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Field and environmental diagnostics for monitoring resistance evolution in *P. infestans*

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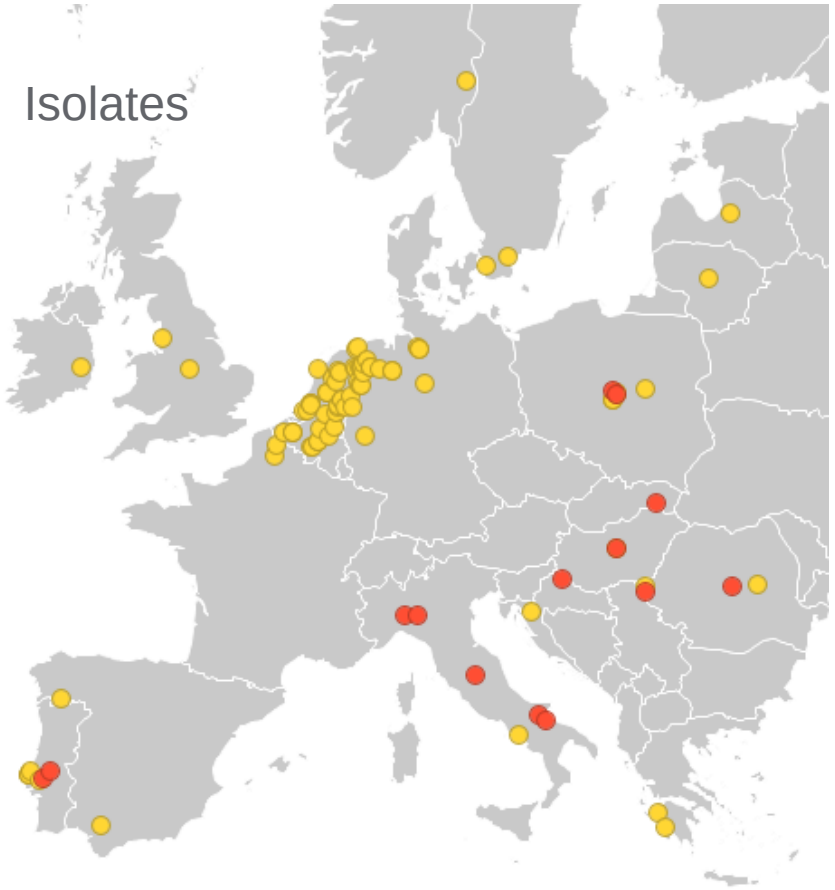
In collaboration with BIOtransfer
Growing innovation for your solutions

Phytophthora infestans European field monitoring 2023

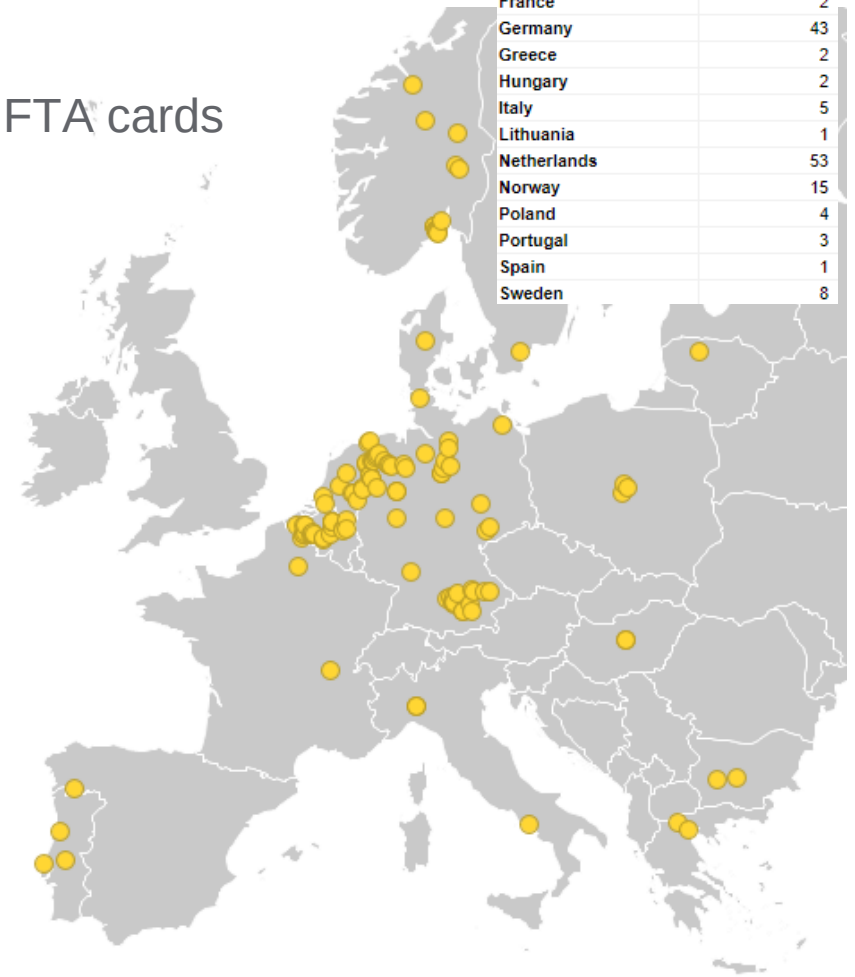
Monitoring 2023 includes 284 isolates from 20 European countries and 182 FTA cards

Isolates



Belgium	38
Croatia	8
France	4
Germany	61
Greece	4
Hungary	4
Ireland	4
Italy	10
Latvia	2
Lithuania	3
Netherlands	89
Norway	1
Poland	13
Portugal	24
Romania	8
Slovakia	2
Spain	22
Sweden	7
United Kingdom	3

FTA cards



Belgium	27
Bulgaria	2
Denmark	14
France	2
Germany	43
Greece	2
Hungary	2
Italy	5
Lithuania	1
Netherlands	53
Norway	15
Poland	4
Portugal	3
Spain	1
Sweden	8

- In 2023, 284 isolates and 182 FTA cards were collected from 20 European countries
- The majority of collected samples are from potato in Germany, Netherland and Belgium

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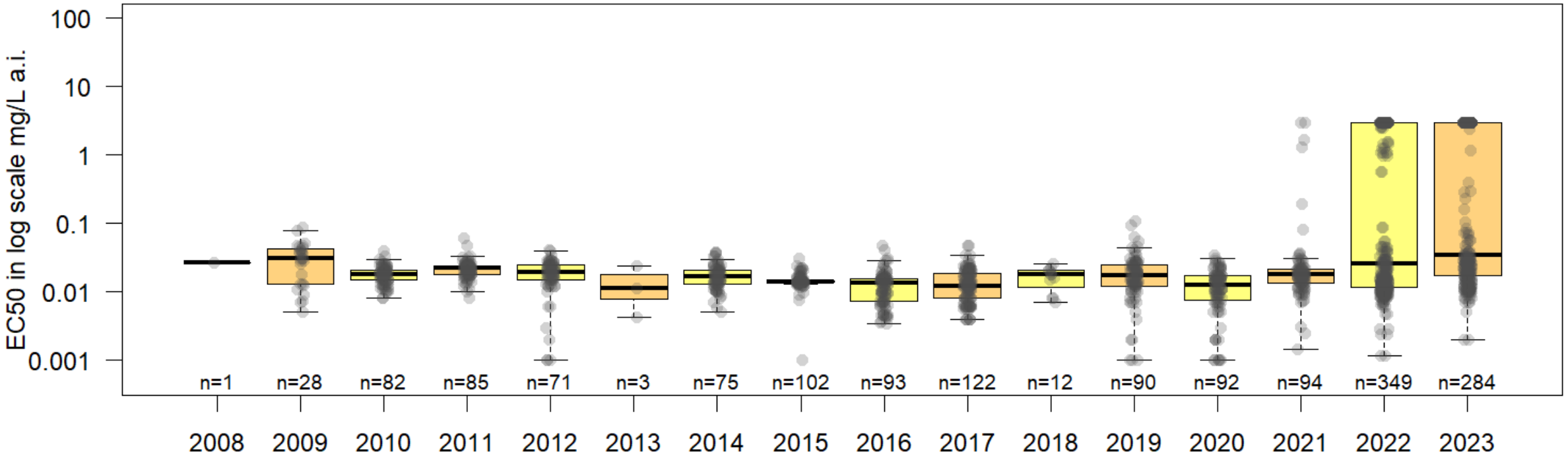
Evolution of *P. infestans* sensitivity to CAA since 2008 (n=1739)

All samples tested up to 2020 showed complete sensitivity to mandipropamid



- **The European population of *P. infestans* was fully sensitive to MPD up to 2020**
- Single resistant isolates were monitored for the first time in Denmark in 2021
- In 2022, moderate frequency of resistance was monitored in Denmark and in Netherland, single isolates in Sweden
- Resistant samples were detected also in 2023

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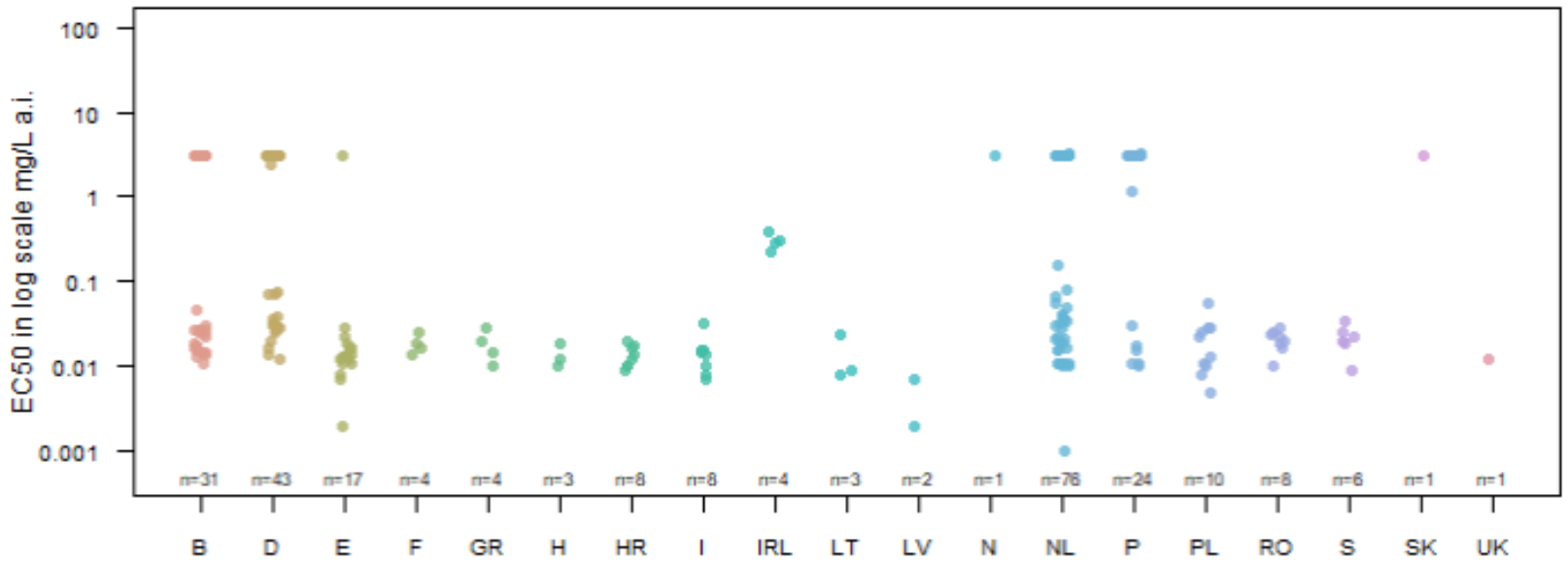
Geographic distribution of sensitivity to CAA (bioassay) in 2023 (n=284)

P. infestans resistance to mandipropamid is present in several European countries



- **Strains showing resistance to CAA in potato were monitored in Belgium, Germany, Spain, Ireland, Norway, Netherlands and Portugal.**
- **Sensitivity to CAA** was detected in France, Greece, Hungary, Croatia, Italy, Latvia, Lithuania, Poland, Romania, Sweden and UK
- From Slovakia, the *P. infestans* resistant strain **originated from tomato**
  - ***P. infestans* strains from tomato in Portugal, Italy, Croatia and Romania are fully sensitive**

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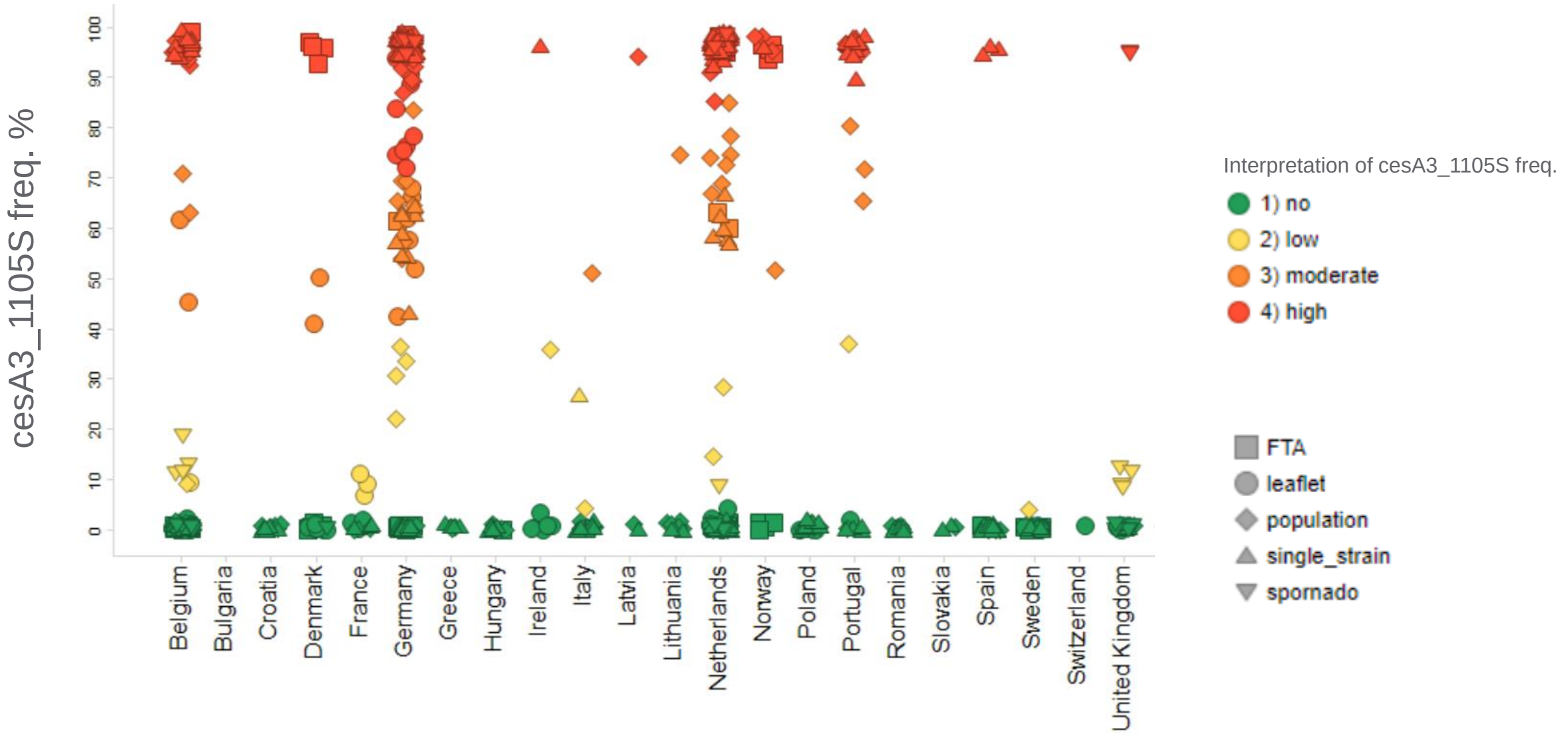
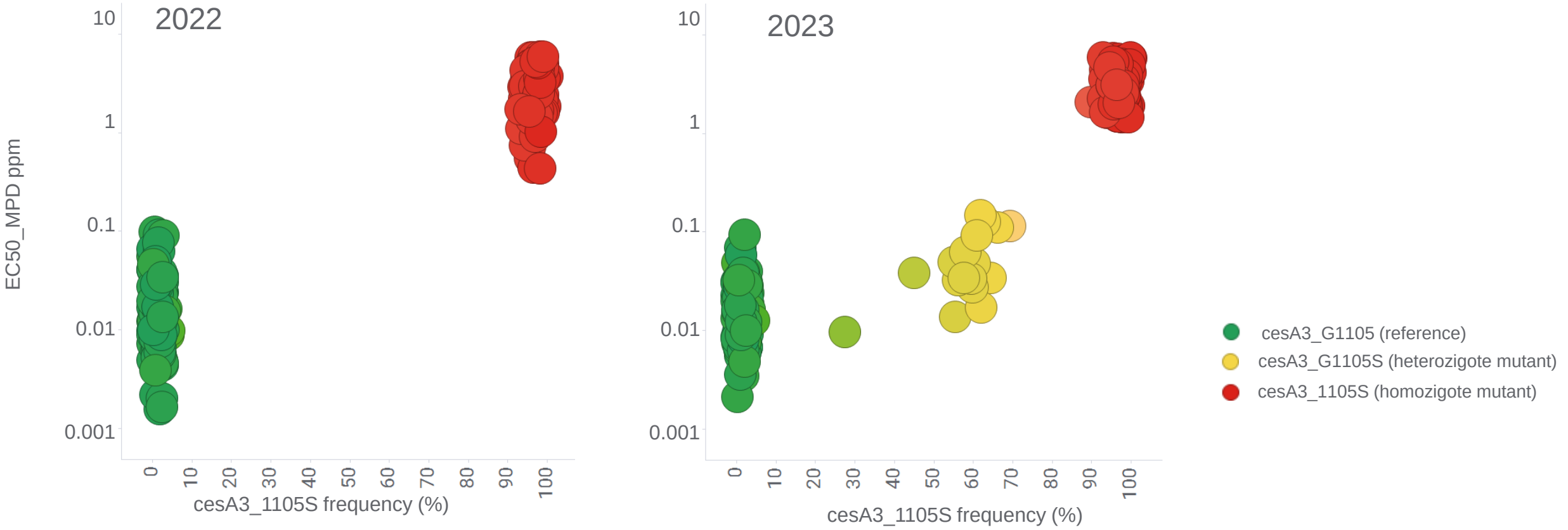
Geographic distribution of sensitivity to CAA (molecular) in 2023

P. infestans resistance to mandipropamid is present in several European countries



P. infestans : correlation between cesA3 zygosis and resistance to MPD

In 2023, cesA3 heterozygote strains are detected for the first time



- **In 2023, *P. infestans* strains were characterized as heterozygote for cesA3_1105S**
- Strains heterozgyote for cesa3_1105S are sensitive to MPD, therefore cesA3_1105S homozygosity causes the phenotype
- The mechanism of inheritance for cesA3_1105S in *P. infestans* seems to be recessive like in *P. viticola*

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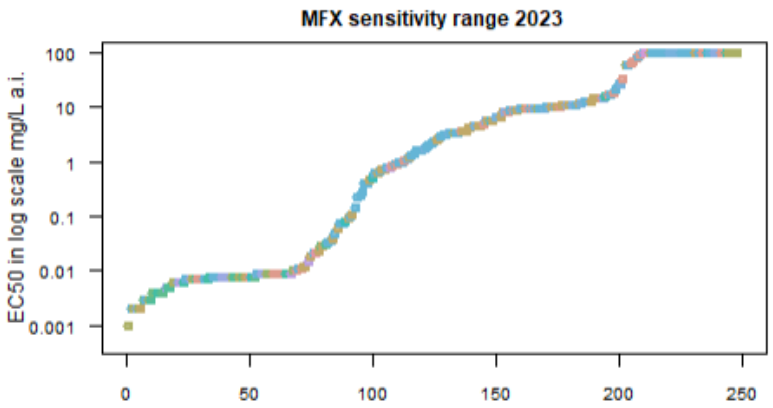
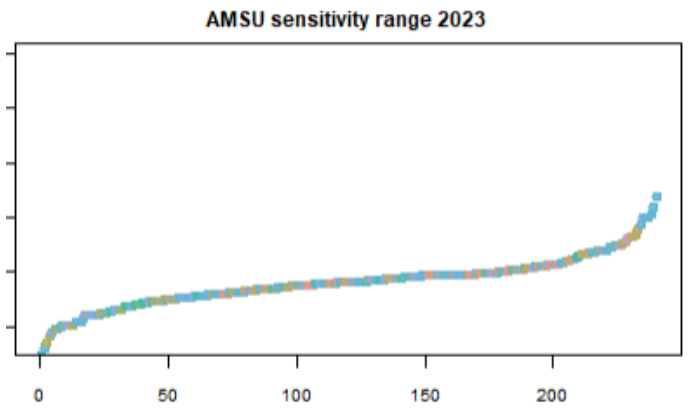
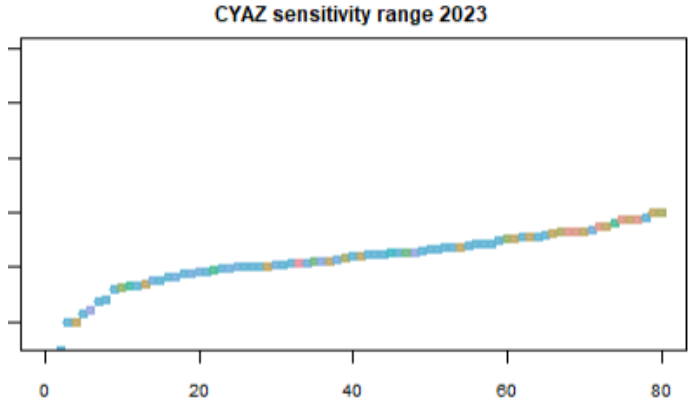
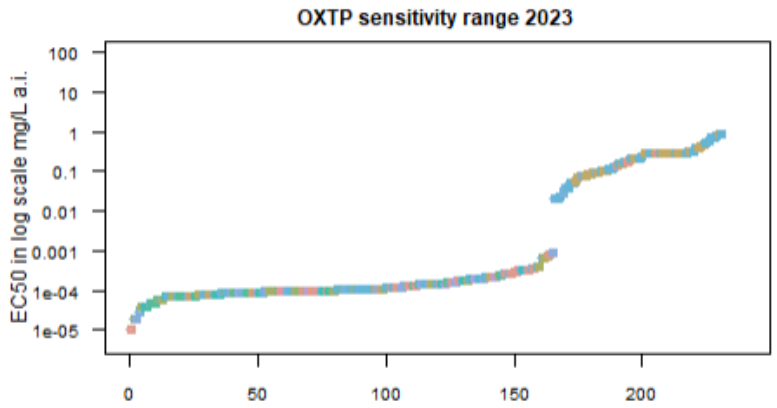
P. infestans sensitivity to other MoAs in samples collected from potato

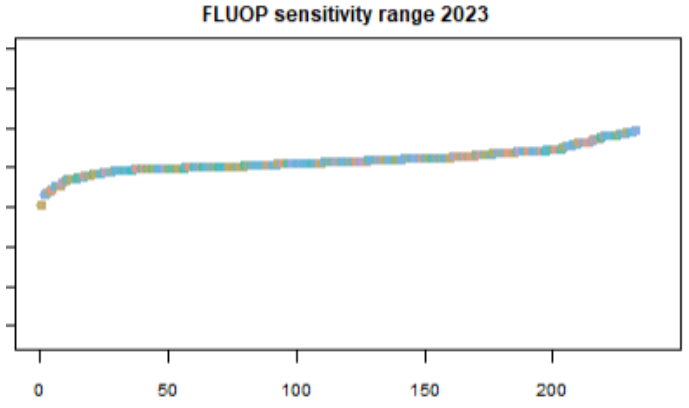
What are the best anti-resistance strategies to apply against the selection of resistance to MPD?

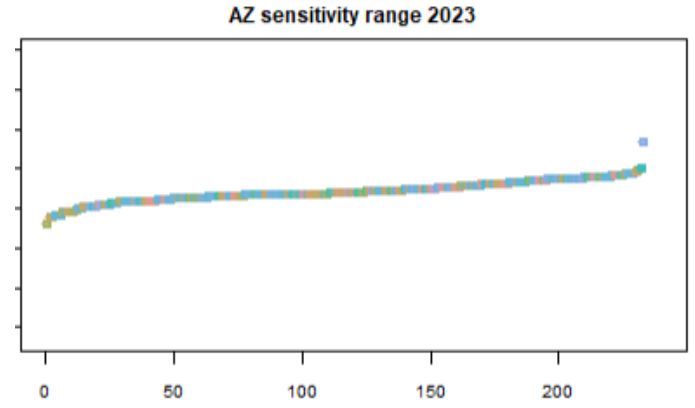












- For the first time, OXTP resistance in *P. infestans* was monitored in 2023
- Resistance is given by the SNPs osbp_770V and osbp_837F (MNP)

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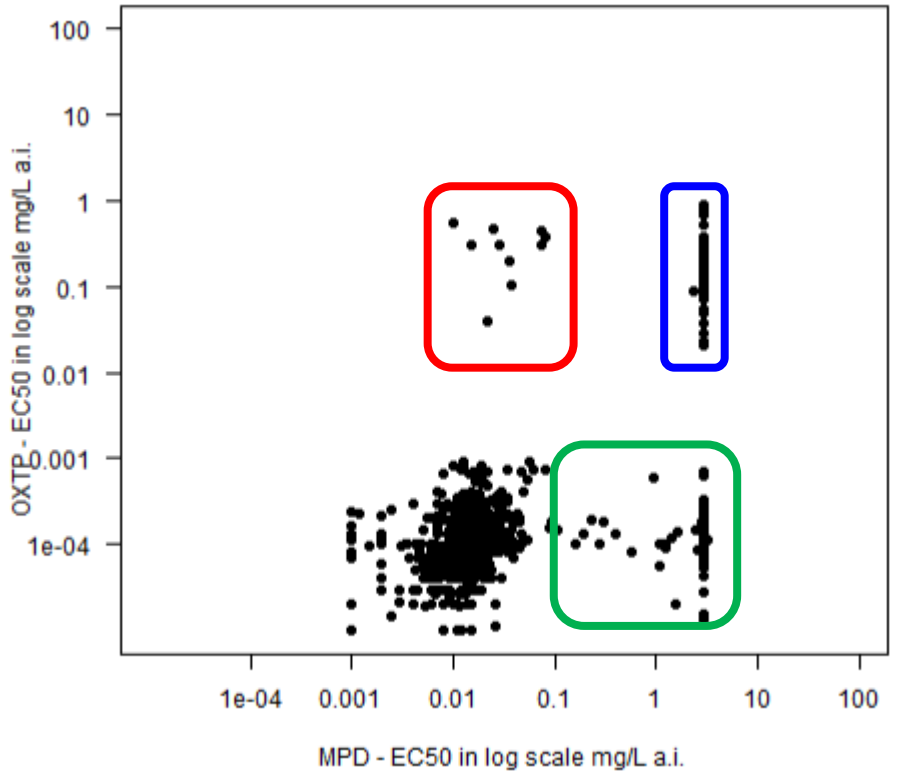
P. infestans multiple resistance CAA x OSBPI

In 2023, OXTP resistance is detected for the first time in *P. infestans*



- MPD and OXTP belongs to different MoA and therefore should not be considered cross resistant
- Strains showing single resistance to MPD or OXTP were observed
- OXTP resistance is NOT present only in strains resistant to MPD
- Strains showing multiple resistance to MPD and OXTP have been monitored

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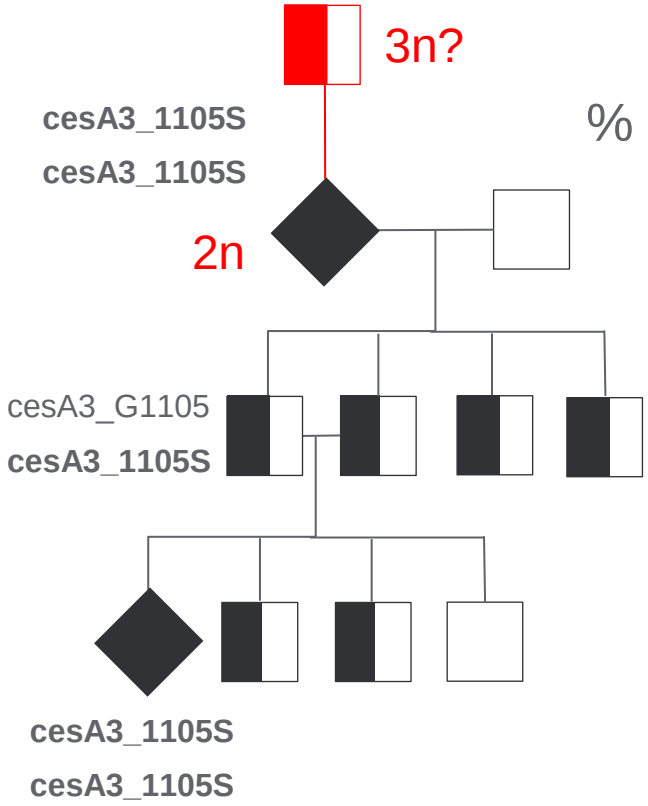
Fungicide resistance management with recessive and dominant mutations

Segregation of recessive (CAA) vs dominant mutant (OSBPI) alleles



% of resistance phenotype

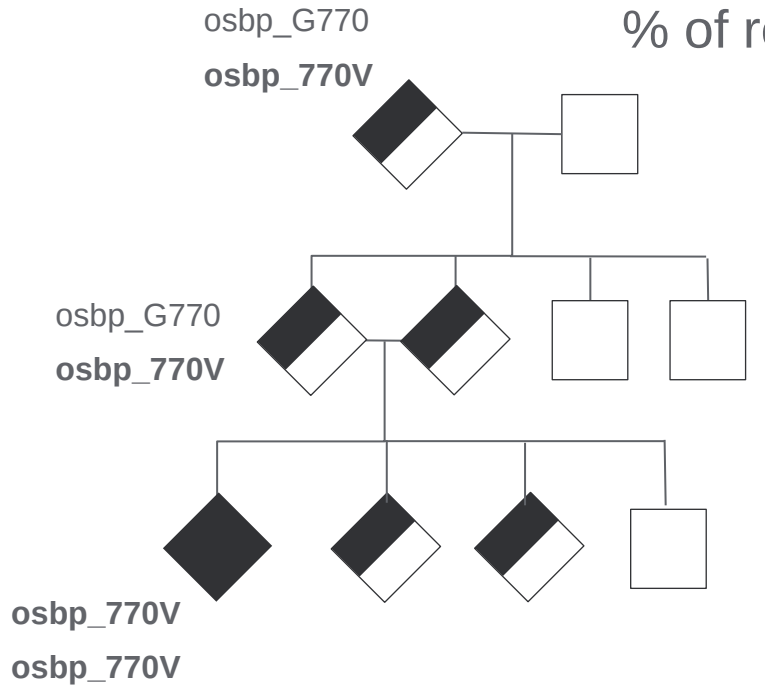
50%

cycle 1

0% (w/o selection)

cycle 2

25% (w/o selection)



% of resistance phenotype

50%

cycle 1

50% (selection)

cycle 2

75% (selection)

cesA3_1105S: recessive inheritance

osbpi_mutations: dominant inheritance (osbp_770V, 837F)

Origin of EU43 hom for cesA3_1105S? Genomic instability?

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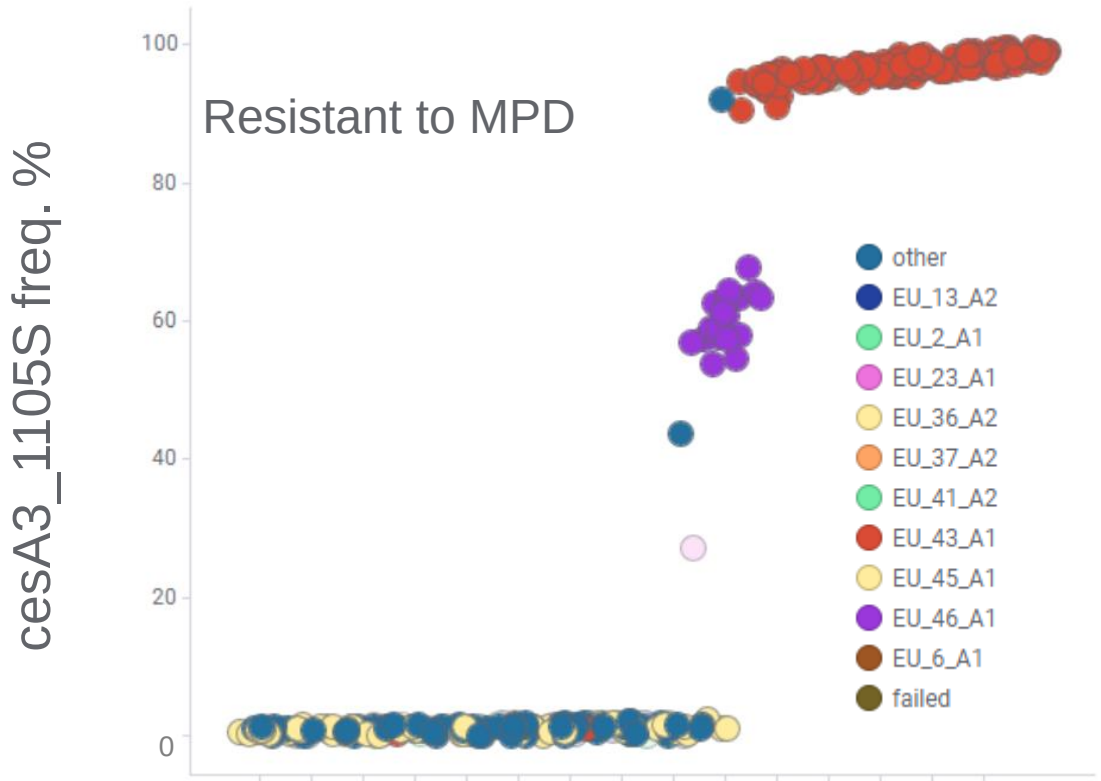
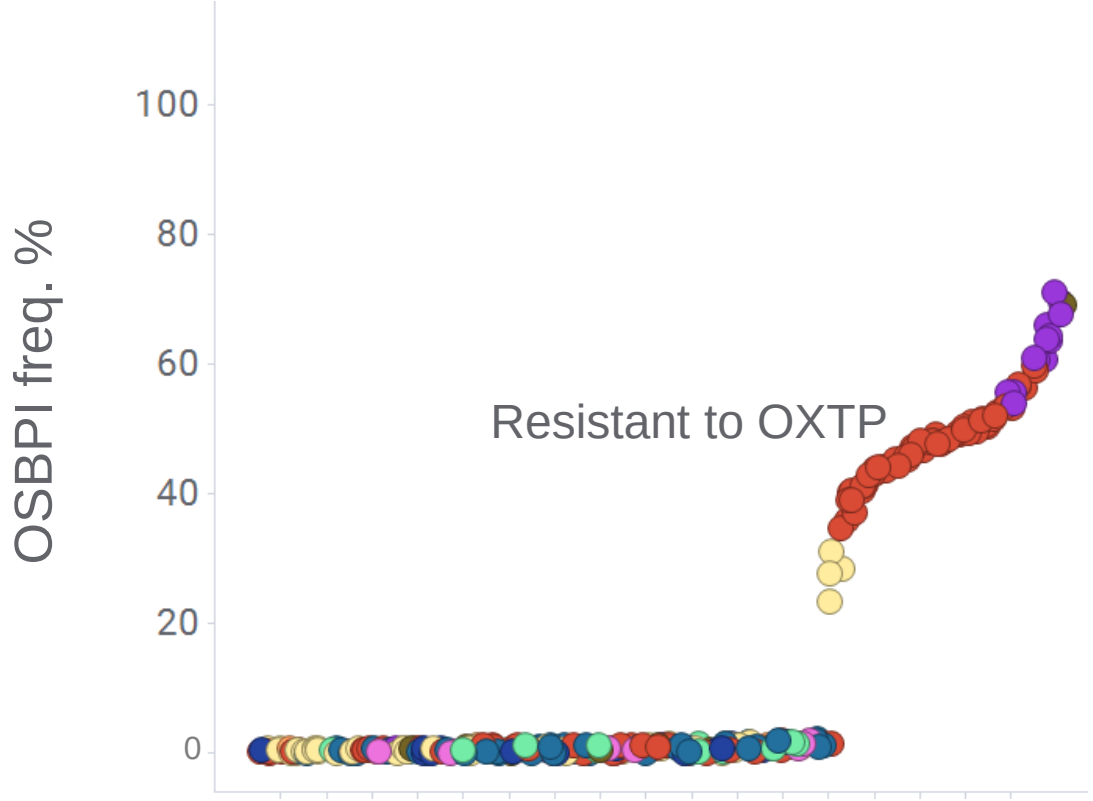
SSR genotypes and non-causal correlation to sensitivity to MPD and OXTP

A new EU46_A1 SSR type is heterozygote for cesA3_1105S and positive for OSBPI dominant mutations





- All samples resistant to MPD are homozygote for cesA3_1105S (plus two “other”, JHI communication)
- **All EU46_A1 are heterozygote for cesA3_1105S**
- **One “other” and one EU_23_A1 are het for cesA3_1105S**
- **Two EU43_A1 have no presence of cesA3_1105S**

- **Samples heterozygote for osbp_mutant alleles (770V and 837Y) are EU_46_A1, EU43_A1 and EU36_A2**
- **EU46_A1 possibly a cross between EU43_A1 and EU36_A2?**

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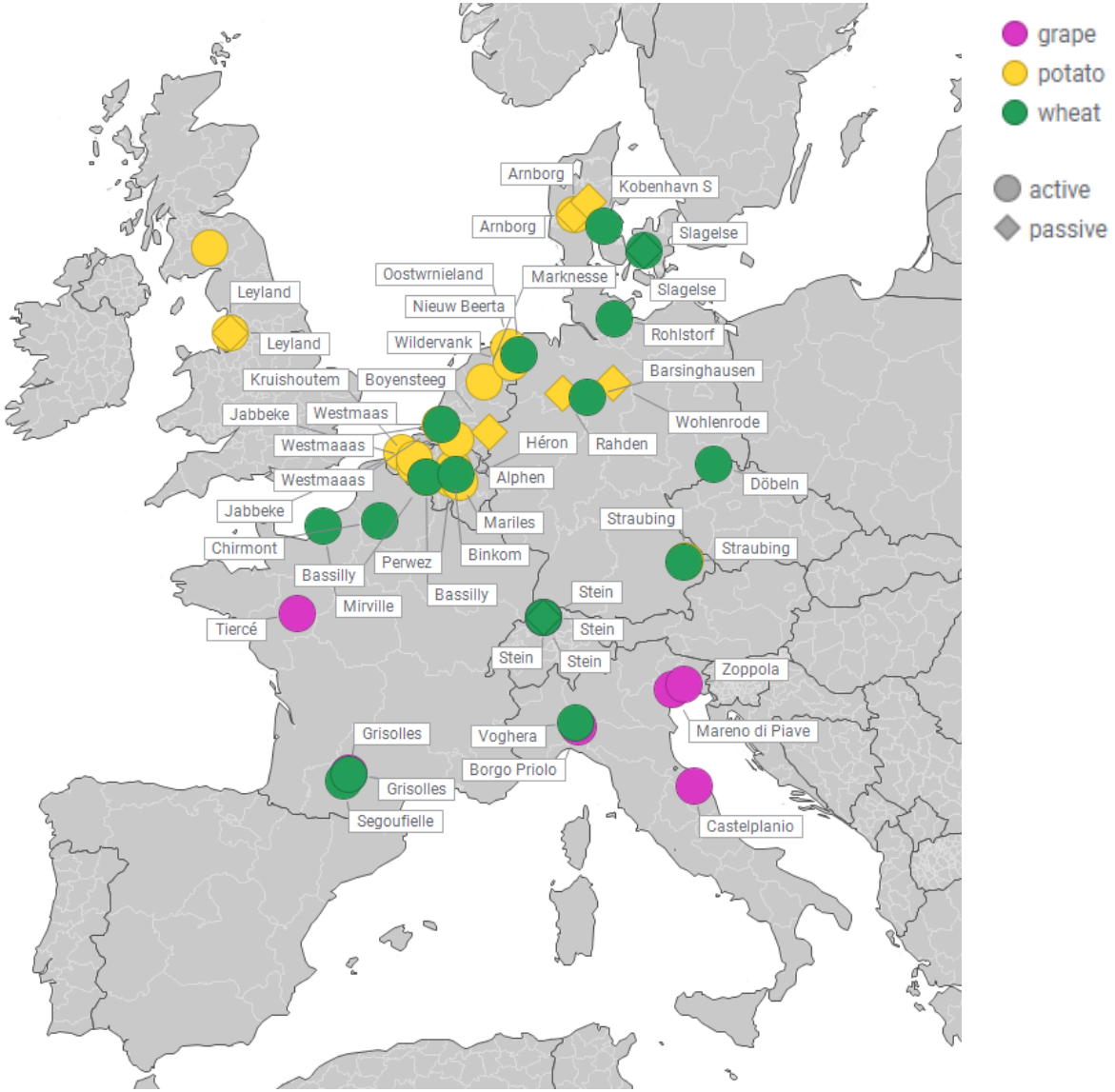
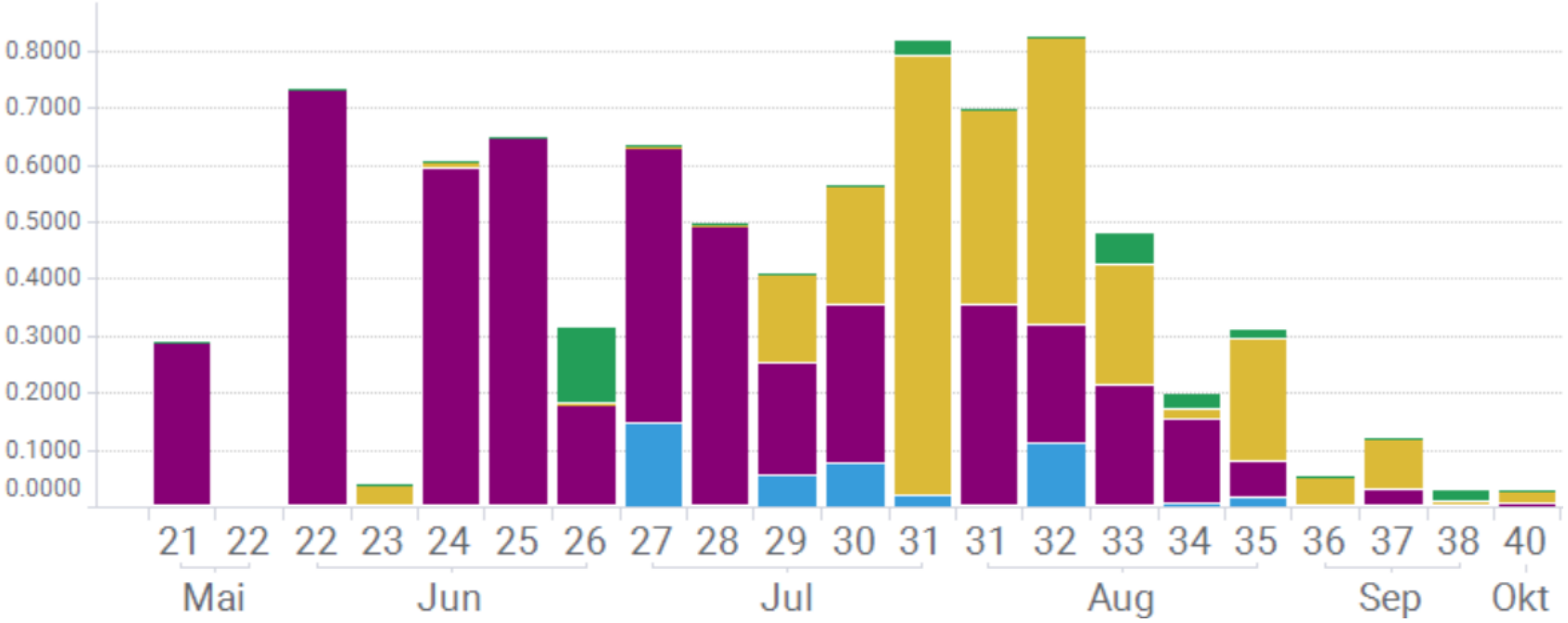
A sporetrap network was established in 2023 in Europe to monitor plant pathogens



Fungal Identification Network Disease Epidemics Resistance

Seasonal profiling of oomycete species (averaged relative abundance)



Plasmopara viticola
Phytophthora Infestans
Pseudoperonospora cubensis
Pythium spp.

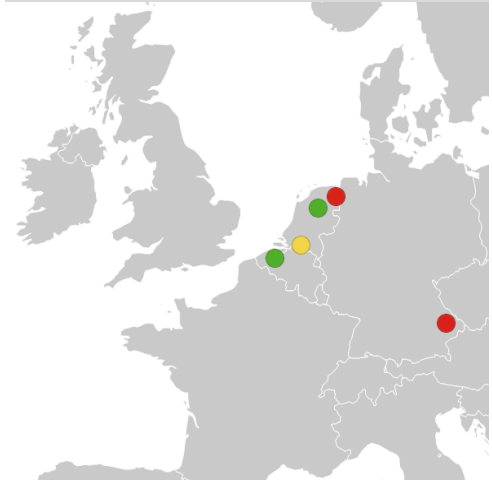
- Environmental profiling as been conducted for the first time in 2023 season in Europe with focus oomycetes
- Data showed the protocol can identify oomycetes from environmental samples
- *Plasmopara viticola* was monitored from May to September, *P. infestans* from June to September

P. infestans: environmental detection and quantification of cesA3_1105S

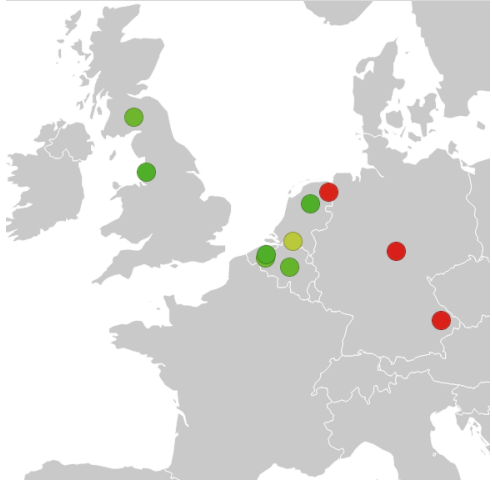
2023 tracking of cesA3_1105S frequencies month by month (signal is proxy for presence)

Sampling from 06.05 to 31.05

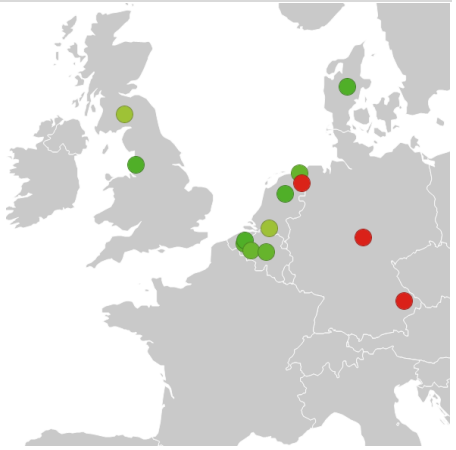
Sampling from 01.06 to 30.06



Sampling from 01.07 to 31.07



Sampling from 01.08 to 31.08



Sampling from 01.09 on

cesA3_1105S frequency (%)

cesA3_1105S Spornado monitoring

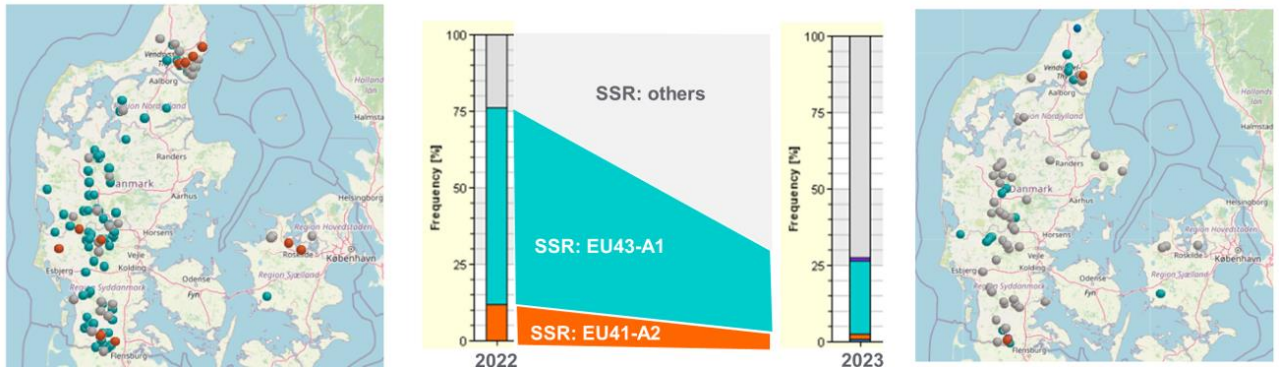
- In **May**, first detection of PHYTIN in two NL sites.
- In **June**, detection of PHYTIN in NL, B and D.
- In **July**, first detection of PHYTIN in UK.
- In **August**, first PHYTIN detection in DK,

2023 wrap up

- In Benelux, mutation pressure variable based on applied on protocols (?)
- In Germany, presence of the mutation across the season (strong selection pressure?)
- In UK, weak selection of the mutation via applied protocols

Wrap up *P. infestans* data analysis 2023

- CAA resistance progression (all Syngenta data sources) monitored in **Belgium, Denmark, Germany, Spain, Ireland, Latvia, Norway, Netherlands, and Portugal.**
- Effectiveness of CAA anti-resistance strategy
  - Mixtures MPD + other MoA recovered full efficacy of MPD (anti-resistance strategy)
  - Mixtures and strict alternations: the virtuoso example of Denmark 2023 with application of new FRAC recommendations: reduction of EU43 SSR selection by 40%



- Emerging of resistance to OXTP and multiple resistance CAA / OSBPI
  - dominant OSBPI mutations difficult to eradicate, CAA mutation (recessive) easier to dilute in the population
  - MFX and OXTP not recommended for fungicide resistance management in strict alternations and mixtures with MPD
  - EU46 SSR type (CAA sens, OSBPI res) possibly originated out of EU_43_A1 and EU_36_A2 sexual recombination
  - Possible individual introgression events in OSBP of osbp_770V and/or osbp_837Y in EU_36_A2 and EU_43_A1