Csoka et al., 1989	Hungary	
Araneus quadratus Clerck	orthopterans		Orthoptera	meadows	Kajak et al., 1968	Poland	
"	"		Orthoptera	meadows	Nyffeler & Breene, 1991	Switzerland	
"	Bird cherry - Oat aphid	Rhopalosiphum padi L.	Hom.: Aphididae	grassland	Nyffeler & Benz, 1982	Switzerland	
"	black bean aphid	Aphis fabae Scop.	Hom.: Aphididae	grassland	Nyffeler & Benz, 1982	Switzerland	
"	green peach aphid	Myzus persicae Sulz.	Hom.: Aphididae	grassland	Nyffeler & Benz, 1982	Switzerland	
Araneus sclopetarius Clerck	red cotton bug	Dysdercus cingulatus F.	Hem.: Pyrrhocoridae	cotton	Battu, 1990	India	
"	spotted bollworm	Earias vitella F.	Lep.: Noctuidae	cotton	Battu, 1990	India	

"	spiny bollworm	Earias insulana Boisd.	Lep.: Noctuidae	cotton	Battu, 1990	India	
Araneus sinhagadensis Tikader	mango jassid	Idioscopus clypealis Lethierry	Hom.: Cicadellidae	mango	Tandon & Lal, 1983	India	
"	spotted stalk borer	Chilo partellus Swinhoe	Lep.: Pyralidae	Maize and sorghum	Sharma & Sarup, 1979	India	
"	"	"	Lep.: Pyralidae	Maize and sorghum	Singh & Sandhu, 1976	India	
"	mango shoot borer	Chlumetia transversa Wlk.	Lep.: Noctuidae	mango	Tandon & Lal, 1983	India	
Araneus sp.	spotted stalk borer	Chilo partellus Swinhoe	Lep.: Pyralidae	Maize and sorghum	Mohan, 1991	India	
"	"	"	Lep.: Pyralidae	Maize and sorghum	Sharma & Sarup, 1979	India	
"	"	"	Lep.: Pyralidae	Maize and sorghum	Singh et al., 1975	India	
"	"	"	Lep.: Pyralidae	Maize and sorghum	Singh & Sandhu, 1976	India	
"	rice leaffolder	Cnaphalocrocis medinalis Guenee	Lep.: Pyralidae	rice	Mun, 1982	Malaysia	
"	gypsy moth	Lymantria dispar L.	Lep.: Lymantriidae	forest	Schaefer et al., 1984	China	
"		Cletus signatus Walker	Hem.: Coreidae	-	Agarwal & Dhiman, 1989	India	
Argiope aemula Walckenaer	rice leaffolder	Cnaphalocrocis medinalis Guenee	Lep.: Pyralidae	rice	Barrion et al., 1979	Philippine	
Argiope argentata Fabricius	rice brown planthopper	Nilaparvata lugens Stal.	Hom.: Delphacidae	rice	Bastidas et al., 1994	Colombia	4.1
Argiope bruennichi Scopoli	slugs	Agriolimax sp.	Mollusca: Limacidae	-	Quicke, 1987	France	
"	Bird cherry - Oat aphid	Rhopalosiphum padi L.	Hom.: Aphididae	grassland	Nyffeler & Benz, 1982	Switzerland	
"	mealy plum aphid	Hyalopterus pruni Geoffr.	Hom.: Aphididae	grassland	Nyffeler & Benz, 1982	Switzerland	
Argiope catenulata Doleschall	white-backed planthopper	Sogatella furcifera Horvath	Hom.: Delphacidae	rice	Kamal & Dyck, 1994	Bangladesh	1-2
Argiope pulchella Thorell	rice brown planthopper	Nilaparvata lugens Stal.	Hom.: Delphacidae	rice	Rao et al., 1978a	India	
"	"	"	Hom.: Delphacidae	rice	Rao et al., 1978b	India	16
Argiope sp.	small rice grasshopper	Oxya nitidula W.	Orth.: Acrididae	rice	Mohan & Manoharan, 1987	India	2
"	sugarcane stalk borer	Eldana saccharina Walker	Lep.: Pyralidae	sugarcane	Leslie & Boreham, 1981	South Africa	
"	sorghum mite	Oligonychus indicus	Acarina:	maize	Manjunatha, 1989	India	

		Hirst	Tetranychidae				
Cyclosa insulana Costa	spotted stalk borer	Chilo partellus Swinhoe	Lep.: Pyralidae	Maize and sorghum	Sharma & Sarup, 1979	India	
Cyrtophora sp.	sugarcane leaf hopper	Pyrilla perpusilla Walker	Hom.: Lophopidae	sugarcane	Miah, 1986	Bangladesh	
Neosconia arabesca Walckenaer	velvet bean caterpillar	Anticarsia gemmatalis Hubner	Lep.: Noctuidae	soybean	Gregory et al., 1989	USA	
"	cotton leafworm	Alabama argillacea Hubner	Lep.: Noctuidae	cotton	Gravena & Sterling, 1983	USA	
"	Douglas-fir tussock moth	Orgyia pseudotsugata McDunnough	Lep.: Lymantriidae	pine forest	Mason & Torgersen, 1983	USA	
Neoscona nautica L. Koch	rose aphid	Macrosiphum rose L.	Hom.: Aphididae	rose	Raychaudhuri et al., 1979	India	
Neosconia theisi Walckenaer	hibiscus jassid	Amrasca biguttula biguttula Shir.	Hom.: Cicadellidae	hibiscus	Rao et al., 1981	India	
Neosconia sp.	spotted stalk borer	Chilo partellus Swinhoe	Lep.: Pyralidae	Maize and sorghum	Mohan, 1991	India	

Appendix A

Table 4. Clubionidae as predators of pests occurring in other ecosystems

Spiders	Common name	Scientific name	Taxon	Crops	Authors	Countries	Daily consumption
Cheiracanthium danieli Tikader	mango jassid	Idioscopus clypealis Lethierry	Hom.: Cicadellidae	mango	Tandon & Lal, 1983	India	
"	tobacco cutworm	Spodoptera litura F.	Lep.: Noctuidae	tobacco	Sitaramaiah et al., 1980	India	
"	"	"	Lep.: Noctuidae	-	Rao et al., 1993	India	
Cheiracanthium diversum L. Koch	noctuids	Heliothis spp.	Lep.: Noctuidae	cotton	Bishop & Blood, 1981	USA	
"	American bollworm	Heliothis armigera Hubner	Lep.: Noctuidae	-	Room, 1979	Australia	
"		Heliothis punctigera Wallengren	Lep.: Noctuidae	-	Room, 1979	Australia	
Cheiracanthium inclusum Hentz	velvetbean caterpillar	Anticarsia gemmatalis Hubner	Lep.: Noctuidae	soybean	Buschman et al., 1977	USA	
"	"	"	Lep.: Noctuidae	soybean	O' Neil & Stimac, 1988	USA	

"	soybean looper	Pseudoplusia includens Walker	Lep.: Noctuidae	soybean	Richman et al., 1980	USA	9.16 eggs
"	cotton leafworm	Alabama argillacea Hubner	Lep.: Noctuidae	cotton	Gravena & Sterling, 1983		
"	tobacco budworm	Heliothis virescens F.	Lep.: Noctuidae	cotton	McDaniel et al., 1981	USA	
"	fall webworm	Hyphantria cunea Drury	Lep.: Arctiidae	-	Warren et al., 1967		
Cheiracanthium melanostomum Thorell	hibiscus jassid	Amrasca biguttula biguttula Shir.	Hom.: Cicadellidae	hibiscus	Rao et al., 1981	India	
Cheiracanthium *mildei* L. Koch	sycamore lace bug	Corythucha ciliata Say	Hem.: Tingidae	Platanus sp.	Balarin & Polonec, 1984	Yugoslavia	8.2
"	fall webworm	Hyphantria cunea Drury	Lep.: Arctiidae	Morus alba L.	Groppali et al., 1993	Italy	
"	carmine spider mite	Tetranychus cinnabarinus Boisduval	Acarina: Tetranychidae	-	Mansour et al., 1995	Israel	27.5
Cheiracanthium sp.	coconut black headed caterpillar	Opisina arenosella Wlk.	Lep.: Xyloryctidae	coconut	Sathiamma et al., 1987	India	
"	spotted stalk borer	Chilo partellus Swinhoe	Lep.: Pyralidae	sorghum and maize	Mohan, 1991	India	2.84-3.04
"	"	"	Lep.: Pyralidae	sorghum and maize	Sharma & Sarup, 1979	India	
"	"	"	Lep.: Pyralidae	sorghum and maize	Singh et al., 1975	India	
"	sorghum mite	Oligonychus indicus Hirst.	Acarina: Tetranychidae	sorghum	Manjunatha, 1989	India	
Clubiona abottii L. Koch	bean butterfly	Lampides boeticus L.	Lep.: Lycaenidae	leguminosae	Singh & Mavi, 1984	India	
Clubiona drassodes	sugarcane leafhopper	Pyrilla perpusilla Walker	Hom.: Lophopiidae	sugarcane	Dhaliwal & Bains, 1983	India	
Clubiona japonicola Boes. et Str.	white-backed planthopper	Sogatella furcifera Horvath	Hom.: Delphacidae	rice	Wu et al., 1990	China	
"	brown planthopper	Nilaparvata lugens Stal.	Hom.: Delphacidae	rice	Wu et al., 1993	China	
"	green leaf bug	Lygocoris *lucorum* Meyer	Hem.: Miridae	cotton	Cao, 1986	China	
"		Adelphocoris suturalis Jakovlev	Hem.: Miridae	cotton	Cao, 1986	China	
Clubiona pickei	corn leaf aphid	Rhopalosiphum maidis Fitch	Hom.: Aphididae	cereals	Provencher & Coderre,	Canada	

Gertsh					1987		
"	Bird cherry - Oat aphid	Rhopalosiphum padi L.	Hom.: Aphididae	cereals	Provencher & Coderre, 1987	Canada	
Clubiona saraswatii Tikader	spotted stalk borer	Chilo partellus Swinhoe	Lep.: Pyralidae	sorghum and maize	Singh et al., 1975	India	
Clubiona sp.	grain aphid	Sitobion avenae F.	Hom.: Aphididae	wheat and barley	Bhagat et al., 1990	India	
"	spotted stalk borer	Chilo partellus Swinhoe	Lep.: Pyralidae	sorghum and maize	Mohan, 1991	India	
"	"	"	Lep.: Pyralidae	sorghum and maize	Singh et al., 1975	India	
"	rice leaffolder	Cnaphalocrocis medinalis Guenee	Lep.: Pyralidae	rice	Mun, 1982	Malaysia	
"	fall webworm	Hyphantria cunea Drury	Lep.: Arctiidae	-	Sharov et al., 1984	USSR	
"	tobacco cutworm	Spodoptera litura F.	Lep.: Noctuidae	tobacco	Sitaramaiah et al., 1980	India	

Appendix A

Table 5. Dictynidae as predators of pests occurring in other ecosystems

Spiders	Common name	Scientific name	Taxon	Crops	Authors	Countries	Daily consumption
Dictyna felis Boes. & Str.	corn leaf aphid	Rhopalosiphum maidis Fitch	Hom.: Aphididae	cereals	Cong, 1992	China	
Dictyna flavescens Walck.	oleander scale	Aspidiotus nerii Bouche	Hom.: Diaspididae	-	Schmutterer, 1953	Germany	
"	soft brown scale	Coccus hesperidum L.	Hom.: Coccidae	-	Schmutterer, 1953	Germany	
Dictyna foliicola Boes. & Str.	fall webworm	Hyphantria cunea Drury	Lep.: Arctiidae	-	Kayashima, 1967	Japan	
Dictyna pusilla Thorell	"	"	Lep.: Arctiidae	Acer negundo L.	Groppali et al., 1994	Italy	
"	"	"	Lep.: Arctiidae	Morus alba L.	Groppali et al., 1993	Italy	
Dictyna volucripes Keyserling	guar bud midge	Contarinia texana Felt	Dip.: Cecydomiidae	guar	Rogers & Horner, 1977	USA	

Appendix A

Table 6. Linyphiidae as predators of pests occurring in other ecosystems

Spiders	Common name	Scientific name	Taxon	Crops	Authors	Countries	Daily consumption
Erigone atra Blackwall	cereal aphids	Rhopalosiphum sp.	Hom.: Aphididae	winter wheat	Janssens et al., 1990	Belgium	
"	grain aphid	Sitobion avenae F.	Hom.: Aphididae	cereals	Sopp et al., 1992	Great Britain	
"	buckthorn - potato aphid	Aphis nasturtii Kalt.	Hom.: Aphididae	potato	Galecka, 1966	Poland	
Erigonidium graminicolum Sund.	cotton aphid	Aphis gossypii Glov.	Hom.: Aphididae	cotton	Dong & Xu, 1984	China	
"	"	"	Hom.: Aphididae	cotton	Mao & Xia, 1983	China	
"	"	"	Hom.: Aphididae	cotton	Zhang, 1985	China	48
"	"	"	Hom.: Aphididae	cotton	Zhang, 1992	China	
"	"	"	Hom.: Aphididae	cotton	Zhou & Xiang, 1987	China	42.8
"	brown planthopper	Nilaparvata lugens Stal.	Hom.: Delphacidae	rice	Cheng, 1989	China	4.2-7.8
"	"	"	Hom.: Delphacidae	rice	Yan & Wu, 1989	China	
"	green leaf bug	Lygocoris lucorum Meyer	Hem.: Miridae	cotton	Cao, 1986	China	
"		Adelphocoris suturalis Jakovlev	Hem.: Miridae	cotton	Cao, 1986	China	
"	American bollworm	Heliothis armigera Hubner	Lep.: Noctuidae	cotton	Dong & Xu, 1984	China	
"	"	"	Lep.: Noctuidae	cotton	Wu et al., 1981	China	
Frontinella communis Hentz	European pine shoot moth	Rhyacionia buoliana Schiff.	Lep.: Olethreutidae	pine forest	Pointing, 1966	Canada	
Linyphia triangularis Clerck	green oak tortrix	Tortrix viridana L.	Lep.: Tortricidae	oak forest	Joly, 1956	Germany	
Oedothorax apicatus Blackwall	cereal aphids	Rhopalosiphum sp.	Hom.: Aphididae	winter wheat	Janssens et al., 1990	Belgium	
Oedothorax insecticeps Boesenberg & Strand	green rice leafhopper	Nephotettix cinctipes Uhler	Hom.: Cicadellidae	rice	Kang & Kiritani, 1978	Japan	
"	"	"	Hom.: Cicadellidae	rice	Nyffeler et al., 1994b	USA	
"	"	"	Hom.: Cicadellidae	rice	Chang & Oka, 1984	Taiwan	

"	zigzag leafhopper	Recilia dorsalis Motsch.	Hom.: Cicadellidae	rice	Chang & Oka, 1984	Taiwan	
"	brown planthopper	Nilaparvata lugens Stal.	Hom.: Delphacidae	rice	Kang & Kiritani, 1978	Japan	
"	"	"	Hom.: Delphacidae	rice	Nyffeler et al., 1994b	USA	
"	"	"	Hom.: Delphacidae	rice	Cheng, 1989	China	4.2-7.8
"	"	"	Hom.: Delphacidae	rice	Lin & Liu, 1984	Taiwan	
"	"	"	Hom.: Delphacidae	rice	Chen & Chiu, 1979	Taiwan	
"	"	"	Hom.: Delphacidae	rice	Chen & Chiu, 1981	Taiwan	
"	"	"	Hom.: Delphacidae	rice	Chang & Oka, 1984	Taiwan	
"	"	"	Hom.: Delphacidae	rice	Chiu & Chen, 1981	Taiwan	
"	white-backed planthopper	Sogatella furcifera Horvath	Hom.: Delphacidae	rice	Chang & Oka, 1984	Taiwan	
"	"	"	Hom.: Delphacidae	rice	Wu et al., 1990	China	
"	tobacco cutworm	Spodoptera litura F.	Lep.: Noctuidae	taro	Nakasuji et al., 1973a	Japan	
"	"	"	Lep.: Noctuidae	taro	Yamanaka et al., 1972	Japan	
Oedothorax formosana	brown planthopper	Nilaparvata lugens Stal.	Hom.: Delphacidae	rice	Heong et al., 1992	Philippine	
"	white-backed planthopper	Sogatella furcifera Horvath	Hom.: Delphacidae	rice	Heong et al., 1992	Philippine	
Troxochrus nasutus Schenkel	bark beetle	Hylurgops palliatus Gylh.	Col.: Scolytidae	forest	Moor & Nyffeler, 1983	Switzerland	
"	bark beetle	Pityogenes chalcographus L.	Col.: Scolytidae	forest	Moor & Nyffeler, 1983	Switzerland	
indet. Linyphiidae	grain aphid	Sitobion avenae F.	Hom.: Aphididae	cereals	Carter et al., 1982	Great Britain	
"	Southwestern corn borer	Diatraea grandiosella	Lep.: Pyralidae	corn	Knutson & Gilstrap, 1989	USA	

Appendix A

Table 7. Lycosidae as predators of pests occurring in other ecosystems

Spiders	Common name	Scientific name	Taxon	Crops	Authors	Countries	Daily consumption
Hippasa holmerae Thorell	white-backed planthopper	Sogatella furcifera Horvath	Hom.: Delphacidae	rice	Barrion & Litsinger, 1981	Philippine	
"	brown planthopper	Nilaparvata lugens Stal.	Hom.: Delphacidae	rice	Barrion & Litsinger, 1981	Philippine	
"	hibiscus jassid	Amrasca biguttula biguttula Shir.	Hom.: Cicadellidae	leguminosae	Barrion & Litsinger, 1981	Philippine	
"	stem fly	Ophiomyia phaseoli Tryon	Dip.: Agromyzidae	leguminosae	Barrion & Litsinger, 1981	Philippine	
Lycosa antelucana Montgomery	tarnished plant bug	Lygus lineolaris Palisot de Beauvois	Hem.: Miridae	cotton	Hayes & Lockley, 1990	USA	
"	tobacco budworm	Heliothis virescens F.	Lep.: Noctuidae	cotton	Hayes & Lockley, 1990	USA	
Lycosa chaperi Simon	brown planthopper	Nilaparvata lugens Stal.	Hom.: Delphacidae	rice	Samal & Misra, 1985	India	
Lycosa helluo Walckenaer	tarnished plant bug	Lygus lineolaris Palisot de Beauvois	Hem.: Miridae	cotton	Hayes & Lockley, 1990	USA	
"	maize armyworm	Pseudaletia unipunctata Haworth	Lep.: Noctuidae	maize	Clark et al., 1994	USA	
"	tobacco budworm	Heliothis virescens F.	Lep.: Noctuidae	cotton	Hayes & Lockley, 1990	USA	
Lycosa pseudoannulata Boesenberg & Strand	rice leaffolder	Cnaphalocrocis medinalis Guenee	Lep.: Pyralidae	rice	Joshi et al., 1987	Philippine	
"	"	"	Lep.: Pyralidae	rice	Pang et al., 1988	China	
"	"	"	Lep.: Pyralidae	rice	Tang et al., 1987	China	
"	white-backed planthopper	Sogatella furcifera Horvath	Hom.: Delphacidae	rice	Kamal & Dyck, 1994	Bangladesh	1-2
"	"	"	Hom.: Delphacidae	rice	Zhou, 1986	China	
"	"	"	Hom.: Delphacidae	rice	Nakamura, 1977	Japan	
"	"	"	Hom.: Delphacidae	rice	Kaushik et al., 1986	India	
"	"	"	Hom.: Delphacidae	rice	Salim & Heinrichs	Philippine	
"	"	"	Hom.: Delphacidae	rice	Salim & Heinrichs, 1986	Philippin	5.9

						e	
"	"	"	Hom.: Delphacidae	rice	Cruz & Litsinger, 1986	Philippin e	
"	"	"	Hom.: Delphacidae	rice	Chang & Oka, 1984	Taiwan	
"	"	"	Hom.: Delphacidae	rice	Heong et al., 1992	Philippin e	
"	"	"	Hom.: Delphacidae	rice	Heinrichs et al., 1984	Philippin e	
"	brown planthopper	Nilaparvata lugens Stal.	Hom.: Delphacidae	rice	Luong, 1987	Vietnam	
"	"	"	Hom.: Delphacidae	rice	Samal & Misra, 1975	India	
"	"	"	Hom.: Delphacidae	rice	Murugesan & Chelliah, 1982	India	6
"	"	"	Hom.: Delphacidae	rice	Reissing et al., 1982	Philippin e	
"	"	"	Hom.: Delphacidae	rice	Gavarra & Raros, 1973	Philippin e	
"	"	"	Hom.: Delphacidae	rice	Thang et al., 1987	Philippin e	
"	"	"	Hom.: Delphacidae	rice	Thang et al., 1988	Philippin e	
"	"	"	Hom.: Delphacidae	rice	Kaushik et al., 1986	India	
"	"	"	Hom.: Delphacidae	rice	Cruz & Litsinger, 1986	Philippin e	
"	"	"	Hom.: Delphacidae	rice	Kuno & Dick, 1984	Philippin e	
"	"	"	Hom.: Delphacidae	rice	Heong et al., 1991	Philippin e	
"	"	"	Hom.: Delphacidae	rice	Sawada et al., 1993	Indonesia	
"	"	"	Hom.: Delphacidae	rice	Chen & Chiu, 1979	Taiwan	
"	"	"	Hom.: Delphacidae	rice	Chen & Chiu, 1981	Taiwan	
"	"	"	Hom.: Delphacidae	rice	Chang & Oka, 1984	Taiwan	
"	"	"	Hom.: Delphacidae	rice	Kobayashi & Shibata, 1973	Japan	
"	"	"	Hom.: Delphacidae	rice	Sasaba et al., 1973	Japan	
"	"	"	Hom.: Delphacidae	rice	Ooi, 1988	Malaysia	
"	"	"	Hom.: Delphacidae	rice	Heong et al., 1992	Philippin e	

"	"	"	Hom.: Delphacidae	rice	Baskaran et al., 1979	India	
"	"	"	Hom.: Delphacidae	rice	Chiu & Chen, 1981	Taiwan	
"	"	"	Hom.: Delphacidae	rice	Ku & Wang, 1981	Taiwan	
"	"	"	Hom.: Delphacidae	rice	Zhou & Chen, 1986	China	
"	"	"	Hom.: Delphacidae	rice	Kartohardjono & Heinrichs, 1984	Philippine	
"	"	"	Hom.: Delphacidae	rice	Heinrichs et al., 1984	Philippine	
"	green rice leafhopper	Nephotettix cinctipes Uhler	Hom.: Cicadellidae	rice	Heong et al., 1992	Philippine	
"	"	"	Hom.: Cicadellidae	rice	Kiritani et al., 1972	Japan	
"	"	"	Hom.: Cicadellidae	rice	Kang & Kiritani, 1978	Japan	
"	"	"	Hom.: Cicadellidae	rice	Kiritani et al., 1977	Japan	
"	"	"	Hom.: Cicadellidae	rice	Suzuki & Kiritani, 1974	Japan	
"	"	"	Hom.: Cicadellidae	rice	Sasaba & Kiritani, 1974	Japan	
"	"	"	Hom.: Cicadellidae	rice	Nakamura, 1977	Japan	
"	"	"	Hom.: Cicadellidae	rice	Xie & Liu, 1992	China	
"	"	"	Hom.: Cicadellidae	rice	Chang & Oka, 1984	Taiwan	
"	green rice leafhopper	Nephotettix virescens Dist.	Hom.: Cicadellidae	rice	Barrion & Litsinger, 1984	Philippine	
"	"	"	Hom.: Cicadellidae	rice	Hsieh & Dyck, 1975	Philippine	
"	"	"	Hom.: Cicadellidae	rice	Kaushik et al., 1986	India	
"	"	"	Hom.: Cicadellidae	rice	Cruz & Litsinger, 1986	Philippine	
"	"	"	Hom.: Cicadellidae	rice	Heong et al., 1992	Philippine	
"	"	"	Hom.: Cicadellidae	rice	Myint et al., 1986	Philippine	
"	"	"	Hom.: Cicadellidae	rice	Heinrichs et al., 1984	Philippine	
"	zigzag leafhopper	Recilia dorsalis Motsch.	Hom.: Cicadellidae	rice	Chang & Oka, 1984	Taiwan	
"	rice stem borer	Chilo supressalis Walk	Lep.: Pyralidae	rice	Barrion & Litsinger, 1984	Philippine	
"	yellow stem borer	Scirpophaga incertulas Wlk.	Lep.: Pyralidae	rice	Barrion & Litsinger, 1984	Philippine	

"	"	"	Lep.: Pyralidae	rice	Rubia et al., 1990	Philippine	
"	diamond-back moth	Plutella xylostella L.	Lep.: Plutellidae	cabbige	Yamada & Yamaguchi, 1985	Japan	
"	rice gall midge	Orseolia oryzae Wood-Mason	Dip.: Cecydomiidae	rice	Barrion & Litsinger, 1984	Philippine	
Pardosa agrestis Westring	Bird cherry - Oat aphid	Rhopalosiphum padi L.	Hom.: Aphididae	cereals	Mansour & heimbach, 1993	Germany	
"	rose-grain aphid	Metopolophium dirhodum Walker	Hom.: Aphididae	cereals	Nyffeler & Benz, 1982	Switzerland	
Pardosa amentata Cl.	rose-grain aphid	Metopolophium dirhodum Walker	Hom.: Aphididae	cereals	Nyffeler & Benz, 1982	Switzerland	
Pardosa astrigera L. Koch	cotton aphid	Aphis gossypii Glov.	Hom.: Aphididae	cotton	Zhang, 1992	China	17.3
"	"	"	Hom.: Aphididae	cotton	Dong & Xu, 1984	China	
"	"	"	Hom.: Aphididae	cotton	Zhao et al., 1989	China	4-8
"	black pine bast scale	Matsucoccus thunbergianae Miller & Park	Hom.: Margarodidae	pine forest	Kim, 1993	Korea	
"	noctuids		Lep.: Noctuidae	cotton	Dong & Xu, 1984	China	
"	oriental tobacco budmoth	Helicoverpa assulta Guenee	Lep.: Noctuidae	cotton	Zhao et al., 1989	China	20-25 eggs
"	American bollworm	Heliothis armigera Hubner	Lep.: Noctuidae	cotton	Zhao et al., 1989	China	0.5-3 larvae
"	oriental corn borer	Ostrinia furnacalis Mutuura & Munroe	Lep.: Pyralidae	corn	Zhao et al., 1989	China	
"	diamond-back moth	Plutella xylostella L.	Lep.: Plutellidae	cabbige	Nemoto, 1993	Japan	
Pardosa crassipalpis Purcell	red spider mite	Tetranychus cinnabarinus Boisduval	Acarina: Tetranychidae	strawberry	Dippenar Schoeman, 1977	Pretoria	
Pardosa laura Karsch	paddy armyworm	Pseudaletia separata Walker	Lep.: Noctuidae	maize	Kanda, 1987	Japan	
Pardosa lugubris	pine needle gall midge	Thecodiplosis japonensis Uchida et Inouye	Dip.: Cecidomyiidae	pine forest	Kim & Kim, 1975	Korea	
Pardosa milvina Hentz	pink bollworm	Pectinophora gossypiella Saund.	Lep.: Noctuidae	cotton	Clark & Glick, 1961	USA	
"	diamond-back moth	Plutella xylostella L.	Lep.: Plutellidae	collard	Muckenfuss & Shepard, 1994	USA	
Pardosa monticola Cl.	cereal bug	Eurygaster integriceps Put.	Hem.: Scutelleridae	cereals	Titova & Egorova, 1978	USSR	
Pardosa palustris L.	rose-grain aphid	Metopolophium dirhodum Walker	Hom.: Aphididae	cereals	Nyffeler & Benz, 1982	Switzerland	

Pardosa pauxilla Montgomery	noctuids	Heliothis spp.	Lep.: Noctuidae	peanut	Agnew & Smith, 1989	USA	
Pardosa ramulosa McCook	aster leafhopper	Macrosteles fascifrons Stal.	Hom.: Deltocephalidae	rice	Oraze & Grigarick, 1989	USA	
"	pea aphid	Acyrthosiphon pisum Harris	Hom.: Aphididae	alfalfa	Yeargan, 1975	USA	
Pardosa tikaderi Tikader	turpod bug	Clavigralla sp.	Hem.: Coreidae	pigeonpea	Arora & Monga, 1993	India	
"	turpod fly	Melanagromyza obtusa Malloch	Dip.: Agromyzidae	pigeonpea	Arora & Monga, 1993	India	
Pardosa t-insignita Boes. & Str.	green leaf bug	Lygocoris lucorum Meyer	Hem.: Miridae	cotton	Cao, 1986	China	
"		Adelphocoris suturalis Jakovlev	Hem.: Miridae	cotton	Cao, 1986	China	
"	fall webworm	Hyphantria cunea Drury	Lep.: Arctiidae	-	Kayashima, 1967	Japan	
Pardosa sp.	velvetbean caterpillar	Anticarsia gemmatalis Hubner	Lep.: Noctuidae	soybean	Reed et al., 1984	USA	3.3
"	Colorado potato bettle	Leptinotarsa decemlineata Say	Col.: Chrysomelidae	potato	Heimpel & Hough-Goldstein, 1992	USA	
Pirata japonicus	cotton aphid	Aphis gossypii Glov.	Hom.: Aphididae	cotton	Zhou & Xiang, 1987	China	42.8
Pirata subpiraticus Boesenberg & Strand	small brown planthopper	Laodelphax striatella Fall.	Hom.: Delphacidae	rice	Okuma et al., 1978	Korea	
"	green rice leafhopper	Nephotettix cinctipes Uhler	Hom.: Cicadellidae	rice	Okuma et al., 1978	Korea	
"	brown planthopper	Nilaparvata lugens Stal.	Hom.: Delphacidae	rice	Okuma et al., 1978	Korea	
"	"	"	Hom.: Delphacidae	rice	Cheng, 1989	China	4.2-7.8
"	"	"	Hom.: Delphacidae	rice	Wu et al., 1993	China	
"	"	"	Hom.: Delphacidae	rice	Kim & Lee, 1994	Korea	17.4
"	white-backed planthopper	Sogatella furcifer Horvath	Hom.: Delphacidae	rice	Okuma et al., 1978	Korea	
"	"	"	Hom.: Delphacidae	rice	Wu et al., 1990	China	
Trochosa terricola Thorell	cereal bug	Eurygaster integriceps Put.	Hem.: Scutelleridae	cereals	Titova & Egorova, 1978	USSR	
indet. Lycosidae	green peach aphid	Myzus persicae Sulzer	Hom.: Aphididae	sugarbeet	Wratten & Pearson, 1982	New Zealand	
"	glasshouse-potato aphid	Aulacorthum solani Kaltenbach	Hom.: Aphididae	sugarbeet	Wratten & Pearson, 1982	New Zealand	
"	large sugarcane borer	Sesamia cretica Led.	Lep.: Noctuidae	sorghum	Temerak, 1978	Egypt	

Appendix A

Table 8. Oxyopidae as predators of pests occurring in other ecosystems

Spiders	Common name	Scientific name	Taxon	Crops	Authors	Countries	Daily consumption
Oxyopes badius Yaginuma	gipsy moth	Lymantria dispar L.	Lep.: Lymantriidae	pine forest	Furuta, 1977	Japan	
"	pine moth	Dendrolimus spectabilis Butler.	Lep.: Lasiocampidae	pine forest	Furuta, 1977	Japan	
Oxyopes elegans Koch	American bollworm	Heliothis armigera Hubner	Lep.: Noctuidae	-	Room, 1979	Ausztralia	
"		Heliothis punctigera Wallengren	Lep.: Noctuidae	-	Room, 1979	Ausztralia	
Oxyopes javanus Thorell	hibiscus jassid	Amrasca biguttula biguttula Shir.	Hom.: Cicadellidae	hibiscus	Rao et al., 1981	India	
"	white backed planthopper	Sogatella furcifer Horvath	Hom.: Delphacidae	rice	Kamal & Dyck, 1994	Bangladesh	2-3
"	brown planthopper	Nilaparvata lugens Stal.	Hom.: Delphacidae	rice	Sawada et al., 1993	Indonesia	
"	Malayan black bug	Scotinophara coarctata F.	Hem.: Pentatomidae	rice	Perez et al., 1989	Philippine	
"	rice leaffolder	Cnaphalocrocis medinalis Guenee	Lep.: Pyralidae	rice	Barrion et al., 1979	Philippine	
Oxyopes mundulus L. Koch	noctuids	Heliothis spp.	Lep.: Noctuidae	cotton	Bishop & Blood, 1981	USA	
Oxyopes pandae Tikader	maize jassid	Ziginidia manaliensis Singh	Hom: Cicadellidae	maize and sorghum	Singh & Sandhu, 1976	India	
"	tobacco cutworm	Spodoptera litura F.	Lep.: Noctuidae	tobacco	Sitaramaiah et al., 1980	India	
"	maize borer	Chilo partellus Swinhoe	Lep.: Pyralidae	maize and sorghum	Sharma & Sarup, 1979	India	
"	"	"	Lep.: Pyralidae	maize and sorghum	Singh et al., 1975	India	
"	"	"	Lep.: Pyralidae	maize and sorghum	Singh & Sandhu, 1976	India	
Oxyopes salticus Hentz	pea aphid	Acyrthosyphon pisum Harris	Hom.: Aphididae	alfalfa	Howell & Pienkowski, 1971	USA	
"	cotton fleahopper	Pseudatomoscelis seriatus	Hem.: Miridae	cotton	Kagan, 1943	USA	

		Reuter					
"	"	"	Hem.: Miridae	cotton	Almand, 1974	USA	
"	"	"	Hem.: Miridae	cotton	Nyffeler et al., 1992a	USA	
"	"	"	Hem.: Miridae	cotton	Nyffeler et al., 1992b	USA	
"	"	"	Hem.: Miridae	cotton	Nyffeler et al., 1994b	USA	
"	"	"	Hem.: Miridae	cotton	Breene et al., 1988	USA	
"	"	"	Hem.: Miridae	cotton	Breene et al., 1989	USA	
"	"	"	Hem.: Miridae	cotton	Breene et al., 1990	USA	
"	"	"	Hem.: Miridae	cotton	Breene & Sterling, 1988	USA	
"	"	"	Hem.: Miridae	cotton	Lockley & Young, 1988	USA	
	tarnished plant bug	Lygus lineolaris Palisot de Beauvois	Hem.: Miridae	cotton	Whitcomb & Bell, 1964	USA	
"	"	"	Hem.: Miridae	-	Young & Lockley, 1986	USA	
"	"	"	Hem.: Miridae	cotton	Scott et al., 1988	USA	
"	"	"	Hem.: Miridae	cotton	Lockley & Young, 1988	USA	
"	rapid plant bug	Adelphocoris rapidus Say	Hem.: Miridae	cotton	Kagan, 1943	USA	
"	Southern green stink bug	Nezara viridula L.	Hem.: Pentatomidae	soybean	Ragsdale et al., 1981	USA	
"	cotton leafworm	Alabama argillacea Hubner	Lep.: Noctuidae	cotton	Gravena & Pazetto, 1987	Brazil	
"	"	"	Lep.: Noctuidae	cotton	Gravena & Da-Cuhna, 1991	Brazil	
"	velvetbean caterpillar	Anticarsia gemmatalis Hubner	Lep.: Noctuidae	soybean	McCarty et al., 1980	USA	
"	"	"	Lep.: Noctuidae	soybean	Reed et al., 1984	USA	7.4
"	soybean looper	Pseudoplusia includens Walker	Lep.: Noctuidae	soybean	McCarty et al., 1980	USA	
"	"	"	Lep.: Noctuidae	soybean	Richman et al., 1980	USA	1.14 larva
"	"	"	Lep.: Noctuidae	soybean	Reed et al., 1984	USA	7.4
"	cabbage looper	Trichoplusia ni Hubner	Lep.: Noctuidae	soybean	Reed et al., 1984	USA	7.4
"	"	"	Lep.: Noctuidae	cotton	Lockley & Young, 1988	USA	
"	tobacco budworm	Heliothis virescens F.	Lep.: Noctuidae	cotton	McDaniel & Sterling, 1979	USA	
"	"	"	Lep.: Noctuidae	cotton	McDaniel et al., 1981	USA	
"	noctuids	Heliothis spp.	Lep.: Noctuidae	cotton	Smith et al., 1978	USA	
"	"	"	Lep.: Noctuidae	soybean	McCarty et al., 1980	USA	

"	lesser corn stalk borer	Elasmopalpus lignosellus Zeller	Lep.: Pyralidae	peanut	Mack et al., 1988	USA	
"	thrips	Frankliniella spp.	Thys.: Thripidae	peanut	Agnew & Smith, 1989	USA	
Oxyopes scalaris Hentz	bark beetle	Ips pini Say	Col.: Scolytidae	forest	Jennings & Pase, 1975	USA	
Oxyopes sertatus L. Koch	diamond back moth	Plutella xylostella L.	Lep.: Plutellidae	cabbige	Yamada & Yamaguchi, 1985	Japan	
"	gipsy moth	Lymantria dispar L.	Lep.: Lymantriidae	pine forest	Furuta, 1977	Japan	
"	pine moth	Dendrolimus spectabilis Butler.	Lep.: Lasiocampidae	pine forest	Furuta, 1977	Japan	
Oxyopes sp.	apple blossom thrips	Thrips flavus Schrank	Thys.:Thripidae	-	Veer, 1984	India	
"	banana thrips	Thrips hawaiiensis Morgan	Thys.:Thripidae	-	Veer, 1984	India	
"	European corn borer	Ostrinia nubilalis Hubner	Lep.: Pyralidae	corn	Godfrey et al., 1991	USA	
"	pink borer	Chilo partellus Swin.	Lep.: Pyralidae	sorghum	Mohan, 1991	India	
"		Dichomeris ianthes Meyr.	Lep.: Gelechiidae	indigo plant	Gope, 1981	India	2-3
Peucetia viridans Hentz	cotton fleahopper	Pseudatomoscelis seriatus Reuter	Hem.: Miridae	cotton	Nyffeler et al., 1987	USA	1
"	cotton leafworm	Alabama argillacea Hubner	Lep.: Noctuidae	cotton	Gravena & Sterling, 1983	USA	
"	"	"	Lep.: Noctuidae	cotton	Nyffeler et al., 1987c	USA	
"	"	"	Lep.: Noctuidae	cotton	Weems & Whitcomb, 1977	USA	
"	tobacco budworm	Heliothis virescens F.	Lep.: Noctuidae	cotton	McDaniel & Sterling, 1979	USA	
"	corn earworm	Heliothis zea Boddie	Lep.: Noctuidae	cotton	Nyffeler et al., 1987c	USA	
"	velvetbean caterpillar	Anticarsia gemmatalis Hubner	Lep.: Noctuidae	soybean	Gregory et al., 1989	USA	
"	Nantucket pine tip moth	Rhyacionia frustrana Comstock	Lep.: Tortricidae	pine forest	Eikenbary & Fox, 1968	USA	
indet. Oxyopidae	greenhouse leafminer	Liriomyza trifolii Burgess	Dip.: Agromyzidae	chrysanthe num	Prieto et al., 1980	Colombia	
"	carmine spider mite	Tetranychus cinnabarinus Boisduval	Acarina: Tetranychidae	-	Mansour et al., 1995	Israel	16.8

Appendix A

Table 9. Philodromidae as predators of pests occurring in other ecosystems

Spiders	Common name	Scientific name	Taxon	Crops	Authors	Countries	Daily consumption
Appolophanes margareta Lowrie & Gertsch	Douglas-fir tussock moth	Orgyia pseudotsugata McDunnough	Lep.: Lymantriidae	pine forest	Swezey et al., 1991	USA	
"	"	"	Lep.: Lymantriidae	pine forest	Mason & Torgersen, 1983	USA	
"	white fir sawfly	Neodiprion abietis Harris	Hym.: Diprionidae	pine forest	Swezey et al., 1991	USA	
Philodromus aureolus Clerck	fall webworm	Hyphantria cunea Drury	Lep.: Arctiidae	Acer negundo L.	Groppali et al., 1994	Italy	
"	"	"	Lep.: Arctiidae	Morus alba L.	Groppali et al., 1993	Italy	
Philodromus dispar Walckenaer	ceanothus leafminer	Tischeria immaculata Braun	Lep.: Tischeriidae	Ceanothus griseus	Fasoranti, 1984	USA	
Philodromus rufus Walckenaer	Douglas-fir tussock moth	Orgyia pseudotsugata McDunnough	Lep.: Lymantriidae	pine forest	Swezey et al., 1991	USA	
"	"	"	Lep.: Lymantriidae	pine forest	Mason & Torgersen, 1983	USA	
"	white fir sawfly	Neodiprion abietis Harris	Hym.: Diprionidae	pine forest	Swezey et al., 1991	USA	
Philodromus speciosus Gertsch	Douglas-fir tussock moth	Orgyia pseudotsugata McDunnough	Lep.: Lymantriidae	pine forest	Swezey et al., 1991	USA	
Philodromus spectabilis Keyserling	"	"	Lep.: Lymantriidae	pine forest	Swezey et al., 1991	USA	
Tibellus sp.	black grass bug	Labops hesperius Uhler	Hem.: Miridae	grassland	Araya & Haws, 1988	Chile	
"	"	"	Hem.: Miridae	grassland	Araya & Haws, 1991	Chile	

Appendix A

Table 10. Salticidae as predators of pests occurring in other ecosystems

Spiders	Common name	Scientific name	Taxon	Crops	Authors	Countries	Daily consumption
Chrysilla versicolor	tea leafhopper	Empoasca pirisuga	Hom.: Cicadellidae	tea	Xie, 1993	China	47.6 adults
"	"	"	Hom.: Cicadellidae	tea	Xie, 1993	China	80.5 nymphs
Hentzia palmarum Hentz	velvetbean caterpillar	Anticarsia gemmatalis Hubner	Lep.: Noctuidae	soybean	O' Neil & Stimac, 1988	USA	
"	soybean looper	Pseudoplusia includens Walker	Lep.: Noctuidae	soybean	Richman et al., 1980	USA	3.71 larva
Hentzia sp.	Royal palm bug	Xylastodoris luteolus		palm trees	Reinert, 1975	USA	
Marpissa tigrina Tikader	citrus psylla	Diaphorina citri Kuwayama	Hom.: Aphalaridae	citrus	Sanda, 1991	India	
Marpissa ludhianaensis		Brahmaloka sp.	Hom.: Fulgoridae	grapevine	Sadana & Sandhu, 1977	India	14.3
Marpissa sp.	mango jassid	Idioscopus clypealis Lethiery	Hom.: Cicadellidae	mango	Tandon & Lal, 1983	India	
"	mango mealybug	Drosicha mangiferae Green	Hom.: Margarodidae	mango	Tandon & Lal, 1983	India	
"	tobacco cutworm	Spodoptera litura F.	Lep.: Noctuidae	-	Rao et al., 1993	India	
"	khapra beetle	Trogoderma granarium Everts	Col.: Dermestidae	stored products	Battu et al., 1975	India	
"	rice weevil	Sitophilus oryzae L.	Col.: Curculionidae	stored products	Battu & Dhaliwal, 1975	India	
"	lesser grain borer	Rhyzopertha dominica F.	Col.: Bostrychidae	stored products	Battu & Dhaliwal, 1975	India	
"	red flour beetle	Tribolium castaneum Herbst.	Col.: Tenebrionidae	stored products	Battu & Dhaliwal, 1975	India	
"	lesser mealworms	Alphitobius sp.	Col.: Tenebrionidae	stored products	Battu & Dhaliwal, 1975	India	
Metaphidippus aeneolus	Douglas-fir tussock moth	Orgyia pseudotsugata McDunnough	Lep.: Lymantriidae	pine forest	Mason, 1988	USA	
Metaphidippus galathea Walckenaer	pea aphid	Acyrtosiphon pisum Harris	Hom.: Aphididae	-	Horner, 1972	USA	
"	cotton fleahopper	Pseudatomoscelis seriatus Reuter	Hem.: Miridae	cotton	Dean et al., 1987	USA	
"	"	"	Hem.: Miridae	cotton	Breene et al., 1988	USA	
"	corn earworm	Heliothis zea Boddie	Lep.: Noctuidae	-	Horner, 1972	USA	
"	tobacco budworm	Heliothis virescens F.	Lep.: Noctuidae	-	Horner, 1972	USA	
"	soybean looper	Pseudoplusia includens Walker	Lep.: Noctuidae	soybean	Richman et al., 1980	USA	3.36 eggs

"	Nantucket pine tip moth	Rhyacionia frustrana Comstock	Lep.: Tortricidae	pine forest	Eikenbary & Fox, 1968	USA	
"	tobacco budworm	Heliothis virescens F.	Lep.: Noctuidae	cotton	Lincoln et al., 1967	USA	
Metaphidippus harfordi Peckham	Douglas-fir tussock moth	Orgyia pseudotsugata McDunnough	Lep.: Lymantriidae	pine forest	Swezey et al., 1991	USA	
Myrmaranchne plataleoides Cambridge	spotted stalk borer	Chilo partellus Swinhoe	Lep.: Pyralidae	maize and sorghum	Sharma & Sarup, 1979	India	
Phidippus audax Hentz	sweetpotato whitefly	Bemisia tabaci Gennadius	Hom.: Aleurodidae	-	Roach, 1987	USA	
"	green cereal aphid	Schizaphis graminum Rond.	Hom.: Aphididae	barley	Muniappan & Chada, 1970	USA	
"	pea aphid	Acyrthosyphon pisum Harris	Hom.: Aphididae	alfalfa	Howell & Pienkowski, 1971	USA	
"	jassids	Magicicada spp.	Hom.: Cicadellidae	-	Smith et al., 1987	USA	
"	buffalo treehopper	Ceresa bubalus F.	Hom.: Membracidae	-	Bilsing, 1920	USA	
"	threecornered alfalfa hopper	Spissistilus festinus Say	Hom.: Membracidae	alfalfa	Young, 1989a	USA	
"	cotton fleahopper	Pseudatomoscelis seriatus Reuter	Hem.: Miridae	cotton	Dean et al., 1987	USA	
"	"	"	Hem.: Miridae	-	Roach, 1987	USA	
"	"	"	Hem.: Miridae	cotton	Breene et al., 1988	USA	
"	"	"	Hem.: Miridae	cotton	Breene et al., 1990	USA	
"	tarnished plant bug	Lygus lineolaris Palisot de Beauvois	Hem.: Miridae	cotton	Young, 1989a	USA	
"	"	"	Hem.: Miridae	cotton	Young, 1989b	USA	
"	Southern green stink bug	Nezara viridula L.	Hem.: Pentatomidae	cotton	Young, 1989b	USA	
"	tobacco budworm	Heliothis virescens F.	Lep.: Noctuidae	cotton	McDaniel et al., 1981	USA	
"	fall webworm	Hyphantria cunea Drury	Lep.: Arctiidae	-	Oliver, 1964	USA	
"	"	"	Lep.: Arctiidae	-	Warren et al., 1967	USA	
"	spotted cucumber beetle	Diabrotica undecimpunctata Barber	Col.: Chrysomelidae	cotton	Young, 1989a	USA	
"	"	"	Col.: Chrysomelidae	-	Roach, 1987	USA	
"	"	"	Col.: Chrysomelidae	-	Roach, 1987	USA	

Phidippus punjabensis Tikader	spotted stalk borer	Chilo partellus Swinhoe	Lep.: Pyralidae	maize and sorghum	Singh & Sandhu, 1976	India	
"	tobacco cutworm	Spodoptera litura F.	Lep.: Noctuidae	tobacco	Sitaramaiah et al., 1980	India	
"	"	"	Lep.: Noctuidae	-	Rao et al., 1993	India	
"	jasminum leaf webworm	Nausinoe geometralis Gn.	Lep.: Pyralidae	Arabian jasmine	Shukla & Sandhu, 1983	India	
Phidippus regius Koch	citrus weevil	Diaprepes abbreviatus L.	Col.: Curculionidae	citrus, sugarcane	Edwards, 1981	USA	
Phidippus sp.	mango mealybug	Drosicha mangiferae Green	Hom.: Margarodidae	mango	Tandon & Lal, 1983	India	
"	mango jassid	Idioscopus clypealis Leth.	Hom.: Cicadellidae	mango	Tandon & Lal, 1983	India	
"	European pine shoot moth	Rhyacionia buoliana Schiff.	Lep.: Olethreutidae	pine forest	Juillet, 1961	Canada	
"	walnut caterpillar	Datana integerrima G. & R.	Lep.: Notodontidae	black walnut	Farris & Appleby, 1979	USA	
"	spotted stalk borer	Chilo partellus Swinhoe	Lep.: Pyralidae	maize and sorghum	Singh et al., 1975	India	
Platycryptus undatus DeGeer	Southern pine beetle	Dendroctonus frontalis Zimmermann	Col.: Scolytidae	forest	Jennings & Pase, 1986	USA	
Plexippus paykullii Audouin	sugarcane leafhopper	Pyrilla perpusilla Walker	Hom.: Lophopiidae	sugarcane	Miah, 1986	Bangladesh	
"	hibiscus jassid	Amrasca biguttula biguttula Shir.	Hom.: Cicadellidae	hibiscus	Rao et al., 1981	India	
"	diamond-back moth	Plutella xylostella L.	Lep.: Plutellidae	cabbige	Yamada & Yamaguchi, 1985	Japan	
"	fall webworm	Hyphantria cunea Drury	Lep.: Arctiidae	-	Kayashima, 1967	Japan	
Salticus ranjitus Tikader	spotted stalk borer	Chilo partellus Swinhoe	Lep.: Pyralidae	maize and sorghum	Sharma & Sarup, 1979	India	
Salticus zebraneus C. L. Koch	fall webworm	Hyphantria cunea Drury	Lep.: Arctiidae	Acer negundo L.	Groppali et al., 1994	Italy	
Salticus sp.	pine bark bug	Aradus cinnamomeus Panz.	Hem.: Aradidae	pine forest	Doom, 1981	Netherlands	
indet. Salticidae	American sugarcane borer	Diatraea saccharalis F.	Lep.: Pyralidae	sugarcane	Sousa-Silva et al., 1992	Brazil	
"	carmine spider mite	Tetranychus cinnabarinus Boisduval	Acarina: Tetranychidae	-	Mansour et al., 1995	Israel	10.1

Appendix A

Table 11. Tetragnathidae as predators of pests occurirng in other ecosystems

Spiders	Common name	Scientific name	Taxon	Crops	Authors	Countries	Daily consumption
Pachygnatha clercki Sundevall	green rice leafhopper	Nephotettix cinctipes Uhler	Hom.: Cicadellidae	rice	Okuma et al., 1978	Korea	
"	small brown planthopper	Laodelphax striatella Fall.	Hom.: Delphacidae	rice	Okuma et al., 1978	Korea	
"	brown planthopper	Nilaparvata lugens Stal.	Hom.: Delphacidae	rice	Okuma et al., 1978	Korea	
"	white-backed planthopper	Sogatella furcifer Horvath	Hom.: Delphacidae	rice	Okuma et al., 1978	Korea	
"	black pine bast scale	Matsucoccus thunbergianae Miller & Park	Hom.: Margarodidae	pine forest	Kim, 1993	China	
Tetragnatha japonica Boes. & Str.	white-backed planthopper	Sogatella furcifer Horvath	Hom.: Delphacidae	rice	Kamal & Dyck, 1994	Bangladesh	1-2
"	brown planthopper	Nilaparvata lugens Stal.	Hom.: Delphacidae	rice	Cheng, 1989	China	4.2-7.8
Tetragnatha javana Thorell	"	"	Hom.: Delphacidae	rice	Luong, 1987	Vietnam	
"	"	"	Hom.: Delphacidae	rice	Vungsilabutr, 1988	Thailand	
Tetragnatha laboriosa Hentz	Bird cherry - Oat aphid	Rhopalosiphum padi L.	Hom.: Aphidiidae	cereals	Provencher & Coderre, 1987	Canada	
"	corn leaf aphid	Rhopalosiphum maidis Fitch	Hom.: Aphidiidae	cereals	Provencher & Coderre, 1987	Canada	
"	cotton aphid	Aphis gossypii Glov.	Hom.: Aphidiidae	cotton	Kagan, 1943	USA	
"	"	"	Hom.: Aphidiidae	cotton	Nyffeler et al., 1989	USA	
"	pea aphid	Acyrthosyphon pisum Harris	Hom.: Aphidiidae	alfalfa	Howell & Pienkowski, 1971	USA	
"	pine cinaran aphids	Cinara spp.	Hom.: Lachnidae	pine forest	Fox & Griffith, 1976	USA	
"	cotton fleahopper	Pseudatomoscellis seriatus Reuter	Hem.: Miridae	cotton	Kagan, 1943	USA	
"	"	"	Hem.: Miridae	cotton	Nyffeler et al., 1989	USA	
"	cotton leaf worm	Alabama argillacea Hubner	Lep.: Noctuidae	cotton	Gravena & Sterling, 1983	USA	
Tetragnatha nitens Audouin	brown planthopper	Nilaparvata lugens Stal.	Hom.: Delphacidae	rice	Luong, 1987	Vietnam	

"	"	"	Hom.: Delphacidae	rice	Vungsilabutr, 1988	Thailand	
Tetragnatha praedonia L. Koch	tea leafhopper	Empoasca pirisuga	Hom.: Cicadellidae	tea	Chen, 1992	China	
"	brown planthopper	Nilaparvata lugens Stal.	Hom.: Delphacidae	rice	Wu et al., 1993	China	
Tetragnatha sutherlandi Gravely	"	"	Hom.: Delphacidae	rice	Rao et al., 1978a	India	
"	"	"	Hom.: Delphacidae	rice	Rao et al., 1978b	India	14
Tetragnatha versicolor Walckenaer	Douglas-fir tussock moth	Orgyia pseudotsugata McDunnough	Lep.: Lymantriidae	pine forest	Mason & Torgersen, 1983	USA	
Tetragnatha virescens	brown planthopper	Nilaparvata lugens Stal.	Hom.: Delphacidae	rice	Luong, 1987	Vietnam	
"	"	"	Hom.: Delphacidae	rice	Vungsilabutr, 1988	Thailand	
"	Malayan black bug	Scotinophara coarctata F.	Hem.: Pentatomidae	rice	Perez et al., 1989	Philippine	
Tetragnatha sp.	brown planthopper	Nilaparvata lugens Stal.	Hom.: Delphacidae	rice	Bastidas et al., 1994	Colombia	0.9-3.5
indet. Tetragnathidae	sugarcane leaf hopper	Pyrilla perpusilla Walker	Hom.: Lophopidae	sugarcane	Miah, 1986	Bangladesh	
"	European corn borer	Ostrinia nubilalis Hubner	Lep.: Pyralidae	corn	Godfrey et al., 1991	USA	
"	rice leaffolder	Cnaphalocrocis medinalis Guenee	Lep.: Pyralidae	rice	Mun, 1982	Malaysia	

Appendix A

Table 12. Theridiidae as predators of pests occurring in other ecosystems

Spiders	Common name	Scientific name	Taxon	Crops	Authors	Countries	Daily consumption
Achaearanea tepidariorum C. Koch	fall webworm	Hyphantria cunea Drury	Lep.: Arctiidae	-	Kunimi, 1983	Japan	
"	Kanzawa spider mite	Tetranychus kanzawai Kishida	Acarina: Tetranychidae	grapevine	Ashihara et al., 1987	Japan	
"	"	"	Acarina: Tetranychidae	grapevine	Ashihara et al., 1992	Japan	
Coleosoma blandum	thrips		Thys.: Thripidae	potato	Amalin & Barrion, 1990	Philippine	
Euryopsis episinoides Walckenaer	giant looper	Boarmia selenaria Schiff.	Lep.: Geometridae	avocado	Wysoki & Izhar, 1980	Israel	
Theridion adamsoni Berland	American palm planthopper	Myndus crudus Van Duzee	Hom.: Cixiidae	coconut	Howard & Edwards, 1984	USA	

Theridion goodnightorum Levi	bark beetle	Ips pini Say	Col.: Scolytidae	forest	Jennings & Pase, 1975	USA	
Theridion lunatum Oliv.	sycamore lace bug	Corythucha ciliata Say	Hem.: Tingidae	Platanus sp.	Tavella & Arzone, 1987	Italy	
"	"	"	Hem.: Tingidae	Platanus sp.	Balarin & Polonec, 1984	Yugoslavia	3.1
Theridion melanostictum	American palm planthopper	Myndus crudus Van Duzee	Hom.: Cixiidae	coconut	Howard & Edwards, 1984	USA	
Theridion octomaculatum Boes. & Str.	brown planthopper	Nilaparvata lugens Stal.	Hom.: Delphacidae	rice	Cheng, 1989	China	4.2-7.8
"	"	"	Hom.: Delphacidae	rice	Ge & Chen, 1989	China	0.25-1.88
"	pink mite	Acaphylla theae Watt.	Acarina : Eriophyidae	tea	Zhao & Hou, 1993	China	
Theridion redimitum L.	sycamore lace bug	Corythucha ciliata Say	Hem.: Tingidae	Platanus sp.	Howard & Edwards, 1984	Italy	
Theridion takayense Saito	fall webworm	Hyphantria cunea Drury	Lep.: Arctiidae	-	Kunimi, 1983	Japan	
Theridion volubile Keyserling	cotton leafworm	Alabama argillacea Hubner	Lep.: Noctuidae	cotton	Gravena & Pazetto, 1987	Brazil	
"	"	"	Lep.: Noctuidae	cotton	Gravena & Da-Cuhna, 1991	Brazil	
Theridion sp.	giant looper	Boarmia selenaria Schiff.	Lep.: Geometridae	avocado	Wysoki & Izhar, 1980	Israel	
"	cotton leafperforator	Bucculatrix thurberiella Busck	Lep.: Lyonettidae	cotton	Herrera & Alvarez, 1979	Peru	
"	sorghum mite	Oligonychus indicus Hirst	Acarina: Tetranychidae	sorghum	Manjunatha, 1989	India	
Theridula gonygaster Simon	cotton leafworm	Alabama argillacea Hubner	Lep.: Noctuidae	cotton	Gravena & Pazetto, 1987	Brazil	
"	"	"	Lep.: Noctuidae	cotton	Gravena & Da-Cuhna, 1991	Brazil	
Theridula sp.	cotton leafperforator	Bucculatrix thurberiella Busck	Lep.: Lyonettidae	cotton	Herrera & Alvarez, 1979	Peru	
"	sorghum mite	Oligonychus indicus Hirst	Acarina: Tetranychidae	sorghum	Manjunatha, 1989	India	
indet. Theridiidae	spruce budworm	Choristoneura fumiferana Clem.	Lep.: Tortricidae	pine forest	Loughton et al., 1963	USA	
"	carmine spider mite	Tetranychus cinnabarinus Boisduval	Acarina: Tetranychidae	-	Mansour et al., 1995	Israel	9.5

Appendix A

Table 13. Thomisidae as predators of pests occurring in other ecosystems

Spiders	Common name	Scientific name	Taxon	Crops	Authors	Countries	Daily consumption
Misumena vatia Clerck	cabbage looper	Trichoplusia ni Hubner	Lep.: Noctuidae	crimson clover	Lockley et al., 1989	USA	
"	spotted cucumber beetle	Diabrotica undecimpunctata Barber	Col.: Chrysomelidae	crimson clover	Lockley et al., 1989	USA	
Misumena sp.	colorado potato beetle	Leptinotarsa decemlineata Say	Col.: Chrysomelidae	potato	Cappaert et al., 1991	USA	
Misumenoides formocipes Walck.	velvetbean caterpillar	Anticarsia gemmatalis Hubner	Lep.: Noctuidae	soybean	Gregory et al., 1989	USA	
Misumenops celer Hentz	cotton fleahopper	Pseudatomoscelis seriatus Reuter	Hem.: Miridae	cotton	Kagan, 1943	USA	
"	"	"	Hem.: Miridae	cotton	Breene et al., 1990	USA	
"		Lygus sp.	Hem.: Miridae	cotton	Plagens, 1983	USA	
"		Lopidea nigridea Uhler	Hem.: Miridae	lupin	McIver & Lattin, 1990	USA	
"	velvetbean caterpillar	Anticarsia gemmatalis Hubner	Lep.: Noctuidae	soybean	Gregory et al., 1989	USA	
"	"	"	Lep.: Noctuidae	soybean	O' Neil & Stimac	USA	
"	American bollworm	Heliothis armigera Hubner	Lep.: Noctuidae	cotton	Kagan, 1943	USA	
"	Southwestern corn borer	Diatraea grandiosella Dyar	Lep.: Pyralidae	corn	Knutson & Gilstrap, 1989	USA	
Misumenops lepidus Thorell	black grass bug	Labops hesperius Uhler	Hem.: Miridae	grassland	Araya & Haws, 1988	Chile	
"	"	"	Hem.: Miridae	grassland	Araya & Haws, 1991	Chile	
"	Douglas-fir tussock moth	Orgyia pseudotsugata McDunnough	Lep.: Lymantriidae	pine forest	Swezey et al., 1991	USA	
"	white fir sawfly	Neodiprion abietis Harris	Hym.: Diprionidae	pine forest	Swezey et al., 1991	USA	
Misumenops tricuspidata F.	flower thrips	Frankliniella intonsa Trybom	Thys.: Thripidae	white clover	Murai, 1988	Japan	
"	cotton aphid	Aphis gossypii Glov.	Hom.: Aphididae	cotton	Zhou & Xiang, 1987	China	42.8
"	green leaf bug	Lygocoris lucorum Meyer	Hem.: Miridae	cotton	Cao, 1986	China	
"		Adelphocoris suturalis	Hem.: Miridae	cotton	Liu & Gu, 1990	China	2.88-4.2

		Jakovlev					
"		Adelphocoris suturalis Jakovlev	Hem.: Miridae	cotton	Cao, 1986	China	
"	diamond-back moth	Plutella xylostella L.	Lep.: Plutellidae	cabbige	Yamada & yamaguchi, 1985	Japan	
Misumenops sp.	tarnished plant bug	Lygus lineolaris Palisot de Beauvois	Hem.: Miridae	cotton	Young, 1989	USA	
"	cotton leafworm	Alabama argillacea Hubner	Lep.: Noctuidae	cotton	Gravena & Sterling, 1983	USA	
"	"	"	Lep.: Noctuidae	cotton	Gravena & Pazetto, 1987	Brazil	
"	walnut caterpillar	Datana integerrima G. & R.	Lep.: Notodontidae	black walnut	Farris & Appleby, 1979	USA	
Thomisus cherapunjeus Tikader	spotted stalk borer	Chilo partellus Swinhoe	Lep.: Pyralidae	maize and sorghum	Singh & Sandhu, 1976	India	
Thomisus lobodus Tikader	tobacco cutworm	Spodoptera litura F.	Lep.: Noctuidae	tobacco	Sitaramaiah et al., 1980	India	
Thomisus onustus Walckenaer	giant looper	Boarmia selenaria Schiff.	Lep.: Geometridae	avocado	Wysoki & Izhar, 1980	Israel	
Thomisus projectus Tikader	tobacco cutworm	Spodoptera litura F.	Lep.: Noctuidae	tobacco	Sitaramaiah et al., 1980	India	
Thomisus shivajiensis Tikader	bean butterfly	Lampides boeticus L.	Lep.: Lycaenidae	leguminosae	Singh & Mavi, 1984	India	
Thomisus sp.	thrips		Thys.: Thripidae	-	Veer, 1984	India	
"	rose aphid	Macrosiphum rosae L.	Hom.: Aphididae	rose	Raychaudhuri et al., 1979	India	
Xysticus cunctator Thorell	black grass bug	Labops hesperius Uhler	Hem.: Miridae	grassland	Araya & Haws, 1988	Chile	
"	"	"	Hem.: Miridae	grassland	Araya & Haws, 1991	Chile	
"	Douglas-fir tussock moth	Orgyia pseudotsugata McDunnough	Lep.: Lymantriidae	pine forest	Swezey et al., 1991	USA	
"	white fir sawfly	Neodiprion abietis Harris	Hym.: Diprionidae	pine forest	Swezey et al., 1991	USA	
Xysticus kochii Thorell	colorado potato beetle	Leptinotarsa decemlineata Say	Col.: Chrysomelidae	potato	Koval, 1976	USSR	
"	"	"	Col.: Chrysomelidae	potato	Sorokin, 1982	USSR	
"	cereal leaf bettles	Oulema spp.	Col.: Chrysomelidae	cereals	Szabolcs & Horváth, 1991	Hungary	
Xysticus sp.	pine bark bug	Aradus cinnamomeus Panz.	Hem.: Aradidae	pine forest	Doom, 1981	Netherlands	
"	alfalfa weevil	Hypera postica Gylh.	Col.: Curculionidae	alfalfa	Ouayogode & Davis, 1981	USA	

Appendix B

Table 1. The characteristics of the investigated orchards

Environment	Woodland in mountain of 300-400 m height				Agricultural lowland							Flooded forest area	
Locality	Nagykovácsi			Beresztelke	Tura		Sárospatak		Kecskemét	Szarkás		Szigetcsép	
neighboring habitats	natural, forest (Cesaro-Quercetum pubescentis)				agricultural fields		agricultural fields		seminatural, Festucetum-vaginatae			flooded forest, agricultural fields	
Fruit species	apple	pear	pear	apple	apple	pear	apple	pear	apple	apple	apple	apple	pear
Year of planting	1967	1967			1964		1950		1963	1981	1962	1977	1988
Size of plantation	5.8 ha	1.1 ha	51 ha		118 ha	5 ha		60 ha	20 ha	3 x 2 ha	5 ha; 6 ha	5.5 ha	4 ha
Cultivars	G; Jt; S	N; B; H; S			Jt; Ap; Ep		Jt	V;B	Jt; S; St	I; Jg; Md	Jt; S	Jt; Jg; G; S	C; V; P; BG
Planting system	8 x 5 m	7.5 x 5 m			8 x 4 m		10 x 10 m			6 x 4 m	5 x4 m	4.5 x 2.5-3.5 m	6 x 4 m
Untreated	+	+	+	+					+				
Conventionally treated				+	+	+	+	+		+	+	+	+
IPM				+						+	+		
No. of treatments / year	-	-	-					10-12	-	7-8	7-8	8-10	10-12
Method	Bm; Sn;Tb;Bt	Bm; Sn;Tb	Tb	Bm	Bm; Sn;Tb	Bm; Sn;Tb	Bm; Sn;Tb	Bm; Sn;Tb	Bm; Sn;Tb	Bm; Sn;Tb;Pt	Bm; Sn;Tb;Pt	Bm; Sn;Tb	Bm; Sn;Tb
Years	1978-82;1995-97	1995-97	1996	1995	1996-97	1996-97	1996-97	1995-96	1996-97	1992-96	1992-96	1995-97	1995-97
Soil	clay	clay	clay		sandy-loam	sandy-loam	clay	clay	sandy	sandy	sandy	sandy-loam	sandy-loam
Weed management	not managed	not managed	not managed	-	cultivated	cultivated	mowed	mowed	not managed	cultivated	cultivated	mowed	mowed

Apple cultivars: Ap: Asztraháni piros, Ep: Egri piros, G: Golden Delicious, I: Idared, Jt: Jonathan, Jg: Jonagold, Md: Mollies Delicious, S: Starking, St: Staymared
Pear cultivars: B: Bosc kobak, BG: Bella di Giugno, C: Clapp kedveltje, H: Hardenpont téli vajkörte, N: Nyári Kálmán, P: Packham's Triumph, S: Serres Olivér, V: Vilmos
Methods: Bm: beating method, Sn: Sweep netting, Tb: Treeband, Bt: Trapping on the bark, Pt: Pitfall trapping

Appendix B

Table 2. List of spiders occurring in the canopy of apple and pear orchards (beating method)

	Nagykovácsi 1995-97		Szigetcsép 1995-97		Tura 1996-97		Sárospatak		Kecskemét 1996-97	Szarkás 1995-96	Beresztelke 1995
	Abandoned		Conventional		Conventional		Conventional		Abandoned	Conventional & IPM	Conventional
	apple	pear	apple	pear	apple	pear	apple 1996-97	pear 1995-96	apple	apple	apple
Mimetidae											
Ero spp.	95								96		
Theridiidae											
Achaearanea lunata (Clerck, 1757)	95										
Dipoena melanogaster (C.L. Koch, 1837)	95,96,97	95,96,97							97		
Enoplognatha latimana Hippa & Oksala, 1982		95			96	96,97			96,97		95
Enoplognatha ovata (Clerck, 1757)											95
Enoplognatha (ovata-latimana) spp.	96	95,96,97	95,96	95,96		97			97	95	95
Steatoda albomaculata (Degeer, 1778)										95	
Steatoda bipunctata (Linnaeus, 1758)											95
Steatoda triangulosa (Walckenaer, 1802)											95
Theridion bimaculatum (Linnaeus, 1767)		96	96,97		97	97	97				
Theridion impressum L. Koch, 1881	95,96			95,96, 97	96				96	96	95
Theridion (sisyphium-impressum) spp.	95,96,97	95,96,97	95,96	95,96, 97	96,97	97	97	95	96,97	95,96	95
Theridion melanurum Hahn, 1831	96	95							96,97		
Theridion (mystaceum) sp.	96,97	95,96,97						96	97		
Theridion nigrovariegatum Simon, 1873	95,96,97	95,96,97	95,96,97						97		
Theridion pinastri L. Koch, 1872	95,96,97	95,96,97			96,97	97	96	95,96	96,97	95,96	95
Theridion simile C.L. Koch, 1836									96		
Theridion tinctum (Walckenaer, 1802)	95,96,97	95,96,97	95,97			97			96,97		95
Theridion varians Hahn, 1833		96,97	96,97			96			96		95

Linyphiidae											
Araeonchus humilis (Blackwall, 1841)			95,96								
Centromerus sylvaticus (Blackwall, 1841)			95								
Erigone dentipalpis (Wider, 1834)			96	96							
Frontinellina frutetorum (C.L. Koch, 1834)	95,96	95									
Linyphia triangularis (Clerck, 1757)	96,97	96									
Meioneta rurestris (C.L. Koch, 1836)		96	96	96		96,97				95,96	95
Microlinyphia pusilla (Sundevall, 1830)	96										
Neriene spp.	97	97									
Porrhomma microphthalmum (O.P. Cambridge, 1871)	96		95	95							
Erigoninae spp.			96,97								
Linyphinae spp.	95,96,97	95,96	95,96,97		96	96,97			96,97	96	
Tetragnathidae											
Metellina segmentata (Clerck, 1757)											95
Pachygnatha degeeri Sundevall, 1830											95
Tetragnatha spp.			95,96,97	95,96, 97	97	97	96,97	95,96	96,97		95
Zygiella spp.									96		
Araneidae											
Agalenatea redii (Scopoli, 1763)	95,96		95,96	95,96	96				96,97	95,96	95
Araneus angulatus Clerck, 1757	95		95,96						96		
Araneus diadematus Clerck, 1757	95	96	95,96,97		96,97			95	96,97	95,96	95
Araneus marmoreus Clerck, 1757			96								
Araneus quadratus Clerck, 1757									97		
Araneus sturmi (Hahn, 1831)	96,97										
Araneus triguttatus (Fabricius, 1775)	95										
Araneus spp.	95,96	95,96,97	95,96,97	95,96, 97	97	97			96,97	95,96	95
Araniella cucurbitina (Clerck, 1757)	95,96	95							96,97		95
Araniella opistographa (Kulczynski, 1905)	96,97	95,96,97						96	96,97		95
Araniella (cucurbitina-opistographa) spp.	95,96,97	95,96,97	95,96,97	95,96,	96,97	96,97	96,97	95,96	96,97	95,96	95

				97							
Argiope lobata (Pallas, 1772)										95,96	
Cyclosa conica (Pallas, 1772)	95,96,97	96,97			97				96,97		
Gibbaranea bituberculata (Walckenaer, 1802)			96		97						
Gibbaranea gibbosa (Walckenaer, 1802)	96	96									
Gibbaranea spp.	95,96,97	95,96,97	97		97				96	95,96	
Hypsosinga pygmaea (Sundevall, 1832)	96						96		97		
Larinioides patagiatus (Clerck, 1757)			95,96,97	95,96, 97							
Larinioides spp.			95,96,97	95,96, 97					96,97		
Mangora acalypha (Walckenaer, 1802)	95,96,97	96,97	95,96,97	97	96,97	97	97	95,96	96,97	95	95
Nuctenea spp.		95,96									
Zilla diodia (Walckenaer, 1802)	95	95,96								96	
Lycosidae											
Aulonia albimana (Walckenaer, 1805)									96		
Pardosa spp.	95,96		95				96		96,97	96	
Trochosa spp.							96				
Pisauridae											
Pisaura mirabilis (Clerck, 1757)	96		96,97	95,96	96	96		96	96,97		95
Agelenidae											
Agelena spp.										96	
Dictynidae											
Dictyna arundinacea (Linnaeus, 1758)		96,97							96,97		
Dictyna latens (Fabricius, 1775)	95										
Dictyna uncinata Thorell, 1856											95
Dictyna spp.			95,96						96,97	96	95
Nigma spp.	95,96,97	95,96								96	
Oxyopidae											
Oxyopes heterophthalamus Latreille, 1804			95,96							95,96	
Oxyopes ramosus (Panzer, 1804)									96		
Oxyopes spp.	96,97	96,97			96,97	96,97			96,97	95,96	95
Anyphaenidae											

Anyphaena accentuata (Walckenaer, 1802)	95,96	95	95,96	95,96	96				96,97	95	
Clubionidae											
Cheiracanthium effosum Herman, 1879									97		
Cheiracanthium mildei L. Koch, 1864	97		96			97			96,97	95,96	95
Cheiracanthium spp.	95,96	95,96,97	95,96,97	95,96, 97		96,97			96,97		95
Clubiona brevipes Blackwall, 1841										95	
Clubiona comta C.L. Koch, 1839		96									
Clubiona diversa O.P. Cambridge, 1862		96									
Clubiona frutetorum L. Koch, 1866											95
Clubiona lutescens Westring, 1851			95,97								
Clubiona marmorata L. Koch, 1866	96,97	95,96									
Clubiona pallidula (Clerck, 1757)			95,96								
Clubiona spp.	95,96,97	95,96,97	95,96,97	95,97	96	97	96		97		95
Gnaphosidae											
Aphantaulax seminigra Simon, 1878									96	95	
Drassodes spp.	96		96							95	
Scotophaeus scutulatus (L. Koch, 1866)			97								
Scotophaeus spp.										95	
Philodromidae											
Philodromus aureolus (Clerck, 1757)	95										
Philodromus (aureolus) spp.	95,96,97	95,96,97	95,96,97	95,96, 97	96,97	96,97	96,97	95,96	96,97	95,96	95
Philodromus cespitum (Walckenaer, 1802)	95,96	95	97						96,97		95
Philodromus dispar Walckenaer, 1826				95,96, 97							
Philodromus emarginatus (Schrank, 1803)		95									
Philodromus longipalpis Simon, 1870		95									
Philodromus margaritatus (Clerck, 1757)					96						
Philodromus (margaritatus) spp.	95,96,97	95,96,97	96	95,96, 97	96,97	96,97			96,97	95,96	95
Philodromus praedatus O.P. Cambridge,	95	96									

1871											
Philodromus rufus Walckenaer, 1826			95,96	95							
Philodromus (rufus) spp.	96,97	96,97	95	95,97						95,96	
Tibellus spp.			95,96	95,96, 97			96,97	95,96	96,97	95,96	
Thomisidae											
Diaea dorsata (Fabricius, 1777)	96						97				
Diaea pictilis (Banks, 1896)		96,97									
Diaea spp.	96										95
Misumena vatia (Clerck, 1757)	95,96	95,96,97		95	96,97	97	97	95,96	96,97		95
Misumenops tricuspidatus (Fabricius, 1775)	95,96,97	95,96,97	95,96,97	95,96, 97	96,97	96,97	96,97	95,96	96,97	95,96	95
Ozyptila spp.	95	95					96	95,96			
Pistius truncatus (Pallas, 1772)	95,96,97	95,96,97				97					95
Runcinia grammica (C.L. Koch, 1837)		95							96	95,96	
Synaema globosum (Fabricius, 1775)	95,96,97	95,96,97				97					95
Thomisus onustus Walckenaer, 1806		96,97								95	95
Tmarus piger (Walckenaer, 1802)	95,96,97	96,97							96		
Tmarus stellio Simon, 1875		97							96		
Tmarus spp.	95,96,97	95,96,97	95	96					96,97	96	
Xysticus kochi Thorell, 1872			96							96	
Xysticus lanio C.L. Koch, 1835	96,97						96,97	95,96			
Xysticus ulmi (Hahn, 1831)								95,96			
Xysticus spp.	95,96,97	95,96,97	95,96,97	95,96, 97	96,97	96,97	96,97	95,96	96,97	95,96	95
Salticidae											
Ballus chalybeius (Walckenaer, 1802)	95,96,97	95,96,97	95,96,97	95,96			96	95,96			
Carrhotus xanthogramma (Latreille, 1819)	95,96	95,96,97	95,96,97	95,96, 97	96,97	96,97			96,97	95,96	95
Eris nidicolens (Walckenaer, 1802)	95,96,97	95,96,97	95,96,97	95,96, 97	96,97	97	97	95,96	96,97	95,96	95
Euophrys aequipes O.P. Cambridge, 1871									96,97		
Euophrys frontalis (Walckenaer, 1802)									97		
Euophrys monticola Kulczynski, 1884									97		
Euophrys obsoleta (Simon, 1869)			95,96	95	96				97		

Euophrys spp.			95	95,96				96	96,97		
Evarcha arcuata (Clerck, 1757)	96										
Evarcha falcata (Clerck, 1757)			96,97								
Evarcha laetabunda (C.L. Koch, 1846)									97		
Evarcha spp.	96		95					96	96,97	96	
Heliophanus auratus C.L. Koch, 1835			95,96	95,96					97		
Heliophanus cupreus (Walckenaer, 1803)			96							96	
Heliophanus flavipes Hahn, 1832								96			
Heliophanus spp.	95,96,97	95,96,97	95,96,97	95,96	96,97		95	95,96	96,97	95	95
Marpissa muscosa (Clerck, 1757)					96,97	96,97					
Pseuditius encarpatus (Walckenaer, 1802)	95,96,97	95	95,96	95,96	96		96	95,96	96,97	95,96	95
Salticus cingulatus (Panzer, 1797)			95,96	95							
Salticus scenicus (Clerck, 1757)											95
Salticus zebraneus (C.L. Koch, 1837)		95,96,97	95,96	95,96			96		97	95,96	
Salticus spp.	95,96,97	95,96,97	95,96,97	95,96,97	96,97	97	96,97	95,96	96,97	95,96	95
Sitticus spp.				95							
Number of species	**56**	**52**	**47**	**33**	**28**	**27**	**22**	**22**	**55**	**39**	**37**
Number of individuals	**1720**	**2584**	**858**	**558**	**658**	**526**	**412**	**325**	**2993**	**434**	**664**

Appendix B

Table 3. List of spiders occurring in the herbaceous layer of apple and pear orchards (sweep netting)

	Nagykovácsi 1995-96		Szigetcsép 1995-96		Tura 1996-97		Sárospatak 1995-97		Kecskemét 1996-97	Szarkás 1995-96
	Abandoned		Conventional		Conventional		Conventional		Abandoned	Conventional & IPM
	apple	pear	apple	pear	apple	pear	apple	pear	apple	apple
Uloboridae										
Uloborus walckenaerius (Latreille, 1806)										95
Theridiidae										
Achaearanea lunata (Clerck, 1757)										
Dipoena melanogaster (C.L. Koch, 1837)		96								

Enoplognatha latimana Hippa & Oksala, 1982			96		96				96	
Enoplognatha (ovata-latimana) spp.		96	95,96	95,96	97	97			96,97	
Theridion bimaculatum (Linnaeus, 1767)			96	95	97	97				
Theridion impressum L. Koch, 1881										96
Theridion (sisyphium-impressum) spp.		95,96	95,96	95	96,97	97			97	
Theridion melanurum Hahn, 1831									96	
Theridion nigrovariegatum Simon, 1873	95,96	96	95							
Theridion pinastri L. Koch, 1872	95,96	96			97	97			96,97	
Theridion sisyphium (Clerck, 1757)										96
Theridion tinctum (Walckenaer, 1802)	96				97					
Theridion varians Hahn, 1833		95								
Linyphiidae										
Erigone dentipalpis (Wider, 1834)			95							
Linyphia triangularis (Clerck, 1757)	96	96			97					
Meioneta rurestris (C.L. Koch, 1836)				95						
Neriene spp.	95	95								96
Tiso vagans (Blackwall, 1834)				96						
Linyphinae spp.		95		95,96		97				
Tetragnathidae										
Metellina segmentata (Clerck, 1757)	96	95,96			97	97	97			
Tetragnatha spp.	95,96	95,96	95,96	95,96	97	96,97		95,96	97	
Pachygnatha spp.			95							
Araneidae										
Agalenatea redii (Scopoli, 1763)		95,96			97		97		96,97	95,96
Araneus diadematus Clerck, 1757						97			96,97	95,96
Araneus quadratus Clerck, 1757									97	
Araneus spp.	95,96	95	95,96	95					96	
Araniella (cucurbitina-opistographa) spp.	95,96	95,96			96,97	97		95,96	96	
Argiope bruennichi (Scopoli, 1772)									96,97	95
Argiope lobata (Pallas, 1772)										95,96
Cercidia prominens (Westring, 1851)		95								
Cyclosa conica (Pallas, 1772)	95								96,97	96
Gibbaranea bituberculata (Walckenaer, 1802)			95,96							95
Gibbaranea spp.	95,96		95	95	97				97	95,96
Hypsosinga pygmaea (Sundevall, 1832)				96		96				

Larinioides spp.			95,96	95,96						95
Mangora acalypha (Walckenaer, 1802)	95,96	95,96	95,96	95,96	96,97	96,97	97	95	96,97	96
Neoscona adianta (Walckenaer, 1802)										
Singa hamata (Clerck, 1757)				95						
Zilla diodia (Walckenaer, 1802)		96								
Lycosidae										
Alopecosa spp.							96			
Pardosa spp.	95	96			97	97	96	95,96	96,97	
Pirata spp.			95				97	96		
Pisauridae										
Pisaura mirabilis (Clerck, 1757)	95,96	95,96	95,96	95,96	96,97	96,97	96,97	95,96	96,97	95,96
Dictynidae										
Dictyna arundinacea (Linnaeus, 1758)									96	
Dictyna spp.		95							96,97	96
Oxyopidae										
Oxyopes heterophthalamus Latreille, 1804									96	95,96
Oxyopes ramosus (Panzer, 1804)										96
Oxyopes spp.					96,97				96,97	95,96
Anyphaenidae										
Anyphaena accentuata (Walckenaer, 1802)										
Clubionidae										
Cheiracanthium mildei L. Koch, 1864									97	
Cheiracanthium pennyi O.P. Cambridge, 1873	95									95
Cheiracanthium punctorium (Villers, 1789)									96,97	
Cheiracanthium spp.	95,96	95								
Clubiona spp.	95	95,96						96	97	
Gnaphosidae										
Aphantaulax spp.		95								
Drassodes lapidosus (Walckenaer, 1802)										96
Zoridae										
Zora spp.									97	
Philodromidae										
Philodromus (aureolus) spp.	95,96	95,96	95,96	95,96	96,97	96,97	96,97	95,96	96,97	
Philodromus (margaritatus) spp.		95							97	
Philodromus dispar Walckenaer, 1826	96									

Tibellus oblongus (Walckenaer, 1802)						97			96	
Tibellus spp.	95,96	95,96	95,96	95,96	97	96,97	97	95,96	96,97	95,96
Thanatus spp.										96
Thomisidae										
Herieus spp.	96									
Misumena vatia (Clerck, 1757)	95,96	95,96		95,96		97		96	96,97	
Misumenops tricuspidatus (Fabricius, 1775)	95,96	95,96	95,96	95,96	96,97	96,97	96,97	95,96	96,97	96
Pistius truncatus (Pallas, 1772)	95,96									
Runcinia grammica (C.L. Koch, 1837)									96	96
Synaema globosum (Fabricius, 1775)	95,96									
Thomisus onustus Walckenaer, 1806										95,96
Tmarus piger (Walckenaer, 1802)	95,96									
Tmarus spp.		95,96								
Xysticus cristatus (Clerck, 1857)			95,96	95						96
Xysticus kochi Thorell, 1872									96	95,96
Xysticus ninnii Thorell, 1872									96	96
Xysticus striatipes L. Koch, 1870									97	
Xysticus ulmi (Hahn, 1831)	95,96									
Xysticus spp.	95,96	95,96	95,96	95,96	96,97	96,97	96,97	95,96	96,97	95,96
Salticidae										
Ballus chalybeius (Walckenaer, 1802)	95									
Carrhotus xanthogramma (Latreille, 1819)	95,96	95,96			96,97	96,97				96
Eris nidicolens (Walckenaer, 1802)	95,96	96				97	96		96	
Euophrys spp.									96	
Evarcha arcuata (Clerck, 1757)	96	96							96,97	96
Evarcha spp.	95,96	95,96							96,97	96
Heliophanus cupreus (Walckenaer, 1803)		95	95,96	96						96
Heliophanus flavipes Hahn, 1832			95,96							
Heliophanus spp.	95,96	95,96					96		96,97	
Salticus zebraneus (C.L. Koch, 1837)		95								95
Salticus spp.	95,96	95,96							96,97	95
Number of species	**32**	**33**	**19**	**19**	**20**	**20**	**13**	**12**	**35**	**30**
Number of individuals	**359**	**404**	**377**	**298**	**119**	**416**	**83**	**140**	**1519**	**579**

Appendix B

Table 4. List of spiders occurring on the bark of apple trees (trapping on the bark)

	Nagykovácsi 1978-82
	Abandoned
	apple
Theridiidae	
Dipoena melanogaster (C.L. Koch, 1837)	81,82
Enoplognatha latimana Hippa & Oksala, 1982	78,79,81
Enoplognatha (ovata-latimana) spp.	79,80,81
Steatoda bipunctata (Linnaeus, 1758)	81
Theridion bimaculatum (Linnaeus, 1767)	80
Theridion nigrovariegatum Simon, 1873	79
Theridion pinastri L. Koch, 1872	78,79,80,81,82
Theridion suaveolens (Simon, 1879)	80
Theridion tinctum (Walckenaer, 1802)	79,81,82
Theridion (mystaceum) sp.	79,81
Theridion (sisyphium-impressum) spp.	78,79,80,81,82
Theridion spp.	78,79,81,82
Linyphiidae	
Araeonchus humilis (Blackwall, 1841)	79
Centromerus similis Kulczynski, 1894	78
Entelecara congenera (O.P. Cambridge, 1879)	81
Erigone atra Blackwall, 1833	82
Meioneta rurestris (C.L. Koch, 1836)	78,80
Oedothorax apicatus (Blackwall, 1850)	79
Thyreosthenius parasiticus (Westring, 1851)	81
Trichoncoides piscator (Simon, 1884)	81
Erigoninae spp.	81
Linyphinae spp.	78,79,80,81,82
Araneidae	
Araniella spp.	79,80,81
Gibbaranea spp.	79
Hypsosinga pygmaea (Sundevall, 1832)	78
Lycosidae	
Pardosa agrestis (Westring, 1862)	82
Pardosa spp.	79,80,81,82
Trochosa (terricola-ruricola) spp.	80
Pisauridae	
Pisaura mirabilis (Clerck, 1757)	78,79
Agelenidae	
Agelena labyrinthica (Clerck, 1757)	79,80,81
Tegenaria agrestis (Walckenaer, 1802)	79,81,82
Tegenaria spp.	81
Dictynidae	
Dictyna spp.	81
Titanoecidae	
Titanoeca schineri (L. Koch, 1872)	79

Clubionidae	
Clubiona marmorata L. Koch, 1866	78,79,80,81,82
Clubiona spp.	78,79,80,81,82
Gnaphosidae	
Drassodes lapidosus (Walckenaer, 1802)	79,80,81,82
Drassodes spp.	78,79,80,81,82
Drassyllus pusillus (C.L. Koch, 1833)	79,80
Zelotes spp.	78,79,80,81
Philodromidae	
Philodromus aureolus (Clerck, 1757)	79
Philodromus cespitum (Walckenaer, 1802)	79,80,82
Philodromus emarginatus (Schrank, 1803)	80
Philodromus longipalpis Simon, 1870	79
Philodromus (aureolus) spp.	78,79,80,81,82
Philodromus (margaritatus) spp.	78,79,80,81
Philodromus (rufus) spp.	80
Thanatus spp.	80
Tibellus oblongus (Walckenaer, 1802)	80
Thomisidae	
Diaea pictilis (Banks, 1896)	81
Misumena vatia (Clerck, 1757)	79,80,82
Misumenops tricuspidatus (Fabricius, 1775)	79
Pistius truncatus (Pallas, 1772)	81
Tmarus stellio Simon, 1875	82
Xysticus acerbus Thorell, 1872	79
Xysticus cristatus (Clerck, 1857)	79,80
Xysticus lanio C.L. Koch, 1835	79,80,81,82
Xysticus spp.	78,79,80,81,82
Salticidae	
Ballus chalybeius (Walckenaer, 1802)	78,82
Carrhotus xanthogramma (Latreille, 1819)	82
Eris nidicolens (Walckenaer, 1802)	78,79,80,81,82
Heliophanus cupreus (Walckenaer, 1803)	80
Heliophanus flavipes Hahn, 1832	80
Marpissa muscosa (Clerck, 1757)	79,82
Pseuditius encarpatus (Walckenaer, 1802)	79,81,82
Salticus zebraneus (C.L. Koch, 1837)	79
Sitticus distinguendus (Simon, 1868)	82
Sitticus pubescens (Fabricius, 1775)	79
Number of species	**57**
Number of individuals	**813**

Appendix B

Table 5. List of spiders overwintering on the trunk of apple and pear trees (treebands)

	Nagykovácsi 1996		Szigetcsép 1997	Tura 1996	Sárospatak		Kecskemét 1996	Szarkás 1994-96
	Abandoned		Conventional	Conventional	Conventional		Abandoned	Conventional & IPM
	apple	pear	apple	pear	apple 1996	pear 1993-94,96	apple	apple
Segestridae								
Segestria bavarica C.L. Koch, 1843		96						
Theridiidae								
Steatoda albomaculata (Degeer, 1778)						94		
Steatoda bipunctata (Linnaeus, 1758)				96	96	94,96		
Theridion bimaculatum (Linnaeus, 1767)						94		
Theridion pinastri L. Koch, 1872						93,94		
Theridion tinctum (Walckenaer, 1802)		96				94		
Theridion (mystaceum) sp.		96		96		94		95
Theridion (sisyphium-impressum) spp.						94		96
Linyphiidae								
Neriene montana (Clerck, 1757)						94		
Neriene spp.		96				96		
Erigoninae spp.		96						
Tetragnathidae								
Tetragnatha spp.			97			93,94,96		
Zygiella spp.								96
Araneidae								
Araneus spp.		96						
Araniella opistographa (Kulczynski, 1905)						93		
Pisauridae								
Pisaura mirabilis (Clerck, 1757)						96		
Dictynidae								
Dictyna spp.		96		96		93,94,96		
Lathys humilis (Blackwall, 1855)		96						
Titanoecidae								

Titanoeca spp.								95
Anyphaenidae								
Anyphaena accentuata (Walckenaer, 1802)		96				94,96		
Clubionidae								
Cheiracanthium mildei L. Koch, 1864				96		93,96	96	94,95,96
Cheiracanthium spp.						93		
Clubiona brevipes Blackwall, 1841						94		
Clubiona comta C.L. Koch, 1839						94		
Clubiona genevensis L. Koch, 1866								95
Clubiona pallidula (Clerck, 1757)						94		
Clubiona phragmitis C.L. Koch, 1843						94		
Clubiona pseudoneglecta Wunderlich, 1994							96	
Clubiona spp.	96	96	97	96	96	93,94,96	96	94,95
Gnaphosidae								
Aphantaulax spp.							96	95
Drassodes lapidosus (Walckenaer, 1802)							96	95
Drassodes spp.	96						96	94,95
Micaria spp.							96	95
Scotophaeus scutulatus (L. Koch, 1866)								95
Scotophaeus spp.		96		96				95
Philodromidae								
Philodromus dispar Walckenaer, 1826		96						
Philodromus (aureolus) spp.	96	96	97	96	96	93,94,96	96	95,96
Philodromus (margaritatus) spp.	96	96	97	96	96	93,94	96	96
Philodromus (rufus) spp.	96	96		96				96
Tibellus spp.						94,96		
Thomisidae								
Diaea spp.	96							
Misumenops tricuspidatus (Fabricius, 1775)		96	97	96	96	93,94,96	96	94,95,96
Ozyptila praticola (C.L. Koch, 1837)					96	96		
Ozyptila spp.						96		
Pistius truncatus (Pallas, 1772)	96	96		96				
Synaema spp.		96						95

Tmarus spp.		96						
Xysticus spp.						94,96		
Salticidae								
Eris nidicolens (Walckenaer, 1802)						94		96
Marpissa muscosa (Clerck, 1757)					96		96	95
Marpissa spp.					96		96	
Pseuditius encarpatus (Walckenaer, 1802)						93	96	96
Salticus zebraneus (C.L. Koch, 1837)							96	95
Salticus spp.						94	96	94,95
Number of species	**7**	**19**	**5**	**11**	**7**	**27**	**11**	**19**
Number of individuals	**13**	**202**	**711**	**44**	**33**	**721**	**237**	**208**

Appendix B

Table 6. List of spiders occurring in the ground level of apple orchards (pitfall trapping)

	Szarkás 1992-95
	Conventional & IPM
	alma
Dysderidae	
Harpactea rubicunda (C.L. Koch, 1838)	92,93,94,95
Theridiidae	
Steatoda albomaculata (Degeer, 1778)	92
Steatoda phalerata (Panzer, 1801)	92
Araneidae	
Argiope lobata (Pallas, 1772)	94
Lycosidae	
Alopecosa cursor (Hahn, 1831)	95
Alopecosa *fabrilis* (Clerck, 1757)	93
Alopecosa mariae (Dahl, 1908)	95
Alopecosa sulzeri (Pavesi, 1873)	92,93,94,95
Alopecosa spp.	92,93,94,95
Arctosa perita (Latreille, 1799)	92,93,94,95
Hogna radiata (Latreille, 1819)	95
Pardosa agrestis (Westring, 1862)	92,93,94,95
Pardosa lugubris (Walckenaer, 1802)	93
Pardosa spp.	92,93,94,95
Trochosa robusta (Simon, 1876)	92
Trochosa terricola Thorell, 1856	92,94,95
Xerolycosa miniata (C.L. Koch, 1834)	92,93,94,95
Xerolycosa nemoralis (Westring, 1861)	92,93,94
Xerolycosa spp.	92,94
Agelenidae	
Agelena gracilens C.L. Koch, 1841	93
Agelena labyrinthica (Clerck, 1757)	92,94
Tegenaria agrestis (Walckenaer, 1802)	93,94
Tegenaria spp.	93
Titanoecidae	
Titanoeca schineri (L. Koch, 1872)	92,93,94,95
Oxyopidae	
Oxyopes heterophthalamus Latreille, 1804	92,93,94
Clubionidae	
Cheiracanthium spp.	94
Clubiona spp.	94
Gnaphosidae	
Drassodes lapidosus (Walckenaer, 1802)	92
Drassodes villosus (Thorell, 1856)	92,93,94,95
Drassyllus praeficus (L. Koch, 1866)	92,94
Gnaphosa mongolica Simon, 1895	95
Haplodrassus signifer (C.L. Koch, 1839)	93,95
Trachyzelotes pedestris (C.L. Koch, 1837)	92,93,94,95
Zelotes apricorum (L.Koch, 1876)	93
Zelotes electus (C.L. Koch, 1839)	92
Zelotes longipes (L. Koch, 1866)	93
Zelotes subterraneus (C.L. Koch, 1833)	93

Zelotes spp.	92,93,94,95
Philodromidae	
Thanatus arenarius Thorell, 1872	92,93,94,95
Thomisidae	
Misumena vatia (Clerck, 1757)	94
Xysticus acerbus Thorell, 1872	92
Xysticus kochi Thorell, 1872	92,93,94,95
Xysticus sabulosus (Hahn, 1832)	95
Xysticus spp.	92,93,94,95
Salticidae	
Aelurillus v-insignitus (Clerck, 1757)	92
Euophrys spp.	93
Number of species	**40**
Number of individuals	**1215**

Appendix C

Table 1. Family composition of canopy spider communities of pome fruit orchards

	NL	Pl	D	CDN	H	I	USA	J
Segestriidae	0	0	0	0	0	1.89	0	0
Mimetidae	0	0	0	0	0.9	1.89	0	0
Uloboridae	0	0	0	0	0	0	1.33	0
Theridiidae	25.71	20.00	21.43	17.07	13.91	15.09	13.33	8.82
Linyphiidae	25.71	20.00	23.81	34.15	7.82	1.89	14.67	8.82
Tetragnathidae	8.57	12.50	7.14	2.44	3.47	3.77	2.67	8.82
Araneidae	17.14	10.00	19.05	14.63	15.65	15.09	17.33	23.53
Lycosidae	0	2.50	0	0	2.6	0.00	0	0
Pisauridae	0	0	0	0	0.9	1.89	0	0
Agelenidae	0	2.50	0	0	0.9	0.00	1.33	2.94
Dictynidae	8.57	5.00	2.38	2.44	3.47	3.77	2.67	2.94
Oxyopidae	0	0	0	0	1.74	5.66	1.33	2.94
Anyphaenidae	2.86	2.50	2.38	0	0.9	1.89	4.00	0
Liocranidae	0	0	0	0	0	1.89	0	0
Clubionidae	5.71	5.00	2.38	0	8.69	7.55	4.00	5.88
Gnaphosidae	0	0	0	0	3.47	1.89	1.33	0
Heteropodidae	0	0	0	0	0	1.89	0	0
Philodromidae	2.86	5.00	9.52	12.20	7.82	5.66	6.67	5.88
Thomisidae	2.86	12.50	9.52	9.76	12.17	15.09	12.00	11.76
Salticidae	0	2.50	2.38	7.32	14.78	13.21	17.33	17.65
Hunters	**14.3**	**30.0**	**26.2**	**29.3**	**54.8**	**58.5**	**46.7**	**44.1**
Web-builders	**85.7**	**70.0**	**73.8**	**70.7**	**45.2**	**41.5**	**53.3**	**55.9**
Number of species	**35**	**40**	**42**	**41**	**115**	**53**	**75**	**34**

NL: Loomans, 1978; PL: Olszak et al., 1992; D: Klein, 1988; CDN: Dondale et al., 1979; H: present study I: Angeli et al., 1996; USA: McCaffrey & Horsburg, 1980; J: Hukusima, 1961

Table 2. The dominant spider species by regions and collecting methods (Hungary 1995-97)

Nagykovácsi, apple	**nr. of indiv.**	**D%**	**Nagykovácsi, pear**	**nr. of indiv.**	**D%**
beating method			**beating method**		
Philodromus (aureolus) spp.	262	23.0%	Philodromus (aureolus) spp.	308	21.2%
Theridion (sisyphium-impressum) spp.	103	9.0%	Theridion pinastri	142	9.7%
Theridion pinastri	95	8.3%	Araniella spp.	110	7.5%
Araniella spp.	81	7.1%	Pistius truncatus	86	5.9%
Carrhotus xanthogramma	62	5.4%	Philodromus (margaritatus) spp.	76	5.2%
total nr. of individuals	1139		*total nr. of individuals*	1452	
total nr. of species	56		*total nr. of species*	52	
sweep netting			**sweep netting**		
Mangora acalypha	56	24.0%	Mangora acalypha	57	21.2%
Xysticus spp.	24	10.3%	Xysticus spp.	30	11.1%
Misumenops tricuspidatus	17	7.3%	Misumenops tricuspidatus	26	9.7%
Tibellus spp.	17	7.3%	Philodromus (aureolus) spp.	25	9.3%
Araniella spp.	14	6.0%	Misumena vatia	23	8.5%
total nr. of individuals	233		*total nr. of individuals*	269	
total nr. of species	32		*total nr. of species*	33	
Kecskemét, apple			**Szarkás, apple**		
beating method			**beating method**		
Oxyopes spp.	528	17.6%	Cheiracanthium (mildei) spp.	95	21.9%
Cheiracanthium (mildei) spp.	394	13.2%	Oxyopes spp.	73	16.8%
Theridion pinastri	387	12.9%	Eris nidicolens	48	11.0%
Araneus diadematus	270	9.0%	Carrhotus xanthogramma	33	7.6%
Eris nidicolens	209	7.0%	Xysticus spp.	32	7.4%
total nr. of individuals	2993		*total nr. of individuals*	434	
total nr. of species	55		*total nr. of species*	39	
sweep netting			**sweep netting**		
Oxyopes spp.	596	39.2%	Pisaura mirabilis	198	34.2%
Xysticus spp.	438	28.8%	Oxyopes spp.	118	20.4%
Araneus diadematus	130	8.5%	Xysticus spp.	88	15.2%
Mangora acalypha	41	2.6%	Agalenatea redii	31	5.3%
Pisaura mirabilis	40	2.6%	Argiope lobata	24	4.1%
total nr. of individuals	1519		*total nr. of individuals*	579	
total nr. of species	35		*total nr. of species*	30	
Sárospatak, apple			**Sárospatak, pear**		
beating method			**beating method**		
Theridion (sisyphium-impressum) spp.	180	43.7%	Misumenops tricuspidatus	69	21.2%
Xysticus spp.	71	17.2%	Philodromus (aureolus) spp.	60	18.5%
Araniella spp.	32	7.8%	Xysticus lanio	45	13.8%

Xysticus lanio	29	7.0%	Araniella spp.	40	12.3%
Philodromus (aureolus) spp.	27	6.5%	Theridion (sisyphium-impressum) spp.	24	7.4%
total nr. of individuals	412		*total nr. of individuals*	325	
total nr. of species	22		*total nr. of species*	22	
sweep netting			**sweep netting**		
Xysticus spp.	42	50.6%	Pisaura mirabilis	52	37.1%
Pisaura mirabilis	19	22.9%	Xysticus spp.	43	30.7%
Philodromus (aureolus) spp.	6	7.2%	Misumenops tricuspidatus	12	8.6%
Misumenops tricuspidatus	4	4.8%	Philodromus (aureolus) spp.	11	7.8%
Tibellus spp.	3	3.6%	Mangora acalypha	7	5.0%
total nr. of individuals	83		*total nr. of individuals*	140	
total nr. of species	13		*total nr. of species*	12	
Szigetcsép, apple			**Szigetcsép, pear**		
beating method			**beating method**		
Philodromus (aureolus) spp.	83	16.0%	Philodromus (aureolus) spp.	104	31.5%
Larinioides spp.	50	9.6%	Larinioides spp.	57	17.3%
Xysticus spp.	48	9.2%	Xysticus spp.	30	9.1%
Carrhotus xanthogramma	38	7.3%	Theridion (sisyphium-impressum) spp.	17	5.1%
Theridion (sisyphium-impressum) spp.	36	6.9%	Misumenops tricuspidatus	16	4.8%
total nr. of individuals	519		*total nr. of individuals*	330	
total nr. of species	47		*total nr. of species*	33	
sweep netting			**sweep netting**		
Theridion (sisyphium-impressum) spp.	52	20.5%	Xysticus spp.	57	29.2%
Mangora acalypha	48	19.0%	Theridion (sisyphium-impressum) spp.	28	14.3%
Xysticus spp.	41	16.2%	Mangora acalypha	14	7.2%
Misumenops tricuspidatus	15	5.9%	Tetragnatha spp.	13	6.7%
Pisaura mirabilis	15	5.9%	Larinioides spp.	11	5.6%
total nr. of individuals	253		*total nr. of individuals*	195	
total nr. of species	19		*total nr. of species*	19	
Tura, apple			**Tura, pear**		
beating method			**beating method**		
Carrhotus xanthogramma	204	31.0%	Araniella spp.	165	31.4%
Theridion (sisyphium-impressum) spp.	156	23.7%	Carrhotus xanthogramma	75	14.2%
Araniella spp.	56	8.5%	Theridion (sisyphium-impressum) spp.	61	11.6%
Philodromus (aureolus) spp.	48	7.3%	Misumenops tricuspidatus	58	11.0%
Misumenops tricuspidatus	32	4.9%	Philodromus (aureolus) spp.	58	11.0%
total nr. of individuals	658		*total nr. of individuals*	526	
total nr. of species	28		*total nr. of species*	27	
sweep netting			**sweep netting**		
Xysticus spp.	28	23.5%	Xysticus spp.	35	24.6%
Pisaura mirabilis	16	13.4%	Mangora acalypha	32	22.5%

Theridion (sisyphium-impressum) spp.	14	11.8%	Philodromus (aureolus) spp.	10	7.0%
Misumenops tricuspidatus	13	10.9%	Theridion bimaculatum	10	7.0%
Oxyopes spp.	7	5.9%	Misumenops tricuspidatus	9	6.3%
total nr. of individuals	119		*total nr. of individuals*	142	
total nr. of species	20		*total nr. of species*	20	

Appendix D

Table 1. The pesticide regime applied in Kecskemét-Szarkás in 1995 (**insecticides, acaricides**, fungicides)

Date	YoungCON, OldCON	Dose (%)	YoungIPM, OldIPM	Dose (%)
22.03.	copper oxychloride	0.5	copper oxychloride	0.5
10.04.	copper oxychloride	0.5	ethoxylated tallow amine	0.1
	endosulfan	0.15	triadimefon	0.03
	mancozeb	0.5	captan	0.3
	sulfur	0.7	**fosalon**	0.2
			esaconazole + captan	0.08
27.04.	esaconazole + captan	0.06	esaconazole + captan	0.08
09.05.	thiophanate-methyl	0.15	difenoconazole	0.03
16.05.	mancozeb	0.25	captan	0.3
	phosphamidon	0.14	triadimefon	0.03
	propineb	0.25	**diflubenzuron**	0.08
	sulfur	0.3		
02.06.	captan	0.3	captan	0.3
	sulfur	0.3	triadimefon	0.03
	phosphamidon	0.14	**fenoxycarb**	0.09
	endosulfan	0.2	**pirimicarb**	0.13
15.06.	**parathion-methyl**	0.25	captan	0.3
	triadimefon	0.03	triadimefon	0.03
	propineb	0.25	**B. *thuringiensis* subsp. *kurstaki***	0.08
05.07.	propineb	0.25	**B. *thuringiensis* subsp. *kurstaki***	0.15
	triadimefon	0.03	captan	0.3
	dimethoate	0.15	triadimefon	0.03
	parathion-methyl	0.25		
	captan	0.3		
22.07.	**B. *thuringiensis* subsp. *kurstaki***	0.15	**B. *thuringiensis* subsp. *kurstaki***	0.15
	captan	0.3	captan	0.3
	triadimefon	0.03	triadimefon	0.03
08.08.	triadimefon	0.03	**B. *thuringiensis* subsp. *kurstaki***	0.15
	parathion-methyl	0.25	captan	0.3
	copper oxychloride	0.5	triadimefon	0.03

Appendix D

Table 2. List of spiders occurring in different strata of an apple orchard in Hungary, ♂/♀(juv) (Kecskemét-Szarkás, 1995)

Family	Taxon	beating	treeband	sweep netting	Family	Taxon	beating	treeband	sweep netting
Agelenidae	*Agelena spp.*	0/0(1)	0	0	**Pisauridae**	*Pisaura mirabilis* Clerck	0/0(1)	0	0
Anyphaenidae	*Anyphaena accentuata Walckenaer*	0/0(4)	0	0	**Salticidae**	*Carrhotus xanthogramma* Latreille	0/4(20)	0	0
						Eris nidicolens Walckenaer	5/4(15)	0	0
Araneidae	*Agalenatea redii* Scopoli	0/0(1)	0	0/0(2)		*Evarcha falcata* Clerck	0	0	0/1(0)
	Araneus diadematus Clerck	0/0(1)	0	0/1(0)		*Evarcha spp.*	0	0	0/0(1)
	Araneus spp.	0/0(6)	0	0		*Heliophanus cupreus* Walckenaer	0/2(0)	0	0/4(0)
	Araniella spp.	0/0(6)	0	0		*Heliophanus spp.*	0/0(3)	0	0/0(1)
	Argiope bruennichi Scopoli	0	0	0/3(0)		*Marpissa muscosa* Clerck	0	0/0(2)	0
	Argiope lobata Pallas	0/8(2)	0	6/0(16)		*Pseuditius encarpatus* Walckenaer	1/2(1)	0	0
	Argiope spp.	0	0	0/0(10)		*Salticus spp.*	0/0(7)	0/0(4)	0/0(5)
	Gibbaranea bituberculata Walckenaer	0	0	1/1(0)		*Salticus zebraneus* C.L. Koch	2/1(0)	0/1(0)	0/1(0)
	Gibbaranea spp.	0	0	0/0(2)					
	Mangora acalypha Walckenaer	0/0(2)	0	0/0(6)	**Tetragnathidae**	*Tetragnatha spp.*	0/0(1)	0	0
Clubionidae	*Cheiracanthium mildei* L. Koch	0/0(49)	0/0(125)	0	**Theridiidae**	*Enoplognatha latimana* Hippa & Oksala	0	0	0/1(0)
	Cheiracanthium pennyi O.P. Cambridge	0	0	1/0(0)		*Steatoda albomaculata* De Geer	0/0(1)	0	0
	Cheiracanthium spp.	0/0(7)	0	0		*Theridion (melanurum) spp.*	0	0/0(3)	0
	Clubiona genevensis L. Koch	0	0/0(1)	0		*Theridion (sisyphium-impressum) spp.*	0/0(7)	0	0
	Clubiona spp.	0/0(2)	0/0(5)	0		*Theridion impressum* L. Koch	7/5(0)	0	0
						Theridion pinastri C.L. Koch	0/2(1)	0	0
Gnaphosidae	*Aphantaulax seminiger* Simon	0/1(0)	0	0					
	Aphantaulax spp.	0	0/0(4)	0	**Thomisidae**	*Misumenops tricuspidatus* Fabricius	0	0/0(2)	0

	Drassodes spp.	0/0(1)	0/0(19)	0		*Ozyptila spp.*	0/0(1)	0	0
	Micaria spp.	0	0/0(1)	0		*Pistius truncatus* Pallas	0/0(1)	0	0
	Scotophaeus spp.	0/0(1)	0/0(4)	0		*Runcinia grammica* C.L. Koch	0/0(1)	0	0/0(2)
						Synaema spp.	0	0/0(1)	0
Linyphiidae	*Meioneta rurestris* C.L. Koch	0/1(0)	0	0		*Thomisus onustus* Walckenaer	0/2(0)	0	0/2(2)
						Xysticus cristatus Clerck	0	0	0/1(0)
Lycosidae	*Pardosa spp.*	0/0(1)	0	0		*Xysticus kochi* Thorell	0/1(0)	0	0/5(0)
						Xysticus ninnii Thorell	0	0	0/3(0)
Oxyopidae	*Oxyopes heterophthalamus* Latreille	3/13(0)	0	8/4(0)		*Xysticus spp.*	0/0(26)	0	0/0(57)
	Oxyopes spp.	0/0(49)	0	0/0(83)					
					Titanoecidae	*Titanoeca spp.*	0	0/0(4)	0
Philodromidae	*Philodromus (aureolus) spp.*	0/0(3)	0/0(4)	0/0(1)					
	Philodromus (margaritatus) spp.	0/0(3)	0	0	**Uloboridae**	*Uloborus walckenaerius* Latreille	0	0	1/1(0)
	Philodromus cespitum Walckenaer	0/1(0)	0	0					
	Philodromus margaritatus Clerck	0/1(0)	0	0		indet.	0/0(1)	0	0
	Tibellus oblongus Walckenaer	0	0	1/0(0)					
	Tibellus spp.	0/0(3)	0	0					
						Total	**295**	**180**	**234**

Appendix D

Table 3. The abundance and diversity of foliage-dwelling spiders in differently treated apple orchards, average (±SD) of 2 trees tapped (Kecskemét-Szarkás, beating method, April-October, 1995) α: scale parameter of Rényi diversity

	YoungCON	YoungIPM	OldCON	OldIPM
Abundance of spiders	9.80(3.56)	26.80(5.97)	4.80(4.26)	17.60(7.50)
Abundance of web-builders	1.00(1.22)	3.40(1.14)	1.60(1.82)	4.40(2.61)
Abundance of hunters	8.80(3.03)	23.40(5.32)	3.20(2.77)	13.20(5.97)
Abundance of *Oxyopes heterophthalamus*	4.60(2.70)	5.40(3.97)	1.40(1.14)	1.60(0.89)
Abundance of *Cheiracanthium mildei*	1.00(1.22)	7.40(1.67)	0.00(0.00)	2.80(1.48)
Abundance of *Xysticus spp.*	0.80(0.45)	2.40(1.67)	0.60(0.89)	1.20(1.30)
Abundance of *Eris nidicolens*	0.20(0.45)	1.60(0.89)	0.20(0.45)	2.80(1.09)
Abundance of *Carrhotus xanthogrmma*	0.20(0.45)	3.60(3.21)	0.20(0.45)	0.80(0.84)
Species richness	5.00(2.12)	9.80(1.79)	3.80(3.11)	10.20(4.32)
α (1)	2.13	2.03	2.86	2.79
α (3)	1.48	1.34	2.29	2.21
α (7)	1.21	1.07	1.92	1.82

Table 4. Table of two-way (treatment x age) ANOVA for abundance, species richness of foliage-dwelling spiders and their two guilds, abundance of *Oxyopes heterophthalamus*, *Cheiracanthium mildei*

		abundance		species richness		Web-builders		Hunters		*Oxyopes heterophtalmus*		*Cheiracanthium mildei*	
Source of variation	d.f.	Mean square	F	Mean square	F	Mean square	F	Mean square	F	Mean square	F	Mean square	F
Treatment	1	1110.05	36.13**	156.80	17.37**	33.80	10.48**	756.45	37.40**	1.25	0.20	105.80	65.11**
Age	1	252.05	8.20	0.80	0.09	3.20	0.99	312.05	15.43**	61.25	9.72**	39.20	24.12**
Treatment x Age	1	22.05	0.72	3.20	0.35	0.20	0.06	26.45	1.31	0.45	0.07	16.20	9.97**
ERROR	16	30.72		9.02		3.22		20.22		6.30		1.62	

Appendix D

Table 5. Comparison of Rényi diversity of canopy spider communities with t - test in different aged (young, old) and differently treated (conventional, IPM) apple orchards.
t values (degree of freedom)

Plots \ Scale parameters	1	2	3	4	5	6	7
YoungCON / YoungIPM	0,53 (115) n.s.	0,45 (104) n.s.	0,53 (108) n.s.	0,57 (114) n.s.	0,59 (118) n.s.	0,59 (120) n.s.	0,59 (121) n.s.
YoungCON / OldCON	4,91 (176) **	3,66 (151) **	2,93 (133) **	2,56 (124) *	2,39 (120) *	2,30 (118) *	2,26 (117) *
YoungCON / OldIPM	4,29 (157) **	3,09 (120) **	2,39 (104) *	2,08 (100) *	1,96 (98) +	1,90 (98) +	1,88 (98) +
YoungIPM / OldCON	4,67 (102) **	3,43 (117) **	3,00 (127) **	2,77 (128) **	2,65 (126) **	2,59 (124) *	2,55 (123) *
YoungIPM / OldIPM	4,17 (104) **	2,99 (116) **	2,54 (115) *	2,33 (111) *	2,25 (108) *	2,21 (107) *	2,19 (107) *
OldCON / OldIPM	0,47 (132) n.s.	0,27 (130) n.s.	0,25 (129) n.s.	0,26 (131) n.s.	0,26 (132) n.s.	0,26 (133) n.s.	0,26 (133) n.s.

n.s.: non significant, + : p< 0.10, * : p< 0.05, ** : p< 0.01

Table 6. The abundance, species richness, abundance of *Cheiracanthium mildei* and *Stephanitis pyri* in differently treated apple orchards, average (±SD) of 2 treebands (Kecskemét-Szarkás, treebands, 1995)

	YoungCON	YoungIPM	OldCON	OldIPM
Abundance of spiders	4.60(1.67)	25.60(16.83)	2.00(0.71)	3.80(1.92)
Species richness	2.80(0.45)	5.20(1.09)	1.60(0.55)	2.40(0.89)
Abundance of *Cheiracanthium mildei*	2.40(2.07)	17.20(10.35)	1.20(0.84)	2.00(1.22)
Abundance of *Stephanitis pyri*	2.80(1.92)	212.20(53.00)	0.80(1.30)	1.20(1.09)

Appendix D

Table 7. Table of two-way (treatment x age) ANOVA for abundance, species richness, abundance of *Cheiracanthium mildei* and *Stephanitis pyri*

		abundance		species richness		*Cheiracanthium mildei*		*Stephanitis pyri*	
Source of variation	d.f.	Mean square	F	Mean square	F	Mean square	F	Mean square	F
Treatment	1	649.80	8.95**	12.80	20.48**	304.20	10.70**	55020.05	78.17**
Age	1	744.20	10.25**	20.00	32.00**	336.20	11.83**	56711.25	80.58**
Treatment x Age	1	460.80	6.35*	3.20	5.12*	245.00	8.62**	54601.25	77.58**
ERROR	16	72.57		0.62		28.42		703.82	

Table 8. The abundance and diversity of grass-dwelling spiders in differently treated apple orchards, average (±SD) of 33 sweeps (Kecskemét-Szarkás, sweep netting, 1995), α: scale parameter of Rényi diversity

	YoungCON	YoungIPM	Edge
Abundance of spiders	7.33(4.16)	40.67(12.58)	30.00(9.16)
Species richness	2.33(1.15)	4.67(1.15)	10.00(3.46)
Abundance of *Oxyopes heterophthalamus*	5.67(2.87)	17.33(3.79)	8.67(2.08)
Abundance of *Xysticus spp.*	0.33(0.58)	12.33(7.02)	8.00(1.73)
α (1)	0.84	1.73	2.45
α (3)	0.34	1.30	1.71
α (7)	0.30	1.15	1.49

Table 9. Comparison of Rényi diversity of herbaceous layer inhabiting spider communities with t - test in different aged (young, old) and differently treated (conventional, IPM) apple orchards, t values (degree of freedom)

Plots \ Scale parameters	1	2	3	4	5	6	7
YoungCON / YoungIPM	3,57 (30) *	4,09 (31) **	4,65 (38) **	4,82 (45) **	4,82 (52) **	4,76 (58) **	4,70 (63) **
YoungCON / EDGE	6,17 (35) **	5,53 (52) **	5,77 (62) **	5,98 (65) **	6,09 (68) **	6,14 (70) **	6,13 (73) **
YoungIPM / EDGE	4,73 (181) **	2,81 (148) *	2,26 (158) +	2,05 (174) +	1,95 (185) n.s.	1,89 (191) n.s.	1,85 (194) n.s.

n.s.: non significant, + : p< 0.10, * : p< 0.05, ** : p< 0.01

Appendix E

Table 1. Frequency of insecticide and acaricide sprays in the experimental apple orchard (Kecskemét Szarkás, 1992-94)

Conventional	1992	1993	1994
DNOC	1	0	1
phosphamidon	1	1	1
propargite	2	0	0
methyl-parathion	2	2	2
chlorpropylate	1	0	0
trichlorphon	1	0	0
Bariumpolysulphid	0	1	0
diflubenzuron	0	3	2
dimethoate	0	0	1
deltamethrin	0	0	1
IPM	1992	1993	1994
sulphur + vaselinoil	1	1	1
fenoxycarb	2	0	1
pirimicarb	1	1	2
diflubenzuron	1	3	1
fenbutatin oxide	1	0	0
Bacillus thuringiensis	2	1	2
lufenuron	0	0	2

Table 2. Numbers of different spider species collected at ground level in differently treated blocks and the edge of an apple orchard, Kecskemét-Szarkás, Hungary 1992-94. 10 (or 5*) pitfall traps/plot, male / female (juv.)

Spiders	CON	IPM/1	IPM/2	EDGE *	Total
Titanoecidae					
Titanoeca schineri L. Koch, 1872	33/1(2)	47/1(1)	30/0(7)	40/2(4)	168
Dysderidae					
Harpactea rubicunda C.L. Koch, 1839	0/4(1)	0/5(1)	3/7(2)	8/4(18)	53
Gnaphosidae					
Drassodes lapidosus Walckenaer, 1802	0	0	0	0/1(0)	1
Drassodes villosus Thorell, 1856	0	0	0	3/0(0)	3
Drassyllus praeficus L. Koch, 1866	2/0(0)	0	0	0	2
Haplodrassus signifer C.L. Koch, 1839	0	0	1/0(0)	0	1
Trachyzelotes pedestris C.L. Koch, 1837	0	2/0(0)	2/0(0)	7/1(0)	12
Zelotes apricorum L. Koch, 1876	0	0	0	1/0(0)	1
Zelotes longipes L. Koch, 1866	0	0	0	0/1(0)	1
Zelotes subterraneus C.L. Koch, 1833	0	0	0	1/0(0)	1
Zelotes electus C. L. Koch, 1839	0	0	0	0/1(0)	1
Zelotes spp.	0/0(9)	0/0(5)	0/0(10)	0/0(5)	29
Clubionidae					
Cheiracanthium spp.	0/0(2)	0	0	0	2
Clubiona spp.	0	0	0	0/0(1)	1
Thomisidae					

Misumena vatia Clerck, 1757	0	0/1(1)	0	0	2
Thanatus arenarius Thorell, 1872	1/3(0)	3/0(0)	3/1(0)	1/1(0)	13
Xysticus acerbus Thorell, 1872	0	0	0	0/1(0)	1
Xysticus kochii Thorell, 1872	68/4(0)	111/6(0)	112/3(0)	61/4(0)	369
Xysticus spp.	0/0(4)	0/0(7)	0/0(5)	0/0(9)	25
Salticidae					
Aelurillus v-insignitus Clerck, 1757	0	0	0	1/0(0)	1
Euophris spp.	0	0/0(1)	0	0	1
Salticidae indet.	0	0/0(2)	0	0	2
Oxyopidae					
Oxyopes heterophtalmus Latreille, 1804	0	2/0(0)	1/0(0)	0	3
Lycosidae					
Alopecosa fabrilis Clerck, 1757	0	0	0	1/0(0)	1
Alopecosa sulzeri Pavesi, 1873	6/3(0)	9/1(0)	13/4(0)	39/5(0)	80
Alopecosa spp.	0/0(13)	0/0(16)	0/0(13)	0/0(36)	81
Arctosa perita Latreille, 1799	2/2(0)	1/1(0)	1/0(0)	0	7
Arctosa spp.	0/0(1)	0	0	0	1
Pardosa agrestis Westring, 1862	12/2(0)	19/3(0)	28/3(0)	24/3(0)	94
Pardosa lugubris Walckenaer, 1802	0	0	0	0/1(0)	1
Pardosa spp.	0/0(30)	0/0(38)	0/0(23)	0/0(56)	147
Trochosa (tericola-ruricola)	0/1(0)	0/1(0)	0/1(0)	0/3(0)	6
Trochosa robusta Simon, 1876	0	0	0	0/1(0)	1
Xerolycosa miniata C.L. Koch, 1834	1/2(0)	2/0(0)	0	2/3(0)	10
Xerolycosa nemoralis Westring, 1861	0	1/1(0)	0/1(0)	2/0(0)	5
Xerolycosa spp.	0/0(4)	0/0(2)	0/0(2)	0/0(2)	10
Agelenidae					
Agelena gracilens C.L. Koch, 1841	0	0	0	1/0(0)	1
Agelena labyrinthica Clerck, 1757	0/1(0)	0	0	0/2(0)	3
Tegenaria agrestis Walckenaer, 1802	0	0	1/0(0)	0	1
Tegenaria spp.	0	0	0	0/0(3)	3
Theridiidae					
Steatoda albomaculata DeGeer, 1778	0	0/1(0)	0	0	1
Steatoda phalerata Panzer, 1801	0/1(0)	0	0	0	1
Araneidae					
Argiope lobata Pallas	0	0	0	0/1(0)	1
indet.	0/0(1)	0	0	0/0(1)	2
Total	**216**	**292**	**280**	**359**	**1147**

Appendix E

Table 3. The abundance and the diversity of ground dwelling spiders in different habitats (alleys and tree rows) of differently treated apple orchards and their edge; mean (±SD) indices / trap (N: 5 traps) (Kecskemét-Szarkás, 1992-94)

	CON		IPM/1		IPM/2		EDGE
	Tree row	Alley	Tree row	Alley	Tree row	Alley	
Abundance of spiders	27.60 (15.08)	15.60 (9.61)	35.40 (10.92)	23.00 (7.84)	29.60 (5.90)	24.20 (2.59)	63.80 (18.91)
Abundance of *Xysticus kochi*	8.20 (4.15)	7.00 (6.74)	14.60 (8.35)	10.20 (5.72)	12.80 (4.97)	11.80 (3.27)	13.00 (10.39)
Abundance of *Titanoeca schineri*	5.20 (3.27)	2.00 (1.41)	6.20 (2.59)	3.60 (2.07)	4.80 (2.95)	2.60 (1.82)	6.20 (4.97)
Abundance of *Pardosa agrestis*	6.00 (5.96)	2.80 (3.11)	8.40 (5.46)	3.60 (3.13)	7.00 (4.85)	3.80 (1.92)	15.80 (6.98)
Species richness	7.00 (1.87)	5.00 (1.58)	6.80 (1.30)	6.20 (1.09)	6.00 (1.00)	6.60 (1.14)	11.20 (1.48)
Berger-Parker index	0.34 (0.07)	0.47 (0.14)	0.45 (0.14)	0.43 (0.12)	0.48 (0.13)	0.47 (0.10)	0.32 (0.09)
Shannon-Wiener function	1.94 (0.15)	1.39 (0.39)	1.65 (0.19)	1.67 (0.11)	1.63 (0.35)	1.69 (0.11)	2.24 (0.20)
Evenness	1.01 (0.07)	0.88 (0.12)	0.90 (0.11)	0.93 (0.11)	0.91 (0.11)	0.91 (0.10)	0.93 (0.03)
Williams alfa	3.40 (0.97)	3.05 (1.02)	2.35 (0.49)	3.07 (0.96)	2.32 (0.52)	3.09 (0.88)	4.19 (1.13)
Q-diversity	3.83 (0.63)	2.78 (0.98)	2.43 (0.32)	3.17 (0.77)	2.58 (0.69)	3.07 (0.60)	4.39 (1.04)

Table 4. Two-way (treatment x habitat) ANOVA for abundance, species richness (treatments: conventional, IPM; habitats: alley, tree row)

		abundance		species richness	
Source of variation	d.f.	Mean square	F	Mean square	F
Treatment	2	151.9	1.68	0.633	0.34
Habitat	1	740.033	8.19**	3.333	1.79
Habitat x Treatment	2	38.633	0.43	4.233	2.27
ERROR	24	90.317		1.867	

** Significant differences: $p < 0.01$

Appendix E

Table 5. Two-way (treatment x habitat) ANOVA for Berger-Parker index, Shannon-Wiener function, Equitability, Alfa diversity, Q diversity (treatments: conventional, IPM; habitats: alley, tree row)

		Berger-Parker index		Shanonn-Wiener function		Equitability		Alfa diversity		Q diversity	
Source of variation	d.f.	Mean square	F	Mean square	F	Mean square	F	Mean square	F	Mean square	F
Treatment	2	0.011	0.8	0	0	0.005	0.47	0.893	1.28	0.803	1.67
Habitat	1	0.011	0.77	0.175	2.89	0.007	0.63	1.087	1.56	0.029	0.06
Habitat x Treatment	2	0.019	1.34	0.285	4.72*	0.017	1.57	1.008	1.44	2.348	4.88*
ERROR	24	0.014		0.06		0.011		0.698		0.481	

** Significant differences: $p < 0.05$

Table 6. Comparison of abundance, species richness of epigeic spider assemblages and abundance of *Pardosa agrestis* in the border and in the different treated plots, Tukey-Kramer pairwise comparison of means (k=7, df=28)

EDGE	CONrow	CONalley	IPM/1row	IPM/1alley	IPM/2row	IPM/2alley
Total abundance	7.14**	9.51**	5.6**	8.05**	6.75**	7.81**
Total species richness	5.38*	6.36**	5.38*	6.11**	6.11**	6.11**
Abundance of *Pardosa agrestis*	4.57*	6.07**	3.45	5.69**	4.11+	5.6**

Significant differences: + $p < 0.10$; * $p < 0.05$; ** $p < 0.01$

Table 7. Two-way (treatment x habitat) ANOVA for abundance of *Xysticus kochi*, *Titanoeca schineri*, *Pardosa agrestis* (treatments: conventional, IPM; habitats: alley, tree row)

		Xysticus kochi		*Titanoeca schineri*		*Pardosa agrestis*	
Source of variation	d.f.	Mean square	F	Mean square	F	Mean square	F
Treatment	2	75.233	2.25	5.233	0.88	12.933	0.75
Habitat	1	36.3	1.09	53.333	8.96**	80.033	4.67*
Habitat x Treatment	2	9.1	0.27	0.633	0.11	4.933	0.29
ERROR	24	33.433		5.95		17.133	

Significant differences: * $p < 0.05$; ** $p < 0.01$

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Curriculum Vitae

Sándor Bogya was born on 9 March 1969 in Budapest, Hungary. After the secondary school, he studied in the Faculty of Horticulture in the University of Horticulture and Food Industry in Budapest from 1989 to 1995, where he obtained his MSc degree with a specialisation in Crop Protection. After he finished the fourth year at this university, he spent 10 months at the Department of Entomology of Wageningen Agricultural University, where he investigated the role of spiders (Araneae) in controlling orchard pests. Since graduation he has been involved in the "Sandwich PhD program" of WAU, where he continued the research on predatory spiders in the experimental orchard "De Schuilenburg". In Hungary, he has been involved in the Apple Ecosystem Research co-ordinàted by the Hungarian Research Institute for Plant Protection, where he first worked on click beetles (Elateridae) and later within a USDA funded project he studied spiders.

Since 1992 he has been a member of the Hungarian Entomological Society. For his research work, he received the "Pro Scientia" medal (1995) from the Hungarian Academy of Sciences and the "Gusztáv Szelényi" Price (1998) from the Hungarian Crop Protection Society.

His research interest is to unravel the ecological factors determining the composition of spider communities in orchards, to study the qualitative and quantitative role spiders play as predators of pest species, and to investigate possibilities for improved Integrated Pest Management by spiders in orchards.