HelmholtzZentrum münchen
Deutsches Forschungszentrum für Gesundheit und Umwelt

„Perspectives and challenges for VOC phenotyping in plants“

Jörg-Peter Schnitzler

Institute of Biochemical Plant Pathology

Research Unit Environmental Simulation (EUS)

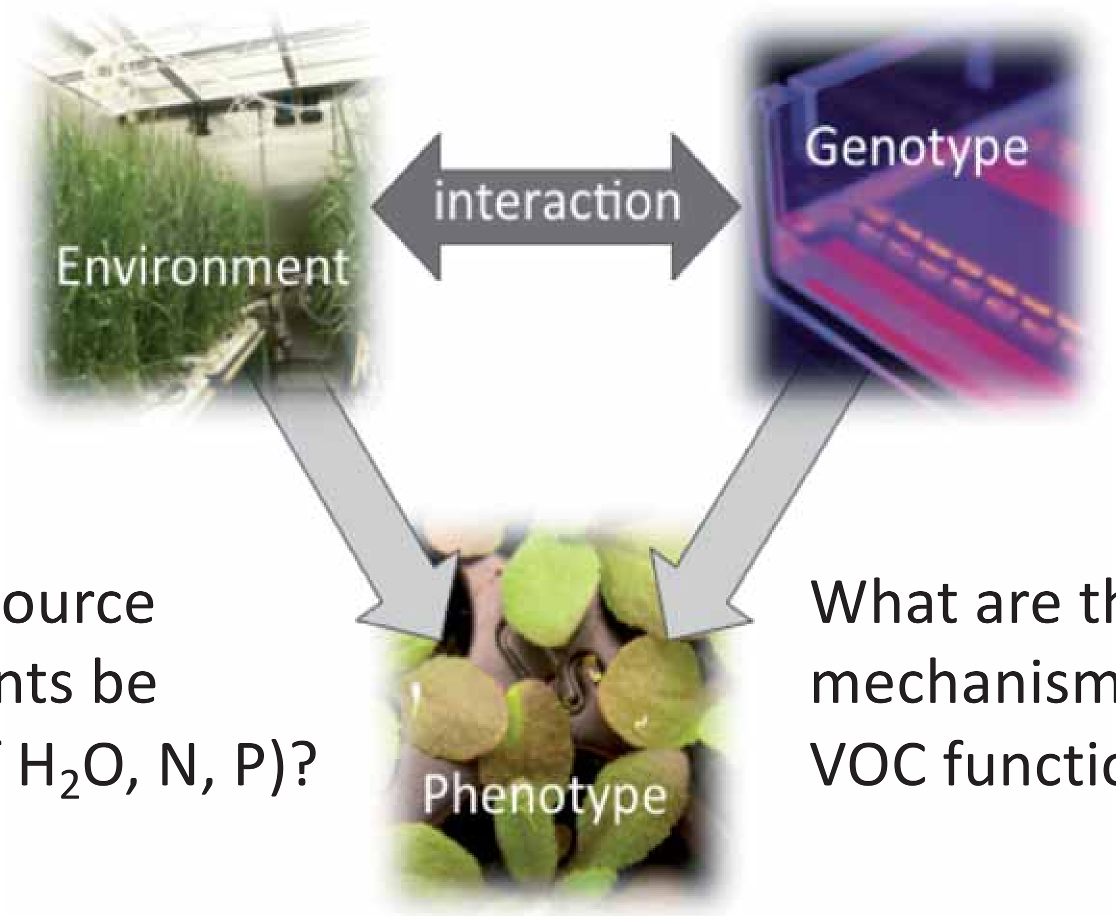
05.-.06. 09. 2018 | The Italian plant phenotyping landscape and the other international initiatives

Deutsches Pflanzen Phänotypisierungs-Netzwerk
DPPN

The Munich phytotron facilities

Our research interests.....

How does biotic (microbe/fungus/herbivore -plant) interactions change with changing climate?



How can the resource efficiency of plants be impoved (use of H_2O, N, P)?

What are the underlying mechanisms of biogenic VOC functioning?

GM plants

Natural phenotypes

VOC-based phenotyping in plants, fungi, & humans

ACS Symposium SERIES

Browse the Series | Info for Authors and Editors | Subscriptions | About ACS Books

Chapter (Book)

Volatile Organic Compounds (VOCs) for Noninvasive Plant Diagnostics

Alexander A. Aksenov1, Ana V. Guaman Novillo2, Sindhuja Sankaran3, Alexander G. Fung1, Alberto Pasamontes1, Frederico Martinelli4, William H. K. Cheung1, Reza Ehsani3, Abhaya M. Dandekar5, Cristina E. Davis*1

PDF [489 KB]
PDF w/ Links[452 KB]
Full Text HTML

Basanta *et al. Respiratory Research* 2012, **13**:72
http://respiratory-research.com/content/13/1/72

RESPIRATORY RESEARCH

RESEARCH Open Access

Exhaled volatile organic compounds for phenotyping chronic obstructive pulmonary disease: a cross-sectional study

Maria Basanta[1], Baharudin Ibrahim[1], Rachel Dockry[1], David Douce[2], Mike Morris[2], Dave Singh[1], Ashley Woodcock[1] and Stephen J Fowler[1,3*]

OPEN ACCESS Freely available online PLOS ONE

Profiling of Volatile Organic Compounds in Exhaled Breath As a Strategy to Find Early Predictive Signatures of Asthma in Children

Agnieszka Smolinska[1,2*], Ester M. M. Klaassen[3], Jan W. Dallinga[1], Kim D. G. van de Kant[3], Quirijn Jobsis[3], Edwin J. C. Moonen[1], Onno C. P. van Schayck[4], Edward Dompeling[3], Frederik J. van Schooten[1]

1 Department of Toxicology, Nutrition and Toxicology Research Institute Maastricht (NUTRIM), Maastricht University, Maastricht, The Netherlands, 2 Top Institute Food and Nutrition, Wageningen, The Netherlands, 3 Department of Pediatric Pulmonology, School for Public Health and Primary Care (CAPHRI), Maastricht University Medical Center (MUMC), Maastricht, The Netherlands, 4 Department of General Practice, School for Public Health and Primary Care (CAPHRI), Maastricht University Medical Center (MUMC), Maastricht, The Netherlands

Fungal Genetics and Biology 54 (2013) 25–33

Contents lists available at SciVerse ScienceDirect

Fungal Genetics and Biology

journal homepage: www.elsevier.com/locate/yfgbi

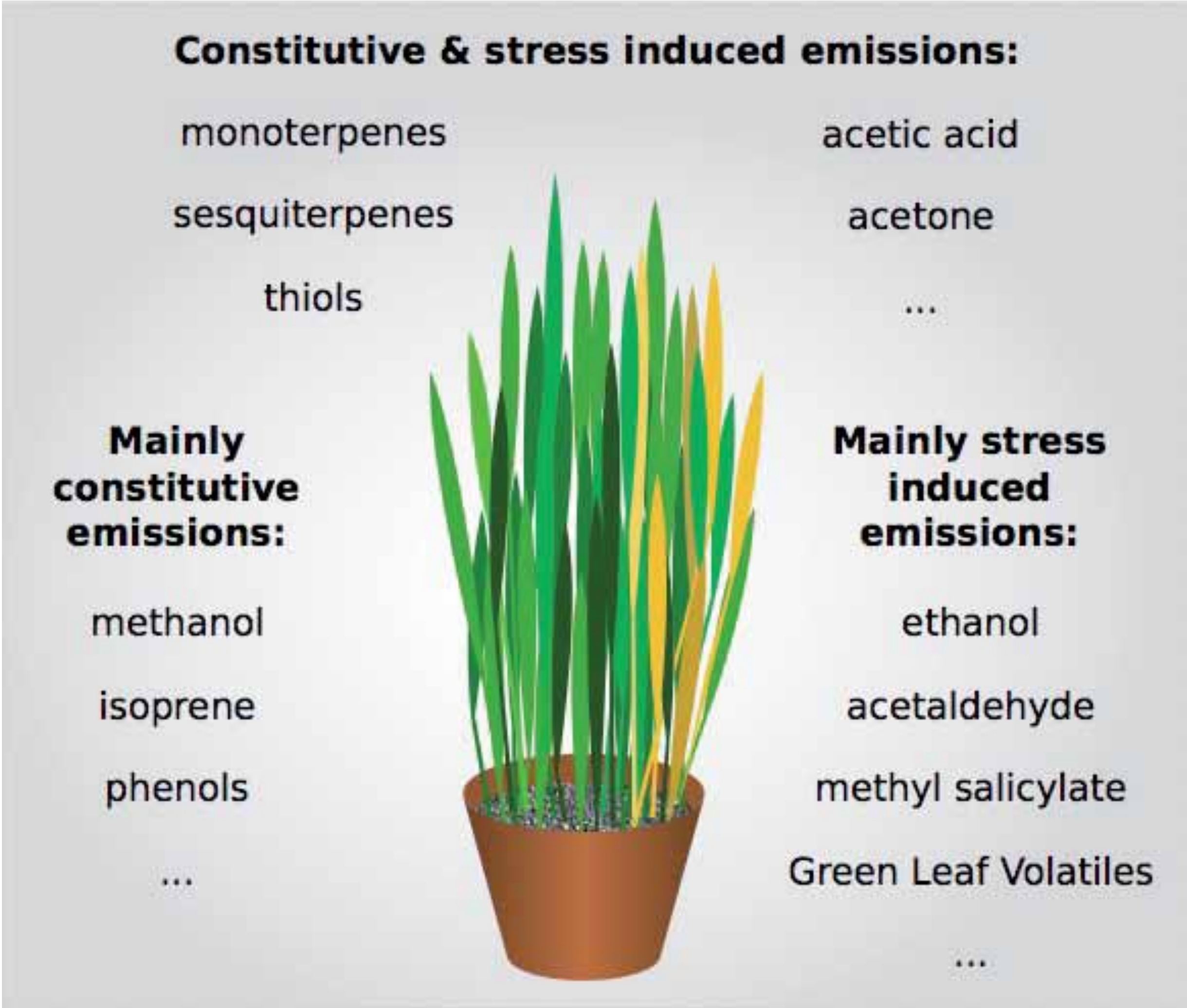
ELSEVIER

Volatile profiles of fungi – Chemotyping of species and ecological functions

Anna Müller[a,2], Patrick Faubert[b,1,2], Michael Hagen[c], Wolfgang zu Castell[c], Andrea Polle[a], Jörg-Peter Schnitzler[b], Maaria Rosenkranz[b,*]

[a] Büsgen Institute, Forest Botany and Tree Physiology, University of Göttingen, Büsgenweg 2, 37077 Göttingen, Germany
[b] Research Unit Environmental Simulation, Institute of Biochemical Plant Pathology, Helmholtz Zentrum München, German Research Center for Environmental Health (GmbH), Ingolstädter Landstraße 1, 85764 Neuherberg, Germany
[c] Research Unit Scientific Computing, Institute of Biomathematics and Biometry, Helmholtz Zentrum München, Ingolstädter Landstraße 1, 85764 Neuherberg, Germany

Typical VOCs released under stress



Jud et al, under revision

Importance of VOCs in plant-pathogen/pest-interaction

- involved in direct (e.g. ROS quenching) and indirect defense (repellent/ attractant) against insect pests
- messengers of plant-plant communication
- priming agents to activate plant defense responses
- variable profiles fro

The Plant Cell, Vol. 29: 1440–1459, June 2017, www.plantcell.org © 2017 ASPB.

Check for updates

Monoterpenes Support Systemic Acquired Resistance within and between Plants

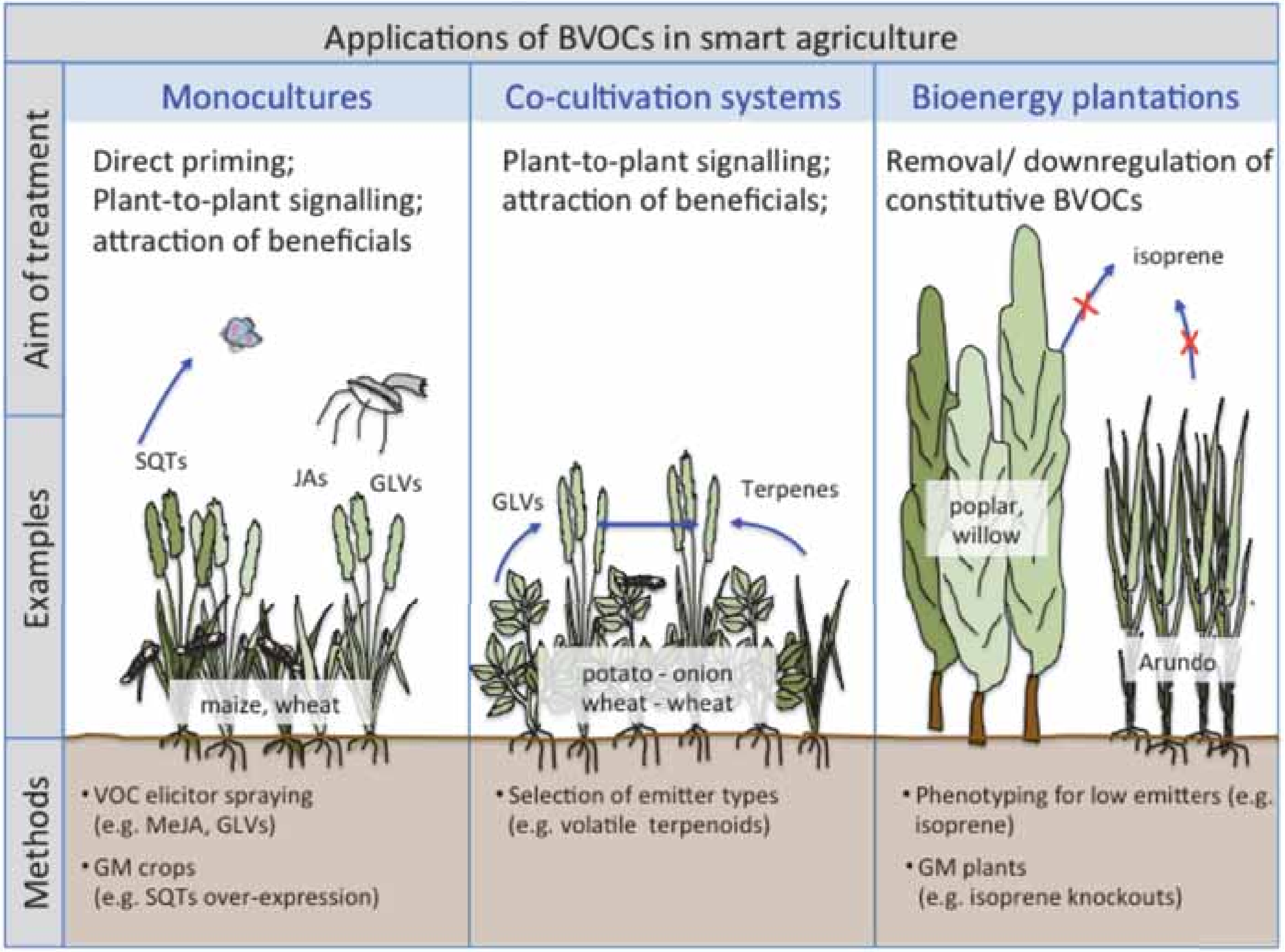
Marlies Riedlmeier,[a,1] Andrea Ghirardo,[b,1] Marion Wenig,[a,1] Claudia Knappe,[a] Kerstin Koch,[b] Elisabeth Georgii,[a] Sanjukta Dey,[a] Jane E. Parker,[c] Jörg-Peter Schnitzler,[b] and A. Corina Vlot[a,2]

Ideal non-invasive

- Online monitoring of pathogenesis (susceptibility/resistance)
- Identification of chemotypes
- Monitoring of priming effects
- Analysis of cross-talk between microbes, fungi, insect pest
- Determination of C-fluxes under pathogenesis (^{13}C labelling)

Deutsches Pflanzen Phänotypisierungs-Netzwerk
DPPN

Potential applications of VOCs..........



Rosenkranz et al. (PC&E 2015)

Comparison of various types of plant disease detection

Challenges

Characteristics	Molecular techniques	Imaging and spectroscopic techniques	VOCs profiling-based techniques
Accuracy of the method	Presently the most accurate method	Accuracy is plant and disease specific.	Unknown accuracy since actual under development
Costs	Moderately expensive.	Expensive (i.e. hyperspectral imaging).	Cost depends on the desired accuracy for VOC profiling.
Applicability for rapid detection	Not fast for a huge amount of samples.	Allows rapid detection of disease symptoms	Shows the potential for rapid plant disease detection.
Applicability for field work/Ruggedness	Field kits are being developed	Moderately ruggedness	Moderately rugged, depending on VOCs detection
Speed of detection	May require 24 - 48 h for reliable results	May require minutes for disease detection	May require less time, if proven as an effective method for a particular disease

Computers and Electronics in Agriculture 72 (2010) 1–13
Contents lists available at ScienceDirect
ELSEVIER
Computers and Electronics in Agriculture
journal homepage: www.elsevier.com/locate/compag

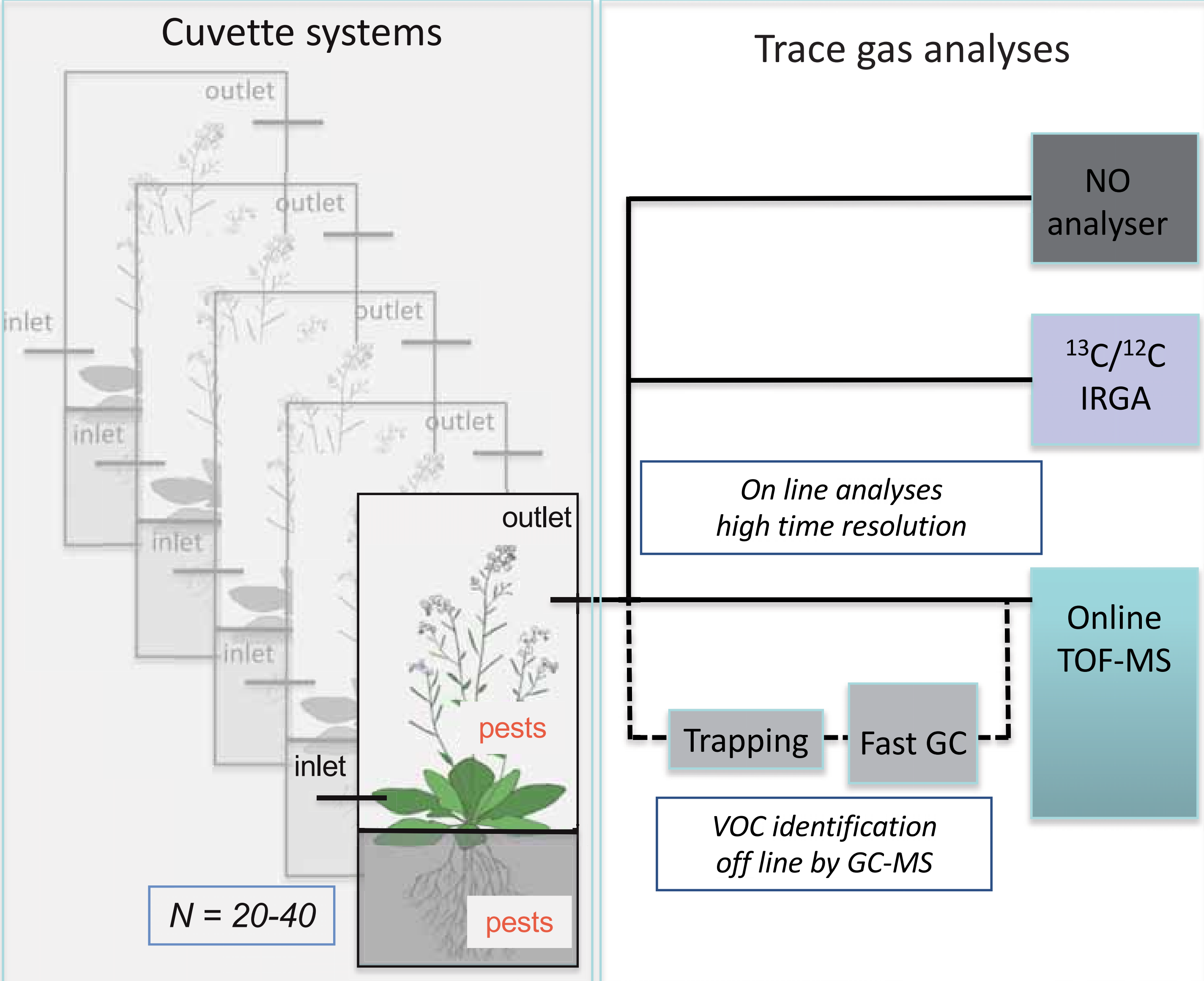
Review

A review of advanced techniques for detecting plant diseases

Sindhuja Sankaran[a], Ashish Mishra[a], Reza Ehsani[a,*], Cristina Davis[b]
[a] Citrus Research and Education Center, University of Florida, 700 Experiment Station Road, Lake Alfred, FL 33850, United States
[b] Department of Mechanical and Aerospace Engineering, University of California, One Shields Avenue, Davis, CA 95616, United States

Pflanzen Phänotypisierungs-Netzwerk
DPPN

Concept of a VOC and gas exchange phenotyping platform



Metabolome database

Non-invasive analysis of:

- ✓ NO
- ✓ CO_2
- ✓ H_2O
- ✓ $^{13}C/^{12}C$ discrimination
- ✓ Green leaf volatiles
- ✓ Terpenes (C_5-C_{15}, C_{11}/C_{16})
- ✓ Shikimic acid derivatives
- ✓ C_1/C_2 (R-OH, R-HCO)
- ✓ ethylene

Challenge of cuvette design

Problems

- Homogeneous air flow
- Gas tightness
- Rapid gas turnover
- No H_2O condensation
- Inertness of materials
- High light permeability
- Minimizing VOC absorption
- VOC-free inlet air
- No overheating

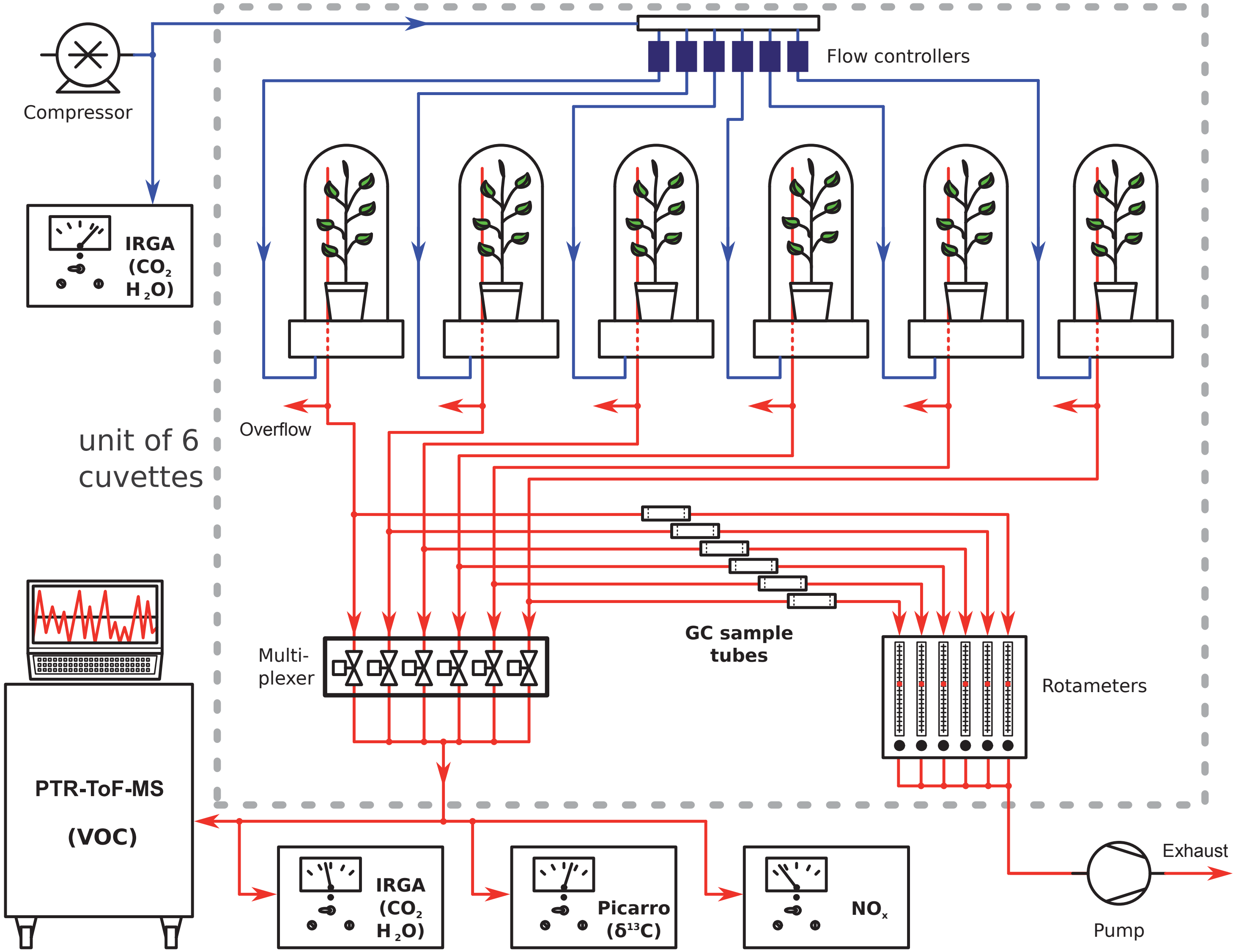
Solutions

- ✓ Circular gas inlet
- ✓ VOC-free sealing
- ✓ High air flow (20L/min)
- ✓ Line heating
- ✓ Stainless steel / teflon
- ✓ Glass
- ✓ Steel / PEEK tubings

- ✓ Catalyst
- ✓ Cooling of chamber

Modular system of cuvette blocks

HelmholtzZentrum münchen
Deutsches Forschungszentrum für Gesundheit und Umwelt



Jud et al, under revision

Deutsches Pflanzen Phänotypisierungs-Netzwerk
DPPN

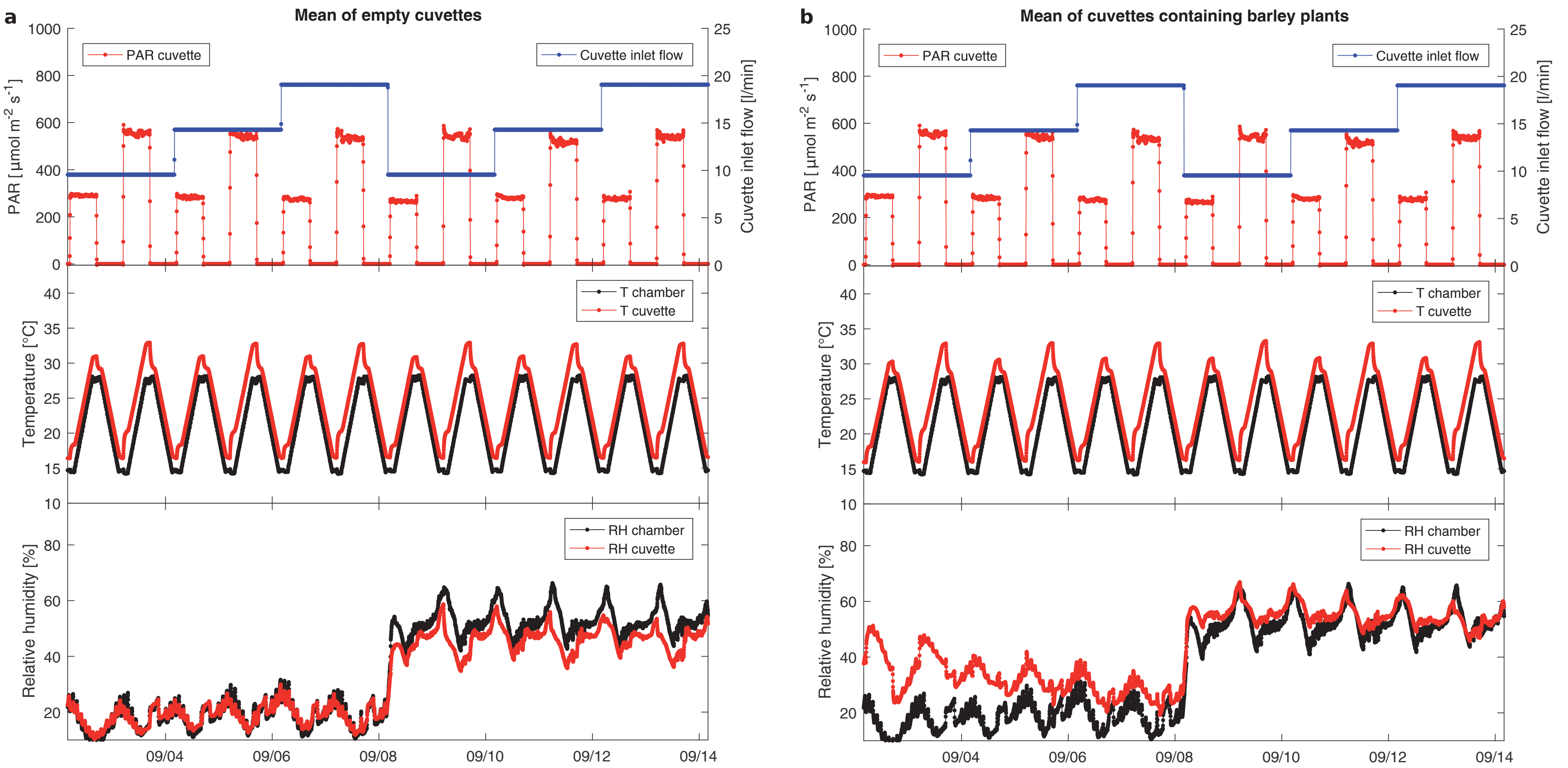
Construction of a 24 cuvette platform

Jud et al, under revision

Deutsches Pflanzen Phänotypisierungs-Netzwerk DPPN

Characterization of cuvette dynamics

HelmholtzZentrum münchen
Deutsches Forschungszentrum für Gesundheit und Umwelt



Jud et al, under revision

Non-targeted volatilomics by online Proton Transfer Reaction Mass Spectrometry (PTR-TOF MS)

HelmholtzZentrum münchen
Deutsches Forschungszentrum für Gesundheit und Umwelt

1) allows for online measurement of VOCs at concentrations as low as a few ppt, no need for pre-concentration
2) soft ionization (little fragmentation) of virtually all VOCs via proton transfer from H_3O^+ ions:

Proton Transfer Reaction

$$H_3O^+ + VOC \rightarrow VOCH^+ + H_2O$$

Deutsches Pflanzen Phänotypisierungs-Netzwerk
DPPN

Workflow for plant volatilome analyses

HelmholtzZentrum münchen
Deutsches Forschungszentrum für Gesundheit und Umwelt

Grow plants

↓

Take plant images for leaf area determination

↓

Plant installation & acclimatisation

↓

Measurements: VOC, CO_2, H_2O,
soil humidity, air and soil temperature

In-between: automated irrigation, data back-up,
instrument calibrations, take plant images,
check flows, temperature, humidities,...

↓

Take plant images for leaf area determination

↓

Evaluate all data measured with instruments
installed downstreams cuvettes (PTR-ToF-MS, etc.)

- Raw data evaluation
- ↓
- Background correction
- ↓
- Apply calibration factors (if available)
- ↓
- Plant-wise separate data

↓

Calculate leaf area, VOC emission rates,
assimilation & evapotranspiration rates

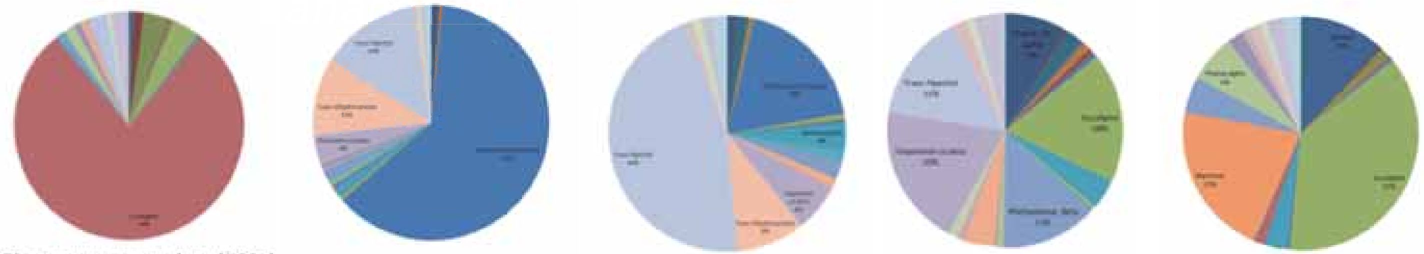
↓

Statistics
→Phenotypic patterns

Jud et al, under review

Deutsches Pflanzen Phänotypisierungs-Netzwerk
DPPN

1st Proof of principle experiment with Tansy terpenoid chemotypes

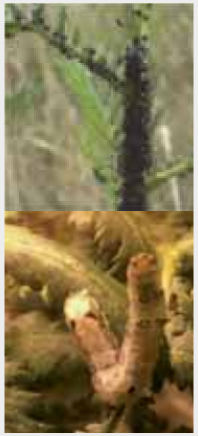


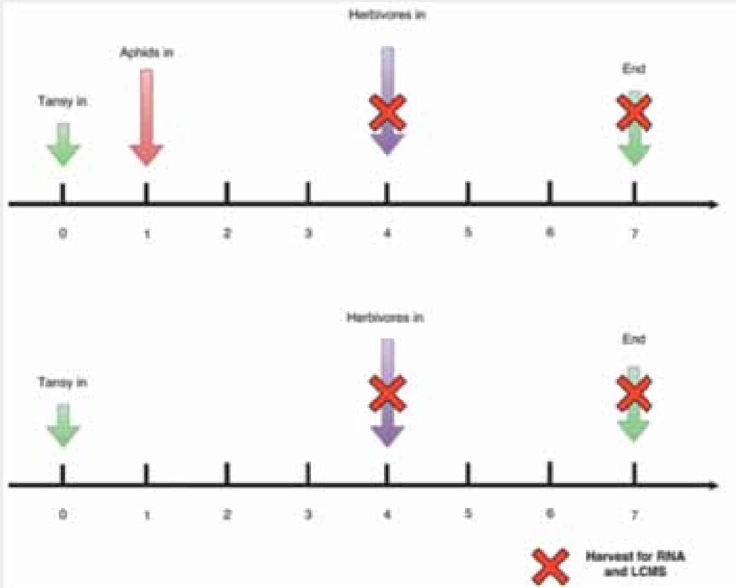
Chemotype: camphor (78%) | Chemotype: dihydrocarvone acetate (62%) | Chemotype: trans piperitol (42%) | Chemotype: mixed | Chemotype: mixed (eucalyptol 37%)

Testing the VOC profiles of 5 chemotypes following subsequent treatments by

Aphids: *Metopeurum fuscoviride*
&
Herbivore: *Spodoptora littoralis*

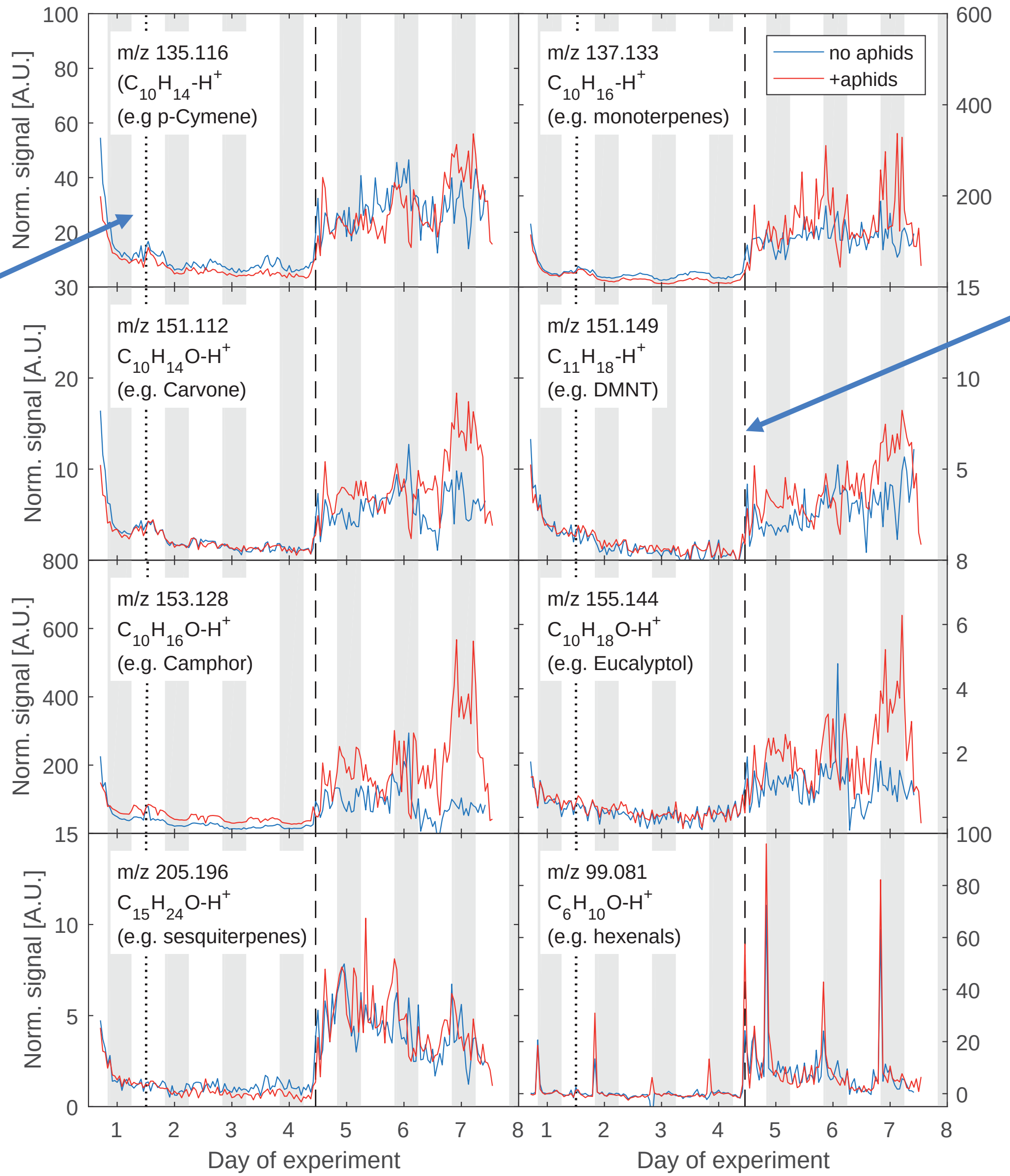
Clancy, Jud et al, in preparation





Profiling of VOC emissions in tansy following herbivory

Addition of aphids



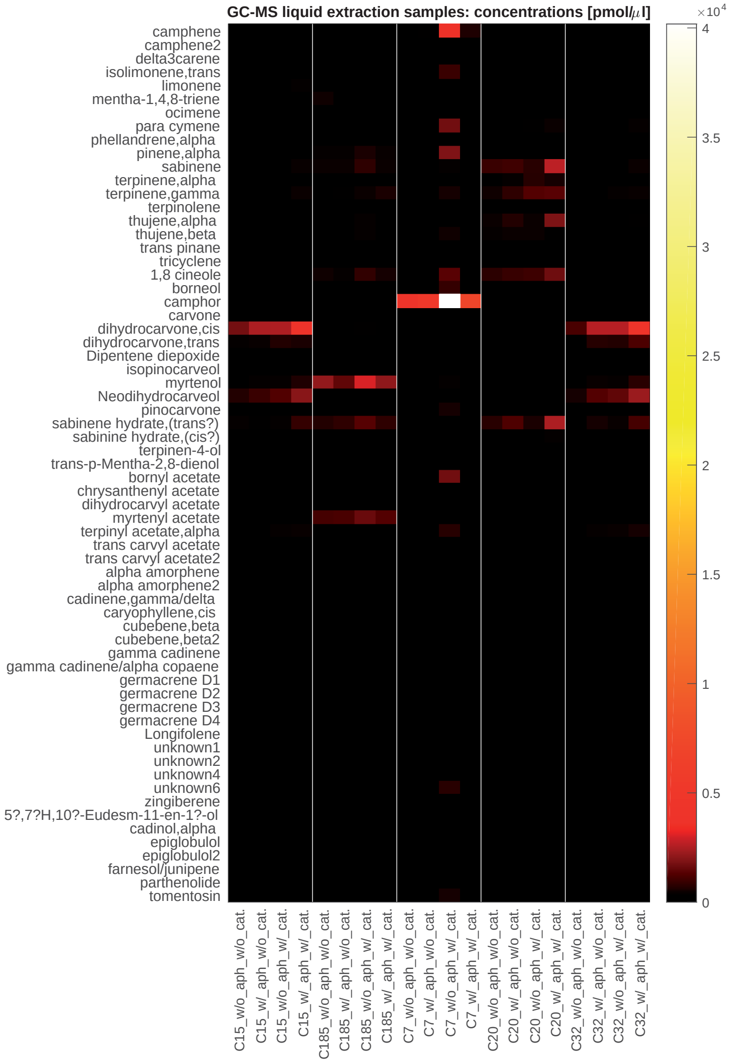
Addition of caterpillar larvae

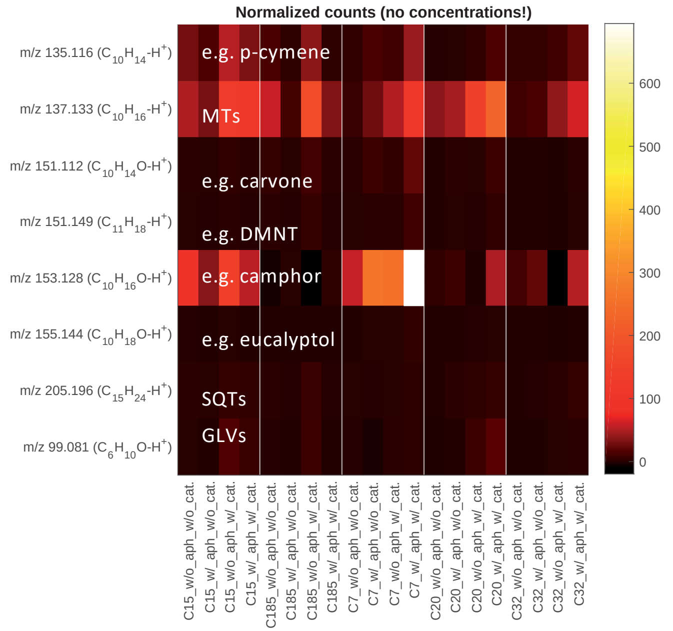
Clancy, Jud et al, in preparation

W. Weisser; S Zytynska

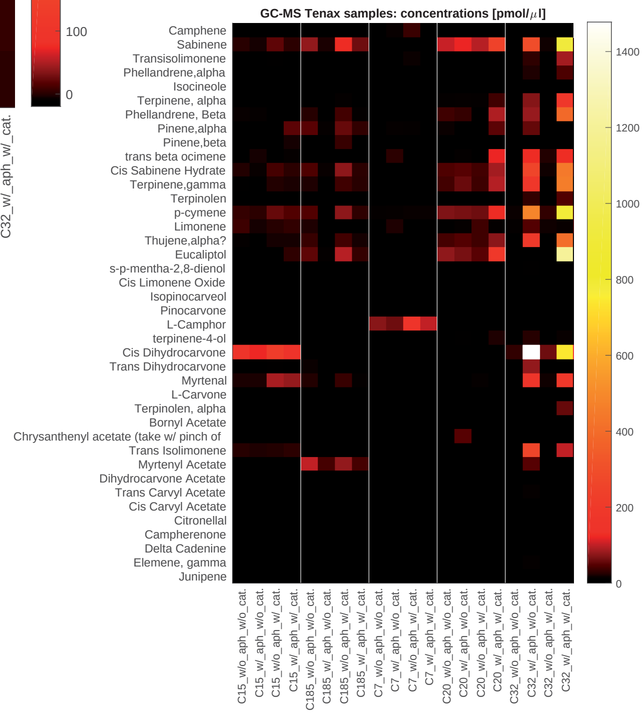
Profiling of volatilomes in tansy following herbivory

Stored terpenoids





Online VOC analysis by PTR-TOF MS



Offline GC-MS VOC analysis

Clancy, Jud et al, in preparation

W. Weisser; S Zytynska

Challenges..........

- Cuvette design and platform construction require indepth experience in gas exchange analysis ansd analytics
- Platform software for automatisation and analysis tools must be developed in your own
- Physical properties (air mixing, tightness, exchange time, line effects, etc...) of the cuvettes must be characterized precisely
- Data analysis of online mass spectrometry (also offline GC-MS) requires automatisation including quality checks
- High maintenance of the system is reqiured

BUT finally it works nicely for low emitting crops☺

24-cuvette system is operational (for interest please contact)
https://www.helmholtz-muenchen.de/eus/index.html

HelmholtzZentrum münchen
Deutsches Forschungszentrum für Gesundheit und Umwelt

Thanks to..........

Jana B. Winkler

Werner Jud

Bishu Niederbacher