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Towards Selection for Waterlogging Tolerance in Barley

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Introduction

Waterlogging tolerance project at BRDC

- Waterlogging is a major abiotic stress that causes crop yield losses globally, and mainly results from prolonged rainfall, flooding or poor soil drainage.
- Crop tolerance: oats > wheat > barley.
- Waterlogging tolerance in barley work at BRDC started in 2013.
- Improving WLT in barley still at first steps stage.
- From small scale greenhouse experiments to large scale field experiment with more than 340 barley genotypes from around the world.



AAFC- Brandon Research and Development Centre (BRDC)



View of 2015 BRDC testing field during WLT treatment

- Gather barley germplasm: Canadian cultivars and breeding lines, USA, Australia, Japan, Europe, etc.
- Testing cultivars, plant development stage, soil type, etc.
- Indicators of stress: visual symptoms, chlorophyll, yield penalty.
- Validation of screening protocols

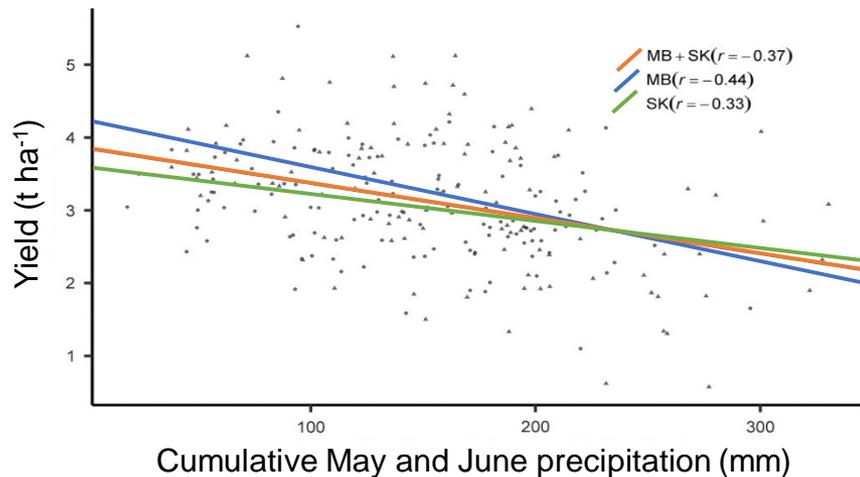


2014 greenhouse testing on different types of soil

Excess moisture in the Canadian Prairies



Examples of the locations of weather stations in MB



(*r*: Pearson's correlation coefficients ($P < 0.001$)).

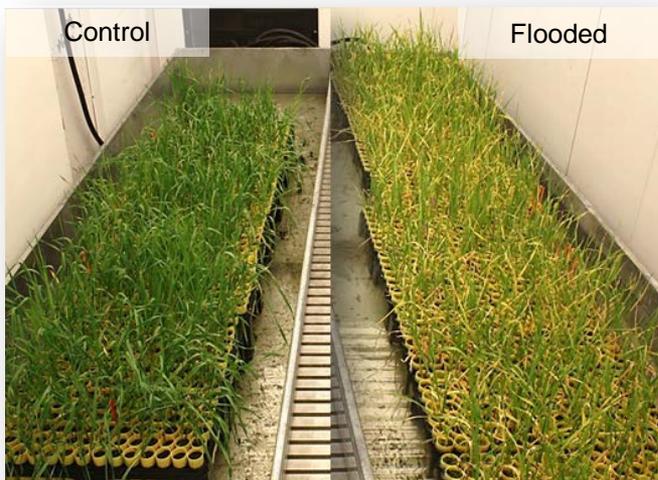
Linear relationship between cumulative May and June precipitation (mm) and barley grain yield (t ha⁻¹) for Manitoba Saskatchewan and combined MB and SK.

- ❖ Analysis of historical (2005-2016) publicly available data from AB, MB & SK:
 - Gathered weather and barley grain yield data
 - Statistical analysis on the effect of monthly accumulated precipitation on barley yield

A significant negative correlation was observed between cumulative May & June precipitation and grain yield in both MB, SK, and MB & SK combined.

Timing of precipitation is a crucial factor for barley yield.
Stage: leaf emergence to tillering - the most sensitive period.

Growth chamber screening of waterlogging tolerance in barley



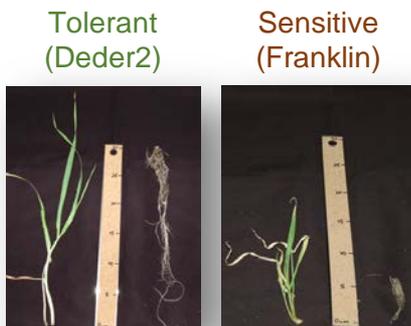
210 two-row barley genotypes screened for response to waterlogging treatment (2017-2018).



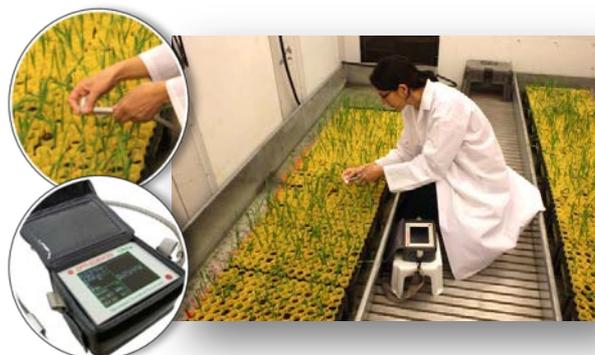
Waterlogging treatment started at 3-leaf stage, and lasted 14 days.



Waterlogging by keeping water level just above soil surface in cones.



14 days after waterlogging treatment
Plant survival rating (Scale 1-9)



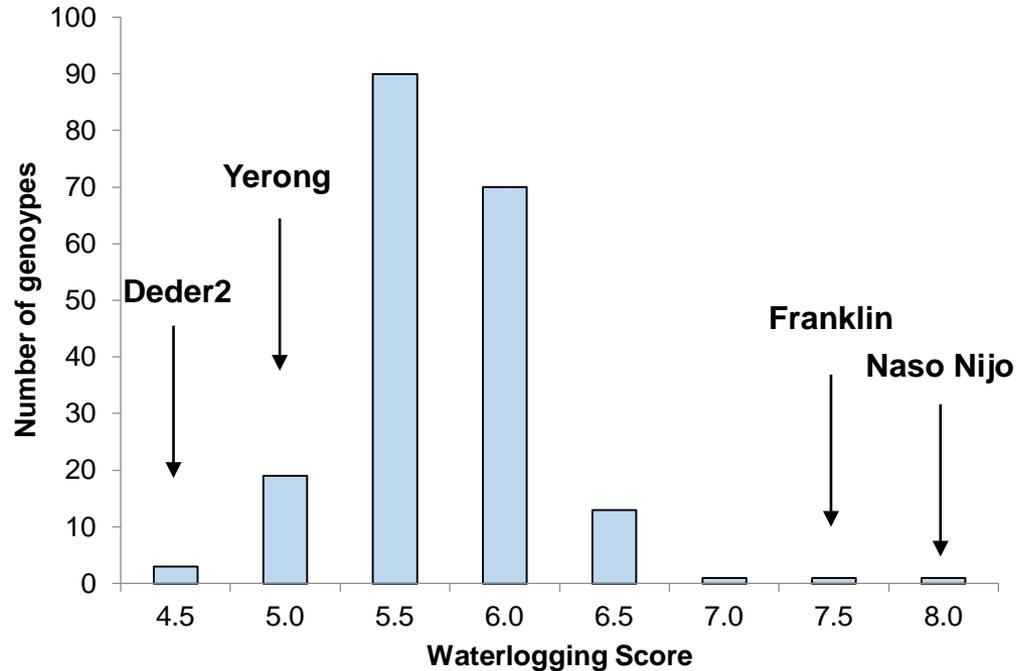
Determination of changes in the efficiency of light utilization for electron transport.
Chlorophyll fluorometer (F_v/F_m ratio)



Above and below ground biomass measurement.
Growth parameters

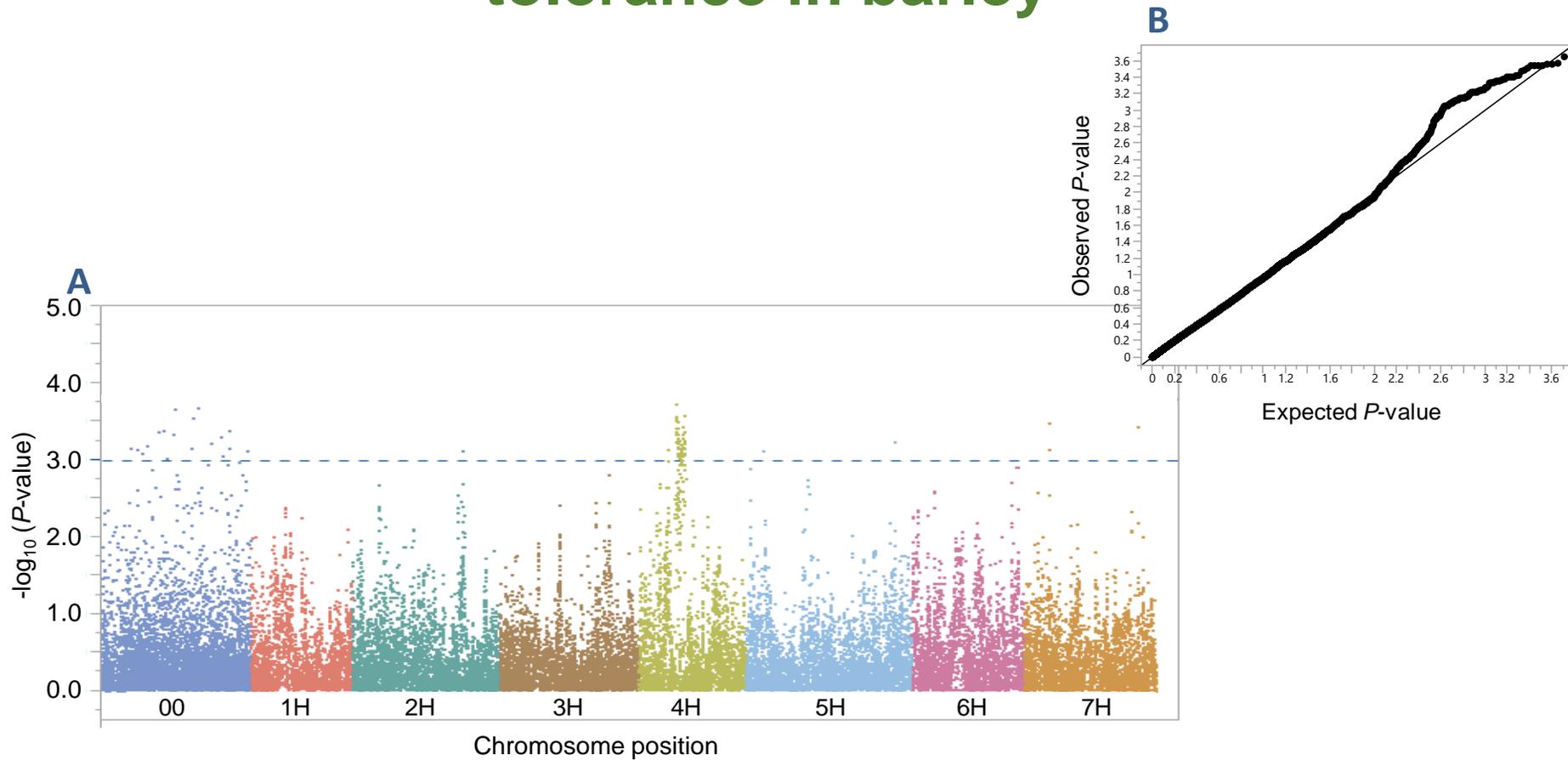
Growth chamber screening of waterlogging tolerance in barley

**Waterlogging
Score
(Scale 1-9)**



Frequency distribution of phenotypic variation of WL Score in the barley collection after 14-days of waterlogging treatment under growth chamber conditions.

Growth chamber screening of waterlogging tolerance in barley

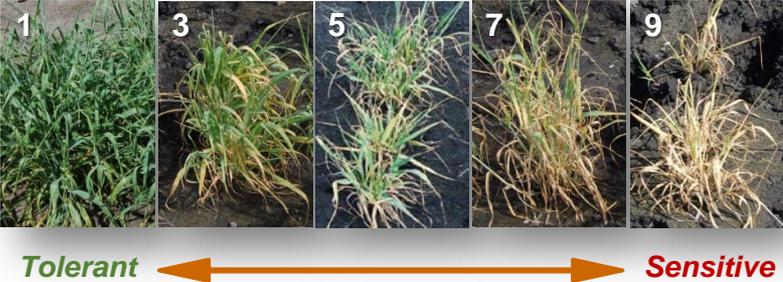


Manhattan plot (A) and corresponding quantile-quantile plot (B) of P -values for chlorophyll fluorescence in barley under waterlogging stress

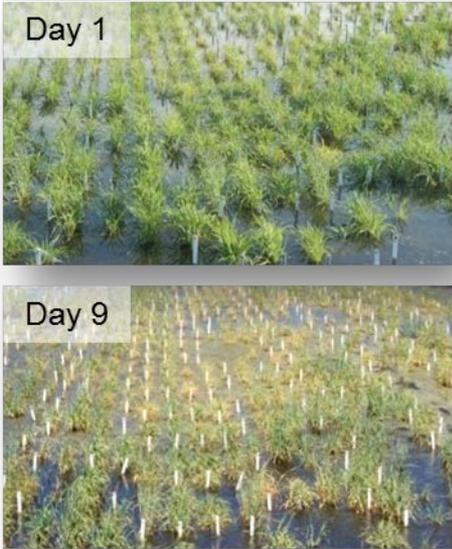
Field screening of waterlogging tolerance in barley

Ratings and assessments

Plant survival rating (Scale 1-9)

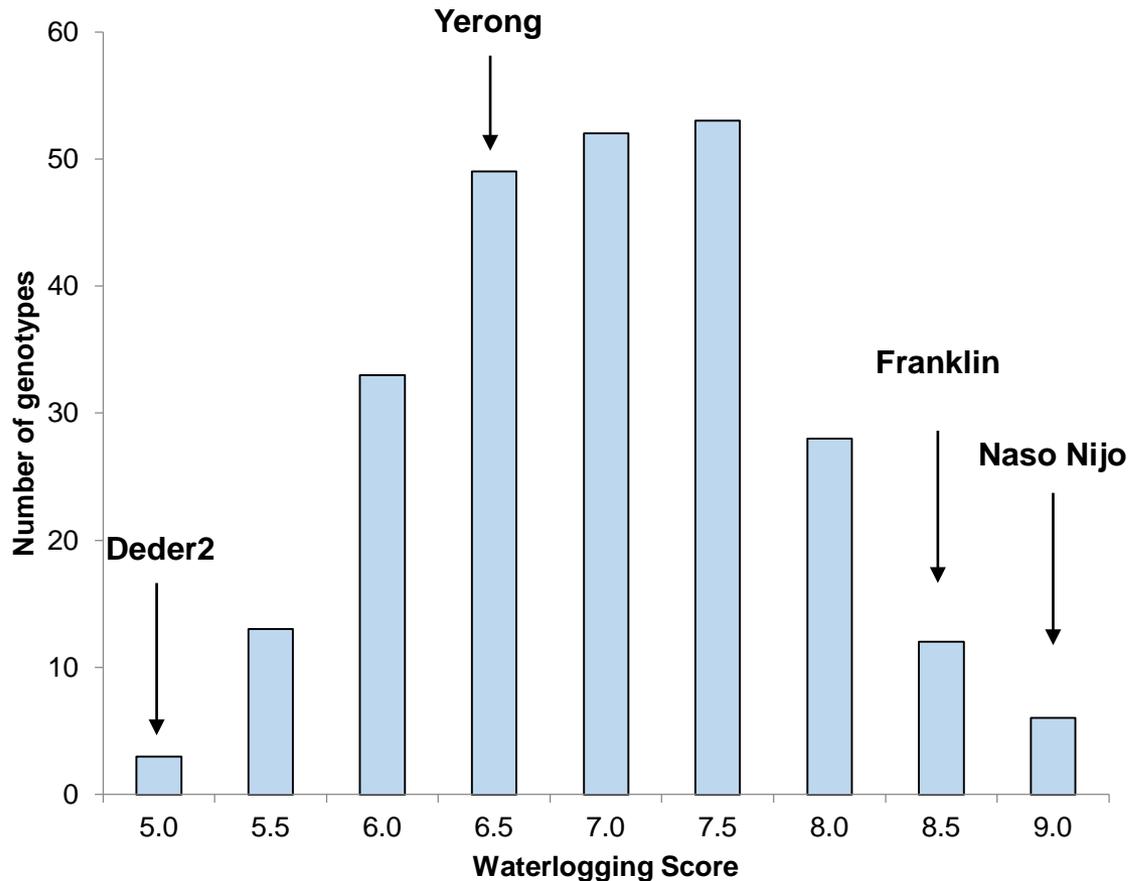


View of 2016 BRDC testing field during WL treatment



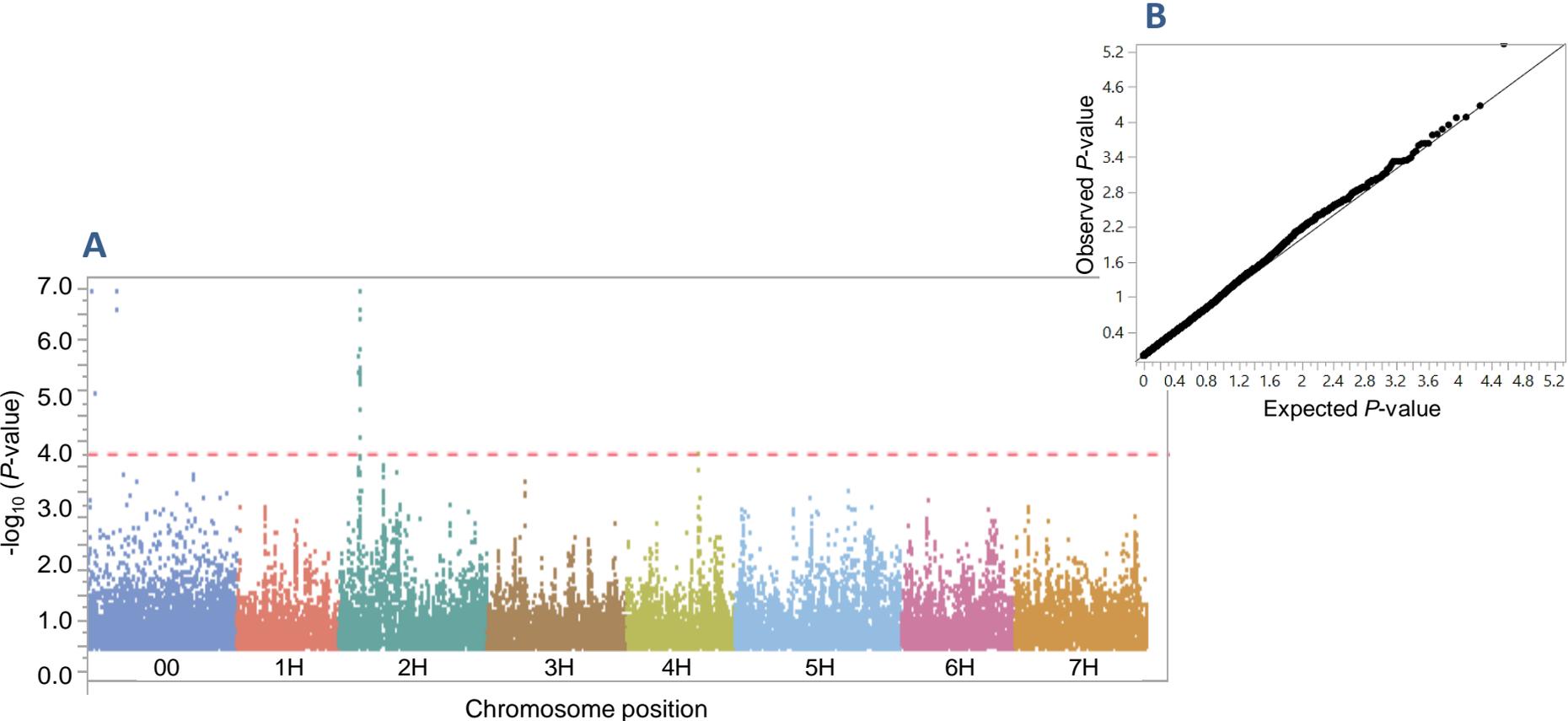
Field screening of waterlogging tolerance in barley

**Waterlogging
Score
(Scale 1-9)**



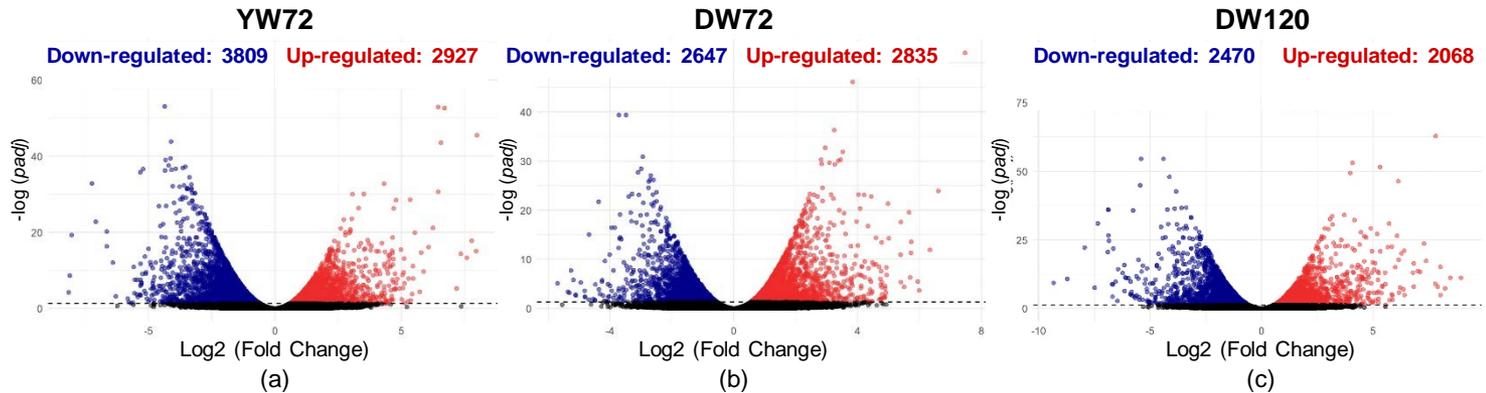
Frequency distribution of phenotypic variation of WL Score in the barley collection after 9-days of waterlogging treatment under field conditions in 2016 and 2017.

Field screening of waterlogging tolerance in barley



Manhattan plot (A) and quantile-quantile plot (B) of P -values for biomass in barley under waterlogging stress

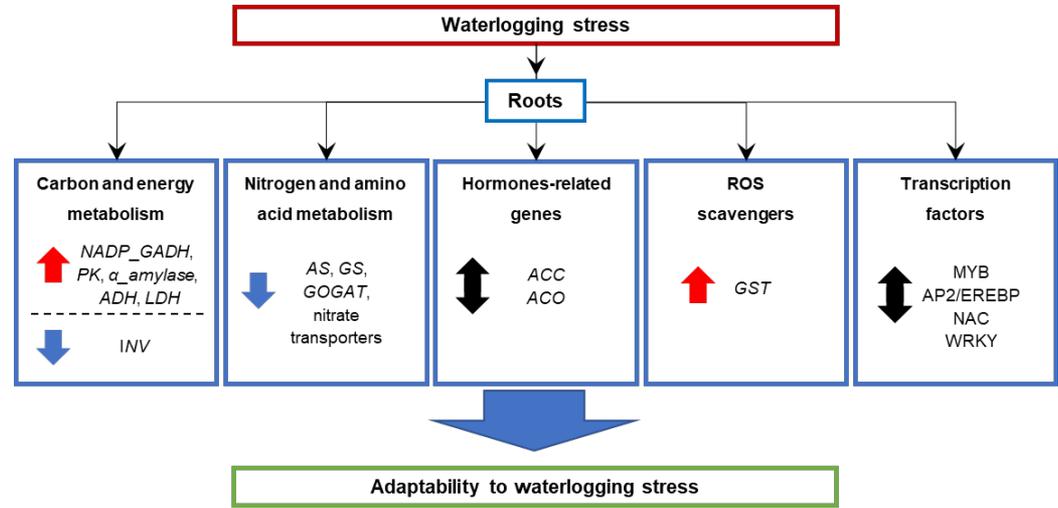
Gene expression responses to waterlogging in roots of barley



Differentially expressed genes under waterlogging.

- *ERF-9* (HORVU7Hr1G110900) gene contains the AP2 superfamily involved in stress tolerance.

- In rice, the gene *SUB1B* (LOC_Os09g11480) with similar domain is one of the three ERF factors within the major QTL *Submergence tolerance 1* (*SUB1*).



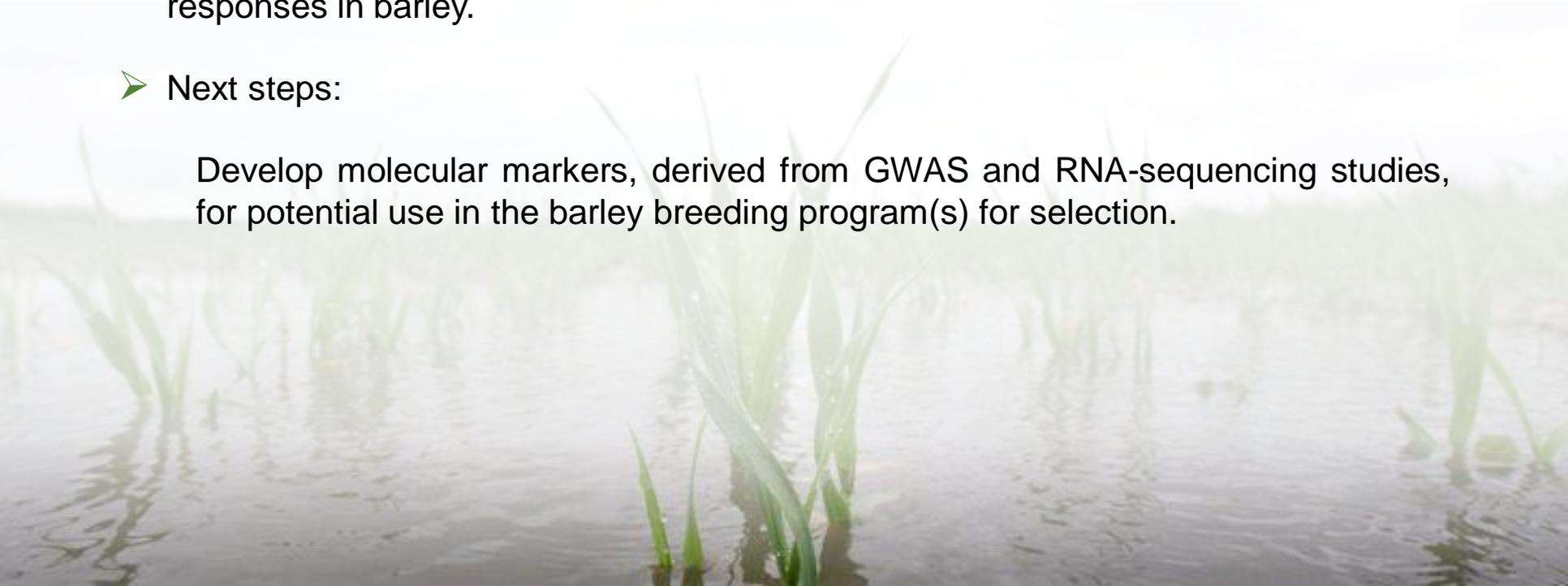
Schematic diagram of the main waterlogging stress responses in the roots of moderately-tolerant (72 h) and tolerant Deder2 (72 and 120 h) barley genotypes.

Final remarks

- Impact of excess moisture on barley grain yield in the Canadian Prairies evaluated.
- Screening conducted in a worldwide collection of barley genotypes for response to waterlogging stress in growth chamber and field conditions.
- Genome-wide association study is used to detect potential QTLs involved in the response to waterlogging stress in barley.
- RNA-Sequencing has been successfully used to interpret the waterlogging responses in barley.

- Next steps:

Develop molecular markers, derived from GWAS and RNA-sequencing studies, for potential use in the barley breeding program(s) for selection.



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