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Introduction

This monothematic issue of Horticultural Science presents a set of works that bring together some results of research carried out in the international research project „Maximizing Biological Control in Integrated Pest Management of Pome Fruits" sponsored by United States Department of Agriculture Grant No. 58-319R-3-02, in 1992–1994. This project was designed by a group of scientists from Appalachian Fruit Research Station, Kearneysville, West Virginia, lead by Mark W. Brown and integrated research activities at several applied laboratories of Central Europe, in Poland, Hungary, Romania and Czech Republic. The works were partly funded from the United States Department of Agriculture.

The project was aimed at research required for introducing Integrated Pest Management (IPM) into the system of protection of apple orchards and comparing the efficiency of new technologies with the classical system of chemical protection. The regional results of Central Europe were compared with results obtained from central-eastern area of the United States of America. The project in fact, started a new era of scientific collaboration between research workers from Central Europe and their colleagues of the United States, a collaboration which was formerly limited by political and material situation. The scientific collaboration and material help hastened the development of IPM programmes of the participating Central European countries and also revealed that the level of applied research in these states could approach the standards of US science.

The project successfully started the transformation of production systems in Central European participants. Already the initial results presented here indicate that introducing IPM is a progressive and both economically acceptable and ecologically favourable technology for apple production. Further results concerning changes of entomocenoses after introducing IPM programmes will be published in the next future. Research projects in participating countries continue the works so promissively started by this collaboration. Some of these projects include bi-lateral international collaboration. Numerous formal and non-formal links between central European and US scientists that participated in the project were established.

The workers participating in the project are partially indebted to the leading person and designer of the research work, Mark W. Brown of the Appalachian Fruit Research Station, Kearneysville, West Virginia. We would like also commemorate our dear colleague Professor Tudorel Baicu of the Research Institute of Plant Protection of Bucharest who deceased early after finishing the project. The published contribution included in this volume is one of his last works and we hope that the redaction did not endanger the valuable results presented in this work.

F. Kocourek, A. Honěk

Úvod

Toto monotematické číslo je souborem prací, které vznikly na základě řešení mezinárodního výzkumného projektu „Maximalizace biologických metod ochrany v systému integrované ochrany jádrovin" (Maximizing Biological Control in Integrated Pest Management of Pome Fruits) částečně sponzorovaného Ministerstvem zemědělství USA (United States Department of Agriculture, grant č. 58-319R-3-02) a řešeného v letech 1992 až 1994. Tento projekt byl navržen pracovníky výzkumné stanice Appalachian Fruit Research Station, Kearneysville, West Virginia, USA, pod vedením dr. Marka W. Browna a podílela se na něm výzkumná pracoviště zemí střední Evropy – Polska, Maďarska, Rumunska a České Republiky.

Cílem řešení projektu bylo zavedení systému integrované ochrany v jabloňových sadech a porovnání této technologie s klasickou ochranou v různých regionech Evropy ve srovnání s podmínkami Západní Virginie. Řešením projektu byla zahájena nová etapa spolupráce mezi vědci ze zemí *střední Evropy a vědci z USA. V průběhu řešení se ukázalo, že úroveň výzkumu integrované ochrany ovocných sadů v uvedených evropských zemích je na srovnatelné úrovni s výzkumem v USA.*

Již dílčí výsledky řešení ukázaly, že zavedení IPM v jabloňových sadech je progresivní, životaschopnou a ekonomicky i ekologicky výhodnou technologií pěstování ovoce. Další výsledky řešení projektu, přinášející analýzy entomofauny sadů po zavedení IPM, a poznatky základního výzkumu budou dále publikovány. Na řešení projektu ve zúčastněných zemích navazují další národní projekty, ve kterých je v řadě případů pokračováno v řešení dvoustrannými projekty i neformální spoluprací pracovišť.

Řešitelé projektu děkují Ministerstvu zemědělství USA (USDA) za iniciativu a podporu při řešení projektu. Zvláštním díkem jsou pak zavázáni za pomoc a kordinaci dr. Marku W. Brownovi z Appalachian Fruit Research Station, Kearneysville, West Virginia. *Naše vzpomínka patří profesoru Tudorelu Baicovi, který zemřel krátce po ukončení prací na řešení projektu. Zde publikovaná studie je jednou z jeho posledních prací. Vydavatelé doufají, že redakce neovlivnila toto dílo nepříznivým způsobem.*

F. Kocourek, A. Honěk

ENHANCED BIOLOGICAL CONTROL IN APPLE ORCHARDS USING GROUND COVERS AND SELECTIVE INSECTICIDES: AN INTERNATIONAL STUDY*

ZVÝŠENÁ BIOLOGICKÁ OCHRANA V JABLOŇOVÝCH SADECH S POUŽITÍM PŘÍZEMNÍ VEGETACE A SELEKTIVNÍCH INSEKTICIDŮ: MEZINÁRODNÍ STUDIE

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ABSTRACT: Conventional apple pest management was compared with the use of selective pesticides and ground cover plantings in paired orchards in Poland, Czech Republic, Hungary, Romania and USA. Orchards, 0.5 to 5 ha, were managed using similar experimental protocols with adaptations for local conditions. There was an increase in biological control at all sites as a result of the experimental management. Some secondary pests were noted to be increasing in abundance due to the reduced usage of broad spectrum pesticides. There was a slight reduction in yield and fruit quality in some plots, but careful selection of ground covers and their management can overcome these reductions. Under the current economic realities of orchard production these practices are not practical. Research continues and as more strict restrictions on pesticide use come into being the use of ground covers and selective pesticides will be a viable alternative.

integrated pest management; apple; cooperative research; biological control; ecosystem management; selective insecticides; scab resistant varieties

ABSTRAKT: V párových ovocných sadech v Polsku, České republice, Maďarsku, Rumunsku a USA byla porovnávaná tradiční ochrana proti jabloňovým škůdcům s použitím selektivních pesticidů a výsadbou přízemní vegetace. Sady o rozloze 0,5 až 5 ha byly řízeny podle obdobných pokusných plánů přizpůsobených místním podmínkám. V důsledku experimentálně řízené ochrany došlo na všech stanovištích ke zvýšení biologické ochrany. Bylo zjištěno, že se počty některých sekundárních škůdců zvyšovaly jako výsledek omezeného používání širokospektrálních pesticidů. Na některých pozemcích došlo k mírnému snížení úrody a kvality plodů, ale toto snížení lze vyrovnat pečlivým výběrem přízemní vegetace a její ochranou. Za dané ekonomické reality produkce sadů nejsou tato opatření praktická. Ve výzkumu se pokračuje a se zaváděním přísnějších omezení týkajících se používání pesticidů se stává perspektivní variantou využití přízemní vegetace a selektivních herbicidů.

systém integrované ochrany; jabloň; výzkumná spolupráce; biologická ochrana; řízení ekosystémů; selektivní pesticidy; odrůdy odolné proti strupovitosti

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INTRODUCTION

In September 1991, the U. S. Department of Agriculture (USDA) convened a meeting of researchers from the USA and the newly democratic countries of Central and Eastern Europe to discuss a three-year cooperative project to demonstrate integrated pest management in these countries. The goal was to transfer technology to maximize biological control and minimize use of pesticides in apple orchards. The justification of the project was both economic development and environmental concerns. A second meeting was convened in Harpers Ferry, West Virginia, USA, in March 1992, to complete work plans for the cooperative project. In November, 1992, a third meeting was held in Pitesti, Romania, to discuss results of the first year's experiments and to coordinate work to be done in the remaining two years of the project. The project was funded with USDA/ICD and US/AID money with matching funds from each participating country. Apple orchards with ground cover plantings and pest management using selective pesticides and a matching control orchard with conventional practices were established in Poland, Czech Republic, Hungary, Romania, and the USA. Although the objective of the project was to demonstrate IPM to private farmers in the region, this project also provided a unique opportunity to replicate a large-plot ecosystem manipulation experiment across a north-south continental gradient (Poland–Romania) and between continents (Europe and North America).

The importance of these studies lies in large scale replication. To evaluate the effects of changes in management practices on the ecology of an agroecosystem, research plots must be large enough to ensure that results are attributable to the change in management and not to edge effects or transient influences. This size requirement makes replication very difficult due to limitations in available manpower, land, and monetary resources. This project not only provided the resources for each country to establish a research plot, but also provided the mechanism to coordinate intra- and inter-regional replication. Details of the methodology were not replicated exactly, so specific results cannot be considered as independently confirmed. However, the overall philosophy of pest control using ground covers and selective pesticides and a reliance on biological control was replicated in five different countries in Europe and North America and general conclusions relating to that philosophy are validly replicated. In the papers that follow, specific results from individual studies are presented. This paper presents general conclusions based on the multinational replication. These conclusions are based on discussions among the authors when we met in March 1995 in Skierniewice, Poland, to present our individual results and to compile overall conclusions.

METHODS

Each country established paired orchards, 0.5 ha minimum size for each orchard, to test the effect of ground cover plantings and selective pesticides with a control of conventional practices. Orchards were monitored for three years to examine the effect of this pest management strategy on pest populations, beneficial organisms, pathogens and the economics of orchard production (yield, fruit quality, and cost of production). Each European country conducted the study on mature, fruit-bearing orchards. In the US, a large orchard was not available so a new orchard was planted to study pest management effects and ground covers were established in a small orchard of 7 year-old trees specifically to test horticultural aspects of ground covers.

In mature orchards, at least 4 species of ground covers were planted in 1.5 m wide strips under the tree canopy. Each ground cover strip was of one species, a second species in the next strip and so on until each species was used, this pattern was repeated with the some order of ground covers throughout the orchard. Alternating rows of ground cover maximized exposure of each apple tree to the effects of each species of ground cover plant. Species selection for the ground covers varied from country to country to suit local conditions and seed availability. The ground cover plants were selected for flower production to supply nectar and pollen for beneficial insects, or as a source of alternate prey to keep beneficials in the orchard ecosystem.

The results presented in this paper are those results that were consistent throughout all five replicates. Because each replicate was not identical, data cannot be presented to support these results but will be published by the individual cooperators. The results are based on replicated trials with the same methodology and have, therefore, been confirmed under the very different environmental conditions of the five cooperating countries.

RESULTS AND DISCUSSION

The use of selective insecticides and ground cover plants in the orchard was a success in that all replicates of this study showed an increase in biological control. In particular, control of *Panonychus ulmi* with predators was achieved. In some cases the successful introduction of the predator *Typhlodromus pyri* was made to supplement native mite predators. Parasitism rates on leafminers and leafrollers were also significantly higher as a result of the experimental protocols. Throughout the various projects, increases were noted in parasitic *Hymenoptera*, predatory *Heteroptera*, predatory mites, predators of aphids, and spiders.

Economically, this philosophy of pest management was not as successful as it was ecologically. Yields from the experimental plots consistently were equal to or slightly less than for the conventional orchards. Fruit quality, as measured by incidence of injury and using USDA fruit grading standards, was generally equal to that of conventional plots. These yield results, when combined with the added cost, in labor and money, of establishing and maintaining the ground covers and the generally more expensive selective pesticides, make this philosophy of pest management currently infeasible. However, legislative and consumer pressures could change the economics for this system to eventually be more cost effective than the conventional system. Continued research to maximize the effectiveness of selective pesticides and ground covers is needed to provide satisfactory alternatives for the future.

One aspect of this experiment that was economically successful was the use of apple scab (*Venturia inaequalis*) resistant cultivars. Eliminating the need for all fungicides for scab control significantly reduced the number of fungicide applications and the cost of fungicides. Caution will have to be used when apple scab resistant cultivars are used because many of the fungicides used for scab also control diseases of secondary importance, many of which are no longer familiar because of the effectiveness of modern fungicides. There is also the problem of the scab fungus overcoming the resistance and once again requiring numerous applications. Before scab resistant varieties can be planted to a large extent, the reluctance of consumers to accept these varieties must be overcome.

One objective of this project was to identify potential pest problems as a result of introducing new plant species into the orchard system. Several insect pests (*Anthonomus pomorum, Dysaphis devecta, Stephanitis pyri*) have increased in the experimental orchards because of the reduced use of broad spectrum insecticides. There were no pests that were observed to build up in the ground cover plants and move into the trees, but numerous predators were observed in both trees and ground covers. One pest (*Synanthedon myopaeformis*) was better controlled in the experimental orchard than in the conventional because of the effectiveness of insect growth regulators on this insect. In one orchard, apple scab was much more serious in the experimental orchard, but this was a result of using ground cover species that grew too tall and created a habitat that had optimal environmental conditions for the pathogen and was protected from fungicides. Another orchard had reduced tree vigor due to planting the ground covers too close to the trees. These last two problems can easily be remedied by better management and species selection of ground cover plants.

CONCLUSIONS

Six conclusions were made based on the replicated results of the cooperating research groups.

1. Biological control of insect pests was enhanced by the use of selective pesticides and ground cover plantings, mite control was especially noted but predation of aphids and parasitism of leafrollers and leafminers was also increased.

2. Secondary pests were not a problem but several pests were observed to be building up in the experimental plots. Potentially, this is a serious problem and shows the need for vigilant monitoring.

3. Economically, the use of ground covers is not currently feasible but more research is being conducted to refine management of ground covers and species selection.

4. Selective pesticides were effective but costs are generally higher and long term effectiveness is not guaranteed.

5. The only adequate control of apple diseases with reduced pesticide use at the current time is with the use of disease resistant cultivars.

6. Fruit quality and yield are close to that attained in conventional orchards. At the present time the environmental and health benefits of using selective chemicals and ground covers is not reflected in the economics of orchard production and at present these new methods can not be implemented.

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IMPACT OF GROUND COVER PLANTS ON PEST MANAGEMENT IN WEST VIRGINIA, USA, APPLE ORCHARDS*

VLIV PŘÍZEMNÍ VEGETACE NA OCHRANU PROTI ŠKŮDCŮM V JABLOŇOVÝCH SADECH V ZÁPADNÍ VIRGINII, USA

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ABSTRACT: Four ground cover species were found to have minimal effect on productivity in a study with mature apple trees in West Virginia, USA. In a second study, two apple orchards were planted in 1992, to test the effects of diverse ground cover plants on integrated pest management (IPM). The conventional orchard was managed according to standard commercial practices and the IPM orchard was planted with *Secale cereale* and *Trifolium pratense*. The IPM orchard received a *Bacillus thuringiensis* spray in May 1993, the conventional orchard had an application of azinphosmethyl. Fungicide applications were similar for the two orchards. An introduction of branches from an unsprayed orchard enhanced biological control of *Panonychus ulmi*. Adult parasitic hymenoptera were more abundant and diverse in the IPM orchard. Ground covers reduced the vigor of the trees which resulted in much lower aphid populations than in the conventional orchard, thus reducing the number of aphidophagous species. However, the beneficial community had similar diversities in both orchards, indicating more diverse community of non-aphidophagous predators. The community of phytophagous insects in the IPM orchard was also more diverse than in the conventional orchard, providing a more stable food source for predators. Of the diseases, only powdery mildew showed a response with fewer mildew infections in the first year after planting in the orchard with ground covers.

apple; agroecosystem; integrated pest management; biological control; ground covers

ABSTRAKT: Během studia dospělých jabloní v Západní Virginii (USA) bylo zjištěno, že čtyři druhy přízemní vegetace mají zanedbatelný vliv na produktivitu. Při dalším studiu byly v roce 1992 vysazeny dva jabloňové sady za účelem zkoumání vlivu rostlin různorodé přízemní vegetace na ochranu proti škůdcům. V tradičním sadu se hospodařilo podle standardních komerčních praktik a sad s IPM (systém integrované ochrany) byl osázen druhy *Secale cereale* a *Trifolium pratense*. V sadu s IPM byl v květnu 1993 aplikován postřik obsahující *Bacillus thuringiensis*, v tradičním sadu azinphosmethyl. Použití fungicidů bylo v obou sadech obdobné. Větve ze sadu bez postřiku zlepšily biologickou ochranu proti *Panonychus ulmi*. Dospělci parazitních blanokřídlých byly početnější v sadu s IPM a vyskytovaly se zde ve více druzích. Přízemní vegetace snižovala vzrůst stromů, což vedlo k mnohem nižším počtům mšic ve srovnání s tradičním sadem a snižovalo počet afidofágních druhů. Příznivě působící společenství však vykazovalo v obou sadech obdobnou diverzitu a naznačovalo rozmanitější společenství neafidofágních predátorů. Společenství fytofágních druhů hmyzu v sadu s IPM bylo rovněž rozmanitější než v tradičním sadu a poskytovalo predátorům stabilnější zdroj potravy. Pokud se jedná o výskyt chorob, v prvním roce po výsadbě v sadu s přízemní vegetací se objevilo pouze padlí travní ve formě méně četných infekcí.

jabloň; agroekosystém; systém integrované ochrany; biologická ochrana; přízemní vegetace

INTRODUCTION

Alternative pest control methods need to be developed to allow production of food and fiber with less reliance on pesticides. One alternative is to encourage more natural control of pest populations. Apple ecosystems are endowed with a large and diverse community of arthropods, including beneficial as well as phytophagous species (Oatman et al., 1964; Horsburg and Asquith, 1968; Mészáros, 1984). There have been numerous reports of how orchard management practices can affect the arthropod community (LeRoux, 1960; Hull and Starner, 1983; Brown and Adler, 1989). However, manipulations

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of the ecosystem specifically for the purpose of pest management has been limited (Solomon, 1981; Prokopy, 1994; Wyss, 1995). Although the dynamics of the arthropod community in the apple ecosystem are influenced by the surrounding habitat (Szentkirályi and Kozár, 1991), modifications in orchard management can impact community development (Brown and Welker, 1992).

In this study, we investigated methods of orchard management that will enable more effective biological control of arthropod pests. Increasing the plant diversity of an orchard should enhance biological control by providing alternative hosts, other food sources such as nectar or poller, refugia, and more diverse habitats for resting, mating or other niche requirements various species may require (Bugg and Waddington, 1994). Use of selective pesticides, only when essential, will protect the beneficial species that are attracted to the diverse habitat (Niemczyk et al., 1990). Herein, we document the development of the arthropod community in an apple orchard for the first three years after planting, and the effects of increased ground cover diversity on that community.

An holistic approach to orchard management such as this study has far-reaching effects beyond just arthropod pest managment. Not only do ground covers affect the arthropod community dynamics but also the micro-organism community, including plant pathogens and their antagonists (Andrews and Kenerley, 1978; Griffiths, 1981). Treatments also have impact on horticultural properties such as growth and yield. Planting of a ground cover may eliminate an insect pest but if it promotes disease pressure or reduces yield, that practice would not be useful and would not be implemented by farmers who must earn a profit from their orchard ecosystem. Much research is needed to define the optimal combination of practices that would be best for each apple production region.

MATERIALS AND METHODS

The first study was conducted to examine the effect of ground cover plantings on yield of mature trees in an established orchard and the effects of irrigation. The orchard was planted in 1985 with spur red Delicious on MM.107 rootstock at 2 x 8 m spacing. Plot size in this study was considered to be too small to evaluate the effects of treatments on the arthropod community and disease incidence so only data on horticultural aspects were taken. From 1985 through 1991, the orchard was maintained with conventional disease and insect protection and a 2.5 m wide herbicide-treated vegetation-free strip. In 1992, a split plot design, replicated four times, was imposed with irrigation (none versus 45.5 liters/tree/day from late June through harvest) as the main plot and ground cover treatment as the subplot. Ground cover treatments were bare soil strip 2.5 m wide; bean, *Phaseolus vulgaris*, seeded at 1.1 kg/m^2; buckwheat, *Fagopyrum sagittatum*, seeded at 0.7 kg/m^2; dill, *Anethum graveolens*, seeded at 0.3 kg/m^2; and sorghum, *Sorghum bicolor*, seeded at 0.9 kg/m^2. The cover crops were seeded in the spring of 1992 to 1994 into a 0.75 x 6.0 m strip under both sides of the trees leaving a 1.0 m wide vegetation free strip in the center of the tree row. Trunk diameter was measured during the dormant season, leaf samples were collected in July to sample leaf nitrogen, and yield data were taken in September. Yield data are reported per cross-sectional area of the tree trunk because size of the trunk is an important determinant of potential yield (Waring, 1920).

In a second study, two adjacent apple orchards were planted in 1992. Three fourths of each orchard was planted with Empire and Golden Delicious, the rest with the apple scab resistant Liberty and Priscilla; all were on M.7A rootstock planted at 5 x 3.5 m tree spacing. One orchard (hereafter referred to as the conventional orchard), 0.75 ha, was managed using conventional management methods, the other orchard (hereafter referred to as the IPM orchard), 0.89 ha, received a diverse ground cover and selective insecticides. The conventional orchard had a 2.5 m herbicide-treated bare soil strip under the trees with Kentucky-31 fescue between rows. The IPM orchard had only a 0.5 m bare strip of soil (herbicide-treated) under the trees and a 1 m strip of mixed rye (*Secale cereale*) and red clover (*Trifolium pratense*) on either side and Kentucky-31 fescue between rows. Diameters of twenty trees per cultivar from each orchard were measured each year after the trees became dormant.

Arthropod pest management was not needed except for mite treatment in 1992 and 1994 and gypsy moth control in 1993. In 1992, *Panonychus ulmi* began to cause visible injury. Bouquets of apple branches from a mature unsprayed orchard were tied onto 4 trees in the IPM orchard on July 17; the mites were left uncontrolled in the conventional orchard. A dormant oil spray was applied to the conventional orchard in March 1994; no treatments were applied to the IPM orchard. The conventional orchard received azinphosmethyl on May 14, 1993, and the IPM orchard *Bacillus thuringiensis* (Bt) also on May 14, reapplied on May 21 because of inadequate control due to heavy rain on the night of May 14.

Monthly arthropod sampling was done with sweep net of the ground cover and visual examination of the tree. Sweep net samples were taken at 5 locations in each orchard, sampling was not done within 3 days of mowing. In 1992, tree sampling was done by examining two transects of 15 trees per orchard recording aphids, leafhoppers, leafminers, spiders and other predators. In 1993 and 1994, whole tree samples of 10 trees per orchard was conduced, recording all arthropods detected. Analysis was with Shannon's Index of diversity for parasitic *Hymenoptera* (identified to family level) in the sweep net samples, and for phytophagous and beneficial communities on the whole tree samples. Comparisons between orchards were with paired *t*-test using variance estimates from Hutcheson (1970).

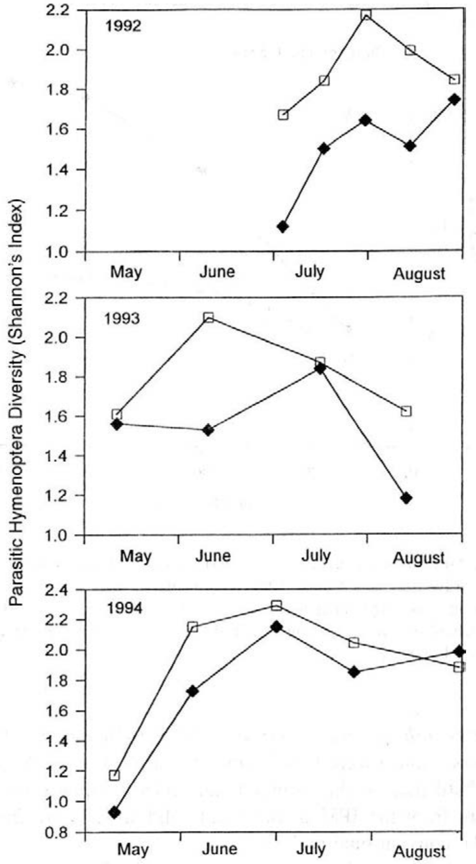
Apple disease control, only on the scab susceptible cultivars, was identical in the IPM and conventional orchards requiring applications of captan on 14 July and 12 August, 1993. No other disease management was implemented. Diseases were monitored by counting the number of trees infested with apple scab (*Venturia inaequalis*), fire blight (*Erwinia amylovora*) and powdery mildew (*Podosphaera leucotricha*) in 1993. In 1994, each tree was rated on a scale of 1 to 4 (1 meaning no infection, 4 meaning heavy infection) and an average for each orchard and cultivar estimated. Significance was tested with a chi-square analysis test for association.

RESULTS AND DISCUSSION

The ground cover plants had no significant effect on the yield of the mature orchard (Tab. I). The overall effect of irrigation was not significant and data for irrigated and non-irrigated were pooled. In 1992 and 1994 there were light crop loads on the trees and in 1993 a heavy crop load, none of the ground cover treatments had a consistent effect on yield. Nitrogen content of the foliage from each treatment ranged from 2.4 to 2.6 per cent, indicating adequate levels of nitrogen for tree vigor (Westwood, 1978).

Diversity of adult parasitic hymenoptera in the ground cover was significantly greater ($P < 0.01$) in the IPM orchard than in the conventional orchard (Fig. 1). At all sample periods there were more families represented and more individuals in the IPM orchard. Although these data are adults without host records, they do indicate that there were more adult parasites foraging in the more diverse ground cover than with conventional management (Bugg and Waddington, 1994).

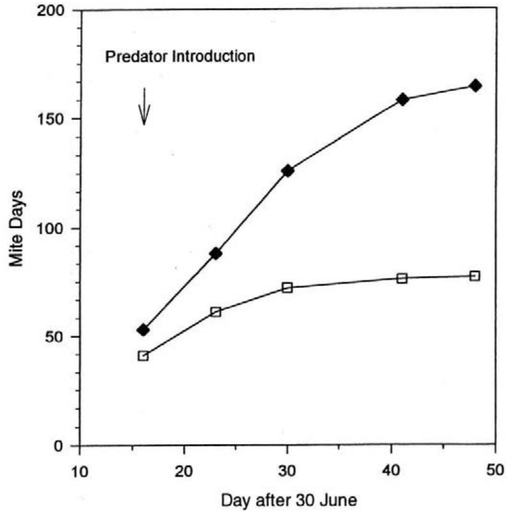
Introduction of apple branches from a mature unsprayed orchard in the IPM orchard was effective in controlling mites (Fig. 2). *Panonychus ulmi* populations were initially lower in the IPM orchard but population growth was slowed three weeks earlier in the IPM orchard than in the conventional, which had no mite control applied. Mite predators were not identified on the bouquets of apple branches but the intent was to introduce a mature mite predator community into the IPM orchard to accelerate the establishment of a viable mite control system (Strickler et al., 1987). The earlier decrease in mite populations does indicate that the predator introduction was succesful. Also, in 1993, the mite predators *Leptothrips mali* (*Thysanaptera:*



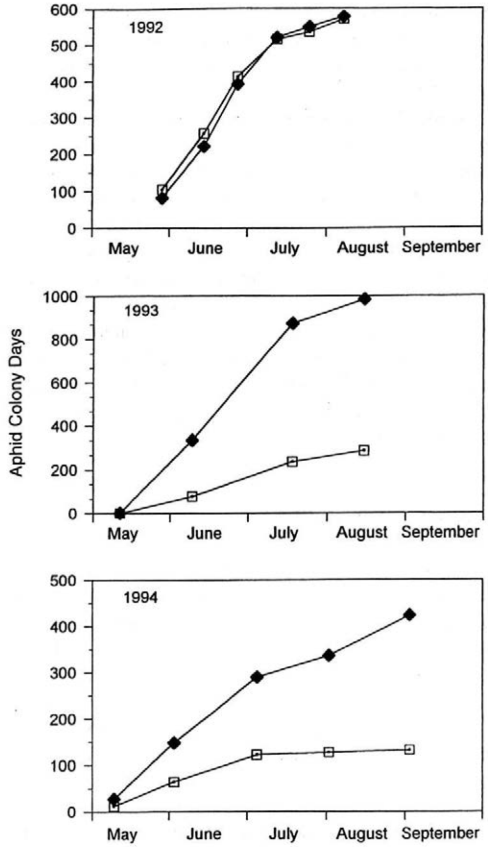
1. Diversity of adult parasitic *Hymenoptera* collected in ground cover in the IPM and conventional orchards with sweep net sampling. Open squares are from the IPM orchard and solid squares are from the conventional orchard

I. Weight of harvested fruit per trunk cross-sectional area from mature apple trees with various ground covers planted under the tree canopy

Ground cover	Fruit weight in kg per cm^2 – trunk cross-sectional area		
	1992	1993	1994
Bare ground	0.18	0.61	0.15
Phaseolus vulgaris	0.14	0.58	0.14
Fagopyrum sagittatum	0.16	0.54	0.11
Anethum graveolens	0.12	0.61	0.09
Sorghum bicolor	0.10	0.52	0.16



2. Mite-day accumulation in the IPM orchard and conventional orchard in July and August, 1992. Mite predators were introduced on bouquets of apple branches from an unsprayed orchard into the IPM orchard on July 17, no mite control was conducted in the conventional orchard



3. Aphid (*Aphis* spp.) colony days, estimated number of days per tree there were aphid colonies present, in the IPM and conventional orchards, 1992–1994. Open squares are from the IPM orchard and solid squares are from the conventional orchard

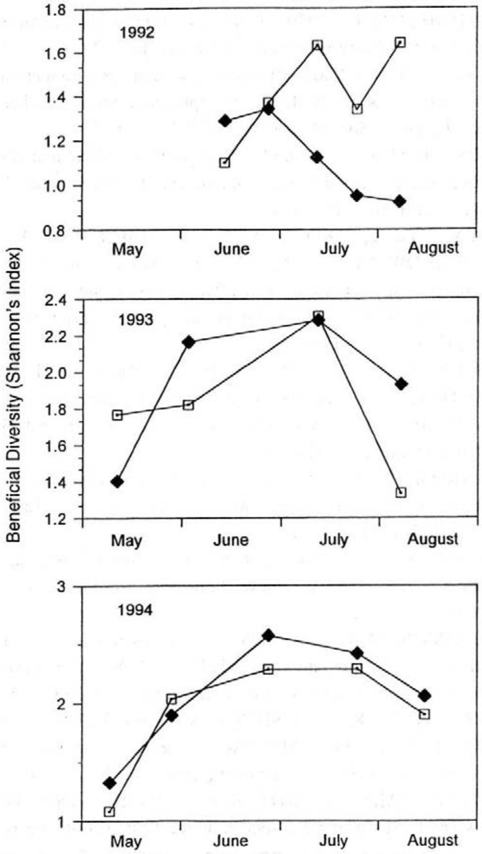
Phlaeothripidae) and *Orius insidiosus* (*Hemiptera: Anthocoridae*) were found a month earlier in the IPM orchard than in the conventional orchard. Open squares are from the IPM orchard and solid squares are from the conventional orchard.

Aphis populations were also under a higher degree of control in the IPM orchard than in the conventional orchard (Fig. 3). The primary factor involved in controlling aphids in the IPM orchard was reduced tree vigor, not an increase of aphid predators. After three years of growth, the trees in the IPM orchard had significantly smaller trunk diameters ($P < 0.05$) than those in the conventional orchard (Tab. II). Increased competition between apple and the ground cover plants did inhibit apple tree growth which limited aphid populations.

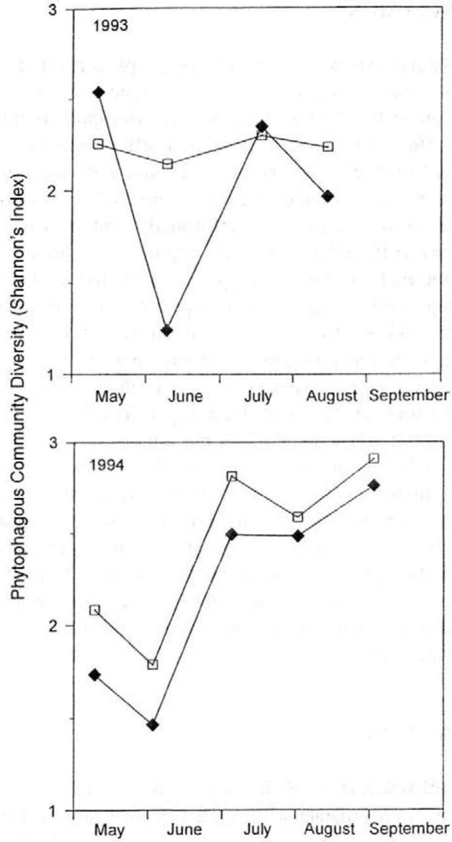
In the first year (1992) the community of beneficials had higher diversity in the IPM orchard, but overall there was no significant difference ($P > 0.10$) between the two communities (Fig. 4). Aphids generally comprise a large proportion of the prey for generalist predators, and as is shown in Fig. 3, the IPM orchard had fewer aphids than the conventional orchard. Even though aphid prey was less abudant, the IPM orchard was able to support an equally diverse beneficial community. The dominant predators in the conventional orchard were the more aphidophagous and acarophagous groups such as chrysopids, cecidomyiids, *O. insidiosus* and *L. mali*. In the IPM orchard the domi-

II. Annual growth in trunk cross-sectional area of various cultivars under conventional (bare soil) or IPM (*Secale cereale* and *Trifolium pratense*) in a young orchard planted in 1992

Cultivar	Growth increases in cross-sectional area (cm^2)			
	1993		1994	
	Conventional	IPM	Conventional	IPM
Empire	6.7	2.9	14.2	7.4
Golden Delicious	6.3	3.1	13.7	9.2
Priscilla	7.9	3.3	13.3	8.7
Liberty	9.0	3.8	9.9	8.8



4. Diversity of the beneficial community in the IPM and conventional orchards, 1992–1994. Open squares are from the IPM orchard and solid squares are from the conventional orchard



5. Diversity of the phytophagous community in the IPM and conventional orchards, 1993–1994. Open squares are from the IPM orchard and solid squares are from the conventional orchard

nant predators were spiders (*Araneae*), especially Salticids, and *Forficula auricularia* (*Dermaptera: Forficulidae*) in 1994.

The phytophagous community (1993 and 1994) was slightly more diverse ($0.10 > P > 0.05$) in the IPM orchard than in the conventional orchard (Fig. 5). A more diverse phytophagous community is ecologically more desirable because there would be a greater range of prey and therefore would support a more stable community of beneficials. In June, 1993, there was a dramatic decrease in diversity in the conventional orchard after the azinphosmethyl application but not in the IPM orchard following use of Bt (Fig. 5). The most striking difference at this sample was a total lack of lepidopterans in the conventional orchard. The elimination of one complete group of insects could have an important depressing effect on the beneficial community by removing prey for a significant portion of the community.

Apple scab occurred with equal rates of infection in both orchards. In 1993, 20 per cent of all scab susceptible cultivars had scab infections. In 1994, the infestation rating ranged from 1.3 to 2.5 with no differences between conventional and IPM treatments. Powdery mildew was only rated in 1993 and there was nearly a two-fold higher infection rate ($P < 0.10$) in the conventional orchard (2.8 per cent of the trees infected) than in the IPM orchard (1.5 per cent of the trees infected). This was a very light infection but reveals a potential benefit in disease management due to the use of ground covers that should be further investigated. Fire blight was rare during the study but in 1994, it was more prevalent in the conventional orchard (a rating of 1.9 of versus 1.1 in the IPM orchard). The higher infection in the conventional orchard is attributable to the greater vigor in that orchard (Tab. II). In 1994, the only apple blossoms were on the cultivar Liberty in the conventional orchard and blossoms are the primary infection site of fire blight (van der Zwet and Beer, 1995). Reducing fungicide applications and relying on greater natural control of diseases may not be practical under current conditions (Penrose, 1995), but this approach to disease management does warrant further study.

CONCLUSIONS

We have shown that increasing the plant diversity in an orchard by planting a variety of ground cover species under the trees does affect the arthropod community. There were some very obvious effects but most of the differences were very subtle and not easily explained. These studies will be continued to evaluate further development of the arthropod community under the two different management regimes. We have also shown that ground cover plants may affect disease management in the orchard, especially with powdery mildew. Ground cover plants also have a direct effect on growth and productivity of the apple trees. In the young orchard, ground covers were planted too close to the trees and reduced their vigor. The lower vigor did inhibit aphid populations but a more serious effect was to lower the yield potential of those trees. However, in the mature orchard there was no significant effect on productivity of the trees showing that ground covers can be managed so that they do not reduce crop yield. The goal of future research is to optimize ground cover species selection and management for pest managment (both insect and disease) and horticultural management.

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THE OCCURRENCE OF DIFFERENT GROUPS OF PHYTOPHAGOUS AND PREDATORY MITES ON APPLE PLOTS SPRAYED ACCORDING TO DIFFERENT PROGRAMS*

VÝSKYT RŮZNÝCH SKUPIN FYTOFÁGNÍCH A DRAVÝCH ROZTOČŮ NA JABLOŇOVÝCH PARCELÁCH S APLIKACÍ POSTŘIKU PODLE RŮZNÝCH PLÁNŮ

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ABSTRACT: In an apple orchard, six plots were sprayed according to different programs with selective or partially selective insecticides and selective fungicides for 3 years. The occurrence of different groups of phytophagous (*Tetranychidae, Eriophyidae*) and predatory mites [*Phytoseiidae* and *Zetzellia mali* (*Stigmaeidae*)] were checked. It was found, that *Typhlodromus pyri* introduced into the orchard, kept spider mite population at a very low level on all experimental plots. Of all tested insecticides (pirimicarb, diflubenzuron, teflubenzuron, fenoxycarb, phosalone, fenitrothion) and *Bacillus thuringiensis*, only fenitrothion distincly decreased the number of predatory mite – *Typhlodromus pyri*.

spider mites; *Phytoseiidae*; *Typhlodromus pyri*; *Aculus schlechtendali*; *Zetzellia mali*; apple orchards; selectivity of pesticides

ABSTRAKT: V jabloňovém sadu byly po dobu tří let aplikovány postřiky ve formě selektivních nebo částečně selektivních insekticidů a selektivních fungicidů na šesti parcelách podle různých plánů. Ověřoval se výskyt různých skupin fytofágních (*Tetranychidae, Eriophyidae*) a dravých roztočů [*Phytoseiidae* a *Zetzellia mali* (*Stigmaeidae*)]. Bylo zjištěno, že introdukce *Typhlodromus pyri* do sadu udržovala populaci svilušky na všech pokusných parcelách na velmi nízké úrovni. Ze všech ověřovaných insekticidů (pirimicarb, diflubenzuron, teflubenzuron, fenoxycarb, fosalon, fenitrothion), a pokud se jedná o *Bacillus thuringiensis*, pouze fenitrothion výrazně snížil počet dravých roztočů, a to u *Typhlodromus pyri*.

svilušky; *Phytoseiidae*; *Typhlodromus pyri*; *Aculus schlechtendali*; *Zetzellia mali*; jabloňové sady; pesticidy

INTRODUCTION

It is well known that predatory mites (*Phytoseiidae*) are effective enemies of phytophagous mites (*Panonychus ulmi* Koch., *Tetranychus urticae* Koch.) occurring on apple trees (Post, 1962; Collyer, 1964; Huffaker et al., 1969, 1970; Croft, 1975, 1976; Oberhofer and Waldner, 1986; Zacharda, 1991). Therefore, several species of Phytoseiids (*Typhlodromus pyri* Scheuten, *Neoseiulus fallacis* Garman, *Amblyseius potentille* Garman, *Metaseiulus occidentalis* Nesbitt, *Amblyseius californicus* McGregor) are exploited on large scale in orchards in Europe, USA, Canada and New Zeland (Hoyot, 1969; Croft, 1975; Wearing et al., 1978; Gruys, 1982; Baillod, 1986; Blommers and Overmer, 1986; Oberhofer and Waldner, 1986; Solomon, 1986). The positive results in exploitation of Phytoseiids is largely due to the presence of resistant or partially resistant strains of those predators to several pesticides in many commercial orchards (Croft, 1976).

Zetzellia mali Ewing (*Acari: Stigmaeidae*) is another predatory mite wide spread in apple orchards (Croft, 1975; Komlovszky and Jenser, 1992) which is considered by some authors as an inefficient predator (Santos, 1976) or inversely efficient predator of phytophagous mites on apple trees (Jenser et al., 1992; Komlovszky and Jenser, 1992). Both, Phytoseiids and *Z. mali* may feed not only on spider mites (*Tetranychidae*) but also on rust mites (*Eriophyidae*) and other so called omnivorous mite species occurred on apple trees (Karg, 1982; Kropczyñska, 1973).

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The objective of this study, which is part of a large scale investigation on integrated pest management (IPM) were:

- to examine how different insecticide spray programs recomended in IPM apple orchards influenced the occurrence the different groups of mites, and
- to evaluate the effect of different insecticide spray schedules on effectiveness of *T. pyri* to spider mites (*P. ulmi*, *T. urticae*) and apple rust mite (*Aculus schlechtendali*). Special attention was paid on selectivity in the field of phosalone and fenitrothion used in Polish IPM apple orchards, to predatory mites partially resistant to those chemicals.

MATERIAL AND METHODS

Experimental orchard and experimental design

The experiment was conducted in Central Poland in a young (4–6 year old) apple orchard consisting of two varieties (Lobo, Spartan) divided into 7 plots of about 0.5 ha each.

Six plots (1–6) differed one from another in the ground cover system (flowering herbaceus plants, planted on the edges of herbicide strips along the tree rows), and – with exception of first year (1992) – the pesticides used. Plot 7, treated as the check, was sprayed as an ordinary commercial orchard (Tab. I).

In alleyways between the tree rows, the grass was mowed several times a year.

Pesticide treatments

In the first year (1992) plots 1–6, treated as Integrated Pest Management (IPM) plots, were sprayed with the same selective (*Bacillus thuringiensis*, B.T.) or partially selective (phosalone) insecticides and fungicides (dithianon, dodine, bitertanol, captane) – Tab. I.

In the second and third year the IPM plots were sprayed with combinations of selective insecticides (B.T., pirimicarb, diflubenzuron, phosalone, teflubenzuron, fenoxycarb) and broad spectrum insecticide – fenitrothion (Tab. I). Beside that in June and July of the first year (1992) predatory mites *Typhlodromus pyri*, partially resistant to phosalone and fenitrothion, were introduced on the apple trees grown on all six IPM plots. About 55 specimens were released every second tree.

T. pyri population used in experiment was oryginated from an apple orchard at Chelcice (Czech Republic). Predators before introduction for over three years were maintained continously in laboratory on bean plants (*Phaseolus vulgaris*) infested with *Tetranychus urticae* Koch. During that period, the predatory mites lost its very high (4% mortality) resistance for fenitrothion and phosalone (10% mortality). In the spring 1992, when *T. pyri* was released in the orchard, the mortality of predators tested in laboratory was near 80% for fenitrothion and 12% for phosalone.

The aim of different insecticide schedules applied on different plots, was to choose the best IPM spray program, highly effective in the control of pests (mainly leaf rollers) and selective to predatory and parasitic arthropods (mainly *T. pyri*).

The two IPM plots (5 and 6) were always sprayed with the same insecticides and pesticides, but flowering plants were maintained only on plot 5. On plot 6, as in check trees (plot 7), the soil was kept bare with the aid of herbicides (glyfosphad). On IPM plots the economic threshold level of the pests – with few exceptions – were respected.

Mite counting

The numbers of phytophagous mites (*P. ulmi, T. urticae*), apple rust mite (*A. schlechtendali*) and predatory mites (*Z. mali, T. pyri* and other Phytoseiids) were counted on the apple leaves under stereomicroscope at weekly intervals. The samples of the leaves were taken randomly from 10 selected trees (5 from Lobo cv. and 5 from Spartan cv.) per plot. A computer program written in Turbo Pascall allowed an instantaneous drawing of a tree sample according to the uniform distribution. From each tree, 10 leaves were collected. Thus each plot was represented by 100 leaves.

The predators found on the leaves were preserved in 70% alcohol for further species identification.

RESULTS

Occurrence of spider mites (*Panonychus ulmi* Koch., *Tetranychus urticae* Koch.)

Spider mites found on apple leaves included fruit tree red spider mite (*P. ulmi*) and in much lower numbers, two spotted spider mite (*T. urticae*). They occurred in high number during all 3 years only on check trees sprayed with non selective insecticides (Tab. I, Fig. 1: plot 7, 1992–1994).

On all IPM plots treated with selective or partially selective insecticides, the spider mites appeared in low amount and exceeded threshold level (3 mites/leaf before 15 July, 5–7 mites/leaf after 15 July) only on four plots in the first year of investigations before introduction of *T. pyri* (Fig. 1: plots 1–4, 1992).

Considering the occurrence of spider mites on all IPM plots during three years, it was observed that populations of this pest gradually decreased over the years (with one exception: Fig.1: plot 2, 1993–1994).

It is worth to underline that in the first year of observations (1992) number of spider mites found on the leaves on all IPM plots was distincly higher than number of Phytoseiids (Fig. 1). In second year of the experiment (1993) the number of spider mites and Phytoseiids on IPM plots were similar (Fig. 1: plots 1–5, 1993). In the last year (1994) spider mites were distincly less numerous compared with Phytoseiids on

I. Insecticide used in experimental orchard

No. of plot	1992	1993	1994
1 IPM	phosalone B.T.	pirimicarb	pirimicarb 2x
2 IPM	phosalone B.T.	pirimicarb	fenitrothion pirimicarb B.T.
3 IPM	phosalone B.T.	diflubenzuron teflubenzuron pirimicarb	pirimicarb 2x fenoxycarb B.T.
4 IPM	phosalone B.T.	phosalone diflubenzuron pirimicarb	phosalone fenoxycarb diflubenzuron
5 IPM	phosalone B.T.	B.T. diflubenzuron pirimicarb	phosalone pirimicarb
6 IPM	phosalone B.T.	B.T. diflubenzuron pirimicarb	phosalone pirimicarb
7 Check	fenitrothion diazinon fenthion	diazinon 3x fenthion pirimicarb	cypermetrine deltametrine fenitrothion fenthion phosalone

B.T. = *Bacillus thuringiensis*

all IPM plots (Fig. 1), except plot 2 (Fig. 1: plot 2, 1994).

In 1992, when IPM plots were sprayed only with B.T. and phosalone, the spider mites were most numerous in the begining of the season, especially on plots 1, 2 and 6 (Fig. 1). In the second year (1993), the relatively high population of spider mites was observed in July, especially on plot 5 (Fig. 1: plot 5, 1993) sprayed with B.T. and pirimicarb. In the third year (1994), distincly more mites were found on apple leaves at the end of the season in July, August and September only on plot 2 sprayed with fenitrothion (Fig. 1: plot 2, 1994).

Occurrence of apple rust mite (*Aculus schlechtendali* Nal.)

Apple rust mite inhabited apple trees on all plots during all three years. Its numbers varied according to year and plot, but generally the population of that pest was very low in the first year (1992) and low in the next two years (1993, 1994) – Fig. 2. They rarely exceeded the estimated threshold level i.e. about 10–100 specimens per leaf at spring (Croft, 1995) and up to 400–500 specimens in summer (Graf – personal communication) – Fig. 2. Differences between the number of rust mites on IPM plots and check plot sprayed often with broad spectrum insecticides were not found (Fig. 2). The population of apple rust mites during the spring (April, first half of March) and autumn (September), in all years was very low. In higher number this species occurred usually from of May (1993) or end of June (1994) to first days of August (Fig. 2).

In the second year (1993), *A. schlechtendali* was most numerous on the trees in plots 1 and 2 sprayed only with pirimicarb and on check trees (plot 7) treated with diazinon, fenthion and pirimicarb. Conversely, rust mites were in much lower numbers on plot 3 sprayed with diflubenzuron, teflubenzuron and pirimicarb and on plot 4 treated with diflubenzuron, phosalone and pirimicarb (Fig. 2).

In the last year of experiment (1994), *A. schlechtendali* appeared in relatively high numbers on plot 2 sprayed with fenitrotion, pirimicarb and B.T. On that plot the population of the predatory mite, *T. pyri*, was very low. On the other hand, the lowest rust mite population was observed on check trees (plot 7) sprayed with cypermetrine, deltametrine, fenitrothion, fenthion, phosalone and lambda-cyhalotrine (Fig. 2).

Occurrence and effectiveness of Phytoseiids

Predatory mites (*Phytoseiidae*) occurring in the experimental apple orchard during first two years were represented by 8 species: *Typhlodromus pyri* (Scheuten), *Phytoseiulus macropilis* (Banks), *Euseius finlandicus* (Oudemans), *Paraseiulus soleiger* (Ribaga), *Neoseiulus fallacis* (Garman), *Metaseiulus occidentalis* (Nesbitt), *Typhlodromus tiliarium* (Oudemans), *Amblyseius massei* (Nesbitt). Of all those mentioned only *T. pyri* was introduced on all IPM plots of the orchard. The other seven species were native.

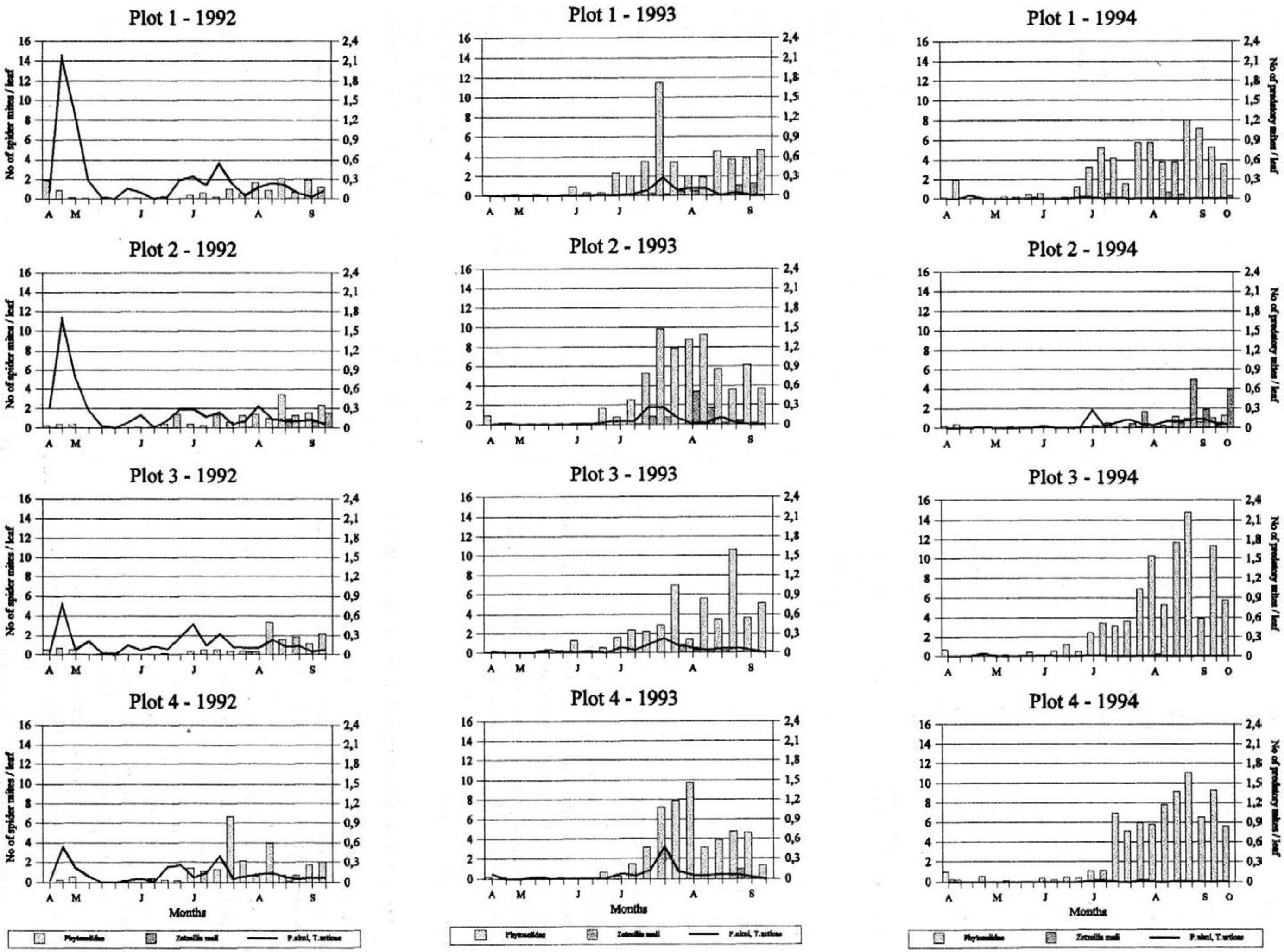
The *T. pyri* distinctly increased in population year by year on all IPM plots. This trend was especially evident in numerical relations between the amount of the spider mites and Phytoseiids in successive years (Fig. 1: plots 1, 3, 4, 5). The results indicated that *T. pyri* was able to keep populations of *P. ulmi* and *T. urticae* on all IPM plots at very low levels (usually less or much less then 1 specimen per leaf) through the second and third year after introduction (Fig. 1: plot 1–5). Only on check trees (plot 7), where selective insecticides were not used, the Phytoseiids appeared sporadically, and due to that, populations of spider mites was high (up to 12 mobile stage per leaf) and exceeded the threshold level (Fig. 1: plot 7, 1992–1994).

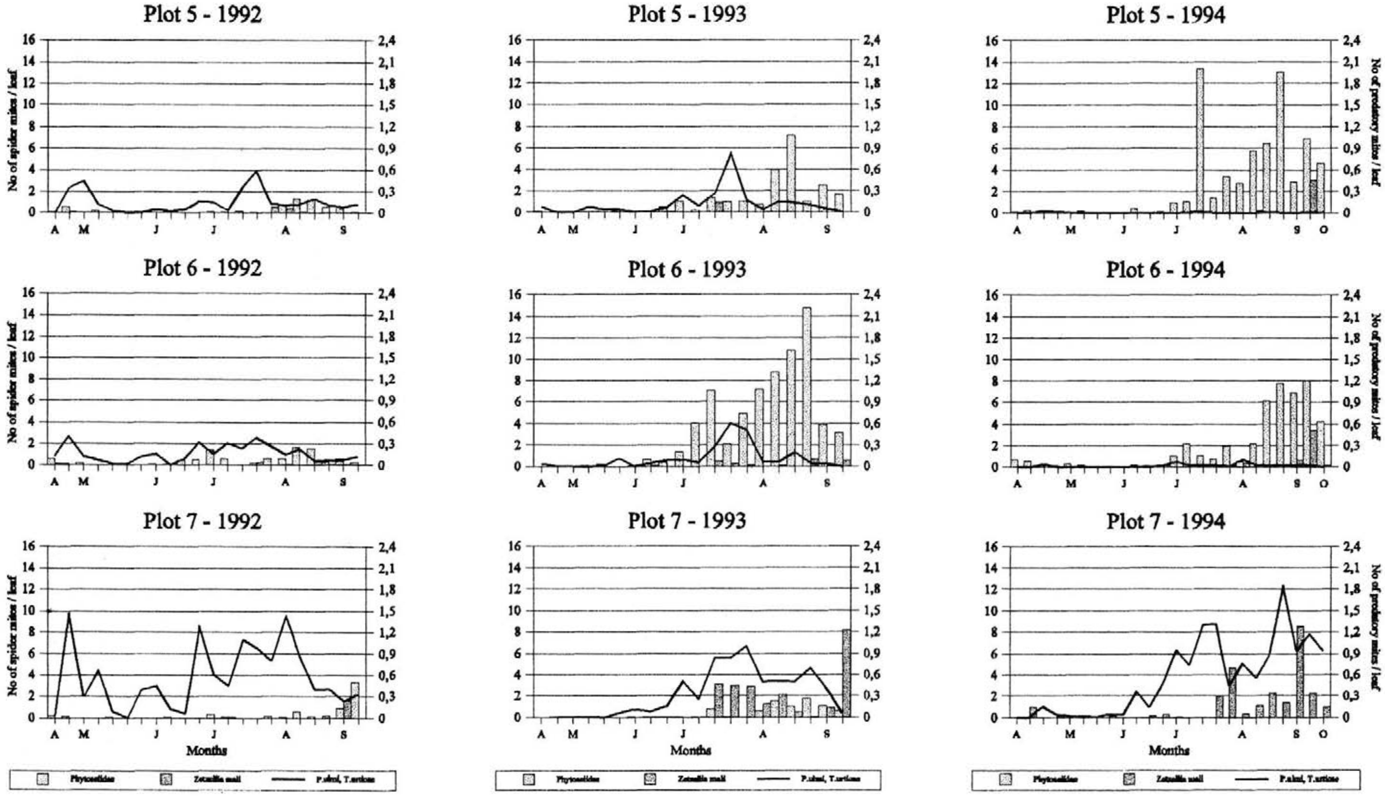
Occurrence *Zetzellia mali* (Ewing) in experimental orchard

The predatory mite *Zetzellia mali* (*Stigmaeidae*) occurred on all IPM plots but in very low numbers. This predator was much less numerous than Phytoseiids during all three years. On the other hand, *Z. mali* on check trees (plot 7) sprayed with non-selective insecticides, was more numerous in last two years (1993, 1994) than *T. pyri* and other Phytoseiids (Fig. 1: plot 7, 1993–1994).

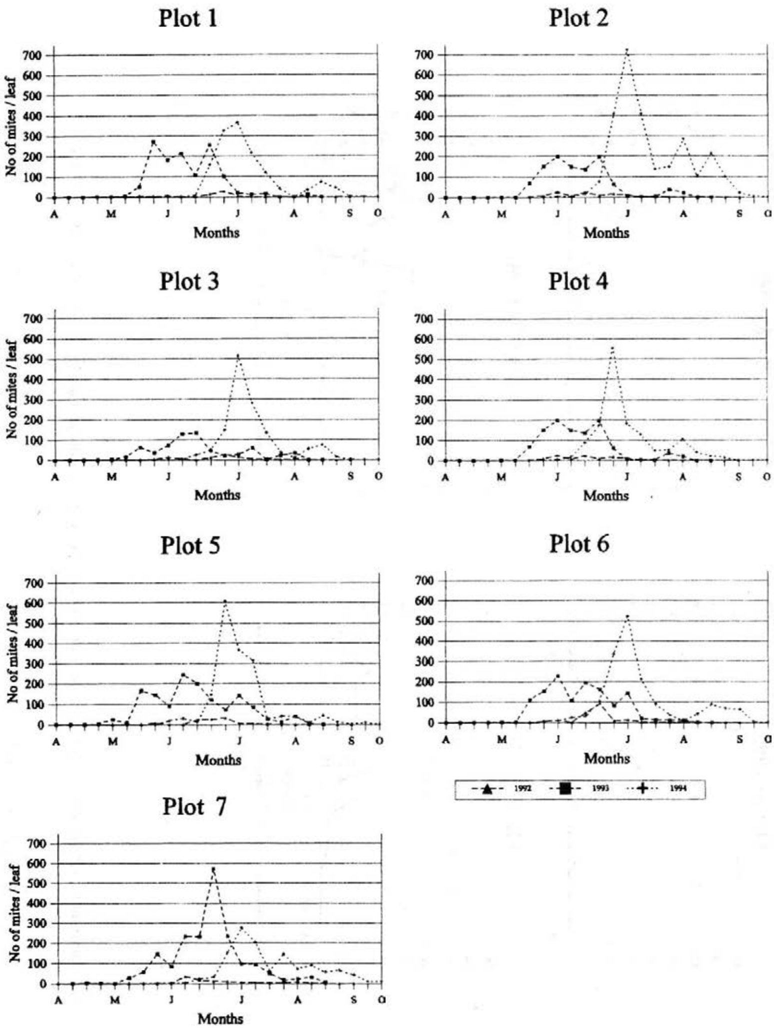
DISCUSION

Based on these results one can state that predatory mites of *Phytoseiidae* family, represented mainly by


Plot 1 - 1992
Plot 1 - 1993
Plot 1 - 1994
Plot 2 - 1992
Plot 2 - 1993
Plot 2 - 1994
Plot 3 - 1992
Plot 3 - 1993
Plot 3 - 1994
Plot 4 - 1992
Plot 4 - 1993
Plot 4 - 1994
No of spider mites / leaf
No of predatory mites / leaf
A M J J A S O
Months



1. Occurrence of spider mites (*P. ulmi, T. urticae*), and predatory mites (*Phytoseiidae, Zetzellia mali*) on different plots in experimental apple orchard (Prusy 1992–1994)



2. Occurrence of apple rust mite (*Aculus chlechtendali*) on different plots in experimental apple orchard (Prusy 1992–1994)

Typhlodromus pyri, exhibited very high effectiveness against spider mites (*P. ulmi*, *T. urticae*) in the experimental apple orchard on all IPM plots (with exception in 1994) sprayed with selective pesticides.

The ability of Phytoseiid mites to keep spider mite populations on a very low level agree with results presented in the very rich world literature summarized by Collyer (1961), Huffaker et al. (1969, 1970) and van de Vrie (1985).

It is difficult to estimate the effectiveness of Phytoseiids on apple rust mite (*A. schlechtendali*). From one side one can say that such effectiveness does exist. The highest number of *A. schlechtendali* in 1994 was noted on plot 2, on which the *T. pyri* appeared in the lowest number (Fig. 1, 2: plot 2, 1994) compared with other IPM plots (Fig. 1, 2: plots 1,3–5, 1994).

From the other side, with increase the Phytoseiid numbers on IPM plots during succesive years, rust mites became more abundant (Fig. 1, 2).

It is not possible to estimate the efficacy of *Z. mali* in controling spider mites and rust mites. This is because the sporadic occurrence of this predator on IPM plots. On check trees *Z. mali* was more abundant, but spider mites were also numerous. Rust mites in 1994 occurred on check trees in the lowest number compared with IPM plots. But this fact probably was due to toxic effect of used pesticides to *A. schlechtendali* on check trees (Fig. 1, 2: plot 7, 1994). *Z. mali*, according to Komlovszky and Jenser (1992), occurred in high numbers may have kept the spider mites population on low level in Hungarian apple orchards.

The collected data allow several conclusions and hypotheses concerning toxicity of different pesticide programs to Phytoseiids. All used fungicides (dithianon, dodine, bitertanol, captane) and all insecticides – except one – (pirimicarb, diflubenzuron, teflubenzuron, fenoxycarb, phosalone) as well as B.T., are known as selective or partly selective (Croft, 1976; Gruys, 1980; Boller et al., 1989; Niemczyk et al., 1990; Niemczyk, 1995), do not affect, or only slightly affect, the Phytoseiid populations in experimental orchard (Fig. 1: plots 1–5, 1992–1994).

The information of special importance was the estimation of selectivity to Phytoseiids to phosalone, a broad spectrum insecticide often used in IPM orchards. The obtained data confirmed its selectivity to Phytoseiids and especially to the resistant strain of *T. pyri* introduced to the orchard.

This result was confirmed by several facts:

- B.T. and phosalone used in first year (1992) on all plots allowed not only *T. pyri* to occurr but also two other Phytoseiid species in relatively high numbers (*P. macropilis, E. finlandicus*) – Fig. 1, plots 1–5.
- In the next two years (1993, 1994) Phytoseiids, represented mainly by *T. pyri*, appeared and increased in number in succesive years on plot 4 sprayed also with phosalone (Fig. 1: plot 3, 1993, 1994).
- In the third year (1994) *T. pyri* was also abundant on plot 5 treated with phosalone and pirimicarb (Fig. 1: plot 5, 1994).

On the other hand, fenitrothion, another very effective broad spectrum insecticide which can be applied in some situations in IPM apple orchard in Poland, used before bloom on plot 2 showed a very high toxic effect to *T. pyri* selected for the resistance to that compound (Tab. I, Fig. 1: plot 2, 1994).

This fact indicates that *T. pyri*, partially resistant to fenitrothion in laboratory (about 70% mortality), lost that property in outdoor conditions after two years without selection pressure.

It was also confirmed that *T. pyri* is more tolerant to pesticides than other Phytoseiid species (Gruys, 1982). *T. pyri* almost entirely displaced other predatory mites on all IPM plots within two years.

Z. mali, the other predatory mite, was naturaly resistant to several very toxic insecticides used on check trees. This fact was also noted by other authors (Komlovszky and Jenser, 1992).

All above mentioned facts showed that – except fenitrothion – the used pesticides not only protected apple trees on IPM plots against diseases and insect pests (Niemczyk et al., 1996), but also allowed the predatory mite, *T. pyri*, to occur in high numbers, which effectively kept the population of spider mite at a very low level. It was, therefore, not necessary to control them with chemicals.

The broad spectrum insecticides (Tab. I) used on the check plot also effectively controlled insect pests, but were very toxic to predatory mites of the *Phytoseiidae* family. Because of that Phytoseiid mites occurred only sporadicaly on the check plot and spider mites exceeded threshold level.

CONCLUSIONS

The predatory mite – *Typhlodromus pyri* Scheut. introduced into an apple orchard occurred in relatively high amount and kept spider mite populations represented mainly by *Panonychus ulmi* Koch and *Tetranychus urticae* at a very low level on 6 plots sprayed with selective of partialy selective fungicides and insecticides.

Of all tested insecticides (pirimicarb diflubenzuron, teflubenzuron, fenoxycarb, phosalone) and *Bacillus thuringiensis*, only fenitrothion used before flowering of apple trees, distincly decreased the number of *T. pyri*, partially resistant to that compound.

The number of apple rust mite (*Aculus schlechtendali* Nal.) varied according to year and plot, but generally the population of that pest was very low or low. However, it is difficult to judge wheather Phytoseiids decreased the apple rust mite population.

Zetzellia mali (Ewing.) (*Stigmaeidae*), an native predatory mite occurred on experimental plots sprayed with selective insecticides on very low amount. Conversaly on check trees sprayed with non-selective insecticides this species was more numerous.

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INTEGRATED PEST MANAGEMENT IN APPLE ORCHARDS - EXPERIMENTS IN ROMANIA*

INTEGROVANÁ OCHRANA PROTI ŠKŮDCŮM V JABLOŇOVÝCH SADECH - POKUSY V RUMUNSKU

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ABSTRACT: The experiment within the IPM (Integrated Pest Management) project was organized in 1992 at the Fruit Tree Research Station Voinesti, in an orchard (26 years). The IPM system has been applied in a 2 ha orchard with Jonathan, Golden Delicious and Red Delicious cultivars. A similar nearby orchard with the same area was used as a check (chemical supervised control). To improve natural control we used sorghum (*Sorghum bicolor*), buckwheat (*Fagopyrum esculentum*), dill (*Anethum graveolens*), vetch (*Vicia* spp.) in 1992, and coriander (*Coriandrum sativum*) in 1993. Comparison between the IPM plot and the chemical supervised control plot. The number of beneficial organisms was much higher in the IPM plot. The key-problem in these experiments was the control of apple scab and wooly aphid. In 1994 we planted a new orchard (some 2 ha), half with cultivars resistant to apple scab and medium resistant to powdery mildew, Generos and Florina. In the young orchard with resistant cultivars superiority of IPM was proved by a lower number of sprayings, smaller amounts of active ingredients (3.12 kg/ha a.i. instead of 10.64) and a sustained activity of beneficial arthropods. Economic analysis in a large orchard with varieties highly resistant to apple scab and good resistance to powdery mildew, evinced a possibility to reduce the number of sprayings from 15.8 per season to 8, while their cost drops from 100% to 44.3%.

integrated pest management; supervised control; apple scab; woolly aphid; selective pesticides; ground cover; resistant cultivars

ABSTRAKT: Pokus v rámci projektu IPM (systém integrované ochrany) se uskutečnil v roce 1992 na Ovocnářské výzkumné stanici ve Voinesti v jednom sadu (26 let). Systém IPM byl použit v sadu o rozloze 2 ha, kde se pěstovaly odrůdy Jonathan, Golden Delicious a Red Delicious. Jako kontrola sloužil podobný sousední sad o stejné rozloze (chemická usměrněná ochrana). Pro podporu výskytu přirozených nepřátel jsme v roce 1992 vyseli čirok (*Sorghum bicolor*), pohanku (*Fagopyrum esculentum*), kopr (*Anethum graveolens*), vikev (*Vicia* spp.) a v roce 1993 koriandr (*Coriandrum sativum*). Srovnání parcely s IPM a parcely s chemickou usměrněnou ochranou ve starém sadu dopadlo ve prospěch IPM. Kvalita plodů byla mírně vyšší na parcele s usměrněnou chemickou ochranou. Počet užitečných organismů byl mnohem vyšší na parcele s IPM. Klíčovým problémem v těchto pokusech byla ochrana proti strupovitosti jabloní a vlnatce krvavé. V roce 1994 byl vysázen nový sad (asi 2 ha). Na polovině jeho plochy byly vysázeny odrůdy rezistentní proti strupovitosti jabloní a středně odolné proti padlí travnímu (Generos a Florina). V tomto sadu s rezistentními odrůdami byla prokázána důležitost IPM na základě nižšího počtu postřiků, menšího množství účinné látky (3,12 místo 10,64 kg/ha ú.l.) a trvalé činnosti užitečných členovců. Ekonomická analýza pro velký sad s odrůdami vysoce odolnými proti strupovitosti jabloní a s dobrou odolností proti padlí travnímu naznačila možnost snížení počtu postřiků za sezonu z 15,8 na 8,0 a pokles nákladů ze 100 na 44,3 %.

systém integrované ochrany; usměrněná ochrana; strupovitost jabloní; vlnatka krvavá; selektivní pesticidy; přízemní vegetace; rezistentní odrůdy

INTRODUCTION

Pome fruit orchard has numerous pests, diseases and orchards which call for a high number of sprayings and a heavy load of pesticides per hectare. On the other side, the market requirements for pome fruit quality are extremely severe.

The increased numbers of sprayings led to enhanced levels of multiple residues, built-up resistant form of mites, fungi and insects, resurgence of some pests, destruction of some beneficial arthropods, etc.

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To improve pome fruit protection it is important to change some grower conceptions. Instead of weak sprayings with different mixtures of pesticides, we have to introduce a rational approach, based on integrated pest and disease management.

To this end, maximizing biological control in integrated pest management is extremely important.

Some of the existing books and papers (Baicu and Savescu, 1986; Niemczyk, 1988; Anonymus, 1990; Freier et al., 1992; Brown et al., 1992) deeply analysed these problems and offer different answers.

The overall goal of the project was to develop methods of fruit production with less environmental and food residues, without reducing fruit quality and yield. To achieve this goal there were several objectives to be met.

a) Create adapted ground cover to enhance and attract beneficial insects.
b) Use selective pesticides.
c) Use pheromone traps and various methods for forecasting and warning.

Since the control of main pests and diseases with specially conceived biological products was not possible, we chose an alternative improvement of activity of beneficial arthropods (natural control), and later on introduction of new varieties resistant to apple scab and powdery mildew, thus avoiding fungicidal sprayings.

MATERIAL AND METHOD

The experiments have been conducted at the Research Fruit Tree Station – Voinesti, and analysis and identification of useful fauna at the Research Institute for Plant Protection – Bucharest, in the period 1992–1994.

Old orchard (1992–1994)

According to the programme established in Kearnsysville, we have chosen an intensive orchard, two hectares in size, for integrated pest and disease management, and a two hectare plot for chemical supervised control.

The experiment has been organized on this plot in 1992 and 1993.

In 1994 we planted a new orchard (some 2 ha) with young 2-year old trees grafted on M-106, using the following apple scab resistant and powdery mildew medium resistant varieties: Generos and Florina.

Other 1 hectare plot has been planted with Jonathan and Golden Delicious, as a chemical control supervised plot.

The goal of this experiment was to develop a system of pest and disease integrated management with reduced numbers of chemical applications and maximizing the biological control.

To improve the natural control, some particular crops have been selected, in order ot attract some zoophages and to enhance their activity. To this end we used sorghum (*Sorghum bicolor*) able to attract aphid predators and lepidopterious species, buckwheat (*Fagopyrum esculentum*), to attract adult parasites to the blossoms, vetch (*Vicia* spp.) in 1992 and coriander (*Coriandrum sativum*) in 1993, to attract zoophages in summer.

The ground cover has been sown in one row for each plant species, along the fruit tree row, on both sides.

Targeted pests (Associated issues)

Codling moth (*Cydia pomonella*). This pest has been controlled with selective pesticides: Dimilin 25 DP (diflubenzuron) – 0.04% (1992) and Insegar 25 WP (fenoxycarb 25%) – 0.05%. The period of sprayings have been determined using sex pheromone traps (2 per orchard), Trécé Sandoz in 1993 and Atrapom – IC Cluj Napoca in 1992. The sum of active temperatures for one generation was about 600 °C. In autumn we used corrugated paper bands to estimate the overwintering population.

Apple weevil (*Anthonomus pomorum*). Periodical inspections during flowering showed low densities. No treatment was needed.

Woolly apple aphid (*Eriosoma lanigerum*) was found throughout the orchard at high densities and the parasitization level by *Aphelinus mali* was low in 1992 and higher in 1993. Against this pest we used selective pesticides Thionex 35 EC (endosulfan) 0.2% and a medium selective insecticide for *A. mali*, Reldan 50 EC – 0.1% (chloropyriphos methyl).

San José scale (*Quadraspidiotus perniciosus*) was noted in the check orchard, and at very low densities in the IPM plot. No spraying was needed.

Leaf miners. Three pheromone traps have been placed for each species: the pheromone trap Atrablanc for *Phyllonorycter blancardella*, Atramal for *Nepticula malella* and Atrascit for *Leucoptera scitella*. The number of captures was very low for *N. malella* and *L. scitella*.

Mites (*Panonchys ulmi*, *Tetranychus viennensis*, *T. urticae*) were controlled using selective acaricides: Neoron 500 EC (bromopropylate) – 0.1% and Pegassus (diafenthiuron) – 0.06% in 1992, and Torque 55 (fenbutatin oxide) – 0.04% and Neoron 500 EC – 0.1%. As an early ovicidal acaricide we used in 1993 Nissorun (hexythiazox) – 0.06%.

Apple scab (*Venturia inaequalis*). Scab was controlled through:

1. Forecasting, using methods elaborated in the previous years (Anonymus, 1979), also using a forecasting station with leaf wetting sensor;
2. Proper use of selective fungicides with prolonged period of action;
3. Use of suitable spraying methods and adequate spray mixtures.

Powdery mildew (*Podosphaera leucotricha*). According to our warning method, the first spray has been applied at 5% twing infection on green tip. Pruning of infected shoots and their removal from orchard was used to control this disease.

Fire blight (*Erwinia amylovora*). This disease was reported by B a i c u et al. (1994), but in our experimental plot was not noticed.

Weeds have been controlled through hand hoeing along the tree rows.

The control plot of the same size had two peculiarities: absence of ground cover with rey grass and spraying was applied using our forecasting methods, not simply as cover sprayings.

Comparison between the two systems, IPM and chemical supervised control, was difficult to be performed.

Climatic conditions were favourable to apple and powdery mildew.

For the IPM experiment we choose the more selective fungicides, acaricides and insecticides available in our country.

Fig. 1 gives a picture of sprayings distribution throughout the season.

As a general remark the old orchard presented at the start (1992) high levels of infestation and high levels of infections.

Ground cover. Sampling methods. Pitfall traps. Five pitfall traps within each ground cover type. Monitoring was conducted for 2 days.

Net sweeping. Each sample comprised five sweeps back and forth 3 times in a year.

Tree sampling. Leaf samples. Ten leaf clusters per tree were removed and examined in field and laboratory for mites, beneficial insects and harmful pests.

Branch terminal counts. Ten terminals have been examined for aphid infestation, aphid predators and mildew.

Limb jaring. 30 branches per replication, one branch per tree, have been jarred in 40 x 62 cm trays (0.25 m^2).

Fruit evaluation. One thousand fruits were randomly selected at harvest and examined for all defects, insects, diseases and physiological discorders.

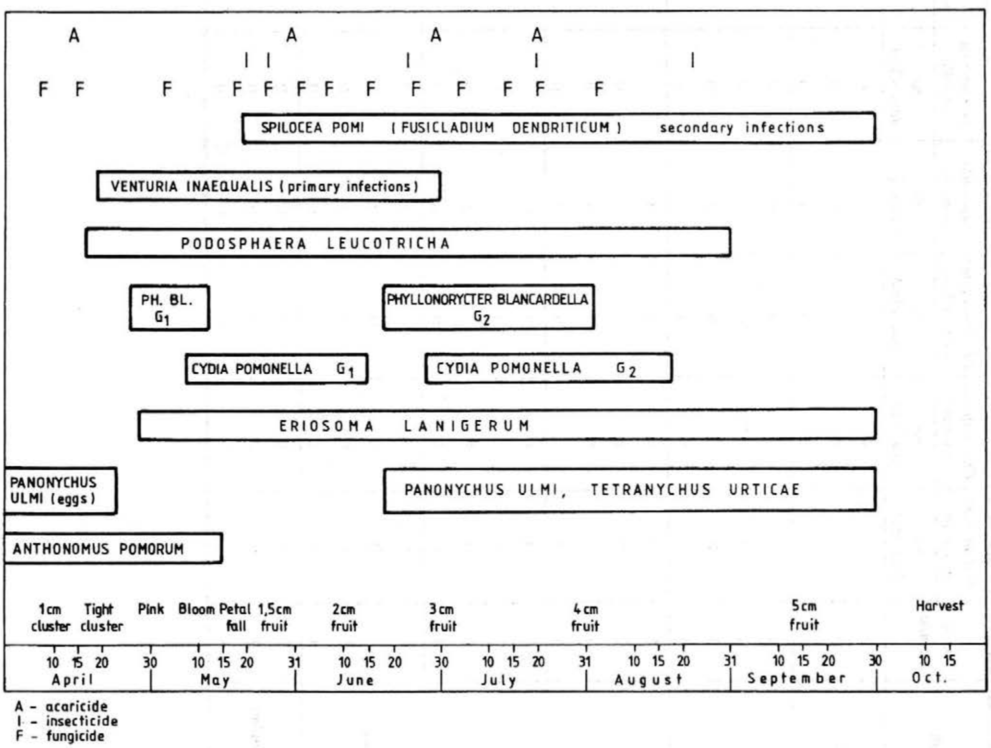
Pheromone traps; traps Trécé Sandoz (1992), Atrapom (1993), Atrablanc, Atrascit and Atramal were weekly counted and graphs have been plotted for each species.

Tree measurements, tree trunk diameter at 30 cm above the soil surface have been measured on 25 trees in the centre of each replication.

For plant and soil contents of N, P, Na, Ca, Mg, Fe, Mn, Cu, and Zn was done by chemical analysis, using C.I.I.A.F. methods.

For pesticide residues we used specific methods. Content analysis for nitrate-nitrites was determined by the ISO-method.

The newly planted orchard covered 1.9 ha. Half of this area was planted with apple cultivars sensitive to



1. Period of species activity and sprayings – 1993

I. Monitoring of different pests – 1993 (S:C:P:P: Voinesti)

Month	Pests decade	*Anthonomus pomorum*	*Cheimatobia brumate*	*Phyllonorycter blancardella*	*Nepticula malella*	*Leucoptera scitella*	*Cydia pomonella*	*Panonychus ulmi*	*Tetranychus urticae*	*Aphis pomi*	*Dysaphis plantaginea*	*Eriosoma lanigerum*	*Quadraspidiotus perniciosus*
		Nr. buds/tree	Nr. leaf/tree	Nr. mines/leaf	Nr. mines/leaf	Nr. mines/leaf	Fruit nr.	Mobile forms/leaf	Mobile forms/leaf	Nr. schoots/tree	Nr. schoots/tree	Nr. of colonies/tree	Nr. of attacked fruit/tree
April	1	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	1.0	0	0	0	0	0	0	0	0	2	0
May	1	0	4.5	0	0	0	0	0	0	0	0	2	0
	2	0	2.0	0	0	0	0	0	0	0	0	3	0
	3	0	0.3	0	0	0	0	0	0	0	0	3.3	0
	4	0	0	0	0	0	0	0	0	0	0	3	0
June	1	0	0	0	0	0	0	0	1	1	0	3	0
	2	0	0	0	0	0	0	0	2	1.3	0	4	0
	3	0	0	0	0	0	0	0	3	1.5	0	4	0
	4	0	0	0	0	0	0	0	3	2.5	0	4	0.5
July	1	0	0	0	0	0	0	–	4	–	0	4	0
	2	0	0	0	0	0	0	3	5	–	0	3	0
	3	0	0	0.2	0	0	0	–	10	–	0	5	0
	4	0	0	0	0	0	0	4	15	3	0	4	0
August	1	0	0	0	0.1	0	0	–	9	2	0.3	2	0
	2	0	0	0	0	0	0	–	6	0	0.5	3	0
	3	0	0	0	0	0	0	5	7	0	0	2	0
	4	0	0	0	0	0	0	–	7	0	0	3.5	0
September	1	0	0	0	0	0	0	2	3	0	0	5.5	1.5
	2	0	0	0	0	0	0	1	3	0	0	7	4.5
	3	0	0	0	0	0	0	–	2	0	0	9.3	6.0

scab and powdery mildew (supervised control) – Jonathan and Golden Delicious, and the other half with cultivars resistant to these diseases: Generos and Florina, grafted on M-106 rootstocks (IPM plot).

After planting (end of April) we performed the new soil management procedures:
- sowing rey grass (*Lolium multiflorum*) strips 1.2 m wide, between rows;
- sowing 4 plant species attractive to some zoophages.

For another orchard 82 ha in size, with scab resistant varieties, we performed a brief economic analysis (1992–1993), comparing the results with those of sensitive cultivars (supervised control).

RESULTS

Old orchard

In 1992, as a consequence of observations on the development of pests and diseases, we applied 12 sprayings in the IPM plot. In the plot with chemical supervised control we used sixteen sprayings with various mixtures of fungicides, acaricides and insecticides. Among these products there were some very toxic (methamidophos and quinalphos). Most of insecticides were not selective for zoophages.

Nissorun effectiveness against the winter eggs of mites was too low, mortality afforded being slight. This explains necessity for treatments against the mobile forms in summer.

Tab. I shows evolution of different pest species, as densities or attack levels. Density of *P. ulmi* justified the number of sprayings likewise, evolution of *E. lanigerum*, in spite of its high parasitisation, required several sprayings.

Apple scab and powdery mildew habe been recorded several times.

In 1992 (Tab. II) the level of apple scab attack was low in the IPM plot, but higher than that in the chemical supervised control. In 1993, the apple scab infection level was high, this fact being not fully explained only by the highly favourable weather conditions. We also suspect Captadin 50 PU quality (its active ingredient content).

Cover crops had an important, positive influence on the soil arthropods, *Lumbricidae* and other animals.

The pitfall traps proved each year a high diversity. The number of animals collected was higher in the IPM plot. The useful arthropods like *Araneae, Staphyilinidae* and *Formicidae* were more numerous.

Soil sampling performed in 1993 at 30 cm depth (25 x 25 cm) gave similar results.

In all cases ground cover allowed to collect an important number of beneficial insects, superior to the chemical supervised control. Dill (*Anethum graveolens*) was the most useful plant for soil beneficial fauna.

Net sweeping collection showed a wide variety of species. The number of insects by species was very high on *Coriandrum sativum* and *Lolium multiflorum*. On *C. sativum* there were large numbers of *Chrysoperla, Braconidae, Chalcididae* and *Empididae*. On *L. multiflorum* the number of *Araneae, Braconidae, Chalcididae, Aphidae, Formicidae* and *Empididae* was more abundant than in other crops.

Comparing with the chemical supervised control (weeds), in all cases the beneficial fauna was more important.

Limb jarring performed in 1993 showed in all 5 periods of collecting aan important number of arthropods in the IPM plot, the total numbers being almost double than in the chemical supervised control plot (Tab. III). The high number of mites collected proved then the existing beneficial arthropods could not prevent their multiplication in the IPM plot.

The fruit harvest per tree was not statistically different, but its quality in the IPM plot was lower, due to high apple scab level.

Leaf content of different nutrients revealed some differences in the N content. Differences are not definite for other elements.

The soil residues are not important. The fruit pesticide residue content (Tab. IV) is below the official maximum residue levels.

Young orchard

In the experimental orchard, after the vegetation start, we checked incidence (as %) every 10 days, as well as intensity using 0–6 scale, in sensitive cultivars Jonathan and Golden Delicious, as compared to resistant ones Generos and Florina (Tab. V).

Generos and Florina were free from apple scab, whilst Jonathan and Golden Delicious evinced a low level of scab attack on leaves.

Powdery mildew (*Podosphaera leucotricha*). The most sensitive cultivars proved to be Jonathan and

II. Diseases observations, IPM – 1992

Period of disease	*Venturia inaequalis*		*Podosphaera leucotricha*		*Monilia fructigenasi*	*Gloeosporium* sp.	*Apple mosaic*
	leaves (%)	fruits (%)	leaves (%)	shoots (%)	attacked fruits (%)	attacked fruits (%)	attacked leaves per tree
July 1–10	17	12	13	3	0.5	0	0
August 1–10	18.6	13.8	17.3	5	0.7	1.0	0
September 1–10	21	15	24	11	1.0	4.0	0.5

III. Harmful and useful species – limb jarring (S.C.P.P. Voinesti)

Group and species	IPM	Chemical supervised control
Harmful fauna		
Taeniothrips inconsequens Uzel.	11.5	5
Carpocoris bacarum L.	6.5	1
Psocidae	6.5	4
Psylla mali Schmid.	3.5	5
Aphis fabae Scop.	3	4
Aphis pomi Deg.	7.5	13
Psammotettix striatus L.	1	1
Anthaxia cichorii L.	1.25	1
Notoxus cornutus F.	1	–
Corticarina gibbosa Hbst.	6	3
Phyllotreta nemorum L.	2.5	3
Lilioceris lilii Scop.	1.25	–
Curculio nucum L.	1	1
Tineidae	2.25	11
Itonidiae	2.25	3
Agromyzidae	2.5	2
Hydrellia griseola Fall.	1.25	4
Tetranychus urticae Koch.	326.5	81
Tetranychus viennensis Zacher.	12.5	3
Panonychus ulmi Koch.	19	24
Total HF	413.5	169
Useful fauna		
Araneae	10.5	1
Rhyotritia ardua Koch.	7	–
Camisia horrida Herm.	4	16
Aeolothrips melalucus Bagnall.	9	4
Ephemeroptera	0.75	4
Scolothrips sexmaculatos Pergante.	2.75	–
Orius vicinus Ribaut.	5	–
Anthocoris nemorum L.	1	–
Chrysoperla carnea L.	5.75	9
Hemerobius humulinus L.	1.75	–
Stethorus punctillum Weise.	5.25	2
Scymnus auritus Thunberg.	1.5	–
Coccinella septempunctata L.	2	1
Staphylinidae	1	1
Eulophidae	1.75	–
Chalcididae	7.75	6
Inostemma contariniae Szel.	1.25	–
Formicidae	4.25	1
Chironomidae	6.5	4
Sciridae	4.25	1
Asilidae	1.75	–
Total UF	97.5	50
Total	511	219

IV. Pesticide residues in fruits (mg/kg) 1992–1993

Variant	Cultivars	Captan		Trimorfamid	Dimethoate		Mancozeb	Methidathion	Malathion		Methyl tyophanate	Quinalfos
		1992	1993	1992	1992	1993	1992	1992	1992	1993	1993	1993
IPM	Golden	0.025	0.34	nil	–	0.27	–	–	–	0.007	0.68	nil
	Jonathan	0.02	0.35	nil	–	0.28	–	–	–	0.005	0.70	nil
	Starkrimson	0.02	0.25	nil	–	0.17	–	–	–	0.035	0.62	nil
Chemical supervised control	Golden	0.05	0.20	nil	0.10	0.05	nil	0.015	Malaoxon 0.005	nil	–	nil
	Jonathan	0.03	0.41	nil	0.30	0.25	nil	0.02	0.005	nil	–	nil
	Starkrimson	0.06	0.37	nil	1.00	0.25	nil	0.02	nil	nil	–	nil

V. Diseases development (incidence and severity)

Month	Ten days period	Sensitive cultivars								Resistant cultivars							
		Venturia inaequalis (leaves)				*Podosphaera leucotricha*				*Ventura inaequalis* (leaves)				*Podosphaera leucotricha* (shoots)			
		Jonathan		Golden D.		Jonathan		Jonathan		Generos		Florina		Generos		Florina	
		I	S	I	S	I	S	I	S	I	S	I	S	I	S	I	S
June	2	0	0	0	0	1.3	1	0	0	0	0	0	0	0	0	1.3	1
	3	0	0	1	1	1.6	1	1.0	1	0	0	0	0	0	0	2.0	1
July	1	2.0	1	2.3	1	2.5	1–2	2.3	1	0	0	0	0	0	0	2.3	1
	2	3.5	1–2	3.9	2	3.0	1–2	4.4	1–2	0	0	0	0	0	0	2.4	1–2
	3	5.0	1–2	9.0	2.3	3.3	1–2	7.0	1–2	0	0	0	0	0	0	2.5	1–2
August	1	6.3	2	22.0	2.5	6.0	1–2	7.2	1–2	0	0	0	0	0.3	1	3.0	1–2
	2	5.7	1–2	23.3	2–5	8.0	1–2	7.6	1–3	0	0	0	0	0.3	1	5.5	1–2
	3	4.5	1–2	25.0	2–4	9.0	1–2	8.0	1–3	0	0	0	0	0.5	1	7.7	1–3
September	1	4.0	1–2	25.5	2–3	9.0	2	8.1	1–3	0	0	0	0	0.8	1–2	8.8	1–3
	2	4.0	1	25.5	2–3	9.0	2	8.1	1–3	0	0	0	0	0.8	1–2	9.5	2
	3	4.0	1	24.5	2–3	9.0	2	8.2	1–3	0	0	0	0	1.8	1–2	11.0	2–3
October	1	–	–	24.0	2–3	9.0	2	8.2	1–3	0	0	0	0	1.8	1–2	11	2–3

Florina. Fungicidal sprayings showed suitable effectiveness against this pathogen.

Aphids (*Aphis pomi*) were the first pest insects noticed in the new apple plantation. Effectiveness of Fernos 50 DP was very high (98–100%), and this spraying stopped the aphid evolution throughout the season.

Fernos 50 DP – 0.05% also proved to be selctive to many zoophages.

Defoliators (*Orgyia antiqua*). In the Voinesti area this insect develops only one generation per year.

Use of the sex pheromone Atraorg revealed that *O. antiqua* can be harmful to a slight foliage of young apple trees, therefore an application with Thionec 35 EC – 0.2% has been performed.

The European red mite (*Panonychus ulmi*). Monitoring this pest at 10 days intervals proved a significant development of this mite.

Leaf miners. Use of pheromone traps (3 traps per species and plot) revealed occurrence of leaf miner species: *Phyllonorycter blancardella* (Atrablanc), *Stigmella malella* (Atramal), and *Leucoptera scitella* (Atrascit).

Ph. blancardella had 3 generations per year (April–September).

S. malella and *L. scitella* captures were quite scarce, these pests having no adverse effect on tree foliage.

Dasyneura mali. This aphid became obvious by the end of August and in September, particularly on Golden Delicious. In Jonathan, Generos and Florina its occurrence was sporadical, no treatment being necessary (Tab. VI).

San José scale (*Quadraspidiotus perniciosus*). Systematic survey of this pest assessed its absence.

Captures of soil surface fauna in September by pitfall traps showed a similar structure of invertebrate animals in all plots. Dominance of harmful fauna was 1.5 (in Golden Delicious and Florina), and 2.5 in Jonathan and Generous, compared to the beneficial fauna.

Beneficial fauna included 3 species found in the sensitive cultivar plot (Golden Delicious and Jonathan), and 6–7 species in the plot with resistant cultivars (Generous and Florina). Differences were dependent on the higher number of active ingredients applied to sensitive pests.

Therefore we can conclude that the invertebrate community on soil surface was not specific to apple orchard, but resulted from the previous maize crop.

Ground cover. Net sweeping collections monthly performed showed that introduction of attractive plants considerably changed structure of insect species. Data indicated that harmful fauna prevailed, mainly on account of *Thysanoptera* in *Anethum graveolens*. As for *Aphis fabae*, and *Lygus campestris* densities, their percentages were higher, 37–47%, compared to beneficial fauna.

Analysis of data also evinced that on *Lolium multiflorum* and *Vicia* spp. we can find 21 and 20 species, respectively, similarly to wild plants.

Only 14–16 species have been found on *Anethum graveolens*, *Sorghum bicolor* and *Fagopyrum esculentum*.

Among these insects, the sucking species, such as aphids, cicadids and heteropterous were prevalent. The Agromyzids and Chrysomelids were also important.

Beneficial fauna was more abundant on *Lolium multiflorum* (22 species) and *Vicia* spp. (20 species). On other attractive plant species, 14 beneficial insect species have been identified.

There was a good relationship between aphids on dill and the number of parasitic hymenopterous species. The high numbers of cicadids and psyllids was corre-

VI. Pests evolution (insects and mites)

Month	Ten days period	*Aphis pomi*	*Phyllonorycter blancardella*	*Nepticula malella*	*Leucoptera scitella*	*Panonychus ulmi*	*Orgyia antiqua*	*Operophtera brumata*	*Dasyneura mali*
		Nr. shoots/tree	Nr. mines/leaf	Nr. mines/leaf	Nr. mines/leaf	Nr. mobile forms/leaf	Nr. of leaves/tree	Nr. of leaves/tree	Nr. leaves/tree
June	3	3	0	0	0	0	0	0.6	0
July	1	1–2	0	0	0	1	0	0	0
	2	1.0	0.1	0	0	1–2	0	0	0
	3	0.6	0.3	0	0	0	1–3	0	0.6–1.0
August	1	0	0.5	0.3	0	0	2–3	0	1–2
	2	0	0.7	0.9	1.1	1–2	0	0	2
	3	0	1.1	0	1.0	1–3	0	0	2–3
September	1	0	0.7	0	0	2	0	0	2–3
	2	0	0	0	0	2	0	0	3–4
	3	0	0	0	0	2–4	0	0	3–4
October	1	0	0	0	0	2–4	0	0	5.0

lated with high numbers of heteropterous species, and coccinellids among predators.

Limb jarring (Tab. VII). In the IPM plot the total number of arthropod species was lower than in the plot treated with chemicals. The harmful fauna was higher in the lot treated with chemicals supervised control. The beneficial fauna was similar, excepting Florina plot.

The beneficial arthropods (*Aranea, Coccinellidae, Hymenoptera*) could potentially control the pests.

Chemical analysis. Soil samples have been analysed for NO_2^- and NO_3^- content, as well as for some pesticide residues.

The lowest residue content was detected for chlorpyrifos-methyl, followed by endosulfan, thyophanate-methyl and captan.

Pesticide residue contents of soil samples were considerably lower than in leaves. Only endosulfan residues were close to values found in leaves. The maximum permissible level (MAL) for endosulfan soil residues is 0.2 mg/kg. The endosulfan soil residues detected were 9.54 times higher than the MAL.

The NO_2^- and NO_3^- soil contents proved that the soil was neutral and its fertilization normal.

DISCUSSION

The experiments in the old orchard proved to be only partially successful. Comparison between supervised chemical control and the proposed IPM system revealed an opportunity to reduce pesticide consumption; quality and quantity of yield was also different in some varieties.

The orchard was too old (26 years), its high quantity of fungal inoculum, great number of pests and its low level of activity of beneficial arthropods did not allow a quick and easy IPM implementation.

According to our determinations we observed a clear imporvement of beneficial arthropod activity. In 2 years the parasitism by *Aphelinus mali* considerably imporved upon *Eriosoma lanigerum*. Probably, during the next 2–3 years a balance will be reached.

In previous reports (Baggiolini and Fiaux, 1975; Metcalf and Luckman, 1975) comparison between chemical control (sprayings being applied as coverage), success of IPM was higher. Sztep by step the chemical control improved, use of non-selective or even very toxic compounds was removed, and use of different warning and forecasting methods, this system became more or less a supervised control.

Under these conditions comparison with IPM asks more time to demonstrate superiority of new methods.

Using selective pesticides, improving the activity of beneficial arthropods and other methods designed to enhance non-chemical control, the IPM system will gain more and more ground.

Evaluation if IPM efficiency is important at the farm level. For the farmer profit is essential.

According to our data the lower number of applications, the lesser amount of active ingredient per hectare for an equivalent yield evinced superiority of IPM system in 1992. In 1993, quality and quantity of fruits was lower in the IPM system.

Introduction of the new resistant cultivars Generos and Florina, having qualities similar to Golden Delicious and Jonathan, influenced strongly and favourably the economic aspects of IPM system.

According to data from 1994 the number of chemical compounds used fell from 6 in the chemical supervised control plot, to 4 in the IPM plot. Consequently, costs of pesticides used fell from 351,855 lei/year (100%) to 135,855 lei(year (38.6%).

Analysis in the 82 ha orchard performed during the last 5 years demonstrated an extremely efficient system of production, even for the case of supervised chemical control.

VII. Harmful and benefical arthropodes captured by limb jarring in apple crops

Group and species	Apple cultivars			
	Sensitive to diseases		Resistent to diseases	
	Golden	Jonathan	Generous	Florina
Harmful fauna				
Class ARACHNIDA				
Ord. ACARI				
Fam. TETRANYCHIDAE				
Panonychus ulmi Koch.	–	48	21	11
Tetranychus urticae Koch.	14	–	–	1
Ord. THYSANOPTERA	3	8	4	7
Ord. HOMOPTERA				
Javesella pellucida F.	27	9	45	4
Fam. CICADIDAE	3	–	8	–
Aphis pomi De Geer.	92	104	35	24
Aphis fabae Scop.	–	–	3	7
Ord. LEPIDOPTERA				
Phyllonorycter blancardella F.	10	9	5	5
Orgyia gonostigma L.	6	3	1	5
Fam. ITONIDIDAE	5	5	–	3
Fam. AGROMYZIDAE	4	12	6	7
Others	20	8	12	33
Total HF	184	206	140	107
Beneficial fauna				
Class ARACHNOIDEA				
Ord. ARANEA	102	80	46	89
Class INSECTA				
Ord. NEUROPTERA				
Chrysoperla carnea Steph.	1	–	–	2
Ord. HETEROPTERA				
Anthocoris nemorum L.	1	–	3	–
Orius vicinus Ribaut.	5	11	10	12
Ord. HYMENOPTERA				
Inostemma contarinae Szel.	–	2	–	–
Superfam. CHALCIDOIDEA	10	21	6	7
Fam. FORMICIDAE	4	6	7	18
Ord. COLEOPTERA				
Fam. CARÀBIDAE				
Lebia humeralis Dej.	–	–	1	–
Fam. COCCINELLIDAE				
Coccinella 7 punctata L.	28	30	22	16
Hippodamia variegata Goese	6	11	3	3
Stethorus punctillum Weise.	–	2	4	2
Fam. CANTHARIDAE				
Cantharis fusca L.	2	2	5	5
Fam. SCIARIDAE	3	3	6	–
Fam. SCATOPSIDAE	3	–	6	14
Others	10	8	–	3
Total BF	175	176	119	171
TOTAL	359	382	259	278

CONCLUSION

1. Comparison between the IPM system and chemical supervised control in the old orchard was favourable to IPM. Quality of fruit was slightly superior in the chemical supervised control plot.
2. The amount of beneficial fauna was much higher in the IPM plot.
3. The key-problem of these experiments was the control of apple scab and woolly aphid.
4. In the young orchard with resistant cultivars superiority of IPM was demonstrated by a low number of sprayings, low quantity of active ingredient per hectare (3.18 kg a.i./ha instead of 10.64 kg a.i./ha), as well as a good activity of benefical arthropods.
5. The economic analysis of a large orchard with resistant varieties to apple scab and powdery mildew evinced a possibility to reduce the number of sprayings from 15.8/year to 8/year while their cost fell from 100% to 44.3%.

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THE EFFECT OF AN INTEGRATED PEST MANAGEMENT PROGRAM ON THE ARTHROPOD POPULATIONS IN A HUNGARIAN APPLE ORCHARD*

VLIV PROGRAMU INTEGROVANÉ OCHRANY PROTI ŠKŮDCŮM NA POPULACE ČLENOVCŮ V JABLOŇOVÉM SADU V MAĎARSKU

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ABSTRACT: Comparative investigation on integrated pest management in an apple orchard was carried out for three years. Significant changes in the structure of the phytophagous and zoophagous population communities have been observed. The meaningful tendencies of this process are presented and discussed. Owing to the regular application of selective insecticides the population density of the parasitoids and predators increased and at the same time the density of the leaf rollers (*Archips rosana, Pandemis heparana*), leaf miners (*Phyllonorycter blancardella, Ph. corylifoliella*) and tetranychid mites (*Panonychus ulmi, Tetranychus urticae*) decreased. The density of pear tingid (*Stephanitis pyri*) and San José scale (*Quadraspidiotus perniciosus*) rose.

integrated pest management; apple orchard; phytophagous and zoophagous arthropods

ABSTRAKT: Srovnávací šetření integrované ochrany proti škůdcům v jabloňovém sadu se provádělo tři roky. Byly zjištěny významné změny společenstev fytofágních a zoofágních populací. Jsou předloženy a diskutovány významné trendy tohoto procesu. V důsledku pravidelné aplikace selektivních insekticidů se zvýšila početnost populací parazitoidů a predátorů, a zároveň vzrostly populace obalečovitých (*Archips rosana, Pandemis heparana*), klíněnkovitých (*Phyllonorycter blancardella, Ph. corylifoliella*) a sviluškovitých (*Panonychus ulmi*).

systém integrované ochrany; jabloňový sad; fytofágní a zoofágní členovci

INTRODUCTION

Owing to the regular application of broad-spectrum insecticides the abundance of the phytophagous arthropod species has changed in Hungarian apple orchards. The population density of some well known dangerous pests decreased. At the same time, notwithstanding the intensive use of organophosphorous insecticides, the population of fruit red spider mite (*Panonychus ulmi* Koch), some species of leaf miners mainly *Leucoptera malifoliella* (Costa), *Nepticula malella* (Stainton), *Phyllonorycter blancardella* (Fabricius), *Ph. corylifoliella* (Hawort) and leaf rollers mostly *Adoxophyes orana* (Fischer von Röslerstamm), *Archips rosana* (Linnaeus), *A. podana* (Scopoli) and *Pandemis heparana* (Denis et Schiffermüller) reached a very high level. The codling moth (*Cydia pomonella* (Linneaus)) appeared frequently in these orchards. Apple clearwing (*Synanthedon myopaeformis* Borkhausen) became a dangerous pest in the last decades. This circumstance is one of the reasons which indicates the necessity of the development of an integrated pest mangement in Hungarian orchards, too.

The population communities of arthropod species occurring in the different types of the Hungarian apple orchards have been studied for 15 years, from 1976 on, supported by the Hungarian Academy of Sciences (Mészáros et al., 1984). During these investigations many significant data about the pests and beneficial insects, their occurrence, population density, distribution, migration as well as their effectiveness have been obtained. By reason of these experiences we had the opportunity to carry out a comparative experiment on integrated plant protection in one apple orchard. Sig-

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nificant changes in the structure of the phytophagous and zoophagous population communities have been observed during this experiment. The meaningful tendencies of this process are presented and discussed in this paper.

MATERIAL AND METHOD

The experiments were carried out in the apple orchard of the Experimental Station of the Research Institute for Fruit-growing and Ornamentals situated at Kecskemét-Szarkás. This orchard was planted in sandy soil in 1981, the sorts of Idared, Jonagold and Mollis Delicious are on rootstock M 4.

The examinations were carried out in three plots of 2 ha each:

1. treated with broad-spectrum insecticides, so-called conventional plot (CONV),
2. treated with selective insecticides, so-called IPM plot (IPM),
3. treated with selective insecticides sown with flowering plants, so-called IPM plot with flowering plants (IPM/fl). This plot was sown in:

1992 Compositae: *Calendula officinalis*; Fabaceae: *Coronilla varia, Onobrychis viciifolia*; Umbelliferae: *Anethum graveolens.*

1993 Compositae: *Calendula officinalis, Guizotia abyssinica*; Fabaceae: *Astragalus cicer, Coronilla varia, Lotus corniculatus, Onobrychis viciifolia, Trifolium resupinatum*; Umbelliferae: *Anethum graveolens, Coriander sativum, Falcaria vulgaris.*

1994 Compositae: *Calendula officinalis, Carthamus tinctorius, Centaurea cyanus, Echinops ruthenicus, Taraxacum officinale, Xeranthemum annuum*; Fabaceae: *Astragalus cicer, Coronilla varia, Onobrychis viciifolia*, Hydrophyllaceae: *Phacelia tanacetifolia*; Onagraceae: *Oenothera biennis*; Scrophulariaceae: *Verbascum phlomoides*; Umbelliferae: *Anethum graveolens, Carum carvi, Coriandrum sativum, Daucus carota* ssp. *sativa, Falcaria vulgaris, Foeniculum vulgare, Pastinaca sativa, Petroselinum crispum, Pimpinella anisum.*

Owing to the drought occurring in consecutive years seed germination was insufficient, therefore the arthropod species living on the different native plants were also collected. The plants of native vegetation in the IPM plot were the following: Amaranthaceae: *Amaranthus chlorostachys, A. retroflexus*; Chenopodiaceae: *Chenopodium album, Salsola kali*; Compositae: *Achillea millefolium, Anthemis ruthenica, Erigeron canadensis, Senecio vernalis, S. vulgaris*; Convulvulaceae: *Convulvulus arvensis*; Cruciferae: *Sisymbrium orientale, S. sophia*; Fabaceae: *Medicago minima, Vicia villosa*; Geraniaceae: *Erodium cicutarium*; Portulacaceae: *Portulaca oleracea*; Zygophyllaceae: *Tribulus terrestris.*

Since it was not practicable to establish a stand of flowering plants in the rows of the trees complying with the reqirements, we have sown them along the two sides of the orchard in the third year.

Pesticides used in the IPM and conventional plots are listed in Tabs. I–III. The active ingredients of insecticides and acaricides applied in the experimental are: insecticides – acaricides: Báriumpoliszulfid = barium-polisulphid, Bi 58 EC = dimethoate, Danatox 50 EC = methylparathion, Decis 2,5 EC = deltamethrin, Dimecron 50 = phosphamidon, Dimilin 25 WP = diflubenzuron, Dipel = Bacillus thuringiensis, Flibol E = trichlorfon, Insegar = fenoxycarb, Match = lufenuron, Nevikén = sulphur + vaselinoil, Novenda = dinitro-orto-cresol, Omite 57 E = propargite, Pirimor 50 DF = pirimicarb, Rospin 25 EC = chlorpropilate, Torque 55 SC = fenbutatin oxide, Ultracid 40 WP = methidathion.

Fungicides: Alto 100 SL = cyproconazole, Bayleton 25 WP = triadimefon, Buvicid K = folpet, Cuprosan Super = zineb + copper, Delan = dithianon, Dithane DG = mancozeb, Dithane M-45 = mancozeb, Kén 80 WP = sulphur, Kén 800 FW = sulphur, Merpan 50 WP = captan, Nimród 25 EC = bupirimate, Polyram DF = metiram, Rézoxiklorid 50 = copper oxychloride, Roccol 400 SC = copper oxychloride, Rubigan 12 EC = fenarimol, Score 250 EC = difenoconazole, Thiovit S = sulphur.

The presence of the arthropod species and their population density as well as their population dynamics were observed by the following methods.

Eleven sex pheromones were used for monitoring the following *Lepidoptera* species: *Adoxophyes orana* (Fischer von Röslerstamm), *Archips rosana* (Linnaeus), *Grapholita lobarzewskii* Nowicki, *Cydia pomonella* (Linnaeus), *Leucoptera malifoliella* (Costa), *Pandemis heparana* (Denis et Schiffermüller), *P. ceresana* (Hübner), *Phyllonorycter blancardella* (Fabricius), *Ph. corylifoliella* (Hawort), *Nepticula malella* (Stainton)), *Synanthedon myopaeformis* (Borkhausen).

The occurrence and the density of *Quadraspidiotus perniciosus* (Comstock) and its parasitoid *Encarsia perniciosi* Tower was studied by pheromone traps (Smetnik, 1991; Hippe et al., 1995).

Ten shoots from 20 trees before blooming and 10 x 100 leaves after blooming were taken each in every plot to establish the percentage of the leaves infested by the caterpillar of the leaf roller or leaf miner species. Parasitoids were reared continuously from the caterpillars of *Microlepidoptera* in the laboratory.

The number of pupal skins (exuvia) of the apple clearwing extracted from the bark was counted weekly 4 times of 5 trees in each treatment.

I. Pesticides used in the experimental orchard (Kecskemét-Szarkás, Hungary, 1992)

Date	Conventional apple orchard	Dosis (%)	IPM apple orchard	Dosis (%)
12. 03.	**Novenda**	1.5	**Nevikén**	2.7
09. 04.	Cuprosan Super	0.5	Rézoxiklorid 50	0.4
14. 04	Dithane M-45	0.3	Merpan 50 WP	0.4
	Kén 800 FW	0.6	Bayleton 25 WP	0.025
24. 04.	Dithane M-45	0.3	Merpan 50 WP	0.4
	Kén 800 FW	0.7	Bayleton 25 WP	0.025
29. 04	Alto 100 SL	0.05	Rubigan 12 EC	0.1
07. 05	Alto 100 Sl	0.075	Rubigan 12 EC	0.1
	Dimecron 50	0.125	**Insegar**	0.1
18. 05.	Alto 100 SL	0.065	Rubigan 12 EC	0.1
	Rubigan 12 EC	0.075		
29. 05.	**Omite 57 E**	0.25	**Pirimor**	0.15
	Merpan 50 WP	0.3	Delan	0.06
	Bayleton 25 WP	0.025	Bayleton 25 WP	0.025
	Ultracid 40 WP	0.1	**Insegar**	0.1
08. 06.	**Omite 57 E**	0.2		
	Bayleton 25 WP	0.025	Bayleton 25 WP	0.025
	Dithane DG	0.3	Buvicid K	0.4
15. 06.	Dithane DG	0.25	Merpan 50 WP	0.4
	Bayleton 25 WP	0.025	Bayleton 25 WP	0.025
25. 06.	Dithane DG	0.25	Merpan 50 WP	0.4
	Bayleton 25 WP	0.025	Bayleton 25 WP	0.025
02. 07.	Dithane DG	0.25	Merpan 50 WP	0.4
	Bayleton 25 WP	0.025	Bayleton 25 WP	0.025
	Danatox 50 EC	0.25	**Dimilin 25 WP**	0.075
16. 07.	**Rospin 25 EC**	0.45	**Torque 55 SC**	0.15
	Polyram DF	0.3	Merpan 50 WP	0.4
	Kén 800 FW	0.375	Nimród 25 EC	0.1
30. 07.	Rézoxiklorid 50	0.3	Merpan 50 WP	0.4
	Kén 800 FW	0.375	Nimród 25 EC	0.1
	Flibol E	0.6	**Dipel**	0.16
10. 08.	Roccol 400 SC	0.25	Merpan 50 WP	0.4
	Kén 800 FW	0.375	Nimród 25 EC	0.1
	Danatox 50 EC	0.25	**Dipel**	0.16

insecticides, acaricides, fungicides

Leaves of 5 shoots were taken from 10 trees each in every plot, and the micro-arthropod species, like phytophagous and zoophagous mites, *Thysanoptera* etc. were selected under microscope.

The aphids were investigated on 10 shoots (leaf cluster) from 9 trees from each plot, as well as by yellow traps.

Ten pitfall-traps were placed in each plot. Five traps were placed on the space between two rows and 5 in the rows of the trees. Five more traps were placed in the edge bordering the orchard.

Limb beating was performed on one branch of 30 trees in each plot.

The samples were taken or traps were emptied or controlled weekly from the middle of April until the middle of October. The pheromone traps for *Lepidoptera* species were inspected weekly while for *Q. perniciosus* and *E. perniciosi* fortnightly.

The infections of apple scab (*Venturia inaequalis* (Cke.) Wint.) and powdery mildew (*Podosphera leucotricha*.(Ell. et Ev.) Salm.) were evaluated on 1 000 shoots in each plot.

Fruit evaluation was carried out on two occasions yearly. 4 x 50 fallen fruits at the end of August, and 4 x 200 fruits at harvesting were investigated in each plot for recording the damage caused by *C. pomonella*, leaf rollers and *Q. perniciosus*.

II. Pesticides used in the experimental orchard (Kecskemét-Szarkás, Hungary, 1993)

Date	Conventional apple orchard	Dosis (%)	IPM apple orchard	Dosis (%)
31.03.	**Báriumpoliszulfid**	3.75	**Nevikén**	4.0
20.04.	Rézoxiklorid 50 WP	0.5	Rézoxiklorid 50	0.5
28.04.	Dithane M-45	0.3	Score 250 EC	0.04
	Kén 800 FW	0.6		
05.05.	Rubigan 12 EC	0.06	Score 250 EC	0.03
13.05.	**Dimecron 50 EC**	0.1	**Dimilin 25 WP**	0.07
	Dithane M-45	0.3	Score 250 EC	0.03
	Bayleton 25 WP	0.03		
20.05.	Dithane M-45	0.3	Bayleton 25 WP	0.03
	Bayleton 25 WP	0.03	Merpan 50 WP	0.3
27.05.	Dithane M-45	0.3	Bayleton 25	0.03
	Bayleton 25 WP	0.03	Merpan 50 WP	0.3
03.06.	**Danatox 50 EC**	0.25		
	Bayleton 25 WP	0.03	Bayleton 25 WP	0.03
	Merpan 50 WP	0.3	Merpan 50 WP	0.3
	Karbamid	0.5	Karbamid	0.5
13.06.	**Dimilin 25 WP**	0.06	**Dimilin 25 WP**	0.06
	Bayleton 25 WP	0.03	Bayleton 25 WP	0.03
	Merpan 50 WP	0.25	Merpan 50 WP	0.25
25.06.	**Dimecron 50**	0.1	**Pirimor 50 DF**	0.15
	Bayleton 25 WP	0.03	Bayleton 25	0.03
	Merpan 50 WP	0.25	Merpan 50 WP	0.25
	Karbamid	0.5	Karbamid	0.5
08.07.	Bayleton 25 WP	0.03	Bayleton 25 WP	0.03
	Polyram DF	0.25	Merpan 50 WP	0.25
19.07.	**Dimilin 25 WP**	0.06	**Dimilin 25 WP**	0.06
	Merpan 50 WP	0.25	Merpan 50 WP	0.25
	Bayleton 25 WP	0.03	Thiovit S	0.3
30.07.	**Danatox 50 EC**	0.25	**Dipel**	0.16
	Thiovit S	0.3	Merpan 50 WP	0.25
	Rézoxiklorid 50 WP	0.25	Nimród 25 EC	0.1
10.08.	**Dimilin 25 WP**	0.06		
	Rézoxiklorid 50 WP	0.25		
	Kén 800 FW	0.4		

insecticides, acaricides, fungicides

RESULTS

Heteroptera

Heteroptera were the most meaningful group among the *Arthropoda* collected by beating from the apple trees and by shaking from the herbaceous plants. Unambiguous differences were established between the indvidual numbers of *Heteroptera* species collected in the conventional and in IPM plots. The number of the species and the specimens were higher in the IPM plots (Tab. IV). The specimens of pear tingid, *Stephanitis pyri* (Fabricius) appeared in low number in 1992. Its density increased in the following year and it became a significant pest in the third year after the cessation of broad-spectrum insecticides in the IPM plots (Tab. V). High numbers of *Heteroptera* specimens were collected both from the apple trees and from the herbaceous plants.

The most frequent *Heteroptera* species collected from herbaceous plants were *Nysius senecionis* (Schilling), *Lygus rugulipennis* Popius and *Eurydema ornatum* (Linnaeus). Individuals of *Heteroptera* species occurring in masses on flowering plants were found in far less numbers on the apple trees, and none of them was a pest. For the predacious species *Calendula offi-*

III. Pesticides used in the experimental orchard (Kecskemét-Szarkás, Hungary, 1994)

Date	Conventional apple orchard	Dosis (%)	IPM apple orchard	Dosis (%)
17.03.	**Novenda**	1.5	**Nevikén**	4.25
30.03.	Rézoxiklorid 50	0.5	Rézoxiklorid 50	0.5
07.04.	Dithane M-45	0.3	Buvicid K	0.3
	Bayleton 25 WP	0.03	Bayleton 25 WP	0.03
			Pirimor	0.1
14.04.	Dithane M-45	0.3	Buvicid K	0.3
	Bayleton 25 WP	0.03	Bayleton 25 WP	0.03
28.04.	Rubigan 12 EC	0.06	Rubigan 12 EC	0.08
04.05.	Dithane DG	0.25	Buvicid K	0.3
	Kén 80 WP	0.3	Bayleton 25 WP	0.03
	Dimecron 50 EC	0.07	**Dimilin 25 WP**	0.05
13.05.	Dithane DG	0.25	Buvicid K	0.3
	Kén 80 WP	0.3	Bayleton 25 WP	0.03
18.05.	Dithane DG	0.3	Buvicid K	0.3
	Kén 80 WP	0.3	Bayleton 25 WP	0.03
	Danatox 50 EC	0.18	**Insegar**	0.07
01.06.	Buvicid K	0.3	Buvicid K	0.3
	Bayleton 25 WP	0.03	Bayleton 25 WP	0.03
08.06.	Buvicid K	0.3	Buvicid K	0.3
	Bayleton 25 WP	0.03	Bayleton 25 WP	0.03
	Bi 58 EC	0.1		
18.06.	Dithane DG	0.2	Merpan 50 WP	0.3
	Kén-Sera	0.3	Bayleton 25 WP	0.03
			Pirimor	0.1
01.07.	Buvicid F	0.25	Merpan 50 WP	0.3
	Kén-Sera	0.3	Bayleton 25 WP	0.03
	Dimilin 25 WP	0.05	**Match**	0.05
20.07.	Rézoxiklorid 50	0.25	Rézoxiklorid 50	0.25
	Bayleton 25 WP	0.03	Bayleton 25 WP	0.03
	Kén-Sera	0.3		
28.07.	Kén 800 FW	0.3		
	Dimilin 25 WP	0.06	**Match**	0.05
04.08.	Dithane DG	0.2	Merpan 50 WP	0.3
	Kén-Sera	0.3	**Dipel**	0.13
	Danatox 50 EC	0.2		
27.08.	**Decis 2,5 EC**	0.03	**Dipel**	0.13

insecticides, acaricides, fungicides

IV. The number of Heteroptera species and specimens collected from apple trees in the conventional and IPM plots (Kecskemét-Szarkás, Hungary, 1993)

Plot	Number of species	Individual number
Conventional	21	153
Integrated	28	821
Integrated with flowers	33	996

V. Density of Stephanitis pyri adults and larvae (mean individual number of weekly sampling) – Kecskemét-Szarkás, Hungary, 1992–1994

Treatments	1992	1993	1994	1994
	April–October	April–October	April–October	August–October
Conventional	0.1	2.1	6.8	6.1
IPM	17.9	29.4	759.1	731.1
IPM/flowers	6.3	36.7	500.7	488.0
SD5%		20.7		
SD10%	11.6		417.0	N.S.

VI. Changes in the densities of the aphid species (Kecskemét-Szarkás, Hungary, 1992–1994)

Species	1992			1993			1994		
	conventional	IPM/flowers	IPM	conventional	IPM/flowers	IPM	conventional/flowers	IPM	IPM
A. pomi	802	561	7 422	6 893	4 871	3 986	2 389	5 741	5 892
D. plantaginea	21	4 856	1 447	1 083	2 741	1 290	34	84	124
D. devecta	180	1 521	–	80	2 815	2 556	42	3 854	4 365
Total	1 003	6 938	8 869	8 056	10 427	7 832	4 265	9 679	10 381

VII. Number of males of the *Quadraspidiotus perniciosus* and the *Encarsia perniciosi* in pheromone traps (average number of insects/traps/inspections) – Kecskemét-Szarkás, Hungary, 1992–1994

	Males				Parasitoids			
	1992	1993	1994	average	1992	1993	1994	average
IPM (8 year)	10.8	9.25	16.9	12.3	3.1	11.8	12.8	9.2
IPM (3 year)	13.9	2.0	6.7	7.5	2.6	5.5	3.2	3.8
IPM/flowers (3 year)	–	1.9	6.7	4.3	–	4.05	5.1	4.6
Conventional (8 year)	4.1	2.0	4.2	3.4	1.6	3.6	1.3	2.2
Conventional (3 year)	–	1.5	5.5	3.5	–	2.25	3.4	2.8

cinalis, Erodium cicutarium, Onobrychis viciifolia and *Vicia villosa* proved to be favourable microhabitats. No predaceous *Heteroptera* species were found on *Anethum graveolens* and *Chenopodium album*. Of the predaceous *Heteroptera* species *Orius niger* frequently occurred. The highest numbers were recorded in the conventional plot associated with the population density of *P. ulmi*. When the number of tetranychid mites decreased, the specimens of *Orius niger* disappeared from the trees.

Homoptera

Aphids

At the beginning of the experiment four aphid species, *Aphis pomi* (de Geer), *Dysaphis plantaginea* (Passerini), *D. devecta* (Wallker) *Rhopalosiphum insertum* Walker were present. Among them *A. pomi* was the dominant species. No significant difference was established in its population density either in the conventional and or in the IPM plots. The density of *D. plantaginea* was low in the conventional plot and simultaneously high in the IPM plot. The density of *D. devecta* was somewhat lower than the population level of *D. plantaginea*.

In the second year *A. pomi* became the dominant species in both plots. The density of *D. plantaginea* was somewhat higher in the IPM plot. Significant difference has been found between the abundance of *D. devecta* and *D. plantaginea*. The population level of *D. plantaginea* increased in the conventional and decreased in the IPM plots. The population of *D. devecta* increased and expanded in the IPM plot. At the same time its number was negligible in the conventional plot. *D. plantaginea* occurred seldom and in low density.

In the third year the tendency of their population dynamics became rather unambiguous. *A. pomi* remained the dominant species. Its colonies were present on the growing shoots and occasionally also damaged the fruits. *D. plantaginea* occurred seldom and in low density both in the IPM and in the conventional plots. The population density of *D. devecta* increased continuously in the IPM plots (Tab. VI). The number of the above-mentioned aphid species in the IPM plot showed some variation, however, the tendency of their population was the same. *Eriosoma lanigerum* (Hausmann) was present in low density in both plots. No increase in its population density was observed.

Scale insects

The males of *Quadraspidiotus perniciosus* and its parasitoid *E. perniciosi* were captured by sex-pheromone traps both in the conventional and the IPM plots. The number of *Q. perniciosus* males was higher in the IPM plots. At the same time it was impossible to find infestation on the trees and the percentage of the infested fruit was very low. In the neighbouring orchard where selective insecticides were applied for 8 years the density of *Q. perniciosus* and *E. perniciosi* was higher (Tab. VII).

Coleoptera

A total of 2 597 phytophagous and zoophagous *Coleoptera* specimens were collected by beating from the canopy of the apple trees. The frequently occurring phytophagous species were: *Anthonomus pomorum* (Linnaeus), *Peritelus familiaris* Boheman, *Anomala vitis* Fabricius and *Scolytus rugulosus* Ratzeberg. The abundace of the phytophagous species was about 2.5 times higher in the IPM than in the conventional plots.

VIII. Changes in the abundance of Carabidae species in the apple orchard and in the edge of the plantation (Kecskemét-Szarkás, Hungary, 1992–1993)

Species	1992			1993		
	conventional	IPM	EDGE	conventional	IPM	EDGE
H. flavescens	16	84	1	108	343	13
H. froelichi	43	191	7	158	284	14
C. ambiguus	12	46	32	113	245	199
C. erratus	1	1	61	21	9	155
Other Carabidae species	37	91	40	142	240	178
Total	109	413	141	542	1 121	559

Anthonomus pomorum (Linnaeus) appeared in the second year after the regular use of selective insecticides in the IPM plot. Its abundance increased mostly in the IPM plots where it reached the economic threshold. The number of the other species was very low and their abundance did not change significantly.

Among the zoophagous species *Stethorus punctillum* Weise was dominant and occurred both in the conventional and in the IPM plots. Its population density in the first year was the highest in the IPM plot. Its numbers decreased in the second year and was present only in a few number in the third year, connected with the abundance of *P. ulmi.*

By the pitfall-traps zoophagous *Coloeptera* species, mainly *Carabidae* were caught in the orchard and at the edges of the plantation. The dominant species were: *Harpalus flavescens* (Piller et Mitterpacher), *H. froelichi* Sturm, *Calathus ambiguus* Payk, *C. erratus* C. R. Saklb. Quite similar *Carabidae* population communities developed in the conventional and the IPM plots. The abundance of the species as well as the species richness were higher in the IPM than in the conventional plot. In the latter the abundance of carabid beetles was reduced occasionally by the effect of the applied broad-spectrum insecticides (Tab. VIII).

The population community found at the edge of the plantation reflected lower abundance and higher species number. It was significantly different from the population communities occurring in the IPM and the conventional plots.

Lepidoptera

The occurrence of the *Microlepidoptera* species *Leucoptera malifoliella, Phyllonorycter blancardella, Ph. corylifoliella, Cydia pomonella, Adoxophyes orana, Archips rosana, Pandemis heparana*, as well as *Synanthedon myopaeformis* were observed by sex-pheromone traps and by examining the infested leaves. Owing to the regular use of selective insecticides in the IPM plots as well as the application of broad-spectrum and from time to time of selective insecticides in the conventional plot significant chages have been observed in the population structure of the leaf miner, leaf roller species and of their parasitoids. *Cydia pomonella* was present in high density until harvesting being more numerous in 1994.

In the first year of the experiment, in 1992 mass swarming of leaf miner species (*Ph. blancardella, Ph. corylifoliella*) was indicated by the pheromone traps, and at the same time the larvae of summer fruit tortricid (*A. orana*) were observed as dominant species on the leaves. In the IPM plots the infestation of leaf rollers, while in the conventional plot that of leaf miners, prevailed. Therefore, chemical control was based on the use of fenoxycarb (Insegar) in spring. Against codling moth (*C. pomonella*) it was necessary to apply diflubenzuron (Dimilin) in summer. In the succeeding year (1993) the population density of leaf miners, *Ph. blancardella* and *Ph. corylifoliella* increased owing to the dry and warm weather conditions. They became dominant pests in the conventional plot, while the parasitoids were able to keep their population level under the economic threshold in the IPM plots. The abundance of the leaf roller species decreased, and the population level of codling moth (*C. pomonella*) remained constant.

In the third year (1994), owing to the effect of IPM technology the population level of the leaf miners became low. The infestation of leaf rollers and leaf miners was much higher in the conventional plot than in the IPM ones. The density of codling moth was high in this year again. In compliance with this circumstance diflubenzuron (Dimilin), fenoxycarb (Insegar), luferon (Match) and *Bacillus thuringiensis* (Dipel) were applied in the IPM plots. The changes in the abundance of leaf miner as well as of leaf roller species are summarized in the Tabs. IX and X.

Among the parasitoids reared from the larvae of leaf miner species are important: *Holcothorax testaceipes* Ratz., *Sympiesis sericeicornis* (Nees), *S. gordius* (Wallk.), *Tetrastichus ecus* (Walk.), *Pnigalio pectinicornis* (L.), *Chrysocharis pentheus* Walk., *Ch. orchestris* Ratz, *Neochrysocharis chlorogaster* (Erd.) Chalcidoidea, *Pholetesor bicolor* (Nees), *Ph. circumscriptus* (Nees) Braconidae. The frequent parasitoid species reared from the larvae of leaf roller species were: *Colpoclypeus florus* Walk., *Dibrachus cavus* Walk. Chalcidoidea, *Macrocentrus linearis* (Nees), *M. pallipes* (Nees) Braconidae.

IX. Percentage of apple leaves infested by leaf miner species (Kecskemét-Szarkás, Hungary, 1992–1994)

Species	Treatment	1992	1993	1994
Ph. blancardella	IPM	0.20	1.1	0.06
	IPM/flowers	0.18	1.8	0.05
	conventional	0.86	2.6	0.20
Ph. corylifoliella	IPM	1.05	5.7	0.69
	IPM/flowers	1.03	6.2	0.95
	conventional	5.80	10.4	3.93
L. malifoliella	IPM	0.95	0.7	0.51
	IPM/flowers	1.29	0.9	0.50
	conventional	0.84	2.2	1.92
Leaf miners in total	IPM	2.20	7.5	1.26
	IPM/flowers	2.50	8.9	1.50
	conventional	7.50	15.2	6.15

X. Percentage of apple leaves infested by leaf roller species (Kecskemét-Szarkás, Hungary, 1992–1994)

Species	Treatment	1992	1993	1994
Adoxophyes orana	IPM	3.70	0.03	0.04
	IPM/flowers	3.75	0.03	0.08
	conventional	1.70	0.0	0.04
Archips rosana	IPM	0.80	0.00	0.19
	IPM/flowers	0.55	0.02	0.42
	conventional	0.90	0.80	1.16
Pandemis heparana	IPM	0.10	0.03	0.92
	IPM/flowers	0.00	0.15	0.90
	conventional	0.00	0.00	0.90
Leaf rollers in total	IPM	4.60	0.06	1.15
	IPM/flowers	4.30	0.20	1.40
	conventional	2.60	0.80	2.10

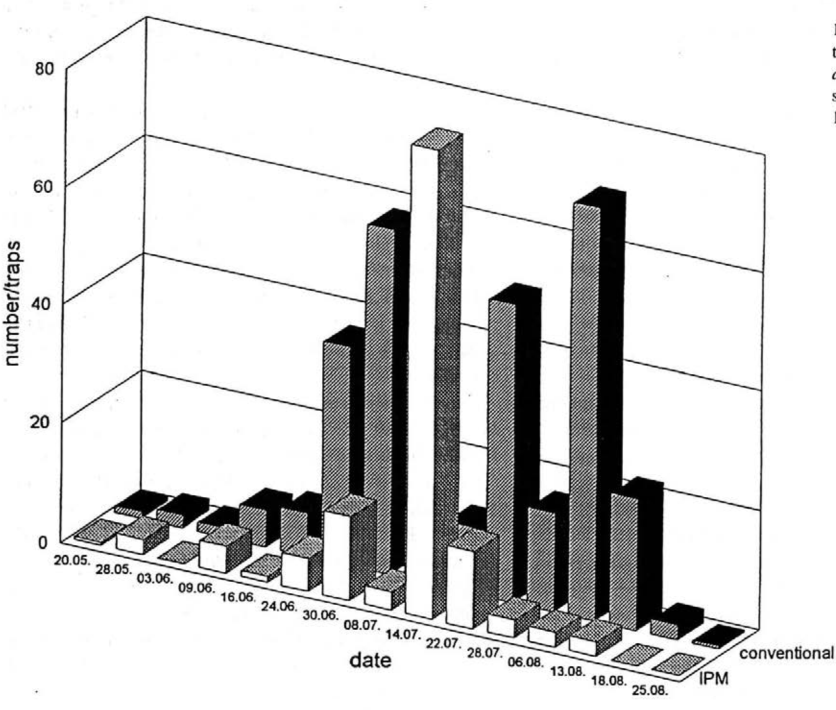
The majority of these species are able parasitize two or three leaf miner or leaf roller species.

High population density of *S. myopaeformis* has been observed in the orchard (Fig. 1). In one experimental plot having received four years integrated plant protection measures it was observed that both the number and distribution of *S. myopaeformis* adults collected by sex-pheromone traps, differed significantly from the one of a neighbouring plot that received conventional plant protection, although their previous record was identical. Similarly to the conventional one swarming lasted longer than in the IPM plot and the number of trapped adults was significantly higher. It was assumed that the differences can be attributed to some environmentally friendly preparation applied in the IPM plot.

Arachnoidea

Acari

Three species of tetranychid mites, *P. ulmi*, *Tetranychus urticae*, *T. viennensis* occurred in the experimental orchard. Among them *P. ulmi* was the dominant spe-



1. Changes in the population density of *Synanthedon myopaeformis*, Kecskemét-Szarkás (Hungary) 1992

XI. Changes in the population densities of phytophagous and zoophagous mite species (Kecskemét-Szarkás, Hungary, 1992–1994)

Year	Plot	*P. ulmi*	*T. urticae*	*T. viennensis*	*Phytoseiidae*	*Z. mali*	*Tydeidae*
1992	conventional	6 944	34	0	0	123	0
	IPM	1 020	110	6	1	1 442	0
1993	conventional	82	92	0	10	3 444	3
	IPM	0	42	0	940	4 276	6
1994	conventional	37	81	1	2	1 187	2
	IPM	1	58	108	413	282	111

cies. Its population density was high at the beginning of the experiment. Predacious mites did not occur at this time in the plantation. Among them *Zetzellia mali* (Ewing), a stigmaeid mite, appeared at first in the IPM plot in June and in low numbers at the end of the summer in the conventional plot.

In the second year of the experiment the population density of *Z. mali* increased both in the conventional and the IPM plots. It has become an effective regulating factor of the phytophagous mites. The population reached its peak in the IPM plot in this year. The specimens of the phytoseiid mites immigrated into both plots, but in the conventional plots they were present only occasionally and, in a few number. The population level of the tetranychid mites decreased in both plots.

In the third year in the conventional plot the abundance of *Z. mali* was low at the beginning of the vegetation period, but it increased at the end of summer. Phytoseiid mites occurred seldom and in low number. At the same time the population density of *P. ulmi* decreased and *T. urticae* and *T. viennensis* were present in a low number. In the IPM plot the population density of the phytoseiid mites increased and at the same time the individual number of *Z. mali* went down. Tydeid mites appeared and they were present in a relatively high number (Tab. XI).

Araneae

During all sampling sessions in 1994 a total of 667 spiders were collected by beating the canopy and by shaking herbaceous plants (Tab. XII). The most numerous families were *Thomisidae* (53%) and *Oxyopidae* (23%). *Oxyopes heterophthalamus* (*Latreille*) was the most dominant spider species of the canopy level (39%), and the second dominant species on the herbaceous plants. Crab spiders, on the other hand, were only dominant in the herbaceous layer, while *Salticidae* occurred predominantly in the canopy.

Cluster analysis revealed that the spider family composition was highly similar in canopies of the various of IPM plots. On the other hand the canopy fauna of the conventional plot was somewhat different from these, while the family composition of the herbaceous plants was markedly different from that of the canopy level in any of the plots. *Oxyopidae* represented a common element in both levels. Spiders of the herbaceous plants were of different compositions, and there is little evidence that by adding further plant species to the herbaceous layer would increase the number of spiders on the trees. Among the ground dwelling spiders, collected by pittfal-traps, wolf-spider (*Lycosidae*) represented some 70% of the material (Tab. XIII).

Most of the species in the *Clubionidae* family were collected by wrapped paper belt on the trunk of trees. Among them the dominant species was *Clubionia pallidula*.

Fruit evaluation

Upon fruit evaluation it was found that the damage caused by codling moth was 0.1–5.0% in the IPM and 0.9–15.1% in the conventional, that caused by leaf rollers 3.9–6.8% in the IPM and 3.5–16.6% in the conventional plots (Tab. XIV). Only a few individuals of San Jose scale were present (0.3–1.0%). No significant difference was established between the percentages of the damaged fruits in the IPM and the conventional plots.

DISCUSSION AND CONCLUSIONS

According to the results of the ecosystem research in the Hungarian apple orchard carried out for 15 years (Mészáros et al., 1984) the phytophagous and zoophagous arthropod species immigrate continuously into the different type of the orchards. Their survival and population dynamics as well as the interactions of their populations are strongly influenced by the anthropogenic effect in the ecosystem of these agrobiotopes. This process was observed in our experimental orchard, too.

Owing to the regular monitoring of the plots in the experimental orchard the type of the insecticides applicable as well as the point of time of spraying were well established both for the IPM and the conventional plots. In compliance with these circumstances the conditions of the survival of beneficial insects were more advantageous than in the former so called conventional orchards.

Phytophagous *Heteroptera* species found on the herbaceous plants are harmless for the apple trees, at the same time the predacious *Heteroptera* individuals are able to survive on the flowering plants and they can occasionally prey on the pests living on the apple trees.

XII. List of spider species collected from apple trees and herbaceous plants (Kecskemét-Szarkás, Hungary, 1994)

Family	Taxon	No. caught
Araneidae	*Araneus* sp.	2
	Araniella opistographa (Kulczynski)	1
	Argiope lobata (Pallas)	5
Clubionidae	*Cheiracanthium effosum* Herman	1
	Clubiona sp.	1
Linyhiinae	*Meioneta rurestris* (C.L. Koch)	4
Erigoninae	*Silometopus reussi* (Thorell)	1
Gnaphosidae	*Zelotes* sp.	1
Oxyopidae	*Oxyopes heterophthalamus* (Latreille)	20
Philodromidae	*Philodromus aureolus* (Clerck)	1
	Philodromus cespitum (Walckenaer)	3
	Tibellus oblongus (Walckenaer)	
Salticidae	*Carrhotus xanthogramma* (Latreille)	1
	Eris falcata (Clerck)	56
	Pseudicus encarpatus (Walckenaer)	2
	Salticidae x1 sp.n.?	1
	Salticus quagga Miller	1
	Salticus scenicus (Clerck)	2
Theridiidae	*Enoplognatha* sp.	4
	Steatoda albomaculata (de Geer)	1
	Theridion impressum L. Koch	10
	Theridion pinastri C.L. Koch	6
	Theridion varians Hahn	2
Thomisidae	*Misumena vatia* (Clerck)	4
	Thomisus onostus Walckenaer	43
	Xysticus kochi Thorell	1

Pear tingid (*Stephanitis pyri*) frequently occurred in the orchards before the regular use of broad-spectrum insecticides (Balázs, 1966). Owing to the disuse of broad-spectrum insecticides it appeared again and its population density increased rapidly in the IPM plots.

XIII. Number of spiders caught by pitfall-traps (Kecskemét-Szarkás, Hungary, 1992–1994)

	Conventional	IPM	EDGE
1992	25	25	114
1993	27	23	75
1994	43	81	149

This process is in connection with the dry and warm weather conditions of the past 2–3 years.

After the cessation of the use of broad-spectrum insecticides among the aphid species *D. devecta* and *A. pomi* became significant pests in the IPM plots. Owing to the regular use of phosphorous insecticides the aphid populations practically did not occur in the commercial orchards. Among the aphid species recorded from the Hungarian orchards (Szalay-Marzsó, 1969; Szalay-Marzsó and Andrásfalvy, 1970) *Aphis pomi, Dysaphis devecta, D. plantaginea* and *Ropalosiphum insertum* appeared in the experimental orchard, especially in the IPM plots. The growing shoots provide suitable conditions for the survival

XIV. Evaluation of the fruit at harvesting (Idared cv., Kecskemét-Szarkás, Hungary, 1992–1994)

Pests	1962			1993			1994		
	IPM	IPM/flowers	conventional	IPM	IPM/flowers	conventional	IPM	IPM/flowers	conventional
	infestation (%)								
Codling moth	0.1	1.0	0.9	2.0	1.8	5.5	3.5	5.0	15.1
Leaf rollers	5.4	3.9	3.5	5.0	6.8	9.5	10.5	11.9	16.1
San Jose scale	0.0	0.0	0.6	1.0	0.5	0.3	0.0	0.0	0.0

and continuous propagation of *A. pomi* until the end of summer. Therefore, the density of *A. pomi* individuals immigrating into the orchard in the summer period increases. From among the *Dysaphis* species, the density of *D. devecta* population increased in the IPM plots. The population of this species occurred formerly frequently in the apple orchard (Szalay-Marzsó, 1969). Since the activity of aphidophagous predators was weak in spring it was necessary to use insecticides to prohibit the increase of the density of *A. pomi* and *D. devecta*. *Aphelinus mali* could survive even in the orchards regularly sprayed with broad-spectrum insecticides living in the underground colonies of *E. lanigerum* on the roots and root collars of the sucker of root-stock M 4, in the Hungarian orchard (Jenser, 1983). After the cessation of the use of broad-spectrum insecticides it is to be expected that the populations of *A. mali* are able to regulate the populations of *E. lanigerum*.

Quadraspidiotus perniciosus is one of the most important scale insect pests of apple all over the world (Kosztarab and Kozár, 1988). In the orchards regularly treated with broad-spectrum insecticides the density of this pest is usually very low (Kozár and Viktorin, 1978), while with less intensive chemical control its density rapidly increased, as it was observed in recent years in Hungary (Vörös and Füzi, 1994). Therefore, it would be necessary to introduce selective insecticides suitable for controling of *Q. perniciosus* in the IPM program.

The codling moth (*C. pomonella*) was recorded as a significant, common pest of apple for a long time past from the Hungarian orchards (Jablonowski, 1912). Its damage became unimportant in the orchards regularly treated with broad-spectrum insecticides. However, its individuals immigrated permamently into the orchards from the surroundings, and therefore it was required to apply insecticides continuously against it (Jenser, 1984). On the occasion of the permament use of selective insecticides it is necessary to consider it as a potential pest. Its specimens were caught by the sexpheromone traps and its damage increased also in the our experimental orchard. Owing to long, dry and hot summers its population density was relatively high close before harvesting time, too. Therefore, it was necessary to apply *Bacillus thuringiensis* insecticide against it.

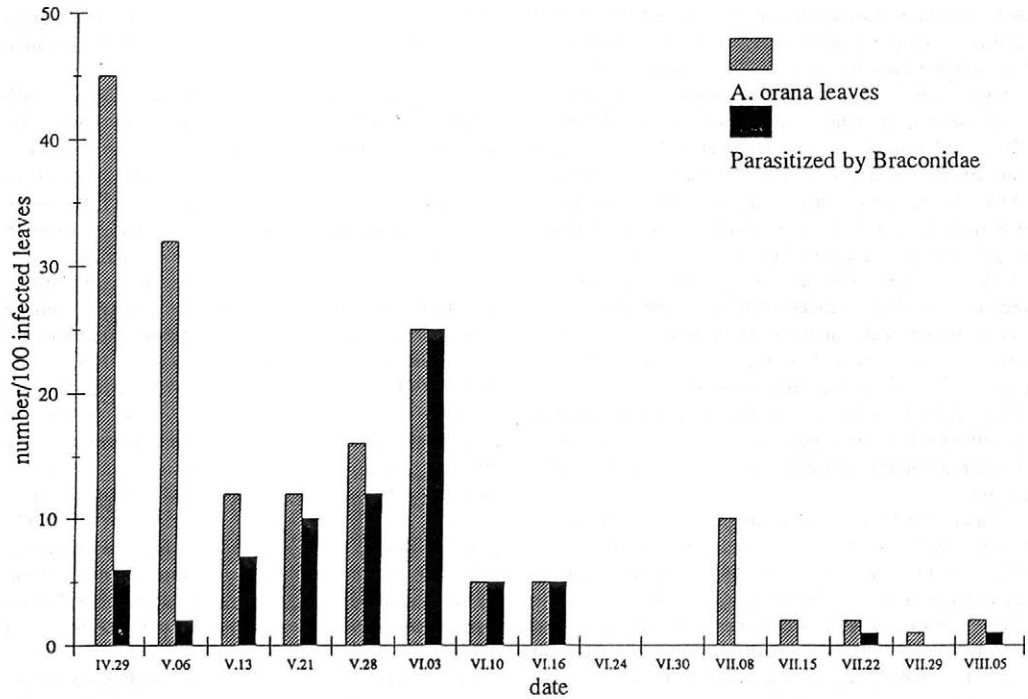
Numerous leaf roller species were recorded as pests from the Hungarian apple orchards. Some of them reached the economic threshold in the orchards treated with broad-spectrum insecticides, too (Reichart, 1972). Populations of *Adoxophyes orana, Archips rosana* and *Pandemis heparana* were observed in our experimental orchard. Their density changed depending on the insecticides used in the plots, on the effectiveness of their parasitoids and on climatic factors (Balázs, 1991, 1992a). According to the our investigations the larvae of the leaf rollers were parasitized in 10–20%, only seldom in 27–30% (Jenser et al., 1992), therefore, it is required to use some insecticides against them from time to time in the IPM orchards, too.

Among the leaf miner species only *Leucoptera malifoliella* and *Lyonetia clerkella* (Linnaeus) were reported from the apple orchards (Jablonowski, 1912), but their serious damage was not observed for long a time. A high population density of *Phyllonorycter blancardella, Ph. corylifoliella* and *Leucoptera malifoliella* were recorded in the 1970s and the 1980s in the Hungarian apple orchards treated with broad-spectrum insecticides. They caused serious damage during these years, even while organophosphorous insecticides were used intesively (Balázs, 1983, 1989, 1991, 1992b). The application of diflubenzuron (Dimilin) brought about suitable results, since it has an effect against their eggs and larvae and at the same time this insecticides save the *Microhymenoptera* parasitoids. The larvae of leaf miners were parasitized in 30–40%, occasionally in 80% (Jenser et al., 1992). In the IPM plots of the experimental orchard the parasitoids were able to regulate the populations of leaf miners after discontinuing the use of organophosphorous insecticides. It was proved that the pest status of leaf miners is exclusively the results of human intervention, as characterized by the conventional treated orchards.

The mutual parasitoids of the larvae of *Microlepidoptera* species gain a real significance when different pests replace each other within the same orchard. The changes in the pest population structure are less frequent under natural circumstances, but occur quite often in agrobiotopes. If, as a result of a selective pesticide, one given pest is effectively suppressed, its place might be taken by another(s). The possibilities of parasitoid replacement are: leaf roller to leaf roller; leaf miner to leaf miner; leaf roller to leaf miner; leaf miner to leaf roller (Balázs, 1997).

From the point of view of parasitoids the first two possibilities are advantageous, because the species has only to change over from one host to an other (e.g. in case of leaf rollers *Macrocentrus* spp., in case of leaf miners *Pholetesor bicolor, Sympiesis* spp., *Pnigalio* spp. (Balázs, 1983, 1989; Balázs et al., 1984). This type of change resulted in 1992 in a high parasitization of *Adoxophyes orana* never observed before. In this case *Macrocentrus linearis* changed over from *Archips rosana* in the IPM orchard. The parasitoid decreased it in the 2nd generation to the economic threshold and in the second year to a subdetection level (Fig. 2).

When the change occurs between leaf roller and leaf miner or leaf miner and leaf roller, the case is less advantageous, because the parasitoid must first immigrate into the orchard and after that can they multiply. It has been established that a 1–3% leaf infestation is at least necessary for the parasitoids to survive. There is an inverted ratio between leaf infection level and parasitism. In the case of the IPM orchards the beneficial effect of parasitoids against leaf miners becomes



2. *Adoxophyes orana* parasitized by *Braconidae* species in the IPM orchard, Kecskemét-Szarkás (Hungary) 1993

very soon noticeable, within 1–3 years any control measures become unnecessary (Balás, 1992b).

Synanthedon myopaeformis has been regarded until the 1960s in the whole of Europe as one of the secondary pests of apple was trees weakened by other factors (Reichart, 1958; Balás, 1966). It has become a significant pest and this can be attributed to changes in apple production technology (Chrestian and Lavy, 1966). Intensive plantations were established, rootstocks with low growing capacity were introduced which resulted in the early death of young (3–4 years old) trees under unfavourable environmental conditions.

Since the imagoes of *S. myopaeformis* swarm from the end of June until the end of August (Mikulás, 1973; Balázs et al., 1995; Khanh et al., 1995) and its larvae live under the bark, despite of the frequent application of broad-spectrum insecticides, its density is high in the commercial orchards. The results with Dimilin and especially with Match are significant, because *S. myopaeformis* fly in high numbers in July and which coincide with the treatments against *C. pomonella*, tortricids or leafminers. The evironmental safe protection against *S. myopaeformis* can be incorporated into the integrated control system of apple. By using suitable forecasting methods the control measure can be connected with treatments against the most important lepidopterous pests of apple and in a given case they do not even require a distinct treatment, only a good choice of selective insecticides (Balázs et al., 1995).

The dominant phytophagous spider mite was *Panonychus ulmi* in the experimental orchard and in the commercial orchard. Owing to the effect of broad-spectrum insecticides and acaricides the population density of the phytophagous tetranychid mites often remains low for months. Owing to the low population density of the phytophagous mites the food sources of predatory mite are missing. This is one of the reasons for which the predacious mites under certain conditions are unable to survive in the commercial orchards, independently from the use of pesticides.

Stethorus punctillum and *Orius niger*, known as effective predators of tetranychid mites (Berker, 1958), appeared in the experimental orchard. Their population level was higher in the conventional than in the IPM plot, connected with the high population density of *P. ulmi*. In compliance with the density of *P. ulmi* their population level changed. When the population density of tetranychid mites went down the specimens of *S. punctillum* and *O. niger* disappeared from the orchard. *O. niger* in the second year of the experiment was not present in the orchard. The abundance of *S. punctillum* decreased in the second year and only a few specimens remained in the experimental orchard in the third year.

The opinion in the literature concerning the population regulator effect of *Zetzellia mali* are dissimilar

(Berker, 1958; Laing and Knop, 1983; Santos, 1976). According to the our former experiences and the data of the present observations, after the cessation of the use of broad-spectrum insecticides its populations proved to be effective regulator factor of tetranychid mites in the first and second years (Komlowszky and Jenser, 1992). When the populations of *Phytoseiidae* species increase the density of *Z. mali* decrease and it became one of the regulating species of the phytophagous mites in the orchard.

The populations the *Tydeidae* species are significant alternative food sources for the phytoseiid mites, which can provide for the survival of their populations in the orchards. The importance of the alternative prey to the population dynamics of predaceous mite species was emphasized by Karg (1972) and Santos (1976).

According to the data of our present experiment, owing to the regular use of selective insecticides a population community could develop which include phytophagous and zoophagous species in low density as well as the alternative food sources of the zoophaguous species. In this community the population density of tetranychid mites is low, their population dynamics is well balanced, and the density of phytophagous species does not increase to a high peak within a short time.

Data about spiders in apple orchards are scattered (Dondale et al. 1979; Hukusima and Kongo, 1962; Legner and Oatman, 1964; Mansour et al., 1982; Altieri and Schmidt, 1986), with only a few studies from Central Europe (Naton, 1976; Samu and Lövei, 1995). The present study demonstrated that apple orchards have a relatively diverse spider fauna. However, no significant difference was found among the abundances of spiders in the canopies of the differently treated plots. The additional treatment of sown flowering plants in the rows did not cause any significant change in the canopy spider fauna either. On the other hand, the partial overlap between the spider fauna of the two vegetation strata of the orchard might be seen as an encouraging sign.

Owing to the regular use of selective insecticides, we conclude:

- the population density of some key pests e.g. leaf miners (*P. blancardella, P. corylifoliella*) decreased below the economic level,
- the density of some dangerous pests as codling moth was kept at low population level,
- many predators and parasitoid species appeared in the orchard and they were able to regulate the population dynamics of some pests as those tetranychid mites (*P. ulmi, T. urticae*), leaf miners (*Ph. blancardella, Ph. corylifoliella*) and leaf rollers (*A. orana*),
- the individual number of a few arthropod species increased, which proved to be alternative food sources for several beneficial arthropds,
- arthropod species which were known formerly as pests, appeared again in the orchard, e.g. *Stephanitis pyri* and *Anthonomus pomorum.*

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THE MANAGEMENT OF *PANONYCHUS ULMI* AND *TETRANYCHUS URTICAE* POPULATIONS BY *TYPHLODROMUS PYRI* PREDATOR MITES IN APPLE ORCHARDS*

REGULACE SVILUŠKY OVOCNÉ (*PANONYCHUS ULMI*) A SVILUŠKY CHMELOVÉ (*TETRANYCHUS URTICAE*) V JABLOŇOVÝCH SADECH POMOCÍ DRAVÉHO ROZTOČE *TYPHLODROMUS PYRI*

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ABSTRACT: The efficiency of regulation of abundance of red spider mite (*Panonychus ulmi*) and two-spotted spider mite *Tetranychus urticae*, by the predatory mite *Typhlodromus pyri* was investigated in a production apple orchards in central Bohemia. A population of *T. pyri* resistant to organophosphorus insecticides was introduced. Spider mite populations were kept below the threshold of economic damage in the first year after introduction but the effect was greater in *P. ulmi* than *T. urticae*. The spider mite populations were less abundant on cv. Spartan where initial abundance of *T. pyri* was greater than in cv. Golden Delicious where initial predatory mite density was lower. Introduction of *T. pyri* enabled to decrease the number of pesticide applications. It is recommended for integrated pest management in apple orchards.

biological control; integrated pest management; introduction of predator mites; monitoring of pest; regulation of populations

ABSTRAKT: V komerčním jabloňovém sadu ve středních Čechách byla sledována účinnost regulace svilušky ovocné (*Panonychus ulmi*) a svilušky chmelové (*Tetranychus urticae*) po introdukci dravého roztoče *Typhlodromus pyri*. Introdukovaná populace *T. pyri*, rezistentní k řadě organofosfátů a daších pesticidů, zajistila snížení populace svilušek pod ekonomický práh škodlivosti již v prvním roce po introdukci. Regulace populace *P. ulmi* byla v prvním roce účinnější než *T. urticae*. Na odrůdě Spartan, kde byla vyšší iniciální populační hustota svilušek než na odrůdě Golden Delicious, byla regulace populace svilušek v prvním roce pomalejší. Introdukce *T. pyri* umožňuje vyloučit používání akaricidů v sadech a je základem pro zavedení systému integrované ochrany.

biologická ochrana; systém integrované ochrany; introdukce dravých roztočů; monitoring škůdců; regulace populací

INTRODUCTION

Red spider mite (*Panonychus ulmi*) and two-spotted spider mite (*Tetranychus urticae*) have become a great problem in apple orchards with intensive production. Their increased presence is closely associated with intensive pesticide applications. Wide-spectrum insecticides, and above all pyrethroids, destroy to a considerable extent populations of natural enemies of spider mites. Spider mites can acquire high resistance to pesticide preparations following their repeated applications. Overpropagation of spider mites in apple orchards is dependent on the degree of their resistance to acaricides and on the intensity of the reduction of the populations of their natural enemies. Efficient biological control of spider mites represents a major prerequisite for the introduction of integrated pest management in fruit orchards.

At present, *Typhlodromus pyri* is widely used as a natural predator to control phytophagous mites. This predatory mite is commonly present in natural ecosystems and in orchards without intensive insecticide applications. In the Czech Republic, the introduction of *T. pyri* has been conducted on commercial basis for several years. Predatory mites are more efficient in spider mite control than insect predators. The development of *T. pyri* is synchronized with red spider mite development. *T. pyri* occurrence pattern is more even, *T. pyri* is characterized by a relatively long life span and, if necessary, it is able to switch to an alternative food source (van de Vrie, 1973).

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Studies conducted in New Zealand (Wearing et al., 1978), the Netherlands (Gruys, 1982), and Great Britain (Easterbook et al., 1985) showed that *T. pyri* could reliably control *P. ulmi* and *T. urticae* populations at experimental localities. Efficient control of spider mite population densities was also confirmed in laboratory experiments and field trials (Nyrop, 1988). *T. pyri* introduction has also been realized with good results for other cultured plants. *T. pyri*, as a biological pest control agent, also proved succesful in vineyards (Hluchý, 1992), where its ability to survive the vineyard chemical treatment regime was utilized.

The aim of our study was to investigate the use of *T. pyri* planted as a biological pest control agent in a commercial apple orchard. Population dynamics of *P. ulmi* and *T. urticae* spider mites, and of *T. pyri* predator mite were monitored and compared at orchard plots with intensive wide-spectrum pesticide applications and at plots with selective pesticide applications after *T. pyri* introduction.

MATERIAL AND METHODS

T. pyri efficiency in spider mite control was investigated in apple orchards at locality Blahotice (central part of Bohemia) in 1990, 1991, and 1992 on Golden Delicious and Spartan apple trees. *T. pyri* was introduced into a part of the orchard (10 hectares), as a biological pest control agent against spider mites, from the farm ZD Chelčice, in autumn 1989 (further referred to as „the biological control variant"). The process of biological control was regulated and monitored by a service advisory system described by Pultar et al. (1992).

Marked trees on which spider mite monitoring and predatory mite monitoring was conducted were situated in the central part of the apple orchard. *T. pyri* was not introduced to the other parts of the apple orchard at which chemical preparations continued to be applied as previously (here referred to as „the chemical control variant"). A selected population of *T. pyri* resistent to several insecticides was introduced. A twig with approximately 20 *T. pyri* was put on each tree. Marked apple trees on which spider mite monitoring and predatory mite monitoring was conducted were situated in the central part of orchard blocks with chemical control, at a distance of approximately 3 km from the biological control variant.

In 1990 and 1991, 10 leaves were collected from 10 marked trees (100 leaves in total) in regular (4-week) intervals from each variant and from each apple variety. The sampling dates were as follows in 1990: May 29, June 25, July 25, August 27; and in 1991: May 23, June 23, July 25, August 28. When preparing diagrams, the following transformation was applied: $y = \log(n + 1)$. For the two spider mite species, the numbers of mobile stages and of eggs per leaf were counted, while only the numbers of individuals per leaf were counted with *T. pyri*. Winter counting checks of overwintering pests were conducted in 1990, 1991, 1992, and 1993. The occurrence rates of overwintering stages of leaf aphids, of *P. ulmi*, of winter moth, of apple psylla, and of larvae leafrollers moth were determined. Besides that, two 0.20 m long 2- to 3-year-old twigs with blossom buds were cut from 10 apple trees of each variety and from both variants. The counts of overwintering stages of various pests thus established at all twigs and shoots were then related to a standard twig length of 1 m.

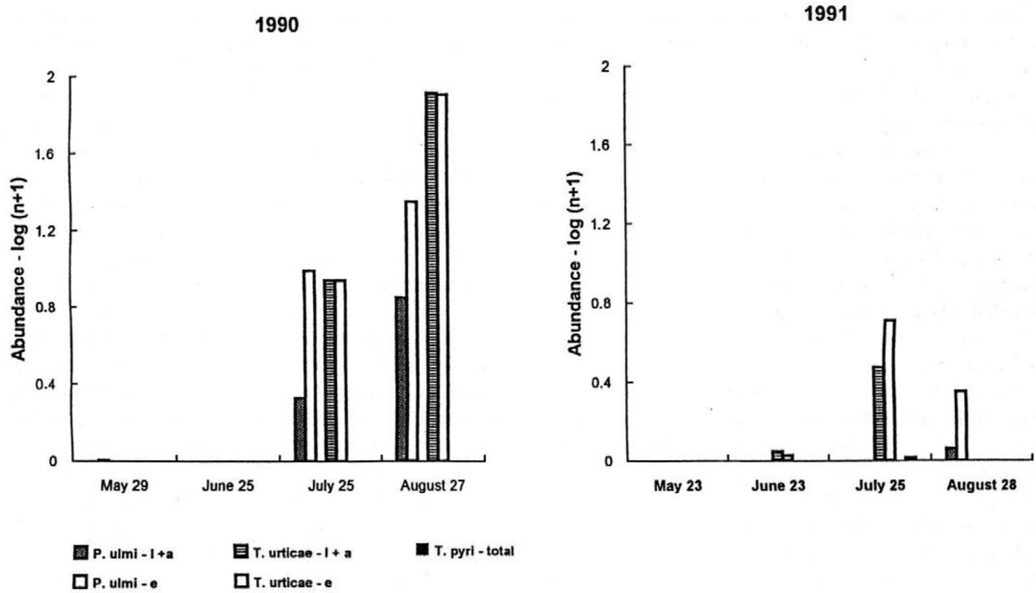
Before starting the experiment, both variants were sprayed each year by pyrethroids (2–3 times against codling moth and other pests) and acaricides (2–3 times against spider mites). After starting the experiment only phozalone was applied in biological control variant, against codling moth. In the chemical control variant, pyrethroids were applied in 1990 (2 times), while phozalone and acaricides were applied in 1991–1993 (1–2 times each year).

RESULTS

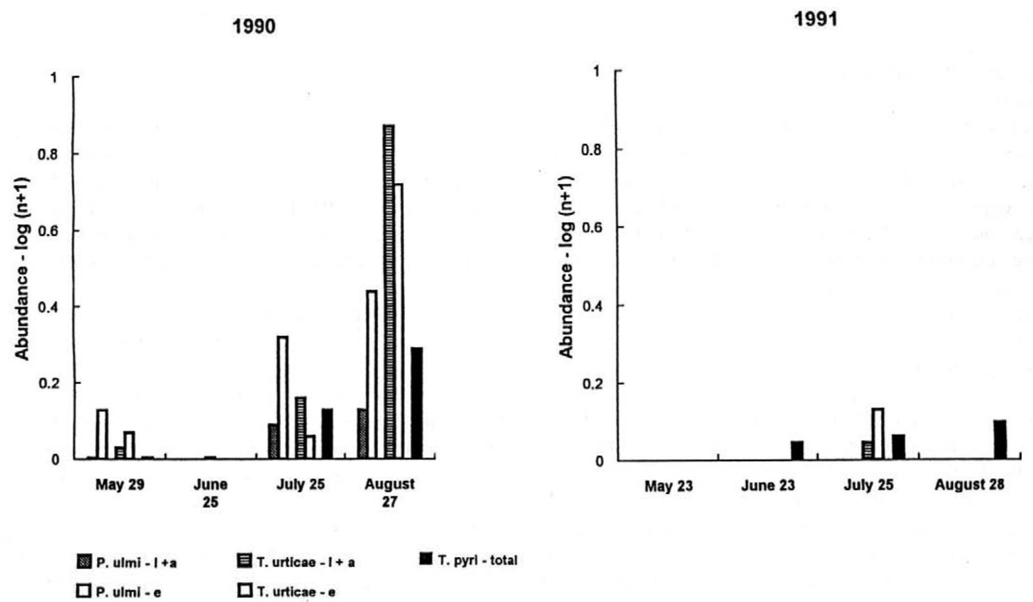
Following autumn introduction of *T. pyri*, initial *P. ulmi* population density was determined in winter season according to egg counts (Tab. I). The initial population density reached approximately 1 000 eggs per meter of shoots in average. In the first growing season following *T. pyri* introduction (1990), the maximum average *P. ulmi* occurrence rate in the chemical control variant was 6.1 mobile individuals and 21.2 eggs per leaf on Spartan trees (Fig. 1), while 2.4 mobile individuals and 9.7 eggs per leaf on Golden Delicious trees (Fig. 3). With *T. urticae*, the corresponding figures were 80.6 mobile individuals and 79.0 eggs per leaf on Spartan trees, and 8.3 mobile individuals and 21.0 eggs on Golden Delicious trees. Thus *T. urticae* population density was on Spartan trees six times as high than *P. ulmi* population, with the difference being three-fold on Golden Delicious trees. Spartan trees showed a five-fold red spider mite infestation rate when compared with Golden Delicious trees.

I. Average number of eggs *P. ulmi* per 1 m twig (winter control), Blahotice 1990–1993

Cultivar	Date	Chemical control	Biological control
Spartan		–	–
Golden Delicious	26. 1. 1990	876	1 088
Spartan	22. 1. 1991	2 005	875
Golden Delicious	22. 1. 1991	938	43
Spartan	24. 1. 1992	811	0
Golden Delicious	24. 1. 1992	617	0.8
Spartan	17. 3. 1993	54	12
Golden Delicious	17. 3. 1993	73	27



1. Abundance of adults (a), larvae (l) and eggs (e) of *P. ulmi, T. urticae* and *T. pyri* (abundance – average number per leaf), Spartan, chemical control, Blahotice, 1990, 1991



2. Abundance of adults (a), larvae (l) and eggs (e) of *P. ulmi, T. urticae* and *T. pyri* (abundance – average number per leaf), Spartan, biological control, Blahotice, 1990, 1991

Marked reductions in population densities of both spider mites species were recorded in the orchard into which *T. pyri* was introduced, already during the first year. On Spartan trees (Fig. 2), maximum mean *P. ulmi* population density reached 0.35 mobile individual and 1.76 egg per leaf, while maximum mean *T. urticae* population density reached 6.5 mobile individuals and 4.3 eggs per leaf. *T. pyri* population density reached 1 individual in August (population density peak).

On Golden Delicious trees, efficient control of both spider mite species took place already in the first growing season following *T. pyri* introduction (Fig. 4).

Maximum mean *P. ulmi* population density reached 0.05 mobile individual and 0.14 egg, while maximum mean *T. urticae* population density reached 0.07 mobile individual and 0.11 egg. *T. pyri* population density was 0.4 individual per leaf.

T. pyri efficiency in *P. ulmi* management was confirmed by winter season egg counts (Tab. I). Egg frequency on Spartan trees decreased by 20 per cent when compared with the preceding year, and by 96 percent on Golden Delicious trees. In contrast to this, egg frequency on Spartan trees in the chemical control variant doubled when compared with the preceding year, and remained at approximately the same level at Golden Delicious trees.

During the first growing season after *T. pyri* introduction, *P. ulmi* population on Spartan trees was sufficiently controlled, while *T. urticae* population was still regulated to an insufficient level. But no economic damage occurred, no bronzing symptoms developed. No acaricide preparations had to be applied to control red spider mites. By contrast, on Golden Delicious trees, the populations of the two spider mites species were efficiently controlled already in the first growing season after *T. pyri* introduction.

The occurrence rates in the chemical control variant somewhat decreased in 1991 when compared with 1990 (Figs. 1 and 3), presumably owing to weather conditions which were less favourable for spider mite development. Maximum mean *P. ulmi* occurrence rates on Spartan trees were 0.15 individual and 1.25 eggs per leaf while 1.88 and 8.5, respectively, on Golden Delicious trees. Maximum mean *T. urticae* occurrence rates on Spartan trees equalled 1.98 mobile individuals and 4.1 eggs per leaf, while 6.5 mobile individuals and 4.75 eggs on Golden Delicious trees. *T. urticae* occurrence rates on Spartan trees were markedly reduced in 1991. By contrast, *T. urticae* occurrence rates on Golden Delicious trees were reduced only to an insignificant extent in 1991. The mite population reduction was much more profound on Spartan trees on which spider mites reach higher population densities than on Golden Delicious trees. In 1991, mean *T. pyri* occurrence rate on Spartan trees at the chemical control plot equalled 0.04 individual per leaf, while 0.13 individual on Golden Delicious trees. This increase could be caused either by revitalization of the autochthonous population of *T. pyri* following exclusion of pyrethroid applications from chemical control in 1991, or by immigration of *T. pyri* from surrounding orchards where this species was newly introduced.

In the orchard into which *T. pyri* was introduced, efficient control of the two spider mite species was recorded on both Spartan and Golden Delicious trees. On Spartan trees (Fig. 2), the maximum mean *T. urticae* occurrence rates reached 0.11 mobile individual and 0.33 egg per leaf, while no *P. ulmi* individuals or eggs could be found. *T. pyri* mean occurrence rate on Spartan trees was 0.25 individual per leaf. On Golden Delicious trees (Fig. 4), the maximum mean *P. ulmi* occurrence rate was 0.05 egg per leaf, and no *T. urticae* individual or egg could be detected. *T. pyri* population density was 0.20 individual per leaf.

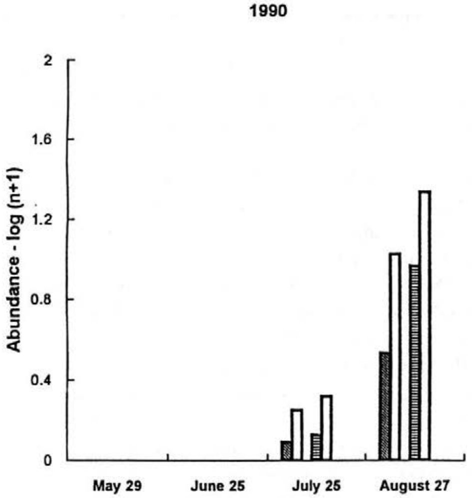
Egg counts conducted in the winter season following the second growing season after *T. pyri* introduction demonstrated complete *P. ulmi* control on trees of both varieties (Tab. I). On the other hand, egg counts on trees at the chemical control plot were similar to those recorded in the year of *T. pyri* introduction (1990 winter season egg counts). Winter season egg counts recorded after the third growing season showed mild increases in *P. ulmi* egg counts. The profound reduction in spider mite population densities in the third growing season after *T. pyri* introduction also resulted in a reduction in *T. pyri* population density. Spider mite individual and *T. pyri* individual frequencies were as low in the first half of that year (the 3rd year after *T. pyri* introduction) that the data recorded could not be quantified. Thus observations in the orchard were discontinued. This shows that spider mite population density reduction also leads to *T. pyri* population density reduction. However, high *T. pyri* population density also allows local *P. ulmi* population increases as evidenced by winter season egg counts conducted by us.

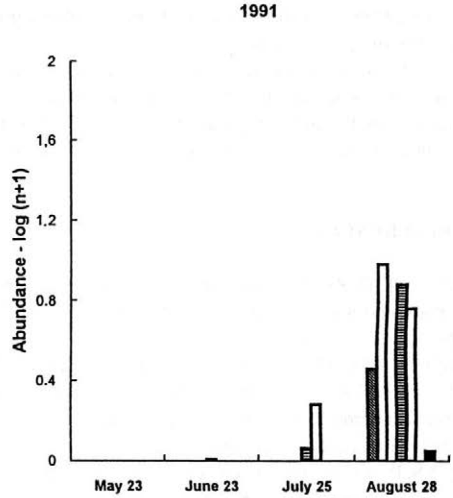
DISCUSSION

The results confirmed a good efficiency of *T. pyri* in regulating spider mite populations in apple orchards. The populations of *P. ulmi* and *T. urticae* were apparently kept below the threshold of economic damage even in the first year after introduction. Kneifl and Kňourková (1991) found a significant reduction of population density of *T. pyri*, on cv. Starkrimson, in the second year after introduction. The results indicate that acaricide treatments may be decreased in the first or second year after introduction.

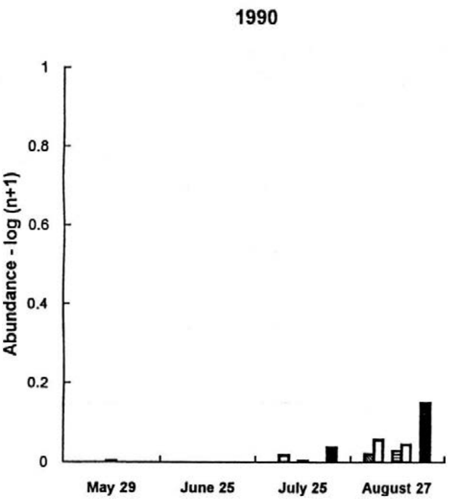
In cv. Spartan, initial abundance of spider mites was higher and its decrease slower than in cv. Golden Delicious. In both cultivars, *P. ulmi* abundance decreased more than abundance of *T. urticae*. In the second year when populations of *P. ulmi* were small, populations of *T. urticae* were more affected. The preference of *T. pyri* for *T. urticae* was already demonstrated by Nyrop (1988) who showed in laboratory experiments that *T. pyri* altered its searching behaviour in response to chemical stimuli associated with *P. ulmi* but did not respond similarly to stimuli from *T. urticae*. Also Dicke (1988) observed that *T. pyri* preferred kairomones of *P. ulmi* but under starvation it accepted also the latter prey species.

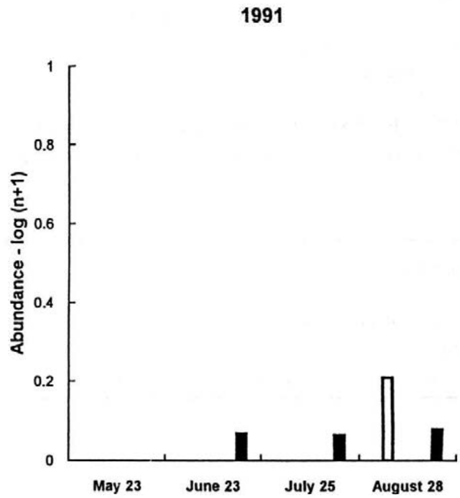
In Central Europe, *T. pyri* is probably the best mite biocontrol agent available for integrated pest management programmes in orchards (Solomon, 1975). This species is most abundant of the 23 phytoseiid species found in the orchards ot the Czech Republic (Hluchý et al., 1990). However, in the past 20 years its populations in production orchards were highly de-





3. Abundance of adults (a), larvae (l) and eggs (e) of *P. ulmi, T. urticae* and *T. pyri* (abundance – average number per leaf), Golden Delicious, chemical control, Blahotice, 1990, 1991





4. Abundance of adults (a), larvae (l) and eggs (e) of *P. ulmi, T. urticae* and *T. pyri* (abundance – average number per leaf), Golden Delicious, biological control, Blahotice, 1990, 1991

creased. Abundant populations however survived at some localities where organophosphorus insecticides were used. These populations became highly resistant to a wide spectrum of insecticides. Similar occurence of resistant *T. pyri* populations was demonstrated also by Hadam et al. (1986).

Seasonal dynamics of *T. pyri* populations in commercial apple orchards is well known (Zacharda, 1989). Our results are in good concert with previous findings. Commercial introductions of *T. pyri* into orchards and wineyards started in mid 1980 (Zacharda, 1988; Pultar et al., 1988) and may become an integral part of integrated pest management programmes in apple orchards.

But it can be concluded that spider mite control by *T. pyri* makes it possible, in a long term prospect, to maintain spider mite population densities below the economic threshold without any acaricide applications.

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Lesnictví – Forestry	12
Zemědělská technika (Agricultural Engineering)	4
Ochrana rostlin (Plant Protection)	4
Genetika a šlechtění (Genetics and Plant Breeding)	4
Zahradnictví (Horticultural Science)	4
Potravinářské vědy (Food Sciencies)	6

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ZAHRADNICTVÍ

Ročník 24, č. 2, 1997

OBSAH

(Toto monotematické číslo je souborem prací, které vznikly na základě řešení mezinárodního výzkumného projektu „Maximalizace biologických metod ochrany v systému integrované ochrany jádrovin".)

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CONTENTS

(This monothematic issue presents a set of works that bring together some results of research carried out in the international research project „Maximizing Biological Control in Integrated Pest Management of Pome Fruits".)

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