Biology and Ecology - PhD. topics for the academic year 2023/2024

Research topic: Alarm pheromones from German chamomile (Matricaria chamomilla L.) – from genes to metabolites

Leader: RNDr. Zuzana Kovalíková, Ph.D.

Annotation

Plants and insects have coexisted for more than 400 million years. The ability of plants to withstand insect predation depends on their ability to quickly recognize the situation and respond to it adequately. One possibility is the production of alarm pheromones, which act as repellents or attractants of insect predators. Chamomile is one of the most cultivated medicinal plants and terpenes in flowers are used in pharmacy. (E)-β-farnesene, germacrene D and germacrene A, can act as pheromones involved in plant-insect interactions. The main goal of the thesis is to better understand the stimulation of alarm pheromone synthesis at gene level due to insect and hormone stimulation and to clarify the relationship between plant ploidy and terpene accumulation. The results will enable growers to use information about the application of natural hormones to stimulate pheromones and thus help reduce the negative impact on plants.

References

Fürstenberg-Hägg J., Zagrobelny M., Bak S. 2013: Plant Defense against Insect Herbivores. *International Journal of Molecular Sciences* **14:** 10242-10297.

Ling Ch., Zheng L., Yu X., Wang H., Wang Ch., Wu H., Zhang J., Yao P., Tai Y., Yuan Y. 2020: Cloning and functional analysis of three aphid alarm pheromone genes from German chamomile (*Matricaria chamomilla* L.). *Plant Science* **294**: 110463.

Scheader J, Bohlman J. 2015.Biotechnology of isoprenoids. Springer, London.

Stahl E., Hilfiker O., Reymond P. 2018: Plant–arthropod interactions: who is the winner? *The Plant Journal* **93**: 703-728.

Research topic: Structure and function of wood parenchyma and how it is driven by environment

Leader: RNDr. Lenka Plavcová, Ph.D.

Consultant: none

Annotation

Wood, i.e. secondary xylem produced by the vascular cambium, represents a specialized plant tissue that facilitates water transport and fulfils mechanical and storage functions. These functions are seemingly divided between three different cell types. Vessels and tracheids represent the conduits specialized for transport of water and dissolved nutrients. Fibers are mostly involved in providing mechanical support. Finally, radial and axial parenchyma cells serve in the transport and accumulation of storage compounds. While the structure and function of xylem conduits and fibers have been widely studied, our knowledge of structural-functional linkages in radial and axial parenchyma is much more limited. The relative fractions of parenchyma as well as the finer scale anatomical traits of these cells varies among species and better understanding of the factors driving this variation is helpful in elucidating the ecophysiological roles of wood parenchyma cells. The results of global surveys suggest that species growing in warmer and dryer regions have higher fractions of wood parenchyma. However, the functional consequences of this anatomical pattern are not clear (e.g. it is possible that the higher parenchyma fractions reflect an increased need for storage compounds). It is also not known if similar differences occur at the intra-specific level (i.e., when comparing individuals of the same species growing along a temperature and precipitation gradient). The changes in metabolic activity of wood parenchyma cells in relation to the seasonal cycles of accumulation and utilization of storage compounds is another intriguing topic requiring further investigations.

The main aim of the dissertation work will be to evaluate the differences in structure and function of radial and axial parenchyma in wood of selected species (e.g., Fagus sylvatica, Quercus robur) in relation to temperature and precipitation. For this purpose, wood samples will be collected from trees growing along a gradient of precipitation and temperature. Repeated seasonal sampling will be conducted at a limited number of sites. Samples will be prepared for anatomical observations, quantification of saccharide content and measurements of activity of carbohydrate-modifying enzymes.

References

Hacke U.G., Sperry J.S. 2001: Functional and ecological xylem anatomy. *Perspectives in Plant Ecology, Evolution and Systematics* **4**: 97-115.

Martínez-Cabrera H.I., Jones C.S., Espino S., Schenk H.J. 2009: Wood anatomy and wood density in shrubs: responses to varying aridity along transcontinental transects. *American Journal of Botany* **96**: 1388-1398.

Morris H., Plavcová L., Cvecko P., Fichtler E., Gillingham M.A., Martínez-Cabrera H.I., ... & Jansen S. 2016: A global analysis of parenchyma tissue fractions in secondary xylem of seed plants. *New Phytologist* **209**: 1553-1565.

Plavcová L., Jansen S. 2015: *The role of xylem parenchyma in the storage and utilization of nonstructural carbohydrates*. pp. 209-234. In: Hacke U.G. (ed.): *Functional and Ecological Xylem Anatomy*. Springer International Publishing.

Research topic: Optimal irrigation in fruit orchards: evaluation of different irrigation schedules on the growth and water relations of fruit trees

Leader: RNDr. Lenka Plavcová, Ph.D.

Consultant: Ing. Martin Mészáros, Ph.D., Research and Breeding Institute of Pomology Holovousy Ltd.

Annotation

Irrigations in fruit orchards are expected to become more important due to an increased frequency, duration and intensity of drought periods. The use of irrigation is often limited by insufficient water supply or by high costs for irrigation water. Therefore, the aim is to utilize water resources with the maximal possible efficiency. Regulated deficit irrigation (RDI) in theory enables substantial reduction of water consumption, while sustaining high yields and good quality of fruits. Assuming that the needs for irrigation are highest during the early phase of fruit development, the principle of RDI is the application of reduced (70-75%) irrigation dose during the less sensitive phase of fruit growth. However, detailed understanding of fruit tree water relations and quantification of important interactions within the soil-plant-air continuum are necessary for optimal irrigation scheduling.

The goal of the dissertation is to evaluate the effect of selected irrigation treatments on growth and hydraulic performance of irrigated fruit trees. The following irrigation treatments will be tested: 1) non-irrigated control, 2) full irrigation, 3) half irrigation, and 4) two RDI irrigation regimes. Leaf gas exchange, leaf water potential, hydraulic conductivity and embolism percentage will be monitored during vegetation period on irrigated trees. Field work will be performed at experimental plots of the Research and Breeding Institute of Pomology Holovousy Ltd. Hydraulic and anatomical observations will be conducted in the plant ecophysiology laboratory at the Faculty of Science, University of Hradec Králové. The acquired data will help to identify the most effective irrigation schedule and will serve as inputs and validation parameters in the models of water balance of fruit orchards.

References

Plavcová L., Mészáros M., Jupa R., Scháňková K., Kovalíková Z., Náměstek J., Mahrová A., Yield and water relations of two apple cultivars under Irrigation. *Irrigation Science*, submitted.

Bodner G., Nakhforoosh A., Kaul H.P. 2015: Management of crop water under drought: a review. *Agronomy for Sustainable Development* **35**: 401-442.

Goodwin I., Boland A.M. 2002: *Scheduling deficit irrigation of fruit trees for optimizing water use efficiency*. In *Deficit irrigation practices FAO*.

Jones H.G. 2004 Irrigation scheduling: advantages and pitfalls of plant-based methods. *Journal of Experimental Botany* **55**:2427–2436.

Research topic: Analysis of plant protein toxins

Leader: RNDr. Alena Myslivcová Fučíková, Ph.D.

Consultant: PharmDr. Jiri Dresler, PhD., Military medical institute, Prague

Anotation:

Plants are able to produce a number of substances of a proteinaceous nature in order to respond effectively to environmental conditions. In terms of activity, it is a diverse group of lectins, ribosomal inactivating proteins, antimicrobial peptides, pore-forming toxins, protease inhibitors and many others. These proteins show varying degrees of toxicity to bacteria, insects, fungi or animals. Some of these proteins are included in high-risk agens, which are subject to a special handling regime. Numerous studies have been demonstrated investigating the toxic effects and mode of action of these plant proteins in order to investigate the possible applications of their effects in many fields. An example is the study of the effect of viscumin from white mistletoe on cancer cells in order to influence their division, etc.

The aim of the work will be to summarize the recent findings, especially in the field of high-risk toxins and to develop and verify methodologies based mainly on mass spectrometry, which can identify and quantify selected protein toxins in complex material with respect to maximum sensitivity. At the same time, we will test and implement other complementary methods. Special emphasis will be placed on the possibilities of detection and identification of toxins in human biological material, especially in blood. Other areas on which the work will focus on will be to prepare these toxins from their natural producers, or via other routes that are currently possible.

References:

1. Duracova, M.; Klimentova, J.; Fucikova, A.; Dresler, J. Proteomic Methods of Detection and Quantification of Protein Toxins. *Toxins* 2018, *10*, 99. doi: 10.3390/toxins10030099

2. Liuyi Dang, Els J.M. Van Damme.: Toxic proteins in plants, Phytochemistry, Volume 117, 2015, Pages 51-64, doi: 10.1016/j.phytochem.2015.05.020

3. Graeme C. Clark, Stuart Armstrong, Abbie Harrison, Karen Moore, Angela Essex-Lopresti, Jon David, Chris Green, Julian Hiscox, Utilisation of 'omic approaches to improve the identification, diagnosis and treatment of exposure to the plant toxin ricin, Toxicon, Volume 177, Supplement 1, 2020, Page S31, doi:10.1016/j.toxicon.2019.12.036.

Research topic: Biodiversity of insect pollinators within central European landscape – potential threats and opportunities

Leader: doc. Ing. Jakub Horák, Ph.D.

Annotation

Insects are the most essential component of the pollinator functional group. These include extremely taxonomically diversified groups of hymenopterans, butterflies, and beetles. All these three groups have experienced a decrease in overall biodiversity in the Central European landscape and at the same time disruption in the composition of their natural communities.

The secret of the influences within this functional group, and above all the influence of the environment, could be revealed by their monitoring within the wider area of the Polabí lowland, including a comparison with the Central European fauna. Multi-taxonomic studies, which would focus not only on the influence within a specific taxonomic group but also their comparison across, i.e., within the entire functional group, seem appropriate.

A very important element will be the consideration of environmental influence. Currently, one can name opportunities for the improvement of the infrastructure of protected areas or the monitoring of the diversification of care within the framework of agri-environmental subsidy schemes. At the same time, threats in the form of a changing climate or the very little-studied relationship of insects to immediate changes in the atmosphere (i.e., weather) can also be mentioned.

The doctoral thesis will be devoted to the study of the functional group of pollinators within larger landscape units, in relation to important environmental factors such as landscape care, the influence of climate and weather, possibly supplemented by the influence of topography and spatial arrangement in general.

References

Bogusch P., Bláhová E., Horák J. 2020: Pollen specialists are more endangered than non-specialised bees even though they collect pollen on flowers of non-endangered plants. *Arthropod-Plant Interactions* **14**:759–769.

Horák J., Rada P., Lettenmaier L., Andreas M., Bogusch P., Jaworski T. 2021: Importance of meteorological and land use parameters for insect diversity in agricultural landscapes. *Science of the Total Environment* **791**:148159.

Horák J., Šafářová L., Trombik J., Menéndez R. 2022: Patterns and determinants of plant, butterfly and beetle diversity reveal optimal city grassland management and green urban planning. *Urban Forestry & Urban Greening* **73**:127609.

Klein A.M., Vaissière B.E., Cane J.H., Steffan-Dewenter I., Cunningham S.A., Kremen C., Tscharntke T. 2007: Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B: Biological Sciences* **274**:303–13.

Research topic: Central European bird fauna and its relationship to the changing landscape

Leader: doc. Ing. Jakub Horák, Ph.D.

Annotation

The entire Central European bird fauna is currently undergoing a series of changes. These changes often have a negative effect, but they can also have a positive effect. A negative manifestation is, for example, a decrease in the species diversity and population density of birds in agricultural landscapes, on the other hand, there is an improvement in the state of forest fauna or very dynamic changes in the urban landscape. This can be caused by the relationship of some species to humans or the invasion of mostly non-native species.

The subject of study will be communities and guilds within the taxonomic group of birds. Examples include water birds, birds nesting in tree vegetation, or grassland communities. Although each group requires different habitats, the big challenge is to find ones that allow their coexistence. Such places include, for example, urbanized areas or bodies of water, including their surroundings.

An important topic will therefore be the consideration of the influence of nuances within a similar biotope – for example, the quality of the forest or the type of water body. Furthermore, it will also reveal the influence of the context or matrix of the surrounding landscape or consider the degree of different categories within a certain type of landscape use (e.g., urbanization or suburbanization).

The doctoral thesis will be devoted to the study of different bird communities within a larger landscape, as well as its comparison within Central Europe. It should primarily consider the effects of urbanization, forest cover, or overall care for the landscape.

References

Horak J., Peltanova A., Podavkova A., Safarova L., Bogusch P., Romportl D., Zasadil P. 2013: Biodiversity responses to land use in traditional fruit orchards of a rural agricultural landscape. *Agriculture, Ecosystems and Environment* **178**:71–77.

Pšeničková T., Horák J. 2022: Influence of forest landscape on birds associated with lowland water bodies. *Forest Ecology and Management* **513**:120199.

Vélová L., Véle A., Horák J. 2021: Land use diversity and prey availability structure the bird communities in Norway spruce plantation forests. *Forest Ecology and Management* **480**:118657.

Xu X., Xie Y., Qi K., Luo Z., Wang X.2018: Detecting the response of bird communities and biodiversity to habitat loss and fragmentation due to urbanization. *Science of the Total Environment* **624**:1561–1576.

Zasadil P., Romportl D., Horák J. 2020: Disentangling the roles of topography, patch, and land use on conservation trait status of specialist birds in marginal forest land use types. *Forests* **11**:103.

Research topic: Age-dependent change in tree sensitivity to geomorphological processes

Leader: prof. RNDr. Karel Šilhán, Ph.D.

Consultant: RNDr. Lenka Plavcová, Ph.D.

Annotation

Trees are already commonly used as a natural archive of geomorphological processes (Stoffel & Bollschweiler, 2008). In the structure of their rings, they are able to record the effect of various natural influences on an anatomical and macroscopic level. Basic growth responses (growth disturbances) include abrupt growth suppression and release, or step changes in the tree-ring eccentricity. Anatomical growth disturbances include the formation of reaction (compression and tension) wood, the formation of traumatic resin ducts, and morphometric parameters of vessels and tracheids (Stoffel & Corona, 2014). However, recent research shows that the formation of these growth responses is subject to age trends, similar to the growth responses of trees to the effects of climatic variables. In contrast to the detailed study of dendroclimatic growth responses, the effect of tree age dependence in the case of dendrogeomorphology has been studied only marginally so far (Šilhán & Stoffel, 2015; Šilhán et al., 2013; Šilhán, 2021). This work will focus on the detailed analysis of dendrogeomorphological data in the form of temporal occurrence of a wide range of growth disturbances. Disturbances caused by different geomorphological processes (rockfall, debris flows, landslides, erosion) will be studied. The data will be analysed with respect to changing tree age (different time intervals) as well as tree size (through different stem diameter intervals).

References

Šilhán K. 2021: The age-dependent sensitivity of Picea abies (L.) H. Karst. to landslide movements. *Science of the Total Environment* **776**.

Šilhán K., Pánek T., Hradecký J. 2013: Implications of spatial distribution of rockfall reconstructed by dendrogeomorphological methods. *Natural Hazards and Earth System Sciences* **13**: 1817–1826.

Šilhán K., Stoffel M. 2015: Impacts of age-dependent tree sensitivity and dating approaches on dendrogeomorphic time series of landslides. *Geomorphology* **236**: 34–43.

Stoffel M., Bollschweiler M. 2008: Tree-ring analysis in natural hazards research - an overview. *Natural Hazards and Earth System Sciences* **8**: 187–202.

Stoffel M., Corona C. 2014: Dendroecological Dating of Geomorphic Disturbance in Trees. *Tree-Ring Research* **70**: 3–20.

Research topic: Pollen specialization of European bees – pollen analysis of scopae

Leader: doc. Mgr. Petr Bogusch, Ph.D.

Consultant: RNDr. Libor Petr, Ph.D., Masaryk university, Brno

Annotation

Pollen is the most important component of food of both solitary and socially living bee larvae, and according to the pollen specialization we can divide bees into monolectic, oligolectic and polylectic, with various authors allocating several other categories (Cane & Sipes 2007; Müller & Kuhlmann 2008; Dötterl & Vereecken 2010). Most Central European bee species are polylectic, i.e. collecting pollen from more unrelated plants (Bogusch et al. 2020). Unfortunately, literary data on bee specialization is mainly based on observations of bees visiting flowers, and the currently increasingly used determination of pollen grains by morphology or molecular analysis of pollen are methods whose use is only signed under the most recent studies. The aim of this work is to solve selected aspects of the Central European bee specialization, especially the differences in the specialization of polylectic species in different types of habitats, individual specialization of females of polylectic bees, and to bring the concept of characterization of so-called mesolectic bees. In addition, non-traditional sources of pollen can be solved - invasive plants, non-native crops. Specific research tasks will be prepared after the communication with potential candidates.

References

Bogusch P., Bláhová E., Horák J. 2020: Pollen specialists are more endangered than non-specialised bees even though they collect pollen on flowers of non-endangered plants*. Arthropod-Plant Interactions*, submitted.

Cane J.H., Sipes S.D. 2006: *Characterizing floral specialization by bees: analytical methods and a revised lexicon for oligolecty*. pp. 99-122. In: Waser N.M., Ollerton J. (eds.): *Plant-Pollinator Interactions: From Specialization to Generalization*. The University of Chicago Press, Chicago and London.

Dötterl S., Vereecken N.J. 2010: The chemical ecology and evolution of bee flower interactions: a review and perspectives. *Canadian Journal of Zoology* **88**: 668-697.

Müller A., Kuhlmann M. 2008: Pollen hosts of western palaearctic bees of the genus Colletes (Hymenoptera: Colletidae): the Asteraceae paradox*. Biological Journal of the Linnean Society* **95**: 719-733.