Report on the 39th Annual Meeting of the Working Group "Beneficial Arthropods and Entomopathogenic Nematodes", 29. – 30. November 2023, Köln-Auweiler, Germany

As usual, our annual meeting took place at the end of November. The venue was the main building and conference hall of the North Rhine-Westphalia Plant Protection Service near Cologne. The conference took place after the so-called "Beratertagung Biologischer Pflanzenschutz (Consultants' Meeting on Biological Control)", which was celebrating its 30th anniversary. The premises were ideal for our meeting. Many thanks to the Landwirtschaftskammer Nordrhein-Westfalen (LWK-NRW) for providing the facilities, to Dr. Elisabeth Götte for organizing everything including the coffee breaks, and to Dr. Ellen Richter, Head of the Plant Protection Service, for her warm welcome to the 40 attendees. The scientific program included three posters and 18 oral presentations during the two days. On the first day, DPG and DGaaE-members were invited to vote for a new leadership of the Working Group. Dr. Christine Dieckhoff (LTZ Augustenberg) and Prof. Dr. Stefan Kühne (JKI Kleinmachnow) were elected one-voice for the new leadership. On behalf of the DPG, Dr. Monika Heupel (LWK-NRW) surprised the leaving Dr. Annette Herz (JKI Dossenheim, 15 years of leading the Group) and Prof. Dr. R-U Ehlers (University of Kiel, more than 20 years of leading the Group) with thanks and farewell on behalf of the DPG.

We would like to thank all the participants, especially those who provided us with short abstracts of their papers, which are summarized in this report.

Dr. Annette Herz & Prof. Dr. Ralf-Udo Ehlers

Flowers decorate the change of group leading of the DPG-/DGaaE-Working Group "Beneficial Arthropods and Entomopathogenic Nematodes" (from left to right): Prof. Dr. Stefan Kühne (JKI), Dr. Christine Dieckhoff (LTZ Augustenberg) (new ones), Prof. Dr. Ralf-Udo Ehlers (University Kiel), Dr. Annette Herz (JKI) (leaving ones) during the 39th meeting in 2023.

Soil, water and nematodes

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Movement of nematodes in the soil, including entomopathogenic nematodes (EPNs) (Steinernematidae, Heterorhabditidae) depends on their biology, mobility, tolerance to environmental factors (soil moisture, temperature), the edaphic parameters and the soil water dynamics. All textbooks tell us that nematodes need a water film to move in the soil. The talk will show that this was a wrong conclusion of experiments conducted in the 1960s. The free-living stage of EPNs is the 3rd juvenile stage, the so-called dauer larva (DL). Due to its diameter of 25-43 µm (depending on the species), it can only move through coarse soil pores (defined at > 10 µm diameter). Considering that nematode can only move when these pores are lined with water, movement would be impossible once these pores are dry. Since the coarse pores are empty at a water potential (pF) < 2.5, infestations of insects by EPN would be impossible. However, results of field trials show that control was obtained at lower values. The talk will explain why the assumptions based on previous experiments were misinterpreted. But how much water is necessary to successfully establish EPN in the soil?

Biological control of Black Fungus Gnats (*Bradysia difformis* Frey, 1948) with Nematodes (*Steinernema feltiae* Filipjev, 1934) and the Parasitoid *Synacra paupera* Macek, 1995 (Hym., Diapriidae)

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As part of a master's thesis, the parasitoid *Synacra paupera* was baited on a horticultural propagation and production site and then mass-reared on laboratory scale. Biological studies on this parasitoid were carried out. Detailed studies depict the developmental stages of the parasitoid in the form of images. Initial studies on the parasitism of *Bradysia difformis* by *S. paupera* in laboratory experiments provided evidence of significant biological regulation. Furthermore, the biological regulation of *B. difformis* was investigated by using nematodes (*Steinernema feltiae* Filipjev, 1934) in various formulations. Nemaplus®depot, nemaplus®, and a paste specially produced for this work were used. The nematode formulations applied according to the application recommendations remained under optimal conditions at 20-24 °C for 1, 2, 3, 4 and 6 weeks until the black fungus gnat larvae were applied onto coco coir. Recommendations for use are derived from the significant biological regulation of larvae of the black fungus gnat *B. difformis* by nemaplus®depot on a laboratory scale in this experiment. Possible uses of the parasitoid *S. paupera* in biological plant protection are discussed. Practical work on nematodes took place at the Julius Kühn Institute in Kleinmachnow. Practical work on *S. paupera* at Katz Biotech AG, Berlin.

Kontrolle der Rostmilbe in Tomate unter biologischen Anbaubedingungen (Kretschab)

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Rostmilben in Tomaten sind in den letzten Jahren bei vielen Betrieben ein zunehmendes Problem in der Produktion, während ideale Bekämpfungsstrategien bisher fehlen. Ziel des Verbundvorhabens ist es, effektive Strategien zur Vermeidung von ertragsrelevanten Schäden an Pflanzen und Früchten biologisch angebauter Tomaten durch die Tomatenrostmilbe *Aculops lycopersici* (Acari: Eriophyidae) zu entwickeln. Das Gesamtsystem soll im Hinblick auf das Management der Tomatenrostmilbe optimiert werden, um mit einem Minimum an Pflanzenschutzmitteln auszukommen. Im Fokus des Projektes stehen die Themen I. Nützlingseinsatz, II. Sortenwahl, III. Früherkennung, IV. physikalische Bekämpfungsmaßnahmen, und V. Klimasteuerung. Damit die Ergebnisse in der Praxis anwendbar sind, werden Exaktversuche sowohl im Versuchsanbau als auch auf Praxisbetrieben durchgeführt. Ein Projektschwerpunkt liegt auf der Optimierung des Nützlingseinsatzes im Rahmen biologischer Pflanzenschutzmaßnahmen, mit dem Ziel das Nützlingssortiment gegen die Tomatenrostmilbe zu erweitern und auf eine breitere Basis zu stellen. Neben *Amblyseius swirskii* (Acari: Phytoseiidae), die bereits standardmäßig als Nützling in vielen Kulturen im geschützten Anbau eingesetzt wird, soll je eine Raubmilbenart der Gattungen *Homeopronematus* und *Pronematus* (Acari: Iolinidae) getestet werden. Diese sind bisher nicht im Einsatz, weisen aber vielversprechende Eigenschaften auf, die Arten wie *A. swirskii* fehlen. Die Raubmilbenarten sollen im Hinblick auf ihre Effektivität und Verträglichkeit mit anderen praxisüblichen Nützlingen und Pflanzenschutzmitteln getestet werden. Ein weiteres Ziel ist es, Sortenempfehlungen für die Praxis im Hinblick auf einen optimierten Einsatz von Raubmilben zu erarbeiten. Dazu wird ein aktuelles, praxisrelevantes Standardtomatensortiment (*Lycopersicon esculentum*) auf die Behaarung der Pflanzen, sowie den Belauf und die Besiedlung mit Rost- bzw. Raubmilben geprüft. Auch der Einfluss auf die Effektivität der Raubmilbenarten bei der Reduzierung von Pflanzenschäden und Ertragsminderungen soll untersucht werden. Weiterhin sollen Empfehlungen für Sorten gegeben werden, die weniger anfällig für Rostmilbenschäden sind. Das Projekt zielt zudem darauf ab, Effekte in der Klimasteuerung zu untersuchen. Dazu werden in der Praxis verschiedene Optionen zur Klimaführung und Beschattung erprobt. Außerdem werden physikalische Barrieren getestet, die im Unterglasanbau eine Ausbreitung der Rostmilben auf den Tomatenpflanzen effektiv verhindern bzw. reduzieren könnten. Auch eine optimierte Früherkennung des Befalls mit Rostmilben soll entwickelt werden. Dabei helfen sollen eine automatisierte Rostmilben-Probenahmetechnik und geeignete Monitoring-Werkzeuge. Um den Einzug in die Praxis zu erreichen, werden die erforschten Maßnahmen kombiniert geprüft, um so die Massenvermehrung im Frühjahr verhindern bzw. verringern zu können.

Biological control of the Red-Legged Shield Bug *Pentatoma rufipes* in organic orchards by the egg parasitoid *Trissolcus cultratus*

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The red-legged stink bug *Pentatoma rufipes* L. has been known in Germany from faunistic surveys in orchards for a long time. For more than ten years, the populations in southern Germany have increased dramatically and it has become a pest. Organically farmed orchards are particularly affected, for which there is currently no sufficiently effective regulatory method available. The aim of the project is to develop an economically viable method for organic fruit production to biologically control the red-legged stink bug through the application of the egg parasitoid *Trissolcus cultratus*, which has been repeatedly observed on this pest in the field, and bringing it to practical maturity gradually during the project period. The project started in early April 2022 and is being sponsored for three years by the Deutsche Bundesstiftung Umwelt (DBU). This presentation aims to introduce the project and present the results achieved in the experiments conducted in 2022 and 2023. The production of *T. cultratus* on its primary host proved to be economically unviable from the outset and was consequently abandoned. Conversely, an established breeding system for other *Trissolcus* species on alternative hosts demonstrated effectiveness, enabling the provision of *T. cultratus* in sufficient quantities within the project. Nevertheless, there is a need for further optimization to reduce the costs of this beneficial organism to an economically viable level. The release of *T. cultratus* took place in 2022 and 2023 in different organic apple orchards, where previous occurrences of *T. cultratus* were excluded according to suction and beating samples. Different release quantities of *T. cultratus*, ranging from approximately 1.7 individuals/m² to 5 individuals/m², were conducted. The releases took place at two distinct time points during the oviposition period of *P. rufipes*. Subsequent counting of young, freshly hatched nymph stages of *P. rufipes* showed a significant reduction regardless of the applied density of *T. cultratus* compared to the control area. Within the various density variants, the effectiveness correlated with the application quantity. Nevertheless, even at the lowest application quantity, an effectiveness of 60% was still achieved. At the highest release quantities, an effectiveness of up to 80% was reached. Furthermore, the areas were examined for the presence of *T. cultratus* from the previous year's experiments to make statements about the establishment of the parasitoid. Indeed, *T. cultratus* was found in all experimental plots in the following year, sometimes even over a period of two years. In spring, the insects seem to prefer staying in the herb layer and migrate back to the tree canopy during the oviposition phase of *P. rufipes* in autumn. In summary it was shown that *T. cultratus* can reduce *P. rufipes* in organically farmed apple orchards with up to 80% efficacy at the highest release quantities. Furthermore, the parasitoid persisted for multiple years within the plots after release. Those results show that *T. cultratus* can be a valuable tool for controlling *P. rufipes* in organically farmed orchards.

Trichopoda pictipennis (Diptera: Tachinidae) – A possible new beneficial for regulating harmful stink bugs?

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In the "BC-InStink" research project (2021 - 2024), which is supported by the Federal Ministry of Agriculture and Food (BMLE), a systematic investigation was conducted for effective antagonists to regulate harmful stink bugs. In addition to egg parasitoids of the genus *Trissolcus* (Hymenoptera: Scelionidae), the tachinid fly *Trichopoda pictipennis* was discerned as a parasitoid with potential application in controlling pentatomids. This dipterid species deposits one to several eggs on adult stink bugs and occasionally on N5 nymphs. The larva hatches after about 24 hours and penetrates the host directly from the egg. The development period over three larval stages spans about 14 days. The larva then leaves the dead host and pupates outside. Due to its direct effect on the damaging developmental stages, the species proves to be a valuable addition to the use of egg parasitoids and could improve the overall efficiacy of pest control success. High parasitization rates and a high potential for regulating *Nezara viridula* are described in the literature, ranging from 20% in field parasitation up to 75% in in the laboratory (Harris & Todd, 180; Gianguiliani & Farinelli, 1995; Salerno et al., 2002). Our own observations are in accordance with those findings. In 2021, the population development of *Nezara viridula* was investigated in a foil greenhouse in the Upper Rhine region over the cultivation period. From the end of July, the stink bugs exhibited repeated parasitation by native *Trichopoda pictipennis*. Over the ensuing weeks, the infestation density steadily declined from eight stink bugs per plant to two stink bugs per plant by early September. In 2023, notable parasitisation rates of *Nezara viridula* were observed in numerous fruit and vegetable crops in the area between Freiburg and Heidelberg, ranging from 20 % to 80 % depending on the location. In 2022, an initial attempt was made to rear *T. pictipennis* at Katz Biotech AG in order to assess their suitability for industrial mass rearing. However, due to limited availability of *N. viridula* specimens with visible *Trichopoda* eggs and the asynchronous hatching of *T. pictipennis*, sucessful rearing was unattainable. In 2023, approx. 100 *N. viridula* parasitized by *T. pictipennis* were collected at different locations and crops. Out of these, 50 *Trichopoda* pupae developed, yielding only 15 imagines of which merely three were female. The subsequent generation exclusively comprised males and breeding could therefore not be continued. Based on previous experience and knowledge, the suitability for mass rearing is assessed as low and uneconomical. The main reasons include a low pupation rate, a complex and therefore vulnerable development cycle and the high cost of rearing the host stink bugs. These factors result a very low yield and elevated beneficial insect costs, surpassing any treatment-related yield gains. Consequently, the refinement of breeding methods is therefore necessary. Additionally, complying to current legal regulations, the release of *T. pictipennis* in Germany is presently prohibited due to its classification as a non-native species, despite its existing prevalence and establishment in the region. Conclusion: *Trichopoda pictipennis* has great potential for regulating detrimental stink bugs, but its application as a beneficial for biological plant protection is currently not possible in Germany for economic and legal reasons.

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Exotisch böse - einheimisch gut? Sicherheitsrisiko oder Xenophobie?

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Immer häufiger wird in Veröffentlichungen postuliert, einheimische Zuchtlinien von Nützlingen seien kommerziellen oder am Standort nicht-endemischen Arten, bzw. Stämmen vorzuziehen. Dabei wird vorausgesetzt, einheimische Antagonisten seien besser an Standortbedingungen angepasst und erzielten dadurch höhere Wirkungsgrade. Dafür liegen jedoch keine überzeugenden Beweise vor. Im Gegenteil wurde nachgewiesen, dass sogenannte „new associations“ im biologischen Pflanzenschutz einheimischen Antagonisten überlegen sind. Bei umfangreichen Phänotypisierungen von Nematoden der Art *Heterorhabditis bacteriophora* wurde bisher nie ein einziger Stamm gefunden, bei dem alle nützlichen Eigenschaften stark ausgeprägt waren. Ein weiteres Argument, was in letzter Zeit immer häufiger ins Feld geführt wird, ist die Behauptung, von Exoten gehe Gefahr für die Umwelt aus, ebenfalls entgegen langläufigen wissenschaftlichen Ergebnissen. Die Geschichte des biologischen Pflanzenschutzes verfügt über nur sehr wenige Beispiele, bei denen es zu ungewollten Nebeneffekten gekommen ist. Ohne Zweifel sind Risiken vorhanden, bloß ist man inzwischen in Deutschland so weit, dass der Einsatz von Arten, die bisher nicht nachgewiesen wurden, grundsätzlich nicht genehmigt wird. Die mit Abstand höhere Gefahr geht von eingeschleppten invasiven Arten, bzw. Schädlingen aus. Dieses Problem ist heute nach der Zerstörung von Biotopen der zweitwichtigste Grund für das Artensterben. Der biologische Pflanzenschutz verfügt über die Mittel und Methoden den Schaden, den diese invasiven Arten für die Umwelt und den Menschen anrichten, zu begrenzen. In Amerika, Afrika und Australien und Neuseeland besteht die Infrastruktur, eine Risiko-Nutzen Analyse durchzuführen zum erheblichen Nutzen der Gesellschaft. In Deutschland und großen Teilen der EU fehlen diese Institutionen. Unsere Gesellschaften vergeben die Chancen und Potentiale, die der Einsatz von Exoten im biologischen Pflanzenschutz bietet.

Further records of *Leptopilina japonica* in Germany, a non-native parasitoid of *Drosophila suzukii*

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Four years after the first European record in Italy and two years after the first catches in Germany, we report further incidences of the parasitoid wasp *Leptopilina japonica* Novković & Kimura, 2011 (Hymenoptera: Figitidae) in Germany. The species is a larval-pupal parasitoid of *Drosophila suzukii* (Matsumura, 1931) (Diptera: Drosophilidae), which is a widespread invasive and economically important pest of soft-skinned fruit. We found specimens of *L. japonica* in southern and western Germany in the years 2021, 2022 and 2023 between June and October. The highest number of specimen was collected in 2023 (N > 150), though the collections were not conducted in a systematic manner. The species was reared from infested fruit (mostly raspberries), additionally, adult wasps were caught. In total, the parasitoid was caught in six different locations; in four of them, it was caught in multiple years from (Bonn (North Rhine-Westphalia), Dossenheim (Baden-Wuerttemberg), Neustadt a.d.W. (Rhineland-Palatinate) and Reinheim (Hesse)). The repeated detections indicate adventive establishment, but it is unknown, for how long *L. japonica* has already been present in Germany. It needs to be observed, to what extent the spread of *L. japonica* contributes to the natural regulation of *D. suzukii* and whether there will be interactions with native fauna.

IPSolut – Basic research on biological control of *Ips typographus* L. with parasitoid Hymenoptera

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In times of increasing forest damage events, currently used methods of bark beetle management are reaching their limits. Norway spruce (*Picea abies* L.) is particularly affected by mass outbreaks of the European spruce bark beetle (*Ips typographus* L. [Coleoptera: Curculionidae]). That is why new, efficient, natural and sustainable regulation methods have to be developed. The aim of the IPSolut project is to decrease the population density of the European spruce bark beetle punctual through inundative biological control by releasing mass-reared parasitoid hymenopterans. After determining naturally occurring parasitoids of *Ips typographus* on Norway spruce in eastern Saxony, potential target species for rearing experiments with the original host were identified. As a basis for these rearing experiments with the target species, a walk-in rearing box with a rotating system for *Ips typographus* was established for permanent host availability. Some preliminary rearing experiments showed that *Rhopalicus tutela* Walker (Hymenoptera: Pteromalidae), a polyphagous ectoparasitic larval parasitoid, and *Tomicobia seitneri* Ruschk. (Hymenoptera: Pteromalidae), a monophagous endoparasitic imaginal parasitoid, are most suitable for rearing under controlled conditions. The rearing methods were adjusted to the biology and ecology of these two parasitoids in order to establish optimized rearing and storage methods. For mass rearing, these methods have to be transferred to a larger scale, under particular consideration of alternative hosts. Additional experiments will help to close existing knowledge gaps on bio-ecological aspects of the target species, e.g. natural food sources or overwintering strategies. Furthermore, field application trials will be carried out to determine the regulatory potential of the parasitoids.

Projekt EIVES - Untersuchungen zur Zucht parasitoider Hymenoptera für die naturnahe Regulierung des Buchdruckers (*Ips typographus* L.)

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In Bezug auf die natürliche Regulation des Großen Buchdruckers (*Ips typographus* L. [Coleoptera: Curculionidae]) durch Antagonisten sind Parasitoide von besonderer Bedeutung. Vor allem parasitoide Arten aus der Ordnung der Hautflügler (Hymenoptera) erreichen vielversprechende Parasitierungs- und Vermehrungsraten, zeigen eine starke Wirtsspezialisierung sowie eine hohe Mobilität. Damit weisen sie ein aussichtsreiches Potenzial für eine künstliche Vermehrung und den Einsatz in der biologischen Kontrolle von rindenbrütenden Borkenkäferarten auf. Das Projekt EIVES verfolgte das perspektivische Ziel, bereits beim ersten Auftreten des Großen Buchdruckers ein hohes Vorkommen dieser Antagonisten auf gefährdeten Flächen zu ermöglichen. Im ersten Schritt wurden in der Region des Tharandter Waldes häufig vorkommende Arten parasitoider Hymenoptera ermittelt und eine Zielart selektiert. Die Art *Coeloides bostrichorum* Gir. (Hymenoptera: Braconidae) bietet neben einer nachweisbaren Dichte-Reduzierung von *Ips typographus* auch Chancen auf eine unkomplizierte und praxistaugliche Vermehrung. Für diese Art sollte anhand von Laborexperimenten eine geeignete Vermehrungstechnik entwickelt werden, welche die Grundlage für die darauf aufbauende künstliche Massenzucht darstellt. Dies umfasste sowohl die Ermittlung von geeigneten Alternativwirten als auch Strategien und Herausforderungen, diese für die Zielarten attraktiver zu machen. Als erster Alternativwirt wurde der Tabakkäfer, *Lasioderma serricorne* Fab. (Coleoptera: Ptinidae) gewählt. Im Rahmen von Parasitierungsversuchen am Original- und Alternativwirt unter Einbeziehung des Bohrmehls aus Larvengängen von *I. typographus* sollte eine Eiablage unter Laborbedingungen herbeigeführt werden. Die größten Herausforderungen bestanden dabei in der Simulation natürlicher Gegebenheiten im Labor sowie dem Mangel an Versuchsindividuen der Zielart. Im Rahmen der bisherigen Versuche konnte keine Parasitierung am Alternativwirt erzeugt werden. Während der Laborversuche und weiteren Projektbearbeitung konnten dennoch wichtige Erkenntnisse zu Lagerung, Handhabung und Verhalten der verwendeten Parasitoide unter kontrollierten Bedingungen erlangt werden. Weitere Versuche müssen durchgeführt werden, insbesondere zur Rolle der zur Wirtsfindung genutzten Volatile und deren Entstehung bzw. Zusammensetzung, um eine fortlaufende Parasitierung unter Laborbedingungen am Alternativwirt herbeizuführen und eine funktionierende Zucht im großen Rahmen zu ermöglichen.

The potential of augmentative biological control of oak forest spring defoliators

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Oaks (*Quercus* spp.) are considered as promising tree species in terms of their ability to cope with the current climatic changes in Central European forests. However, thermophilic pest insects are also expected to benefit from these developments. Population outbreaks of spring defoliators like the winter moth (*Operophtera brumata*), the mottled umber (*Erannis defoliaria*) (Lepidoptera: Geometridae), or the European oak leafroller (*Tortrix viridana*) (Lepidoptera: Tortricidae), regularly cause significant damage in oak forests already nowadays. As natural enemies, parasitoids significantly contribute to the regulation of pest population dynamics, help to maintain an ecological balance and prevent economic losses. Our objective was to investigate the potential of autochthonous parasitoids of oak spring defoliators for their use as biological control agents, by augmentative releases at critical pest population density levels. We investigated the spectrum of parasitoids of geometrids and tortricids in four oak stands in Münsterland (North Rhine-Westphalia, Germany) over a period of three years. Among the parasitoids observed, species that may be suitable for laboratory rearing were identified. Various pupal parasitoids of *T. viridana* were identified as the most promising species, in particular the ichneumon wasps *Pimpla turionellae*, *Itoplectis maculator* and *Apechthis quadridentata* (Hymenoptera: Ichneumonidae). Data on the parasitization efficiency under varying environmental conditions were obtained from semi-field trails in 8 m^3 tents, equipped with potted trees, host pupae and female wasps. The effect of the release of 100 females of *I. maculator* and 88 females of *P. turionellae* was investigated in a 4-hectare oak stand. Heat waves and temperatures up to 34 °C had low effects on the parasitization efficiency of ichneumon wasps, while temperatures below 22 °C and high air humidity were associated with low parasitization activity in the semi-field trails. While pupal parasitoids of *T. viridana* are well-suited for small-scale rearing in the laboratory, on time mass-rearing is a major challenge. The field released parasitoids only parasitized a small proportion of artificially provided host pupae. In combination with intensive monitoring, augmentative releases of parasitoids could serve as additional control measure for particularly endangered outbreak foci. On larger scales, the provision of food sources, winter shelters etc. appear to be a more promising strategy to promote the regulatory effects of parasitoids on pest insects.

Predatory dance flies (Diptera: Hybotidae) – beneficial insects in winter wheat cropping systems

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Predatory flies are natural enemies of plant pests (e.g. wheat gall midge, stem and leaf miner flies). The small dance flies (Diptera: Hybotidae), which are only 1–5 mm long, are predatory both as larvae and adults and often occur in high abundances in all cereal ecosystems. They are particularly sensitive to synthetic pesticides, and reduction in population density as a consequence of pesticide application is only slowly compensated for by immigration of new specimens. This group of flies is therefore suitable both as an indicator of agrobiodiversity and for mapping the effects of cropping systems on predator-prey relationships. To examine whether the absence of chemical synthetic pesticides stabilises or even supports predator-prey relationships in the long term, Hybotidae abundance and species were analysed in three winter wheat cropping systems managed at different intensities (organic, conventional and hybrid system). Hybotidae diversity was surveyed using sweeping net and eclector trap collection methods. Sampling was conducted over three years from 2020 to 2022. Morphological identification of captured insects was supplemented by COI barcoding in case of damaged or morphologically similar specimens. No significant differences were obtained between the cropping variants in the abundance of Hybotidae emerging from soil and collected by eclector traps. By contrast, significant differences occurred in the number of individuals between the cropping variants in the sweeping net collections: numbers of Hybotidae caught in the organic and hybrid cropping systems were significantly higher than in the conventional cropping variant. According to the biodiversity indices 'Shannon Index' and 'Evenness', the cropping systems without chemical synthetic pesticides did not show a higher hybotid diversity than the conventional cropping system. Regarding the predator-prey relationships, it turned out that the highest seasonal number of prey insects was present at the beginning of the season in May. However, with the increase in predator occurrence over the course of the season, the number of pests decreased. The peak of Hybotidae was reached in mid-June in all experimental years. With predatory fly numbers decreasing from this point onwards, a slow increase in the numbers of stem and leaf-mining flies and midges was observable. Correlation analyses between the Hybotidae (as predators) and the stem and leaf-mining flies as well as gall and fungus gnats (as prey) only showed a positive correlation in the hybrid cropping system and sweeping net collections: the increase in prey was accompanied by an increase in the numbers of Hybotidae. The other two cropping systems showed no significant correlation. The results of the study suggest that despite their small activity radius, the Hybotidae actively fly into habitats without disturbance in the form of chemical synthetic plant protection. A more extensive cultivation of winter wheat (without chemical synthetic pesticides) might increase the number of individuals in the crop.

Vergleichende Untersuchungen zur funktionellen Biodiversität in unterschiedlich intensiv geführten Winterweizenanbausystemen am Beispiel der Blattläuse und ihrer natürlichen Gegenspieler

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The aim of the study is to investigate and evaluate the functional biodiversity based on aphids and their natural counterparts in different intensive cropping systems of winter wheat. Plots with organic management, a hybrid variant (no chemical synthetic pesticides) and the conventional management type are investigated. To perform this, the sweeping net and whole plant insect index score are used and the results are compared. To make the feeding performance of the natural counterparts comparable, they are converted to Predator Units (PU) and presented. The scores show statistically measurable differences concerning the results to the aphid numbers in all three cultivation variants. The more extensive the cultivation variant, the more aphids were found in the plots, whereas no significant differences could be determined for the predators. The sweeping net method shows differences in the PU and aphid numbers. Differences between the conventional variant and the two more extensive variants are measurable here, but not between the organic and the hybrid variant. Furthermore, in the organic farming system and the hybrid variant, higher numbers of individuals and also species numbers of the counterparts were found, thus demonstrating a greater biodiversity of predators. Since the immediate airspace above the wheat stand and the weeds are sampled with the sweeping net, insects can be determined which are not present on the wheat plants. This does not happen during the index score sampling, so that no conclusions can be drawn about the entire stand, but only about the wheat plants. The results on higher insect numbers (aphids as well as counterparts) can be explained by the absence of chemical synthetic pesticides and herbicides in the organic and hybrid variant plots. This creates a habitat which better supports the aphid predators.

Attraktivität verschiedener Blühstreifen für Nützlinge landwirtschaftlicher Kulturpflanzen

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Blühstreifen sind eine prominente Agrarumweltmaßnahme, die das Potenzial hat, dem Rückgang wildlebender Insektenpopulationen entgegenzuwirken. Das Hauptziel dieser Maßnahmen ist der Erhalt der biologischen Vielfalt und die Aufrechterhaltung von Ökosystemleistungen so wie die natürliche Schädlingsbekämpfung. Der Ansatz, Nützlingspopulationen durch die Optimierung ihres Lebensraums zu fördern, ist eine vielversprechende Methode des integrierten Pflanzenschutzes. In dieser dreijährigen Feldstudie (2020-2022) wurden zwei einjährige (11 bzw. 13 Pflanzenarten) und zwei mehrjährige (30 bzw. 51 Pflanzenarten), kommerziell erhältliche Blühstreifenmischungen in drei Naturräumen in NRW (Haarstrang, Soester Börde und Münsterland) auf landwirtschaftlichen Betrieben auf ihre Attraktivität gegenüber Nützlingen untersucht. Die Blühstreifenmischungen sowie eine Feldrand-Vegetation (Kontrolle, 4 Grasarten) wurden an jedem Untersuchungsstandort in einem randomisierten und 3-fach replizierten Parzellendesign angelegt. Insgesamt wurden neun Nützlingsgruppen untersucht: Schwebfliegen, Marienkäfer, Florfliegen, Schlupfwespen, Raubwanzen, Laufkäfer, Kurzflügler und pflanzen- bzw. bodenbewohnende Spinnen. Die Arthropoden wurden jährlich in neun Bonituren in einem zehntägigen Rhythmus im Sommer (Juni – August/September) mit standardisierten Methoden (Streifnetzkescher und Bodenfallen) erfasst. Um die verfügbaren Nahrungsressourcen in Form von Blüten bzw. dessen Nektar und Pollen in jeder Parzelle zu bewerten, wurde außerdem die artenspezifische Blütendeckung pro Bonitur geschätzt. Unsere dreijährigen Daten zeigen, dass sich die untersuchten Blühstreifen in ihrer Attraktivität für Nützlinge unterscheiden. Die Auswirkungen der fünf Saatgutmischungen auf die Häufigkeit von Arthropoden waren im zweiten und dritten Versuchsjahr am stärksten, wenn auch die Unterschiede in den Pflanzenartengemeinschaften der Mischungen am größten waren. So weisen beispielsweise mehrjährige Blühstreifen an allen Standorten die höchste Attraktivität für parasitäre Wespen, pflanzenbewohnende Spinnen sowie Raubwanzen und Kurzflüglerlarven auf. Im Gegensatz dazu weisen einjährige Blühstreifen die höchste Attraktivität für Laufkäfer auf, während sich die Schwebfliegen in ihrer Häufigkeit zwischen den Behandlungen nicht unterscheiden, mit Ausnahme zur Kontrolle. Diese Unterschiede unterliegen einer räumlichen und zeitlichen Dynamik und sind eher durch die Pflanzenartzusammensetzung und die strukturellen Eigenschaften des Blühstreifens bedingt als durch die Anzahl der Pflanzenarten per se. Aufgrund der unterschiedlichen Behandlungseffekte auf die Nützlingsgruppen und für eine Optimierung der schädlingsregulierenden Wirkung ist es notwendig, genaue Ziele für Blühstreifen zu formulieren und diese anschließend auf ein bestimmtes Ziel zuzuschneiden.

Functional biodiversity in agrivoltaic systems

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In order to achieve climate protection targets set by the German Government, an enormous expansion of renewable energy will be necessary, including photovoltaic (PV) systems. To avoid a land-use conflict between agriculture and energy production, agrivoltaic systems could be increasingly used. In agrivoltaic systems, the PV modules are either installed elevated above the crop itself or vertically next to the crop, so that the area below or in between the modules can still be used agriculturally. Currently, there is still a substantial knowledge gap regarding the compatibility of the dual agricultural and PV use. In particular, the potential impact on functional biodiversity as an important factor for high yields and healthy crops in agrivoltaic systems is still unexplored. Therefore, the aims of the interconnected research projects 'Solarnützlinge' and 'VAckerBio 2' are: (1) To explore the influence of agrivoltaic systems on the functional biodiversity, and (2) Determine how agrivoltaic systems can be designed to support settlement and promotion of beneficial arthropods and hence reduce certain pests. Project partners are the Fraunhofer Institute for Solar Energy Systems, the University of Hohenheim and Next2Sun Technology GmbH. In cooperation with operators of agrivoltaic systems, the projects are investigating the biodiversity and abundance of beneficial arthropods around existing agrivoltaic systems, with focus on hoverflies, Spheciformes wasps and spiders. Currently, three locations are being examined in Germany by us: two elevated systems in Baden-Württemberg and one vertical system in the Saarland. In order to promote beneficial insects, perennial flower stripes were sown below the modules of the vertical system. Here, the effect on arthropods, the development of vegetation and the compatibility with the agrivoltaic systems is studied. Furthermore, the projects are developing and field-testing the performance of other elements that can be integrated into agrivoltaic systems (e.g. nesting aids installed in the mounting fixtures). Overall, the projects aim to provide knowledge about how agrivoltaic systems can be designed in an environmentally friendly way, generating additional benefits to agriculture through pest control and pollination.

Flower reservoirs in stone fruit orchards: creating self-regulating systems with a low input strategy

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Promotion of biodiversity has great potential to contribute to organic fruit growing by increasing and facilitating natural pest control. Flower strips are a known management strategy used in orchards and vegetable production and used to provide habitat for beneficial insects increasing biocontrol of pests and pollination of crop plants. However, in organic stone fruit production perennial flowers strips are not as widely implemented because of the logistical challenges (for example additional machinery) and high efforts needed for maintenance of flowers strips. Pest population build up in orchards is facilitated by enclosures and therefore there is a need to promote biocontrol agent's diversity and abundance in orchards as well as pollination. In this project, we will exploit our large experience in Agroecology, to promote biodiversity and natural pest control in organic orchards with a low input strategy. The overall goal of this research project is to test whether flower reservoirs implemented in areas adjacent to the tree rows and in anchoring areas where tractors do not transit can provide similar benefits as those provided by flower strips in the orchard alley. This approach should reduce the logistical challenges and maintenance efforts needed from farmers, and therefore, increasing its acceptance and implementation.

Mobilität und Verteilung des Ohrwurms *Forficula auricularia* L in Obstanlagen

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Im Obstbau stellt der Einsatz von Nützlingen eine potentielle Alternative dar, um die geforderte Reduktion von chemischen Pflanzenschutzmittel umzusetzen. Der wirksame Einsatz von Nützlingen im Pflanzenschutz setzt jedoch voraus, dass Parameter, die die Nützlingsleistung beschreiben, charakterisiert sind. Der Ohrwurm, *Forficula auricularia* L (Dermaptera: Forficulidae) ist ein wichtiger omnivorer Prädator im Kernobst, der in anderen Kulturen wie Kirschen jedoch auch als Schädling auftreten kann. Im Kernobstanbau ist er als Fraßfeind von schädlichen Hemipteren, vor allem der Apfelblutlaus, *Eriosoma lanigerum* Hausmann (Hemiptera: Aphididae), nützlich. Obwohl sich die augmentative Freisetzung von Ohrwürmern in stark mit Apfelblutlaus befallenen Anlagen bereits bewährt hat, ist noch unklar, wie sich freigesetzte Ohrwürmer durch die Anlage bewegen. Eine Kenntnis der Ausbreitungsmuster ist jedoch wichtig um einerseits optimale Freisetzungsorte zu bestimmen und andererseits das Risiko des Ohrwurmeinsatzes in Nachbarschaft von anderen Kulturen, die potentiell von Ohrwürmern geschädigt werden können, abzuschätzen. Hier wurden auf dem dorsalem Prothorax markierte Ohrwürmer (Edding ® 751) über eineinhalb Monate in einer Apfelanlage wöchentlich freigesetzt und ihre Verteilung mittels Bambusrohrfallen bonitiert. Insgesamt wurden 850 Ohrwürmer freigelassen. 95% der wiedergefundenen freigesetzten Ohrwürmer (n = 299) wurden innerhalb von ca. 20 Metern, und 75% (n = 236) ca. 10 Meter von der Freisetzungsstelle gefunden. Die Bewegung der Ohrwürmer geschah in alle Himmelsrichtungen mit ähnlicher Häufigkeit (χ^2 (2,79;3), p = 0.42) und kann daher als zufällig aufgefasst werden (‘random walk‘). Die Markierungen zeigten eine gute Stabilität in der Umwelt. Unsere Ergebnisse zeigen, dass mit einer Verteilung von Ohrwürmern nach einer Freisetzung zu rechnen ist. Diese scheint überwiegend innerhalb eines 20 Meter Radius von dem Freisetzungsort statt zu finden. Um Schädlinge in einer gesamten Anlage zu kontrollieren sind daher, je nach Fläche, mehrere Freisetzungsorte notwendig. Die optimale Distanz der Freisetzungsloci muss anhand weiterer Studien bestimmt werden. Gleichzeitig zeigen unsere Daten, dass bei ausreichendem Abstand (> 30 Meter) Schäden an benachbarten Kulturen durch freigelassene Ohrwürmer unwahrscheinlich sind.

10 years of research on odor-mediated host location by the larval ectoparasitoid *Holepyris sylvanidis*, natural enemy of stored-product pest beetles

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The use of entomophagous invertebrates (e.g., parasitoids) and behavior-modifying compounds (= semiochemicals) are biologically based strategies that are common in integrated management of agricultural pests. However, the potential of these two alternative control methods for protection of stored products is only partially exploited. One reason for this is the still existing efficacy gap compared to conventional pesticides, which is partly due to the limited knowledge about biology and behavior of many natural enemies of stored-product pests. Another problem is that studies in storage environments and efficacy analyses of parasitoids are mostly the exception. Understanding the role of semiochemicals in parasitoid host search, and ultimately their correct use, is essential for practical application. Therefore, we investigated in more detail the chemically mediated interactions between the larval ectoparasitoid *Holepyris sylvanidis* (Hymenoptera: Bethylidae) and its hosts. Female *H. sylvanidis* parasitize larvae of several beetle species that attack stored grain, (refined) grain products, and dried fruit, making this parasitoid a promising candidate for biological control. The preferred hosts are 4th instar larvae of the confused flour beetle *Tribolium confusum* (Coleoptera: Tenebrionidae), one of the most important storage pests in the food processing industry worldwide. In laboratory studies, we examined the importance of directly and indirectly host-associated odors during host search of *H. sylvanidis,* and what function they may have in long-range and short-range host location, host recognition and acceptance. We collected volatiles from the host-habitat complex (i.e., adults, larvae, feces, host-feeding substrate), extracted compounds from the host cuticle and chemically analyzed them by coupled gaschromatography–mass spectrometry (GC-MS). The parasitoid's physiological and behavioral responses to these host odors were measured by electroantennography (EAG) and different olfactometer bioassays (e.g., 4-field-, Y-tube olfactometer, trail following tests, flight cage experiments). We further analyzed structural changes of host larval cuticular hydrocarbon (CHC) trails over time by cryo-scanning electron microscopy (cryo-SEM).
Our main results were that

i) fecal volatiles from *T. confusum* larvae, i.e., (*E*)-2-nonenal and 1-pentadecene, attract *H. sylvanidis*, and addition of habitat background volatiles (i.e., wheat grist) enhances the parasitoid's response to these host odors (= long-range host location),
ii) CHCs from *T. confusum* larvae elicit trail-following behavior in host-searching *H. sylvanidis* (= short-range host location),
iii) the kairomonal activity of host larval trails decreases over time and gets lost after 48 hours due to gradual solidification of the long-chain CHCs (= short-range host location),
iv) female parasitoids discriminate host from non-host larvae by their CHC profiles and the presence of methyl-branched alkanes (= host recognition),
v) release of synthetic host-associated key volatiles accelerates host location by *H. sylvanidis* and significantly increases parasitation rate (= host acceptance).

Overall, these findings provide a deeper insight into the chemically mediated host-searching behavior of *H. sylvanidis*, showing that application of semiochemicals can improve the host-finding success of parasitoids and thus their efficacy in controlling a pest population. This knowledge could be transferred to other parasitoid-host systems and help advance biological control in stored-product protection.

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Oilseed rape production at its limits – can antagonists support sustainable pest management without insecticides

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The major source of vegetable oil in Northern Europe is oilseed rape (OSR, *Brassica napus*). Worldwide, OSR is the second-largest source of protein meal and the third-largest source of vegetable oil. The crop is attacked by a wide range of insect pests. The most common are *Delia radicum* (L.), *Dasineura brassicae* (Winn.), *Psylliodes chrysocephala* (L.), *Brassicogethes aeneus* (Fab.), *Ceutorhynchus assimilis* (Payk.), *Ceutorhynchus pallidactylus* (Marsh.) and *Ceutorhynchus napi* (Gyll). Almost all these pests have developed resistance against pyrethroide insecticides except one compound. Time will come when insecticides can no longer be used. In this case farmers will depend on the natural antagonistic potential. The pests are all susceptible to entomopathogenic nematodes (EPN) and pupate in the soil providing a biomass of > 15 kg per ha and year, a paradise for *Steinernema* and *Heterorhabditis* spp. However, checking 11,000 soil sample of arable crop rotation winter wheat, winter barley and OSR, only 0,2% were positive for EPN. The talk will present results on application of EPN in OSR and discuss models for future agro-ecosystem management without insecticides.