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Federal Department of Economic Affairs,
Education &Research EAER
Agroscope

Cropping factors: The key for sustainable mycotoxin management in cereals

S. Vogelgsang, M. Beyer, M. Pasquali, E. Jenny, T. Musa, T. Bucheli, F. Wettstein, H.R. Forrer

Agroscope, Ecological Plant Protection in Arable Crops
Luxembourg Institute of Science and Technology
University of Milan, Food, Environmental and Nutritional Sciences
Agroscope, Environmental Analytics

December 4, 2018
National FHB Forum, St. Louis (MO), USA

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Outline

- **Surveys on *Fusarium* species and mycotoxins in wheat, barley and oats**
- **Our resulting research to reduce the risk in cereals:**
  - “Healthy & Safe” cereal varieties
  - “MycoKey”: Biocontrol, cover crops and biofumigation

Maximum / recommended limits for unprocessed cereals (ppm) – EU & CH

Toxin	Limit Cereals	Limit Maize	Rec. limit * Feed / indicative levels
DON	1.25	1.75	0.9 - 12
ZEA	0.1	0.35	0.1 - 3
T-2, HT-2	in prep.	in prep.	0.1 – 1 (wheat-oats)

No intention so far for NIV…

* complete feeding stuffs to all feed materials

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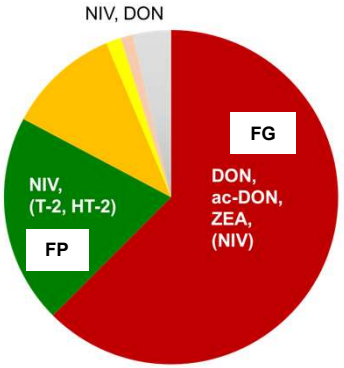
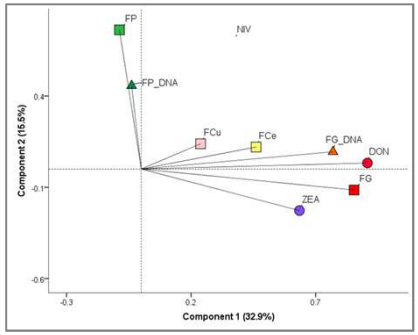
Swiss *Fusarium* surveys
Objectives

- Abundance & distribution of species



- Correlation between species abundance & toxin content



- **Effect of cropping factors for the most prevalent species**

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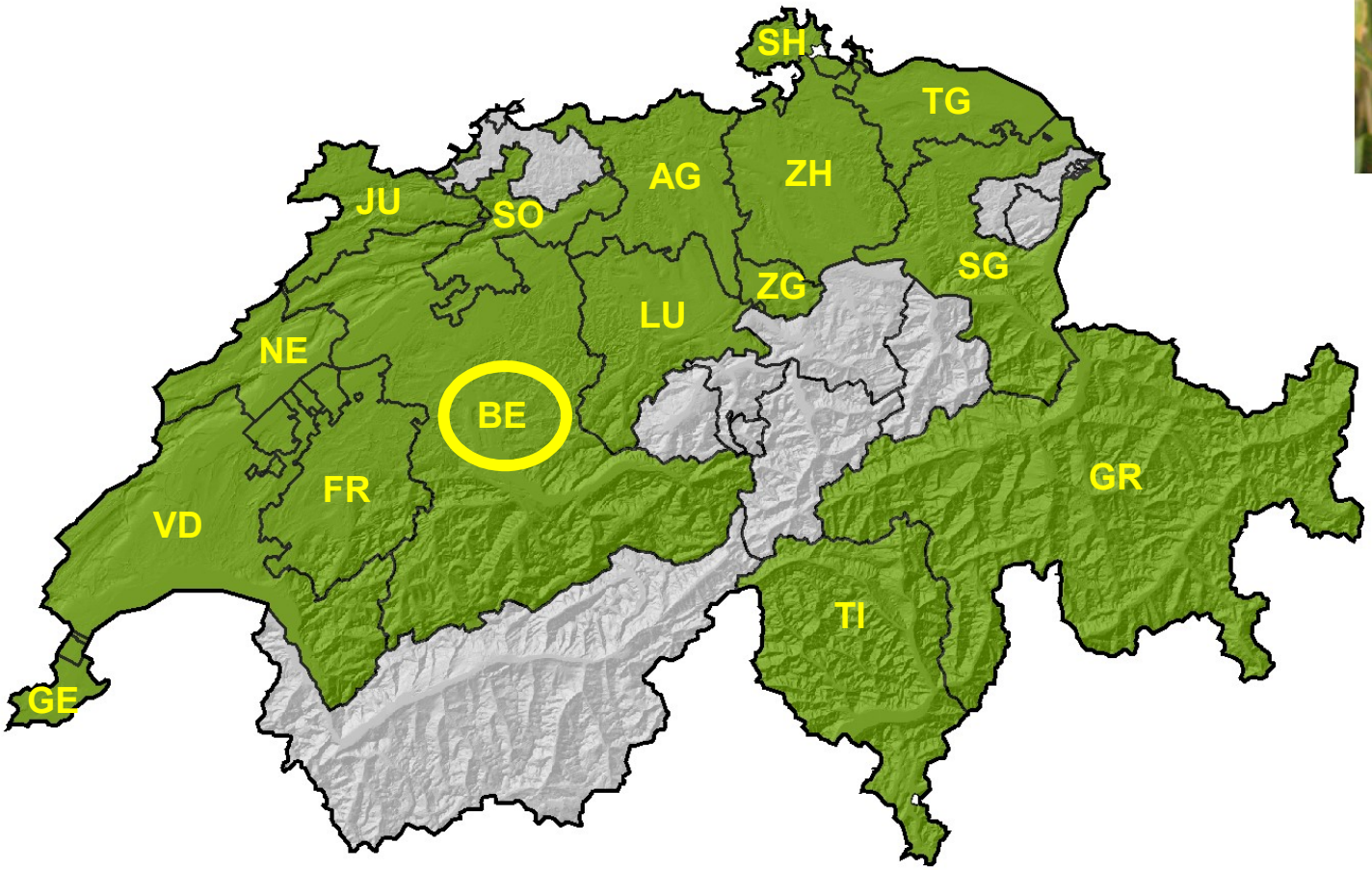
Wheat samples from growers

- 527 grain samples from 17 cantons (2007-10)
- 159 grain samples from Berne (2011-14)



Questionnaire on cropping factors

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Eidgenössisches Volkswirtschaftsdepartement
Forschungsanstalt
Agroscope Reckenholz-Tänikon ART

Fragen zur Getreideprobe (Weizen) - Ernte 09

Angaben zum Schlag, aus dem die Probe stammt

Name und Adresse des Betriebsleiters
...millo, Renato De Giorgio, Mont-
2075 Thielle-Wavre
...756 90 09 E-Mail: Farm@doncamillo.ch

Konv. ☐
ÖLN ☒
IP-Label ☒ Suisse
Extenso ☒
Bio ☐

Ort des Schlages (falls nicht Wohnort):

Getreideart & Sorte: WW, Runal

Vorfrucht (2008), bei Mais Angabe Silo oder Körnermais: KW

Vor-Vorfrucht (2007):

Haben Sie in ihrem Getreideschlag Fusarien beobachtet?
Ja ☐ Nein ☒ Bemerkung:

Mähdrescher mit Unterflurhäcksler (2008)	☐ ja	☒ nein	☐ unbekan
Zusätzliches Häckseln/Mulchen von Ernteresten	☐ ja	☒ nein	Wenn gemulcht welchem Gerät
Pflug	☐ ja	☒ nein	
Einarbeiten von Ernteresten: Grubber ☐; Federzinkenegge ☐; Scheibenegge ☐; Kreiselegge ☐; Rototiller ☐		Andere: ☐	
Direktsaat	☒ ja	☐ nein	

Sädatum: 20.10.2008 Blüh-Beginn (DC 61), falls bekannt: /

N-Düngung: kg N / ha	1 32	2 27	3 27 (86)
Handelsname, falls bekannt	Gellor 4kale	NA	NA 3 Knoten
Fungizid, falls verwendet	Produkt		dium
Wachstumsregulator, falls verwendet	Produkt		

Bitte den ausgefüllten Fragebo... ...cken.
Besten Dank!
Susanne Vogelgsang

...riculture
...ire cantonal
...-agronome
Aurore 1 - CH-2053 Cernier
T 032 889 36 82 - F 032 889 37 01
E Michel.Horner@ne.ch

Variety

Production system

Previous crop

Tillage & residue management

Fungicide

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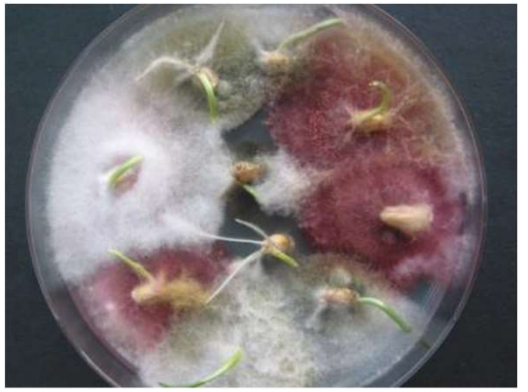
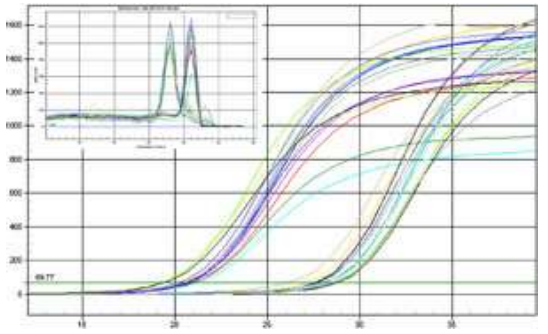
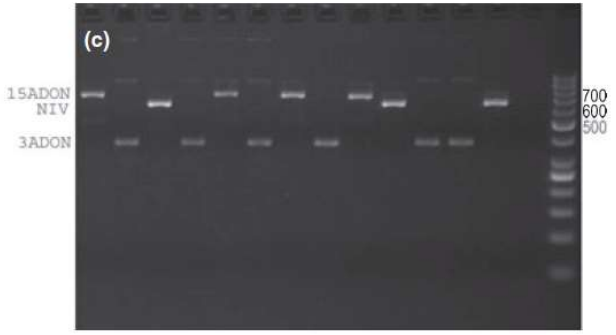
Wheat survey 2007-2014

- **Harvest samples from growers**
  686 wheat samples from 17 cantons
- **Questionnaire on production factors**
- **Seed health test**
  Incidence of *Fusarium* species
- **Toxin content**
  LC-MS/MS: DON, other trichothecenes & ZEA
- **qPCR** for top-two dominant species
- **Genetic chemotypes**
  15-ADON, 3-ADON, NIV

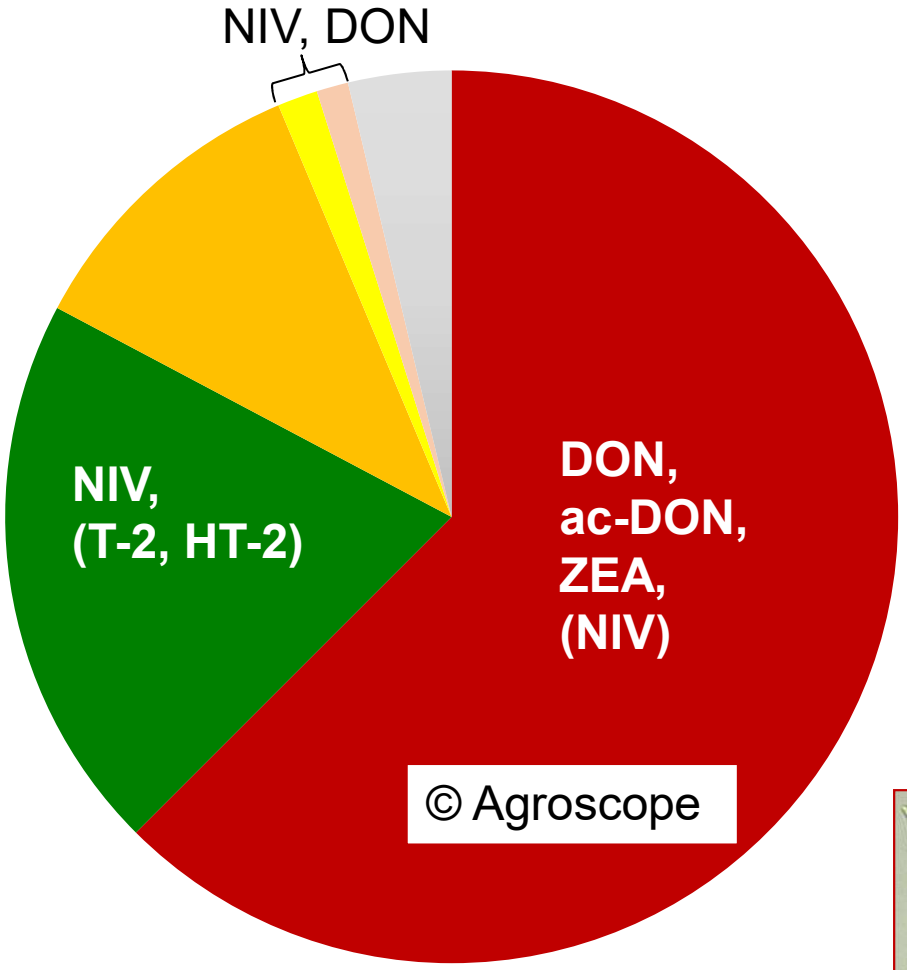




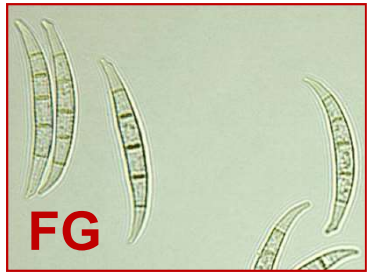


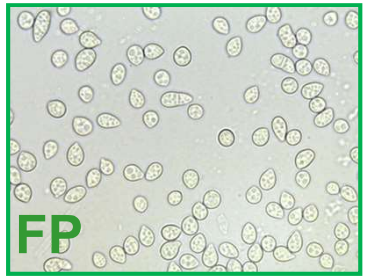
Ratio of isolated *Fusarium* species

n=686



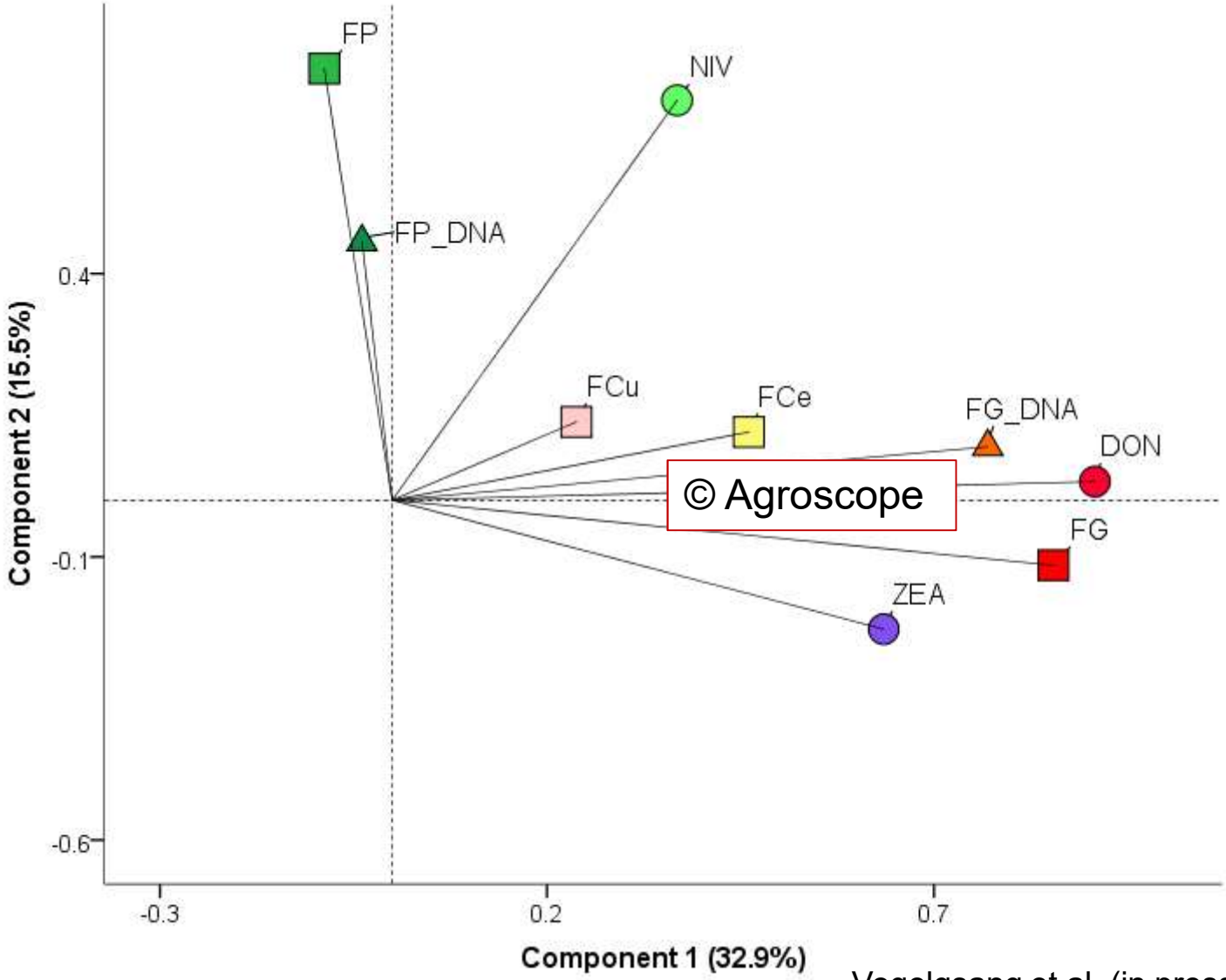
- *F. graminearum*
- *F. poae*
- *F. avenaceum*
- *F. cerealis*
- *F. culmorum*
- F. spp





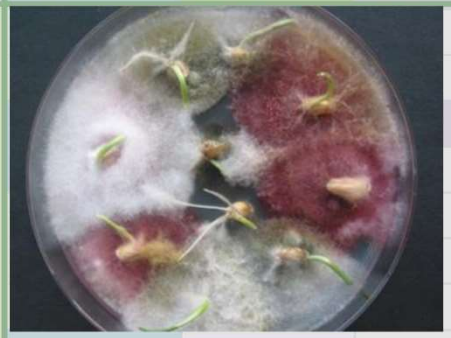
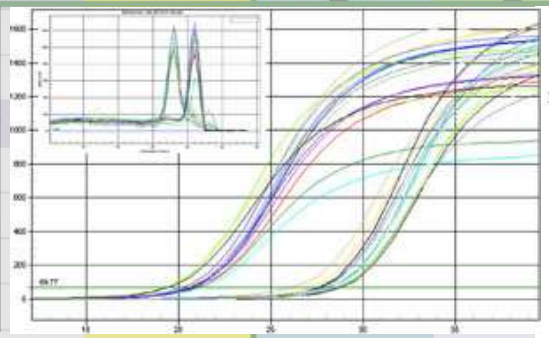
Vogelgsang et al. (submitted) Eur J Agronomy

Correlations fungal abundance and mycotoxin contents - PCA



Vogelgsang et al. (in press) Eur J Agronomy

Three analysis methods to trace the origin of NIV

?	Incidences				qPCR		Chemotypes		
NIV ppb	FG%	FP%	FC%	Fcrook%	DNA_FG	DNA_FP	15aDON_K	3aDON_K	NIV_K
470									
403									
210									
187									
187									
173									
170									
159	38	0	0	6	720.0	1.4	374.4	11.2	26.5
158	4	1	0	0	28.2	0.8	14.8	0.0	0.0
157	1	3	2	0	1.7	5.2	1.3	1.4	0.0
142	20	0	5	0	375.0	6.4	38.2	1.6	1.7
130	5	4	1	0	39.3	16.3	15.0	0.6	1.5
110	2	5	0	0	9.2	4.9	5.3	0.7	0.0
110	1	2	0	3	30.7	0.5	7.5	1.7	7.2
110	1	6	0	0	0.3	279.0	0.0	0.0	0.0
104	0	3	0	0	6.4	8.9	1.1	0.0	0.0
102	44	1	2	0	993.0	0.6	43.3	4.0	2.4
101	17	22	0	0	26.6	58.6	6.2	1.1	0.5
96	17	6	0	3	623	23.8	136.3	2.3	1.6

frontiers in Microbiology

ORIGINAL RESEARCH
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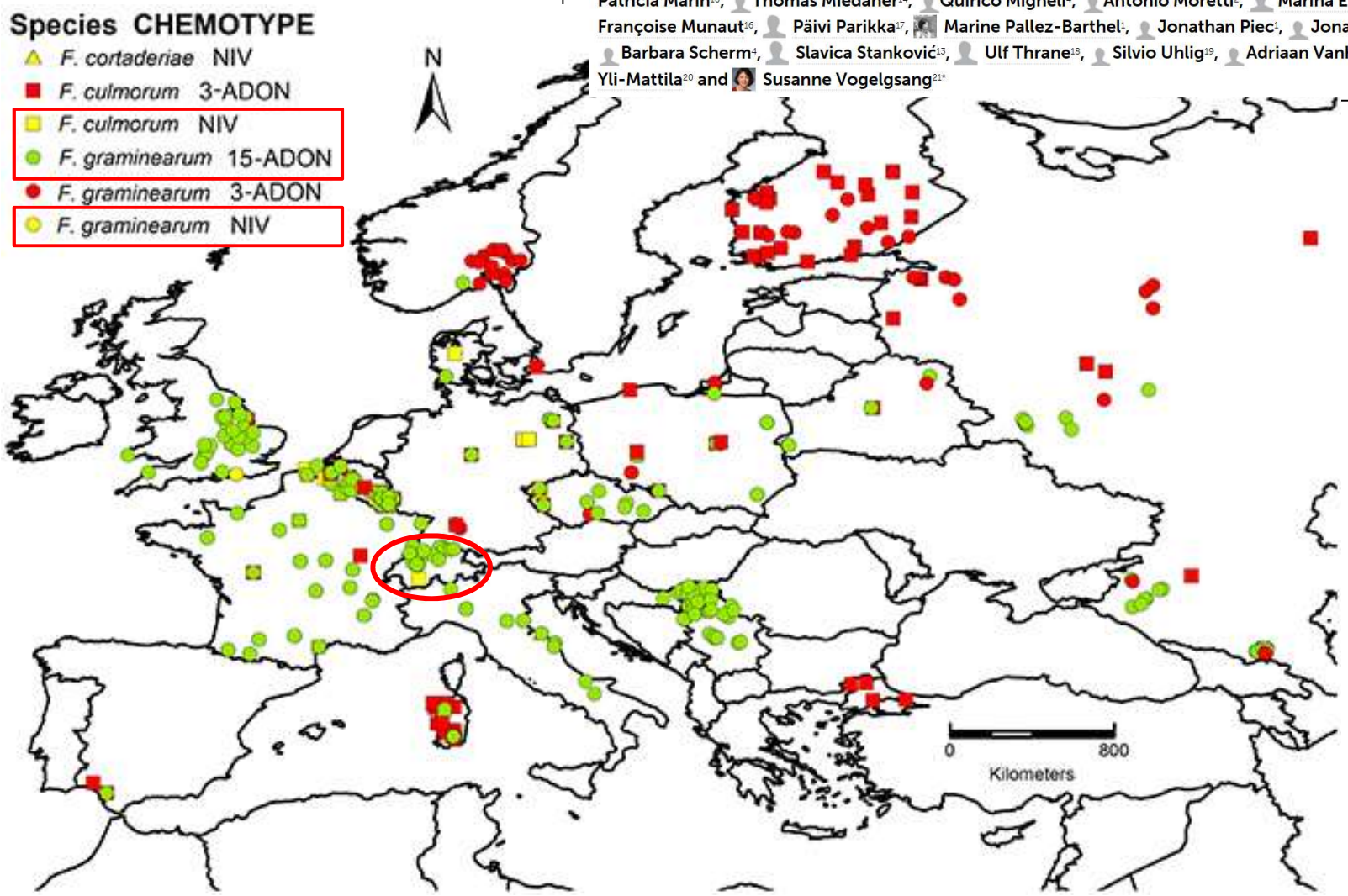
A European Database of *Fusarium graminearum* and *F. culmorum* Trichothecene Genotypes

Matias Pasquali[1*], Marco Beyer[1], Antonio Logrieco[2], Kris Audenaert[3], Virgilio Balmas[4], Ryan Basler[5], Anne-Laure Boutigny[6], Jana Chrpová[7], Elżbieta Czembor[8], Tatiana Gagkaeva[9], María T. González-Jaén[10], Ingerd S. Hofgaard[11], Nagehan D. Köycü[12], Lucien Hoffmann[1], Jelena Lević[13], Patricia Marin[10], Thomas Miedaner[14], Quirico Migheli[4], Antonio Moretti[2], Marina E. H. Müller[15], Françoise Munaut[16], Päivi Parikka[17], Marine Pallez-Barthel[1], Jonathan Piec[1], Jonathan Scauflaire[16], Barbara Scherm[4], Slavica Stanković[13], Ulf Thrane[18], Silvio Uhlig[19], Adriaan Vanheule[3], Tapani Yli-Mattila[20] and Susanne Vogelgsang[21*]



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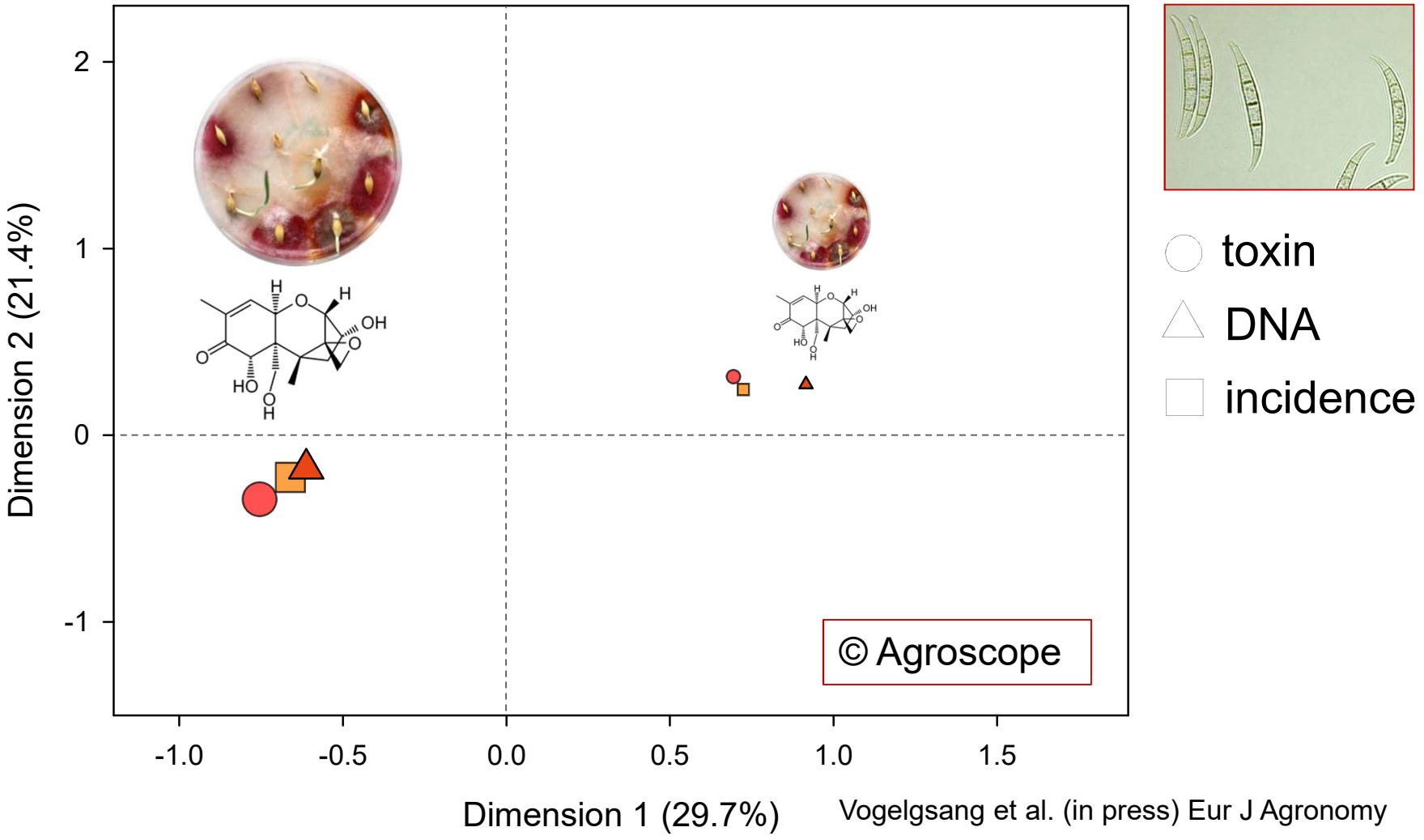
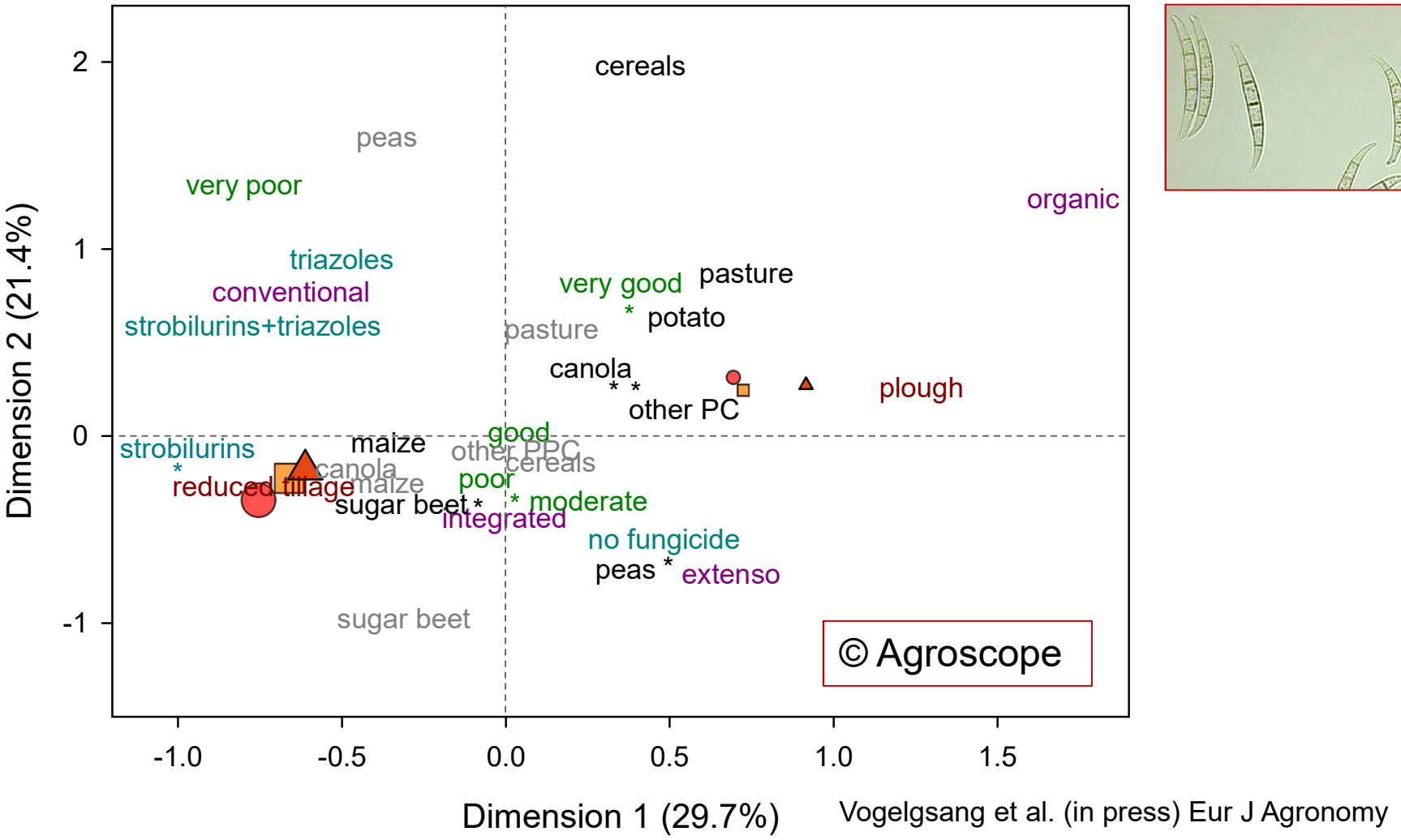
Multiple correspondence analysis FG/DON



Vogelgsang et al. (in press) Eur J Agronomy

Agroscope

Multiple correspondence analysis FG/DON



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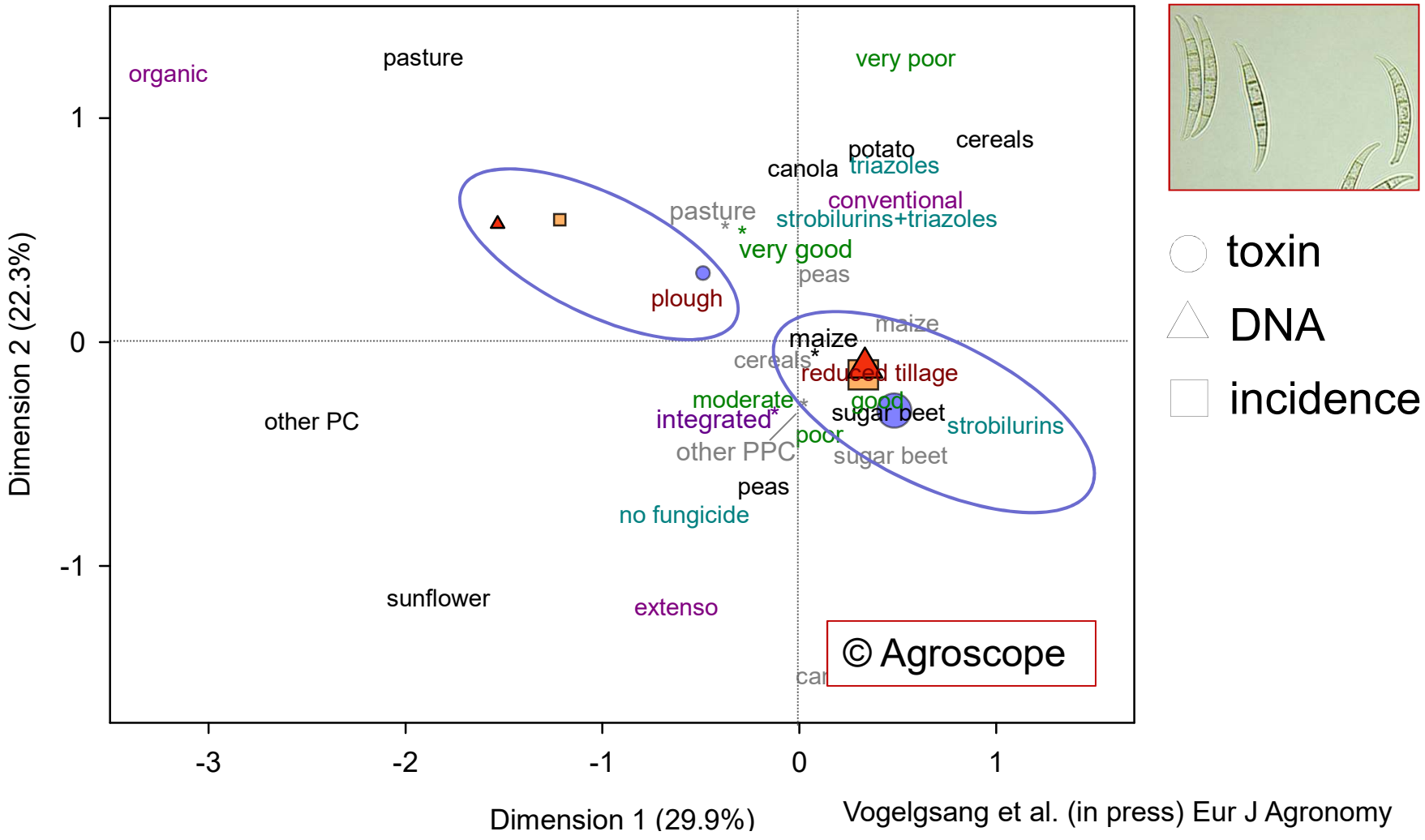
Agroscope

Multiple correspondence analysis FG/ZEA



toxin

DNA

incidence

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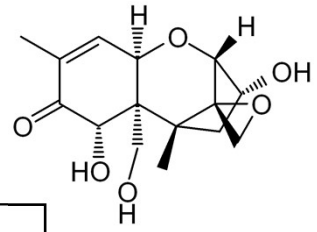
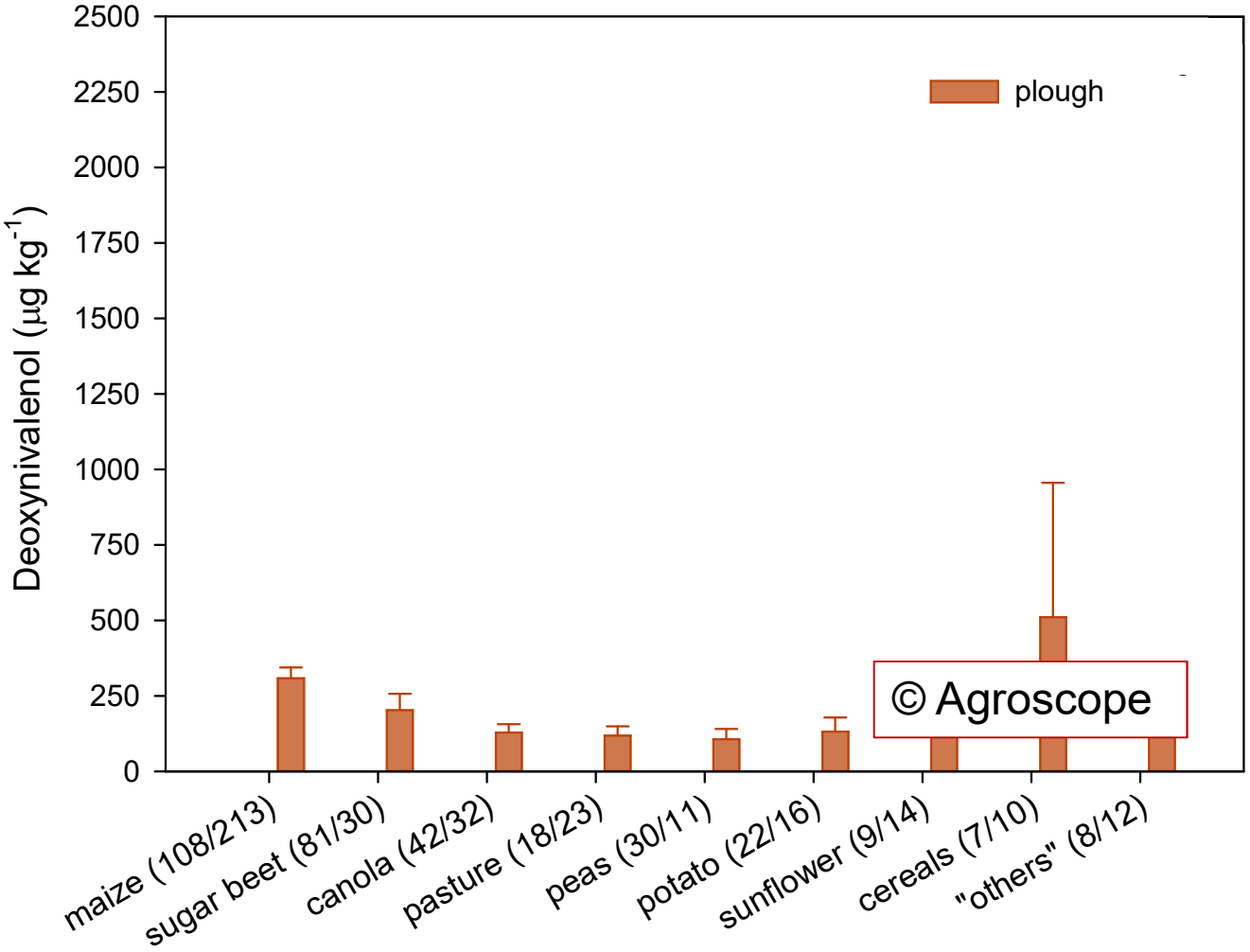
Agroscope

Exceeded maximum limits - DON





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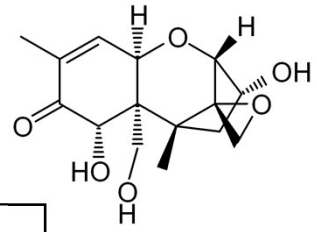
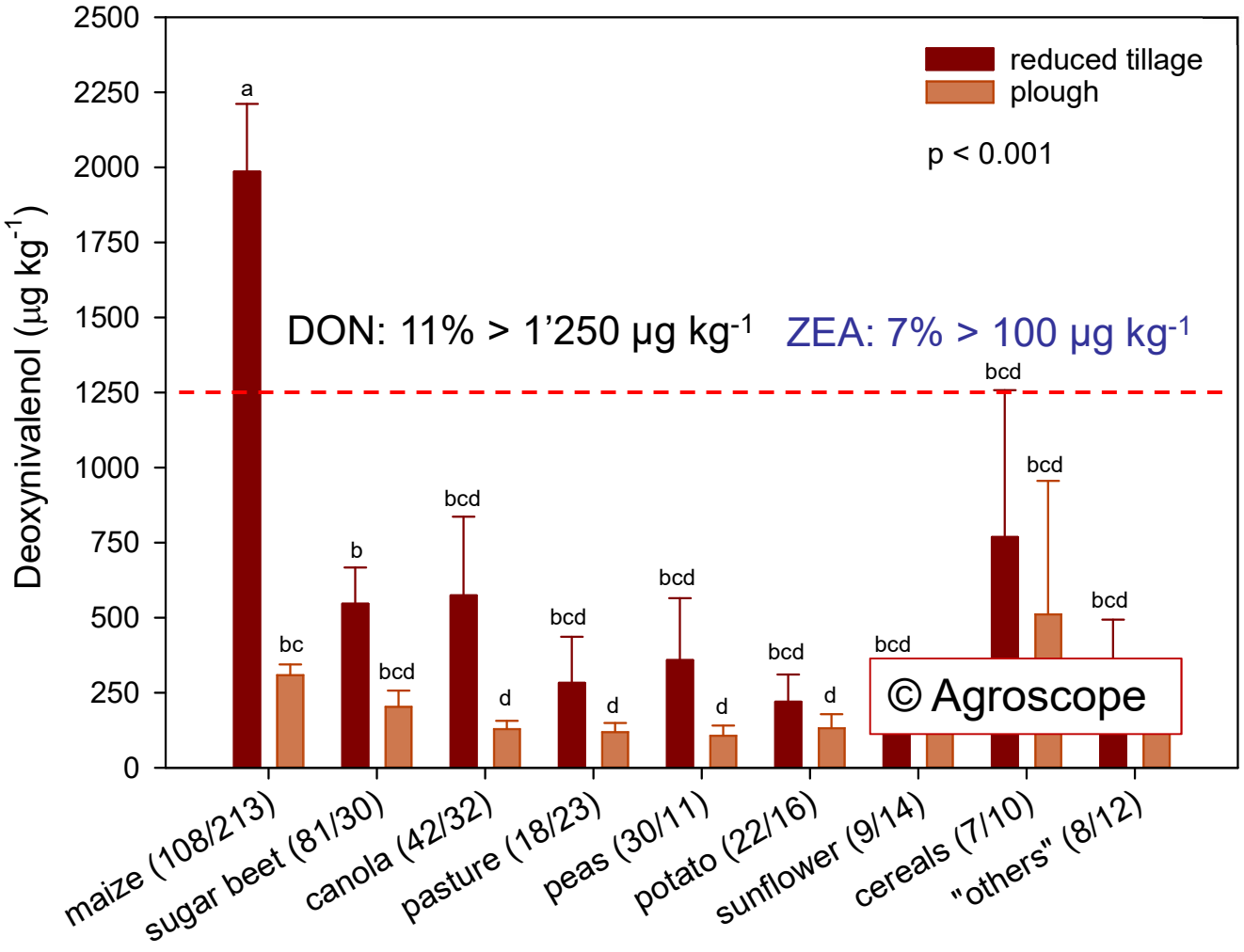
Agroscope

Exceeded maximum limits - DON





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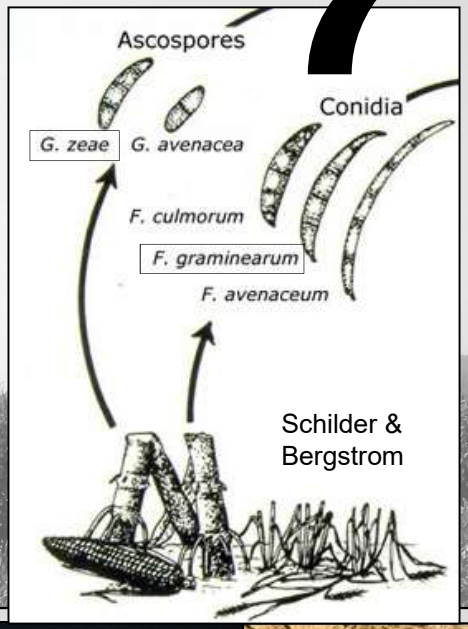
Life cycle *F. graminearum*

Life cycle *F. graminearum*



Determining ascospore deposition using „self-made“ and commercial spore traps

Trapped spores in wheat plot (RZ 30.05.07)

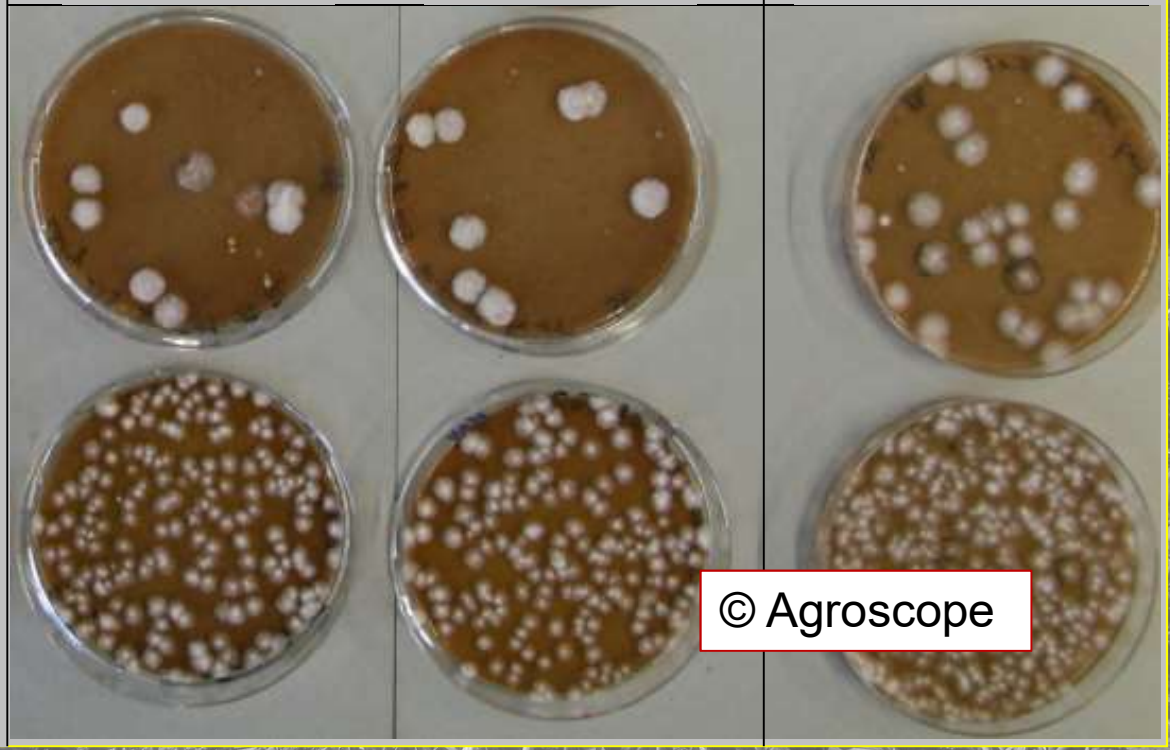
No precrop maize (plot 109)

With precrop maize

Spore trap © H.R. Forrer

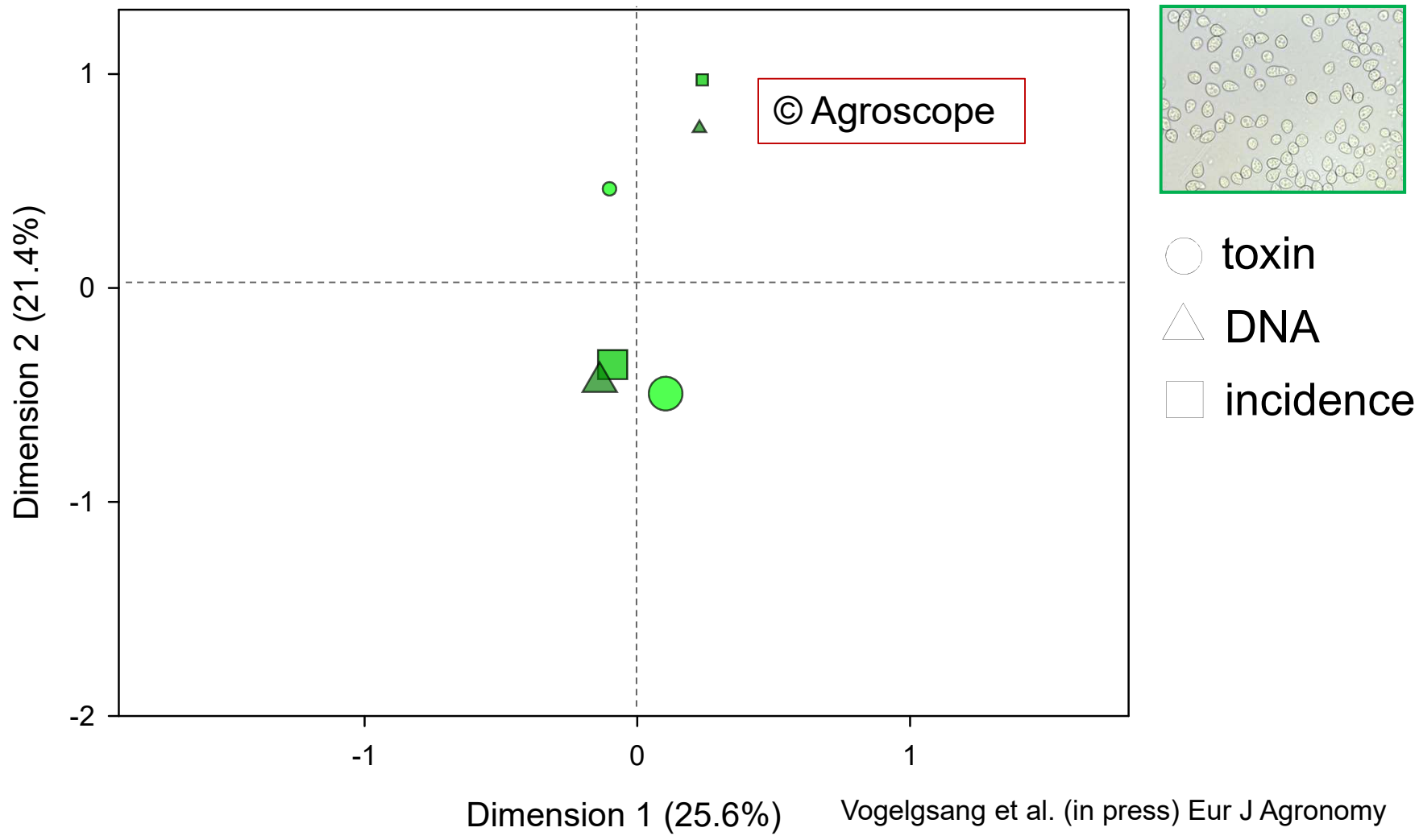
Model „T“ Model „L“

Burkard Jet Spore sampler



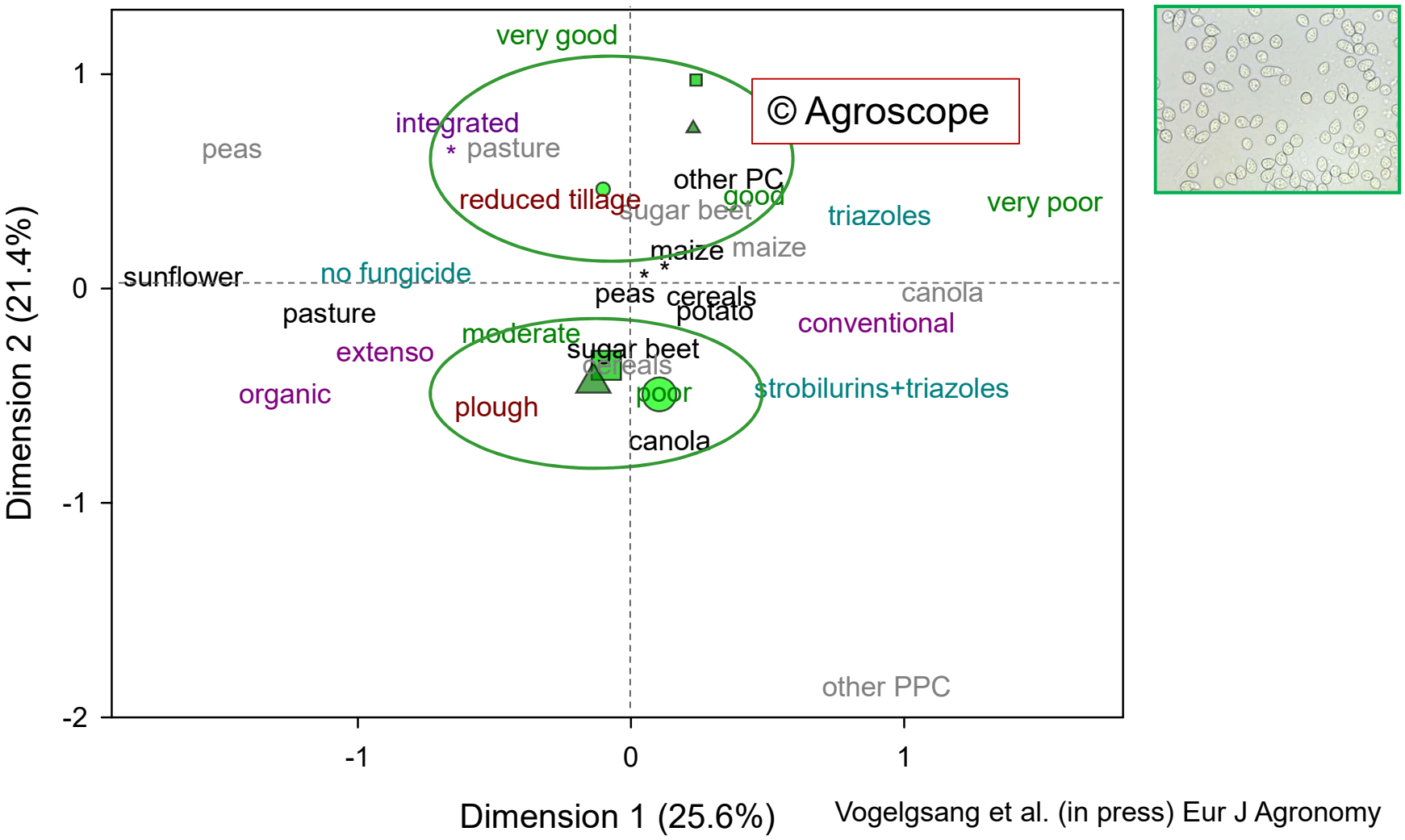
 # colonies in Petri plates = parameter of spore deposition

Multiple correspondence analysis FP/NIV



Vogelgsang et al. (in press) Eur J Agronomy

Multiple correspondence analysis FP/NIV



Vogelgsang et al. (in press) Eur J Agronomy

Outline

- **Surveys on *Fusarium* species and mycotoxins in wheat, barley and oats**
- **Our resulting research to reduce the risk in cereals:**
  - Identification of crucial factors and forecasting of *F. graminearum*/DON
  - "Healthy & Safe" cereal varieties
  - "MycoKey": Biocontrol, cover crops and biofumigation

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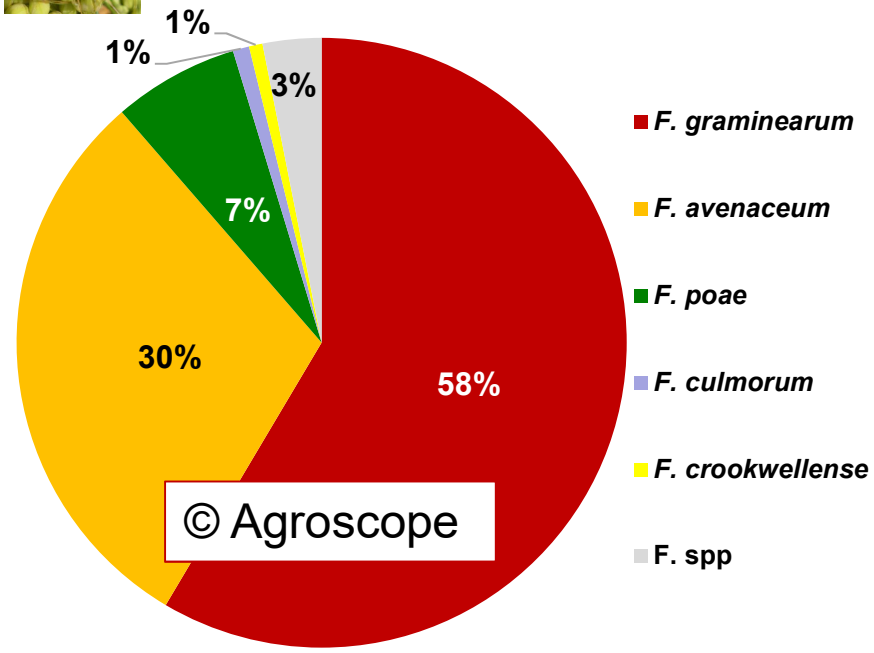
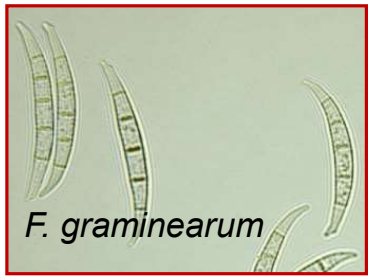
Fusarium occurrence in barley

Schöneberg et al. (2016)
Food Add Cont 33: 1608-6019

2013-2014: n=440





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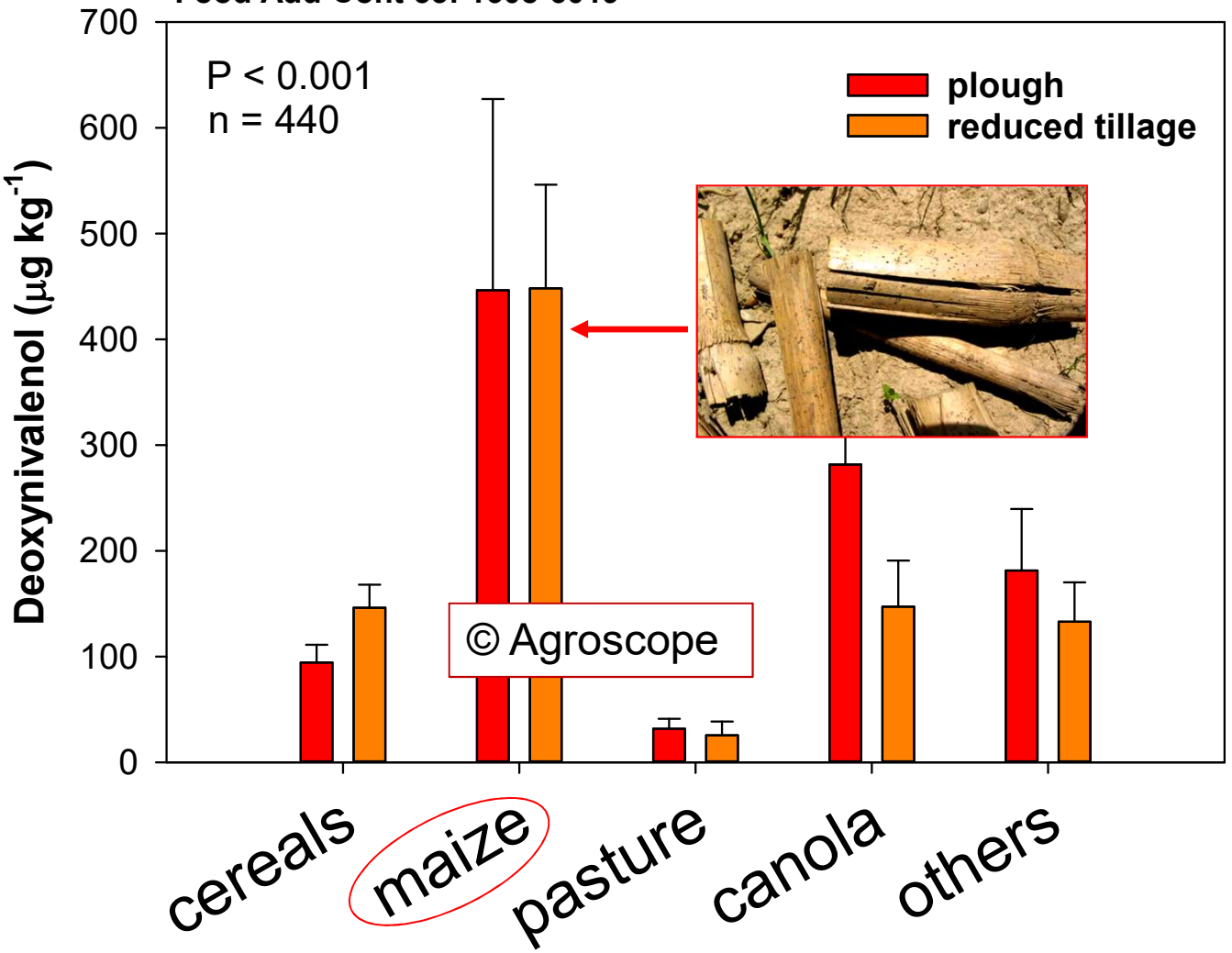
Effect of precrop/tillage on DON in barley

Schöneberg et al. (2016)
Food Add Cont 33: 1608-6019

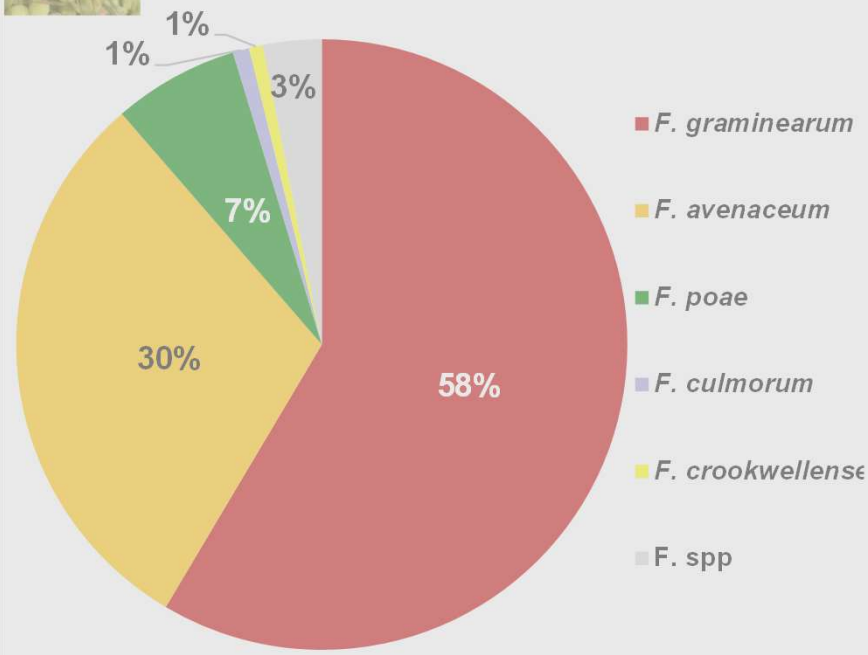
…work in progress



Fusarium occurrence in barley and oats

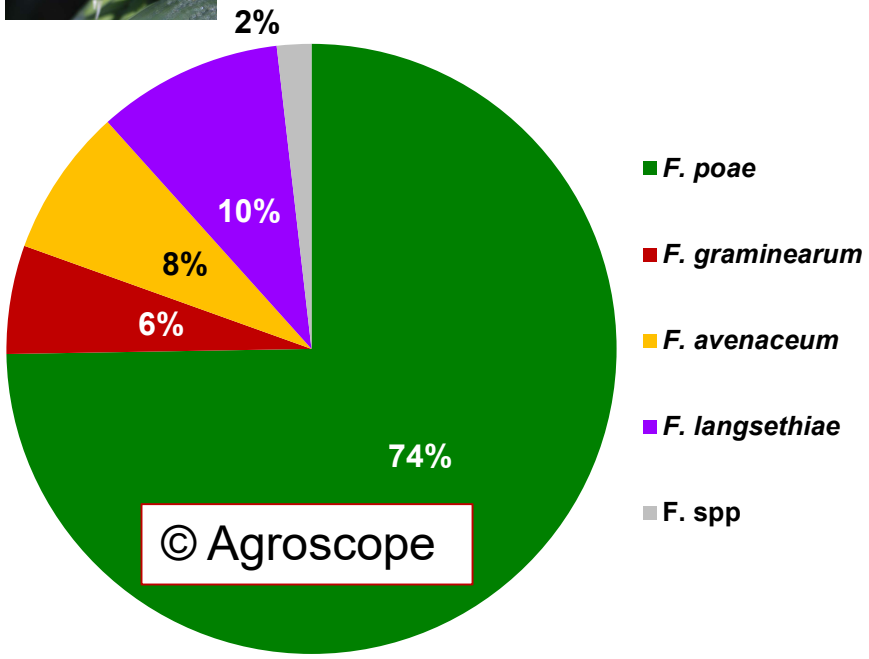
Schöneberg et al. (2016)
Food Add Cont 33: 1608-6019

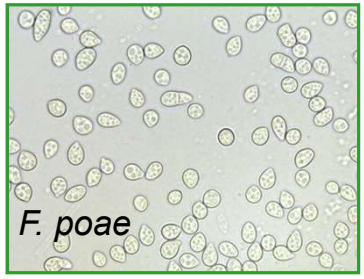
2013-2014: n=440



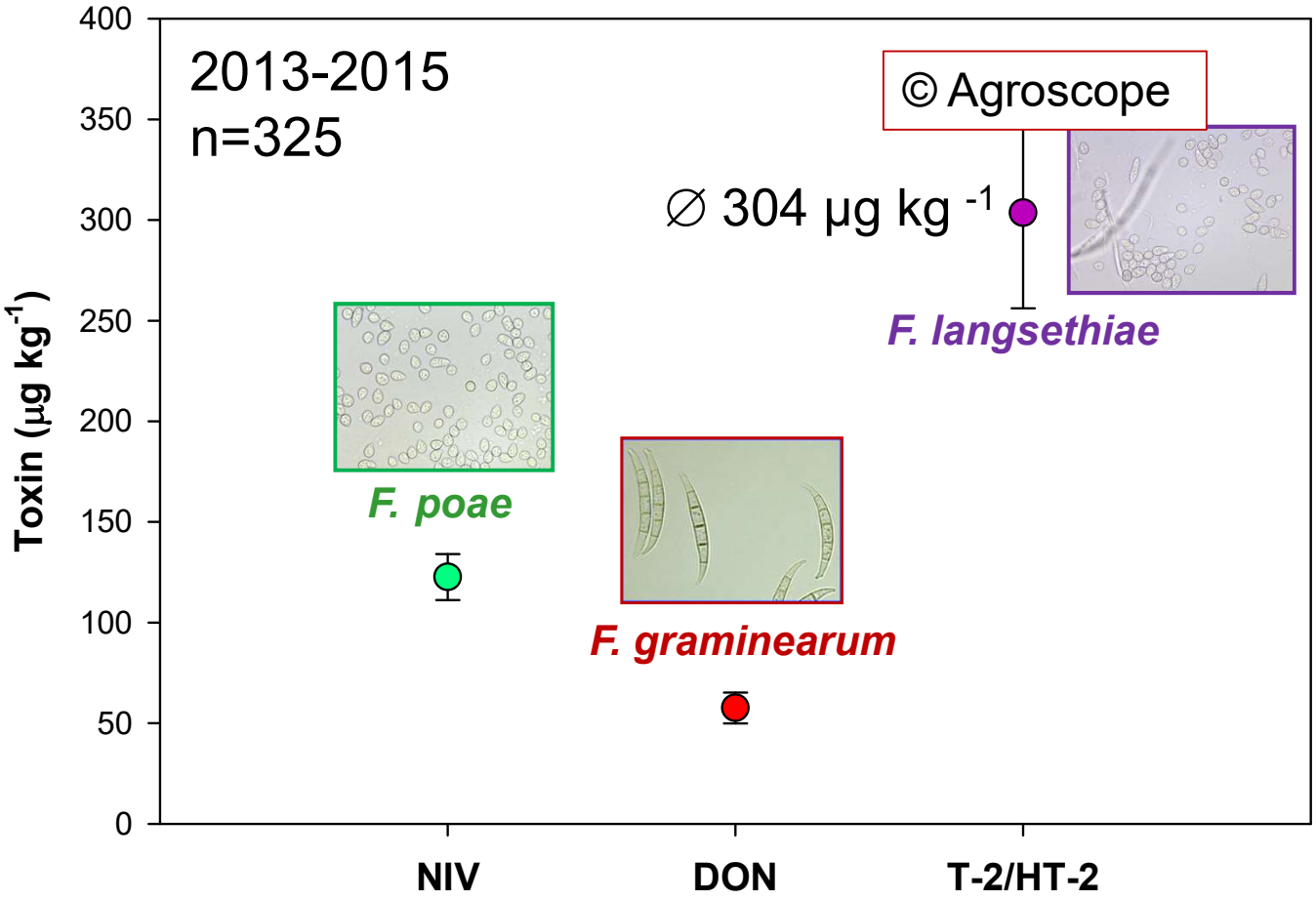
Schöneberg et al. (2018)
Eur J Agron 92: 123-132

2013-2015: n=325

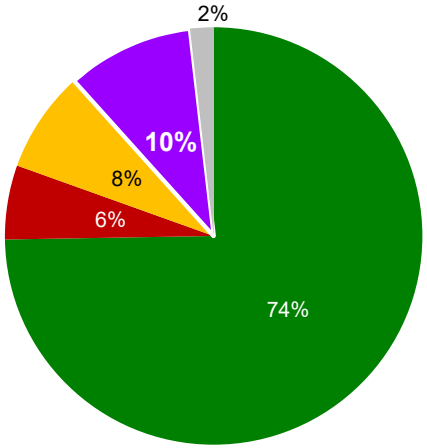




Toxins in (hulled) oats from growers



From a ratio of only 10%
→ qPCR: 33%



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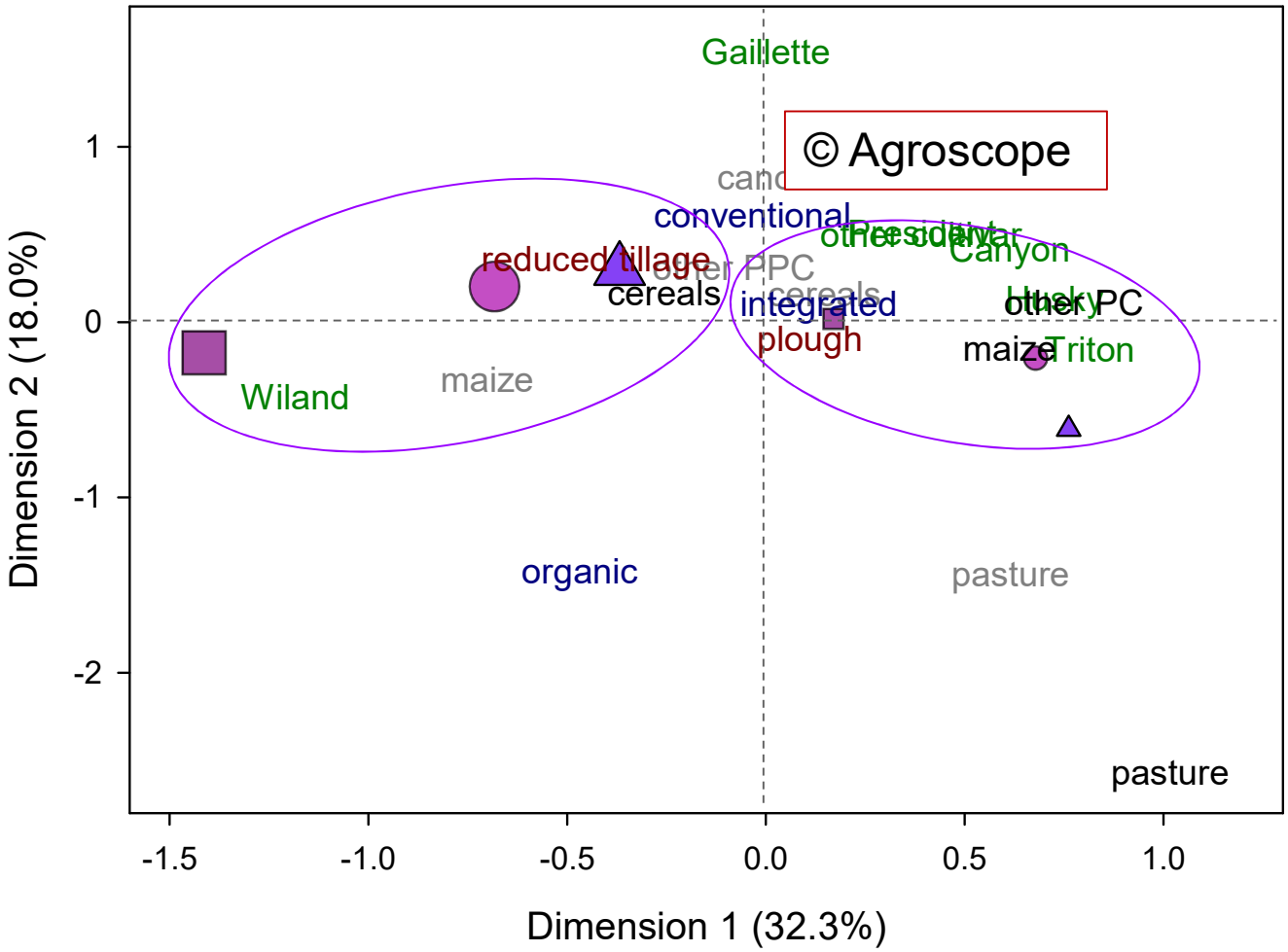
MCA for oats: *F. langsethiae* & T-2/HT-2



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Outline

- Surveys on *Fusarium* species and mycotoxins in wheat, barley and oats
- **Our resulting research to reduce the risk in cereals:**
  - “Healthy & Safe” cereal varieties
  - “MycoKey”: Biocontrol, cover crops and biofumigation

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«Healthy & Safe» cereals

Romina Morisoli, Charlotte Martin, Mario Bertossa, Torsten Schöneberg, Susanne Vogelgsang, Fabio Mascher

- **Wheat, barley and oat cultivars**
  Health promoting compounds (**HPCs**): anthocyanins, phenolic acids, β-glucans
- **Healthy <u>and</u> safe food**
  HPCs might inhibit infection through toxigenic *Fusarium* species

Research questions

→ Dominant species and toxins, impact of cropping factors?
→ Epidemiology of the dominant species?
→ **Differences in susceptibility of cultivars?**

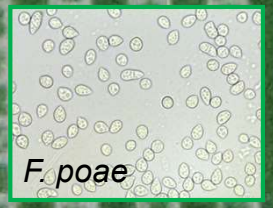
Healthy Nutrition and Sustainable Food Production
National Research Programme NRP 69

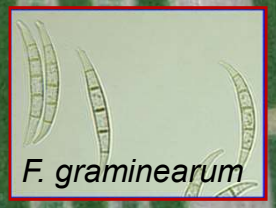
Charlotte Martin

Resistance experiments

Torsten Schöneberg

- 3 sites across Switzerland
- Wheat, oat, barley varieties with different contents of HPCs
- Artificial infections with selected *Fusarium* species





Picture: M. Bertossa

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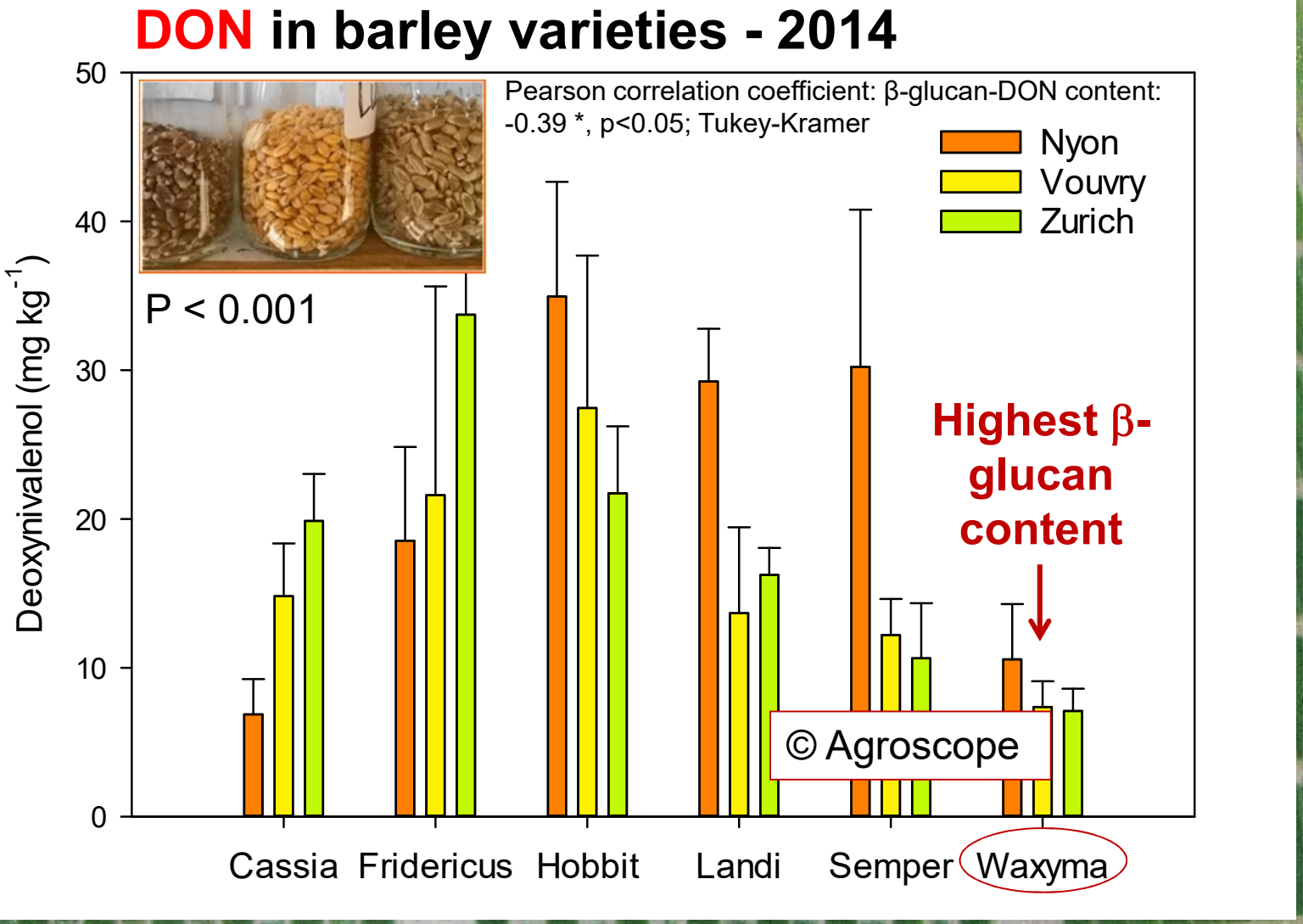
Resistance experiments



Picture: M. Bertossa

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Outline

- Surveys on *Fusarium* species and mycotoxins in wheat, barley and oats
- **Our resulting research to reduce the risk in cereals:**
  - "Healthy & Safe" cereal varieties
  - **…if prevention is not enough:**
    Biocontrol, cover crops
    and biofumigation

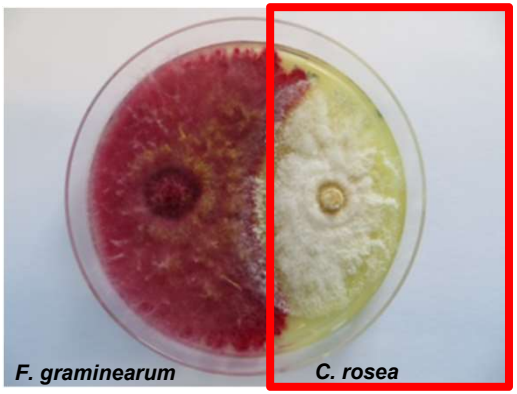


If prevention is not enough…

→ Avoid spore discharge from perithecia

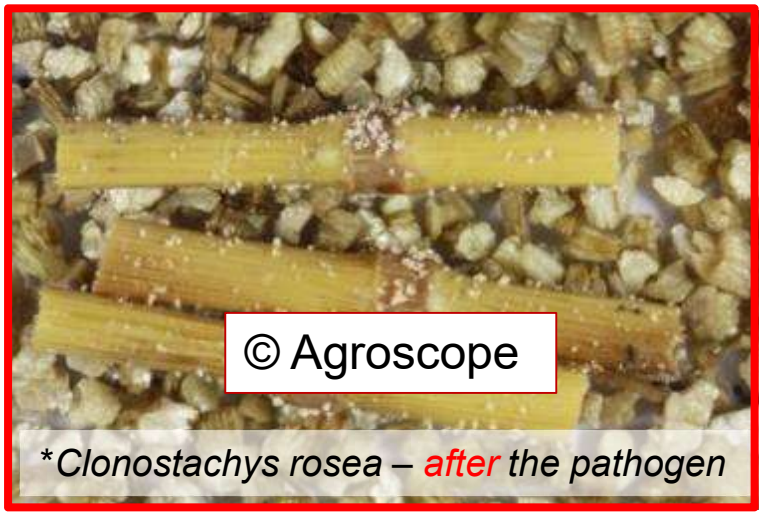
Biological control

- Fungal antagonists on residues from pre-crop



*Schöneberg et al. (2015) J Appl Microbiol

… MycoKey comes in



Agroscope

Biological control

Fungal antagonist *Clonostachys rosea*

- On residues from pre-crop or directly on wheat heads
- Inoculum production

Agroscope

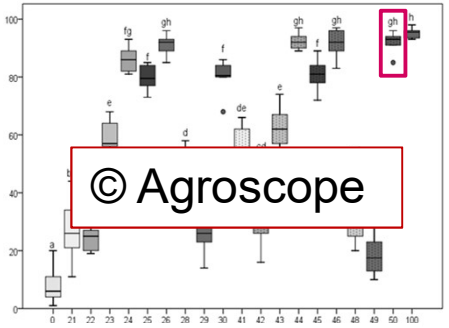
Biological control

Fungal antagonist *Clonostachys rosea*

- On residues from pre-crop or directly on wheat heads
- Inoculum production
- Formulation (shelf-life, UV resistance)

Formulation development

Controlled environment



Oil formulations [1% & 5% in H_20]

Field experiments 2016-2018

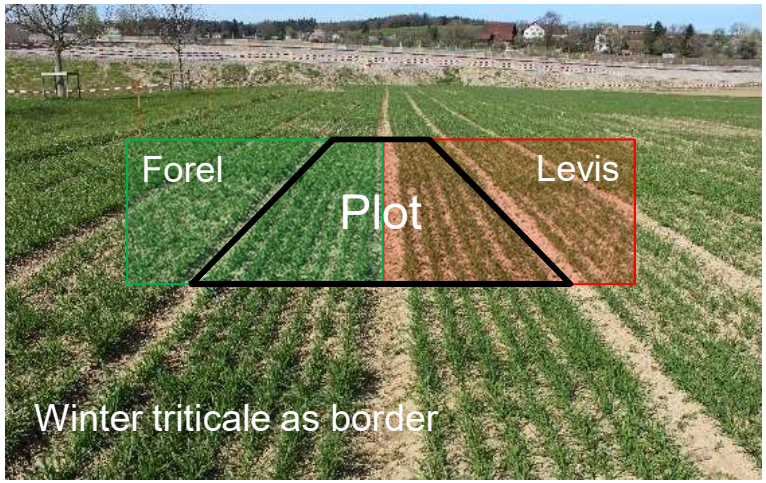
Antagonist treatments of infected maize stalk residues

F. graminearum infected maize stalks

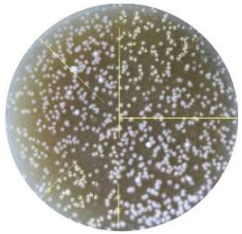
Antagonist suspensions of different formulations

Agroscope

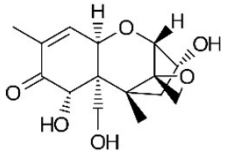
Antagonist treatments of infected maize stalk residues



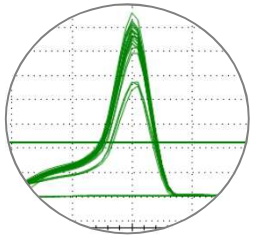
FHB symptoms (%)



Spore deposition



Mycotoxins DON, ZEA



qPCR *F. graminearum*

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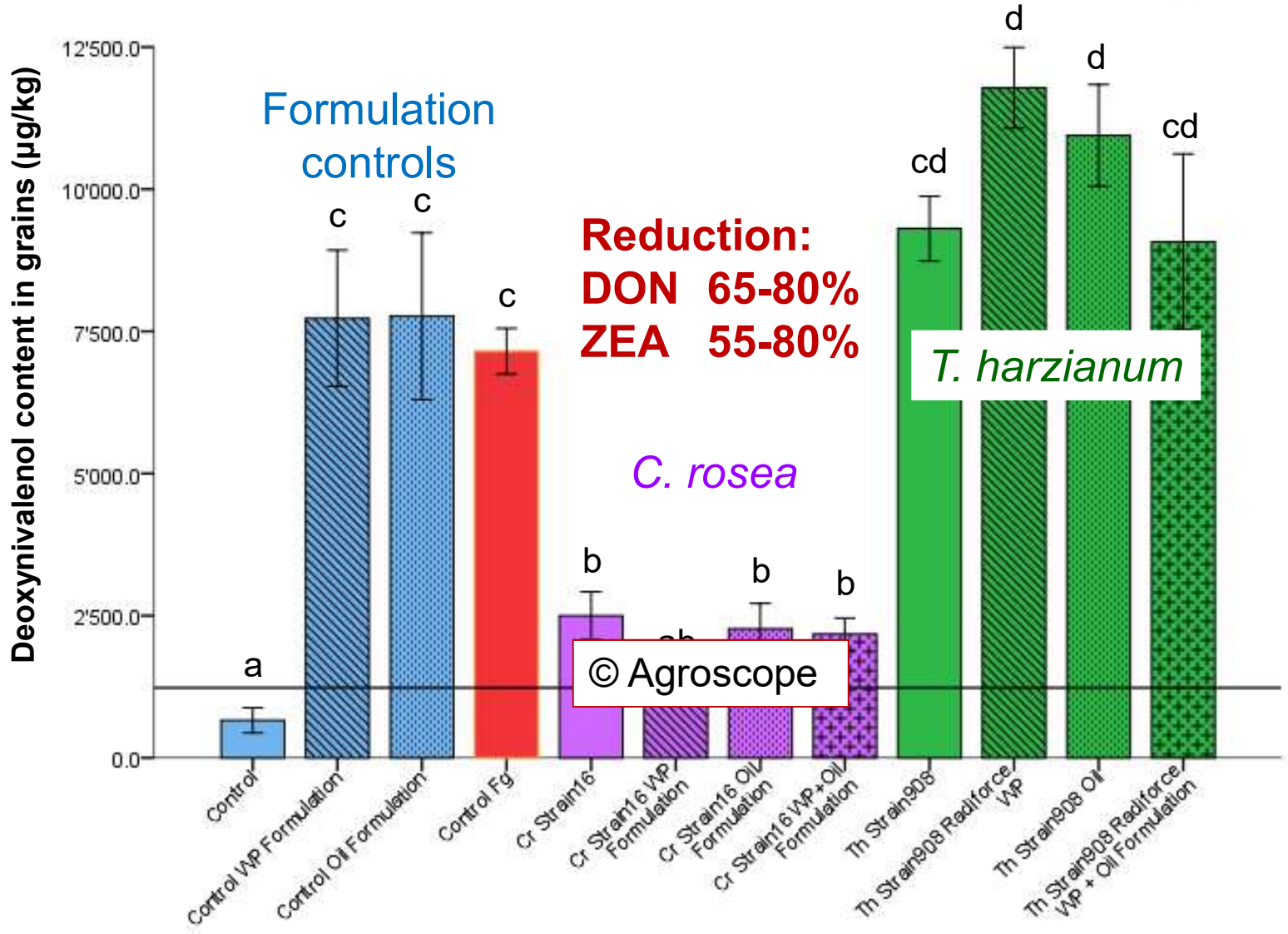
DON in grains (Levis/Forel)



Suppression of inoculum

- Various **intercrop/cover crop species** on residues from pre-crop: coverage, increased microbial activity or directly anti-fungal
- **Biofumigation**, botanicals

Biofumigation of infected maize stalks

White mustard
Sinapis alba

Indian mustard
Brassica juncea

Berseem clover
Trifolium alexandrinum

Application rate 1.9 kg m^{-2}
(mustards “plot to plot”)

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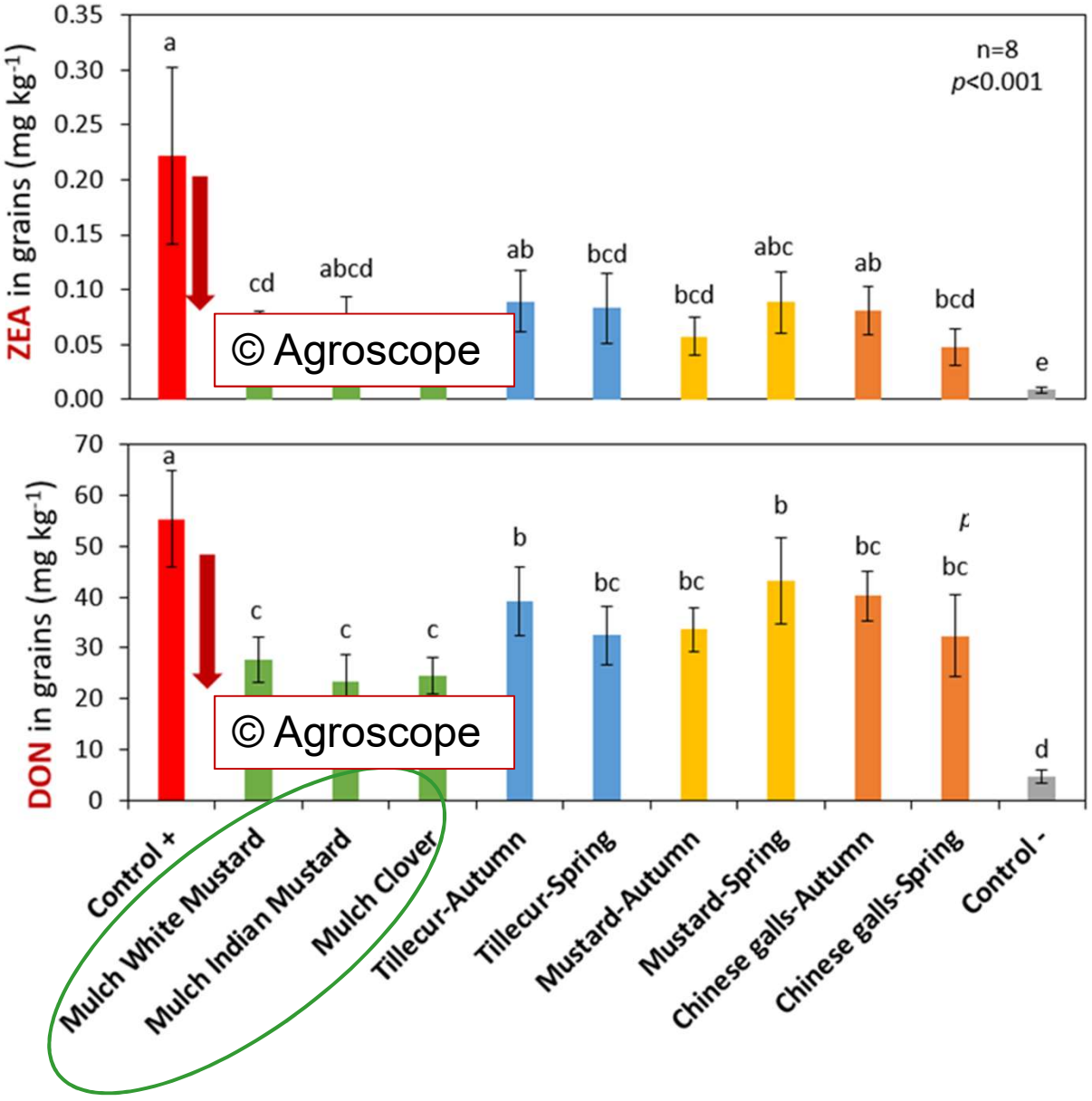
Biofumigation of infected maize stalks



Reduction:
ZEA up to 60%
DON up to 75%

Conclusions

- **Significance of mycotoxin surveys?**
  → Crucial to identify dominant *Fusarium* species and influencing cropping factors
- **Wheat = barely = oats?**
  → Extrapolation not possible due to different *Fusarium* species and/or different effects of cropping factors
- **Which measure to choose?**
  → One single measure not sufficient
  → Meaningful combination of puzzle pieces needed

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Acknowledgements

- **Research group** “Ecological Plant Protection in Arable Crops”, in particular:
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Kanton Bern
Canton de Berne

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Questions?