C_3E NEWSLETTER 2019/20

CENTRE OF COMPETENCE IN CHEMICAL ECOLOGY

UNIVERSITÉ DE NEUCHÂTEL

FACULTÉ DES SCIENCES

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Cover illustration

A triple of whiteflies *Bemisia tabaci* (see Page 5) on a cotton leaf. Photo credit Prof. Run-zhi Zhang

IMPRESSUM

Centre of Competence in Chemical Ecology (C_3E)
Faculty of Sciences, University of Neuchâtel
Rue Emile-Argand 11, CH-2000 Neuchâtel, Switzerland

Editor: Thomas Degen
E-mail: thomas.degen@unine.ch
www.unine.ch/centres-of-excellence/home/ecologie-chimique.html

CENTRE OF COMPETENCE IN CHEMICAL ECOLOGY

UNIVERSITÉ DE NEUCHÂTEL

Still buzzing

Ted Turlings

Felix Kessler

Stephan von Reuss

It has been exceptionally quiet in most hallways of our science building the last five months. Still, with the exception of a few weeks many labs continued to buzz with activity. In this time of mayhem we still do our best to progress with our science, even if some of it may seem a bit less relevant in light of the health and societal problems that urgently need to be resolved. Like many, we looked for ways to help, we offered our expertise to contribute to novel Covid-19 diagnostic tools and even the fabrication of effective facemasks. Some of this seems to have penned out, but we are now mostly back to what we do best, and that is basic chemical ecology, occasional including an applied twist, with the conviction that some of the knowledge that we generate will eventually be of use and will contribute to solutions to the multitude of problems that mankind is facing.

In this long overdue fifth newsletter of our Center of Competence in Chemical Ecology we celebrate the tenth anniversary of the Neuchâtel Platform for Analytical Chemistry (NPAC), highlight some of our research accomplishments during 2019 and 2020 and present three new research projects. The value of NPAC goes well beyond the University of Neuchâtel, which is evident from the large numbers of analyses done for external research groups. Its success is due to the competences and management skills of Dr. Gaetan Glauser and Armelle Vallat, who have been at the helm of NPAC. Researchers are not merely turning to NPAC for routine analyses, which they could in most cases also carry out at their own institutions, but they prefer NPAC because of the expert method development and data interpretation it offers. We highlight the nice example of an exceptionally sensitive method to detect and quantify neonicotinoids, which has led to several impactful publications.

In this issue we further feature several publications that reveal novel aspects of chemically-mediated interactions. For instance, how rats can smell the nutritional needs of conspecifics, the importance of pyrrolizidine alkaloids in flower pollen, the adaptive role of herbivore-induced signals, and how insect pests exploit and manipulate such plant defense responses.

Finally, we are delighted to announce that Dr. Ricardo Machado, who received a prestigious *Ambizione* grant from the Swiss National Science Foundation, joined us in Neuchâtel. As explained in this newsletter, his team explores the ecological role of bioluminescence in the bacterial symbionts of entomopathogenic nematodes.

Like many other things, this newsletter was on hold for some time. Here it finally is, and we intend to send out the next one within half a year from now, hopefully at the time when the world has rid itself of some its worst torments.

ORGANISATION 4

STEERING COMMITTEE

Ted Turlings (director C_3E) *fundamental and applied research in chemical ecology (FARCE)*
Felix Kessler (vice-rector research UniNE) *plant physiology*
Stephan von Reuss (director NPAC) *bioanalytical chemistry*

COORDINATION

Thomas Degen *chemical ecology*

NPAC

Gaétan Glauser *mass spectrometry and metabolomics unit*
Armelle Vallat *mass spectrometry and metabolomics unit*
Sylvain Sutour *nuclear magnetic resonance unit*

PARTICIPANTS UNINE

Betty Benrey *evolutionary entomology*
Redouan Bshary *behavioural ecology*
Daniel Croll *evolutionary genetics*
Edith Joseph *microbiology*
Pilar Junier *microbiology*
Jacob Koella *ecology and epidemiology of parasites*
Ricardo Machado *chemical ecology and microbiology* **(joined in 2020)**
Brigitte Mauch-Mani *molecular and cell biology*
Sergio Rasmann *functional ecology*
Gregory Röder *chemical ecology*

EXTERNAL PARTNERS

Consuelo De Moraes & Mark Mescher *ETH-Zürich*
Matthias Erb *University of Bern*
Ted Farmer *University of Lausanne*
Cris Kuhlemeier *University of Bern*
Felix Mauch *University of Fribourg*
Heinz Müller-Schärer *University of Fribourg*
Philippe Reymond *University of Lausanne*
Christelle Robert *University of Bern*
Urs Schaffner *CABI, Delemont, Switzerland*
Florian Schiestl *University of Zurich*
Jean-Luc Wolfender *University of Geneva*

Whiteflies trump plants to make them spread fake news

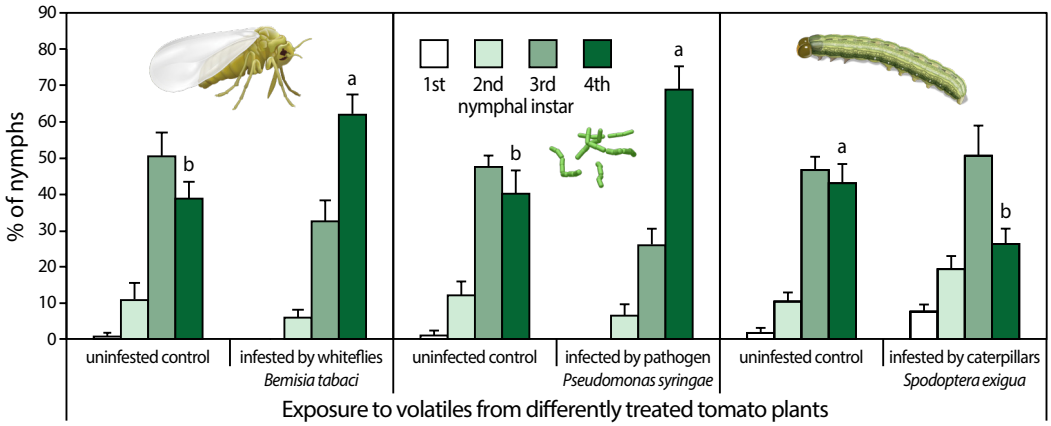
Peng-Jun Zhang

Whitefly *Bemisia tabaci*

Over the past two decades, Ted Turling has established connections with an increasing number of Chinese research groups active in the field of chemical ecology. An ongoing collaboration with Peng-Jun Zhang from the China Jiliang University in Hangzhou, Zhejiang Province, and his colleagues from other State Key Laboratories has given rise to a joint publication in PNAS. The paper reports on a fascinating case of host–plant manipulation that extends to neighbouring plants via airborne signals.

Earlier investigations had revealed that plants attacked by the phloem-feeding whitefly *Bemisia tabaci* specifically mobilize salicylic acid (SA)-dependent defences, which mainly target pathogens. At the same time, jasmonic acid (JA)-dependent defences, which are normally activated in response to herbivory, are gradually suppressed in whitefly-infested plants, making them more suitable hosts for the insects. The new study, which used tomato as a model plant, now demonstrates that these effects are not limited to the attacked plants, but are passed on to neighbouring plants via whitefly-induced volatiles. This odorous signal is picked up by these not yet infested plants, which are fooled into anticipating pathogen infection and thus ramping up SA-dependent defences, while JA-dependent defences are inhibited. The offspring of colonizing whiteflies performs better on these "wrongly" primed tomato plants, in the same way as they do on plants that really have been exposed to an airborne signal from plants infected by a pathogen. By contrast, plants receiving an odour blend induced by feeding *Spodoptera exigua* caterpillars upregulate JA-dependent defences and consequently show enhanced resistance against whiteflies. Moreover, the researchers were able to mimic the observed priming reaction with synthetic versions of the compounds that were specifically released in response to whitefly attack.

The authors conclude that the ability of whiteflies to manipulate plant defense responses through induced volatile emissions might explain the rapid spread of *Bemisia tabaci* and its status as one of the world's most important invasive crop pests. The article has drawn considerable media attention and has been featured by a variety of newspapers across the world, e.g. *The Economist*, *The Atlantic* and *Süddeutsche Zeitung*.



Performance of whiteflies *Bemisia tabaci* on volatile-exposed tomato plants, as expressed by the developmental rate, i.e. the percentage of nymphs represented by each instar at 21 days after adults had been added to exposed plants.

Zhang P-J, Wei J, Zhao C, Zhang Y-F, Li C, Liu S-S, Dicke M, Yu X, **Turlings TCJ** 2019. Airborne host-plant manipulation by whiteflies via an inducible blend of plant volatiles. ***Proceedings of the National Academy of Sciences of the United States of America*** 116: 7387-7396.

Further evidence for the role of tritrophic interactions in the evolution of volatile emissions by plants

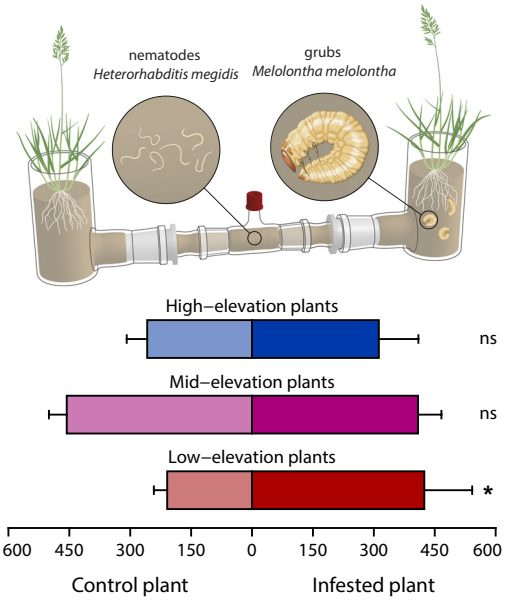
Alan Kergunteuil

Sergio Rasmann

The Functional Ecology lab of Sergio Rasmann is interested in the ecology and evolution of species interactions, with a focus on plant-herbivore-predator interaction and community ecology along climatic gradients. Alan Kergunteuil, a former post-doctoral fellow in the group, has published the results of a study, which uses elevational gradients as a tool for determining the adaptive role of plant defences, in the renowned journal *Ecology Letters*.

In ecological food webs, the second and third trophic level, i.e. herbivores and their associated predators and parasites, are often considered important selective drivers of the evolution of direct and indirect plant defences. In the latter case, i.e. for herbivore-induced volatile compounds that attract predators to the attacked plants, solid evidence in favour of this claim is still rather scarce, though. As a general pattern it can be observed that the abundance of herbivores and predators decreases continuously from lower to higher altitudes. To determine whether plant adaptation along such an elevational gradient influences top-down control of herbivores by predators, the authors manipulated soil predatory nematodes, root herbivore pressure and plant ecotypes in a reciprocal transplant experiment. To this end, they chose a belowground tritrophic system that comprised ecotypes of a predominant plant species colonising all the altitudinal zones of the Alps, the red fescue grass *Festuca rubra*, a generalist herbivore that feeds on the roots, grubs of the cockchafer *Melolontha melolontha*, and the widespread entomopathogenic nematode *Heterorhabditis megidis*, which parasitizes and kills insect larvae.

Conducting two common garden experiments at different elevation, the authors found that the survival of red fescues plants was higher when root herbivores were inoculated with the predatory nematodes, but only for low elevation plant ecotypes. In line with these results, when infested by grubs, only plants originating from low elevation attracted more nematodes than the corresponding uninfested plants in belowground olfactometer bioassays. Furthermore, according to GC-MS analyses of odours collected from roots of experimental plants, the total volatile emissions and the diversity of volatile profiles decreased with increasing elevation. The study thus highlights relaxed defences in high-elevation habitats, where herbivore and predator abundances are low, as predicted by theory. The authors conclude that their findings suggest that variation in herbivore pressure and predator abundance count indeed among the chief selective agents of volatile production mediating top-down control of herbivores in nature.



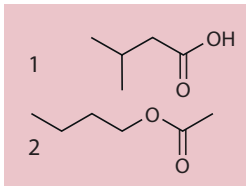
Attraction of entomopathogenic nematodes in two-arm belowground olfactometer assays towards grub-infested plants as compared to uninfested plants, depending on the elevation from which the plants originated (* $P < 0.05$).

Kergunteuil A, Röder G, Rasmann S 2019. Environmental gradients and the evolution of tri-trophic interactions. ***Ecology Letters*** 22: 292-301.

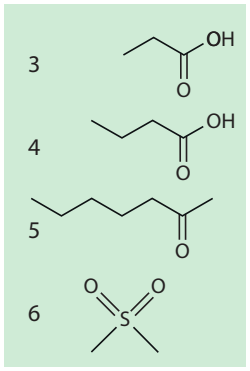
Smelling a not so big, not so fat rat

Karin Schneeberger

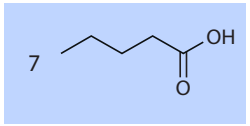
Gregory Roeder



with hungry rats only



higher with satiated rats

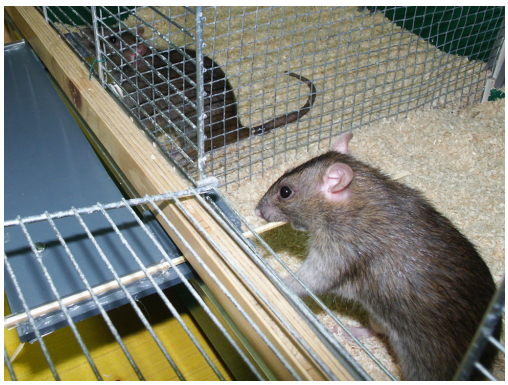


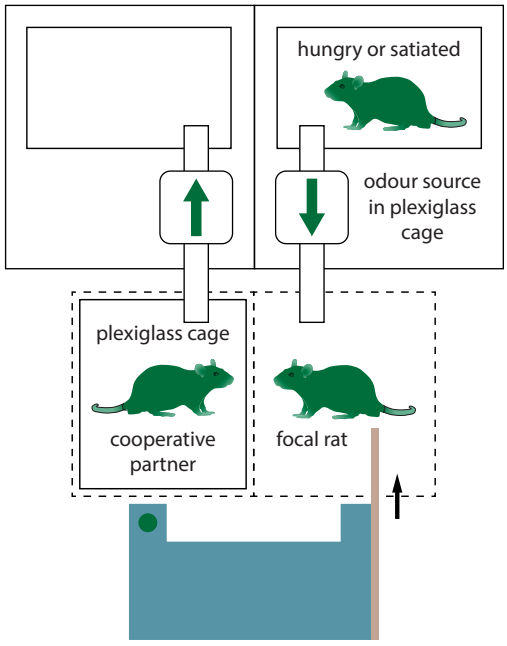
with satiated rats only

Gregory Roeder is the specialist on volatile-mediated interactions among vertebrates in the FARCE group. He provided the chemical analytical expertise for a joint publication with Karin Schneeberger, a former postdoctoral researcher at the Behavioural Ecology Division of the University of Bern headed by Michael Taborsky. The researchers worked with rats *Rattus norvegicus* to study under which circumstances cooperative behaviour can establish within an animal population.

Reciprocally cooperating animals should consider the relative benefit for the receiver when deciding to help, as a needy individual will be more inclined to return a favour in a future interaction. Rats can take into account both the cost of helping and the potential benefit to the receiver when they exchange food. With the experimental set-up depicted opposite, it could be demonstrated that rats may determine the need of another individual by olfactory signals alone, as suggested by the observation that they pull in the tray to provide food for the previously cooperative partner quicker when they receive odour cues from a hungry rather than from a satiated conspecific.

To characterize the odour of hungry and satiated rats, air samples were collected from the cages with the experimental rats using Tenax traps and analysed by GC-MS. A principal component analysis of the 27 identified volatile compounds clearly separated the individuals according to their hunger status. Significant differences among hungry and satiated rats were found for seven components: 3-methylbutanoic acid (1) and butyl acetate (2) were only present in the odour of hungry rats, propanoic acid (3), butanoic acid (4), 2-heptanone (5) and dimethyl sulfone (6) were detected in higher amounts in the scent of satiated rats, while pentanoic acid (7) was exclusively found in satiated individuals. Contrary to behavioural means to solicit help, such as vocal communication, which can be manipulative, the chemical signals can serve as reliable cues of need in reciprocal cooperation, which supports the hypothesis of honest signalling.





Experimental setup during the test phase. The focal rat has the opportunity to reciprocate the help it had received during the experience phase by pulling a stick attached to a tray containing a food reward for the previously cooperative partner in the adjacent plexiglass box, while receiving odour from a hungry or satiated individual. During the preceding experience phase the cooperative partner produced food for the focal rat, which was exposed to air from a satiated rat.

Schneeberger K, **Röder G**, Taborsky M 2020. The smell of hunger: Norway rats provision social partners based on odour cues of need. ***PLoS Biology*** 18: e3000628. doi: 10.1371/journal.pbio.3000628

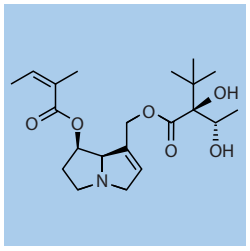
In quest of the primary role of secondary compounds in pollen of Boraginaceae

Vincent Trunz

Christophe Praz

Borrago officinalis

Myosotis forget-me-not

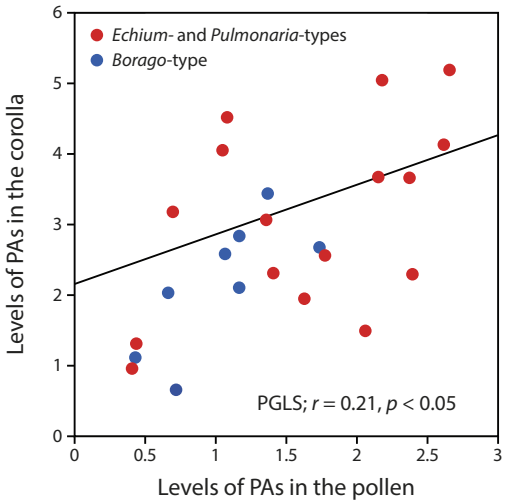


echimidine

In 2017, Vincent Trunz had completed his dissertation on evolution of the leafcutter bees and chemical ecology of bee-flower relationships, supervised by Christophe Praz. An article based on one of the chapters of this doctoral thesis appeared recently in the journal *Functional Ecology*, co-authored by several other C_3E-participants. The study aimed to elucidate the ecological significance and evolutionary origin of secondary "toxic" compounds in pollen, using a range of plant species belonging to the family Boraginaceae from the western Palearctic and the associated bee pollinators as model system.

The fact that nectar and pollen, meant to be pollination rewards, can contain toxic secondary metabolites remains somewhat mysterious, particularly in the case of pollen, where the levels are often remarkably high. The authors wanted to find out whether the presence of defensive compounds in pollen is rather a pleiotropic physiological effect due to "spillover" from other floral tissues, which the plant needs to protect from herbivory, or whether it serves an adaptive purpose related to plant-pollinator interactions, e.g. to dissuade pollen thieves. In addition, the authors tested the hypothesis that bees tend to specialize on toxic host plants, as many other herbivorous insects. To this end, pyrrolizidine alkaloids (PAs) such as echimidine, characteristic of boraginaceous plants, were extracted from pollen and corollas of 26 species and quantified with an ultra-high performance liquid chromatograph coupled to a quadrupole time-of-flight mass spectrometer. The levels of PAs in the pollen were found to be significantly correlated with those in the corolla. From this the authors conclude that baseline levels of secondary compounds in pollen may partly be due to spillover from floral tissues and are in most cases not linked to plant-pollinator interactions in this plant family.

In bioassays, the researchers observed that the development of non-specialized bee species was negatively affected when the larvae were fed with pollen from their host plants supplemented with realistic levels of pollen toxins, supporting the idea that these compounds can have a strong impact on the fitness of pollen-feeding visitors. Taxa of the *Echium*- and *Pulmonaria*-type (e.g. *Myosotis*), where the main reward to pollinators is postulated to be nectar, show significantly higher levels of toxic compounds in the pollen than phylogenetically independent taxa belonging to the *Borago*-type, which reward pollinators with pollen in addition to nectar. In the latter case, selection appears to have led to reduced levels of PAs in the pollen, possibly to avoid deterring legitimate pollinators. Lastly, contrary to the initial expectation of the authors, no positive association between toxin levels in the pollen of a given plant taxon and the number of bee species specialized on this taxon could be ascertained, suggesting that other factors drive host-plant specialization in bees.



Correlation between the levels of pyrrolizidine alkaloids in the pollen and those in the corolla. The regression analysis between the average values of PAs (fourth root transformed values in µg/mg) for each species takes into account the phylogenetic relationship among species (PGLS = Phylogenetic Generalized Least Square).

Trunz V, **Lucchetti MA**, **Bénon D**, Dorchin A, **Desurmont GA**, Kast C, **Rasmann S**, **Glauser G**, **Praz CJ** 2020. To bee or not to bee: The 'raison d'être' of toxic secondary compounds in the pollen of Boraginaceae. ***Functional Ecology*** 34: 1345-1357. doi: 10.1111/1365-2435.13581

The astonishing benefits of sharing your host plant with another herbivore

Yunhe Li

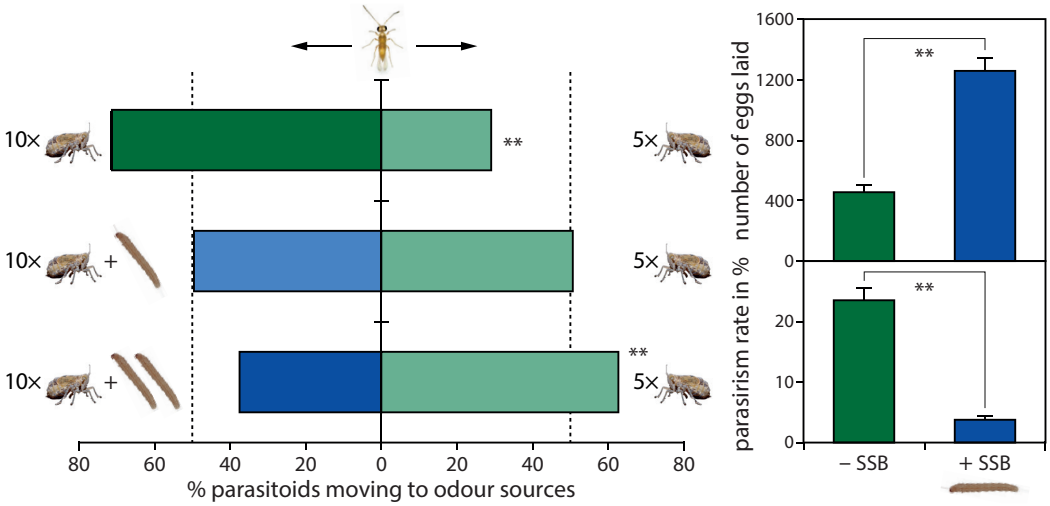
Nilaparvata lugens

Chilo suppressalis

Anagrus nilaparvatae

Another ongoing "Chinese connection" of the FARCE Lab came recently to fruition with an article published in the journal *eLife*, co-authored by Ted Turlings. Yunhe Li, the head of the group that carried out the research at a state key laboratory of the Chinese Academy of Agricultural Sciences in Beijing, has an old link to Switzerland that goes back to when he conducted his PhD thesis at Agroscope Reckenholz in the framework of the NCCR *Plant Survival*, at that time directed by Ted Turlings. The paper, which was chosen by the editors of the journal to be featured in an insight article (Joo & Schuman 2020), reports about a fascinatingly intricate plant-insect interaction mediated by herbivore-induced volatiles.

The study originated from the observation that females of the brown planthopper *Nilaparvata lugens* prefer to lay their eggs on rice plants that are already attacked by another insect, the rice striped stemborer *Chilo suppressalis*. Seeking to explain this unexpected predilection, the researchers discovered that the most important natural enemy of the planthopper, the egg parasitoid *Anagrus nilaparvatae*, avoids stemborer-infested plants, as indicated by the results of olfactometer choice assays. The specific volatile components were identified in collected plant odour samples. Tests using blends assembled with synthetic compounds could reproduce the findings obtained with the respective herbivore-infested plants, which confirmed the function of the plant volatiles in these interactions. Moreover, parasitism rates of planthopper eggs were considerably lower on plants co-infested with stemborers in greenhouse and field cage experiments. The combined evidence suggests that the observed oviposition strategy of the female planthoppers is adaptive. So, the released odorous signal, generally interpreted as benefitting the plant by attracting natural enemies of its attackers, is exploited in this particular case by another herbivore to secure host plants for its progeny that are comparatively free of enemies. This presents another example of the unsuspected roles that plant volatiles can play in complex ecological relationships.



Left: Choices of female *A. nilaparvatae* wasps in a Y-tube olfactometer, when offered odour of rice plants infested by 10 planthoppers without or with stemboring caterpillars next to the odour of rice plants only infested by 5 planthoppers. **Right: Oviposition by planthoppers and parasitism rates of planthopper eggs in field cage experiments;** ** p<0.01.

Hu X, Su S, Liu Q, Jiao Y, Peng Y, Li Y, **Turlings TCJ** 2020. Caterpillar-induced rice volatiles provide enemy-free space for the offspring of the brown planthopper. ***eLife*** 9: e55421. doi: 10.7554/eLife.55421

Joo Y, Schuman MC 2020. Hiding in plain smell. ***eLife*** 9:e60912 doi:10.7554/eLife.60912

Hunting down neonics – residues in honey revisited with unprecedented analytical sensitivity

Gaétan Glauser

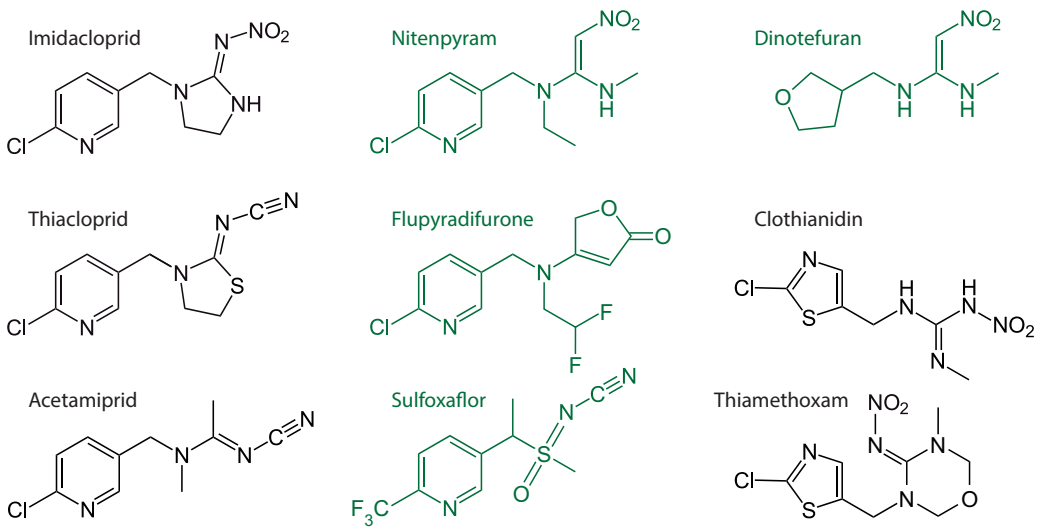
Edward Mitchell

Alexandre Aebi

In 2017, researchers at UniNE had published a first study on neonicotinoid residues in honey (Mitchell *et al.*, DOI: 10.1126/science.aan3684), which had received a large echo in the media. Since, Gaétan Glauser of the NPAC has refined the analytical method to detect neonicotinoids and closely related insecticide classes at ultra-trace levels. The newly developed method is up to a thousand times more sensitive than the ones previously used, reaching limits of quantification as low as 2-20 pg/g of honey. This is particularly important, as it is becoming increasingly clear that potential negative effects of neonicotinoids on non-target organisms, including pollinators such as bees, may occur at extremely low concentrations.

Honey samples kept from the previous study were re-analyzed to determine the long-term stability of the five most common neonicotinoids: acetamiprid, clothianidin, imidacloprid, thiacloprid and thiamethoxam. All compounds proved to be stable over a period of several years at -20 °C, and only acetamiprid and thiacloprid partially degraded at room temperature. In addition, the study was extended to cover also the levels of dinotefuran, nitenpyram, sulfoxaflor and flupyradifurone, and found that 28% of the samples were contaminated by at least one of these pesticides.

Further studies on neonicotinoid residues carried out by the NPAC have already benefited from the improved analytical method. It was applied to measure neonicotinoid levels in Swiss milks (Lachat & Glauser 2018, DOI: 10.1021/acs.jafc.8b03005), in feathers of house sparrows (Humann-Guilleminot *et al.* 2019, DOI: 10.1016/j.scitotenv.2019.01.068) as well as in soils, plants and water (Humann-Guilleminot *et al.* 2019, DOI: 10.1111/1365-2664.13392; Bonmatin *et al.* 2019, DOI: 10.1016/j.envpol.2019.03.099). These studies revealed that neonicotinoids are ubiquitously or almost ubiquitously present in the environment, although at levels considered to be safe for humans.



Structures of the nine neonicotinoids and related pesticides analysed in the study.

Kammoun S, Mulhauser B, Aebi A, Mitchell EAD, **Glauser G** 2019. Ultra-trace level determination of neonicotinoids in honey as a tool for assessing environmental contamination. ***Environmental Pollution*** 247: 964-72.

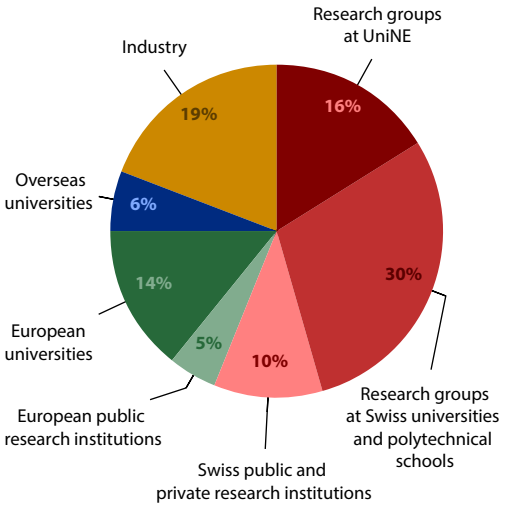
Ten years of Neuchâtel Platform for Analytical Chemistry

Neuchâtel Platform of Analytical Chemistry

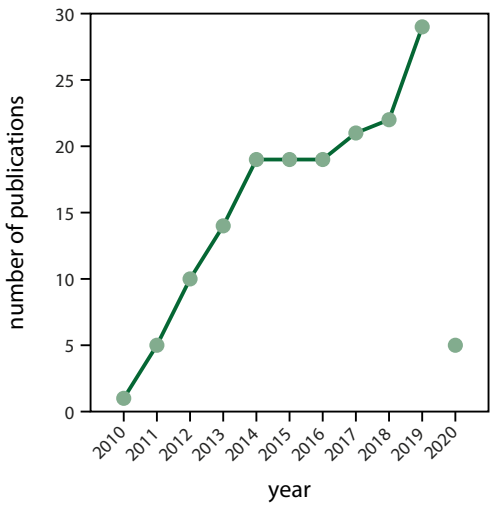
As a spin-off of the National Centre of Competence in Research *Plant Survival* (2001-2013), the *Neuchâtel Platform for Analytical Chemistry* (NPAC) was initially created in 2010 to provide chemical analytical services for the *Swiss Plant Science Web*. After a merger with the existing chemical analytical service of the faculty of science it was launched under its present name in 2014 and is now considered a research infrastructure of national importance. Over the past ten years, the NPAC has established itself as one of the leading institutions in analytical chemistry in Switzerland and beyond. We feel that it is a nice occasion to sum up some of its major achievements over the last ten years and to provide a few up-to date figures.

Since its inception, the NPAC has performed more than 125'000 analyses. Analytical services have been provided to over a hundred different customers from a variety of sectors as illustrated below in the pie chart. The majority of the clients come from Swiss universities or other research institutions in Switzerland, whereas one fourth of the clients are from abroad, mostly from European universities, and almost one fifth of the mandates stems from the industry sector. Traditionally research topics from the plant sciences are dominant (61%), followed by those from zoology (20%, e.g. entomology, ornithology), but disciplines outside the life sciences are represented as well (e.g. environmental chemistry, hydrogeology).

Projects may be carried out merely on a service basis, but in many cases, they are of a collaborative nature and result in joint publications. Thus, since the creation of NPAC, the senior researchers who run the service have co-authored a total of 164 papers, mostly articles in peer-reviewed journals, but also several reviews and book sections, and this output has steadily increased over the years, culminating in almost 30 publications in 2019. These achievements have been recently rewarded with funds that allowed the acquisition of two new high resolution instruments in the fields of mass spectrometry and nuclear magnetic resonance (see page 12), which will significantly reinforce the analytical capabilities of the facility.



Proportion of the customers according to sector and geographical location.



Publication output co-authored by senior researchers of the NPAC.

Two new analytical instruments for the NPAC

Neuchâtel Platform of Analytical Chemistry

In order to provide the best possible analytical services to its customers, the NPAC strives to regularly complete its machine park with state-of-the-art equipment. Both the *Mass Spectrometry and Metabolomics Unit* and the *Nuclear Magnetic Resonance Unit* recently managed to obtain a new instrument.

In our last C_3E newsletter (2017/2018), we reported that the NPAC had been awarded a *R'equip* grant, which allowed it to acquire an ultra-high performance liquid chromatography-high resolution tandem mass spectrometer (UHPLC-HRMS/MS) with matching funds from the Swiss National Science Foundation and the University of Neuchâtel. After a meticulous evaluation of several instruments available on the market, the choice eventually fell on the *Waters SYNAPT XS*. It benefits from the latest advances in the field and fully matches the two required key features, namely speed of acquisition (50 Hz) and high sensitivity. It will enable a metabolomics workflow that consists of acquiring numerous selective MS/MS spectra for the generation of highly informative molecular networks.

Waters SYNAPT XS ion mobility time-of-flight high resolution mass spectrometer.

Bruker ASCEND 600 MHz NMR magnet system.

The *Nuclear Magnetic Resonance Unit* now houses a *Bruker Avance Neo Ascend* 600MHz, replacing the previous 400 MHz instrument, which was approaching its end of life. The purchase was financed both by the University of Neuchâtel and by own funds of the NPAC. The acquisition of this high field 600 MHz NMR instrument will significantly improve the NPACs capabilities to identify biologically relevant small molecules detected using already established MS metabolomics techniques. It also offers a unique opportunity to simultaneously develop NMR metabolomics as a complementary tool in chemical ecology research.

Cotton communication

Luca Grandi

Mary Clancy

Carlos Bustos

Marine Mamin

At the end of 2019, the FARCE lab of Ted Turlings launched a new SNF-funded research project that aims to study the application potential of volatile-mediated interactions among cotton plants. The project builds on the results of the doctoral thesis of Luca Grandi, which was accomplished in 2020, and involves two postdoctoral researchers, Mary Clancy and Carlos Bustos, as well as a doctoral student, Marine Mamin.

Cotton is the world's dirtiest crop in terms of pesticide use, causing tremendous environmental and health issues. The push to drastically reduce pesticide application in cotton cultivation is also motivated by the potential of exploiting cotton's highly nutritious seeds as food for animals and humans. One promising strategy to decrease the need for pesticides has been proposed by partners of the FARCE lab at the French Agricultural Research Centre for International Development (CIRAD). They had found that topping, a pruning practice adopted by many cotton growers, reduces insect damage. This beneficial effect is not only evident for the topped plants, but also for intact neighbour plants. The available evidence suggests that volatiles released by the topped plants are responsible for the enhanced resistance in the neighbouring plants, much like undamaged plants can perceive herbivore-induced volatiles emitted by infested plants and get their defence ready for imminent attack.

The new project intends to investigate plant-plant interactions in cotton mediated by volatiles under natural conditions to unravel the true ecological significance of the phenomenon. It also strives to identify the key volatiles needed for optimal responses. The most commonly cultivated cotton species, *Gossypium hirsutum*, has been domesticated in Mexico. That is why the role of volatiles in inducible chemical defences will be studied in different populations of wild cotton plants from the Mexican Yucatán peninsula, as well as in cultivated varieties, under the hypothesis, that the crop plants may have partially lost the capacity to "communicate" via volatile signals during domestication. Ultimately, the fundamental understanding of cotton defence signalling shall be exploited to restore and enhance cotton resistance against pests in order to boost production and reduce the need for pesticide application, in particular in developing countries.

Wild cotton plants *Gossypium hirsutum* on the Yucatan Peninsula.

Title	**Understanding and exploiting communication between cotton plants**
Funding Organization	Swiss National Science Foundation
Funding Scheme	***Project funding in biology and medicine (division III)***
Budget	964'338 CHF
Start/End	1.10.2019 - 30.9.2023

Fighting an invasive pest in Africa

Patrick Fallet

Stefan Toepfer

Spodoptera frugiperda

The PhD thesis of Patrick Fallet, as part of a collaboration between Stefan Toepfer of CABI in Delémont, Switzerland, and Ted Turlings of the FARCE Laboratory, aims at contributing to the control of a highly destructive pest insect. The fall armyworm *Spodoptera frugiperda* from the Americas has invaded Africa only a few years ago and has since spread already all over the subsaharan part of the continent, causing tremendous crop losses particularly in maize fields. It continues to expand its range and has in the meantime also started to colonize the Indian peninsula as well as South East Asia and China.

It is long known that entomopathogenic nematodes (EPN) are good biocontrol agents against many soil-dwelling insect pests. In the context of the National Research Programme 68 *Sustainable Use of Soil as a Resource*, the FARCE lab had developed and evaluated new alginate-based formulations meant to overcome limitations of traditional aqueous formulations in terms of application costs and shelf-life. These formulations also opened the perspective to apply EPN to pest insects feeding on above-ground plant parts, like the armyworm.

In a first step, Patrick Fallet made a survey of local EPN strains in Rwanda that are adapted to the African environment. The isolated strains were compared with strains from Mexico, a part of the armyworm's native range, and with commercially produced EPN for their suitability against fall armyworm in terms of virulence and reproductive capacities. Selected EPN are then to be incorporated in a formulation that can be applied into the whorl of maize plants, where armyworms feed. From the whole range of potential substrates that were evaluated (gels, alginate beads, oils, sand and water), a gel-based formulation turned out to be most promising. It was found to be just as effective as pesticide sprays in a field trial conducted in collaboration with plant protection scientists of the Rwanda Agriculture and Animal Resource Development Board and with farmers. It is expected that this can be further improved if the caterpillars are actively feeding on the EPN formulations. Therefore, it is ultimately planned to identify feeding stimulants and/or attractants for armyworm larvae that can be added to the medium in an attempt to increase the efficacy of the EPN-based control strategy.

"Biocontrol agents" armed with newly developped EPN-gel dispensers fighting on the African maize field.

Provisional Title	**A novel strategy to control the fall armyworm with entomopathogenic nematodes**
Funding Organization	University of Neuchâtel, CABI Delémont (Donors: DGIS, Netherlands; DFID, UK)
Funding Scheme	***PhD thesis***
Start/End	2018 - 2022

Shedding light on the ecological role of the bioluminescence of soil-dwelling bacteria

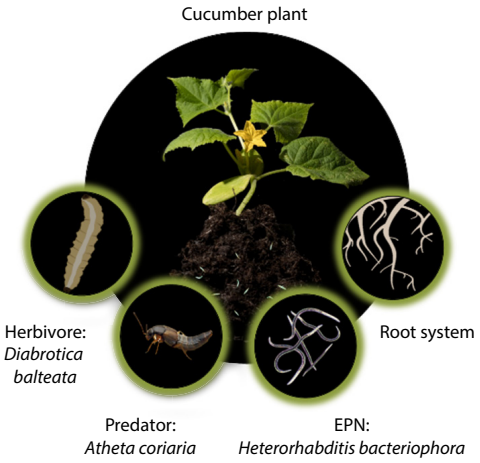
Ricardo Machado

Insect larvae infected by EPNs and their bio-luminescent bacterial symbionts

Ricardo Machado has recently been awarded an *Ambizione* grant by the Swiss National Science Foundation, which allows him to do research on the ecological and evolutionary significance of bioluminescence in soil-dwelling organisms. He has chosen the Institute of Biology of the University of Neuchâtel to carry out this new project and to establish his own research group. There, he is affiliated with the FARCE and the Microbiology laboratories, headed by Ted Turlings and Pilar Junier, respectively, and at the same occasion has also become a new C_3E member.

Ricardo Machado studied Agronomic Engineering at the Universidad Nacional de Colombia, in Medellin, before moving to Germany to obtain his Master degree in microbiology at the Friedrich Schiller University in Jena, where he also conducted his doctoral studies in chemical and molecular ecology at the Max Planck Institute for Chemical Ecology under the supervision of Ian Baldwin and Matthias Erb. Then, in 2015, he joined Matthias Erb's research group at the University of Bern in Switzerland as a post-doctoral fellow and project leader to work on different aspects of the chemical and molecular ecology of below-ground ecosystems.

Bioluminescence, the chemical production and emission of light by living organisms, is a well-studied phenomenon in aquatic ecosystems, but less is known about its role in terrestrial ecosystems, particularly so when it comes to soil-dwelling organisms. Ricardo Machado intends to fill this gap of knowledge by studying bioluminescent *Photorhabdus* bacterial symbionts, which live in association with entomopathogenic nematodes (EPNs) of the genus *Heterorhabditis*. These nematodes penetrate soil-dwelling insects and release their symbiotic bacteria, which then start to multiply, produce toxins and immune suppressors that eventually kill the insect. During the colonization process, *Photorhabdus* bacteria emit blue light, which causes the characteristic glow of the infected organisms. Whether and how other associated organisms, namely EPNs, predatory and scavenging insects, and plants, respond to this bioluminescence remains unknown, as well as the potential benefits or adaptive value for the light-emitting bacteria and for their nematode hosts. The project aims to answer these questions by investigating the biological consequences of *Photorhabdus* bioluminescence.



Conceptual framework of the research plan. The study aims to elucidate how the bioluminescence produced by *Photorhabdus* bacteria impacts other trophic levels directly, or indirectly through plant-mediated effects.

Title	**Glowing belowground: bioluminescence as regulator of multi-trophic interactions in the rhizosphere**
Funding Organization	Swiss National Science Foundation
Funding Scheme	***Ambizione***
Budget	941'451 CHF
Start/End	1.2.2020 - 31.1.2024