STATUS OF HERBICIDE RESISTANCE IN DENMARK

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STATUS OF HERBICIDE RESISTANCE IN DK, FEBRUARY 2021

Weed species	Herbicide MoA	First case	No. of locations
Stellaria media	ALS-TSR	1991	36
Galeopsis tetrahit	ALS-TSR	1999	1
Alopecurus myosuroides	ALS, ACCase	2001	104
Papaver rhoeas	ALS-TSR	2003	12
Tripleurospermum perforatum	ALS-TSR	2010	20
Lolium multiflorum	ALS, ACCase	2010	63
L. perenne	ALS, ACCase	2014	3
Apera spica-venti	ALS, ACCase	2010	8
Capsella bursa-pastoris	ALS-TSR	2011	1
Poa annua	ALS TSR	2015	5

METHODS TO FOLLOW RESISTANCE DEVELOPMENT

- Test of samples from farmers field (based on herbicide failure)
- Monitoring project 2013-15 (8 weed species from untreated plots). To be repeated in 2021.
- Monitoring project in Lolium (126 populations from sprayed fields with suspected resistance)
- RELIUM (ERA net project in cooperation with Greece and Italy)
- Resistant ryegrass – evolution and prevention (2018-21)

RESISTANCE TEST AT AU

Pot experiments comparing the susceptibility of samples with susceptible and resistant reference populations

Susceptible

Ubeh. 1/4N ½ N 1N 4N

- Broadway
- Lexus
- Primera S.
- Topik

Resistant

Ubeh. 1/4N ½ N 1N 4N

MONITORING FOR RESISTANCE 2013-2015

8% of 300 tested samples were resistant

30 % Alopecurus myosuroides (SU og fop/dim)
15 % Stellaria media (SU)
14 % Lolium multiflorum (SU)
19 % L. perenne (SU)
5 % Papaver rhoeas (SU)
1 % Tripleurospermum perforatum (SU)

No resistance in Apera spica-venti and Centaurea cyanus

MONITORING IN LOLSS, 2017

LOLMU: 93
LOLPE: 31

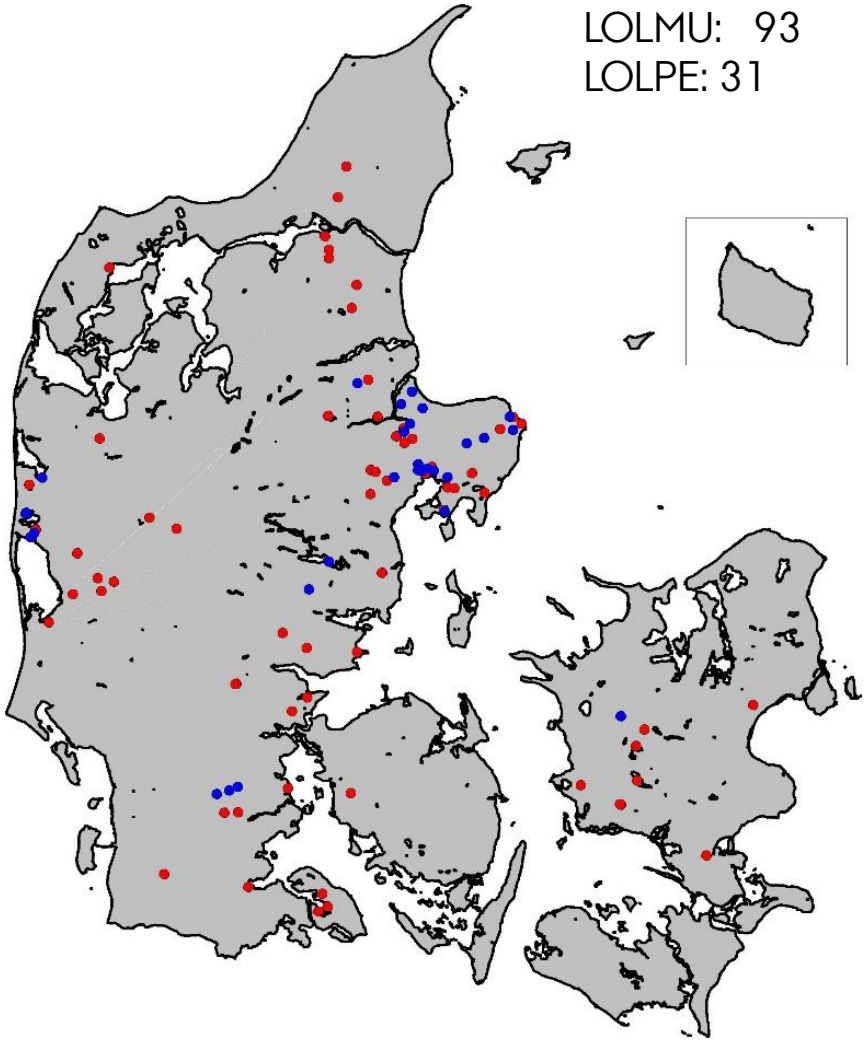
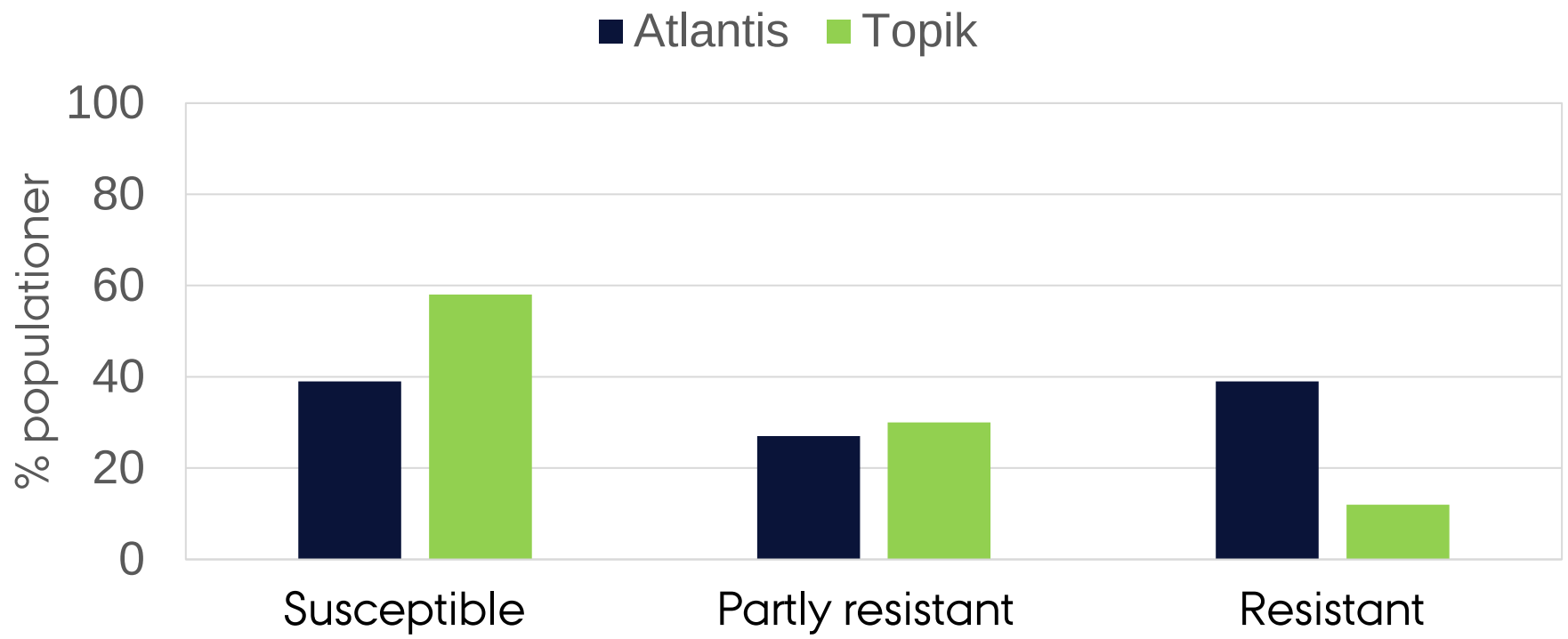


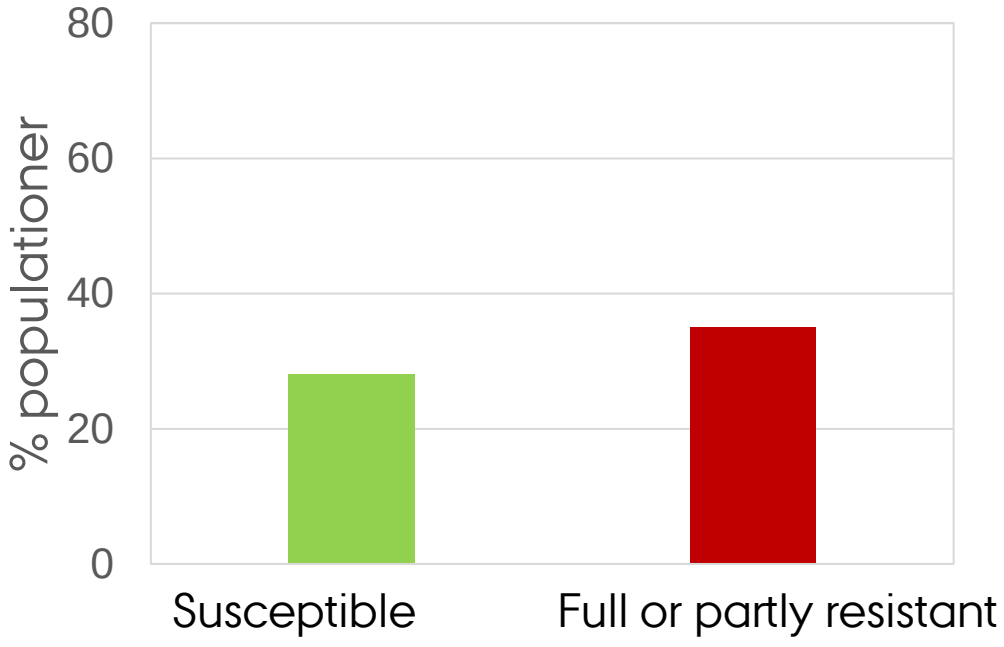
Foto: M. Sattin

LOLMU

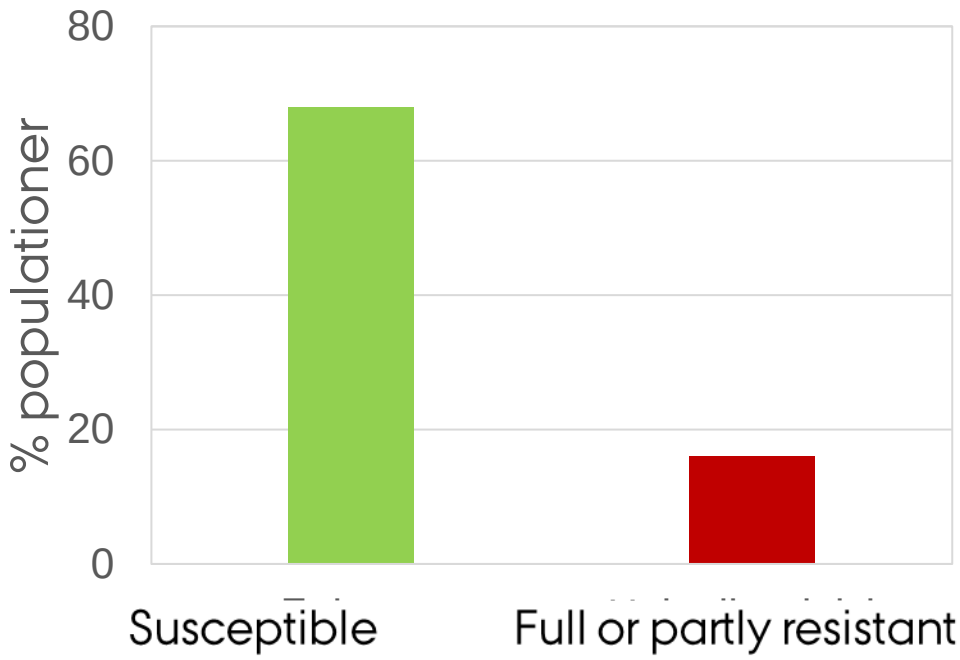

Atlantis
Topik
100
80
60
40
20
0
% populationer
Susceptible
Partly resistant
Resistant

MULTI-RESISTANCE (ALS AND ACC-ASE), 124 SAMPLES TESTED

LOLMU

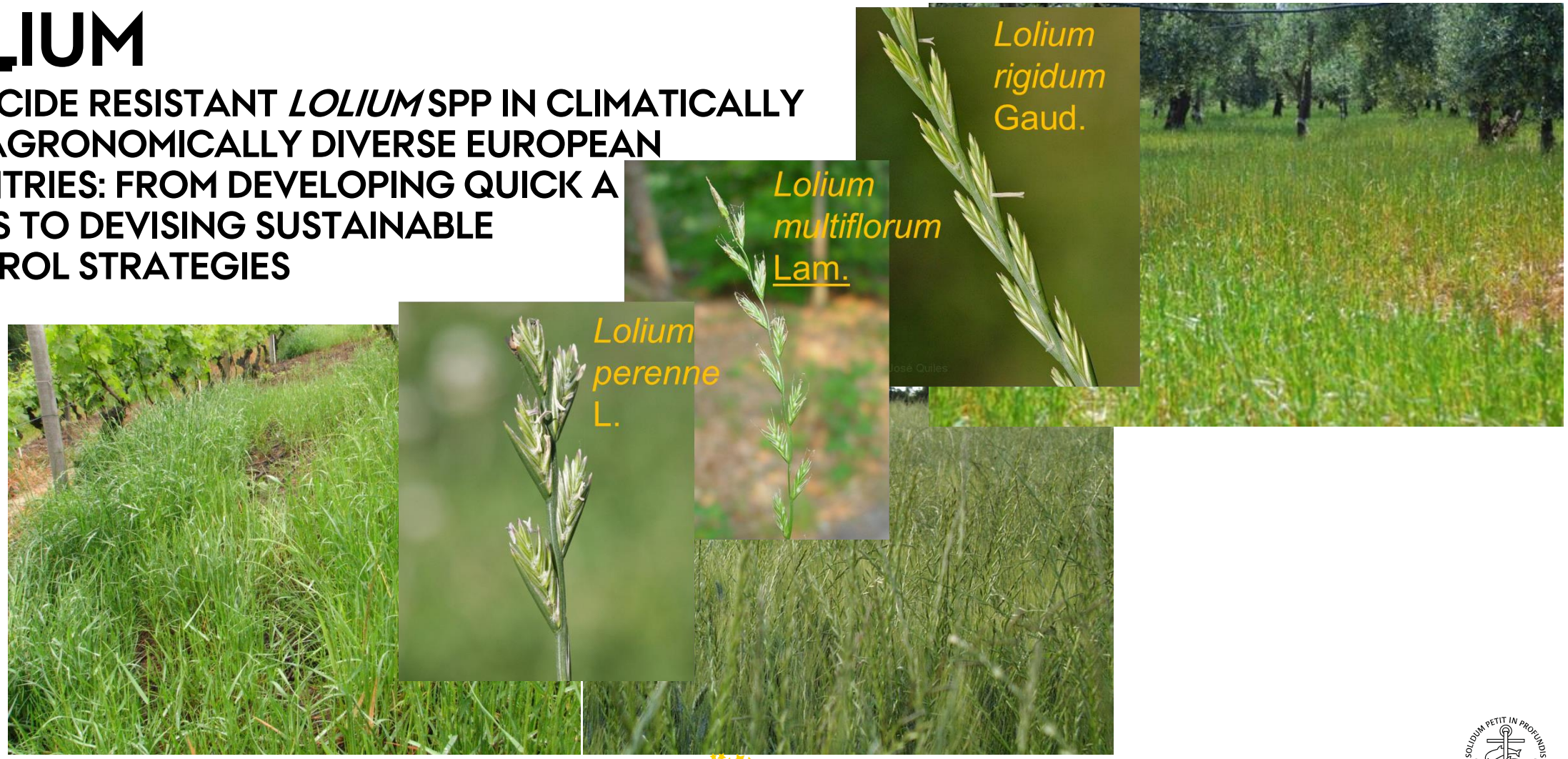


LOLPE



RELIUM

HERBICIDE RESISTANT *LOLIUM* SPP IN CLIMATICALLY AND AGRONOMICALLY DIVERSE EUROPEAN COUNTRIES: FROM DEVELOPING QUICK A TOOLS TO DEVISING SUSTAINABLE CONTROL STRATEGIES



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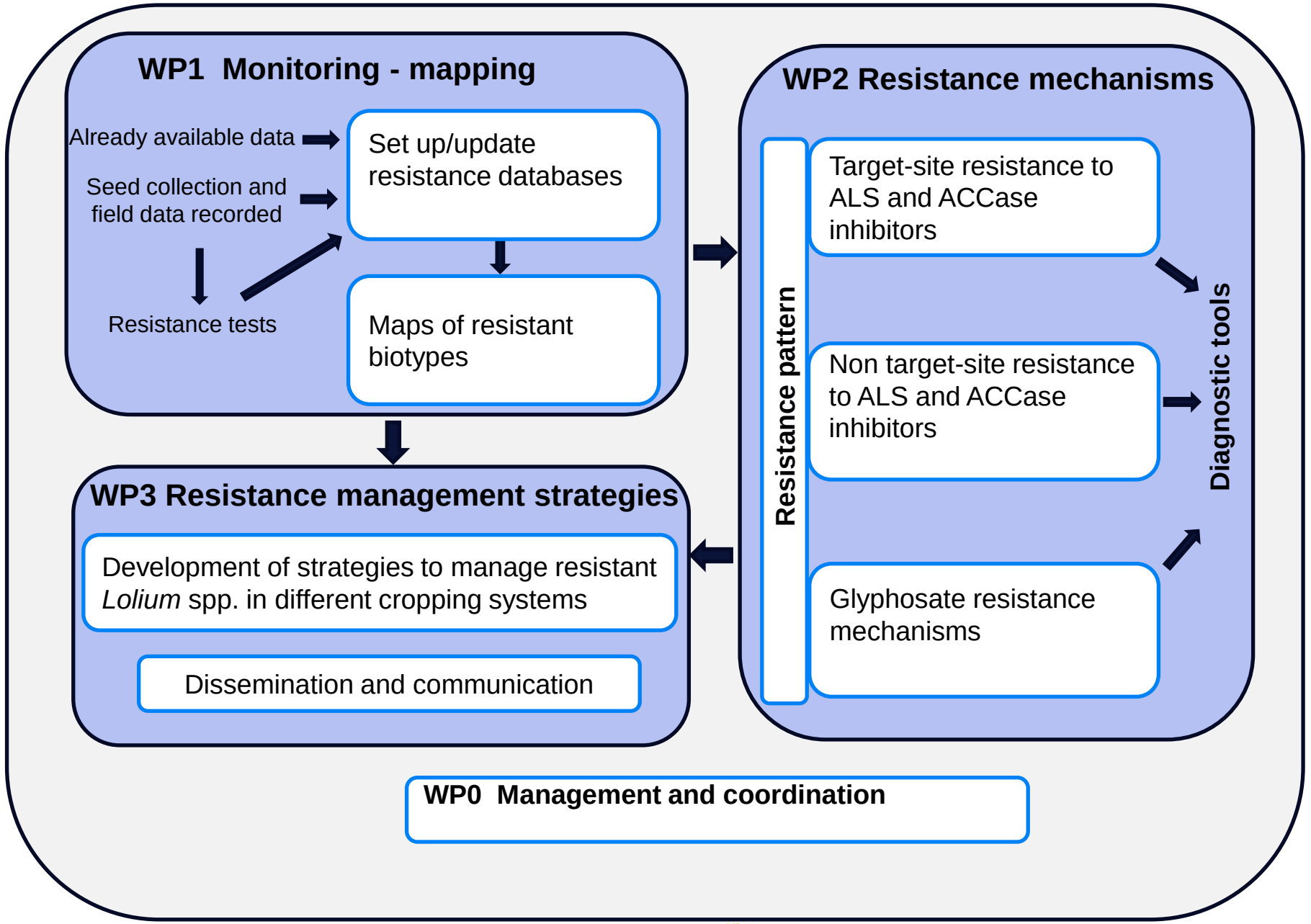
C-IPM

SOLIDUM PETIT IN PROFUNDIS · UNIVERSITAS ARHUSIENSIS


WP1 Monitoring - mapping
Already available data
Seed collection and field data recorded
Resistance tests
Set up/update resistance databases
Maps of resistant biotypes
WP2 Resistance mechanisms
Resistance pattern
Target-site resistance to ALS and ACCase inhibitors
Non target-site resistance to ALS and ACCase inhibitors
Glyphosate resistance mechanisms
Diagnostic tools
WP3 Resistance management strategies
Development of strategies to manage resistant *Lolium* spp. in different cropping systems
Dissemination and communication
WP0 Management and coordination

CONCLUSIONS

High resistance level to ALS-inhibitors in all countries

Resistance level to clodinafop lower in DK populations compared with populations from IT and GR

DK populations susceptible or low resistance level to pinoxaden

Multiple resistance exists in all countries

Wide range of responses to glyphosate in GR populations

MUTATIONS

ACC-ase gen

Pop. origin	1781	1999	2027	2041	2078	2088	2096
Danish							
Greek	x		x	x	x	x	
Italian	x				x		x

ALS gen

Pop. origin	122	197	205	376	574
Danish					x
Greek		x		x	
Italian	x	x	x	x	x

PUBLISHED PAPER

frontiers in Plant Science

ORIGINAL RESEARCH
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Check for updates

Diversified Resistance Mechanisms in Multi-Resistant *Lolium* spp. in Three European Countries

Laura Scarabel[1], Silvia Panozzo[1], Donato Loddo[1], Solvejg K. Mathiassen[2], Michael Kristensen[2], Per Kudsk[2], Thomas Gitsopoulos[3], Ilias Travlos[4], Eleni Tani[4], Dimosthenis Chachalis[5] and Maurizio Sattin[1]*

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OPEN ACCESS

Edited by:

RESISTANT RYEGRASS - EVOLUTION AND PREVENTION

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ACTIVITIES

Determine the level of resistance in 65 samples of ryegrass samples in dose-response trials

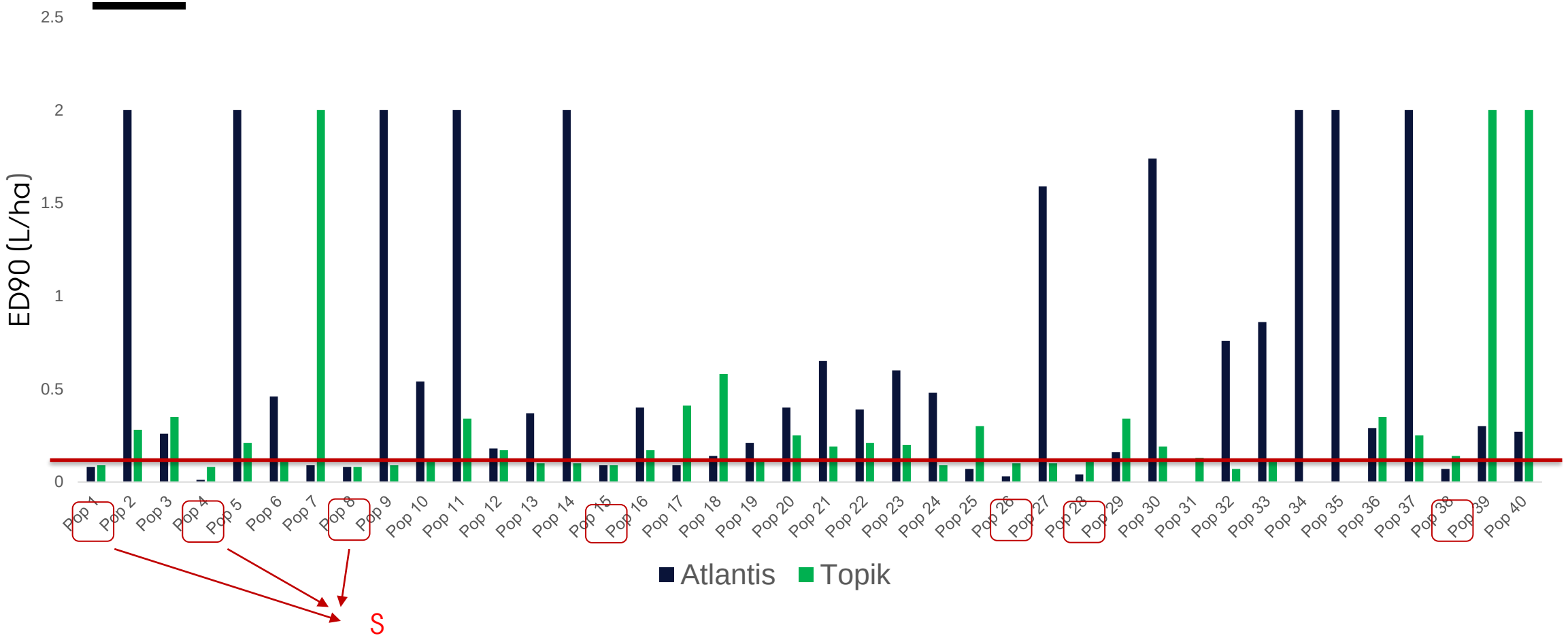
Interviews with farmers to collect information on cropping practice in 10 fields with high resistance level, 10 fields with low level of resistance and 10 fields with no resistance. Re-sampling in 2019-2020.

Multivariate statistical analyses to establish correlations between cropping practice and resistance.

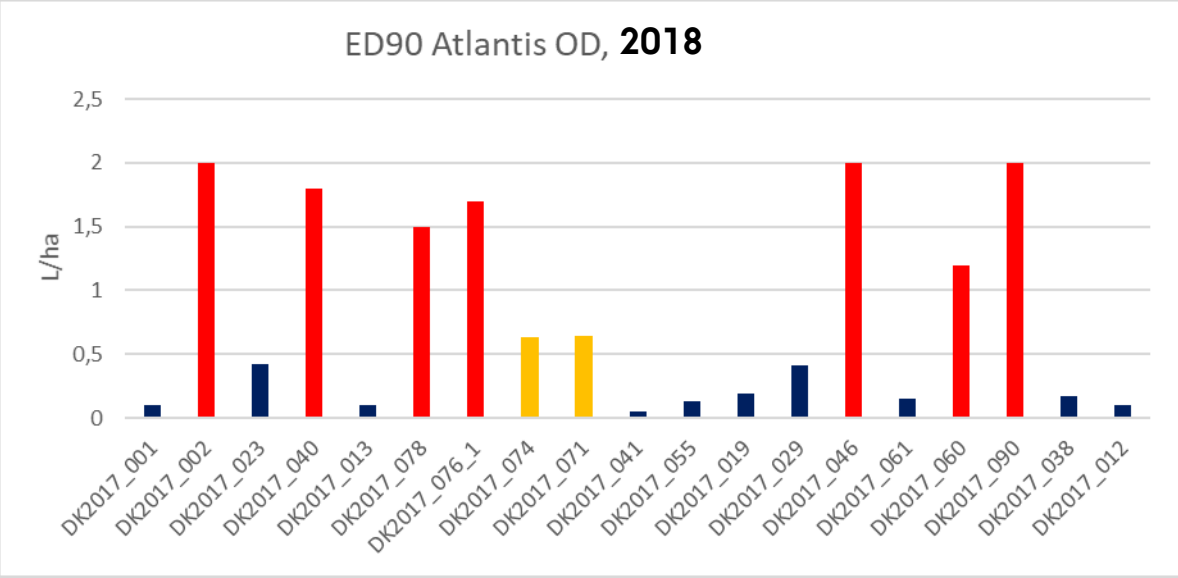
Validation with resistance cases from RELIUM.

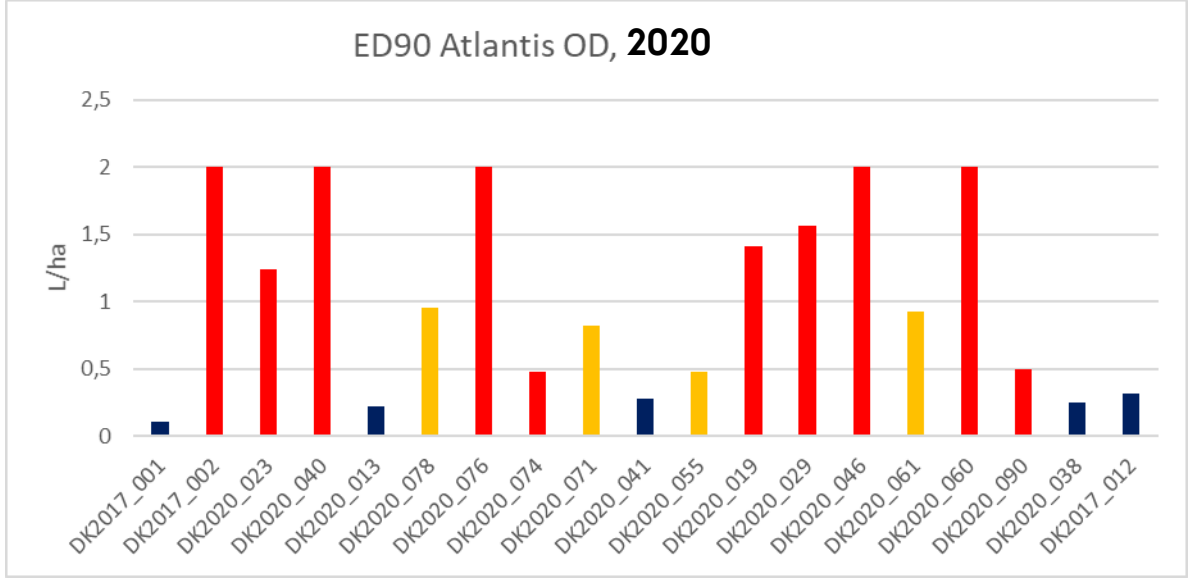
Development of anti-resistance strategy

SUSCEPTIBILITY OF POPULATIONS, 2017



REPEATED SAMPLING





TSR MUTATIONER

ALS

Mutations in 11 of 21 populationsr

Only two known mutations present - Pro-197 og Trp-574 .

5 populations with both mutations

ACCase

Mutations in 4 of 21 populations

Only two known mutations present – Trp-2027 og Ile-2041

2 populations with both mutations

No populations with mutations to both ALS and ACCase

RESULTS FROM INTERVIEWS WITH 28 FARMERS

- Age from 34 til 76 years
- Properties from 40 ha til 740 ha – from hobby farms to companies with 17 employes
- Crop rotations varies from different parts of DK
- Conventional soil cultivation to CA
- Great differences in stubble cultivation
- Mainly chemical weed control – varying use of glyphosate
- Limited knowledge on herbicide resistance
- Most important information source is the advisor service
- Crop and herbicide use for the previous 7 years collected
- Frequent use of ALS inhibitors

IMPROVED MODELS FOR RESISTANCE MANAGEMENT IN DK-RIM

Thank you for your attention

Questions?

RESISTANCE CASES IN POA ANNUA

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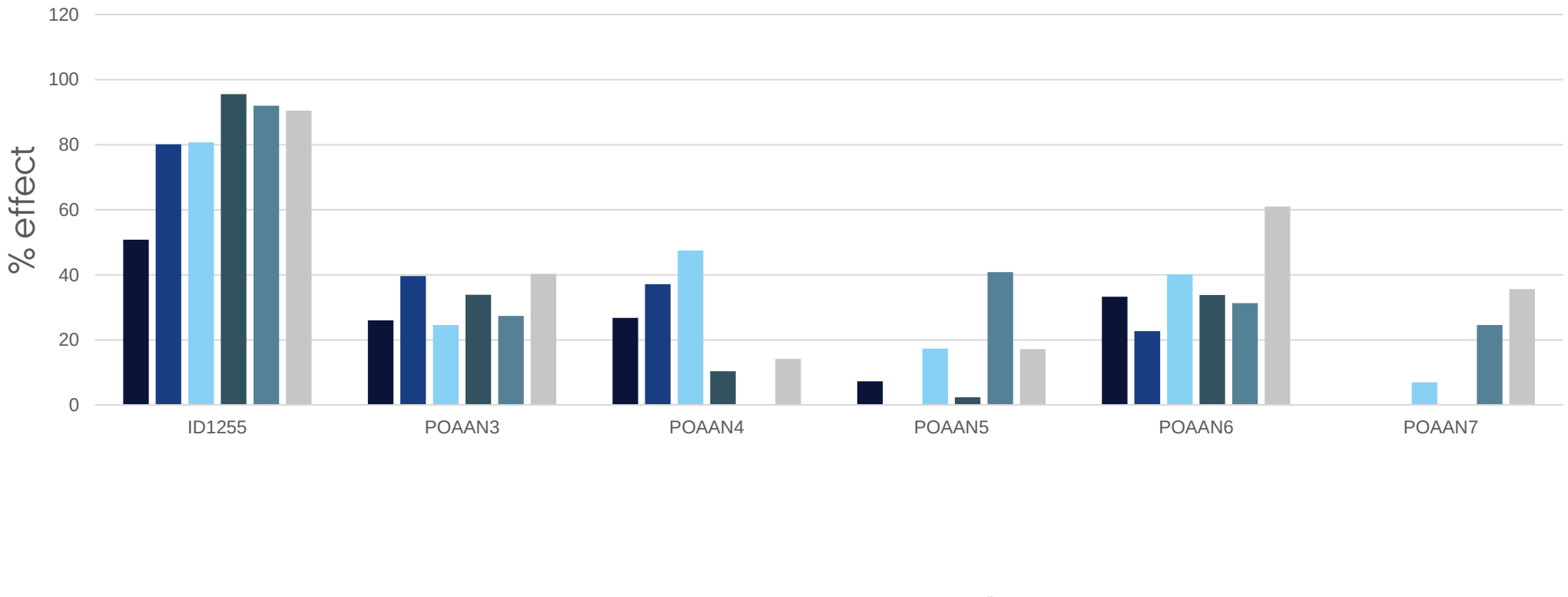
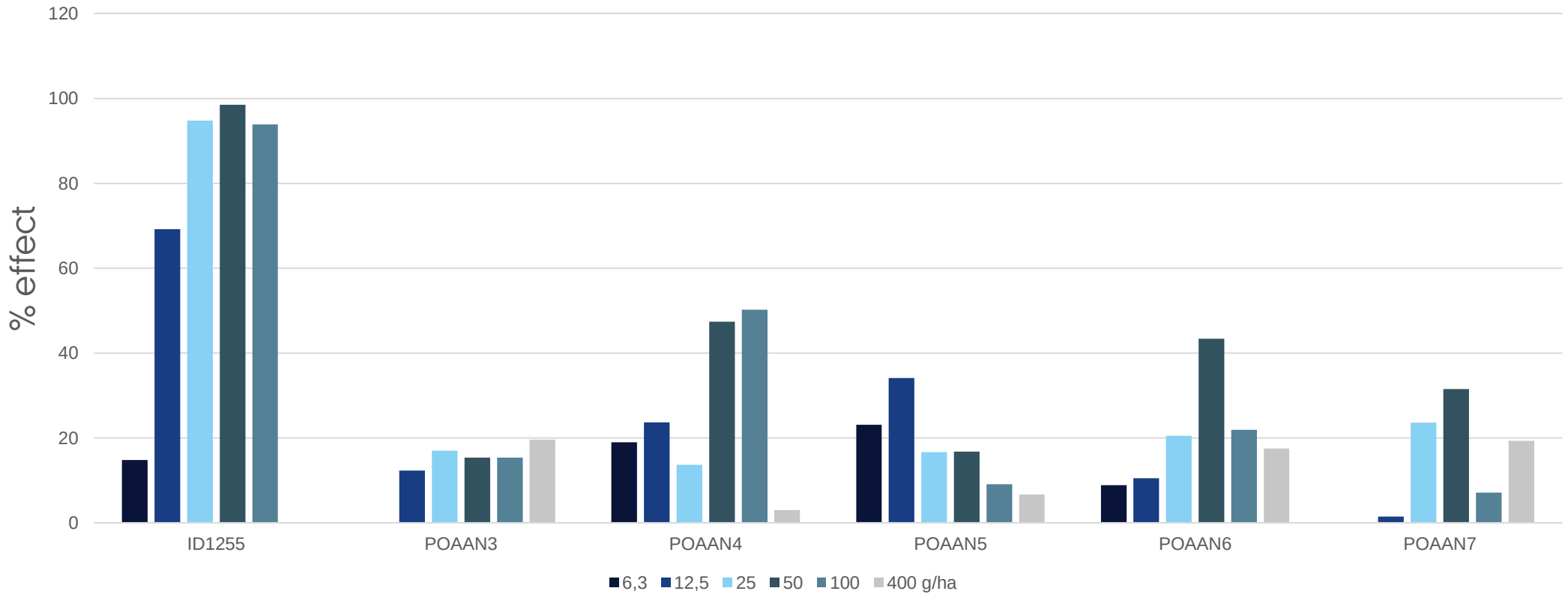
POSITIVE TEST FOR ALS RESISTANCE (5 OF 7 CASES)

Year/ ID	Herbicides tested	Crop rotation	Herbicide history	Location
2015 POAAN3	Hussar, Broadway, Select, Boxer	2 x winter wheat, spring barley, WOSR,	ALS inhibitors in 5 of 6 years	Northern Zealand
2017 POAAN4	Hussar, Broadway, Select, Boxer	Cereals with seed grasses	Hussar has a minor use authorization in seed grasses (including split appl.)	Northern Zealand
2019 POAAN5	Hussar, Broadway, MaisTer	Maize in 8 of 9 years	Maister used in 7 years	Southern Jutland
2020 POAAN6		Maize in 7 of 16 years 2016-19: alfalfa with grass 2015: spring barley 2014: rye 2011-13: maize	MaisTer used first time in 2004	Fuen
2020 POAAN7		Monoculture maize for 18 years (one year winter wheat)	MaisTer used every year	Fuen

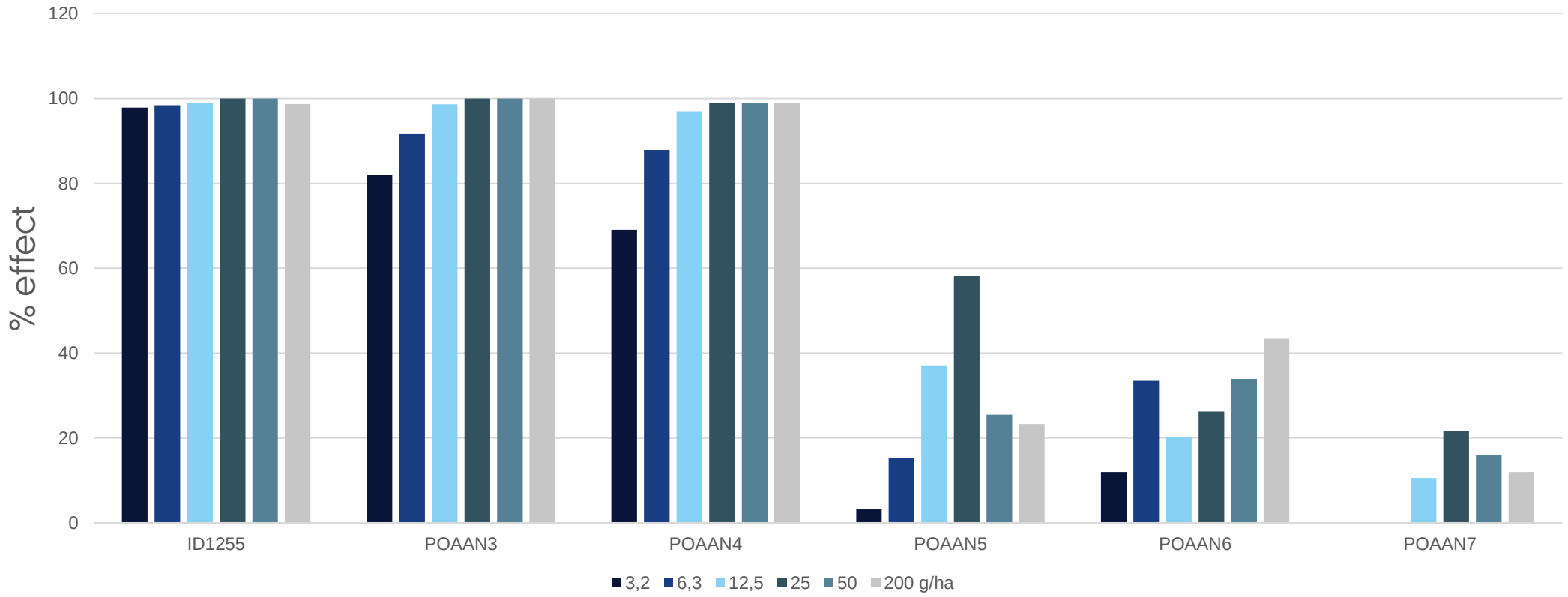
RESISTANCE TEST IN POAAN – HUSSAR OD



RESISTANCE TEST IN POAAN - BROADWAY



RESISTANCE TEST IN POAAN - MAISTER



RESISTANCE TEST IN POAAN

ID1255, POAAN3, POAAN4, POAAN5, POAAN6 og POAAN7

Back row: Untreated. Front row: 0,075 L/ha Hussar OD

ID1255, POAAN3, POAAN4, POAAN5, POAAN6 og POAAN7

Back row: Untreated. Front row: 50 g/ha MaisTer

Poa annua samples collected in maize fields

9 samples collected in Denmark 2020
- 4 fields with monoculture of corn
- 5 fields with diversified crop rotation

All fields with suspected resistance

Result from seed testing

POAAN7 POAAN6

	Target						1 POAAN	2 POAAN	3 POAAN	4 POAAN	5 POAAN	6 POAAN	7 POAAN	8 POAAN	9 POAAN	10 POAAN	11 POAAN
	-Characteristic						DNK20S0001	DNK20S0002	DNK20S0003	DNK20S0004	DNK20S0005	DNK20S0006	DNK20S0007	DNK20S0008	DNK20S0009	DEG19R0002 (S)	Gärtn. Appel 1>
	Assessment Date						12/01/2021	12/01/2021	12/01/2021	12/01/2021	12/01/2021	12/01/2021	12/01/2021	12/01/2021	12/01/2021	12/01/2021	12/01/2021
	Days after last Appl.						26 DAA	26 DAA	26 DAA	26 DAA	26 DAA	26 DAA	26 DAA	26 DAA	26 DAA	26 DAA	26 DAA
1	UNBEHANDELT						35	38	38	36	38	16	19	14	27	29	31
2	HUSSAR OD	40	G A/HA	0,1	L/HA	B	20	18	15	18	18	35	18	23	18	95	98
	MERO	367	G A/HA	0,5	L/HA	B											
3	ATLANTIS OD	37,8	G A/HA	0,9	L/HA	B	25	23	23	23	23	45	23	28	23	99	99
	MERO	367	G A/HA	0,5	L/HA	B											
4	COSSACK OD	34,9	G A/HA	0,93	L/HA	B	43	50	33	30	28	50	48	40	28	99	99
	MERO	367	G A/HA	0,5	L/HA	B											
5	MAISTER POWER	86,3	G A/HA	1,5	L/HA	B	58	48	40	48	40	63	38	40	40	99	99
6	BROADWAY	35,1	G A/HA	0,22	KG/HA	B	28	35	23	20	15	43	23	30	20	98	99
	PG26N	49,5	G A/HA	0,5	L/HA	B											
7	RALON SUPER (fenoxaprop)	144	G A/HA	1	L/HA	B	23	28	20	23	20	20	10	0	0	0	0
	MERO	733	G A/HA	1	L/HA	B											
9	FOCUS ULTRA	150	G A/HA	1,5	L/HA	B	25	23	18	20	18	28	10	5	0	0	8
10	ROUNDUP WEATHERMAX	1080	G A/HA	2	L/HA	B	100	100	100	100	100	100	100	100	100	98	99

Result from leaf testing

Target site		POAAN							
		DNK20L0001	DNK20L0002	DNK20L0003	DNK20L0004	DNK20L0005	DNK20L0006	DNK20L0007	DNK20L0008
ALS	P197								
	W574								
ACCase	I1781	Natural mutation							
	W2027								
	I2041								
	D2078								
	G2096A								

POAAN IN MAIZE, JULY 2020

01.06.2020: 100 g/ha MaisTer
14.06.2020: 50 g/ha MaisTer

27.06.2020: 100 g/ha MaisTer
03.06.2020: Row harrow

Photos: Hans Erik Larsen

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HIGH RISK

Fields with high densities of *P. annua*

Maize monoculture (no tillage from harvest to spring)

Fields with frequent use of ALS inhibitors (winter cereals, seed grasses, maize)

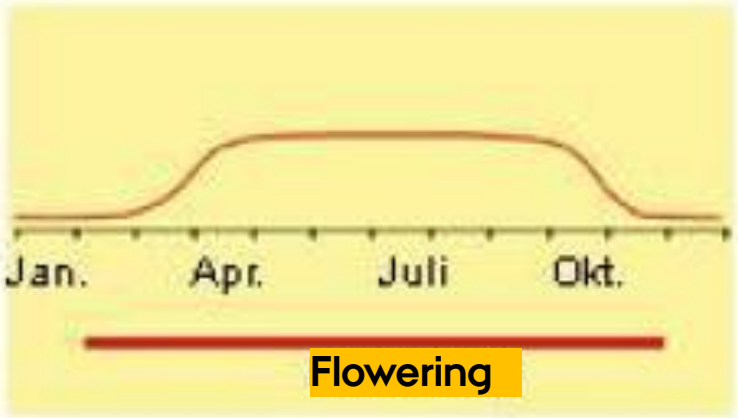
No till cultivation

ALS-RESISTANCE IN POAAN

#	Year	Species	Country	MOAs	Actives	Situations
1	2017	*Poa annua*	Australia (New South Wales)	ALS inhibitors (B/2)	bispyribac-sodium, rimsulfuron, iodosulfuron-methyl-sodium, foramsulfuron	Golf courses
2	2017	*Poa annua*	Australia (New South Wales)	ALS inhibitors (B/2), EPSP synthase inhibitors (G/9), Microtubule inhibitors (K1/3), Photosystem II inhibitors (C1/5), Unknown (Z/27)	endothall, bispyribac-sodium, rimsulfuron, simazine, glyphosate, propyzamide = pronamide, iodosulfuron-methyl-sodium, foramsulfuron	Golf courses
3	2017	*Poa annua*	Australia (South Australia)	ALS inhibitors (B/2)	bispyribac-sodium, rimsulfuron, iodosulfuron-methyl-sodium, foramsulfuron	Golf courses
4	2017	*Poa annua*	Australia (Victoria)	ALS inhibitors (B/2)	bispyribac-sodium, rimsulfuron, iodosulfuron-methyl-sodium, foramsulfuron	Golf courses
5	2015	*Poa annua*	France	ALS inhibitors (B/2)	iodosulfuron-methyl-sodium, mesosulfuron-methyl	Wheat
6	2012	*Poa annua*	United States (Alabama)	ALS inhibitors (B/2)	imazaquin, bispyribac-sodium, foramsulfuron, trifloxysulfuron-sodium	Turf
7	2014	*Poa annua*	United States (Mississippi)	ALS inhibitors (B/2)	foramsulfuron	Golf courses
8	2013	*Poa annua*	United States (Tennessee)	ALS inhibitors (B/2), Photosystem II inhibitors (C1/5)	simazine, foramsulfuron, trifloxysulfuron-sodium	Golf courses, Turf

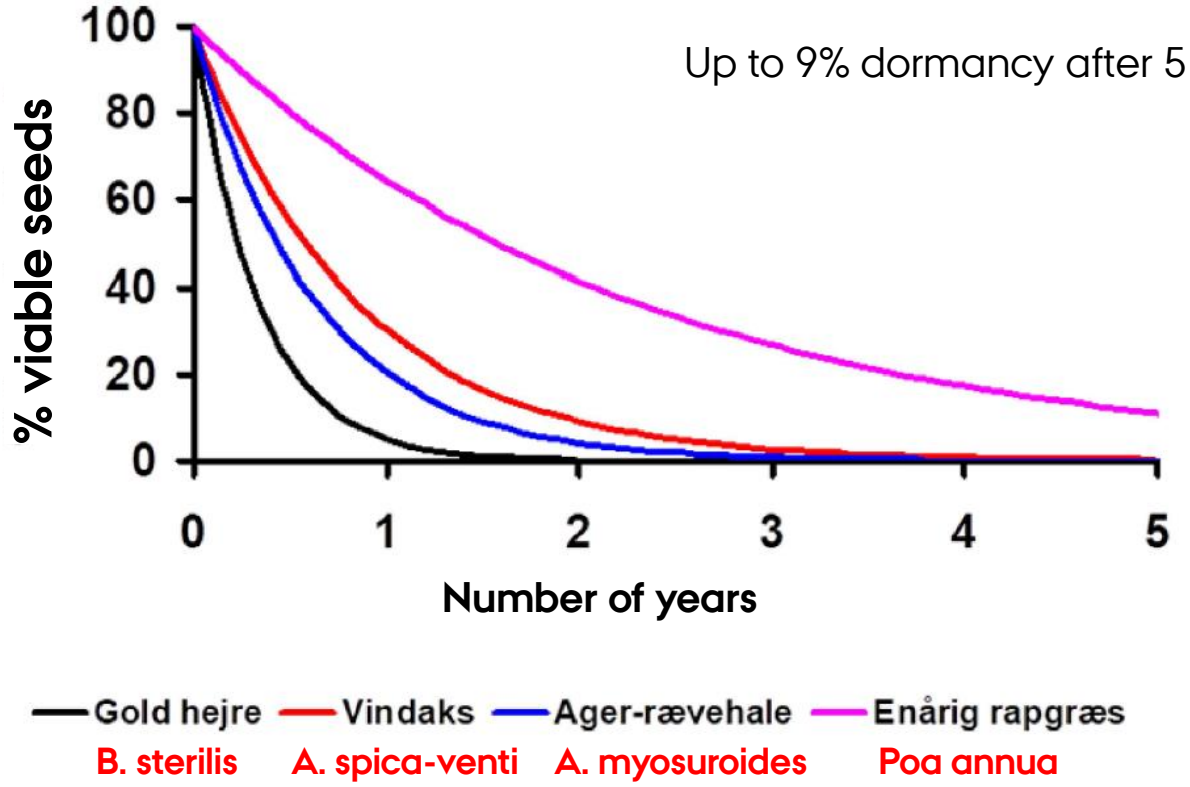
Heap, I. The International Herbicide-Resistant Weed Database. Online. Tuesday, February 16, 2021 . Available www.weedscience.org

BIOLOGY



- Annual weed species
- Germinates from early spring to late autumn
- Pruduce seeds after 6 weeks (up to 7 generations/year)
- Each plant produces from 200 to 1000 seeds
- Long seed survival in soil

SEED SURVIVAL



Up to 9% dormancy after 5 years in soil (Roberts, 1964)

IPM TOOLS

Tool	Example	Efficacy
Crop rotation	Maize in crop rotation with other crops Spring cereals Perennial crops	***
Ploughing	Dilution of seed bank	***
Late sowing of winter cereals	Reduced germination	***
Stubble management	Leave stubble undisturbed	**
Increased seeding rate	Increased crop competion	**
Effective chemical control	Residual herbicides, other MoA than ALS inhibitors	**
Row harrowing	In maize	*

IPM TOOLS

Tool	Example	Efficacy
Reduced row distance	Increased crop competition	*
Clean machinery	Equipment for tillage and harvest	*
False seedbed	Lower effect than for other grasses due to germination pattern	*
Catch crops	A good coverage of the soil surface reduces germination of P. annua	*

CONCLUSIONS

ALS resistance in *Poa annua* can evolve in different crop rotations – high risk in maize monoculture

Resistance mechanism is target-site caused by a mutation in the ALS gene at codon 574 (resistance to foramsulfuron related to the use of this a.i.)

Resistant seeds of *Poa annua* can survive in the field for many years

Pro-active resistance mangement required including IPM tools


Thank you
for your attention