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Resistance against Fusarium Head Blight in wheat varieties with coloured grains



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AGROSCOPE



Healthy Nutrition and Sustainable Food Production
National Research Programme NRP 69



Introduction

- FHB resistance is an important trait in plant breeding programs
→ new indicators for the scoring of resistance are needed
- Indicators of spike and/or grain resistance



Type I:
resistance
against the
primary
infection

Type II: against
pathogen
propagation
throughout the
spike

Type III: resistance
of the grains

Ideotype

- Reduced yield losses
- **Grains free of mycotoxins**
- **New traits**

(Photo: C. Martin)



Introduction

Health Promoting Compounds (HPC) for cereals with added value

→ Antioxidants

Pigments with antioxidant properties. Plant breeders provide modern varieties with elevated pigment content in the grain.

Antioxidants play a role in plant resistance. **HPCs have been suggested as a source of resistance against Fusarium head blight.**

→ Cereals more resistant while providing health benefits



Photo: C.Martin

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J. Agric. Food Chem. 2007, 55, 3729–3736 3729

Antioxidant Properties of *Fusarium* Head Blight-Resistant and -Susceptible Soft Red Winter Wheat Grains Grown in Virginia

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Natural phenolic acids from wheat bran inhibit *Fusarium culmorum* trichothecene biosynthesis *in vitro* by repressing *Tri* gene expression

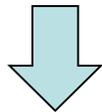
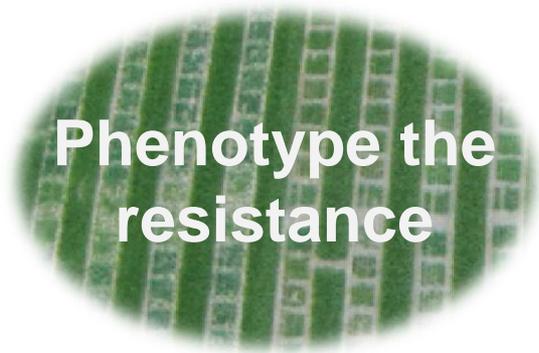
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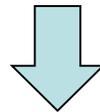


Objectives

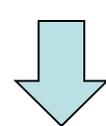
Understand the contribution of antioxidant compounds in FHB resistance



Field resistance tests :
wheat, barley and oats varieties with elevated amounts of antioxidant compounds.



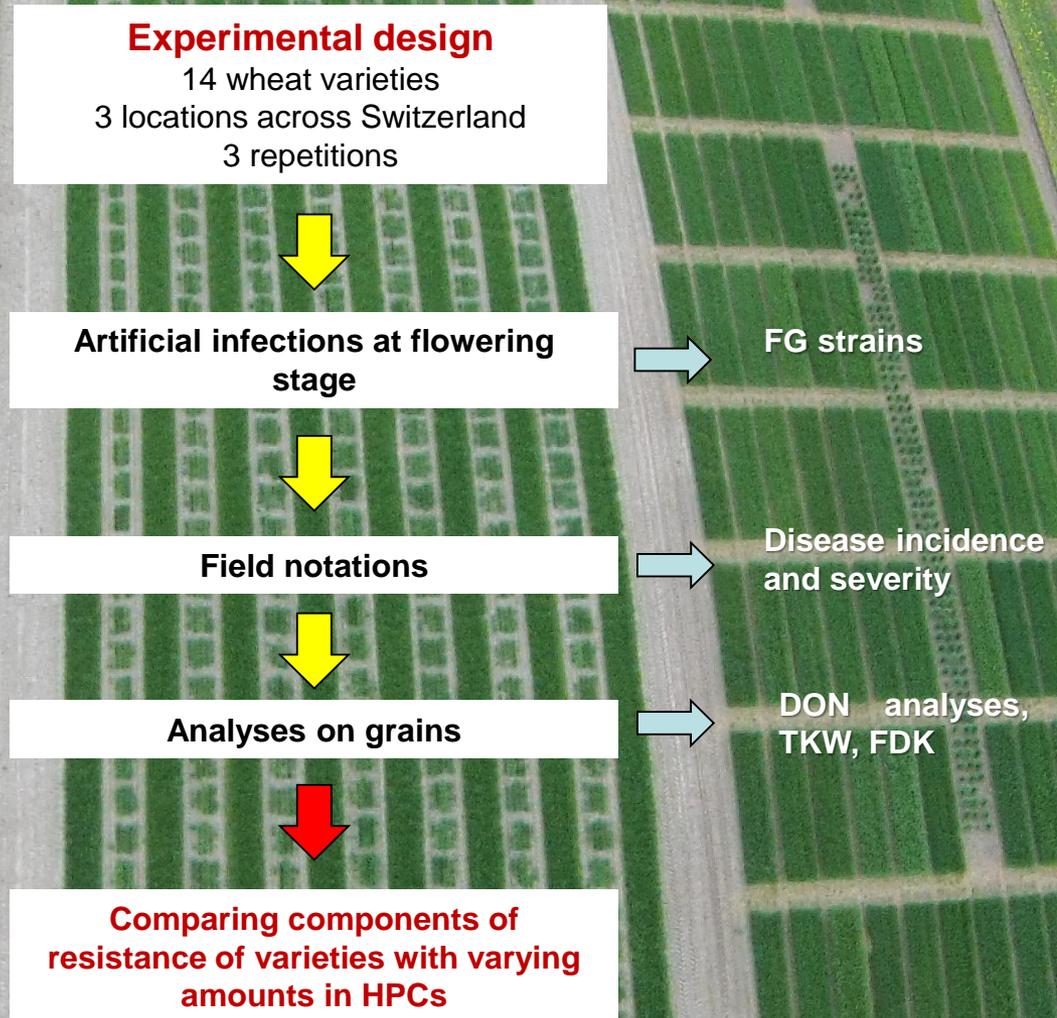
Determine the anthocyanin content in grains, and their impact on resistance and toxin accumulation in grain.



Assess the impact of lutein against FHB. Understand the heritability of traits linked with resistance.

1. Phenotyping the resistance

Dissecting the FHB resistance of wheat with elevated content of HPCs





1. Phenotyping the resistance

Field notations

Incidence: risk for the plant to develop the disease.

Severity: proportion of the spike actually infected.

→ Observations of 30 spikes:
proportion of infected spikes.
→ 3 notations → AUDPC

→ Observations of 30 spikes:
number of infected spikelets.
→ 3 notations → AUDPC



Resistance test in Cadenazzo (photo: F. Mascher)

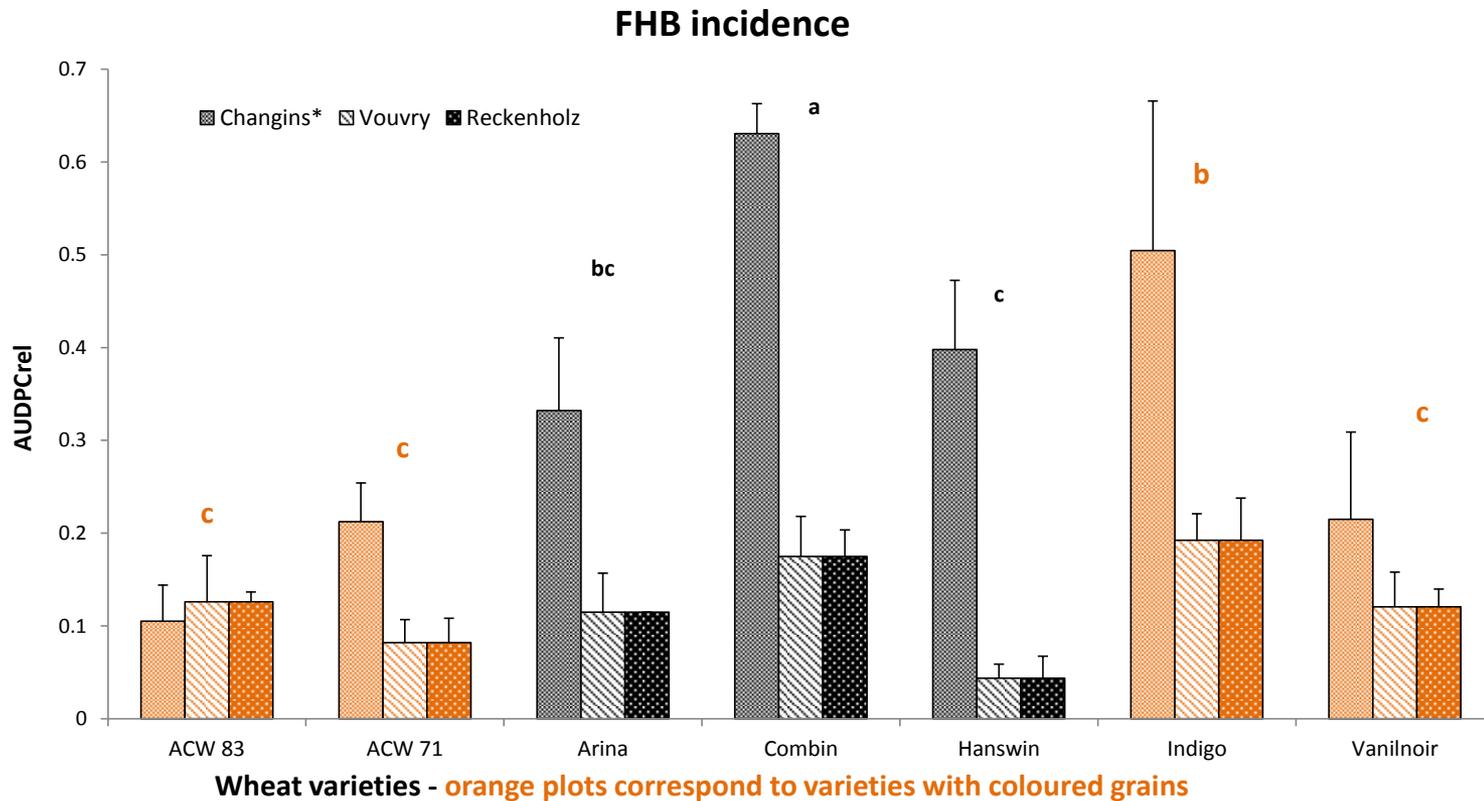


Photo : F. Mascher



1. Phenotyping the resistance

Field notations



- Significant differences in field symptoms between varieties.
- GxE interactions on resistance.
- Most of the coloured lines are among the more resistant varieties.



1. Phenotyping the resistance

Grain analyses

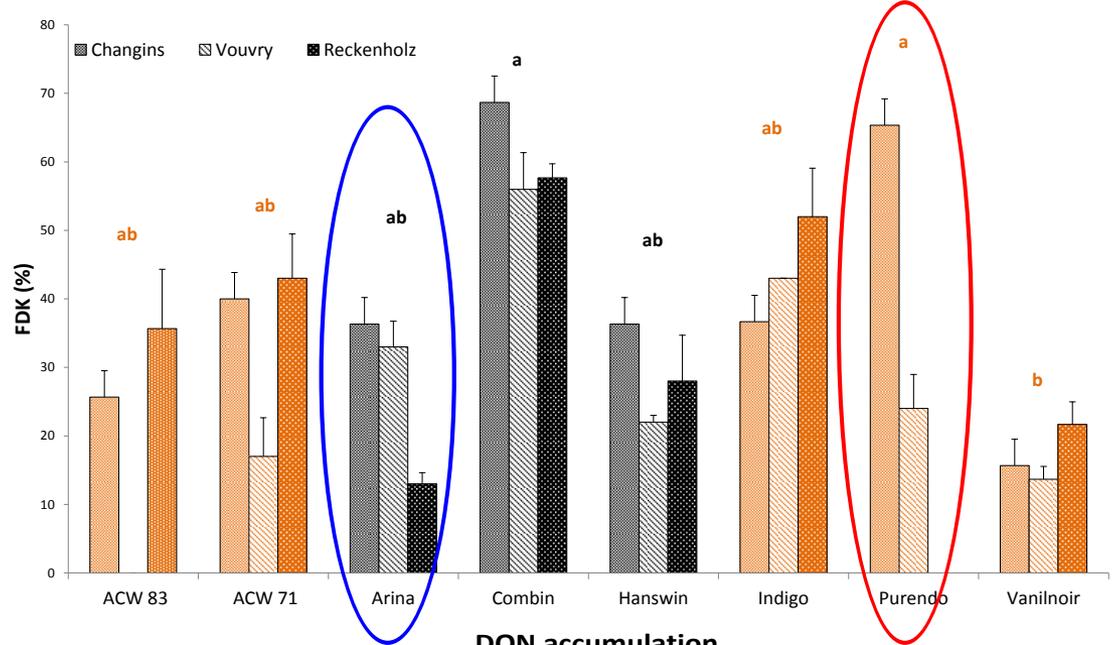
TKW reduction
Yield losses

FDK
Quality losses

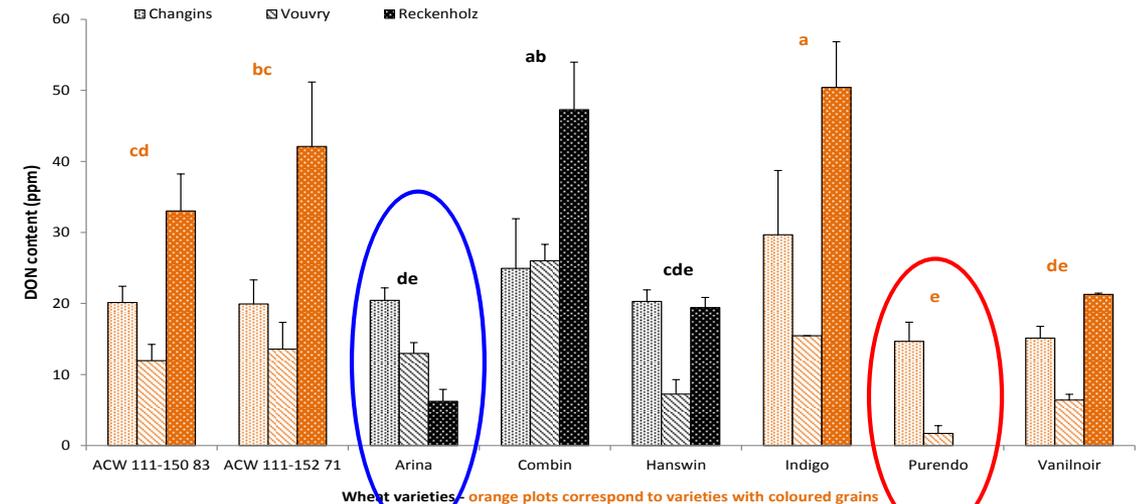
DON acumulation
Quality losses

→ Distinct resistance mechanisms.
→ GxE → Reckenholz
→ Enhanced grain resistance in some coloured varieties.

Fusarium Damaged Kernel



DON acumulation



Wheat varieties - orange plots correspond to varieties with coloured grains



1. Phenotyping the resistance

Conclusions

- Good correlations between the observed parameters

Spearman's rank correlation rho

	Disease severity	Disease incidence	DON content (ppm)	TKW losses (g)
Disease incidence	0.90***			
DON content (ppm)	0.23.	0.24.		
TKW losses (g)	0.61***	0.60***	0.67***	
FDK	0.56***	0.50***	0.60***	0.60***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

- The observed parameters can be linked to the resistance type (1-3) providing a measure of global resistance.
 - Coloured lines were among the most resistant varieties for several of the observed parameters.
 - Coloration of the grains as an indicator of resistance ?

2. Assess the role of anthocyanins in resistance

Anthocyanins are antioxidant compounds, but also pigments. **Blue to dark coloration.**



Present in outer layers of wheat grains but also in the spike.

- **Effect in plant resistance ?**
- **A new trait for plant breeding ?**

Experimental design

Extraction of anthocyanins in whole meal flour¹

- Infected samples
- Non infected samples



Vanilnoir

Hanswin

Indigo

Purendo

Photo : C.Oberson

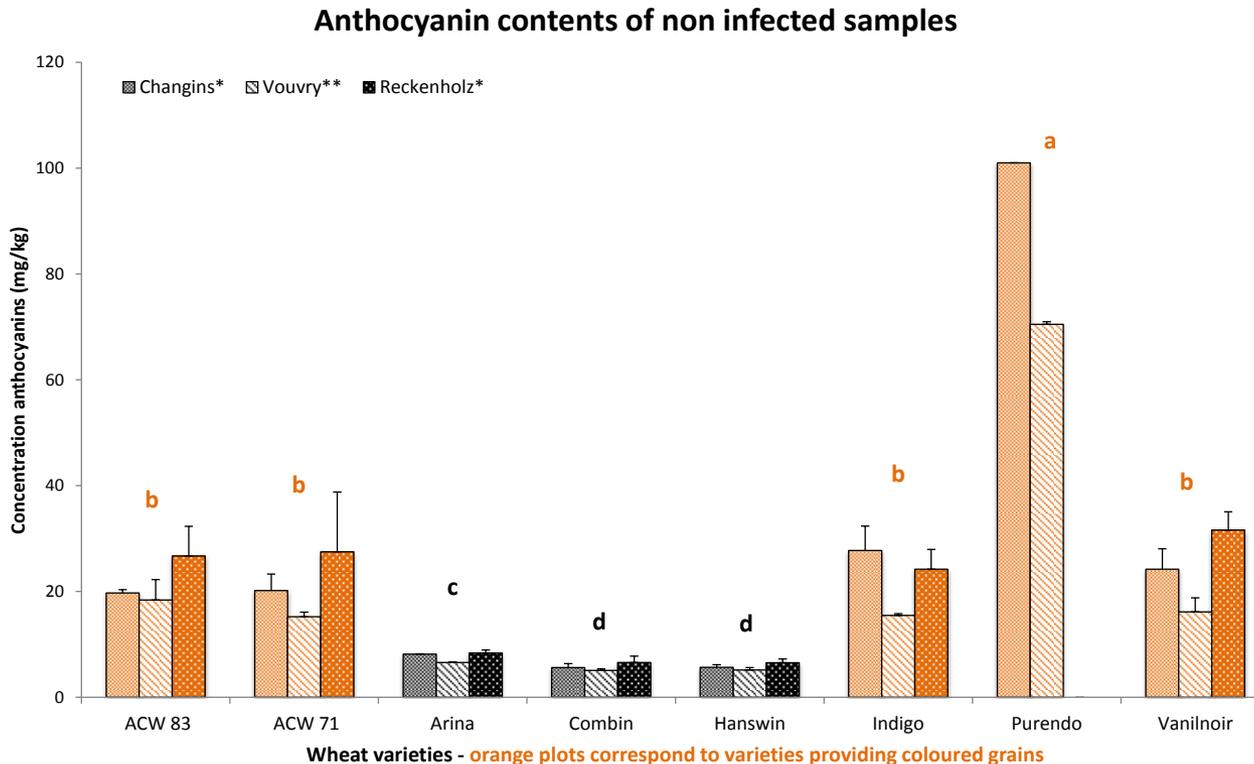
Spectrophotometry measurements



Anthocyanins content

2. Assess the role of anthocyanins in wheat

Results for 2 environments



GxE interactions → anthocyanin content depends on the environment.

Tendency to higher concentrations of anthocyanins in infected grains.

No correlation with DON content, TKW

→ Determination of anthocyanins spectrum by LC MS/MS in progress

→ Development of a new tool for plant breeding of value added cereals.
→ The content in anthocyanins alone did not explain the enhanced resistance of coloured varieties.

→ Implication of other compounds? Ferulic acid, flavonoids, lutein ?



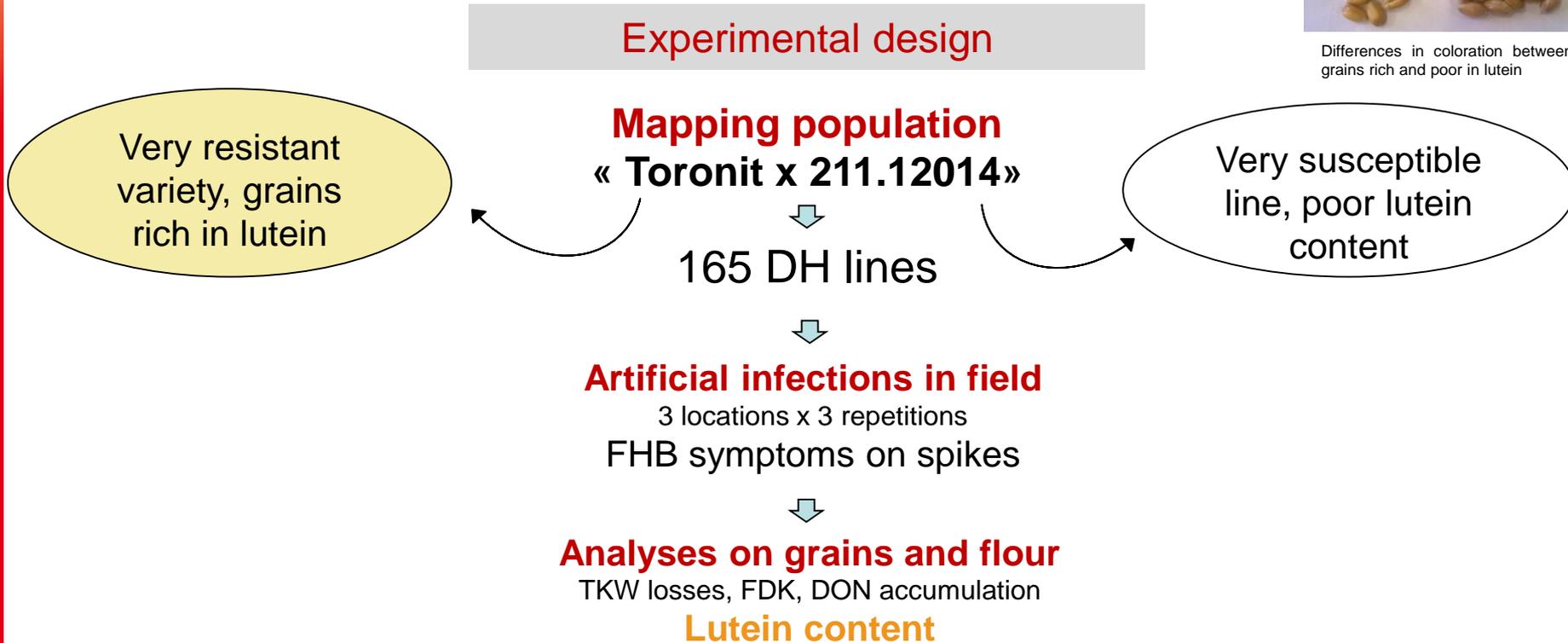
3. Dissect impact of lutein on the resistance of variety Toronit

Lutein is a carotenoid with antioxidant action, giving a yellow pigmentation to the grains



Differences in coloration between grains rich and poor in lutein

Photo: C. Martin





3. Dissect impact of lutein on the resistant variety Toronit

Agroscope | 2015

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IMPACT OF LUTEIN ON WHEAT KERNEL RESISTANCE AGAINST *FUSARIUM GRAMINEARUM*

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Wheat disposes of several resistance mechanisms against *Fusarium* head blight (FHB). They can impede the primary infection, the growth of the fungus in the spike, kernel infection, mycotoxin accumulation and possibly yield losses. Secondary metabolites contribute to resistance. The antioxidant properties of carotenoids may contribute to kernel resistance. Lutein is the main carotenoid present in wheat kernels. High lutein concentrations confer a yellow coloration to the flour. The goal of the present work was to decipher the role and the impact of lutein on the resistance in bread wheat (*Triticum aestivum*) kernels against *Fusarium graminearum* (FG).

Materials and methods

Impact of lutein on kernel resistance was evaluated with the Toronit X ACW 211.12014 doubled haploid population (n=107). Toronit is a cultivar rich in lutein and is moderately resistant while the breeding line ACW 211.12014 contains low amounts of lutein and is susceptible. The grain samples came from FG infected and control plots from a field trial in Delley, Switzerland, in 2014. Lutein concentration in whole meal flour was evaluated through measurement of the yellow index b* (Commission Internationale de l'Éclairage (CIE), Vienna, Austria). Measurements of b* (see Fig. 2) were taken with a Chroma-Meter CR-400 colorimeter (Konica Minolta, Tokyo, Japan). Deoxynivalenol (DON) mycotoxin accumulation was measured with quantitative ELISA Ridascreen® Fast DON test kits (R-Biopharm, Darmstadt, Germany). The percentage of *Fusarium* damaged kernels (FDK%) was counted manually on 100 kernels (see Fig. 1). Thousand kernel weight (TKW) was measured with a Marvin optical grain analyser (GTA Sensorik, Neubrandenburg, Germany).

Results

The lines showed a significant variation in yellow index b* values (p<0.001). Significant variation in FDK% (p<0.001) and DON (p<0.001) were observed among the lines. FG infection resulted in a slight (3%), yet highly significant (p<0.001) reduction of TKW. The relationship between b* and disease symptoms are displayed in Fig. 2 and Table 1.

Relationship between flour b* and *Fusarium* damaged kernels

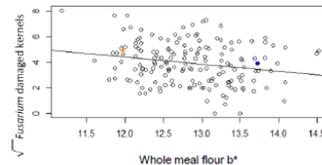


Fig. 2: Relationship between whole meal flour b* and the square root of the percentage of *Fusarium* damaged kernels. The blue circle represents the moderately resistant parent Toronit. The orange circle represents the susceptible parent ACW 211.12014.

	FDK% ¹	DON ¹	TKW loss ²
Yellow index b*	-0.21 p<0.01	-0.15 p<0.05	-0.12 n.s. (p=0.11)

Table 1: Correlation coefficient between yellow index b* and FG infection symptoms. 1: Pearson's r; 2: Spearman's r estimate.



Fig. 1: Healthy and *Fusarium* damaged kernels of bread wheat. a: Healthy grains; b: Kernels with evident damage caused by FG. The kernels are covered with pinkish white mycelium.



Fig. 2: Colorimetric measurement of the yellow index b* in flour. Lutein concentration in the flour is closely correlated with the b* index.

Conclusions

- Lutein content is significantly and negatively correlated with the proportion of *Fusarium* damaged kernels and with DON content in grains.
- High lutein contents contribute to resistance and to reduction of DON accumulation in grains.
- Further studies on larger genetic bases are needed.

Agroscope good food, healthy environment





Conclusions

Field resistance tests for wheat varieties with anthocyanin enriched grains give encouraging results

- The lines with enhanced antioxidant content (anthocyanins and lutein) seems to be more resistant
- These results have to be confirmed by another year of repetition (GxE interactions)
- Open doors to explore: how antioxidants actually impact the resistance, the pathogen, genetic link...
- Analyses of barley with enhanced contents in HPCs are in progress.
- May be conjugated impacts of different antioxidants compounds
 - Analyses of ferulic acid



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Healthy and Safe team

