The 1st International Workshop of IOBC-APRS -Predatory Mites as Biological Control Agents Working Group

ABSTRACT BOOK

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Contents

Special Talks

IOBC and the Asia and Pacific Regional Section

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The International Organisation for Biological Control (IOBC) http://www.iobc-global.org/index.html was established in 1955 as a global organisation affiliated to the International Council of Scientific Unions (ICSU). It is a non-profit scientific body which promotes sustainable pest and disease management. IOBC provides a forum for biocontrol practitioners to network and contribute globally. The organisation promotes international cooperation, communication and advocacy for biocontrol, providing training, assistance to non-English speaking members, financial support to young scientists and professional independent advice to policy makers. IOBC actively seeks to raise public/stakeholder awareness of the importance and potential for biocontrol. Amongst other activities, IOBC coordinates global working groups, and commissions on specific biocontrol and IPM issues. For example, the Commission on Biological Control and Access and Benefit Sharing (part of the Convention on Biological Diversity) has been a focus of activity over the last few years with the aim of ensuring that exploration and exchange of biocontrol organisms can continue unencumbered by excessive bureaucracy. IOBC comprises six regional sections. The Asia and Pacific Regional Section (IOBC-APRS) is one of the largest and most geographically diverse and includes most Asian nations and Australasia. The executive committee with members from Australia, New Zealand and China is working hard to recruit members and to facilitate interaction between biological control researchers, practitioners and industry in the region. Our website http://www.aprs.iobc.info/ and twice-yearly newsletters are vehicles by which members can find out what is happening in biocontrol in the region including conferences and other events, significant publications, job and scholarship opportunities, and awards for young members to attend and present their work at conferences. We are very proud now to have our first APRS Working Group for some time which will be launched here in Beijing at this meeting.

A Brief Introduction of Institute of Plant Protection, Chinese Academy of Agricultural Sciences

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Introduction

The Institute of Plant Protection (IPP), Chinese Academy of Agricultural Sciences (CAAS), was established in August 1957. It is a national non-profit scientific research institute that specializes in crop pest research, prevention, and control. In the evaluations organized by Ministry of Agriculture during the Eleventh Five-Year Plan, IPP ranked the second place in the comprehensive capacity and the first place in the major among all the agricultural research institutes in China. Since 2012, IPP ranked the first place in the per capita strength among all the institutes in CAAS.

Organization and Discipline

There are 7 administrative departments in IPP: Department of general administration, Department of Human Resources, Department of Scientific Research Management, Department of International Cooperation and Graduate Student, Department of Achievement Transfer, Department of financial management. Infrastructure construction office.

There are 7 research departments in the institute, including Plant Pathology, Agricultural Entomology, Pesticide Sciences, Biological Control, Plant Protection Biotechnology, Biological Invasions, Weed and Rodent Sciences and Grassland Pest Control. Aimed at the global developing trends in plant protection and domestic agricultural industry needs, IPP has identified five dominant disciplines: plant diseases (including fungal diseases, bacterial diseases, viral diseases, and nematodes); plant pests (including food crop pests, cash crop pests, and natural enemy insects); pesticides (including chemical pesticides and bio-pesticides); weeds and rodents (including farmland weeds and rodents); and crop biosafety (including prevention and control of alien invasive species and genetically modified organism safety).

Faculties and Staffs

IPP currently has 227 employees, including 62 professors and 69 associate professors, 140 persons with PhD degree. Among them, there are 2 academicians of Chinese Academy of Engineering, 4 Distinguished Young Scholars awarded by

National Natural Science Foundation of China, 1 talent under the "Thousand-Talent Scheme", 2 chief scientist of National Basic Research Program (973).

IPP has been selected to be one of the pilot institutes in the first batch supported by the Agricultural Science and technology Innovation Program (ASTIP) in CAAS initiated in 2013. Sixteen innovation teams are involved

Education & Training

IPP has the authority of conferring Master and PhD degrees in Plant Pathology, Agricultural Entomology and Pest Control, Pesticide Science, Weed Science, Invasion Biology, GMO Safety, Biological Control, Agricultural Microbiology, Biochemistry and Molecular Biology. The institute offers a broad range of academic programs that lead to postgraduate degrees. Currently, there are nearly 600 Chinese graduate students and 17 foreign graduate students study in IPP in every year. As the remarkable achievement has been made in IPP, Department of International Cooperation and Graduate Student has been continuously awarded as the Excellent Administrative Unit in CAAS.

"The Scholarship of IPP for Graduate Student" has been set up to inspire up excellent students on innovative research and benefit for their career development. Postgraduate association has been founded and a lot of scientific as well as social activities have been well organized. IPP provides excellent research and living conditions, good learning environment for students.

A working station for postdoctoral research of plant protection is set up as well and currently there are 63 postdoctoral researchers in the institute. IPP has gradually developed into an important training center for advanced young scientists and extension experts of plant protection in China.

Research Platforms

IPP has established 14 national or ministerial key laboratories, including State Key Laboratory for Biology of Plant Diseases and Insect Pests, National Agricultural Biological Security Science Center, National Center for International Research of Agricultural Bio-security, the Key Laboratory of Crop Integrated Pest Management (MOA), Laboratory of Risk Assessment on Biological Hazard Factor Influencing the Quality and Safety of Agricultural Products (MOA),Center for Management of Invasive Alien Species (MOA), MOA Inspection Test Center for Environmental Safety of Transgenic Crops (Beijing), MOA Supervision and Test Center for Disease and Insect Pest Resistance in Plant (Beijing), MOA-CABI Joint Laboratory of Bio-safety, Sino-American Biological Control Laboratory, etc, and 8 field experimental stations among the major growing area in China.

Research Achievements

In recent years, more than 350 national and international research projects are under implementation and the total budget in contract amounted to 1660 million Yuan RMB. IPP has won 5 National Awards for Science and Technology progress. "Integrated Management of Wheat Stripe Rust" won the first prize of National Prize for Progress in Science and Technology in 2012. In addition, the institute has received 57 ministerial or provincial awards. Scientists in IPP have published more than 2280 original research articles, over 630 published in the SCI/EI indexed journals, 2 research articles published in "Science", 1 research article published in "Nature" and 1 review published in "Nature Biotechnology". IPP has published more than 100 books and owned 103 patents.

International Cooperation and Exchanges

IPP places great importance on international exchanges and cooperation, and has made great achievements, therefore, IPP was named as "National Center for International Research of Agricultural Bio-security" by Ministry of Science and Technology in 2012.

IPP has established long-term cooperative partnership in the frontiers of plant protection with institutions, universities and companies from more than 30 countries or international organizations around the world. These are mainly done through various collaborative programs and initiatives, such as scientific research projects, joint laboratories, visiting professors, academic visits, joint graduate training, bilateral workshops and international conferences, etc.

Two joint laboratories and two bases for introducing talents have been established in IPP, that is MOA-CABI Joint Laboratory of Bio-safety and Sino-American Biological Control Laboratory, and one base for biological control of locusts with *Metarhizium* and the other for demonstration and extension of pollution-free microbial pesticide production and application technology. The two joint laboratories and two bases are becoming the international cooperation and exchange platforms for our scientists.

Advances in Research and Applications of Predatory Mites in China

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Predatory mites have been considered as important biological control agents since 1960s. At that time, massive use of chemical pesticides greatly induced resistance of pests in agro-ecosystems, especially of small piercing and sucking pests, such as spider mites, thrips, and whiteflies, etc. Entomologists and acarologists started to turn back to seek for biological control strategies and methods, which led to a new round of natural enemy survey and investigation worldwide. Entomologists in China realized this trend, and kept up with the pace.

Since then, research of predatory mites in China have experienced 4 periods: initiation in 1960s and 1970s, the 1st boosting period from 1980 to 1995, a short falloff in late 1990s, and a stable developing period in the 21st century. Now, there are more than 20 research groups that work on predatory mites in China, covering multiple provinces of China. Six species have been introduced, and more than 320 new species or new native records in Phytoseiidae have been described. More than 800 research articles published in Chinese.

The main focus of predatory mite research in China has switched from introducing and releasing foreign species to surveying and evaluating native species. More than 20 native species have been studied, and biological control agents of 6 pest categories (pest mites, thrips, whiteflies, nematodes, pest beetles, and aphids) have been selected. More than 10 species are mass produced in China. The total production capacity exceeded 8 trillion mites per year. Five industrial standards for production and application have been established or issued. Main species produced in China includes *Phytoseiulus persimilis*, *Neoseiulus californicus*, *Neoseiulus barkeri*, *Neoseiulus cucumeris*, *Amblyseius pseudolongispinosis*, *Amblyseius orientalis*, and *Stratiolaelaps scimitus*, etc.

A total of 44 invention patents have been issued in China related to predatory mite sampling, producing, release and applications in different agro-ecosystems, such as greenhouses, and fruit tree orchards, etc. Multiple new techniques have been developed. Predatory mites are now applied widely in China. Some integrated pest management strategies effectively enhanced pest management potential of predatory mites, such as integrated thrips management with biological and physical control, conservation of predatory mites in orchards through herb planting, and using predatory mites to carry entomopathogenic fungus spores, etc.

Overall, research and application of predatory mite in China is developing with stable steps. We look forward to more new species and strains, more detailed

biological studies, more efficient mass rearing and field application techniques, and more international communications and cooperation in the future.

Biology, Behavior, and Interactions between Predatory Mites and Pests

Mechanisms and Cascading Effects on Plant-Herbivore-Predator Interactions: from the Laboratory to the Field

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Plant fluid uptake by predatory mites has been demonstrated with dyes, pesticides and isotopes. However, only recently has it been shown that phytoseiids, such as species belonging to the genus *Euseius*, actually feed from the plant. Interestingly we found *Euseius* species to be more effective citrus rust mite predators than the non-plant feeding species *Amblyseius swirskii*. As plant feeding pest mites are known to be affected by cultivar we hypothesized that plant feeding predatory mites would be more affected by cultivar than the non-plant feeding *A. swirskii*. Additionally we asked whether intraguild predation between *Euseius* species and the more aggressive *A. swirskii* could be affected by cultivar. Another host plant effect on mites that has been ignored is the plant mediated effects of the light spectrum, which is especially important when moving from lab to field. Predatory and pest species were monitored monthly on pomelo and Shamouti (an orange CV) trees in the field, provisioned with windborne pollen from flowering cover crops, following the sequential releases of *Euseius scutalis* and *E. stipulatus*. Under semi field conditions establishment of these two species was evaluated on pomelo and Shamouti seedlings, provisioned twice a week with pollen, naturally colonized with the non-plant feeding species *A. swirskii*. To determine the effect of light spectrum we exposed the seedlings to a full spectrum, full spectrum minus UVB (glass), full spectrum minus UVA and UVB (polycarbonate). A separate experiment was conducted to determine light spectrum effects on the establishment of *Tetranychus urticae* on lemon Volka rootstock, known to be resistant to this pest under field conditions.

In the field on pomelo the establishment of *E. stipulatus* was minimal whereas population levels of the naturally occurring *A. swirskii* were very high. In contrast in the Shamouti plot the populations of *E. stipulatus*, adjacent to the pollen source, were higher than those of *A. swirskii*. Establishment of *E. scutalis* in both plots and in the seedling trial was nil and very low, respectively. In the *E. stipulatus* seedling trial the levels of *A. swirskii* were substantially higher on pomelo than on Shamouti, whereas the populations of *E. stipulatus* were not affected by cultivar. These differences were less apparent when UVB was filtered. This result contradicts our hypothesis as it was

the non-plant-feeding predator *A. swirskii* that was affected by cultivar, perhaps because *E. stipulatus* is a citrus adapted species, naturally occurring on many citrus cultivars in Europe and North Africa. With respect to our second research question, it does appear that the cultivar affects the degree of intraguild competition between *A. swirskii* and *E. stipulatus* and could explain why is was not possible to establish *E. stipulatus* on pomelo trees. Light spectrum impacted the establishment of *T. urticae* on citrus seedlings, where populations were high under polycarbonate and minimal under the full spectrum. Similarly, certain volatiles were highest on infested plants exposed to the full spectrum, implying that the effect on *T. urticae* is plant mediated. Clear host plant effects, both cultivar and light plant mediated, need to be considered when evaluating pest control by phytoseiid predators, regardless of whether they feed on the plant or not.

Functional Response of *Neoseiulus californicus* and *Neoseiulus longispinosus* (Acari: Phytoseiidae) on *Tetranychus urticae* and *Tetranychus kanzawai* (Acari: Tetranychidae)

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Tetranychus urticae Koch and *Tetranychus kanzawai* Kishida are important pest mites of various crops of economic importance around the world. Prey consumption and functional responses of two species of phytoseiid mites on these two spider mites were evaluated at 25 ± 1°C, 65 ± 10% RH in the climatic chamber with a photoperiod of 16:8 (L:D). The functional response of both *Neoseiulus* species was type II on three immature stages (egg, larva and protonymph) of *Tetranychus* species. The value of attack rate coefficients (α) of *N. californicus* to each stage of *Tetranychus* was greater than *N. longispinosus*, and the shortest handling time (T_h) was obtained on larvae followed by nymphs and eggs. The maximum attack rate (T/T_h) on eggs, larvae and nymphs of *T. urticae* was estimated as 11.87, 37.23 and 26.95 for *N. californicus*, and 18.43, 28.98 and 20.67 for *N. longispinosus*. The maximum attack rate (T/T_h) on eggs, larvae and nymphs of *T. kanzawai* was estimated to be 11.90, 42.97 and 39.60 for *N. californicus*, and 24.15, 31.60 and 24.45 for *N. longispinosus*. The ability of *N. californicus* preying on larvae and nymphs of both *Tetranychus* species was significantly greater than *N. longispinosus* at high prey densities, but *N. longispinosus* consumed more eggs than *N. californicus*. Comparing the mean daily consumption of *Neoseiulus* spp. at different densities of different stages of *Tetranychus urticae* and *T. kanzawai*, more *T. kanzawai* larvae and nymphs were consumed by *Neoseiulus* spp, although the differences were not significant. Our study showed that *N. californicus* was more effective in preying on larvae and nymphs of *Tetranychus* spp. than *N. longispinosus* which preferred the eggs of *Tetranychus* spp. So mixed releasing of these two *Neoseiulus* spp. may enhance the control effect of *Tetranychus* spp, which need further trials to test.

Keywords: predatory capacity, two-spotted spider mite, red-mite, phytoseiid mites

Thermal Strains of the Predatory Mite, *Neoseiulus barkeri* (Acari: Phytoseiidae)

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Climate change predictions depict scenarios where arthropods will be more intensely and frequently exposed to extreme high temperatures. In this study, population of high temperature adapted strain (HTAS) of *Neoseiulus barkeri* was built under 35°C, and its performance with short heat stress was compared with that of conventional strain (CS) which was built under 25°C. The results showed that when exposed to 42°C for 12h, CS of *N. barkeri* held a 73.4% adult mortality, while that of HTAS was only 11.9%. The half lethal time (LT_{50}) of HTAS (15.2d) was significantly higher than that of CS (1.9d) when exposed at 45°C. The preovipositional period of CS significantly increased and the fecundity reduced after heat stress at 42°C for 2 and 4h. However, the preovipositional period and fecundity of HTAS was not affected by the heat stress. The mating behavior of virgin females and males of two strains of *N. barkeri* was also observed. However, the copulation period of two strains had no significantly difference. The results of functional response to *Tetranychus urticae* nymphs showed that when exposed at 38°C and 42°C for 2and 4h, the instant attack rate (a) decreased, the handling time (T_h) increased and the predation capacity (a/T_h) reduced, respectively. While the functional response of HTAS was not affected when exposed the same condition. The results evaluated that the HTAS of *N. barkeri* was not sensitive to heat stress and suggested that the HTAS may had better control capacity and performance in higher temperature circumstance.

Keywords *Neoseiulus barkeri*, heat stress, adult mortality, fecundity, functional response

Feeding Young by Predacious Mite to Cope Counter-Attack of Social Spider Mite

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Sociality of animals sometimes evolved anti-predatory strategies, i.e. defense (Aoki 1997, Crespi & Mound 1997, Mori and Saito 2005). In such species, specialized predators of these prey must also evolve some kinds of counter adaptation to keep their trophic level. If they could not cope prey's attack effectively, they might be extinct or shift their prey to other prey species. Therefore, complex coevolution between such predator and prey is expected, as complex predator-prey relationship among different stages was reported. In spider mites, there are several species having developed sociality (Saito 1986a, b; Zhang 2002; Mori and Saito 2005). As reported by Saito (1986a), the adult females and males of *Stigmaeopsis longus* (Saito) strongly counterattack its specific predator, *Typhlodromus bambusae* Ehara and the prey males frequently killed (and preyed upon) the predator larvae and protonymphs, although the adult females of *T. bambusae* could prey upon *S. longus* adult females and males. Whether *T. bambusae* females kill the prey adults to gain the fitness of their offspring, or only they preyed upon the prey need to be questioned. As a nature of predators, killing prey is equal to preying upon it, such that it is so difficult to discriminate these two explanations, i.e. "positive attacking of predator females against the prey adults to remove the risk of offspring" and/or "simply preying upon the prey adults". After Saito (1986a, b), several biological observations on *Stigmaeopsis* spp. and *T. bambusae* (Saito 1990a; Mori and Saito 2004; 2005; Zhang et al. 2014; Yano et al. 2011; Saito et al. 2013) provided some hints related to the above question. *T. bambusae* is a very specific predator that tends to live under the nests of *S. longus* and strongly decreased their life history performance with other prey other than *Stigmaeopsis* spp. (Saito 1990a). This predator has a strong tendency to live aggregately with their offspring in the prey nests, and never cannibalize their offspring even if there is no available prey (food) (Zhang et al. 2014). Even though *S. longus* and *Stigmaeopsis nanjingensis* (Ma et Yuan) perform strong counterattack against this predator (Saito 1986b; in this study, suppl. data), *T. bambusae* is regarded as the most important predator species that can regulate the population of *S. nanjingensis* on moso bamboos in China and also on *Sasa* bamboo in Japan (Takahashi 1987; Zhang 2002; Gotoh and Shida 2007). Therefore, how *T. bambusae*

maintain their predacious status in nature is a question in air, because such a tight relationship must be vulnerable without homeostatic mechanism. In this report, we observed the counterattack efficiency of *S. nanjingensis* against *T. bambusae* in the details and detected how the predators can cope such prey counterattack as well as discuss the existence of sociality in *T. bambusae*.

Keywords: Tetranychidae, *Stigmaeopsis nanjingensis*, *Typhlodromus bambusae*, subsociality, coevolution, double counterattack, Phytoseiidae

Allothrombium sp. (Acari: Trombidiidae) as Biocontrol Agent of Pear Psylla – the First Insights and Phenological Model

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Pear psylla *Cacopsylla pyri* (Hemiptera: Psyillidae) is the main pest in European pear orchards causing lots of economic damage each year. Feeding by pear psylla reduces plant growth, while excreted honeydew attracts sooty molds that damage leaves and fruits. Control of pear psylla has always been difficult in Belgium and because of increasing resistance and restrictions on the use of chemicals, the need for alternative management strategies is stronger than ever. The role of natural enemies has become more important in both IPM and organic orchards. Observations in orchards and predator-prey PCR's showed that *Allothrombium* (Acariformes: Trombidiidae) mites are promising natural enemies of pear psylla in Belgian pear orchards. Mites of the genus *Allothrombium* are already known as biocontrol agents of several pests around the world. Utilising these mites efficiently as beneficials requires more detailed information about their presence in different orchards, resistance to plant protection products, feeding capacity and preference, development during the season etc.

The main goals of this project are 1) to stimulate the presence of *Allothrombium* mites in orchards in order to improve biocontrol and 2) to develop phenological models of pear psylla and its natural enemies, including *Allothrombium* mites. These models will be implemented in a software tool that can aid pear growers in decision making. During the season of 2015 mites were counted in 6 IPM and 6 organic orchards using the beating tray method. Large variation between orchards was found, but numbers peaked in late summer or at the beginning of fall in all orchards. Half of the orchards showed another peak in April. Organic orchards generally have more mites than IPM orchards. 122 mites were collected and kept in the lab for rearing. Data on development times were gathered, but development could only be completed up to the deutonymph stage. First versions of the models were developed based on literature data.

Host-Parasite and Predator-Prey Associations between *Allothrombium* spp. (Actinotrichida, Trombidiidae) and Crop Pests

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The mites of the family Trombidiidae have complex life cycle with the heteromorphic active instars, including ectoparasitic larvae and predatory deutonymphs and adults. The members of *Allothrombium* spp. are expected to have high potential as biological control agents, as they hosts and prey include insect and arachnid of economic importance. The genus *Allothrombium*, of worldwide distribution, comprises more than 70 nominal species; most of them (ca 70%) are known exclusively from active postlarval forms, ca 20% – exclusively from larvae and only few (ca 10%) - from both. Due to the incomplete knowledge of life cycle and double systematics, carried out independently for larvae and active postlarval forms but also due to the poor knowledge of intraspecific variation of morphological characters, many species urgently need re-evaluation and redescription. The latter influences also the inference on host specificity displayed by the members of *Allothrombium*. The data on host-parasite associations of *Allothrombium* spp., were summarized by Welbourn (1983), who listed hosts of five species (mostly Hemiptera excl. Heteroptera (Aphididae) also Lepidoptera, Opiliones) and prey of two species (Hemiptera excl. Heteroptera, Hymenoptera, Isopoda, Lepidoptera and Araneae). Further records are scattered in the literature.

Here I summarized the data on host-parasite and predator-prey association between *Allothrombium* mites and others arthropods, including important crop pests. The list prepared based on published data and results of own observations, carried out in the laboratory and in the field, contains data on host of 18 species and on prey of seven species. Host records of *Allothrombium* include the following taxa: Coleoptera (Chrysomelidae, Cicindellidae, Coccinellidae), Diptera (Muscidae), Hemiptera (Diaspididae, Marchalinidae), Hemiptera excl. Heteroptera (Aphididae, Drepanosiphidae, Eriosomatidae), Lepidoptera (Pieridae, Pyralidae, Noctuidae), Orthoptera (Acrididae) and Actinotrichida (Erythraeidae, Smarididae), Opiliones (Phalangiidae), whereas the prey records include eggs, larvae or adult of Coleoptera (Curculionidae), Hemiptera (Cicadellidae, Coccidae, Marchalinidae, Pseudococcidae, Tingidae), Hemiptera excl. Heteroptera (Adelgidae, Aphididae, Eriococcidae), Hymenoptera (Formicidae), Isopoda (Porcellinidae), Lepidoptera (Crambidae,

Gelechiidae, Geometridae, Lymantriidae, Noctuidae, Pyralidae) and Actinotrichida (Tetranychidae), Araneae (Lycosidae, Linyphidae). The host range and preference towards prey vary among species. The data on both the host-parasite and predator-prey associations are known exclusively for four species (*A. fuliginosum*, *A. monospessulanum, A. pulvium* and *A. triticium*). Except for *A. pulvinum*, which is widely studied in regard to its potential use in biological control of agricultural pests, for the majority of species little or nothing is known about their host and prey associations and their actual role as natural enemies of pests.

Predatory Mites Feeding on Life Stages of *Bemisia tabaci* Mediterranean Species

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The UK continues to hold Protected Zone status against the sweet potato whitefly *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae). As a result, *B. tabaci* entering on plant material is subjected to a policy of eradication. There has recently been a shift from Middle East-Asia Minor 1 to the more chemical resistant Mediterranean species entering the UK. Predatory mites (*Amblyseius swirskii, Transeius montdorensis and Typhlodromalus limonicus*) were screened for their impact upon various life stages of *B. tabaci*. Mediterranean species in the effort to integrate them into existing eradication strategies. Approximately 30% of eggs were fed upon by *A. swirskii* following a 5 day period. Feeding rates slightly decreased for all mite species when feeding on first instar life-stages (27%, 24%, 16% respectively) and significantly decreased when feeding on second instars (8.5%, 8.5%, 8.7% respectively). Combining the two mite species (*A. swirskii* and *T. montdorensis*) increased mortality of *Bemisia* eggs to 36%. The potential of incorporating the mites into existing control/eradication strategies for *B. tabaci* is discussed.

Further reading:

Cuthbertson, A.G.S. (2014). The Feeding Rate of Predatory Mites on Life Stages of *Bemisia tabaci* Mediterranean Species. *Insects*, **5:** 609-614.

Cuthbertson, A.G.S. & Vänninen, I. (2015). The importance of maintaining protected zone status against *Bemisia tabaci*. *Insects*, **6:** 432-441.

Can the Predatory Mites *Amblyseius swirskii* and *Amblyseius eharai* Reproduce by Feeding Solely upon Conspecific or Heterospecific Eggs?

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Amblyseius swirskii (Athias-Henriot) is an exotic biological control agent of mites and small insect pests, while *Amblyseius eharai* Amitai & Swirski is a native predacious mite common throughout East and South-east Asia. Understanding the ways introduced predators affecting native ones is vital if we wish to use the former as biological control agents in the field. In order to evaluate the interactions between these two predacious mites, we observed their life histories when they cannibalized or fed upon intraguild prey (IGP) under laboratory conditions. Most intraguild predation occurred between different developmental stages of these two predator species. Both male and female *A. eharai* and *A. swirskii* could develop to adulthood by feeding upon both conspecific and heterospecific eggs. However, *A. swirskii* females supplied with heterospecific eggs had shorter developmental durations, higher fecundity, and higher intrinsic rates of increase (r_m) than those supplied with conspecific eggs. On the other hand, *A. eharai* females supplied heterospecific eggs had lower r_m than those supplied with conspecific eggs, suggesting that *A. eharai* females may prefer to prey upon conspecific immatures, even when *A. swirskii* immature stages are present. As a result, *A. swirskii* females may decrease *A. eharai* populations, when extra-guild prey species, such as spider mites, are scarce.

Key words: invasion risk, intraguild predation, cannibalism, development, oviposition, life history parameters, competitive exclusion

Female Performance towards Offspring under Starved Conditions in Four Phytoseiid Species (Acari, Phytoseiidae)

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There is an important difference of cannibalism between unrelated individuals and mother and offspring. The former can be defined as a form of intraspecific competition, but the latter affects the inclusive fitness of individuals. Many examples of cannibalism have been reported in predacious phytoseiid mites. The sib cannibalism avoidance is known in several species. However, whether females' actually prey upon their offspring under starved conditions has not yet been established. Here, female performance towards their offspring under no-prey-other-than-offspring was observed in four phytoseiid species, *Amblyseius eharai, Amblyseius swirskii*, *Neoseiulus cucumeris* and *Typhlodromus bambusae* under water-available and humidity-selectable conditions. *T. bambusae* females only survived for 4.14 ± 0.42 days, which showed a significant difference in survival duration between *T. bambusae* and the other three species (all survived more than 8 days). *N. cucumeris* females survived longer than *A. eharai* and A. swirskii females, whereas there was no difference between *A. eharai* and *A. swirskii* females. On the other hand, the offspring (immature stages from egg to larva or protonymph) of *A. eharai*, *A. swirskii* and *N. cucumeris* died earlier in mother-presence than in mother-absence (egg alone) experiments, suggesting that cannibalistic interactions occur between mother and offspring. The survivorship of *T. bambusae* offspring in the mother-presence condition did not differ from the mother absent condition, indicating that kin cannibalism was rare in this species. It might be related to the phenomenon that mothers tended to die before their offspring. The short longevity of *T. bambusae* mothers is one of the reasons why there is no significant difference in immature survival between the mother-presence and mother-absence experiments. The reason(s) behind such variation in female phytoseiid performance towards their offspring is addressed in relation to the diet-specialization hypothesis.

Keywords: kin cannibalism, subsociality, *Typhlodromus bambusae, Neoseiulus cucumeris, Amblyseius eharai, Amblyseius swirskii*

Survey, Evaluation, and Mass Rearing

A Conspectus of Medicinal Plant Associated Predatory Mites of India and Their Potentiality in Pest Management Program

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The importance of predatory mites has reached to a new height globally because of the fact that the use of conventional pesticides is appearing to be no more safe because of environmental and health hazards on one hand and on the other hand due to increasing trend in development of resistance and resurgence problems. All these are making pest management program a more difficult task. Hence, the worldwide attention has been focused to explore the predatory mites, study their bioecology and utilize those judiciously in pest management program. This communication makes a humble attempt to discuss the plant associated predatory mites of India and their potentiality in biocontrol program of plant feeding mites.

The important plant associated predatory mites of India belong to 4 orders and the total number of species stands at 373 belonging to 71 genera and 18 families. Those are: Order-I Prostigmata. Anystidae (11 spp, 3 genera), Bdellidae (14 spp, 6 gen), Caligonellidae (1 spp), Cheyletidae (16 spp, 11 gen), Cunaxidae (25 spp, 5 gen), Erythraeidae (15 spp, 7 gen), Raphignathidae (15 spp, 2 gen.), Stigmaeidae (30 spp, 6 gen), Tydeidae (24 spp, 5 gen), Order- II. Astigmata: Acaridae (3 spp, 3 gen), Order- III Cryptostigmata: Galumnidae (1 sp), Mochlozetidae (1 sp), Xylobatidae (1 sp), Order- IV: Mesostigmata: Phytoseiidae (211 spp, 11 gen), Ascidae (11 spp, 5 gen), Laelapidae (2 spp, 1 gen), Otopheidomenidae (1 sp). The important predatory mites under different families along with some of the major works done on diverse aspects, *viz* bioecology, rate of prey consumption, alternate food, predator – prey interaction, feeding potentiality, mass multiplication, effect of pesticides on predatory mites, introduction of exotic predators, which have mostly been done on Phytoseiidae, have also been discussed. Future work will be undertaken thorough exploration, identification, documentation of predatory mites, mites' bioecology, food preference, feeding potentiality, mass multiplication and field evaluation, effect of conventional pesticides on predatory mites, response of predatory mites to chemical cues produced by plant, and etc. In India, the use of predatory mites in biocontrol program is still at its infantile stage. It is urged to generate awareness among farmers in this regard and also the government provides encouragement in undertaking IPM of plant mite pests incorporating predatory mites as one of the components.

The Story of *Neoseiulus californicus* Chinese Strain: How We Evaluate a New Species or Strain

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In a field survey in Dinghushan Natural Reserve, Guangdong Province in Nov. 2010, some *Neoseiulus* sp. specimen were collected from loquat leaves. We tried to rear these predatory mites on spider mites, and found they have very high consumption rate of the prey, which evoked our interest to further evaluate it.

The specimens were identified as *N. californicus* and reported as the 1st record of this species in China based on morphological index. However, we pointed out 3 morphological features that differentiate the Chinese specimens from other *N. californicus* population. To verify the taxonomic status of this population, we compared DNA sequences from three molecular markers-12S rRNA, Cyt b mtDNA and ITS-with those of other *N. californicus* populations from multiple countries, using *N. idaeusas* outgroup. All 3 molecular markers were congruent and supported them to be *N. californicus*.

Using *Tetranychus urticae* as the prey, development, life table parameter, functional response, and dispersal of the *N. californicus* Chinese strain was estimated. The maximum consumption rate of spider mite by *N. californicus* was ca. 35% higher than *Amblyseius pseudolongispinosus*. The latter was considered as the best native predator of spider mites in China. Field experiment showed that *N. californicus* was able to reduce *T. urticae* population by up to 85% within 14 days on greenhouse cucumbers. When simultaneously released with *Phytoseiulus persimilis*, *N. californicus* showed higher capability in establishing its population at low prey density, which suggested possible longer control and less repeated release. This strain also showed potential in controlling other pests, such as thrips. It was able to complete its life cycle on *Frankliniella occidentalis*, and its consumption to the 1st instar larvae ranked the 2nd when compared to *N. cucumeris*, *N. barkeri*, and *A. orientalis*. It didn't show prey preference when both spider mites and thrips were available. We compared the biology of the Chinese strain with other strains based on literature data. The Chinese strain had the second shortest developmental duration when fed with *Tetranychus urticae*, and moderate fecundity and intrinsic rate of increase when fed with spider mites or thrips.

Neoseiulus californicus was generally mass reared with spider mites. We also tried to rear them on alternative prey. Although lower population increasing potential was observed when using alternative prey, we found this method still anticipated because appropriate nutritional content of prey diet is able to enhance population increase of *N. californicus* on alternative prey. Besides, we are planning to establish a

cost-benefit model based on current data to better evaluate release strategies of *N. californicus* for spider mites and thrips control on greenhouse vegetables.

Verification of Specific Status of *Allothrombium fuliginosum* (Hermann, 1804) and *A. pulvinum* Ewing, 1917 (Actinotrichida, Trombidiidae), Potential Agents in Warfare against Orchard Pests

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The representatives of *Allothrombium* are considered the most effective agents in biological control of pests of crops and orchards among Trombidioidea. The difficulties in species identification, caused mainly by limited knowledge of intraspecific variation of morphological characters, with special reference to active postlarval forms, constitute the main obstacles in studies on biology of species and their use in biological control. The identification of species still largely depends on larval morphology. The problem of separate identity of *Allothrombium fuliginosum* and *Allothrombium pulvinum*, species widely distributed in the northern hemisphere, is especially crucial due to the overlapping distribution and frequency of occurrence of both taxa. The aim of the study is to verify the status of *A. pulvinum* and *A. fuliginosum* based on morphological and molecular data. We hypothesize that both nominal taxa represent one species, whereas hitherto pointed differences should be attributed to intraspecific variation. The material for study included representatives of active postlarval forms (larvae, deutonymphs and adults) from different localities within the distribution range of *A. fuliginosum* and *A. pulvinum*.

Larvae of both nominal species were obtained at laboratory conditions from field-collected ovigerous females. The verification of the research hypothesis was based on the morphological and molecular data (barcodes COI and ITS2). T-test showed statistically significant differences with respect to 36 out of the 54 analyzed metric parameters of postlarval forms. DNA analysis was made for 13 individuals representing *Allothrombium* from Belgium (3), Poland (9) and Iran (1). We obtained 18 sequences (13 COI and 5 ITS2 sequences). In analysis we also used ITS2 sequences of *A. pulvinum* from the NCBI database.

Phylogenetic trees were constructed using maximum likelihood estimation (ML), based on the model of nucleotide substitution Tamura-Nei. Distance between sequences was calculated by Kimura's two-parameter model (K2P). Analysis was carried out in MEGA6. The intraspecific genetic distance (K2P) for specimens representing *A. fuliginosum* was: 0-0.013 for COI and 0.001-0.005 for ITS2; whereas

for *A. pulvinum*: 0.005-0.028 and 0-0.005 respectively. The interspecific distance in the COI region (0.018-0.023) was lower than intraspecific one, and in the ITS2 region (0.015-0.022) was only four times higher. The results point to the common specific affiliation of *A. fuliginosum* and specimens originating from Western Palaearctics and assigned to *A. pulvinum*. Further comparison with members of *A. pulvinum* collected from the original distribution limits (type locality) should ultimately solve the problem of common identity of both nominal species.

Fine Structure of Mouthparts and Gnathosoma of Tetranychidae and Phytoseiidae

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Spider mites in Tetranychidae are important pests worldwide, and predatory mites in Phytoseiidae are important natural enemies of them. Both these pests and predators are very tiny, and only a few studies investigated the ultrastructure and function of their mouthparts. To further explore their feeding behavior and mechanisms, we investigated the appearance and ultrastructure of the mouthparts of 3 tetranychid mite species and the gnathosoma of 8 phytoseiid predatory mite species.

The ultrastructure of mouthparts of *Tetranychus urticae*, *T. viennensis*, and *Panonychus ulmi* were observed with optical microscope and scanning electron microscope. For each of the three species, its stylophore appears to be two symmetric arms merged at the end and formed a reversed-U-shaped sac with longitudinal striates. The stylophores of *T. urticae* and *T. viennensis* are slender than that of *P. ulmi*. The lengths of stylets are 162.5μm, 203.0μm, and 155.0μm for *T. urticae*, *T. viennensis*, and *P. ulmi*, respectively. Each spider mite has only one whole stylet, which is consisted of two separated parts, i.e. left and right stylet. Only when probe or feeding starts do the two separated stylets zip up and form a complete food channel and a complete salivary channel. Both *T. urticae* and *T. viennensis* have ridge-shaped flanges in their food channels, while that of *P. ulmi* was relative smooth inside. A dendrite canal is observed in both left and right stylet of all three species. All the three species have rostral fossette, which is trapezoid for *T. urticae*, heart-shaped for *T. viennensis*, and suborbicular for *P. ulmi*. The claws of the thumb-claws of the three species are all furcated. There is an ostiole on the base of each claw. The terminal sensillum of *T. urticae* is slender, while those of *T. viennensis* and *P. ulmi* are short cone-shaped, respectively. The so-called terminal sensillum should be called spinneret, because that silk exudes from a hole in its top could be observed. The dorsal sensillum of *T. urticae* is fusiformed, while those of *T. viennensis* and *P. ulmi* are dendritic. The setiform setae of the three species are all dendritic. Possible relationships between mouthparts morphology and feeding habits of spider mites were also discussed.

On phytoseiid species we investigated, their gnathosoma ultrastructures were observed with optical, scanning and transmission electron microscope. Under

scanning electron microscope the gnathosoma includes a pair of chelicera and a hypostome. We recorded a stylet-like organ in *Neoseiulus californicus* and a tiny hole on the tip of fixed digit found only in *Phytoseiulus persimilis*, which were not reported before based on our literature search. We measured 24 indexes of different parts of gnathosoma for all the species, and processed the data using principal component analysis (PCA). The result showed that PCA is able to separate specialist and generalist predatory mites based on the indexes. Under transmission electron microscope, we observed the cross section of gnathosoma of *Neoseiulus californicus*. Chelicera, salivary stylus, labrum, paralabrum and pharyngeal chamber can be clearly seen through the pictures we took. However, there was not stylus-like duct found in the cross section of gnathosoma. Under optical and fluorescence microscope, we found a sloping feeding duct that started from a certain spot at gnathosoma and extended to the base of gnathosoma. We also observed the feeding behavior of predatory mites and discussed their feeding mechanisms.

Greenhouse Performance of Cold-Stored Indigenous Population of *Phytoseiulus persimilis* (Acari: Phytoseiidae) Against *Tetranychus urticae* (Tetranychidae) in Two Host Plants Species

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In this study, greenhouse performance of cold stored indigenous population of *Phytoseiulus persimilis* Athias-Henriot (Acari: Phytoseiidae) were investigated against *Tetranychus urticae* Koch (Tetranychidae) in two host plants species. *P. persimilis* were obtained from a laboratory culture established from adults collected in a *T. urticae* infected bean plants in Samandag-Hatay (Turkey). In order to obtain the best storage conditions of the predatory mite, storage experiments were conducted at 5, 7.5 and 10 °C and high humidity level over 96% RH, before greenhouse trials. Depending on the data obtained from the experiments, the best storage conditions of the *P. persimilis* was found at 5 °C and over 96% RH and could be stored up to 40 days with a high vitality. Greenhouse trials were carried out in 3x3x3m net cages established in a greenhouse, during the period of 2014 spring and fall and 2015 spring seasons on eggplant and cucumber. In each experiment, performance of 30 days cold-stored adult females of *P. persimilis* against *T. urticae* was compared with unstored *P. persimilis* and non-released control. In all experiments beginning predator-prey ratios were 1:7.5. In 2014 and 2015 spring seasons in eggplant, total mean number of *T. urticae* was found 3.97, 0.73 and 0.85 and 3.63, 0.77 and 0.25 total stages/cm^2 leaf area in control, unstored and cold-stored releases, respectively. In 2015 fall season in cucumber above given means were found as 21.16, 0.08 and 0.07 total stages/cm^2 leaf area in control, unstored and cold-stored releases, respectively. In both years, total mean numbers of *T. urticae* were not statistically different between cold-stored and unstored but significant in control vs. releases. The results of this study showed that cold-stored indigenous population of *P. persimilis* was very successful in controlling *T. urticae* in two host plant species. This study was supported by TUBITAK (Scientific &Technical Research Council of Turkey), Grant No. 111G150.

Keywords: Storage, predatory mite, spider mite, eggplant, biological control

Small-Scale Rearing Technique of a Predatory Mite *Hypoaspis aculeifer*

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Hypoaspis aculeifer is a soil-dwelling predatory mite which feeds on various soil pest insects and nematodes, such as thrips, springtails, fungus gnats, root mites and root-knot nematodes. *H. aculeifer* is thus a good natural enemy for the practical application in most greenhouse cultivation in Korea. We developed a simple and economic technique for the mass rearing of *H. aculeifer*, which can be managed by farmers themselves. A cosmopolitan mold mite, *Tyrophagus putrescentiae,* is used as a prey for *H. aculeifer*. This mite can be easily reared using the mixture of rice bran and dried yeast within the small container. Humidity can be maintained providing water in the outer plastic container. Then predatory mites were reared in the small inner plastic container using chaff (rice husks) which can be easily obtained from rice mill. Farmers can practice mass rearing of predatory mites with low cost. This technique is highly useful for farmers who want to use natural enemies for their eco-friendly agriculture.

Keywords: Natural enemies, self-rearing technique, environment-friendly agriculture, practical application

Some Important Predatory Mites on Medical Plants from Coastal Bengal with Note on Their Potentiality in Biocontrol

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The present communication reports the occurrence of predatory mites on medicinal plants from coastal region of West Bengal, India on the basis of collection made during 2014-2015. As many as 36 species belonging to 15 genera and 7 families under 3 orders are reported. These belong to Phytoseiidae- 19 species under 7 genera, Ascidae - 1 species, Stigmaeidae - 6 species under 1genus, Cunaxidae - 3 species under 1 genus, Bdellidae - 1 species, Tydeidae - 5 species under 3 genera and Acaridae - 1 species. Among these, the species which were abundantly seen on medicinal plants and had shown potentiality in doing a good job of feeding mostly upon Tetranychidae and Tarsonemidae mites are: *Paraphytoseius multidentatus* on *Polyphagotarsenemus latus* infesting *Ocimum gratissimum*, *Agistimus gambli* feeding on *Eutetranychus orientalis* infesting *Rauvolfia tetraphylla*, *Amblyseius largoensis* on *Tetranychus neocaledonicus* on *Ricinus communis*, *Agistemus fleschneri* on *Polyphagotarsonemus latus* infesting *Ocimum tenuiflorum*, *Pronematus fleschneri* feeding upon *Eutetranychus orientalis* on *Ocimum sanctum*. The promising phytoseiid predators were *Amblyseius largoensis*, *Neoseiulus longispinosus*, *Euseius finlandicus*, *Euseius alstoniae* and *Euseius coccineae*. All these mostly fed upon various stages of Tetranychid mites. Attempts are being made to find out suitable strategy to conserve those promising predators and also doing mass multiplication of *Amblyseius largoensis* and *Neoseiulus longispinosus*, the two most dominating predators along with doing their field evaluation for ascertaining their potentiality as biocontrol agents. This paper discusses all these aspects in details for utilizing predatory mites in bio-control programme of mite pests.

Some Predatory Mites Associated with Medical Plants of the Himalayan Foothills

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The medicinal plants are gaining increasing importance globally because of their manifold uses not only in preparation of herbal drugs which can cure a wide range of human ailments without having any bad side effects, but also are used as flavouring, colouring agents, nutraceuticals, food supplements, cosmetics, phytopesticides etc. Like other agricultural crops, medicinal plants are also attacked by a large section of pests like mites, insects, nematodes and etc. However, unlike other agricultural crops, use of chemical pesticides for pest control purpose on medicinal plants is unadvisable because of residue problem making those herbs useless for preparation of herbal drugs. Therefore, search is on to find out alternative method of control and in that biocontrol method using predatory mites appears to be promising. In view of this, an exploratory program was taken up in the foot hills of the Himalayas, where is considered to be abode of diverse species of medicinal plants during 2013-2015, for occurrence of predatory mites and the present communication repots the result thereof. A total of 36 species of predatory mites belonging to 11 genera and 5 families are documented here and those are Phytoseiidae -19 spp, 6 genera (5 spp. most abundant), Ascidae-1 sp, Stigmaeidae -7 spp, 1 genus (4 most abundant), Cunaxidae - 4 spp, 1 genus (2 most abundant), Anystidae -5 spp, 2 genera (2 most abundant). On the basis of field observation, the predatory mites found feeding upon tetranychid mites were *Amblyseius largoensis*, *Amblyseius channabasavannai*, *Euseius alstoniae*, *Neoseiulus suknaensis*, *Neoseiulus longispinosus* - among Phytoseiidae; *Anystis baccarum*, *Anystis nagalandensis* - among Anystidae; *Agistemus fleschneri*, *Agistemus industani*, *Agistemus simplex* - among Stigmaeidae; *Cunaxa capreolus*, *Cunaxa womersleyi* - among Cunaxidae. Therefore, their conservation and profitable utilization need to be stressed.

Predatory Mites (Acari: Phytoseiidae) as a Bio-Control Agent on Different Ornamental Crops in Himachal Pradesh, India

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Himachal Pradesh is a hilly state of India and located between 30^0 22' to 30^0 12' North latitude and 75^0 47' to 79^0 4' East longitude, altitude varying from 350mts to 7000mts amsl. Being as horticulture state ornamental cultivation plays an important role in uplifting the economy of farmers especially in rural areas. Introduction of modern technologies, exotic flowers and polyhouse, ornamental cultivation attracts the farmers in different parts of the state. But these crops are attacked by various pests under protected as well as in open field. These pests are one of the important limiting factors in the production of ornamental crops and affect the quality and quantity under both conditions. Mites are one of them and more serious due to their short life cycle and high reproductive potential. Indiscriminate use of insecticides/Acaricides kills the natural enemies and pest resurgence. Resistance has been reported on different crops throughout the world against different pesticides by mites. Therefore, the time is to use natural enemies for successful management of these pests. Predatory mites are important bio-control agents of mites and keep their population under check naturally. Keeping this in view, the investigation was carried out during 2013 and 2014 to know the status of predatory mites inhabiting different ornamental crops in polyhouse and open field.

A total, 11 species of predatory mite belonging to six genera of three families were recorded inhabiting different ornamental crops in the state. Species were *viz. Euseius finlandicus* (Oudemans), *Euseius prasadi* (Chant & McMurty), *Euseius delhiensis* (Narayanan & Kaur), *Euseius alstoniae* Gupta, *E. eucalypti* Ghai & Menon *Neoseiulus paspalivorus* (DeLeon), *Neoseiulus longispinosus* (Evans), *Phytoseius roseus* Gupta, *Typhlodromus* (*Anthoseius*) *darjeelingensis*, *Lasioseius* sp. and *Walzia darjeelingensis* Gupta. Results of diversity indices of phytophagous and predatory mites on ornamental crops showed that 91% (10) species were dominant and 9% (1) species were evenly distributed in different ornamental ecosystem. In all the recorded mites, species richness was 2.39 and Shannon index was 2.18.

The study will be helpful in finding the potential species which can be mass multiplied and used in IPM programme. This can improve the crop health by checking

the use of synthetic chemicals in future.

Keywords: Pest, Predator, Bio-control, Natural enemies, IPM

Phytoseiid Mite Species (Acari: Mesostigmata) of Turkey from Cultivated and Uncultivated Plants

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Species of the mite family Phytoseiidae (Acari: Mesostigmata) are of great importance in terms of regulating not only pest mite populations but also small soft bodied insects such as thrips and whiteflies. Although, some phytoseiid species are currently utilized for augmentative biological control purpose, determination of the natural populations is essential in order to develop successful pest management programs. Up to date, 85 species belonging to 19 genera and three subgenera were recorded for the Turkish fauna. The Phytoseiidae species of Turkey showed great similarity with those recorded from Armenia, Georgia, Greece, Iran, Israel, Russia, Ukraine, as well as North African countries with high richness. While, *Euseius stipulatus*, *E. scutalis*, *E, finlandicus*, *Typhlodromus* (*Typhlodromus*) *athiasae*, *Amblyseius swirskii*, *Neoseiulus californicus*, *Phytoseius finitimus*, *Phytoseiulus persimilis* are common on cultivated plants, most of the collection are related with uncultivated plants. The reasons of the phytoseiid richness in Turkey can be considered as a result of a) the highest endemism rate (30%) with more than 3000 endemic plant species, in Europe b) three bio-floral region (Euro-Siberian, Mediterranean and Irano-Turanian) c) preserved natural resources (lakes, mountains, canyons, waterfalls etc) d) favorable climatic features especially in Mediterranean coast. In this regard, it is obvious that number of the phytoseiid species could be increased with detailed surveys that carried out in non-cultivated areas of Turkey.

Keywords: Mesostigmata, Phytoseiidae, biological control, fauna, Turkey

Field Application and Integrated Pest Management

Monitoring Population Dynamics and Structure of Phytoseiid Mites in Orchards and Tea Fields

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In order to reduce chemical pesticides, enhancement of natural enemies' activities by habitat management is essential. In Japanese law requires that natural enemies released in agricultural fields should be registered as chemical pesticides; effectiveness to control pests should be guaranteed. Thus natural enemies have been registered only in greenhouses in most cases, and we should adopt the conservation biological control (CBC) strategy if we aim to use natural enemies in open fields such as fruit orchards and tea plantations. Natural enemies can be enhanced by using banker plants and/or insectary plants in CBC. However the natural enemies should be reached from the banker plants to the crop plants infested by pest species. Hence, it is necessary to understand how far the natural enemies can move in the agricultural fields, and the understanding reveal the effective range of habitat management.

The predatory mite, *Neoseiulus womersleyi* (Acari: Phytoseiidae) is one of the most important biological control agents for spider mites in Japan. They feed on *Tetranychus urticae* and *T. kanzawai* (Acari: Tetranychidae), which are common pest species in fruit orchards, tea plantation, and many of vegetable crops. Here, we introduce researches on population structures of *N. womersleyi* by using microsatellite DNA markers in tea plantations and in peach orchards. In tea plantations, detected population structure was clear; the kinship coefficients between individuals did not differ significantly within a site, but the coefficients gradually decreased as the distance increased. In peach orchards, the population structure is also detected. *N. womersleyi* was showed little move to long distance. These observations suggested that the managing strategies of this mite and frequent plantation of banker and/or insectary plants required to control pests.

Biology and predatory potential of *Neoseiulus longispinosus* (Evans) (Acari: Phytoseiidae) against red spider mite in pointed gourd, *Trichosanthes dioica* Roxb. (Cucurbitaceae)

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Among many of the phytoseiid predatory mites, *Neoseiulus longispinosus* (Evans) is one of the most commonly occurring and potential predatory mites found in spider mites infested crops in West Bengal, India. Biology and feeding potential of the predator have been studied on *Oligonychus oryzae* (Hirst) under laboratory condition and the efficacy of the predator was tested against red spider mite, *Tetranychus urticae* Koch in pointed gourd ecosystem. The egg laying capacity of the predator was recorded, as 4 eggs/day/female with fecundity of 65 eggs /female. The preying rate per day/female was recorded as 34 eggs, with a life span of 34 days. The life cycle of the predator was found to be completed within 5 days at 26^{o}C and 60% RH. The predator was observed to be very effective in suppressing population of red spider mite when released @ 2 predators/ square meter at an interval of 10 days commencing from February observing early infestation of red spider mites in pointed gourd ecosystem. The predators were also found to disperse in the adjacent plots within 5 days after release in search of new preys.

A Novel Use of Predatory Mites for Dissemination of Fungal Pathogen for Insect Biocontrol: The Case of *Amblyseius swirskii* and *Neoseiulus cucumeris* (Phytoseiidae) as Vectors of *Beauveria bassiana* against *Diaphorina citri* (Psyllidae)

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This study tested the novel use of predatory mites for dissemination of a fungal pathogen for insect biocontrol in the laboratory. We first evaluated the pathogenicity of *Beauveria bassiana* at several spore suspension concentrations against the nymphs of both the Asian citrus psyllid (*Diaphorina citri*) and two predatory mite species (*Amblyseius swirskii* and *Neoseiulus cucumeris*). The *B. bassiana* spores at suspension concentrations greater than 10^4 spores ml^{-1} were highly effective against *D. citri* nymphs, resulting in a mortality approaching 100% after 7 days, but caused only low mortality rates of *A. swirskii* and *N. cucumeris* nymphs (15 and 10%, respectively) after 7 days. We then observed whether these two predatory mites, when dusted with *B. bassiana* spores, could disseminate the pathogen to *D. citri* residing on small twigs of potted *Murraya paniculata* (Rutaceae) plants under high humidity conditions. Several days after the release of "dusted" *A. swirskii* and *N. cucumeris* females, most *D. citri* had been killed by *B. bassiana*. As these phytoseiid predators exhibit a relatively high tolerance to this pathogen and are attracted to *D. citri*, we believe that this method might represent a new technique for using the *Beauveria* to control this pest insect. This method should be further explored for dissemination of entomophagous fungi to various insect pests in greenhouse and field conditions.

Keywords: Acari, *Neoseiulus cucumeris*, *Amblyseius swirskii*, entomophagous fungi, vector, huanglongbing

Interactions between *Beauveria bassiana* and the *Neoseiulus barkeri* and Biological Control of *Frankliniella occidentalis*

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Interactions between fungal entomopathogens and pest predators are relevant in control of agricultural insect pests. The entomopathogenic fungus *Beauveria bassiana* and predatory mite *Neoseiulus barkeri* are both potential biocontrol agents against their shared pest west flower thrips, *Frankliniella occidentalis*. The greenhouse study evaluated the effects of single and combined applications of the two agents for control of *F. occidentalis*. We showed that a separate application, either *B. bassiana* or *N. barkeri*, significantly reduced both adult and larval *F. occidentalis*. The effect by the fungus was more rapid than that by the predators in a 7-week experiment, whereas the level of *F. occidentalis* suppression in the combination of *B. bassiana* and *N. barkeri* was nearly similar to that of *B. bassiana* alone. Although the density of *N. barkeri* was not affected by *B. bassiana*, the population fluctuations of *F. occidentalis* indicated possible negative interactions between the fungus and the predators.

We then explored the interaction between *B. bassiana* and *N. barkeri* by scanning electron microscopy and detected predator behavior in laboratory experiments. We confirmed the presence of *B. bassiana* conidia on mites. Though a benefit of this was dissemination of the pathogen to the target pest, resulting in 77.5% mortality of adult thrips, mites also engaged in self-grooming behavior. Consequently, any potential benefits of fungal dissemination by the predatory mites were possibly weakened by mite grooming since large amounts of conidia adhered to the body were removed. It likely reduced the searching activity and predation rates of *N. barkeri*. Overall, our results suggest that simultaneous application of *B. bassiana* and *N. barkeri* is not beneficial for biological pest control.

Anystis baccarum: an Efficient Predatory Mite in Apple Orchards

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Within apple orchards integrated pest management (IPM) programmes play a very important role in the control of invertebrate pests. Many current IPM strategies concentrate only on the role of a given specialist predatory species. However, generalist beneficial insects, such as several mite species, must also be fully evaluated for their potential in controlling pests. Recent research has shown that the generalist predatory mite *Anystis baccarum* (Linnaeus) can offer much potential in controlling invertebrate pests within UK apple orchards. This mite species has been confirmed as the most commonly occurring predatory mite in Northern Irish apple orchards. Research has shown that this mite plays an efficient role in controlling pest species populations (for example, *Aculus schlechtendali*) within the orchards. It also shows a level of compatibility with various chemical pesticides and fungicides. However, apple growers have been mis-identifying this beneficial species as the economic pest European fruit tree red spider mite, *Panonychus ulmi* (Koch). As a result, unnecessary pesticide applications have been applied against what has now been confirmed to be a beneficial species. To aid apple growers and horticultural advisors in the identification of *A. baccarum*, identification cards have been produced. The benefits of encouraging *A. baccarum* populations within orchard ecosystems are discussed.

Further reading:

Cuthbertson, A.G.S. & Murchie, A.K. (2010). Ecological benefits of *Anystis baccarum* in an orchard ecosystem and the need for its conservation. *International Journal of Environmental Science and Technology*, **7(4):** 807-813.

Cuthbertson, A.G.S. & Murchie, A.K. (2012). *Anystis baccarum* - a predatory mite in UK apple orchards. *Research Journal of Chemistry and Environment*, **16:** 18-21.

Cuthbertson, A.G.S., Qiu, B-L. & Murchie, A.K. (2014). *Anystis baccarum*: An important generalist predatory mite to be considered in apple orchard pest management strategies. *Insects*, **5:** 615-628.

Evaluation of *Neoseiulus barkeri* Hughes Yanshan Strain (Acari: Phytoseiidae) as Biological Control Agent against *Oligonychus ununguis* (Jacobi) (Acari: Tetranychidae) on Chestnut

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A mass-reared predatory mite *Neoseiulus barkeri* Hughes was introduced into chestnut orchards in to control phytophagous mites *Oligonychus ununguis* (Jacobi), which is a major pest of chestnut. *N. barkeri* was collected on apple orchard from Yanshan Mountain Range in eastern Hebei Province in 2009 and reared on alternative prey *Aleuroglyphus ovatus* (Troupeau) (Acari: Sarcoptiformes). We evaluated the functional response of *N. barkeri* to various stages of *O. ununguis*. The predation trials were conducted on Chestnut leaf discs over a 24h period at 27±1℃, 80%RH and LD 16:8. *N. barkeri* prey on all stages of *O. ununguis*, except eggs. Selectivity coefficient of adult female *N. barkeri* to eggs, larvae, nymph and adult of *O. ununguis* were 0, 2.02, 1.22, 0.76, respectively, suggesting larval and nymph stages preferred. Function responses of adult female *N. barkeri* to various stages of *O. ununguis* all fit Holling type Ⅱ model. The equations of predation functional response of adult female predator to adult female prey, nymph prey and larva prey was Na=N/(2.2892+0.0832N), Na=N /(1.1578+0.0382N), Na=N /(1.3375+0.00060N), respectively.

Field experiments were conducted from 2009 to 2012 to determine the effectiveness of the predatory mite *N. barkeri*, in controlling *O. ununguis* in several chestnut orchards located at Qian'an, east Hebei Province. The treated chestnut trees were 5-6 year-old. The damage duration of *O. ununguis* in the experimental region was from early May to the end of August. The annual average relative humidity in May and June were 45% and 67%, the relative humidity of June was more suitable for development of *N. barkeri*. As a result, *N. barkeri* released at June. The release rate was 500-1000 predatory mites per tree according to the size of the tree crown. Leaves were sampled and pest densities were recorded 1 day before and 30-45 days after predatory mite release. The initial density of *O. ununguis* ranged between 0.05 to 28.43 mites per leaf, significantly differ across orchards or years. The experimental results showed that the control efficacy to *O. ununguis* ranged between 26.86% and 98.30%, with better efficacy (y) expected in trees with lower initial density (x) of *O. ununguis* ($y = 0.0669x^2 - 4.1845x + 96.141$ ($n=8$, $R^2=0.9764$)).

Field experiments also showed that *N. barkeri* has strong dispersal capability. They gradually dispersed from release site along branches of chestnut tree, the population density reached peak after 1d, 1d, 3d and 7d at the distance of 1m, 2m, 3m and 4m from the release site, respectively. The greatest dispersal distance was more than 4m at 7d. Density of *N. barkeri* gradually decreased along branches, while density of *O. ununguis* gradually increased, which was lower than the control at 1m, 2m and 3m from the release point, but was not significantly lower at 4m.

Safety Evaluation of Six Chemicals Commonly Used in Orchard on *Neoseiulus barkeri* Hughes (Acari: Phytoseiidae)

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Neoseiulus barkeri is the most commonly used predatory mite in orchards of China. It can reduce chemical sprays and improve fruit quality. In order to explore the possibilities to integrate chemical control and biological control, indoor toxicity test was done to evaluate the impact of six commonly used chemicals on *N. barkeri* via leaf-immerse method. We estimated safety factor as LC_{50} for *N. barkeri* / the recommended dosage for the 6 chemicals. Results showed safety factors ranked as following: spirodiclofen > myclobutanil > tebuconazole > emamectin benzoate > hexythiazox > azocyclotin. Overall, they all had low toxicity to *N. barkeri*. Safety factor of the most poisoning chemical, azocyclotin, was between 0.5 and 5, suggesting medium level of risk to *N. barkeri*. This project was supported by Special Fund for Agro-scientific Research in the Public Interest (200903032, 201103020) and Special Fund from Hebei Province (2013055002)

Keywords：*Neoseiulus barkeri*, toxicity, food safety

Biological Control of *Lycoriella* sp. in Mushroom Cultivation with Predatory Mites *Macrocheles glaber* (*Macrochelidae*) and *Stratiolaelaps scimitus* (*Laelapidae*)

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Subterranean predatory mites are efficient biological control agents of Dipteran pests, especially for targeting *Lycoriella* sp. To evaluate the effectiveness of the predatory mites, *Stratiolaelaps scimitus and Macrocheles glaber*, in controlling *Lycoriella* sp. in *Agrocybe aegeritas* cultivation, we investigated the influence of mites in single or combined releases. Both mite species were found to reduce sciarids emergence. To confirm the influence of producing mushroom (*A. aegeritas*) and yield by predatory mites, the clumps of fruiting body and mushroom yield were recorded under different treatments. No decrease in clump of fruiting body was observed when only *S. scimitus* were released. In contrast, decreases were observed either when *M. glaber* were released only and the two species were combined released. No significant decrease in mushroom yield reduction were observed when each of the predator species were released separately, but was significant in combined releases. These findings highlight the independent application of *S. scimitus* provided more comprehensive control of sciarids than other treatments with *M. glaber* releases.

Keywords: Macrochelidae; Laelapidae; Sciaridae; Biological control; *Agrocybe aegeritas*

Control Aphids and Spider Mites by *Neoseiulus cucumeris* Dusted Conidia of *Paecilomyces fumosoroseus* on Eggplants

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The germination condition for *Paecilomyces fumosoroseus* (Wize) Brown & Smith conidia was 25-30℃, 95%-100%RH, estimated based experiments conducted in small containers with relative humidity controlled by saturated salt solution. Under suitable conditions, the pathogenicity of *P. fumosoroseus* against the aphids grew up with the conidia suspension of 1.0×10^4-1.0×10^8 spores·ml^{-1}. The moralities of aphids and *Neoseiulus cucumeris* at the 10th day under the conidia suspension of 1.0×10^8 spores·ml^{-1} was 86.52% and 41.78%, respectively. The pathogenicity of this strain against *Neoseiulus cucumeris* was lower than that against *Myzus persicae* Sulzer, so this strain could be used to control aphids when carried by *N. cucumeri*s. Pot experiment was conducted with 6 treatments: 1. control; 2. releasing 50 *N. cucumeri*s; 3. spraying 20ml conidia suspension of 10^7conidia·ml^{-1}; 4. releasing 50 *N. cucumeri*s after spraying 20ml conidia suspension of 10^7conidia·ml^{-1}; 5. releasing 20 *N. cucumeri*s dusted conidia of *P. fumosoroseus*; 6. releasing 50 *N. cucumeri*s dusted conidia of *P. fumosoroseus*. Our results showed that treatment 3, 4 and 6 were more effective to control aphids, and almost eliminated aphids within 8 days. Among the three treatments, releasing 50 *N. cucumeri*s dusted conidia of *P. fumosoroseus* was the most economic and labor-saving. Overall, we conclude that using *N. cucumeri*s dusted conidia of *P. fumosoroseus* is an efficient way to control aphids.

Keywords: *Neoseiulus cucumeris*, aphids, *Paecilomyces fumosoroseus*, integrated control

Effectiveness of Predatory Mite *Anystis baccarum* and Entomopathogenic Fungi *Lecanicillium lecanii* in Controlling Tea Scarlet Mite *Brevipalpus obovatus* (Acari: Tenuipalpidae)

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Brevipalpus obovatus is an important pest mite on tea plants in almost four major tea-growing regions in China. It damages flowers and ornamental plants, medical plants and economic herb plants as a vector of several plant viruses. Integrated pest management (IPM) has been popularized to ameliorate the environmental pollution and health-hazard issues associated with the overuse of synthetic pesticides. Predatory mite *Anystis baccarum* and entomopathogenic fungi *Lecanicillium lecanii* are two important natural enemies of mites in the tea orchards. In laboratory experiments, the effect of either untreated or treated deutonymph by *L. lecanii* (1×10^5 conidial/ml) with four time intervals: 0, 24, 48, and 72 h, on some biological parameters (searching time, feeding time and predation rate) of *A. baccarum* were investigated at 28℃, 70-80% RH and a photoperiod of 16:8 h (L:D). The searching time of the predatory mite increased on treated deutonymph with *B. obovatus* (more than twice of those on untreated deutonymph of *B. obovatus*), and feeding time and predation rate decreased. However, the predatory mite *A. baccarum* had no significant effect on fecundity and longevity, comparing feeding on *L. lecanii* conidial suspension treated *B. obovatus* deutonymph, and on untreated *B. obovatus* deutonymph. In greenhouse experiments, the effectiveness of the two biological agents in controlling *B. obovatus* on tea plants was determined either with separate released or combined release. The results showed that after spraying *L. lecanii* (4.3×10^8 spores/ml, twice per generation) and releasing *A. baccarum* (3 mite adults per plant, once per generation), 52.7% and 50.9% *B. obovatus* were controlled, respectively. However, 86.4% of *B. obovatus* were controlled with combined release of two biological control agents with the same rate mentioned above (*L. lecanii* spraying twice followed by releasing *A. baccarum* once or twice in one generation). Combined releases provided a better effect on mites than separated, highlighting the compatibility of *L. lecanii* with *A. baccarum* for biological control of *B. obovatus*.

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