Getting more out of resistance monitoring: big data, epidemiology and other ‘buzz’ words.

Paul Neve

Plant & Environmental Sciences, University of Copenhagen

The Blackgrass Resistance Initiative

ROTHAMSTED RESEARCH

Newcastle University


Rob Edwards


Alina Goldberg-Cavalleri


Nawaporn Onkokesung

- **Molecular genetics and biochemistry of NTSR**

ZSL LIVING CONSERVATION


Ken Norris

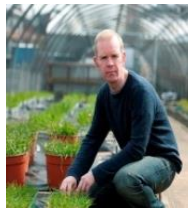

Alexa Varah

- **Economic and environmental impacts**

ROTHAMSTED RESEARCH


Lieselot Nguyen


Laura Crook


Richard Hull


Paul Neve


David Comont


Andrea Dixon

- **Genetics, ecology, evolution and management**

The University Of Sheffield.


Rob Freckleton


Dylan Childs


Helen Hicks


Shaun Coutts

- **Population biology, modelling & management**

UNIVERSITY of York

THE UNIVERSITY OF EDINBURGH

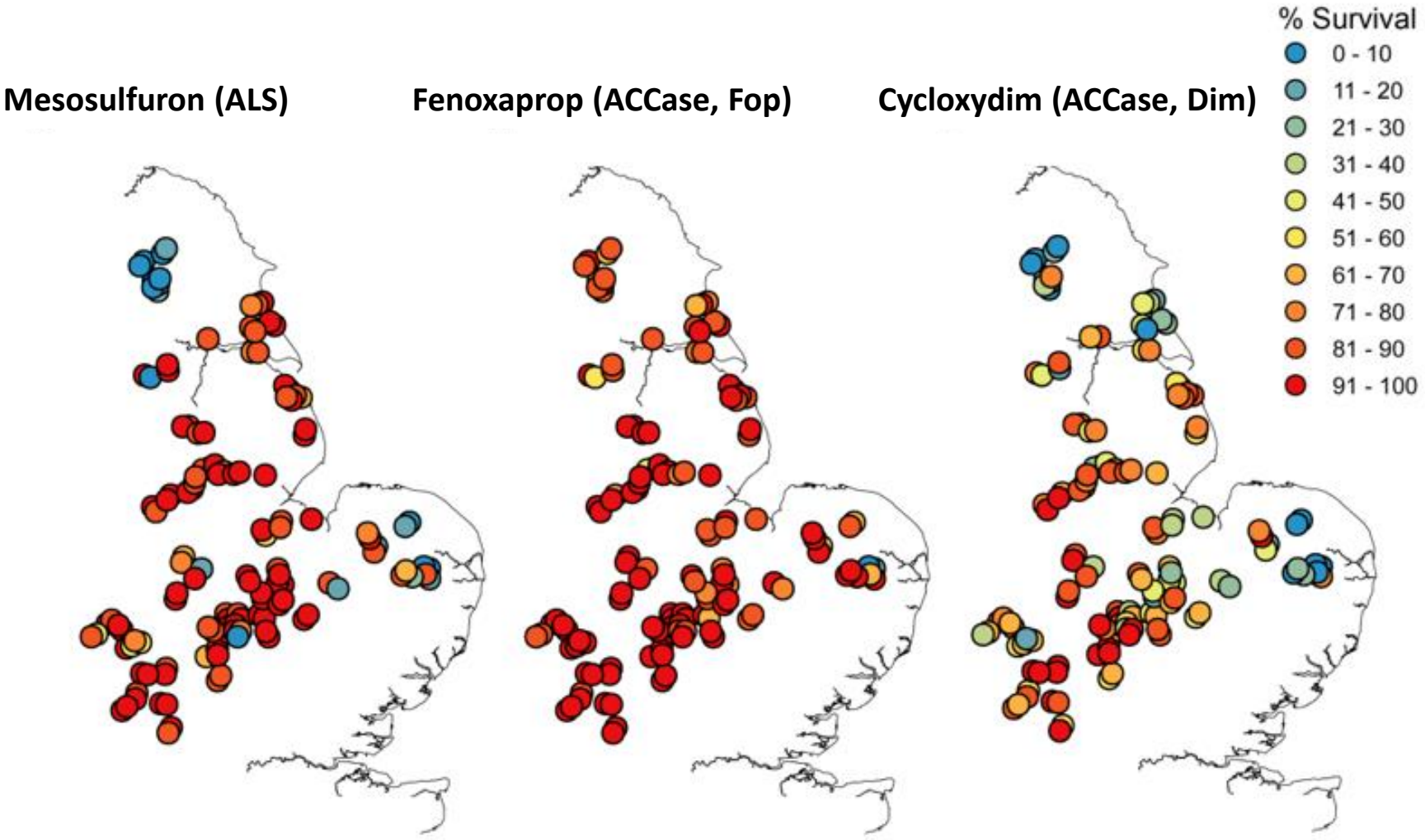

Louise Jones

- **Epigenetics**


Jarrod Hadfield

- **Quantitative genetics**

Herbicide resistance at a national scale

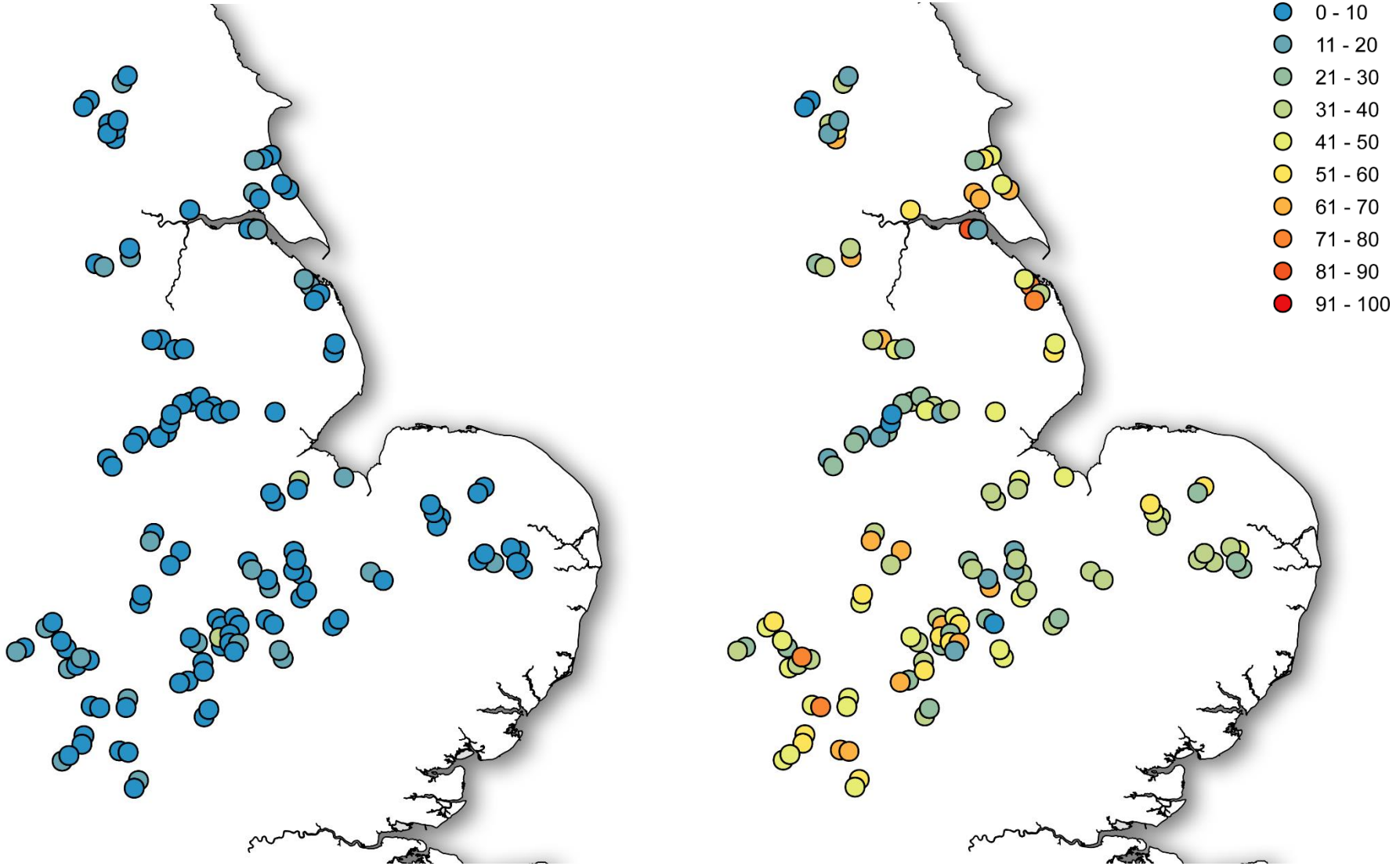


Glyphosate sensitivity in the UK

ROTHAMSTED RESEARCH

Field rate (540 g ha^{-1})

¾ rate (405 g ha^{-1})



Not just ***where and what*** but ***how and why?***

Can we use resistance monitoring studies to do more than simply describe the problem (after it happens)?

Yes, if we adopt ***epidemiological*** approaches!

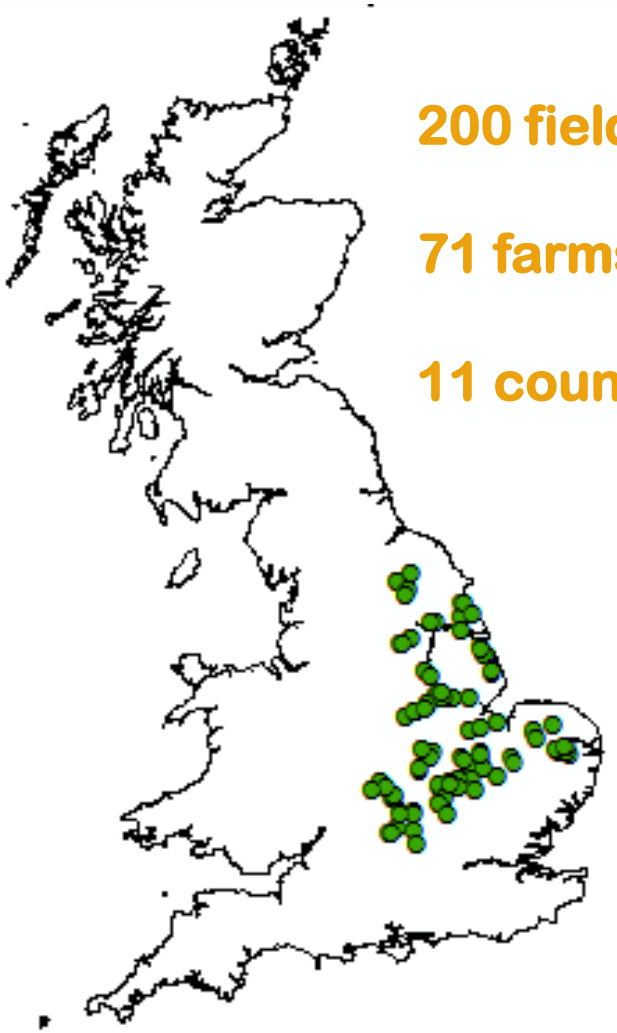
Epidemiology is the systematic study of the distribution and **determinants** of a harmful organism, disorder or event.

Herbicide resistance as pandemic.

- The study of the distribution, abundance, dynamics, evolution and management of weed populations is inherently an epidemiological discipline.
- "A pandemic is basically a global epidemic - an epidemic that spreads to more than one continent"
- Epidemiological approaches can be enabled by increasing access to ‘big data’, collected on-farm and at scale.
- In general, approaches from human health / biomedicine have much to offer – epidemiology, public health and community-based approaches, early detection and diagnostics, evidence-based medicine, prevention rather than cure ……

The BGRI farm network

Black-Grass Resistance Initiative



200 fields

71 farms

11 counties

- Annual population monitoring (density maps)
- 190 seed populations collected
- Resistance assays (phenotype + genotype)
- Historical management data
- Environmental data (soils, weather etc.)

Field epidemiology

Blackgrass mapping at a national scale

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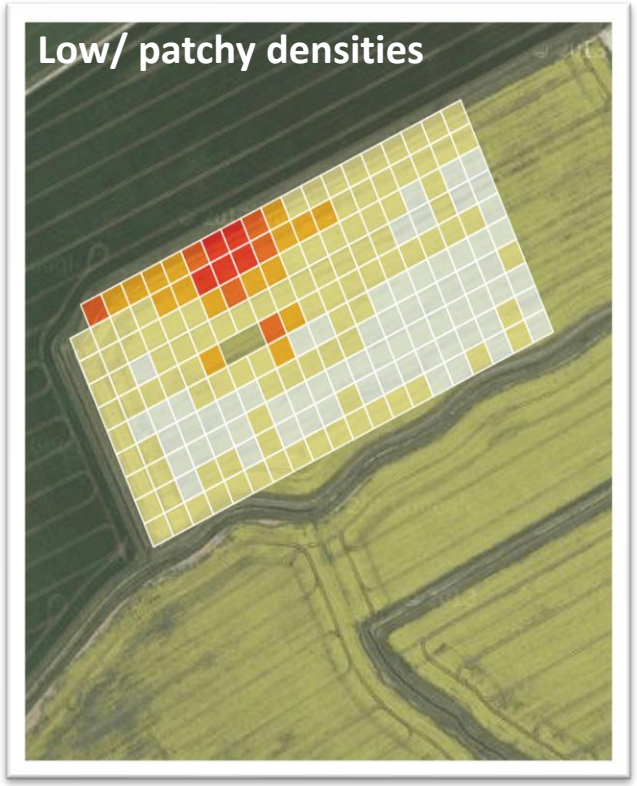

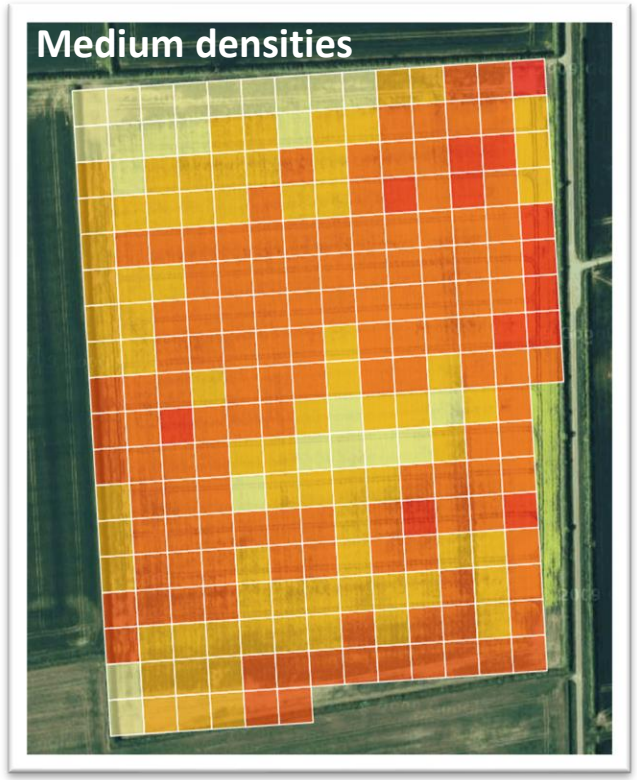

Positive correlation between density and resistance

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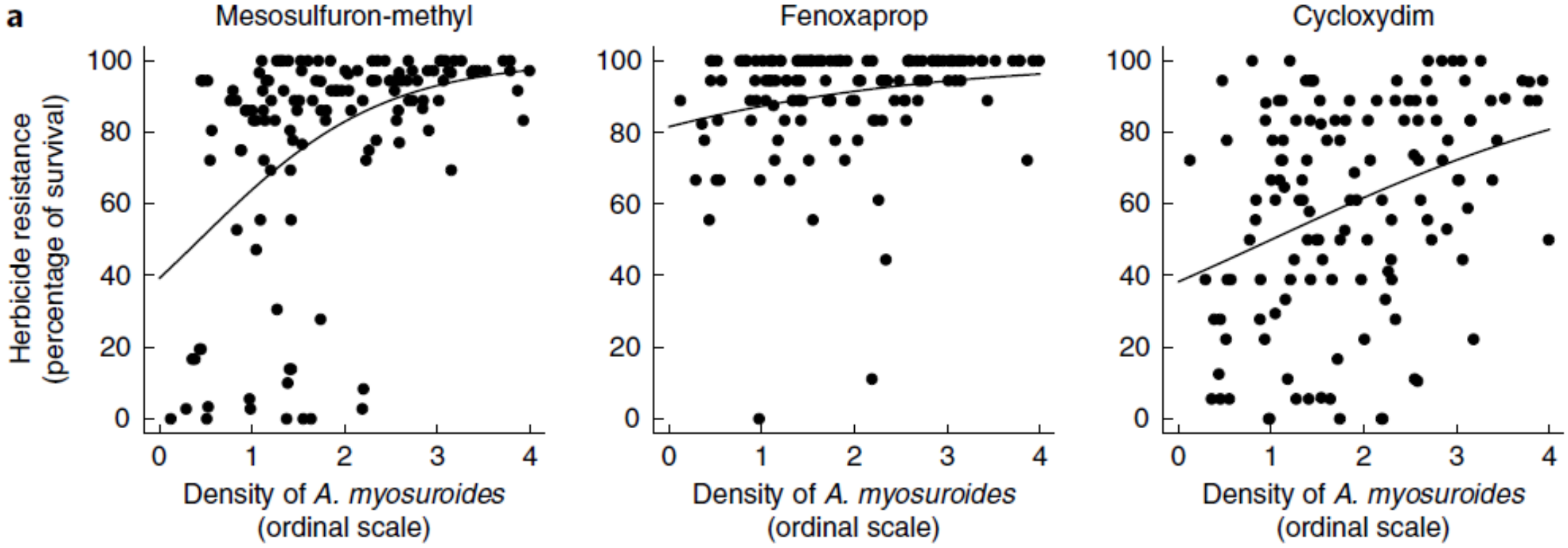

But what drives evolution of resistance?

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We looked for relationships between herbicide resistance and these common agricultural practices

Herbicide regimes

Herbicide intensity (applic. yr^{-1}) ***

Herbicide diversity (MOA yr^{-1}) ***NS***

Cropping

Autumn vs spring sown ***NS***

Cereal vs other crop types ***NS***

Proportion w.wheat in rotation ***NS***

Cultivation histories

Proportion of years ploughed ***NS***

Cultivation intensity score ***NS***

*** P < 0.005

NS Not significant

Evolution of resistance is driven only by intensity of herbicide use, no mitigation by herbicide diversity (mixtures)

nature ecology & evolution

ARTICLES

https://doi.org/10.1038/s41559-018-0470-1

The factors driving evolved herbicide resistance at a national scale

Helen L. Hicks[1], David Comont[2], Shaun R. Coutts[1], Laura Crook[2], Richard Hull[2], Ken Norris[3], Paul Neve[2], Dylan Z. Childs[1] and Robert P. Freckleton[1*]

Target site resistance in blackgrass

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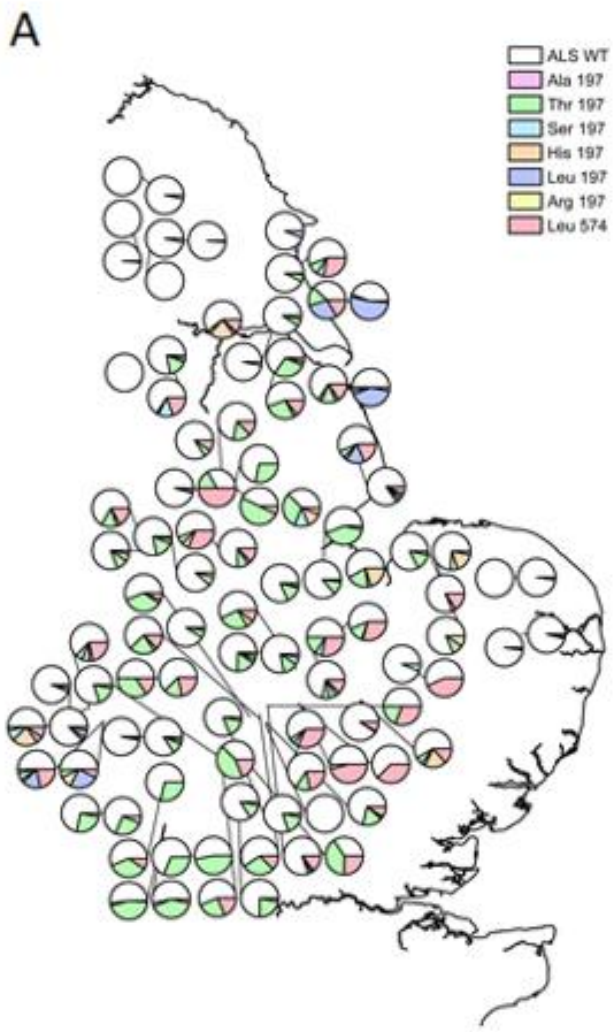
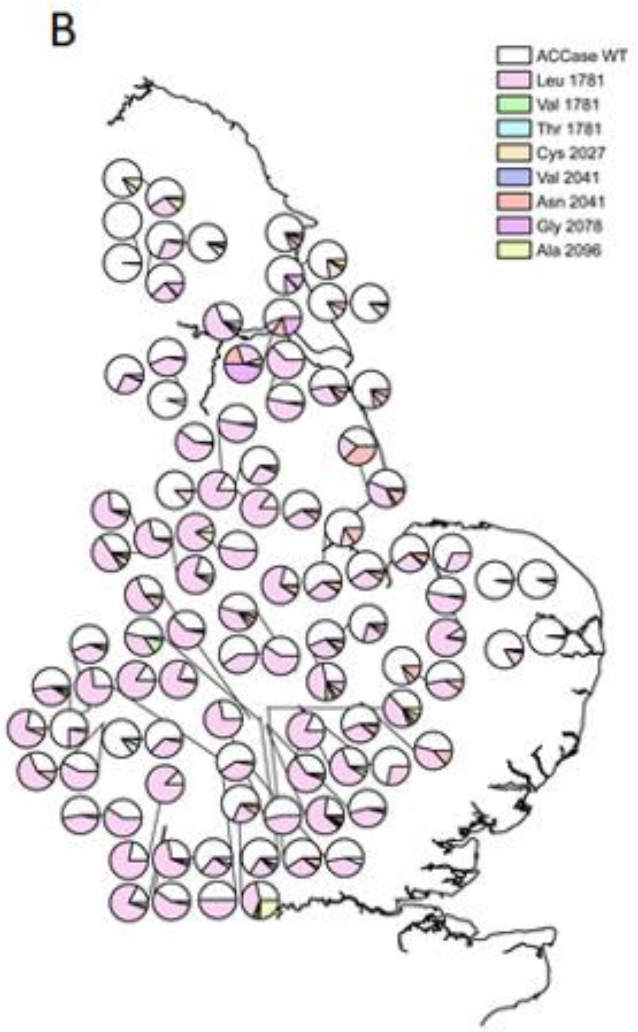
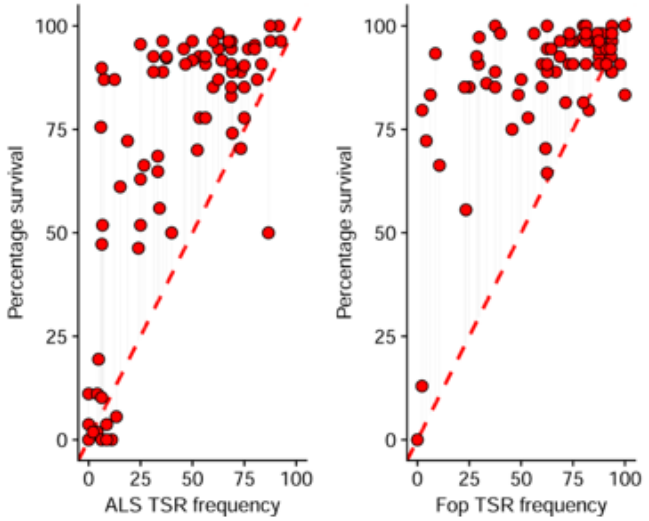


ALS

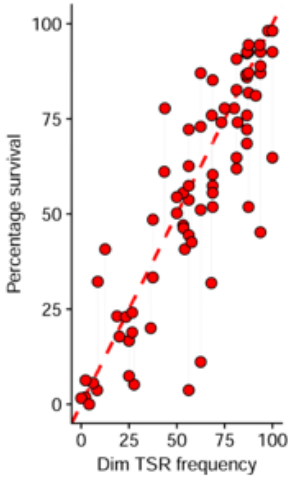


ACCase



For fenoxaprop and mesosulfuron TSR frequency does not account for all observed resistance

Resistance to cycloxydim is conferred by TSR mutations



Biomarkers for non-target site resistance

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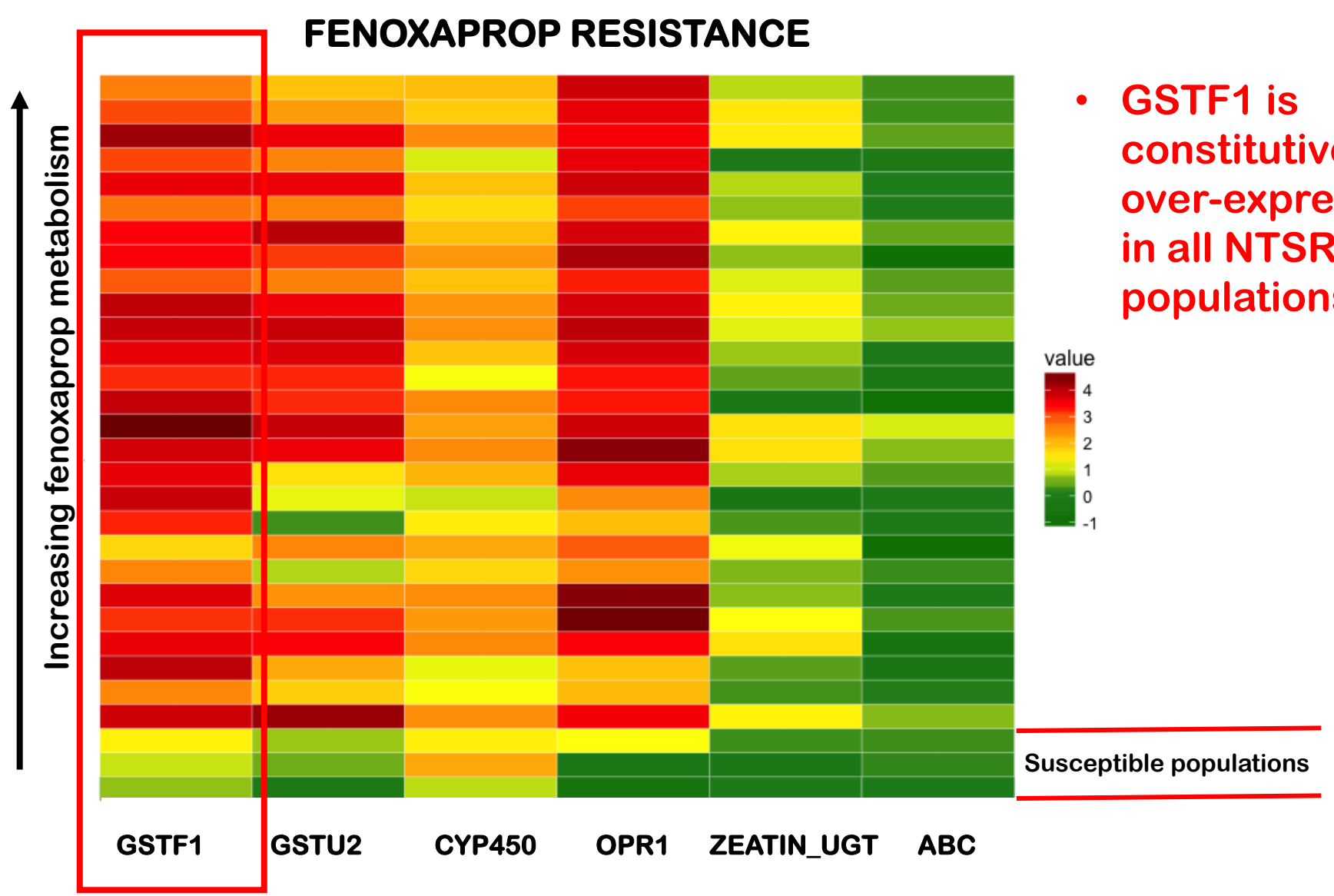

- GSTF1 is constitutively over-expressed in all NTSR populations

BAYER

Non-target site resistance in blackgrass

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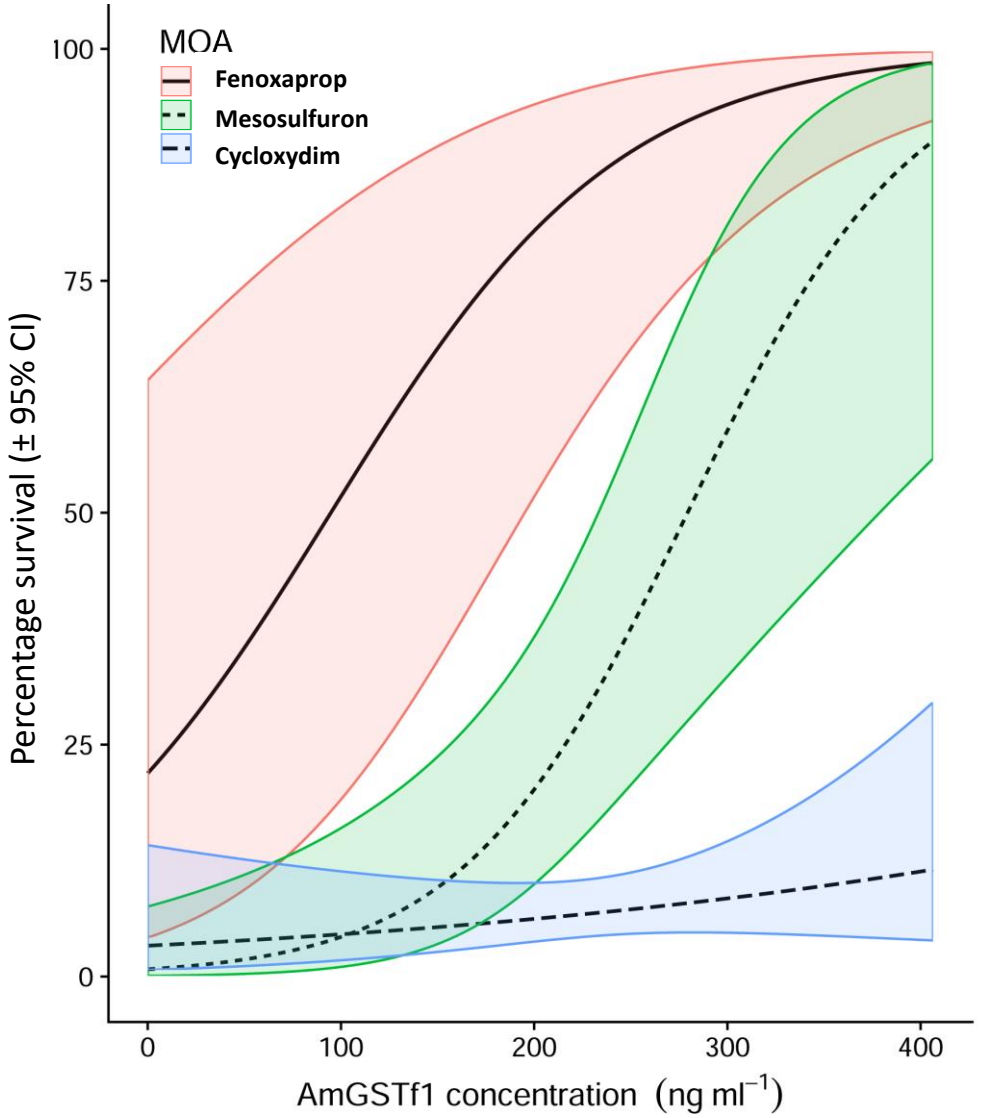

	TSR	NTSR
Fenoxaprop	✓	✓
Cycloxydim	✓	✗
Mesosulfuron	✓	✓

- **Resistance to fenoxaprop and mesosulfuron are conferred by a combination of TSR and NTSR mechanisms. Cycloxydim is conferred by TSR**

A trade-off in resistance management

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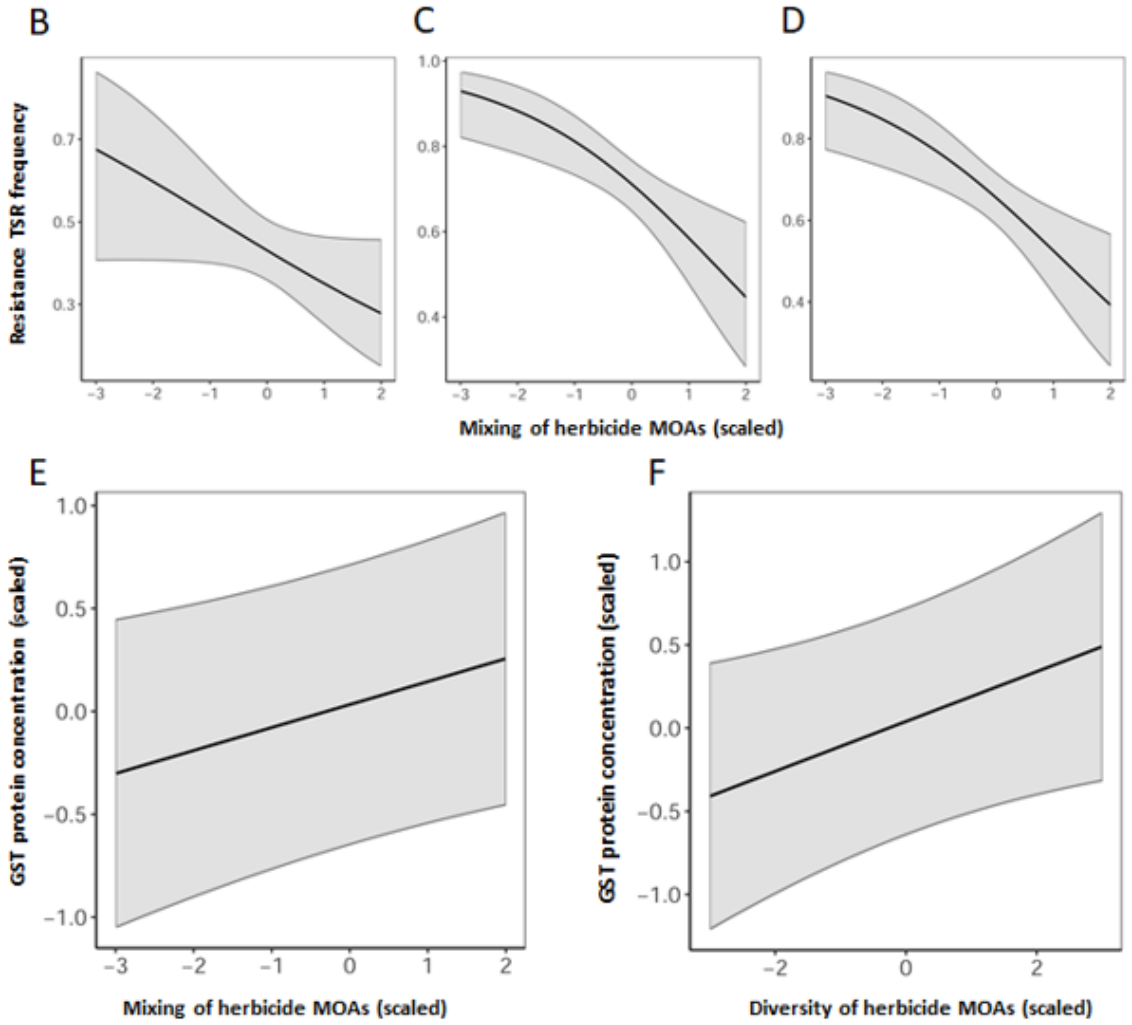

TSR

- Herbicide mixtures are associated with reduced TSR

NTSR

- Herbicide mixtures and diversity are associated with higher levels of NTSR

- **Herbicide mixtures slow evolution of specialist resistance, but promote selection for generalist resistance.**

Comont et al. (2021). Evolution of generalist resistance to herbicide mixtures reveals a trade-off in resistance management. *Nature Communications.*

Pre-emptive resistance management: glyphosate

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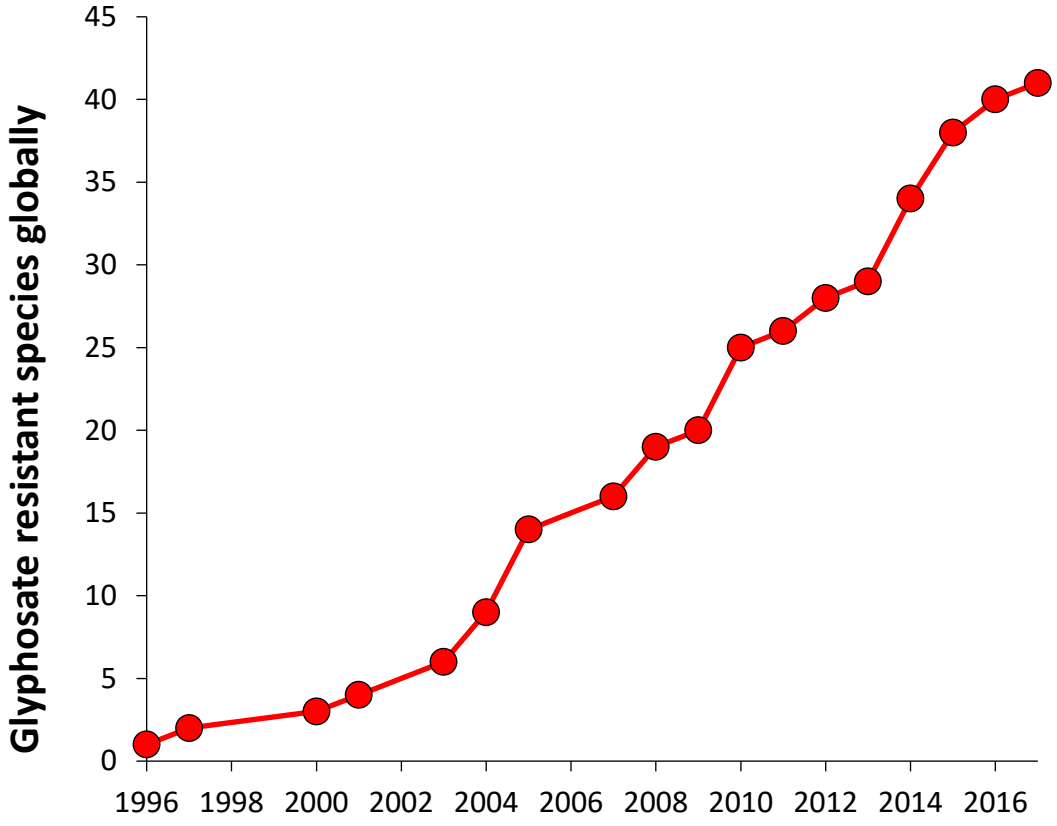
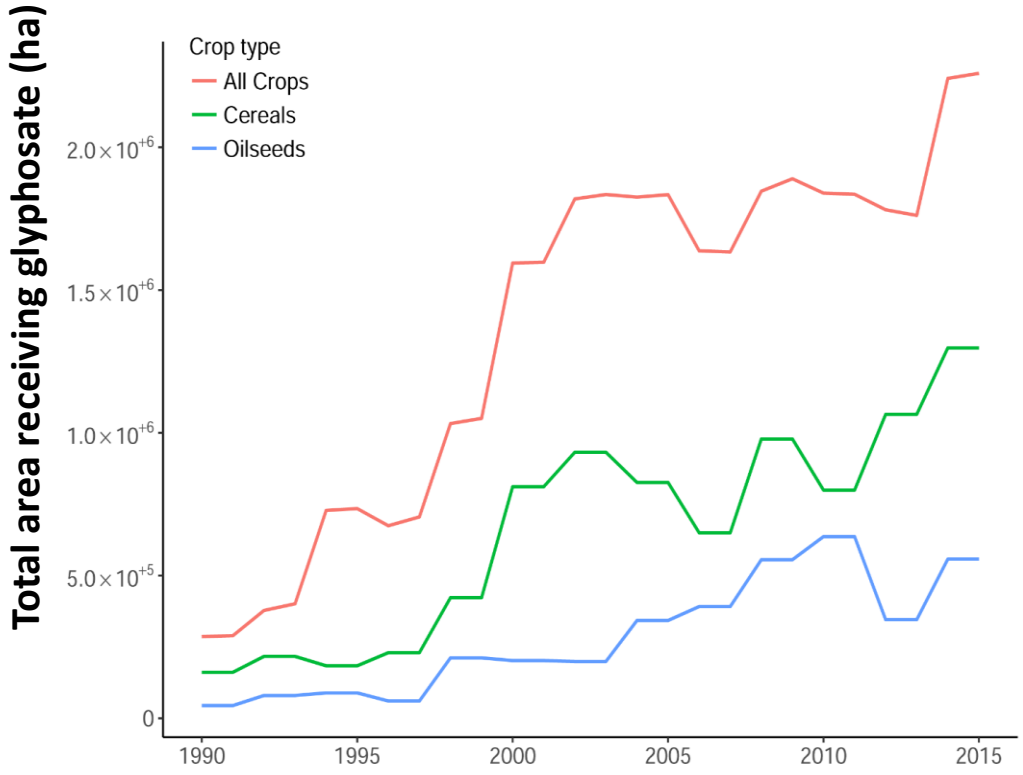
of species evolving glyphosate resistance



Source: www.weedscience.com

Glyphosate use trends in the UK



Source: www.FERA.co.uk/pesticide-usage-survey

Creeping resistance to glyphosate?

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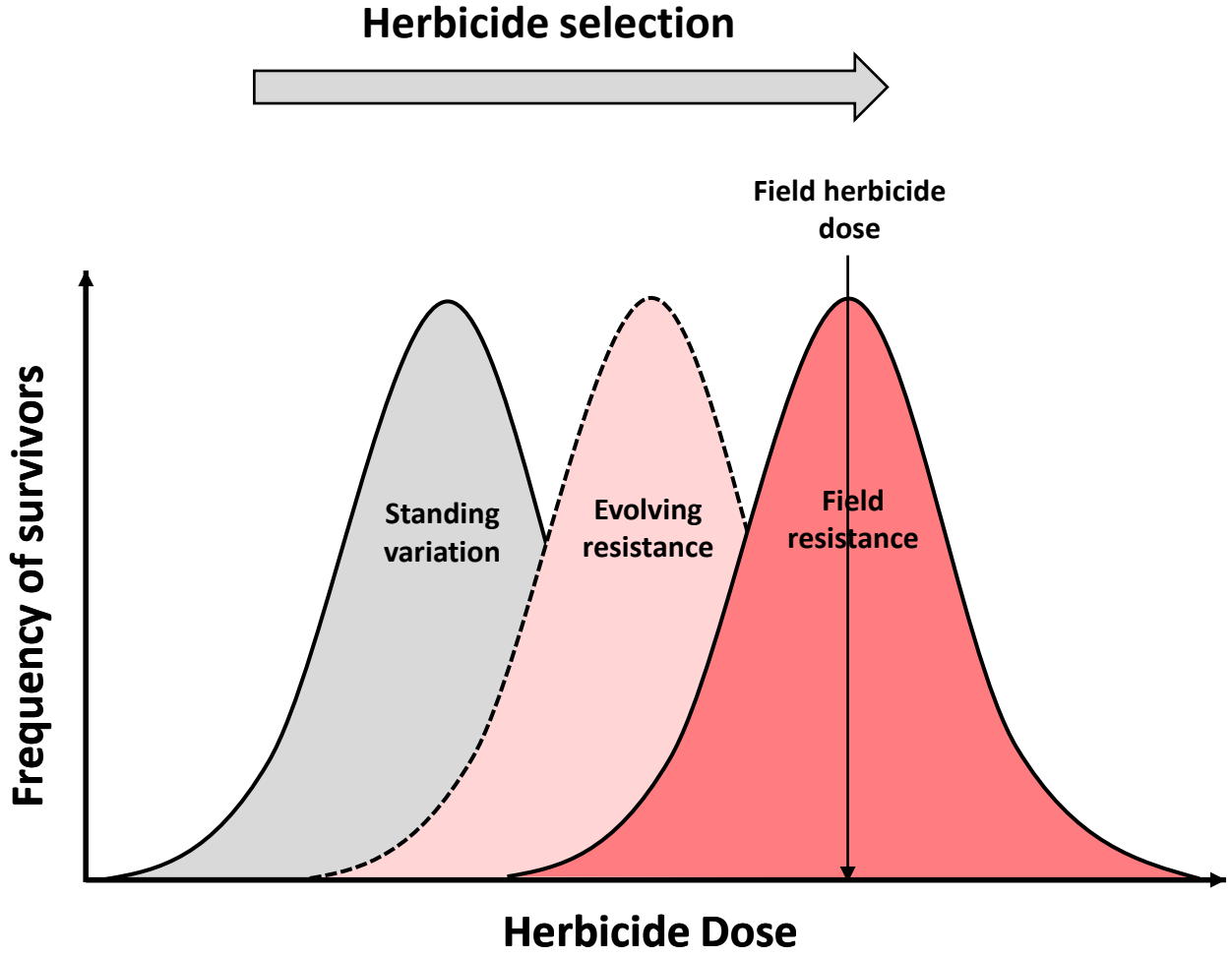


Can we use epidemiological approaches to detect creeping glyphosate resistance in blackgrass?

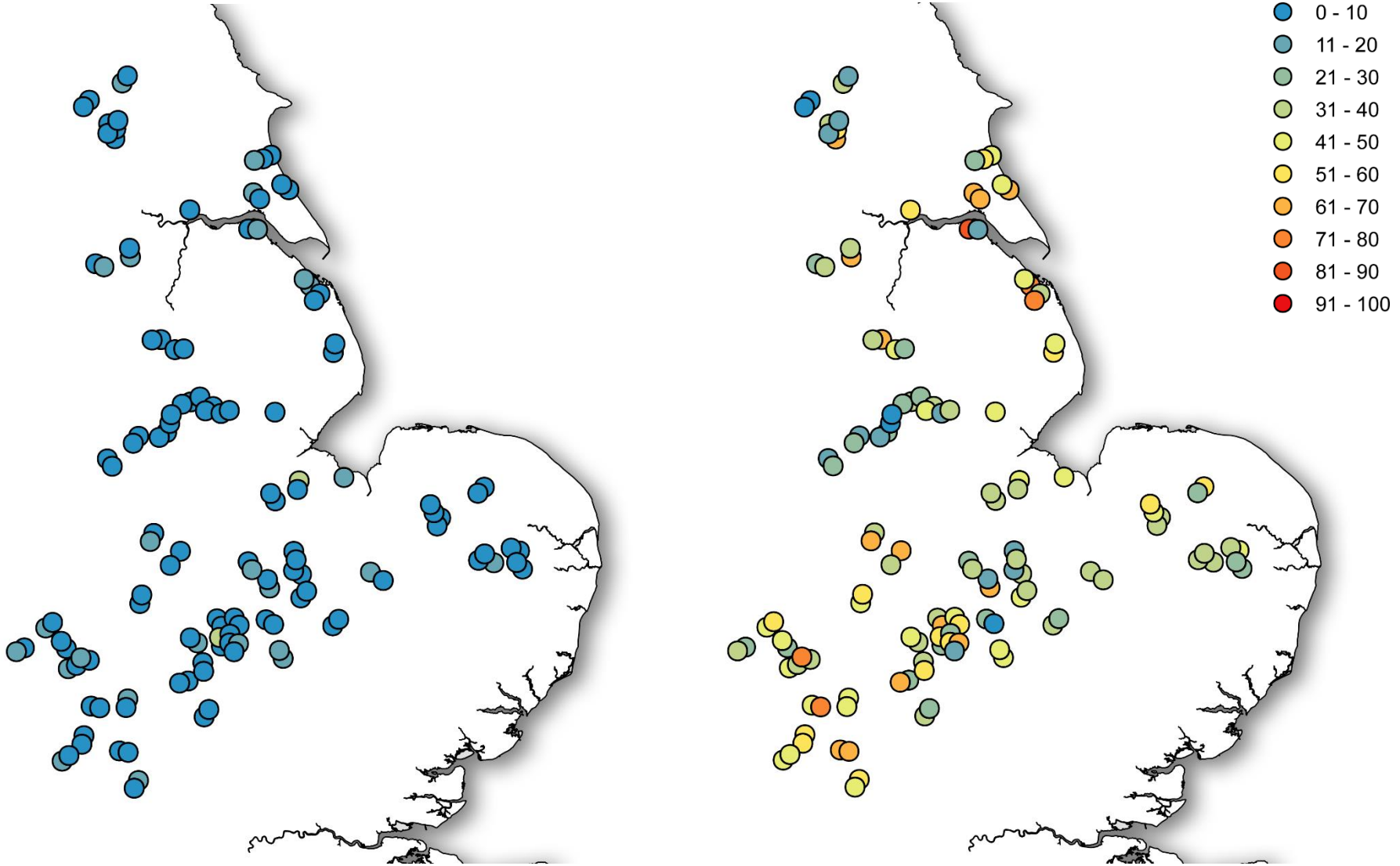
Can we do this pre-emptively, *before* resistance has become a problem?

Glyphosate sensitivity in the UK

ROTHAMSTED RESEARCH

Field rate (540 g ha^{-1})

¾ rate (405 g ha^{-1})



Glyphosate ‘insensitive’ blackgrass

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Quantitative genetics for glyphosate sensitivity

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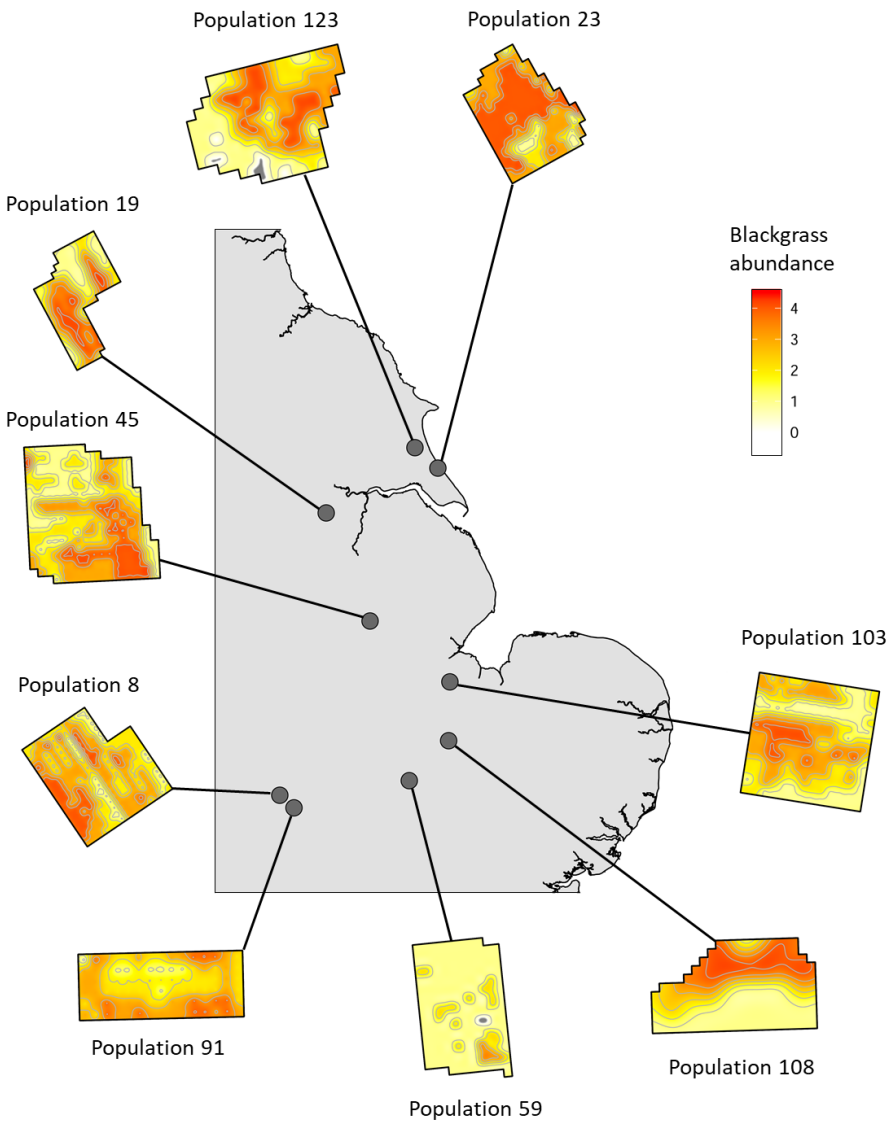

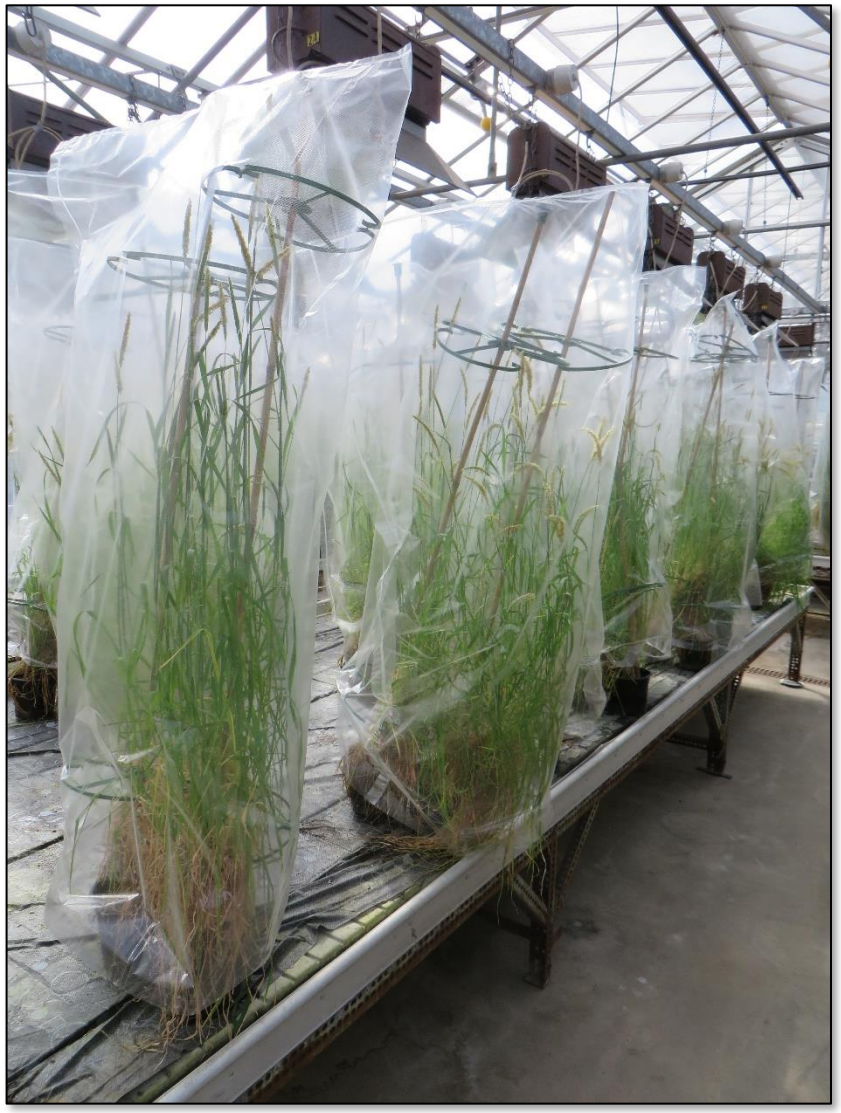

Nine blackgrass populations chosen

Individual pairs of plants cross pollinated to produce seeds

400 seed families produced

Quantitative genetics for glyphosate sensitivity

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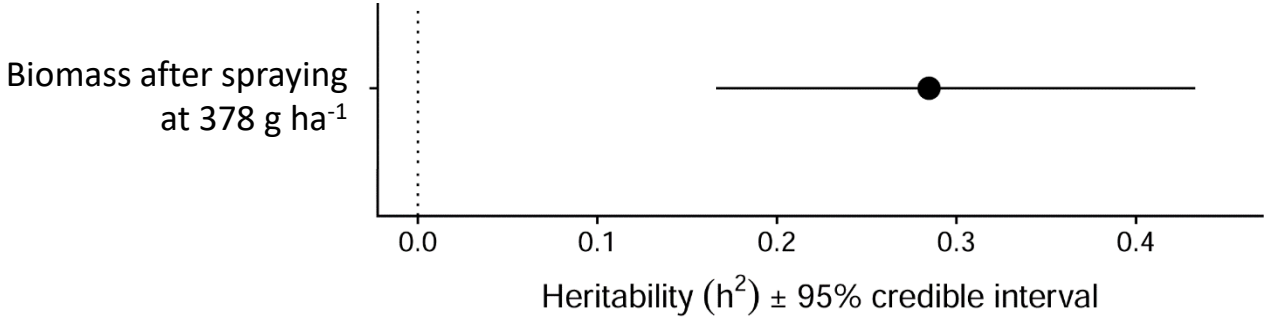
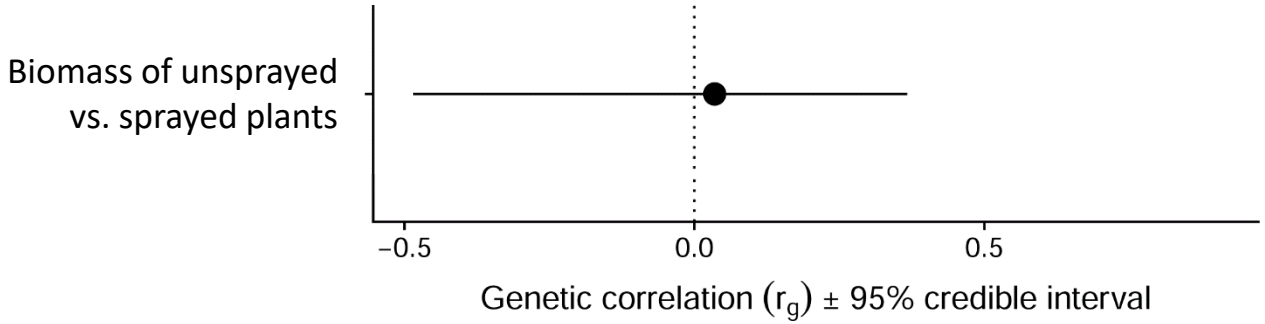
Narrow-sense heritability:
(How much of the phenotype is due to additive genetic effects)



Genetic correlation:
(Do the same genes determine unsprayed and sprayed biomass)



Response to glyphosate selection

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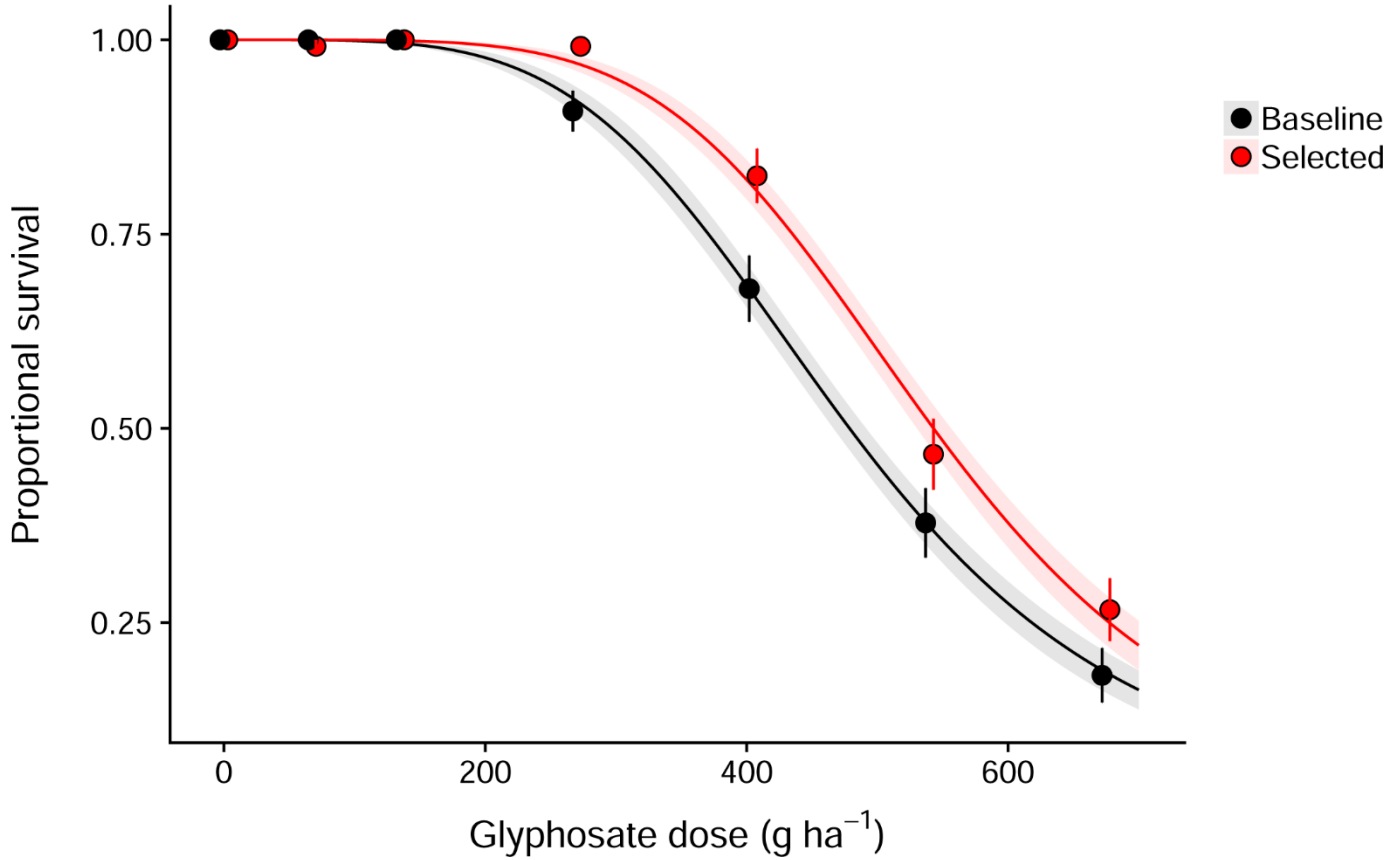

Reduced sensitivity to glyphosate *does* respond to further selection

See also: Davies and Neve (2017). *Weed Research*. 57, 323–332

Predictors for reduced glyphosate sensitivity

Management factor	Sums of squares	P value
<u>Population size and cultivation</u>		
Black-grass abundance	-0.007	0.217 ns
Proportion autumn sown	0.408	0.517 ns
Black-grass emergence	0.270	0.026 *
Cultivation intensity	0.150	0.661 ns
<u>Herbicide usage</u>		
Herbicidal Glyphosate	**0.452**	**0.008 ****
MOA turnover	0.164	0.142 ns
MOA diversity	-0.126	0.447 ns
MOA mixing	-0.092	0.763 ns
<u>Herbicide resistance</u>		
Mesosulfuron resistance	0.277	0.081 ns
Cycloxydim resistance	-0.330	0.096 ns
Fenoxaprop resistance	0.170	0.238 ns

R^2 marginal: 0.240

R^2 conditional: 0.565

Glyphosate use is the strongest predictor of current glyphosate sensitivity (LD_{50})

Fields with higher glyphosate usage have higher survival of glyphosate

Reduced glyphosate sensitivity is evolving

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1. Does blackgrass show variability in glyphosate sensitivity? - Glasshouse glyphosate sensitivity assays of UK populations	✓
2. Does that variability have a heritable genetic basis? - Classical genetics on pedigreed seed families	✓
3. Can glyphosate selection cause further reduction in sensitivity? - Sensitivity screening in generation following glyphosate selection	✓
4. Is there evidence for this occurring in the field? - Epidemiological analysis of field management data	✓

Research

New Phytologist

Evolutionary epidemiology predicts the emergence of glyphosate resistance in a major agricultural weed

David Comont[1], Helen Hicks[2], Laura Crook[1], Richard Hull[1], Elise Cocciantelli[1], Jarrod Hadfield[3], Dylan Childs[4], Robert Freckleton[4] and Paul Neve[1]

Collecting data on blackgrass density, resistance status, wheat yields and input costs enables us to ***count the cost*** of blackgrass resistance.

nature sustainability
ANALYSIS
https://doi.org/10.1038/s41893-019-0450-8

The costs of human-induced evolution in an agricultural system

Alexa Varah[1*], Kwadjo Ahodo[1], Shaun R. Coutts[2,3], Helen L. Hicks[2,4], David Comont[5], Laura Crook[5], Richard Hull[5], Paul Neve[5], Dylan Z. Childs[2], Robert P. Freckleton[2] and Ken Norris[1]

Can we use resistance monitoring studies to do more than simply describe the problem? Yes, we can ☺ .....

- Demonstrate impacts of resistance on weed population dynamics
- Explore impacts of herbicide use (selection history) on selection for resistance
- Adopt proactive approaches to assess future risks of resistance
- Determine economic cost$ of resistance
- Determine patterns of resistance spread across the landscape (data not shown here)