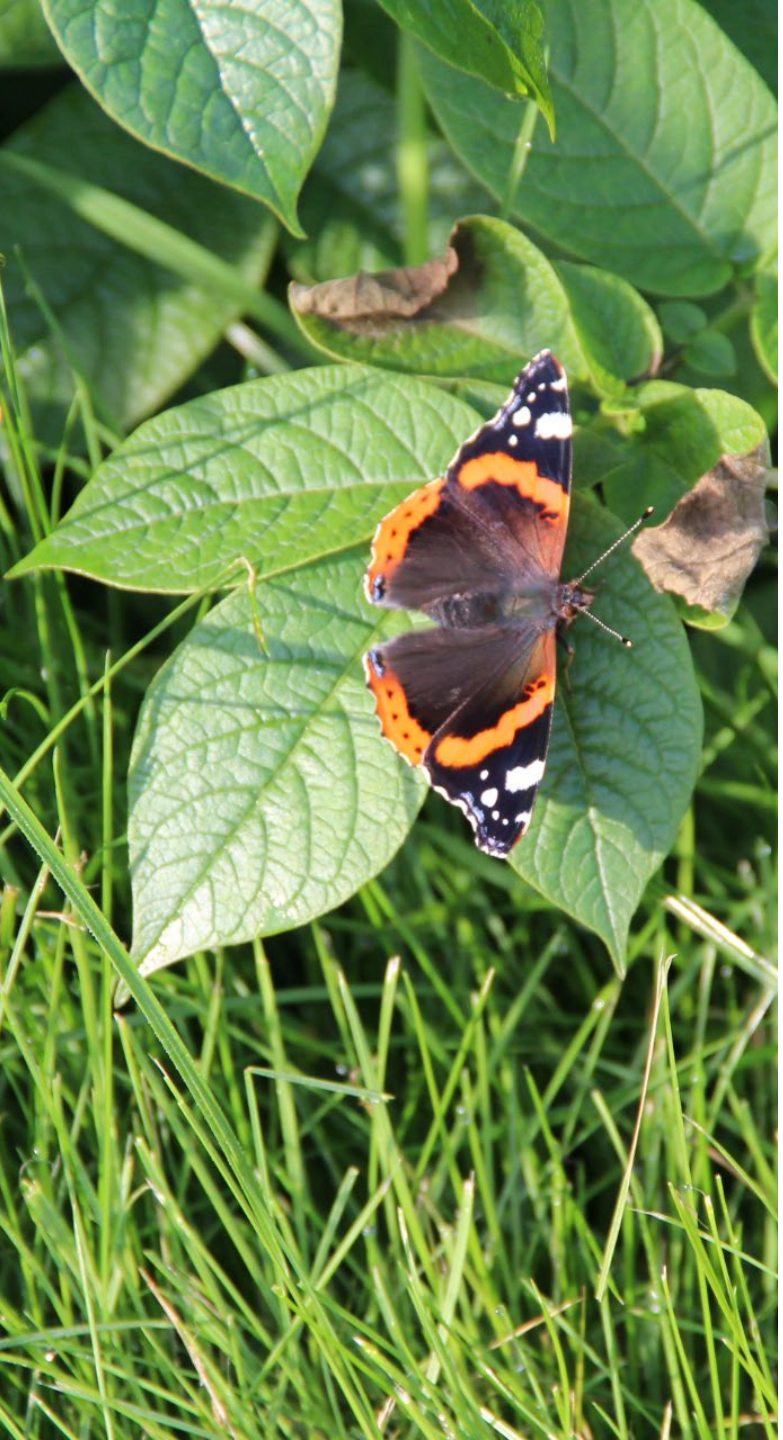


The history of EU43 and resistance to mandipropamid in Denmark

Jens G. Hansen & Isaac K. Abuley, Aarhus University

Outline

- EU43 resistance against mandipropamid – sounding the alarm
- Key results on the Danish *P. infestans* population
- The evolution and spread of EU43 in Europe, 2017-2023 – focus on DK with a reference to NL

AARHUS UNIVERSITY

EuroBlight
A potato late blight network for Europe

Miljøministeriet
Miljøstyrelsen

Ministry of Food, Agriculture and Fisheries of Denmark
gudp

PLANTER | 30-08-2022 08:35:45 |

Risiko for resistens mod Revus

I flere forsøg ses der nu en vigende effekt af Revus mod skimmel i kartofler. Derfor anbefaler landskonsulent, at midlet indtil videre ikke anvendes, hvor der er udbredt skimmel.

Forsøgsmæssigt er der anvendt ren Revus i forsøgmarken i Arnborg. Den vigende effekt giver mistanke om resistensudvikling. Arkivfoto

SEGES sounding the alarm

News from SEGES, 30 August 2022

Risk for resistance against Revus
(a.i. = mandipropamid). Obs from trials and commercial fields

Resistance to mandipropamid in EU_43_A1 reported

AARHUS UNIVERSITY

For students · For PhDs · For employees · Dansk · Find

Department of Agroecology

About the department · Research · Education · Collaboration · Current news

Department of Agroecology › Current news › News › show

A new variant of the late blight pathogen Phytophthora infestans is threatening the potato production

The results of a study on late blight show 100% resistance to one of the most important fungicides in potato production. Researchers find the development of the new variant of late blight worrying in relation to future control in Danish fields.

Resistance has been found in late blight to one of the most widely used pesticides. This raises concerns among researchers from Aarhus University.

Photo: Jens G. Hansen

6 January 2023 by Camilla Brodam Galacho

https://agro.au.dk/en/current-news/news/show/artikel/kartoffelproduktionen-trues-af-stigende-resistens-hos-kartoffelskimmel-mod-kemiske-bekaempelsesmidler

Press release by Aarhus University, 6 Jan 2023

5 isolates tested – all resistant to mandipropamid

- Home
- About EuroBlight
- EuroBlight workshop 13-16 May 2024
- EuroBlight workshop 9-12 May, 2022
- EuroBlight Zoom meetings 2021 - presentations
- Pathogen monitoring
- Control strategies
- Alternaria
- Late blight Survey Mapper
- News
  - News
- Workshop proceedings 1996-2017
- Research projects
- Protocols

Results of the EuroBlight potato late blight monitoring in 2022

EuroBlight now reports on the 2022 results. Approximately 1100 samples from 22 countries genotyped.

21 March 2023

21. marts 2023 af Jens Grønbech Hansen

Download the news story as pdf

Key findings:

- Late blight pressure in 2022 was lower than average across many parts of Europe. Disease outbreaks from 22 countries were sampled by 23 teams in 2022 resulting in 1098 genotyped samples
- The frequency of genotype EU_43_A1 (EU43) increased from 2 % in 2021 to 15.8 % of the population in 2022, mainly sampled in Denmark, the Netherlands and Belgium. EU43 was also found in Norway, Sweden, Germany and Portugal
- Isolates of EU43 from several regions in Denmark were resistant to mandipropamid at doses of up to 100ppm. Other genotypes (EU_36_A2, EU_37_A2 & EU_41_A2) were all sensitive.
- Reduced sensitivity of EU37 to fluazinam has reduced its use, prevented management failures & driven a decline of this genotype to 2.6% of the sampled population
- Comprising 36% of the samples, EU36 was the most frequently sampled genotype which suggests it remains fitter than other clones but conclusive evidence of a specific fitness trait is challenging to demonstrate *in vitro*
- Primary inoculum is locally generated and spread. Better management of all inoculum sources is required
- The proportion of 'other' genotypes generated from sexual oospore inoculum remained stable between 20-30%

Isolates of EU43 from several regions in Denmark were resistant to mandipropamid at doses of up to 100ppm. Other genotypes (EU_36_A2, EU_37_A2 & EU_41_A2) were all sensitive.

Plant Pathology An International Journal edited by the British Society for Plant Pathology

28 April 2023

ORIGINAL ARTICLE | Open Access

The EU43 genotype of *Phytophthora infestans* displays resistance to mandipropamid

Isaac K. Abuley, James S. Lynott, Jens G. Hansen, David E. L. Cooke, Alison K. Lees

First published: 28 April 2023 | https://doi.org/10.1111/ppa.13737

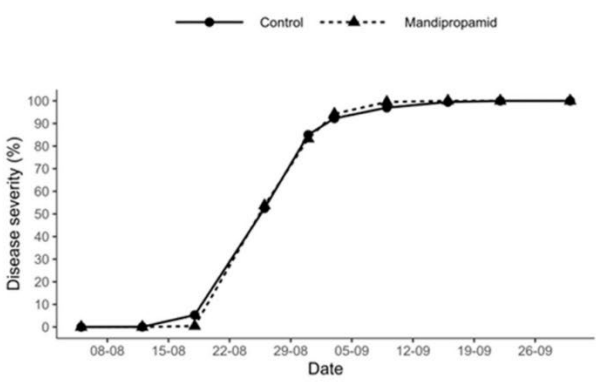
Abstract

Mandipropamid is an active ingredient in the carboxylic acid amide group of fungicides and plays a key role in current potato late blight (*Phytophthora infestans*) management programmes. However, reports from Danish potato growers in 2022 suggested that mandipropamid had lost its efficacy. A study was therefore conducted to investigate the sensitivity of isolates collected from fields in which mandipropamid had been reported to be ineffective. Seventy-two isolates of *P. infestans* collected from potato fields in Denmark were genotyped using microsatellite markers, revealing a dominance of the clonal lineage EU43 and fewer isolates of EU41 and 'other' genetically distinct genotypes. Isolates belonging to the EU43 and EU41 lineages were selected, in addition to representative isolates of clones EU36 and EU37 from Scotland, and tested for sensitivity to mandipropamid at five concentrations ranging from 0.1 to 10 µg/mL on potato leaf discs (cultivar Maris Piper). The EU43 genotype infected leaf discs at all tested concentrations, and therefore no dose–response curve could be calculated. A dose response was observed for isolates of genotypes EU36, EU37 and EU41 with EC_{50} values ranging from 0.35 to 0.75 µg/mL. Field experiments confirmed resistance of tested isolates of genotype EU43 to mandipropamid, with no significant difference in the area under the disease curve between the untreated and mandipropamid treatments. Analysis of the Danish population of *P. infestans* showed that EU43 was widely distributed across the country. To our best knowledge, this is the first report of resistance to mandipropamid in *P. infestans*.

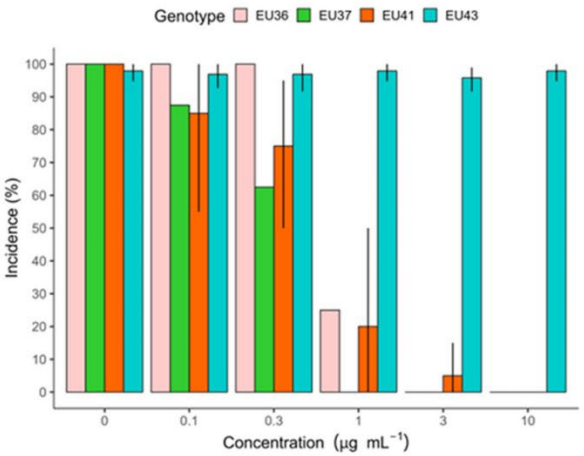
***Phytophthora infestans* was isolated from late blight lesions**

Isolates were tested for their sensitivity to mandipropamid

Field experiment with EU43

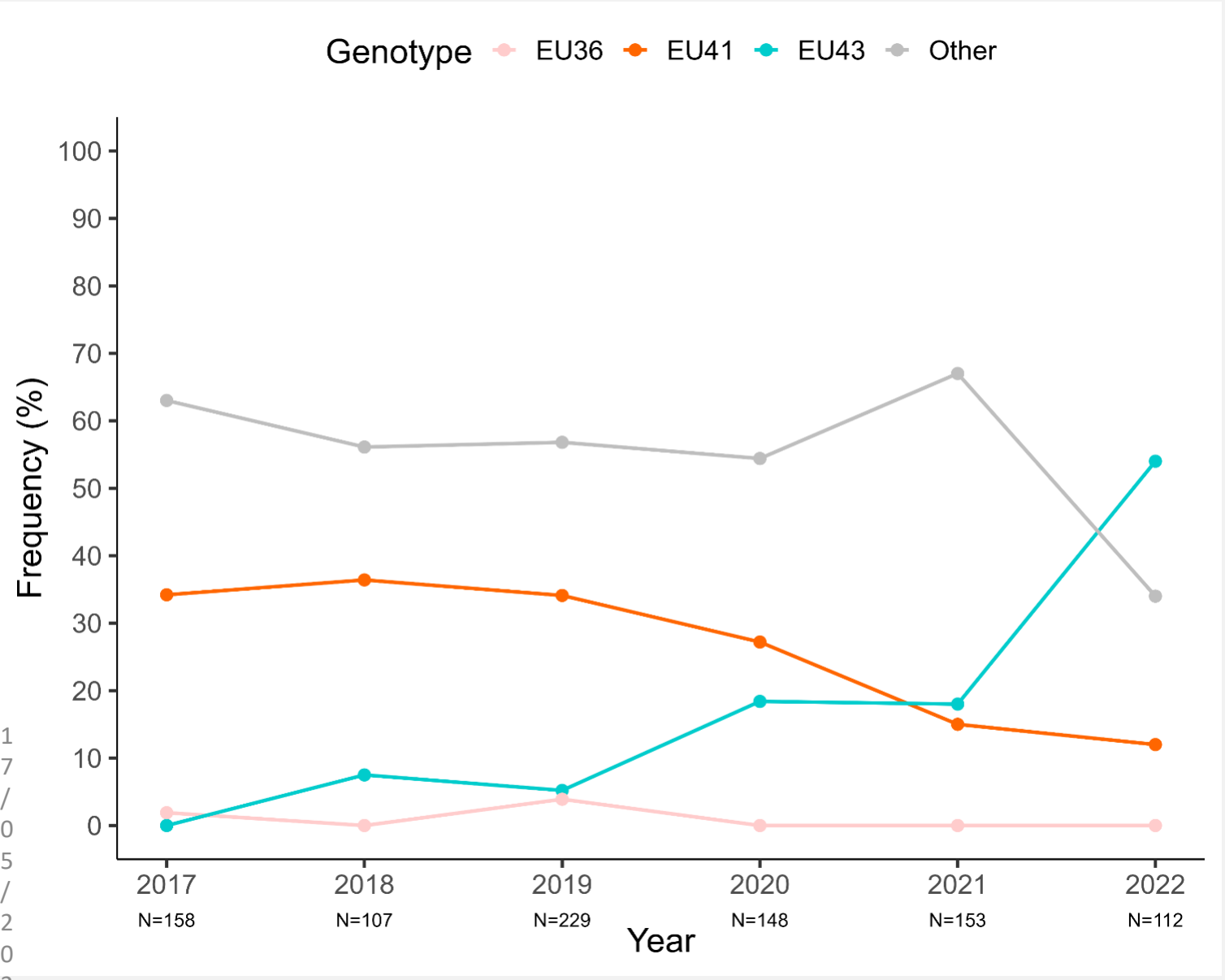


Disease development in the untreated control and mandipropamid treated plots

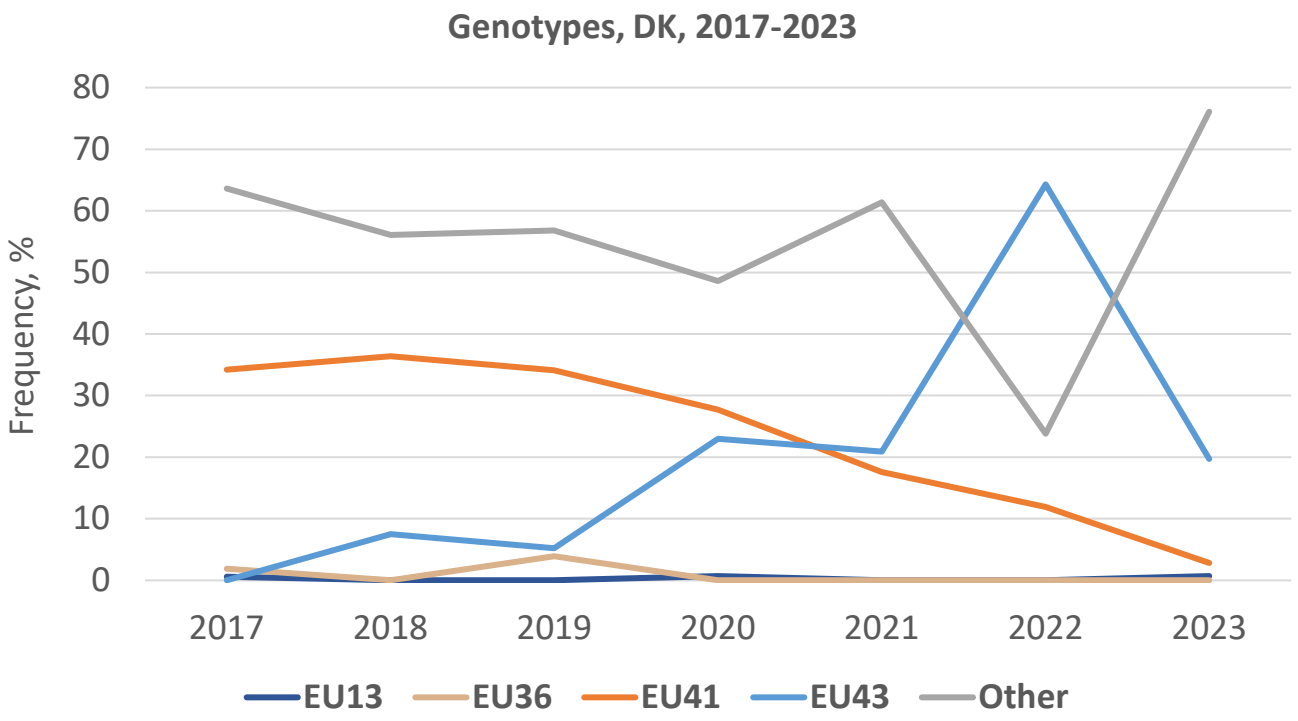


EU43 infected leaf discs at all concentrations of mandipropamid

The spatial and temporal distribution of EU43 in Denmark until 2022



17/05/2022

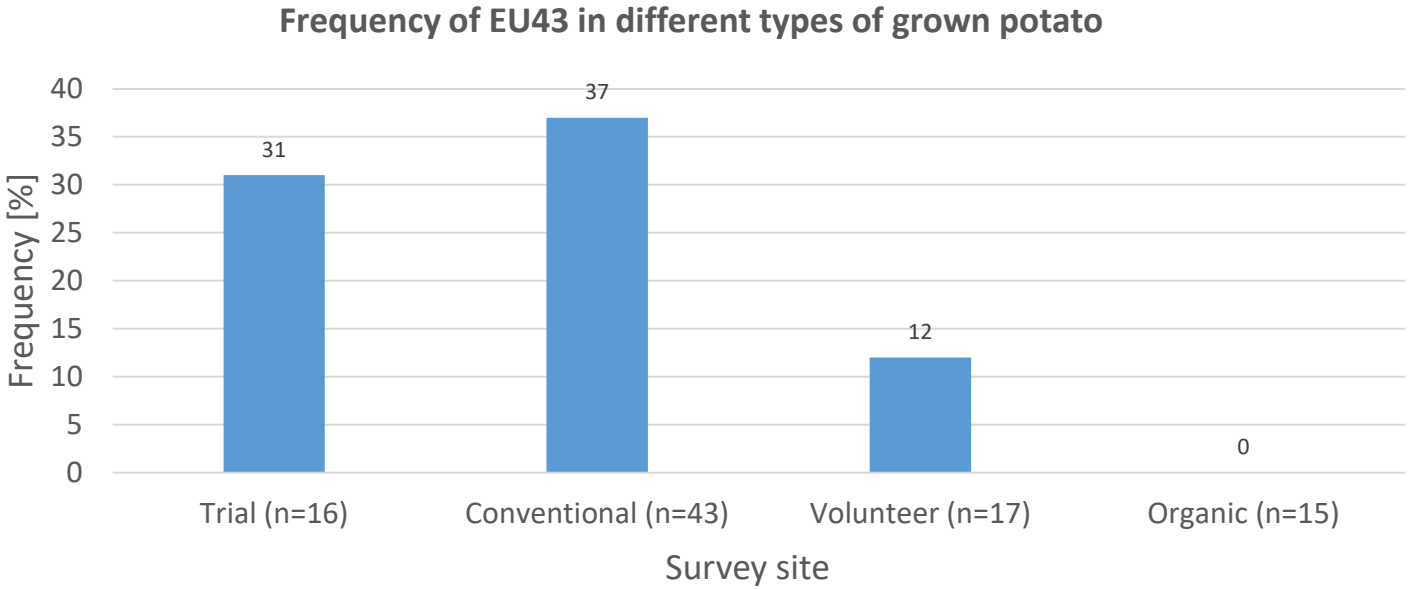


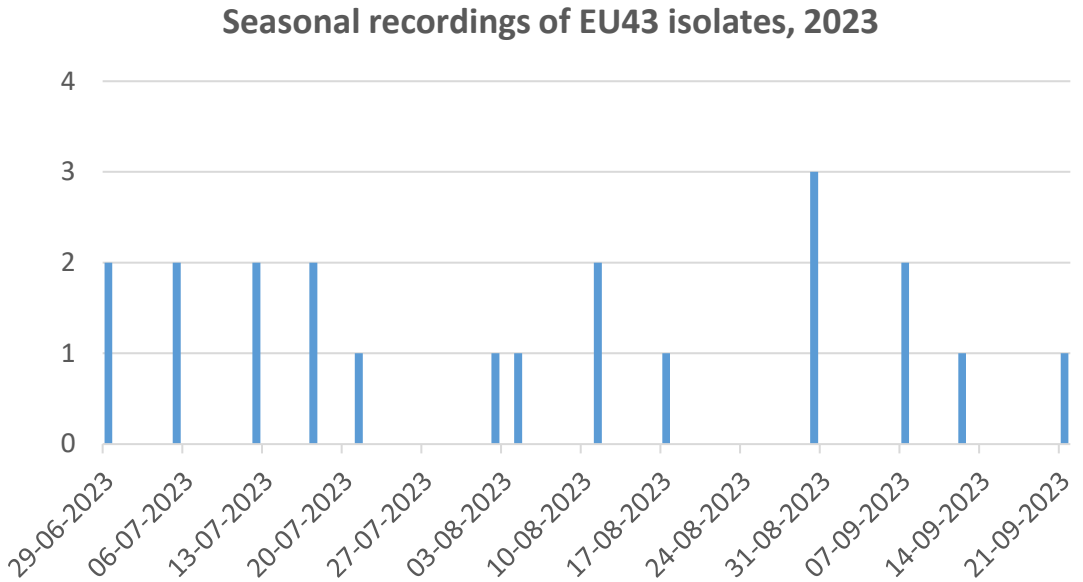
Status Denmark, 2023

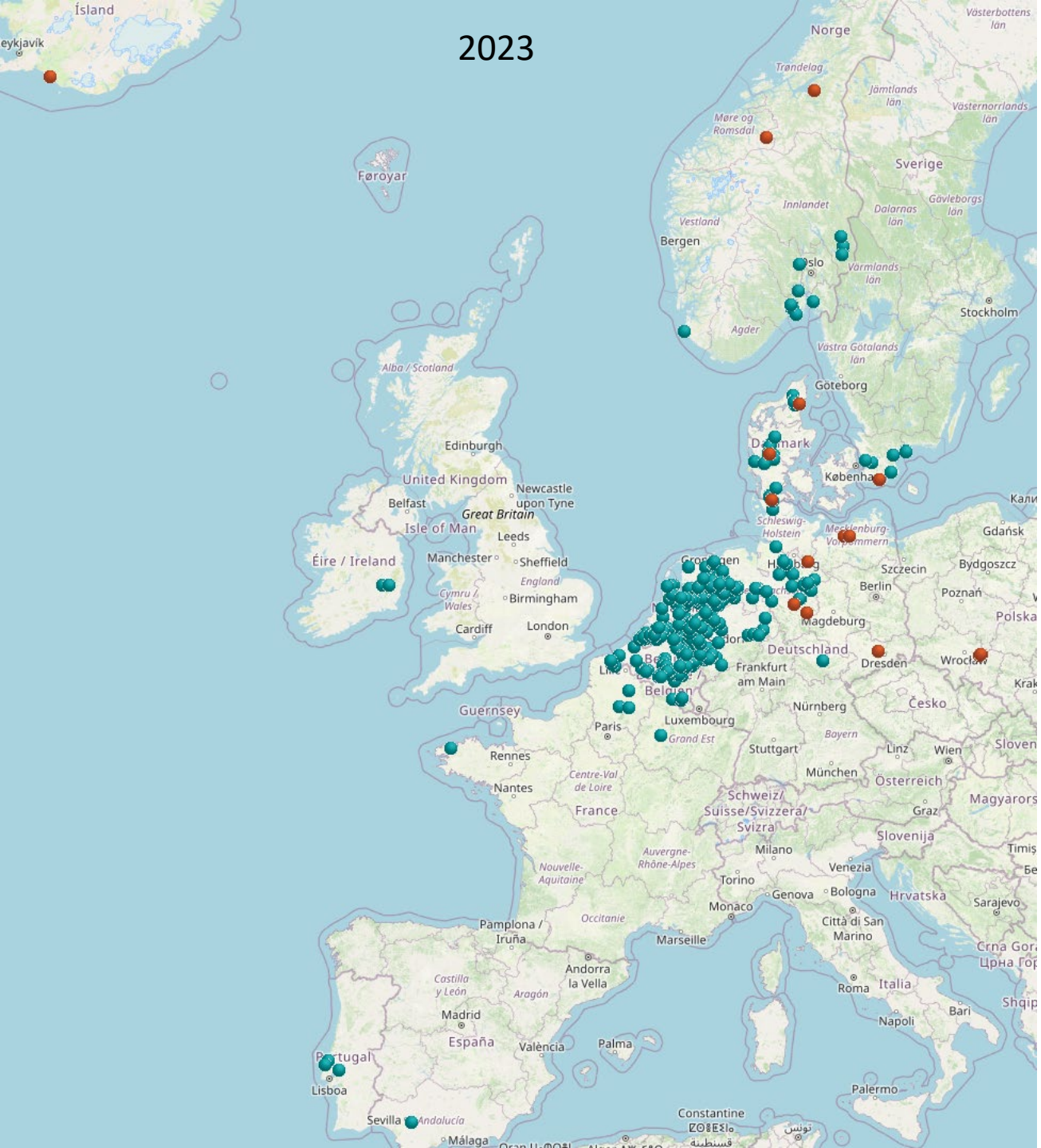
EU43: from 64% in 2022 to 19,7% in 2023.

EU41: from 12 to 1% and

Others: from 24% to 76%

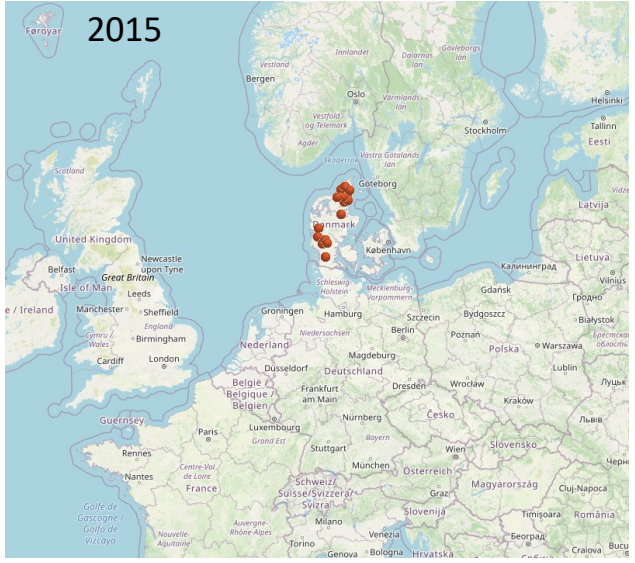


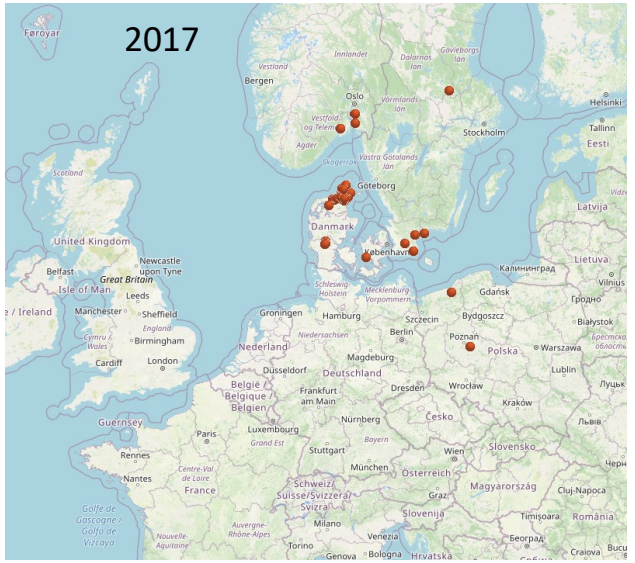


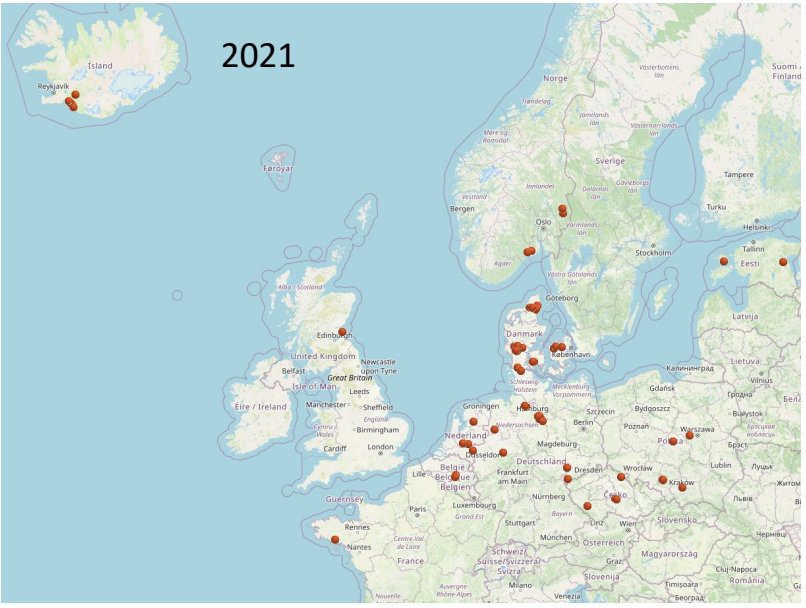


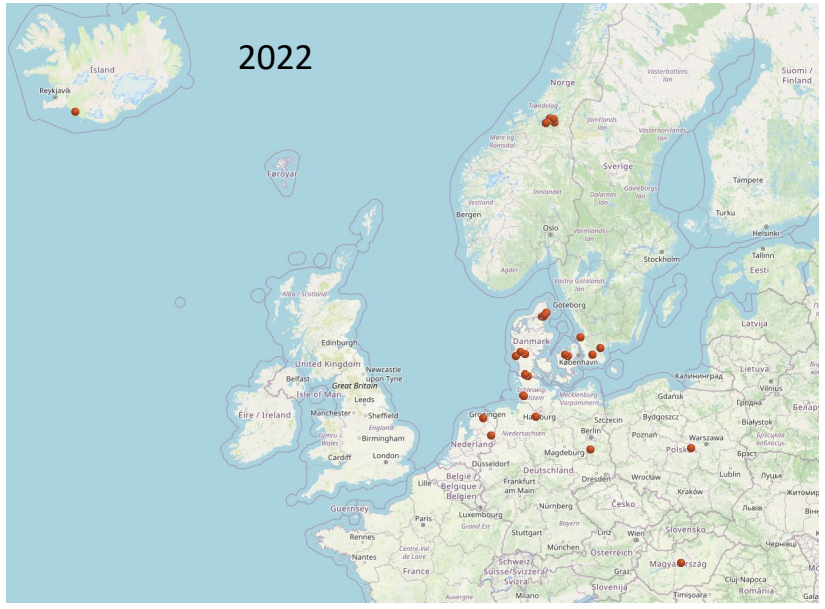
What is the history in time and space of two clones, initially found in Denmark

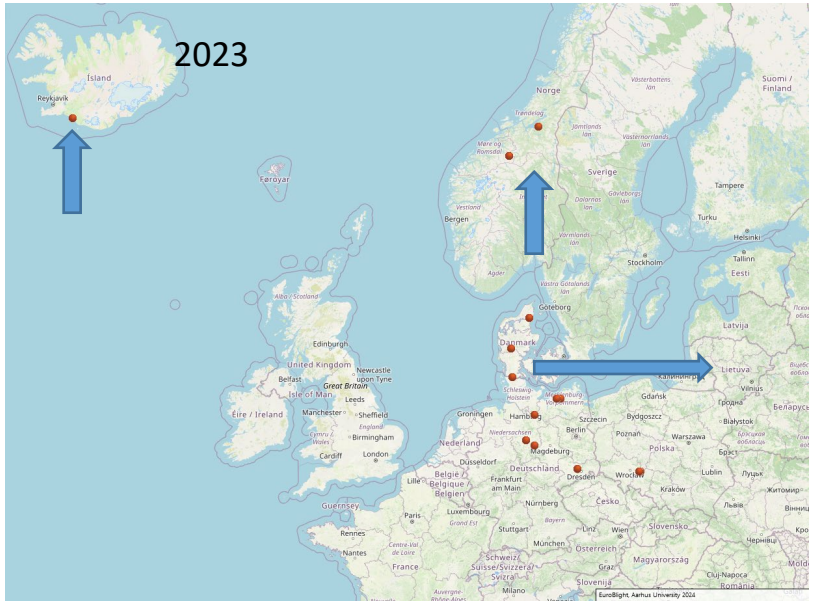
- EU41 in DK 2013
- EU43 in DK 2018





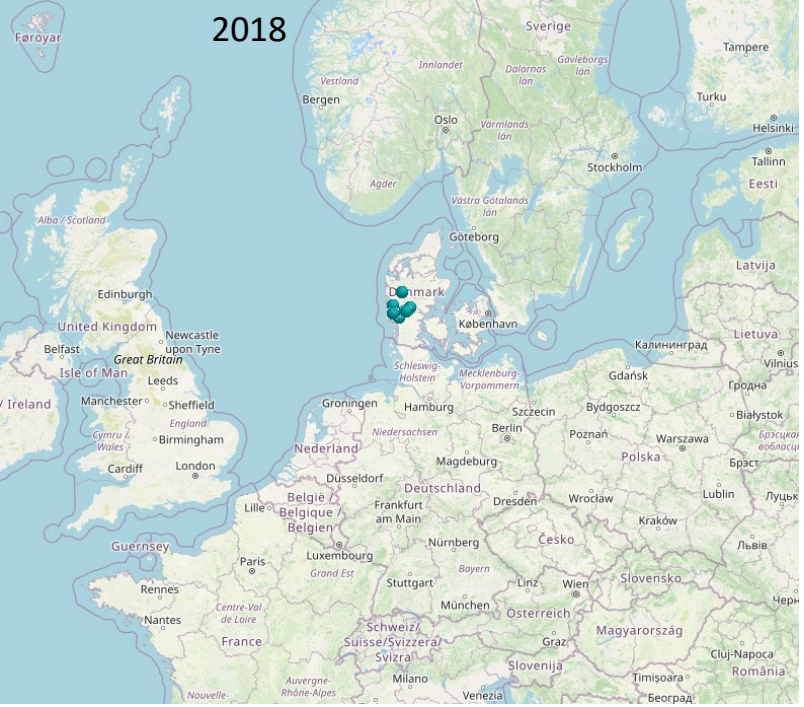




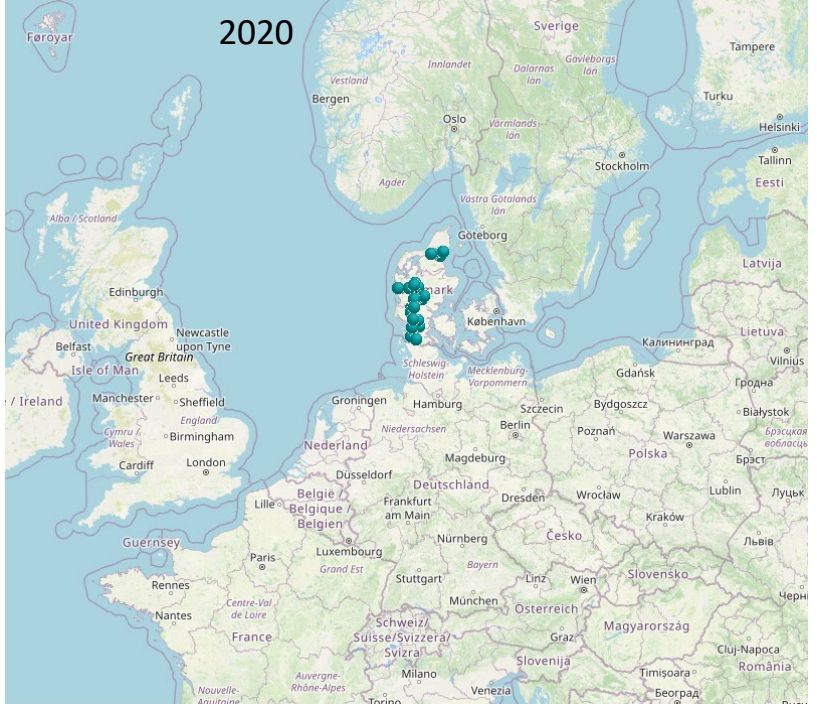


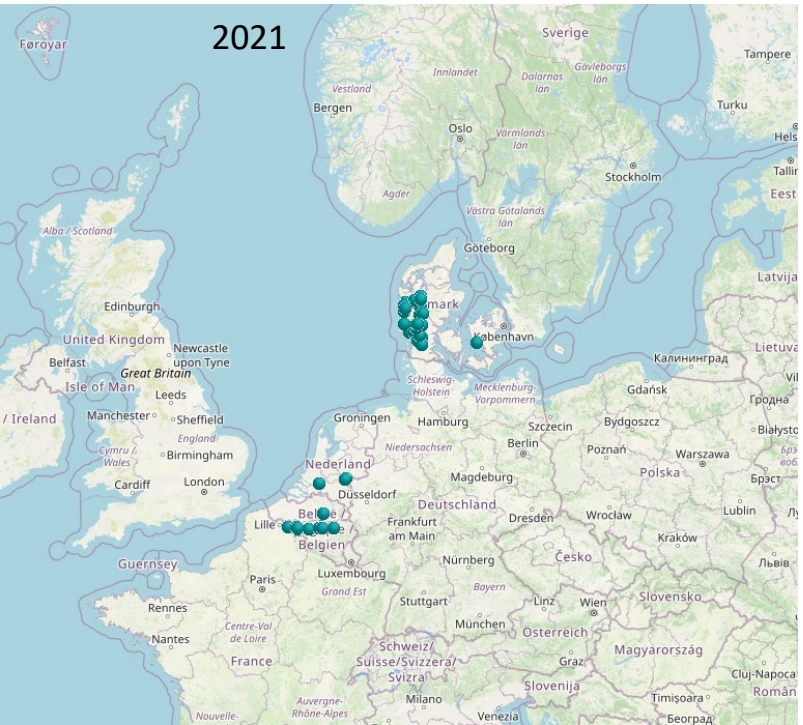
The evolution and spread of EU41

Go East and North

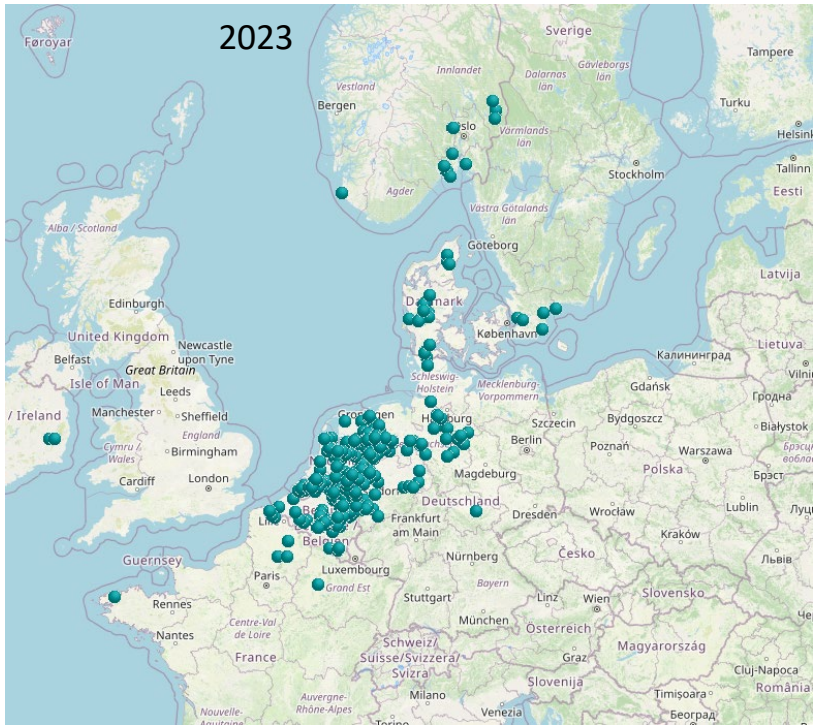

2018

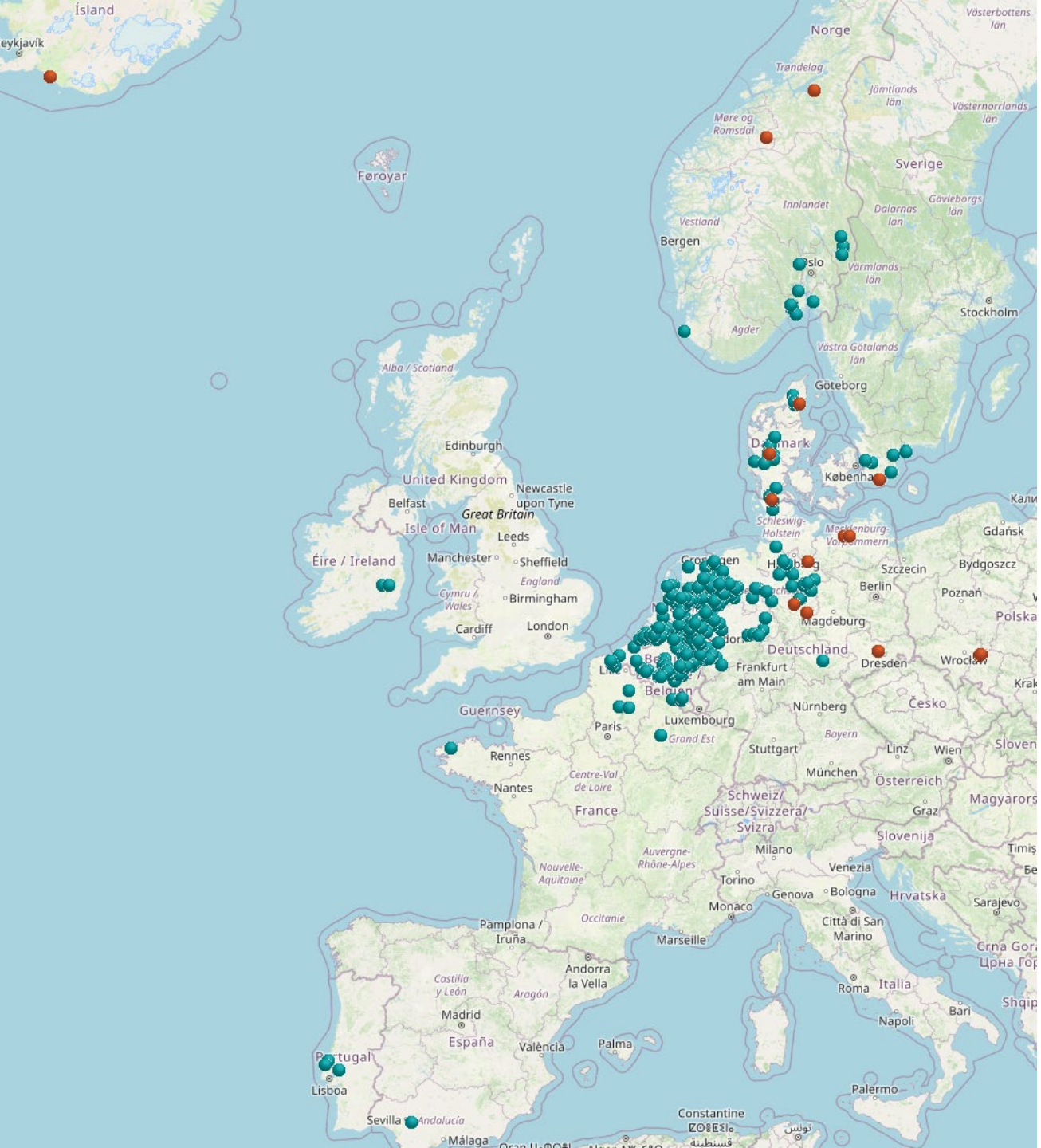

2019


2020


2021


2022


2023



Dataflow – management – display and analysis:

- Late blight disease surveillance
- Isolate characterisation
- Genotype * host cultivar interactions

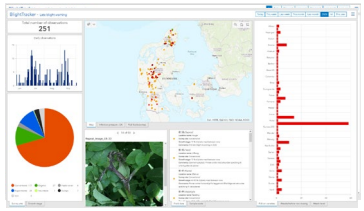
Building the Dashboard for analysis

Survey123

BlightTracker
Browser App

or

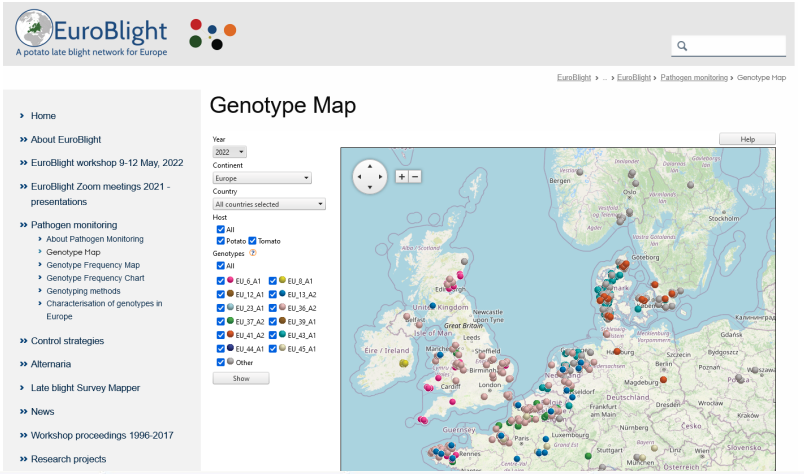
BlightTracker
Smartphone App



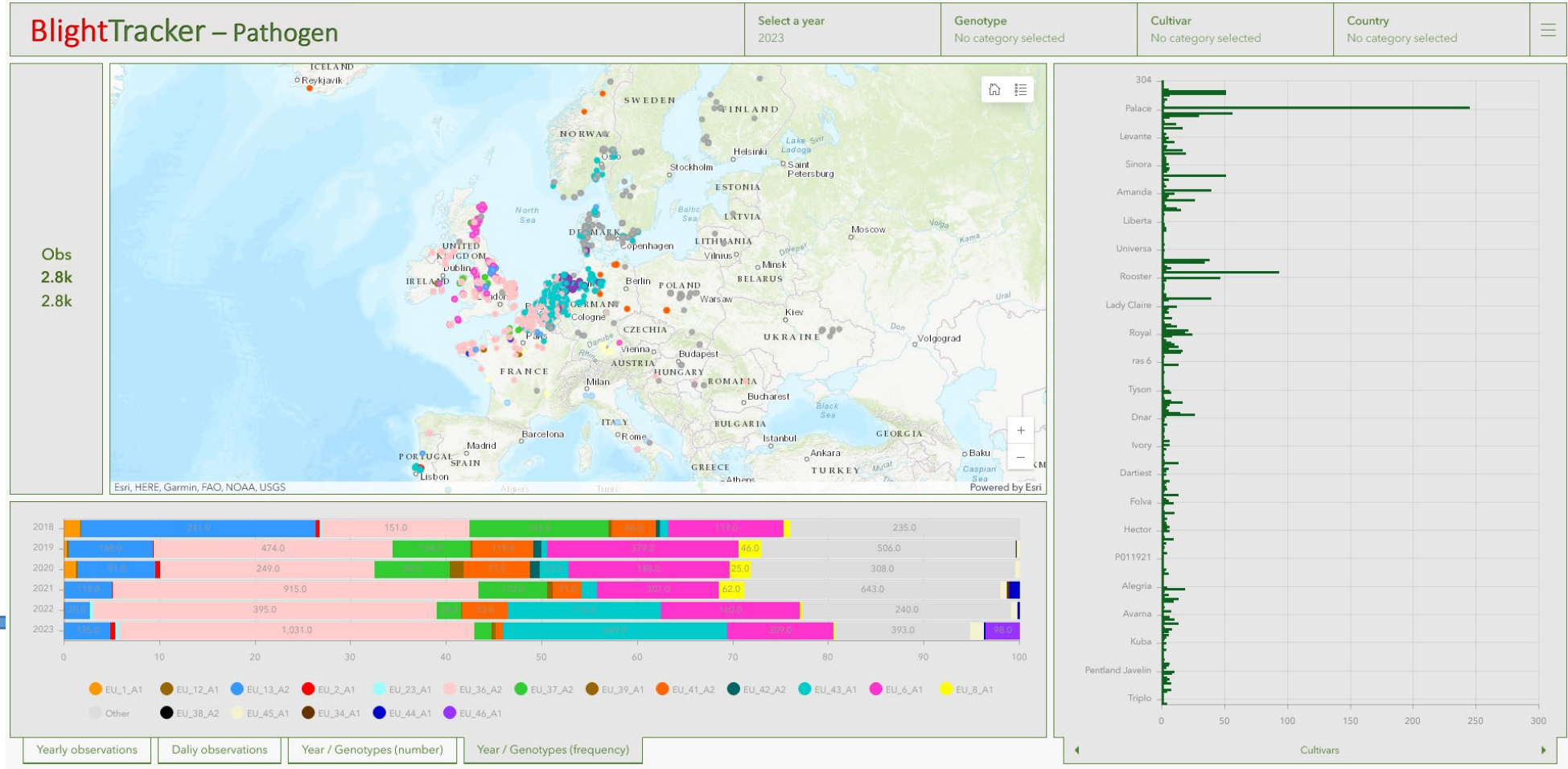
ESRI Cloud dashboard

Barcode scan the
code on FTA card

Public in EuroBlight
(Open Street map)



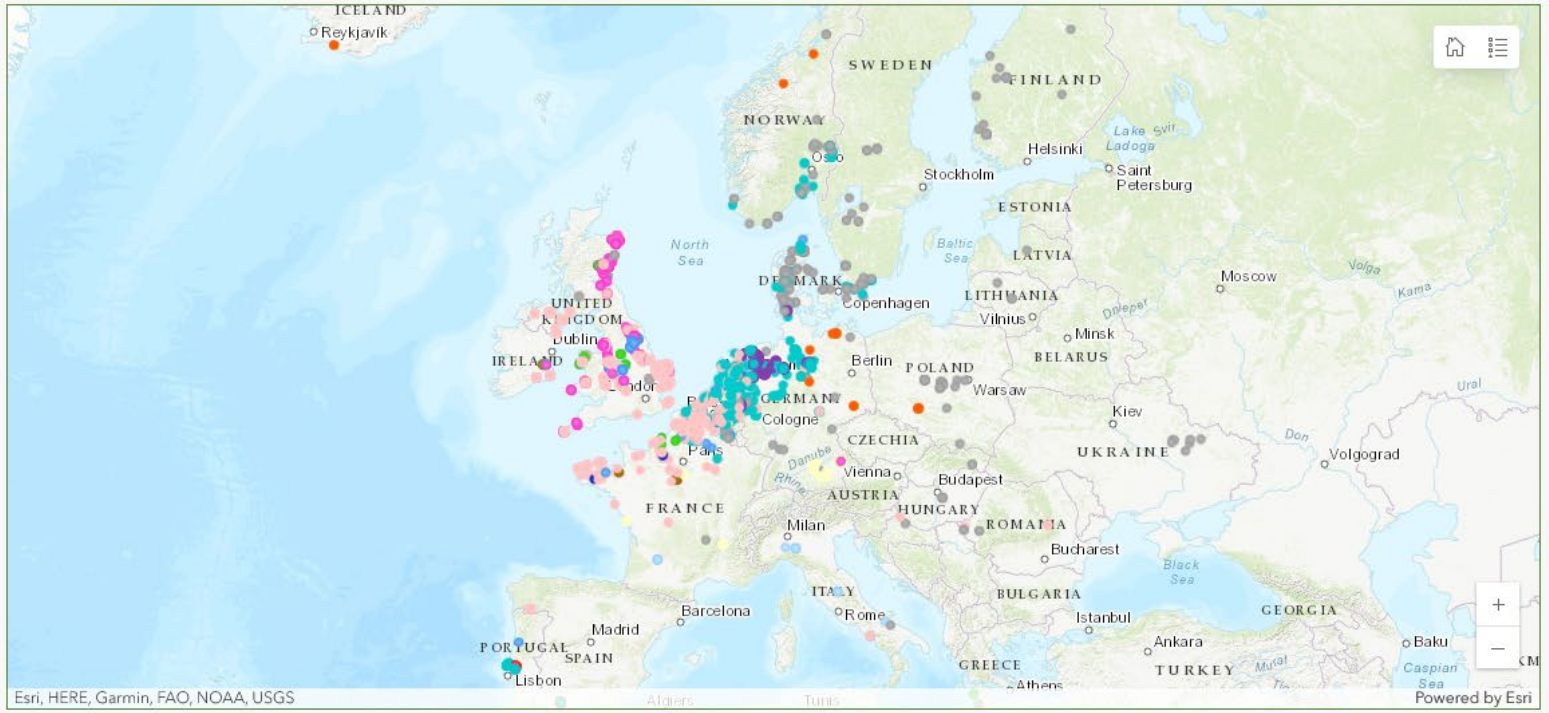
Start using the ESRI Dashboards
For analysis and dissemination

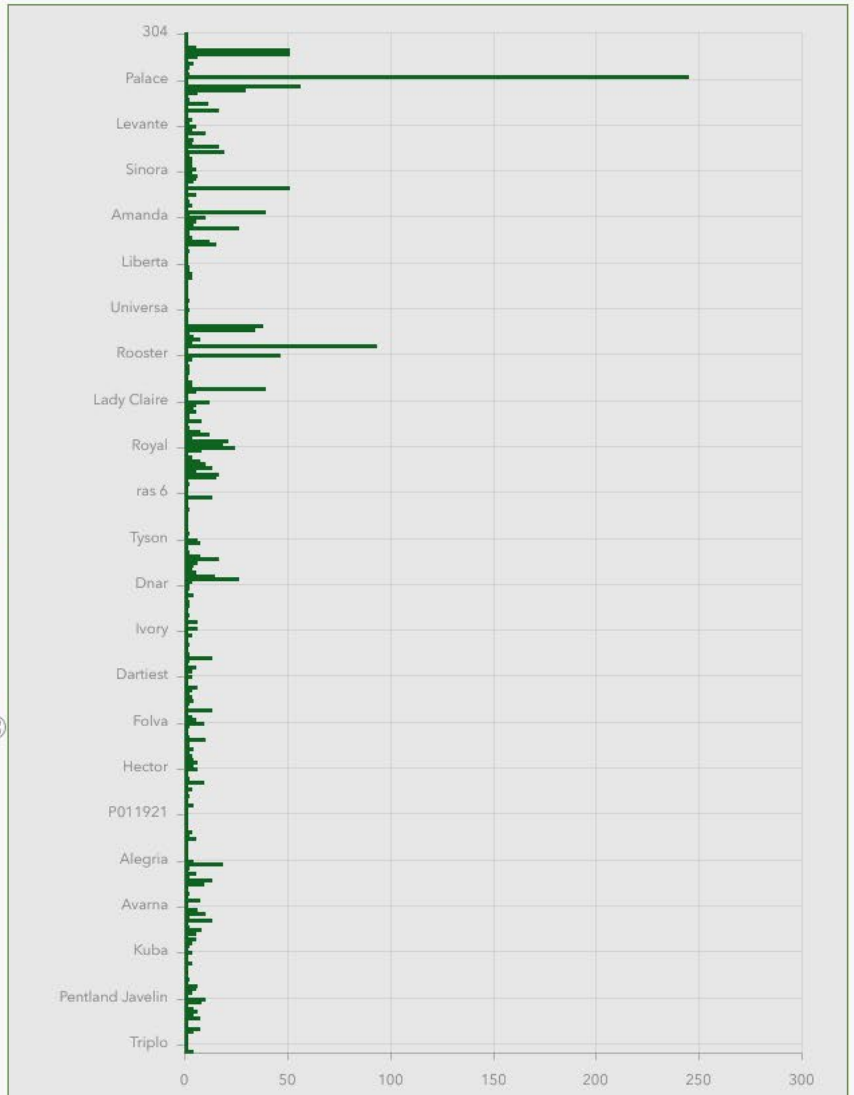


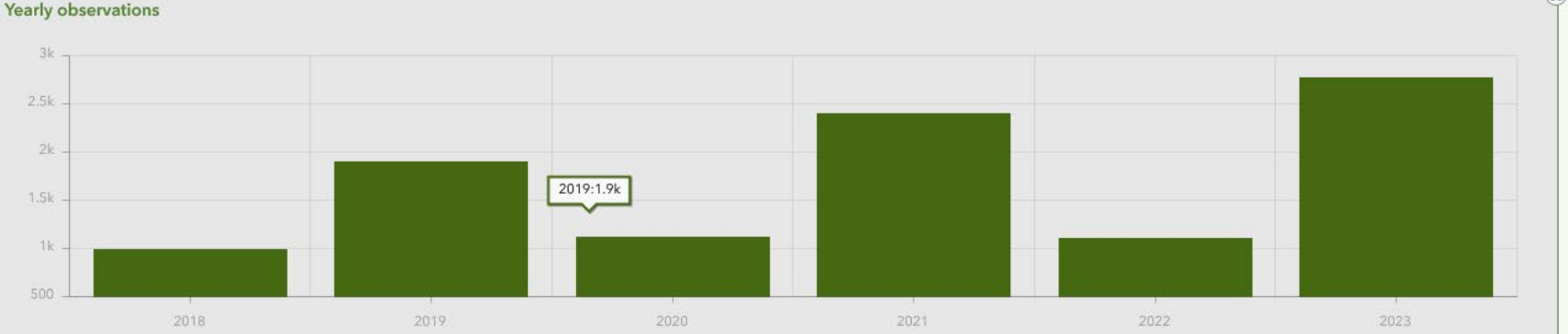
BlightTracker – Pathogen

Select a year	Genotype	Cultivar	Country
2023	No category selected	No category selected	No category selected

Obs
2.8k
2.8k





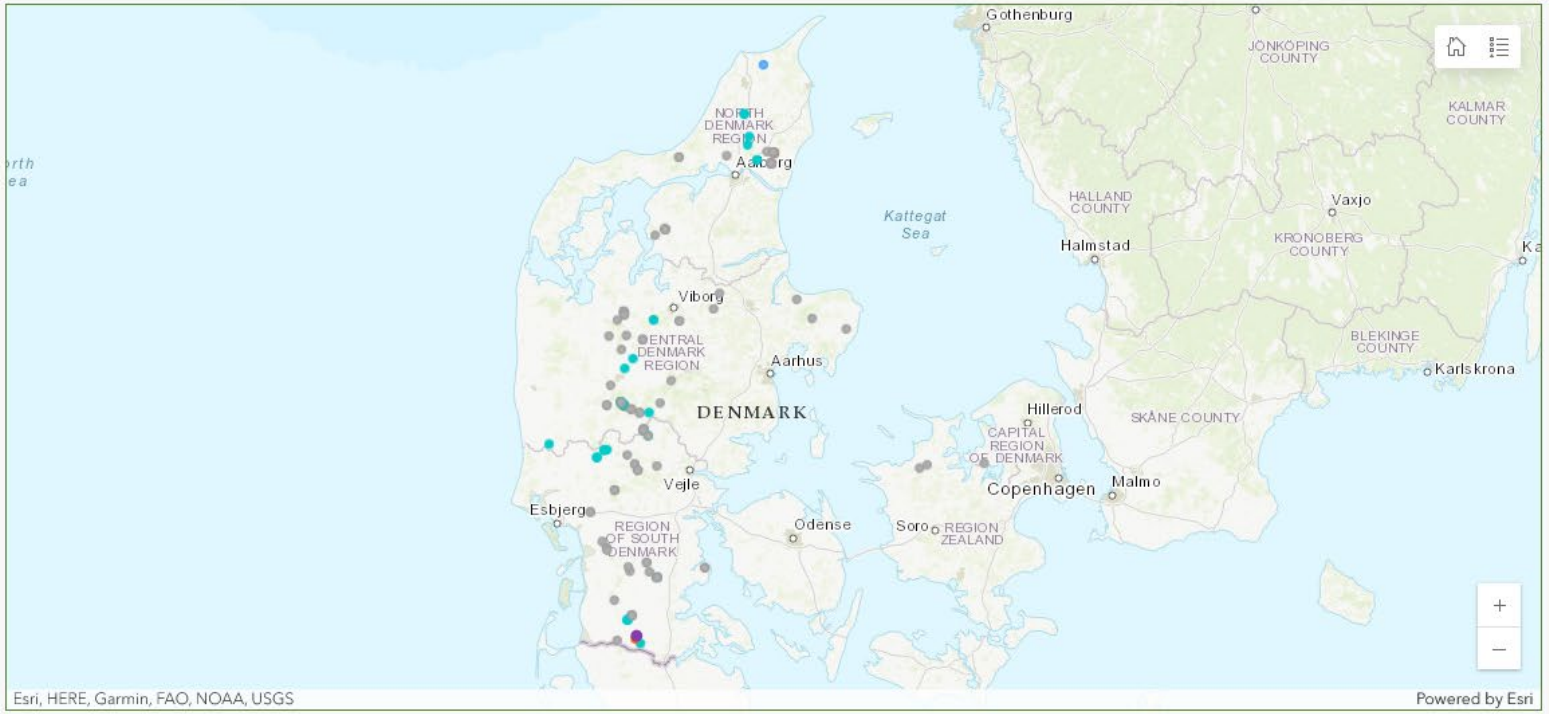


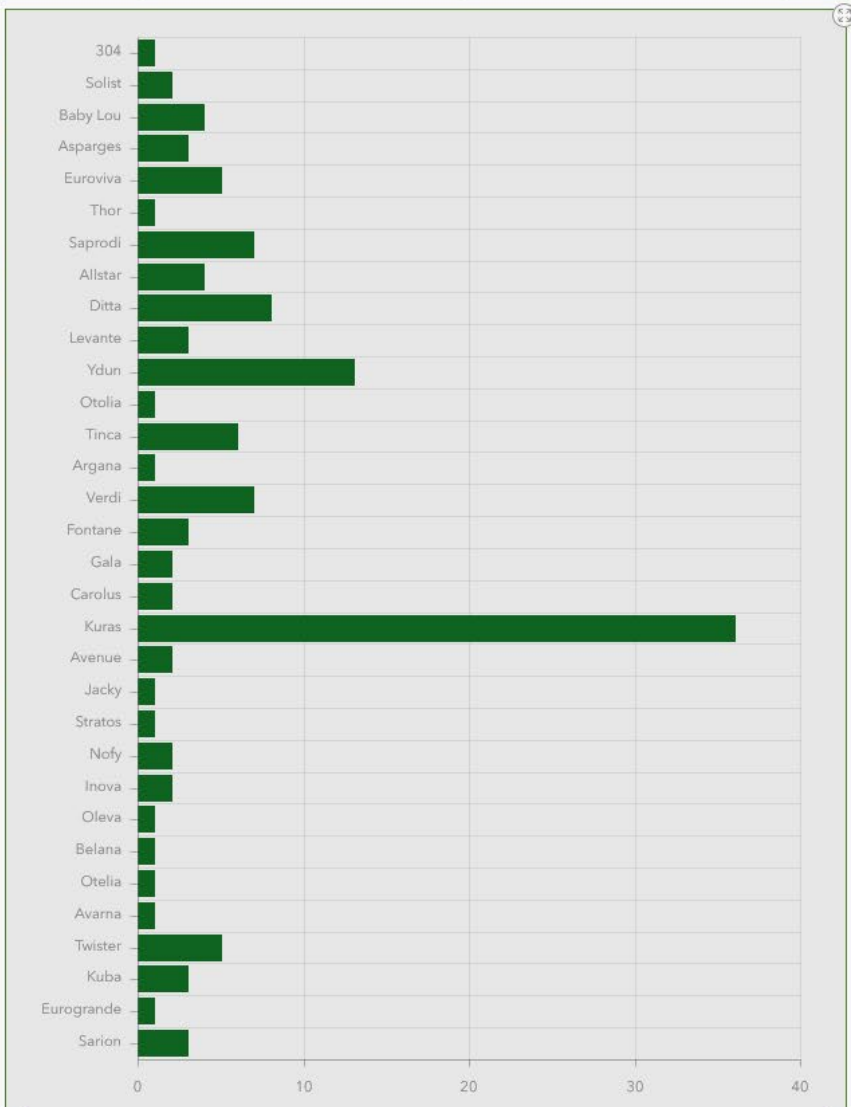
Yearly observations | Daliy observations | Year / Genotypes (number) | Year / Genotypes (frequency)

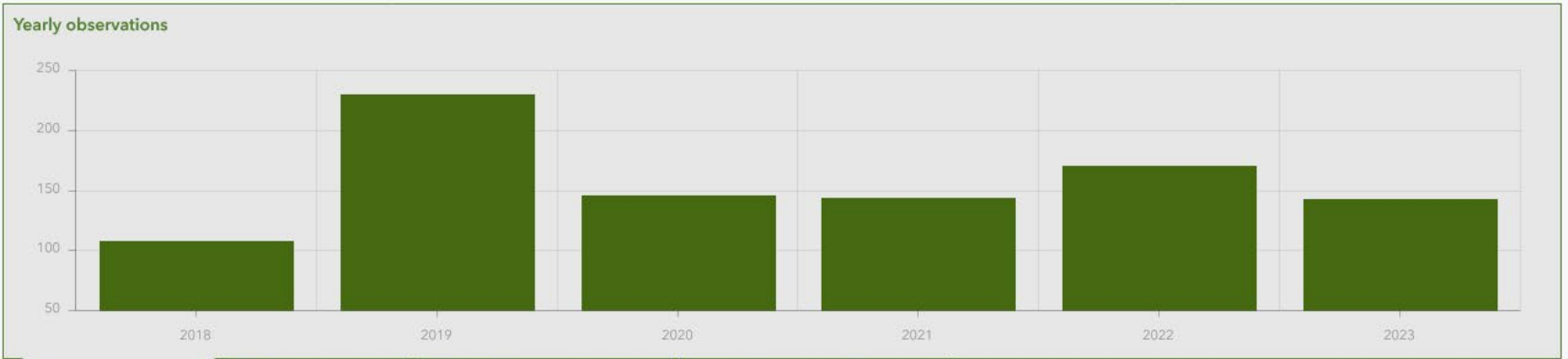
BlightTracker – Pathogen

Select a year	Genotype	Cultivar	Country
2023	No category selected	No category selected	Denmark

Obs
142
2.8k





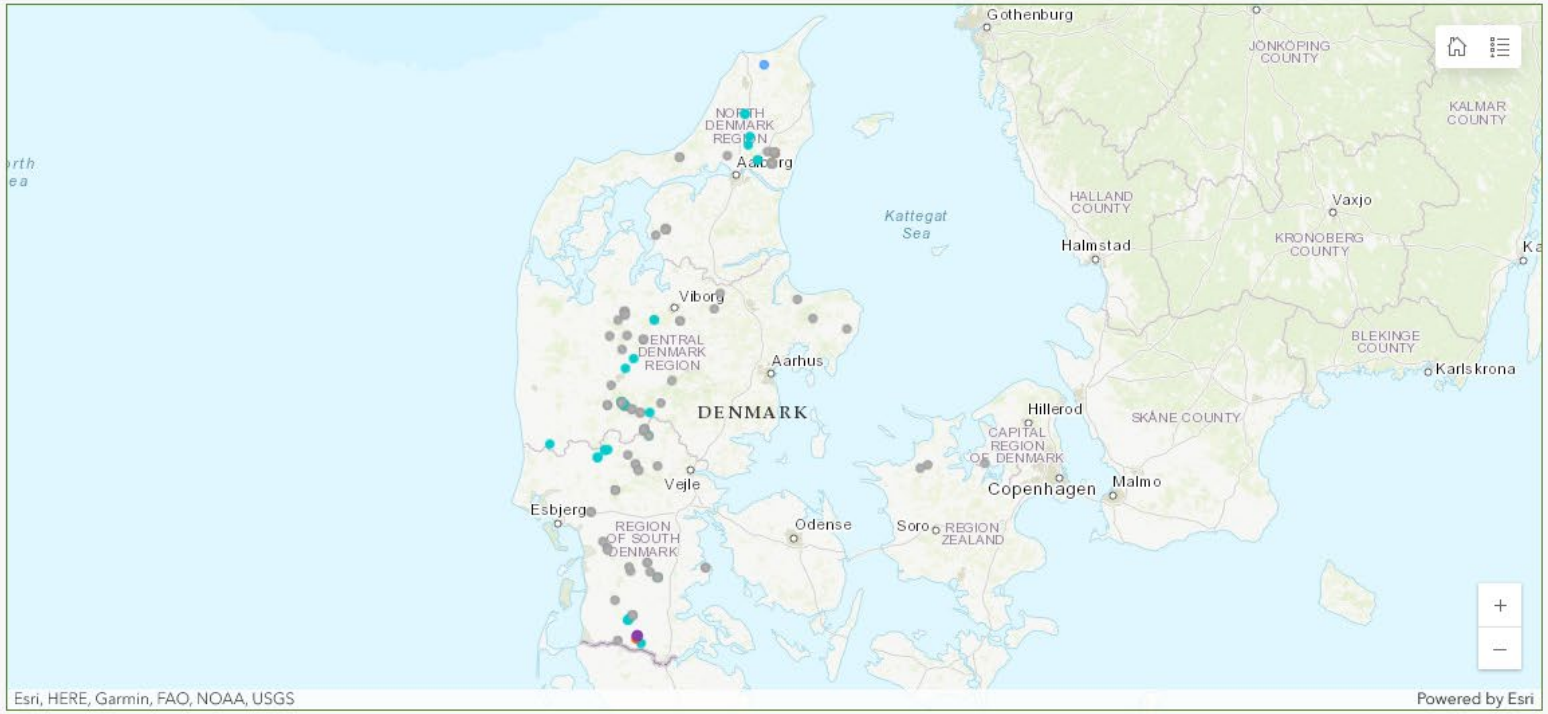


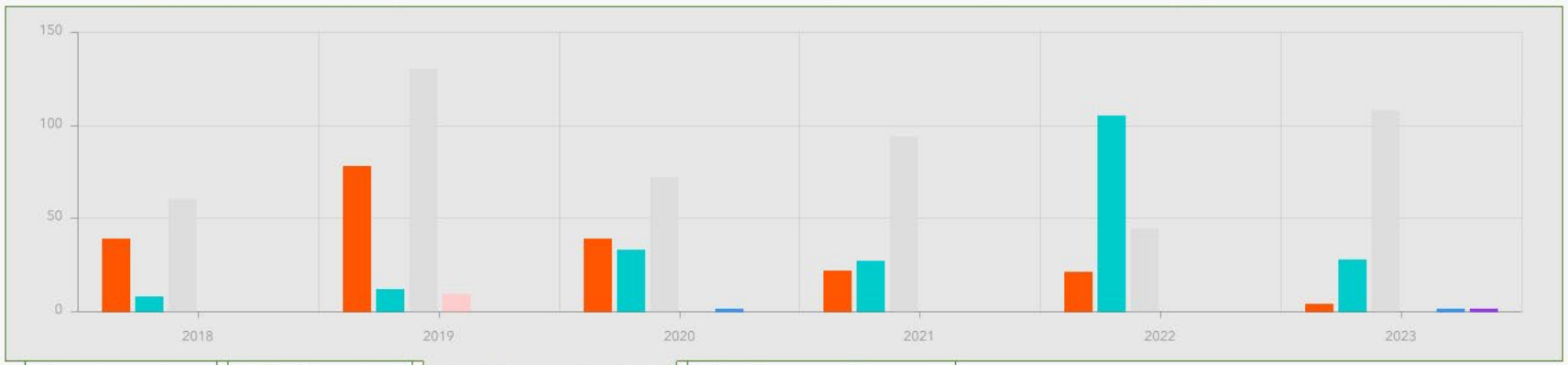
Yearly observations | Daliy observations | Year / Genotypes (number) | Year / Genotypes (frequency)

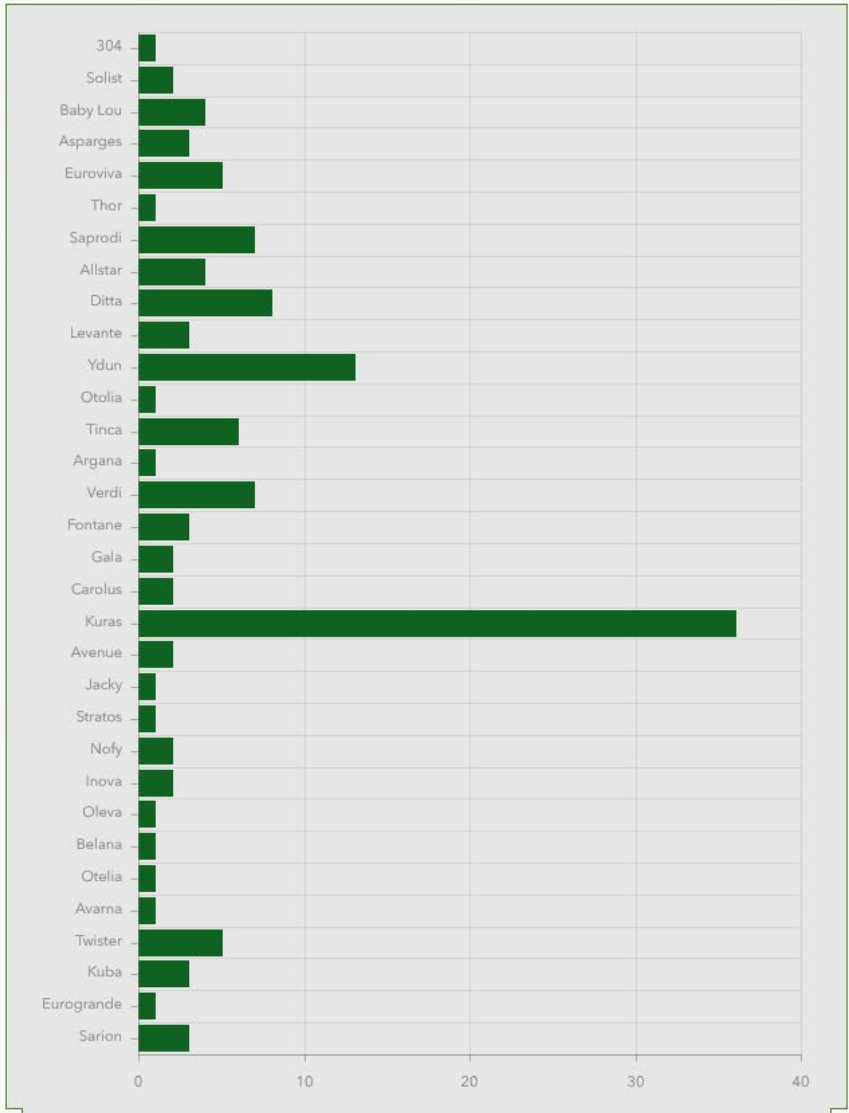
BlightTracker – Pathogen

Select a year	Genotype	Cultivar	Country
2023	No category selected	No category selected	Denmark

Obs
142
2.8k





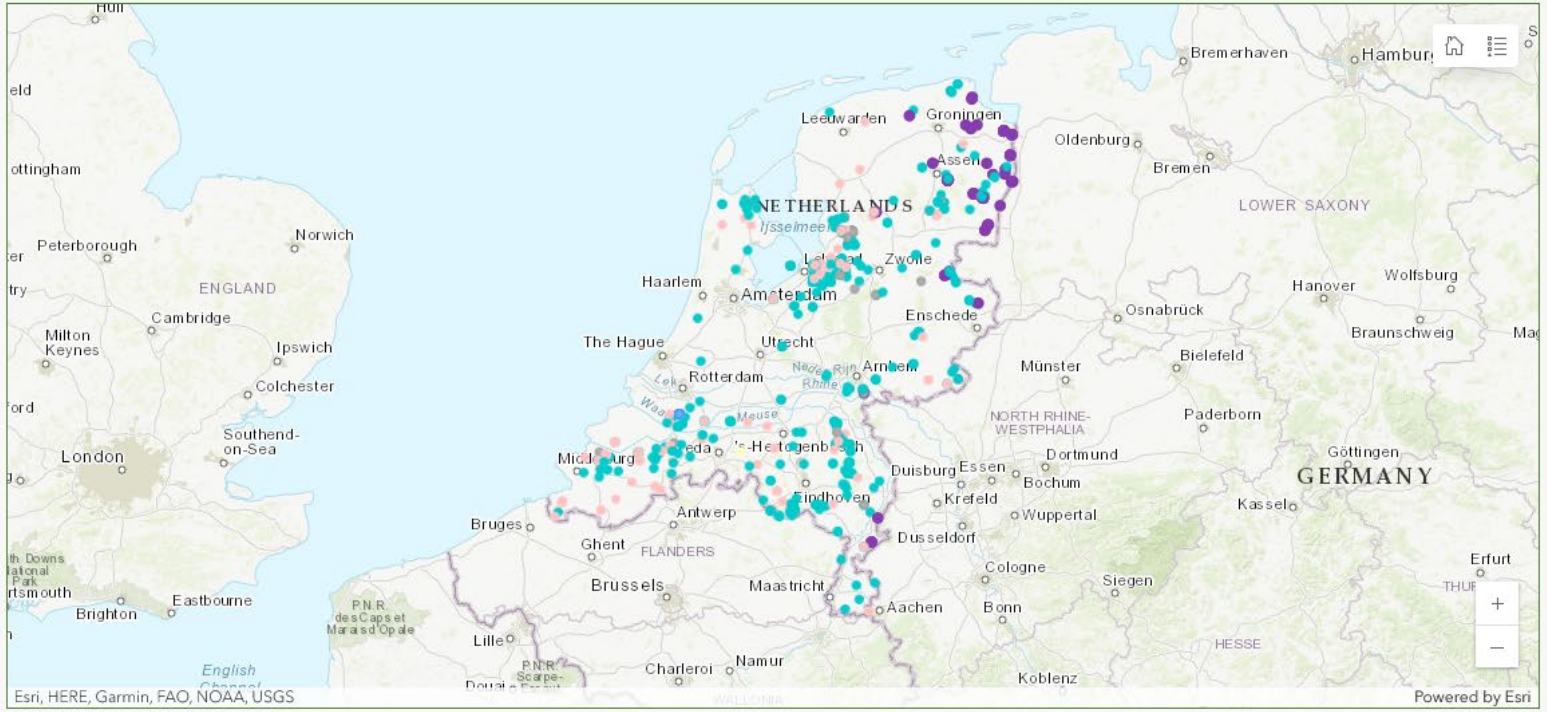


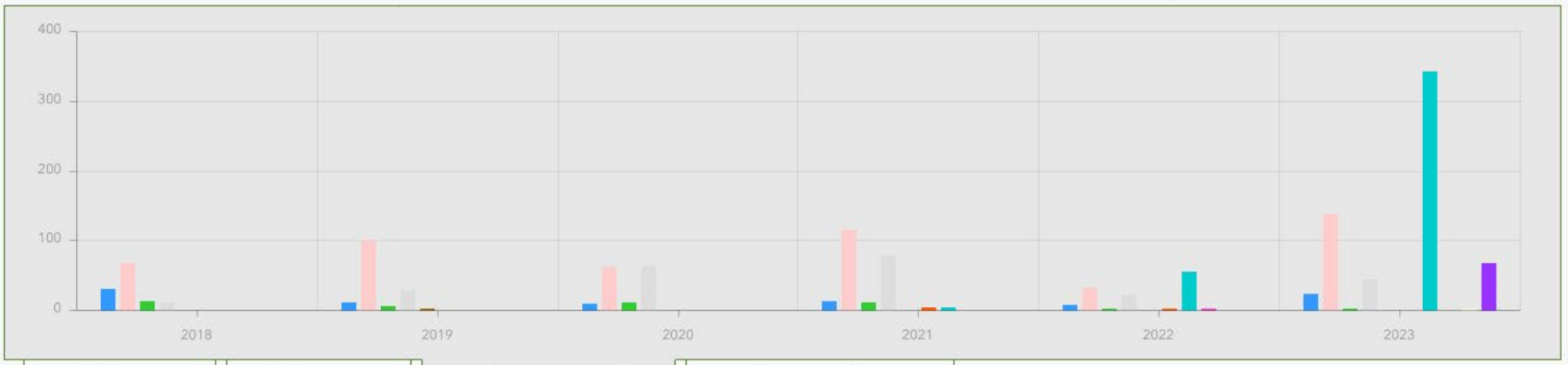
Yearly observations | Daliy observations | Year / Genotypes (number) | Year / Genotypes (frequency)

BlightTracker – Pathogen

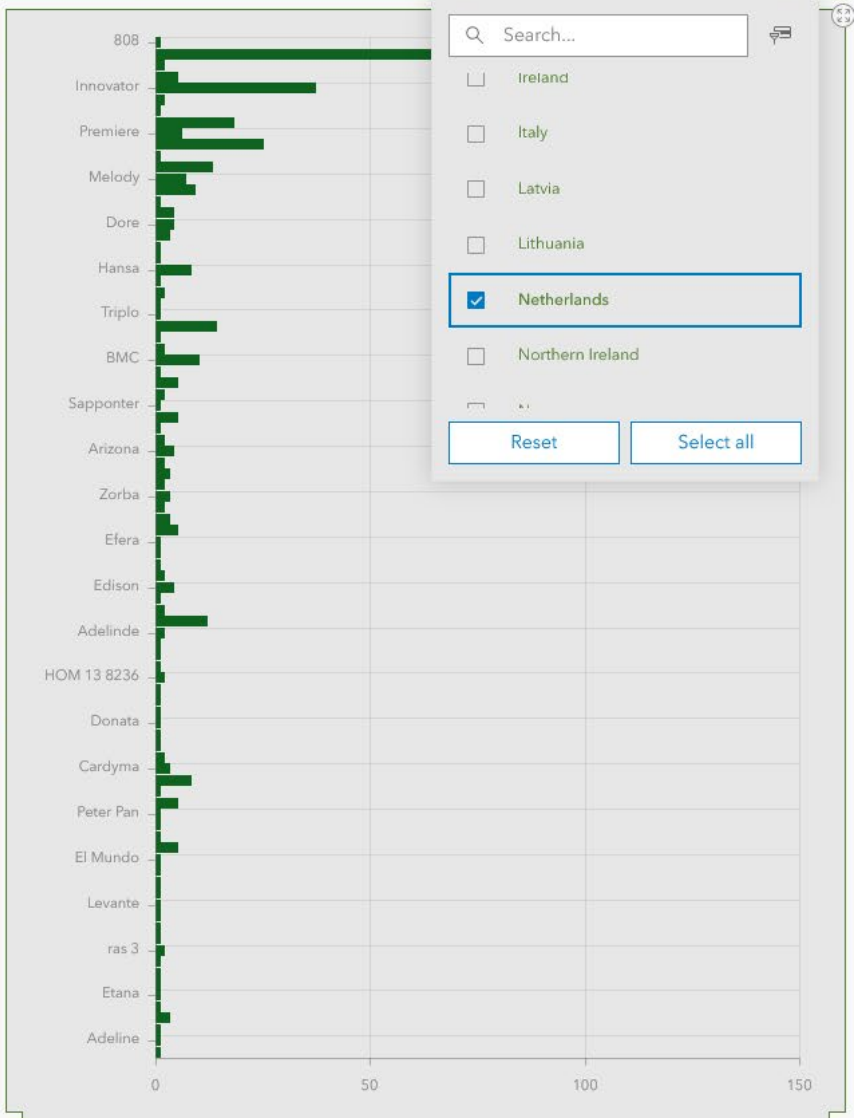
Select a year	Genotype	Cultivar	Country
2023	No category selected	No category selected	Netherlands

Obs
616
2.8k





Yearly observations | Daliy observations | Year / Genotypes (number) | Year / Genotypes (frequency)



Search...

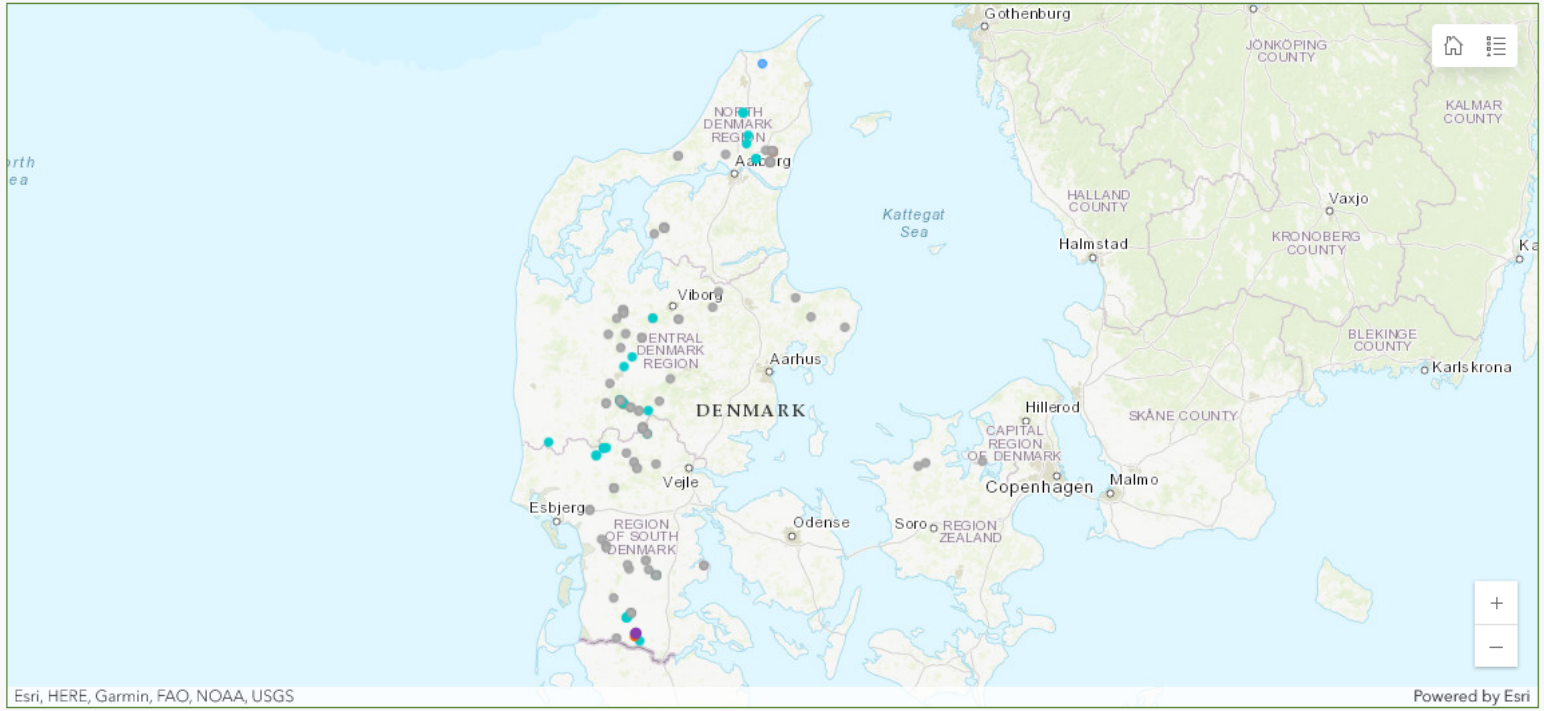
- [ ] Ireland
- [ ] Italy
- [ ] Latvia
- [ ] Lithuania
- [x] Netherlands
- [ ] Northern Ireland

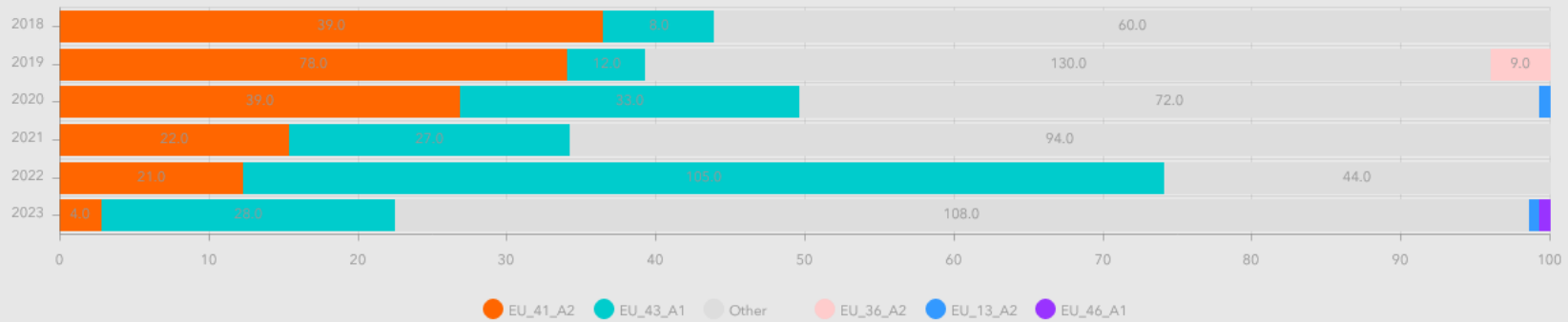
Reset | Select all

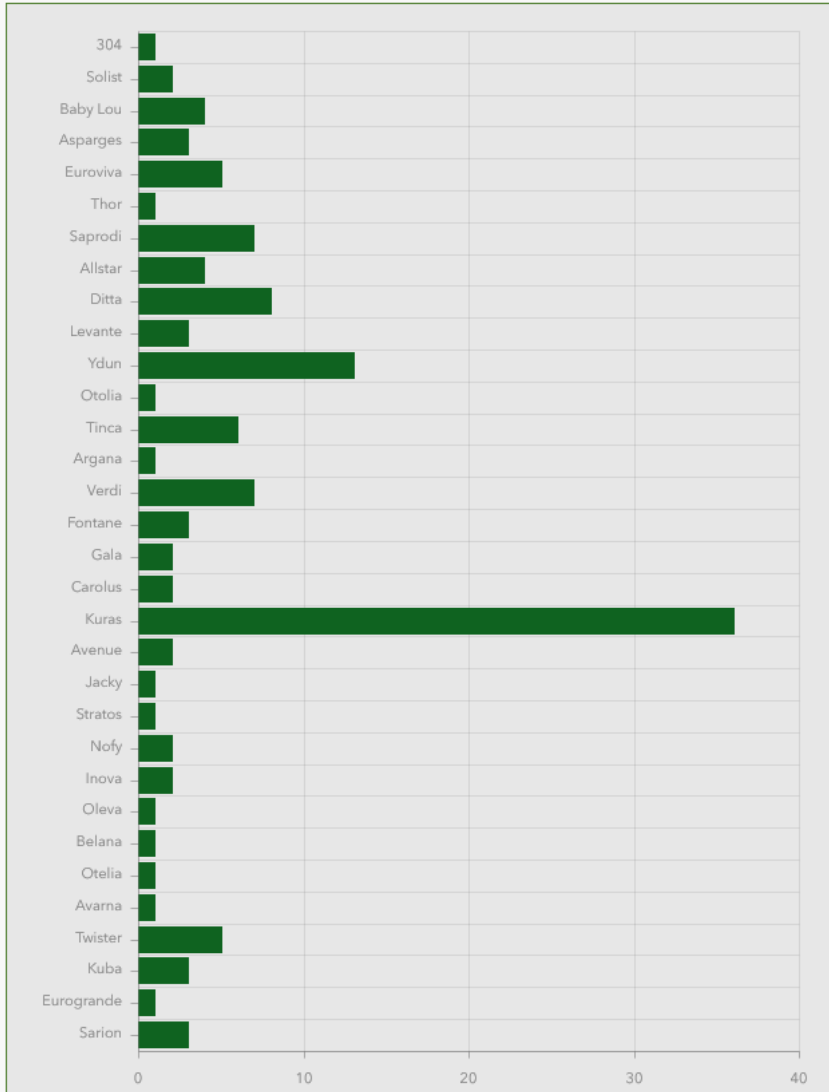
BlightTracker – Pathogen

Select a year	Genotype	Cultivar	Country
2023	No category selected	No category selected	Denmark

Obs
142
2.8k





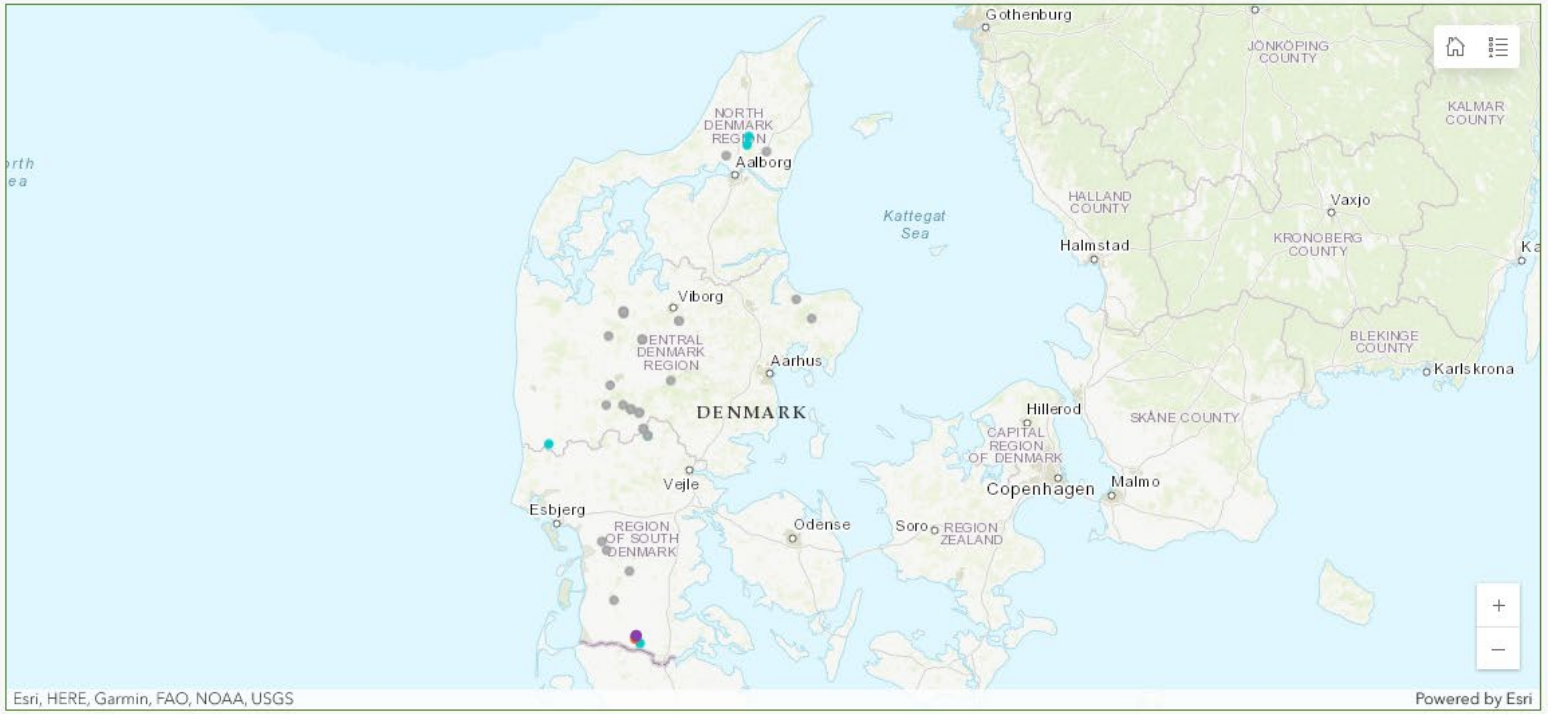


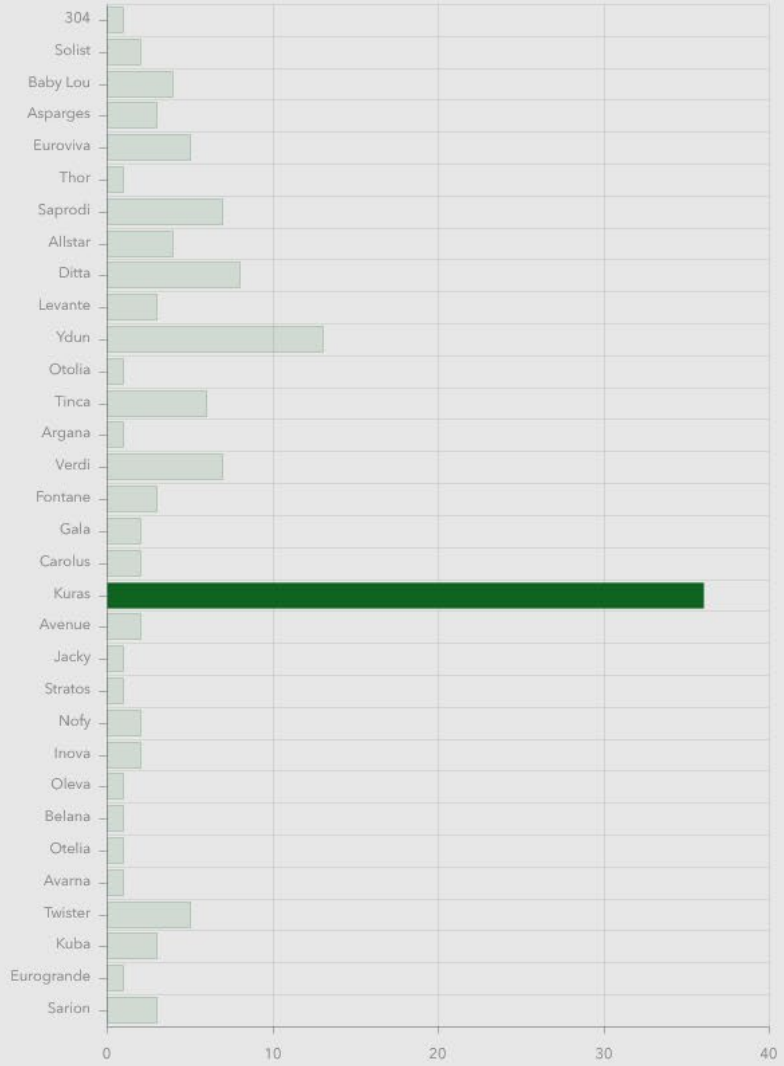
Yearly observations | Daliy observations | Year / Genotypes (number) | Year / Genotypes (frequency)

BlightTracker – Pathogen

Select a year	Genotype	Cultivar	Country
2023	No category selected	No category selected	Denmark

Obs
36
2.8k



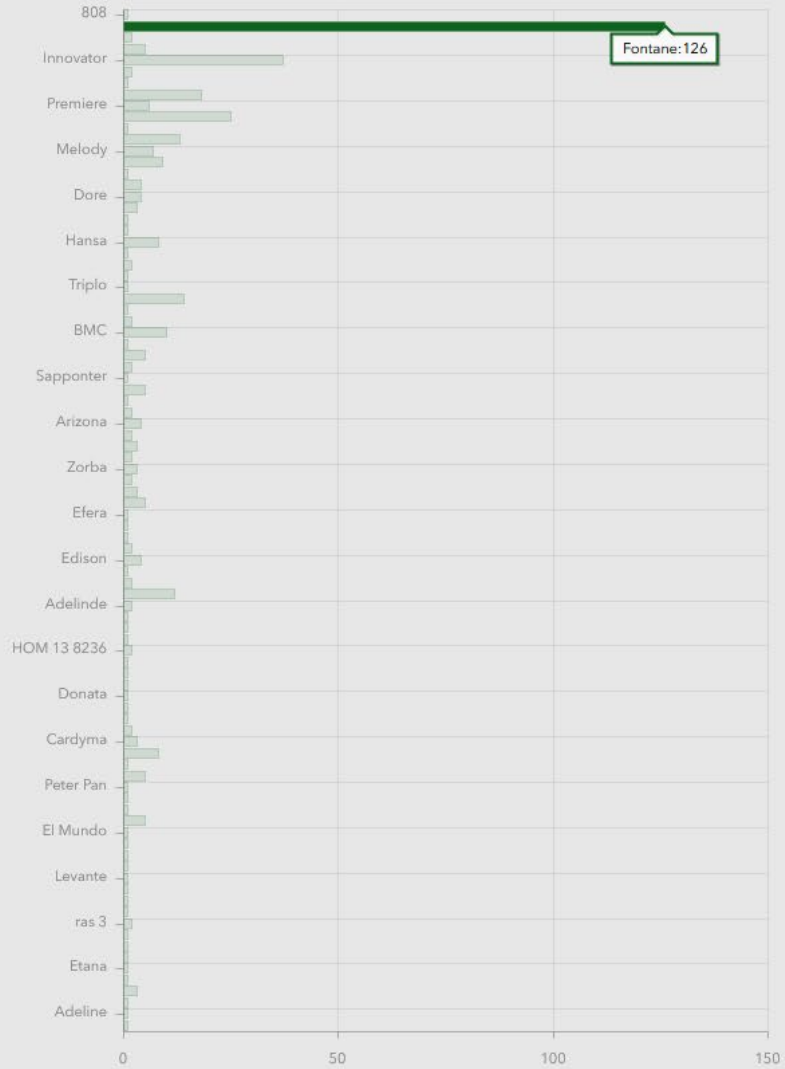


Yearly observations | Daliy observations | Year / Genotypes (number) | Year / Genotypes (frequency)

BlightTracker – Pathogen

Select a year	Genotype	Cultivar	Country
2023	No category selected	No category selected	Netherlands

Obs
126
2.8k



Yearly observations | Daliy observations | Year / Genotypes (number) | Year / Genotypes (frequency)

Cultivars

Potato Late Blight Toolbox

Home | Survey | Samples | Trials | Models | Fungicides | DSS Tools | DSS Tools for Sverige | DSS Tools for Island | Partners | API | Administration

Welcome Jens Grønbech Hansen logout

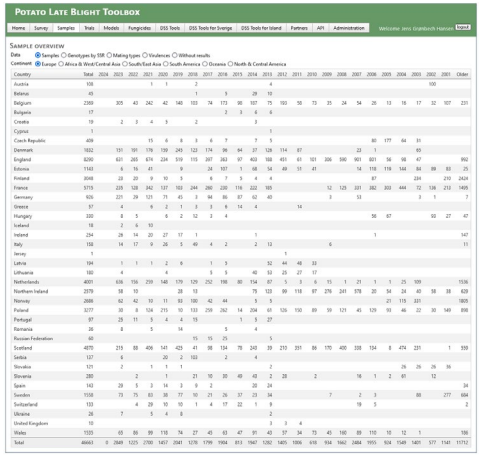
Sample overview

Data: (•) Samples ( ) Genotypes by SSR ( ) Mating types ( ) Virulences ( ) Without results

Continent: (•) Europe ( ) Africa & West/Central Asia ( ) South/East Asia ( ) South America ( ) Oceania ( ) North & Central America

Country	Total	2024	2023	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	Older
Austria	108				1	1		2					4											100		
Belarus	45							1		5		29	10													
Belgium	2369		305	43	242	42	148	103	74	173	98	187	75	193	58	73	35	24	54	26	13	16	17	32	107	231
Bulgaria	17									2	3	6	6													
Croatia	19		2	3	4	5		2				3														
Cyprus	1												1													
Czech Republic	409				15	6	8	3	6	7		7	5							80	177	64	31			
Denmark	1832		151	191	176	159	245	123	174	96	64	37	126	114	87				23	1			65			
England	8290		631	265	674	234	519	115	397	363	97	403	188	451	61	101	306	590	901	801	56	98	47			992
Estonia	1143		6	16	41		9		24	107	1	68	54	49	51	41			14	118	119	144	84	89	83	25
Finland	3048		23	20	9	10	5		6	7	5	4	4							87			234		210	2424
France	5715		235	128	342	137	103	244	260	230	116	222	185				12	125	331	382	303	444	72	136	213	1495
Germany	926		221	29	121	71	45	3	94	86	87	62	40				3		53				3	1		7
Greece	57		4		6	2	1	3	3	6	14	4			14											
Hungary	330		8	5		6	2	12	3	4										56	67			93	27	47
Iceland	18		2	6	10																					
Ireland	254		26	14	20	27	17	1				1								1						147
Italy	158		14	17	9	26	5	49	4	2		2	13				6									11
Jersey	1													1												
Latvia	194		1	1	1	2	6		1	5			52	44	48	33										
Lithuania	180		4			4			5	5		40	53	25	27	17										
Netherlands	4001		636	156	259	148	179	129	252	198	80	154	87	5	3	6	15	1	21	1	1	25	109			1536
Northern Ireland	2579		58	10			28	13				75	123	99	118	97	276	241	578	20	54	24	40	58	38	629
Norway	2686		62	42	10	11	93	100	42	44		5	5								21	115	331			1805
Poland	3277		30	8	124	215	10	133	259	262	14	204	61	126	150	89	59	121	45	129	93	46	22	30	149	898
Portugal	97		25	11	5	4	4	15			1	5	27													
Romania	36		8		5		14			5		4														
Russian Federation	60							15	15	25			5													
Scotland	4870		215	88	406	141	425	41	98	134	78	243	39	210	351	86	170	400	338	134	8	474	231		1	559
Serbia	137		6			20	2	103		2		4														
Slovakia	121		2		1	1	1						2									26	26	26	36	
Slovenia	280			2		1		21	10	30	49	43	2	28		2			16	1	2	61		12		
Spain	143		29	5	3	14	3	9	2			20	24													34
Sweden	1558		73	75	83	38	77	10	21	26	37	23	34				7		2	3			88		277	684
Switzerland	133			4	29	10	10	1	4	17	22	1	9						19	5						2
Ukraine	26		7		5	4	8						2													
United Kingdom	10												3	3	4											
Wales	1535		65	86	99	118	74	27	45	63	47	91	43	57	34	73	45	160	89	110	10	12	1			186
Total	46663	0	2849	1225	2700	1457	2041	1278	1799	1904	813	1947	1282	1405	1006	618	934	1662	2484	1955	924	1549	1401	577	1141	11712

46663 samples from 38 countries



EuroBlight database

DK: EU41 EU43

2004 2010 2013 2018 2023

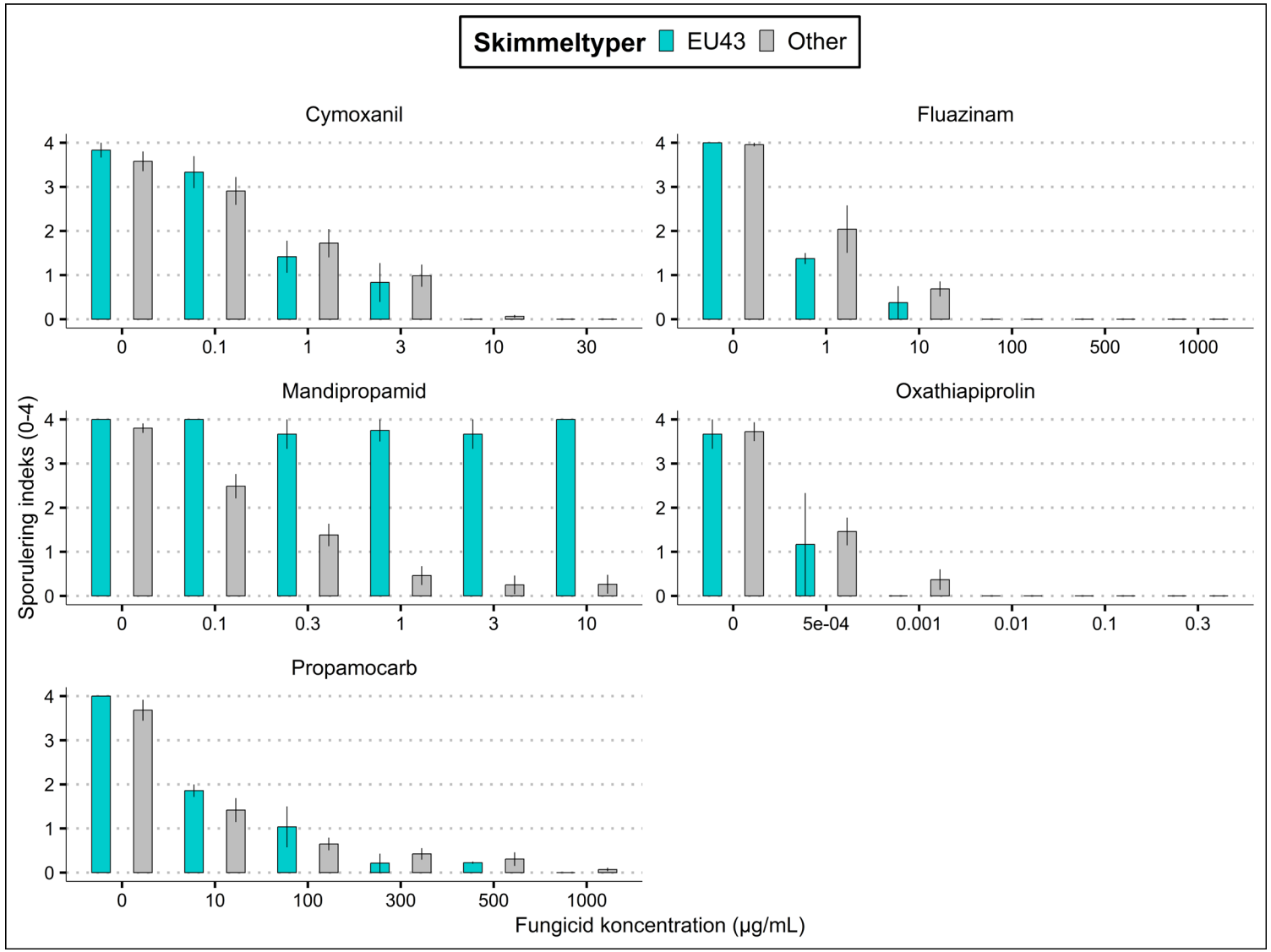
NL: EU13 EU33 EU36 EU37 EU46

Why do NL and DK have the highest number of MLGs in Europe

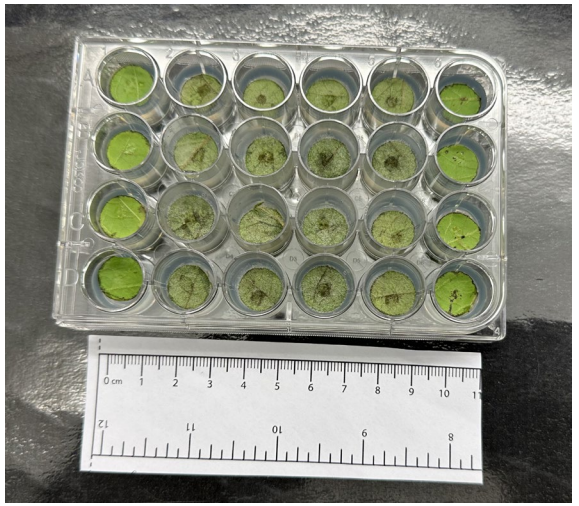
Where is the centre of diversity in Europe?

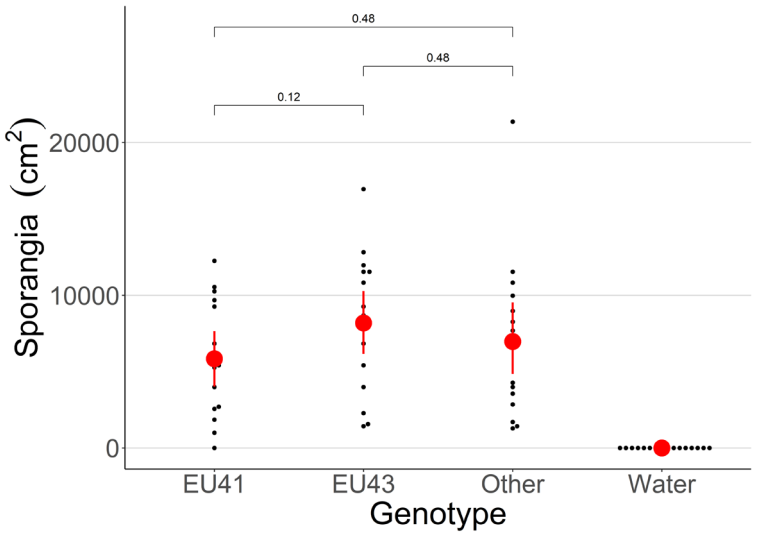
Country	No of MLGs in 2023	N
The Netherlands	114	633
Denmark	101	144
Eng, Sco & Wa	94	909
Belgium	81	305
France	69	235
Germany	67	219

Except EU43 and mandipropamid, all tested isolates were sensitive to the fungicides tested



Agressiveness tests of EU43
See presentation by Isaac K Abulay later





This a game of Chess and **we won the first match against Phytophthora**.
But the game is best out of 5 matches!

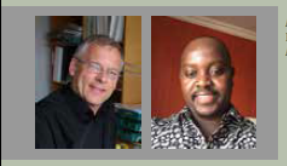
Farmers' journal, May 2024

Variants of *P. infestans* in 2023 – What can we expect in 2024?

The 10 principles for control strategy 2024

From Science to Practice

From Practice to Science



AF JENS GRØNBECH HANSEN & ISAAC KWESI ABULEY, AARHUS UNIVERSITET

SKIMMELTYPER 2023
– og hvad kan vi forvente i 2024?

Vi forventer, at EU43 kun i mindre grad udvikles fra inficerede knolde på grund af et sundt læggemateriale. Derfor skal der være fokus på de alternative smittekilder, bl.a. affaldsdynger, spildkartofler, spredning af smitstof med vinden fra Tyskland og indført inficeret læggemateriale fra områder i Holland, Belgien og Nordtyskland.

I 2022 kom der mere skimmel end forventet, fordi en Revus resistent variant, EU43, bredte sig markant i Danmark, fra 21 procent i 2021 til 64 procent i 2022 (Fig.1).

Tilsvarende skete i Holland hvor EU43 steg fra en procent i 2021 til 42 procent i 2022. Det var et vink med en vognstang.

I 2023 ændrede anbefalingerne i Danmark sig til, at Revus ikke skulle bruges i starten, og at der skulle bruges blandinger af produkter med forskellig virkemekanisme. Målet var klart. Vi kan ikke undvære mandipropamid (aktivstof i Revus) i vores arsenal af aktivstoffer, dels fordi det ifølge EuroBlight er et af de bedste midler mod skimmel, dels fordi Ranman Top lige er blevet forbudt og endelig, fordi fraværet af de to midler vil lægge et alt for stort selektionspres på de resterende tilladte midler- ikke mindst fluazinam, som er aktivstoffet i bl.a. Shirlan.

Planen virkede, men kun fordi forskning, rådgivning, industri og avlerne arbejdede sammen om at forstå, hvad der skete og om at finde de rette løsninger. Aarhus Universitet har netop analyseret de sidste prøver for både genotypning (genetisk fingeraftryk) og fænotypning (resistens, sporuleringskapacitet, etc.). Vi kan nu lave en endelig opgørelse om genotyper i 2023. Kan man også forudsige, hvad der vil ske i 2024?

Måske, hvis man forstår fortiden.

Udviklingen af skimmeltyper i Danmark 2017-2023

I 2023 blev der fundet ét eksemplar af EU13, i en have i Nordjylland med aspargeskartofler. Der blev også fundet en ny skimmel type for første gang i Danmark, EU46, i en konventionel mark med Kuras tæt på den tyske grænse.

EU41 er faldet fra 30-40 procent i 2017-2019 til 2,8 procent (4 isolater) i 2023.

EU43 er faldet fra 64 procent i 2022 til 20 procent i 2023. Til gengæld er gruppen "andre" steget fra 24 procent til 76 procent (Fig. 1).

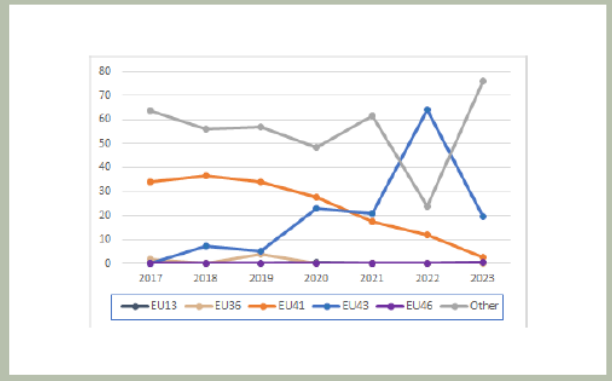
Forskel i hyppigheden af EU43 mellem konventionel og økologisk

I 2023 startede et nyt projekt om økologiske kartofler: "Sustainability and Resilience in Organic Potato Production - SROPP".

I dette projekt har vi indsamlet skimmel fra mange økologiske marker for at sammenligne populationen af skimmel i marker med forskellig dyrkning. Det viste sig, at der var stor forskel på hyppigheden af EU43 imellem de forskellige dyrkningstyper.

Af skimmel, indsamlet i 69 konventionelle marker, var 25 procent EU43, tilsvarende var 27 procent EU43 i indsamlinger fra forsøg, 12 procent EU43 i indsamlin-

Figur 1. Udviklingen af skimmeltyper i Danmark, 2017-2023



AVLERINFO

AF LARS BØDKER
LANDSKONSULENT
SEGES INNOVATION

Der udvikles hurtigt resistens i kartoffelskimmel, når specifikke svampemidler anvendes i blokke med flere behandlinger efter hinanden uden blandingspartnere og hvis fx. Zorvec Enicade udsprøjtes på etableret skimmel i marken. Foto: Lars Bødker.

SKIMMELSTRATEGI 2024

Skimmelstrategien i 2024 er præget af meget få tilbageværende svampemidler til forebyggelse af kartoffelskimmel, resistens overfor Revus og en stærk stigende risiko for resistens overfor både Shirlan/ Banjo/Zignal og Zorvec Enicade. Det kan stadig lade sig gøre, men det kræver, at alle overholder nogle fælles principper.

Udvikling af resistens

Ligesom bakterier er i stand til at udvikle resistens overfor antibiotika, er kartoffelskimmel i stand til at udvikle resistens overfor både svampemidler med forskellige virkemekanisme men også bryde resistensgener i resistente kartoffelsorter. Jo flere gange, der behandles med det samme svampemiddel og jo oftere en sort dyrkes, jo nemmere er det for en mutation i en spore af kartoffelskimmel at blive opformeret og spredt ikke blot til Danmark men til hele Europa. Dette er sket med fx den resistente genotype af skimmel (EU43) overfor mandipropamid (Revus), som er muteret, opformeret og spredt fra Danmark helt til Portugal.

I de sidste 25 år har forskere, rådgivere og avlere haft stor fokus på reduktion af forbruget af svampemidler ved bekæmpelse af kartoffelskimmel på grund af både et økonomisk og miljømæssigt fokus. Der er lavet et utal af forsøg med forskellige beslutningsstøttesystemer (NegFry, Skimmelstyring, BlightManager, PlantPlus, Akkerweb), som har gjort det muligt at reducere dosering og variere intervaller samt anvende de stærkeste midler på de mest skimmelfavorable tidspunkter. Dette har sikret, at der i Danmark over en 25-årig periode er brugt en langt mindre mængde svampemidler og ressourcer end i vores omgivende lande.

I 2023 forekom der udbredt resistens (EU43) overfor mandipropamid (Revus) i store dele af specielt Nordeuropa. Kilde: EuroBlight.

Har dette været en fejl, når vi nu ser udbredt resistens overfor svampemidler? Et bakspejl er nu bedst til at bakke efter, men det er OK at blive klogere set i lyset af historien og ny viden. Kartoffelskimmel kender ingen grænser, og der er skabt resistens overfor kartoffelskimmel i andre lande end Danmark med langt større forbrug af pesticider fx Ridomil Gold, Shirlan i flere omgange og nu også Zorvec Enicade efter blot få års brug. Men set i bakspejlet har det været forkert, specielt efter forbuddet mod det bredspektrede mancozeb (Dithane), at anvende specifikke soloprodukter udbragt i blokke med 2-3 behandlinger i træk på etableret skimmel. Dette har ført til et unødigt højt risiko for opformering og spredning af resistente mutationer, risiko for opformering og spredning af resistente mutationer. Dette er ikke kun sket i Danmark, men i hele Europa.

Nu står specielt dansk kartoffelavl i en situation, hvor der er udviklet resistens overfor Revus i (EU43) 2022, og hvor registreringen af Ranman Top er trukket tilbage i januar 2023. Der er kun Shirlan/ Banjo/Zignal, Zorvec Enicade, Sporax/ Raport og Cymbal WG/Option WG tilbage i Danmark, hvor aktivstofferne i de to sidstnævnte kendes fra Proxanil. I lande, som grænser tæt op til Danmark, er der nu resistensdannelse overfor både Shirlan/ Banjo/Zignal og Zorvec Enicade, men som endnu ikke er bekræftet fundet i Danmark. Dette betyder, at der skal lægges en ny strategi for skimmelbekæmpelse for 2024, men som grundlæggende bygger videre på samme principper som i 2023.

Thank you for your attention

AARHUS UNIVERSITY

EuroBlight
A potato late blight network for Europe

Thanks to many partners and colleagues for contributing

Ministry of Food, Agriculture and Fisheries of Denmark
gudp

Miljøministeriet
Miljøstyrelsen