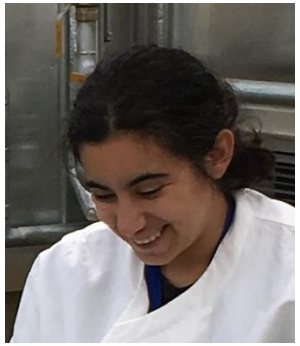
What is ergot: The challenges and solutions

Speaker: Dr Lesley A. Boyd

Numerous people involved in research over a number of years

Nelzo Ereful

Eleni Tente



Lesley Boyd

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Paul Grant

AHDB
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BBSRC
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- **Anna Gordon**
- Eleni Tente
- Donal O'Sullivan
- Rosemary Bayles
- Jane Thomas
- And many more

Ergot

- What is ergot?
- Ergot infection – Sources of infection - primary, ascospore and secondary, conidia.
- Ergot management on farm.
- Ergot resistance in wheat.
- Ergot alkaloid synthesis and contamination of grain: Physical and i*n-planta* transfer.

What is ergot?

- Fungal disease of flowers.
- In cereals and grasses ergot is caused by the fungus *Claviceps purpurea*
- A fungal mass filling the ovary cavity, replacing the seed.
- Asexual stage produces conidia

suspended in honeydew.

- Overwinter structures, ergot sclerotia,

produce sexual structures in early spring.

- Ergot sclerotia contain high levels

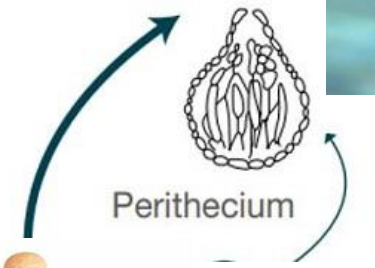
of toxic alkaloids.

St Anthony's Fire

Ergot infection

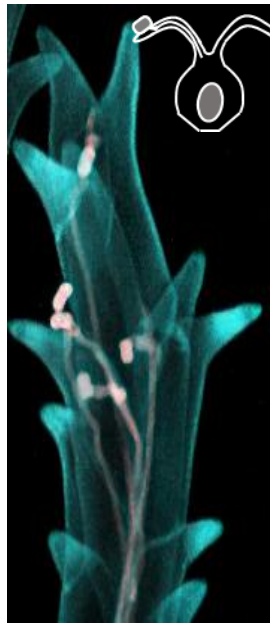
Perithecia release ascospores

Spores land on stigma and grow down style



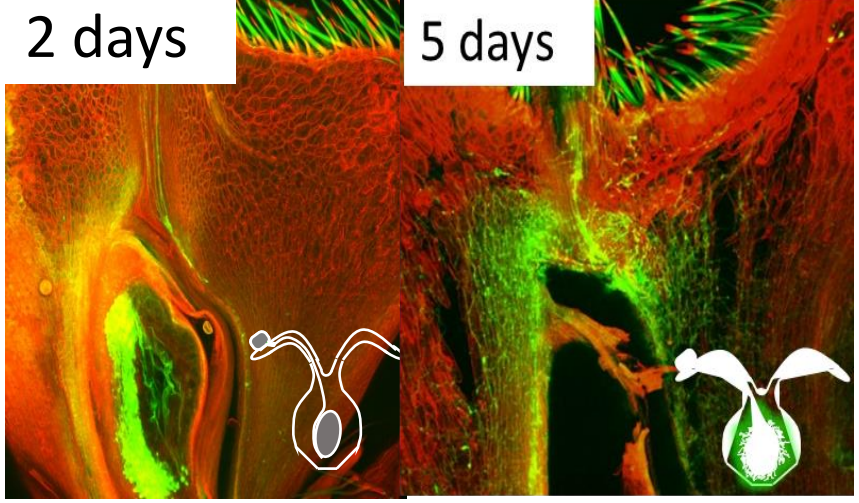
By 21 days sclerotia (ergot).

Ergot germinates producing stroma baring perithecia



2 days

5 days



The leading tip of the fungal hypha grows to the base of the ovary, replacing the ovule with fungal mycelium – sphacelial stage (7 days).

14 days

By 14 days the sphacelial produce spores suspended in a sugary liquid - honeydew.

7 days

Whole Farm Approaches to Ergot Management (2005-2009)

Defra LINK project between NIAB, ADAS, Limagrain, RAGT, Velcourt

With financial support from AHDB (HGCA) and in-kind from a number of industry members.

HGCA Report No. 456

Claviceps purpurea infection: Source of infection

To establish to what extent grass-margins act as a source of ergot infection for wheat on farm margins were surveyed (2005-2007)

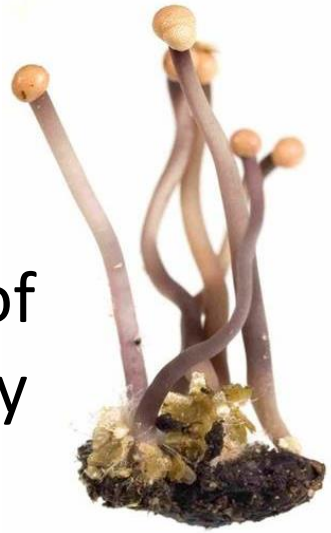
- Ergot found on 37 grass species, with most ergots found on couch grass, Italian ryegrass, black-grass, perennial ryegrass, cocksfoot, tall oat grass, timothy, tall fescue and Yorkshire fog.

- Ergot isolates from black-grass, couch grass, Italian ryegrass and perennial ryegrass were able to infect wheat.

The same isolates of *Claviceps purpurea* can infect cereal and wild grass species.

*Claviceps purpurea i*nfection: Cycle of infection

No conclusive evidence that grass margins were the main source of ergot infection. Grass weeds within the crop thought to be primary source.



Stroma produced from ergot sclerotia

- Primary infection: Ascospores release from stroma believed to peak in May, infecting wild grasses.

- Secondary infection: Honeydew produced by infected grasses transferred to cereals.

Arvalis, France: Ergot Risk Management Tool 2021

1. Risk of ergot inoculum being present in your field

Ergot found in last 2 years	Tillage before sowing this season's crop		Ergot in seed	Risk of inoculum
	< 10 cm	> 10cm		
No	✓		No	LOW
		✓	No	LOW
	✓		Yes	MEDIUM
		✓	Yes	MEDIUM
		✓	No	MEDIUM
Yes	✓		No	HIGH
		✓	Yes	HIGH
	✓		Yes	HIGH

2. Risk of ergot infection:

Risk of ergot inoculum	Grass weed control	Favourable climate for ergot development	
		No	Yes
LOW	Satisfactory	Low	Medium
	Unsatisfactory	Low	Medium
MEDIUM	Satisfactory	Low	Medium
	Unsatisfactory	Medium	High
HIGH	Satisfactory	High	High
	Unsatisfactory	Very High	Very High

Weather conditions between flag leaf unfolding and pollen shed: Temperatures below 4ºC and/or more than 40 mm of rain.

2. Factors that will increase the level of ergot infection:

Grass weed control: Poor control of wild grasses within the crop will increase honeydew inoculum levels and spread the disease.

Ergot control measures:

1) An effective year-round weed control strategy for a minimum of 2 years can minimize the risk of ergot.

2) The ergot inoculum in the field must be controlled by a deep tillage after harvest followed by a shallow tillage the following year, and the use of ergot free seed.

3) Adapt rotation, avoid growing straw cereals for at least 2 years.

4) Harvest ergot infected areas separately.

Ergot resistance

Project (BB/G020418/1): Integrated transcriptome and genetic analysis of early events determining tissue susceptibility in the Claviceps purpurea – wheat interaction

With financial support from Biotechnology and Biological Sciences Research Council (BBSRC) and the Department for Environment Food and Rural Affairs (Defra) Government Partnership Award

Sources of ergot resistance in wheat

At NIAB we have developed a system for assesses the level of ergot infection, and have used these scales to look for natural ergot resistance in wheat

Honeydew scores on a scale of 1 to 4, scored 14 days after inoculation. (1) No honeydew; (2) Honeydew is confined within the glumes; (3) Small droplets of honeydew exuded from the floret; (4) Large droplets of honeydew exuded from the florets.

MARVIN seed analyser used to obtain average sclerotia weigh and the number of sclerotia within each size category.

Sclerotia Sizing Scale for *Claviceps purpurea*

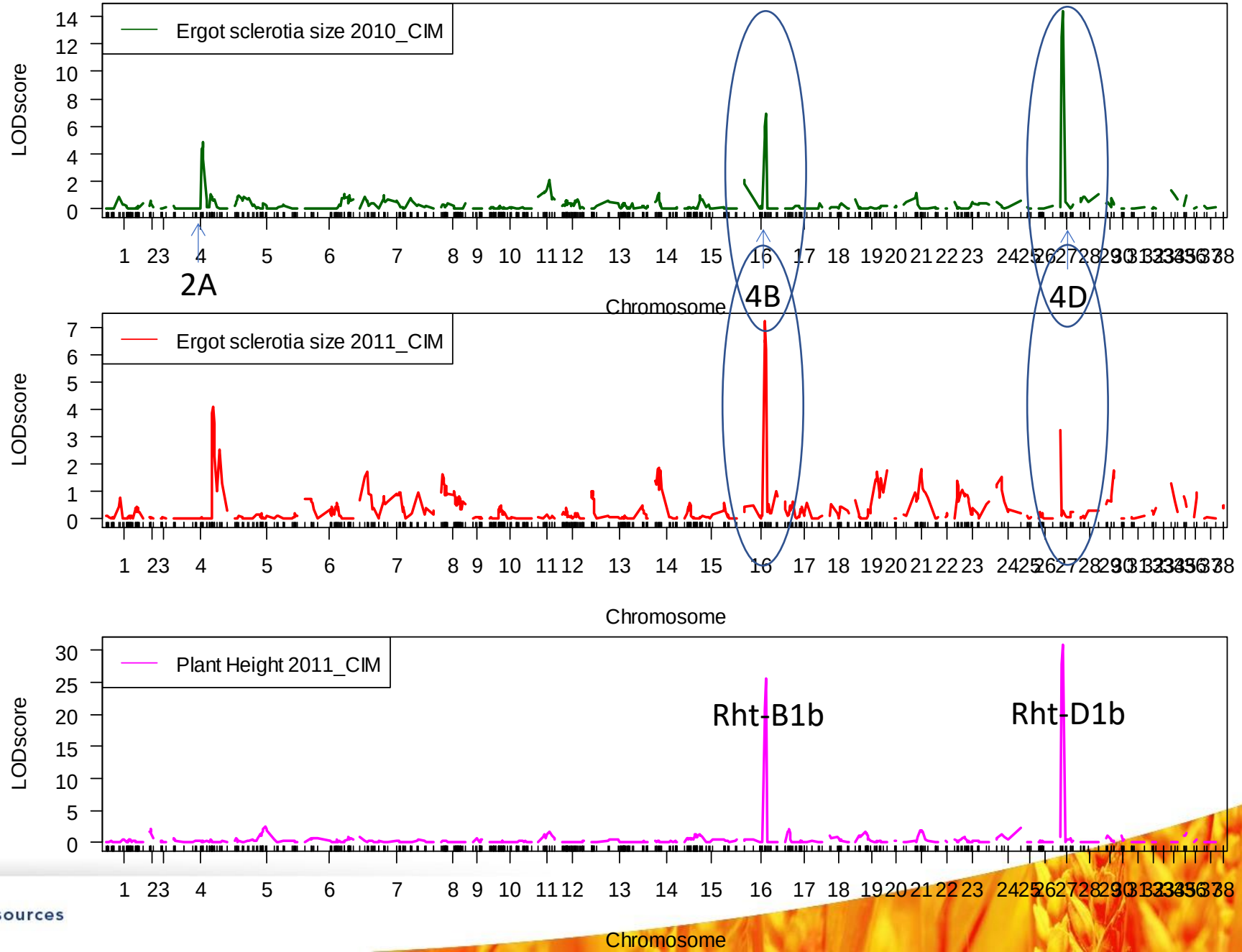
Scale	0	1	2	3	4	5	6	7
Example sclerotia								
Length range / mm	0	≥ 1.5	1.5 - 3	3 – 4.5	4.5 – 7	7 – 9	9 - 11	≥ 11
Width range / mm	0	≥ 1.5	1.5 - 2	≥ 2.5	≥ 2.5	≥ 3	≥ 4	> 4
Further comments	Infection but no sclerotia formed. No seed set	Sclerotia that are the size of an ovary – usually round	Sclerotia that are larger than the size of an ovary – usually oblong	Sclerotia that are smaller than a seed	Sclerotia that are approx the size of a wheat seed	Sclerotia that completely fill the seed cavity	Sclerotia visible before extracting from ear	Massive. More than half is extending from the glumes

Quantitative Trait Loci (QTL) for ergot resistance in the Robigus x Solstice

QTL for sclerotia size were identified on chromosomes 2A, 4B, 4D and 6A.

2A and 4B - Robigus
4D and 6A - Solstice

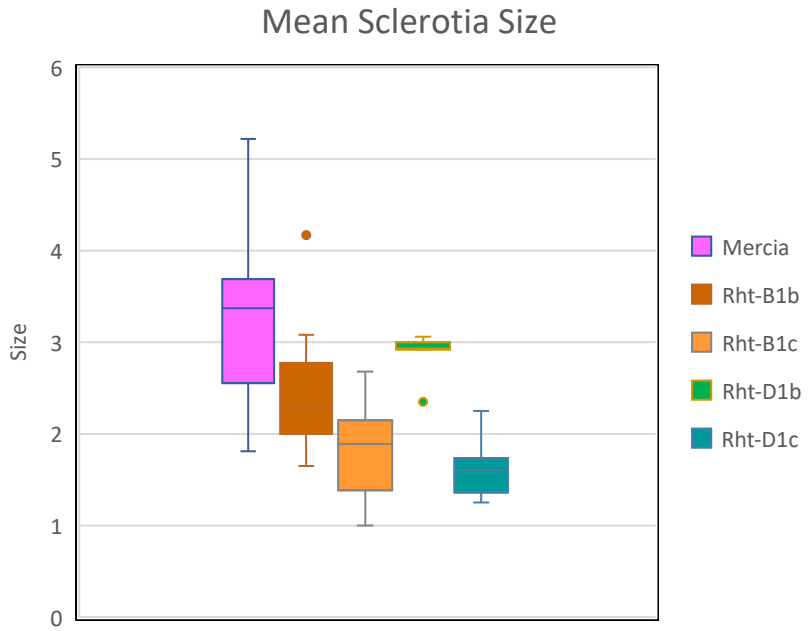
The QTL on 4B and 4D co-located with the dwarfing alleles *Rht-B1b* (Robigus) and *Rht-D1b* (Solstice).

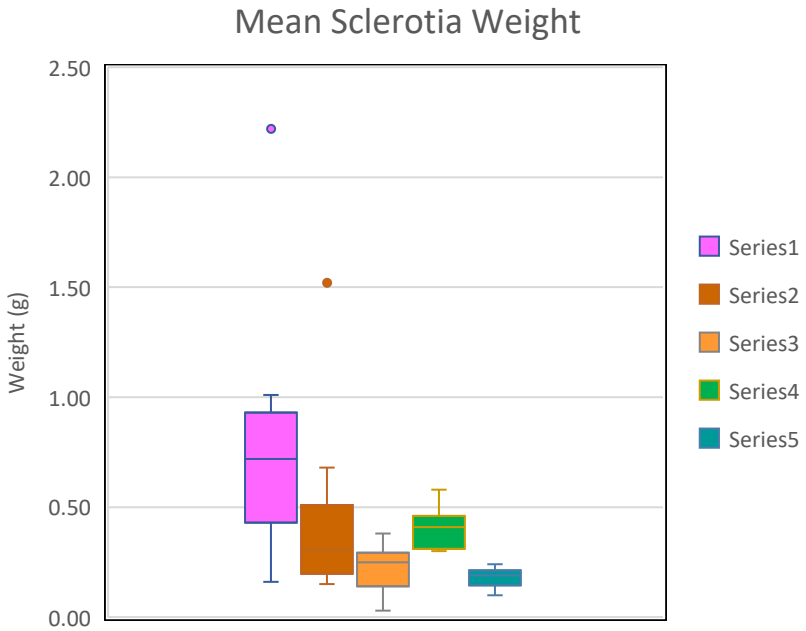


The role of the Reduced height genes in ergot resistance

A general trend towards increased resistance to *C. purpurea*, with smaller and lighter sclerotia, was observed on the NIL *Rht-B1b*, *Rht-D1b, Rht-B1c* and *Rht-D1c* compared to Mercia.

Mercia NIL: carrying the gibberellic acid (GA)-insensitive semi-dwarf alleles *Rht-B1b* and *Rht-D1b* and the severe dwarf alleles *Rht-B1c* and *Rht-D1c.*



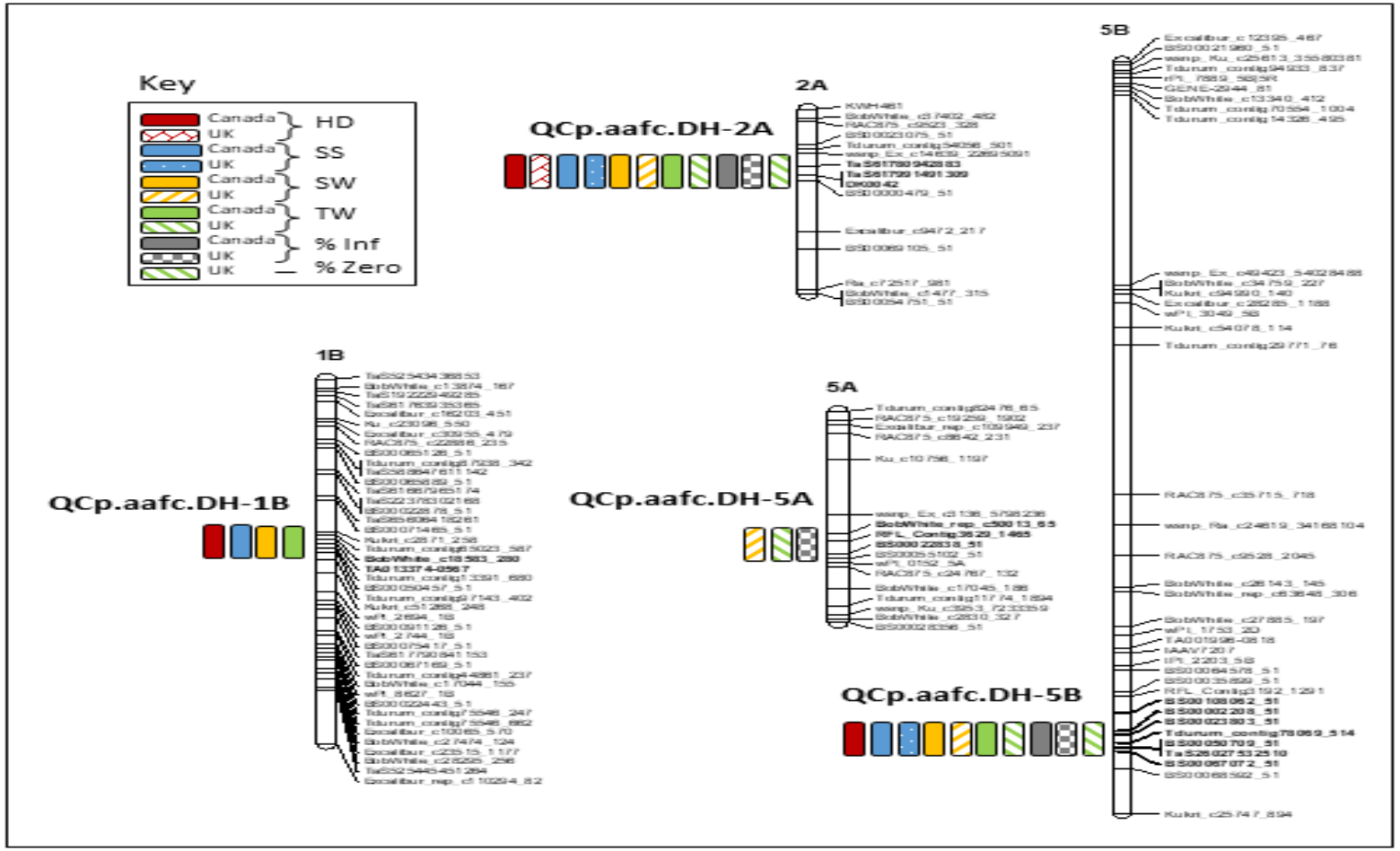


Our results suggest that GA-mediated degradation of the DELLA proteins supports infection of wheat by *C. purpurea*.

QTL in the durum wheat variety Greenshank

Four QTL identified on chromosomes 1B, 2A, 5A and 5B.

The QTL on 2A was particularly interesting as it was associated with a large reduction in honeydew production.



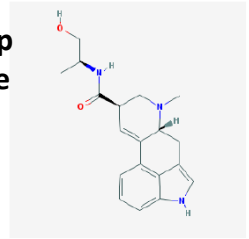
Grain contamination with ergot alkaloids

Financial support from AHDB: Project report 603 (2019)

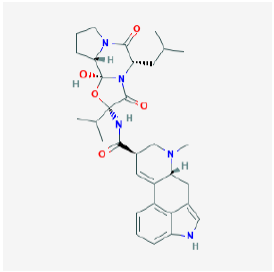
Ergot Alkaloids (EAs) produced by Claviceps purpurea

6 ergot alkaloids and their epimer were quantified using LC-MS carried out by CampdenBRI

Used in childbirth to stop haemorrhage and induce 3rd stage of labour

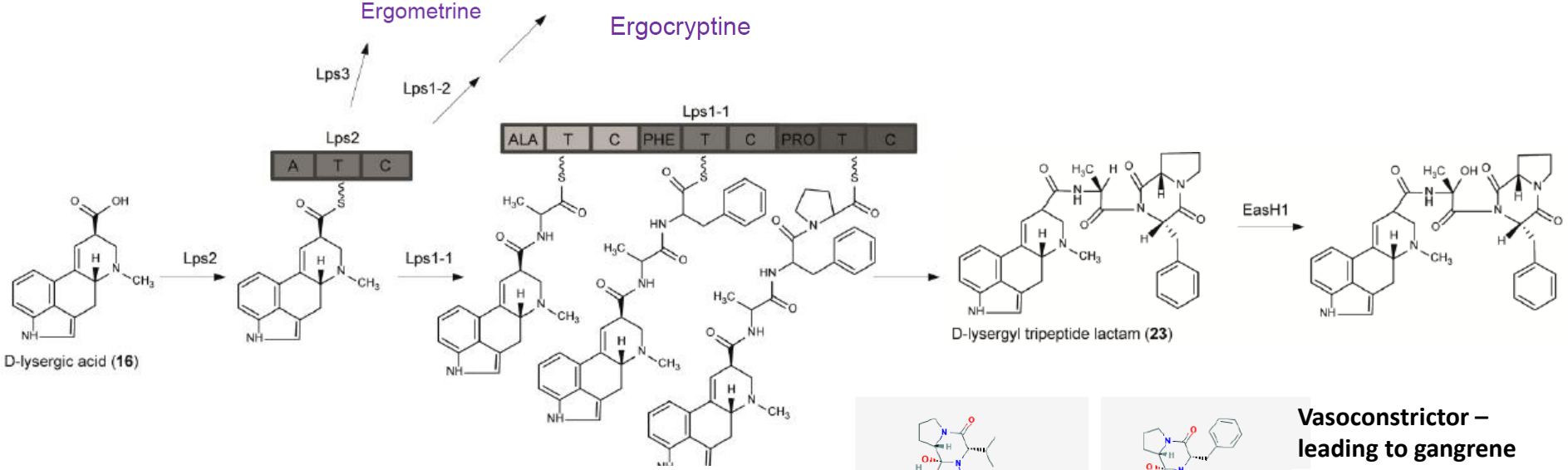


Ergometrine

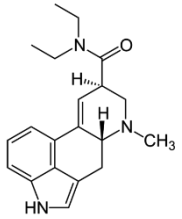


Ergocryptine

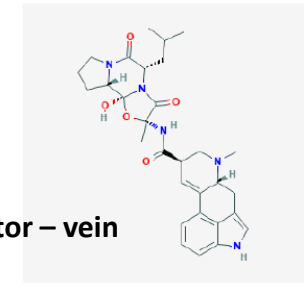
Derivatives of ergocryptine, are being used in treatments for Parkinson's disease and other dementia type; prophylaxis migraine treatment



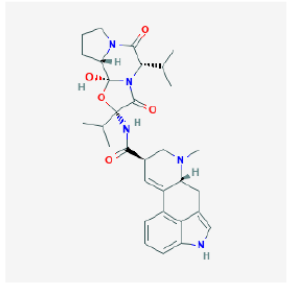
All 13 genes of the EA biosynthesis pathway are turned on at 5 days after infection.



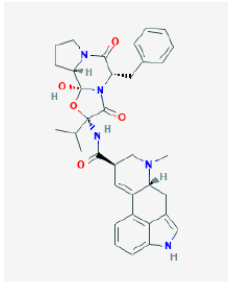
Venoconstrictor – vein narrowing



Ergosine



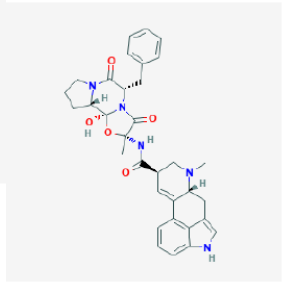
Ergocornine



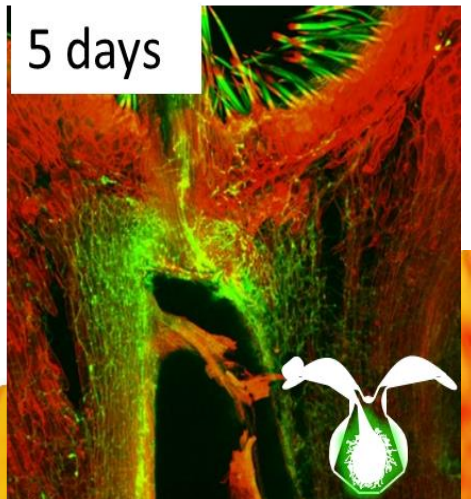
Ergocristine

ergocornine and ergocristine derivatives are being use to treat symptoms of dementia

Vasoconstrictor – leading to gangrene



Ergotamine



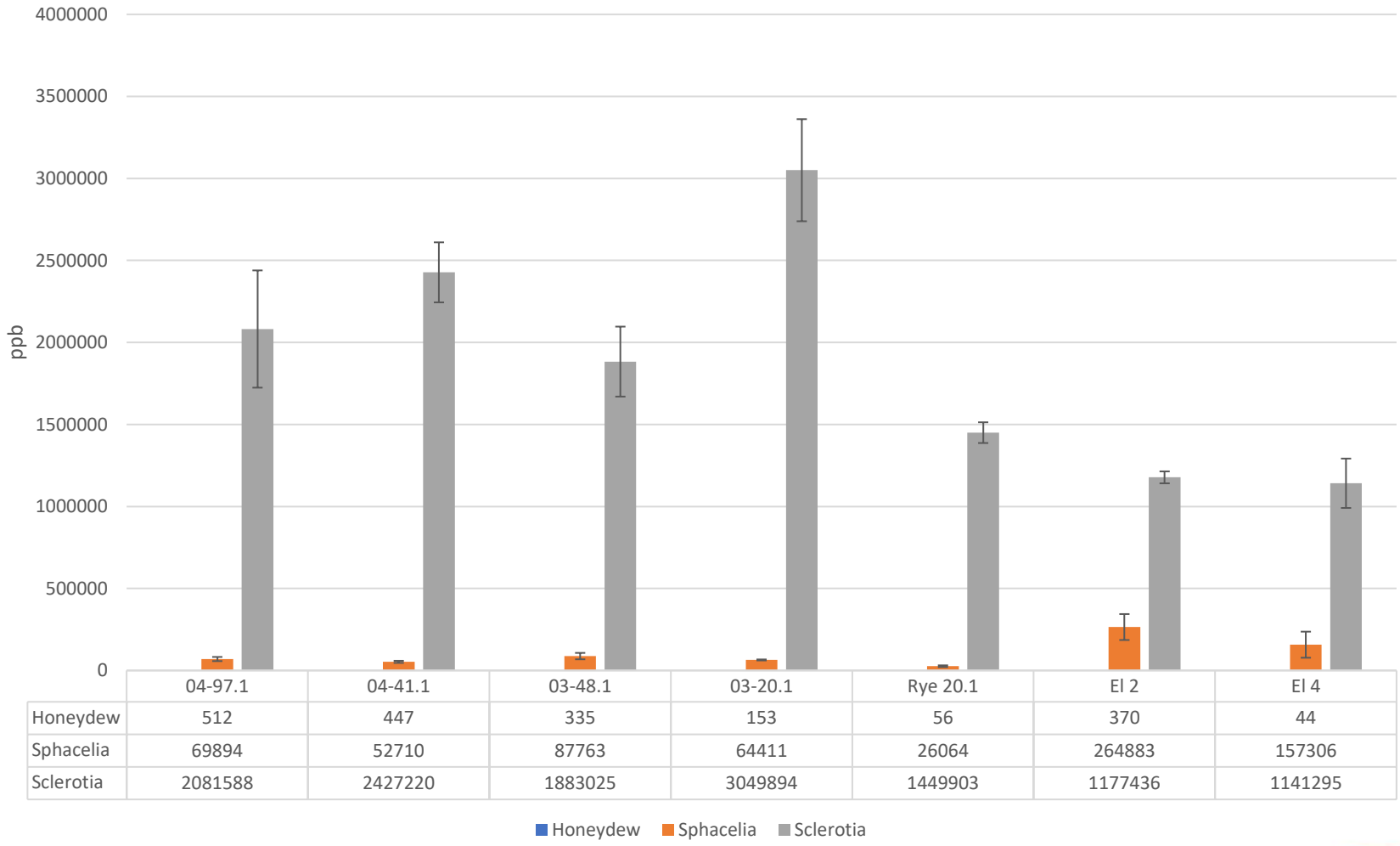
Ergot alkaloid contamination of healthy grain

- To determine whether ergot alkaloids can be transferred from *C. purpurea* infected flowers onto healthy grain developing within the same ear.

- To determine to what extent ergot alkaloids are transferred to healthy grain during direct, physical contact with whole, partial and sclerotia dust.

The levels of ergot alkaloids in different *C. purpurea* tissues, comparing honeydew, sphacelia and sclerotia.

Wheat variety Mulika



	04-97.1	04-41.1	03-48.1	03-20.1	Rye 20.1	El 2	El 4
Honeydew	512	447	335	153	56	370	44
Sphacelia	69894	52710	87763	64411	26064	264883	157306
Sclerotia	2081588	2427220	1883025	3049894	1449903	1177436	1141295

Honeydew
2.7×10^2

Sphacelia
1.0×10^5

Sclerotia
1.9×10^6

To determine whether ergot alkaloids are transferred from *C. purpurea* infected flowers onto healthy grain within the same ear.

Using a single isolate: 04-97.1

Test grain above inoculation site

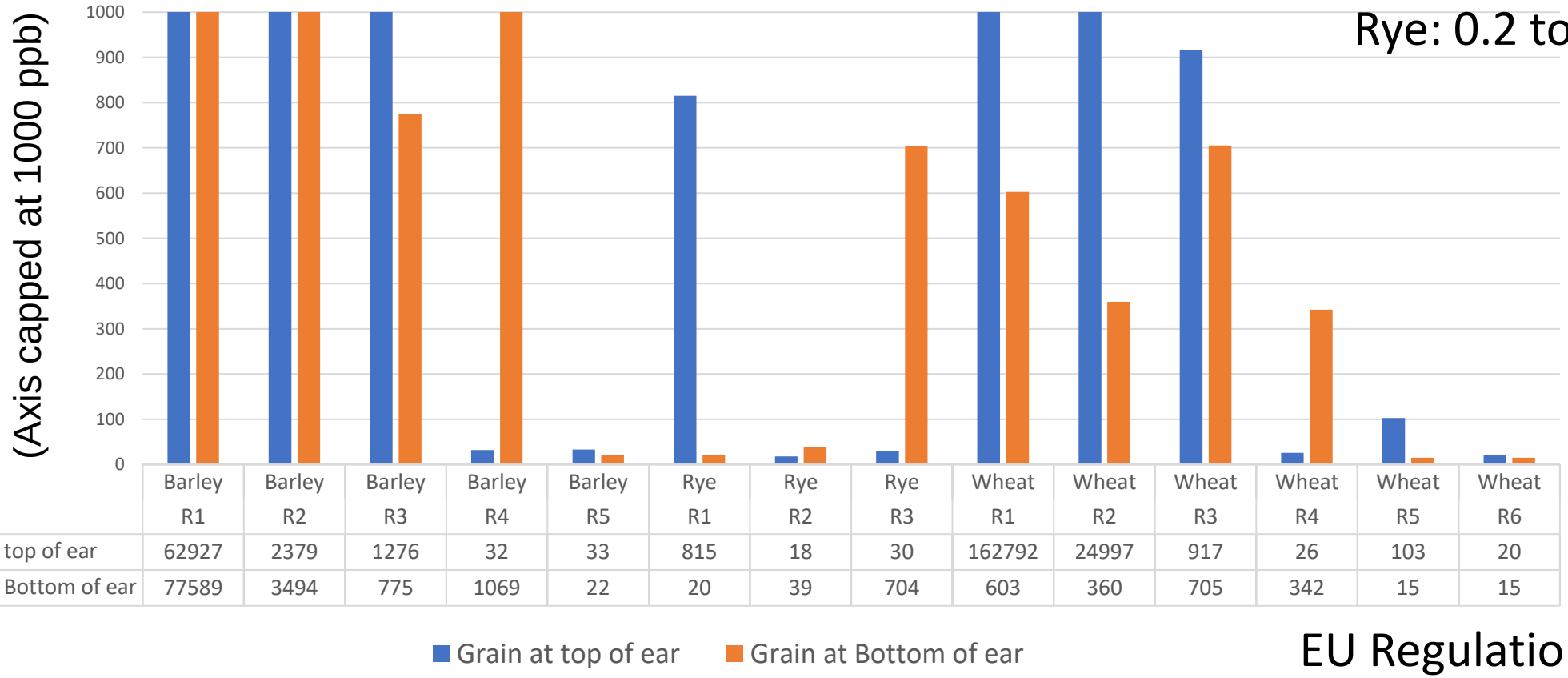
Inoculation site

Test grain below inoculation site

Total ergot alkaloids on grain that formed above and below an ergot

(axis capped at 1000 ppb)

Wheat: 0.2 to 160mg/kg
Barley: 0.3 to 77 mg/kg
Rye: 0.2 to 8.1 mg/kg



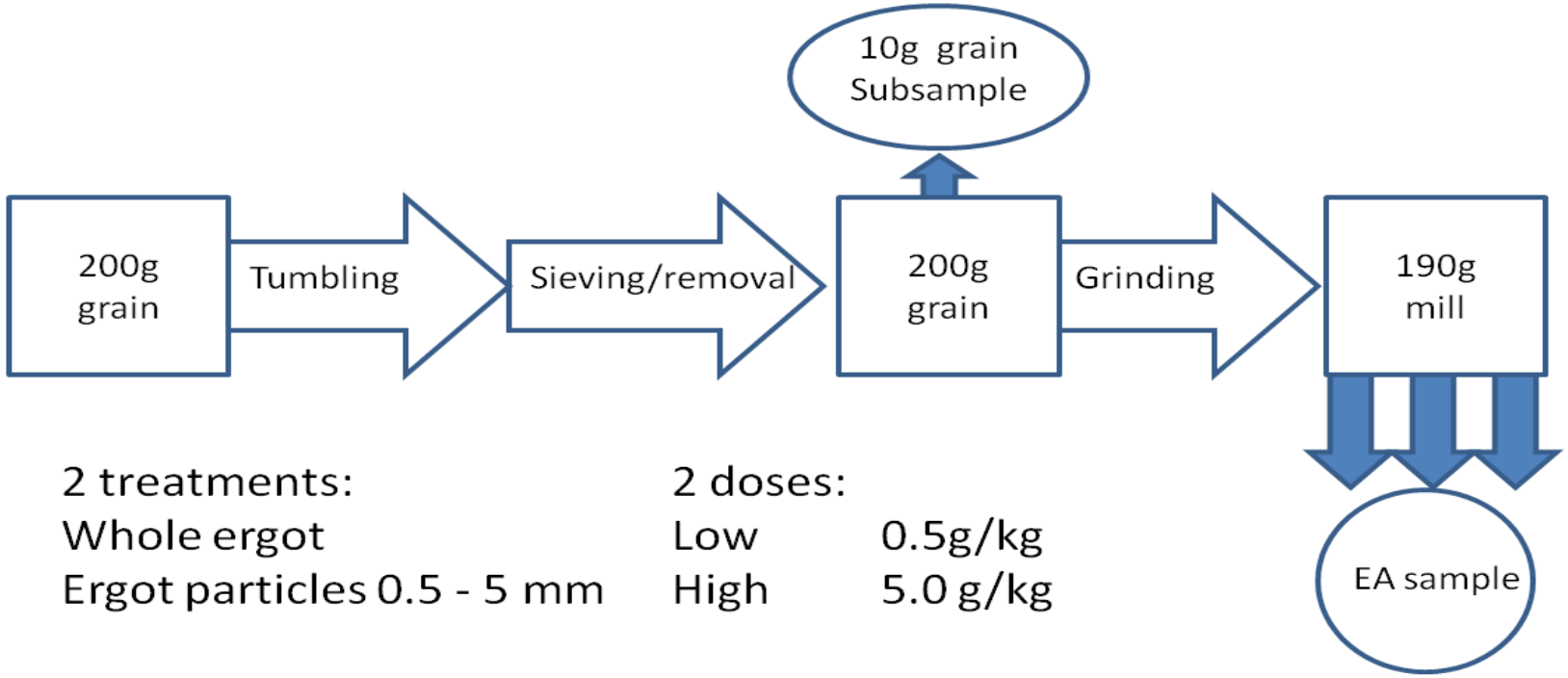
	Barley R1	Barley R2	Barley R3	Barley R4	Barley R5	Rye R1	Rye R2	Rye R3	Wheat R1	Wheat R2	Wheat R3	Wheat R4	Wheat R5	Wheat R6
Grain at top of ear	62927	2379	1276	32	33	815	18	30	162792	24997	917	26	103	20
Grain at Bottom of ear	77589	3494	775	1069	22	20	39	704	603	360	705	342	15	15

EU Regulation 2021/1399:
0.1 mg/kg

A high level of variation in total ergot alkaloid between replicates.

Physical transfer of ergot alkaloids onto grain

To determine to what extent ergot alkaloids are transferred to healthy grain during direct, physical contact with whole, partial and sclerotia dust.

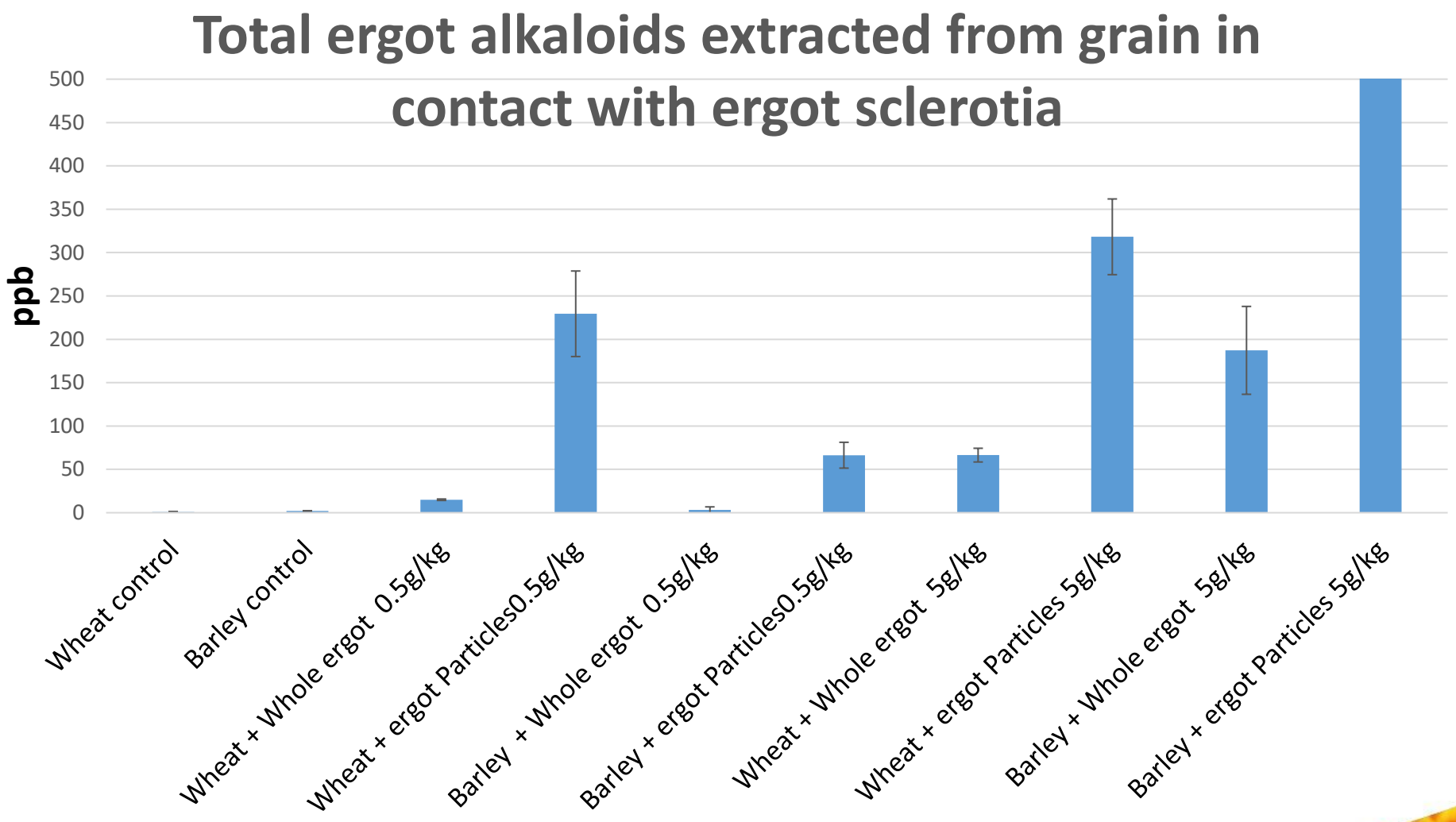


Work undertaken by Campden BRI

Physical transfer of ergot alkaloids onto grain

More ergot alkaloids transferred by broken sclerotia.

Wheat: 3.2 mg/kg
Barley: 5.0 mg/kg



Whole ergot and broken ergot sclerotia 0.5g or 5g of sclerotia per kg grain

NIAB
world-class experience, skills and resources

Take home message:

As ergot alkaloids are able to contaminate otherwise clean seed before harvest it is imperative that ergot disease management is focussed on farm.

Thank-you