IMPROVING NUTRIENT USE EFFICIENCY IN CEREAL CROPS FOR SUSTAINABLE FOOD PRODUCTION

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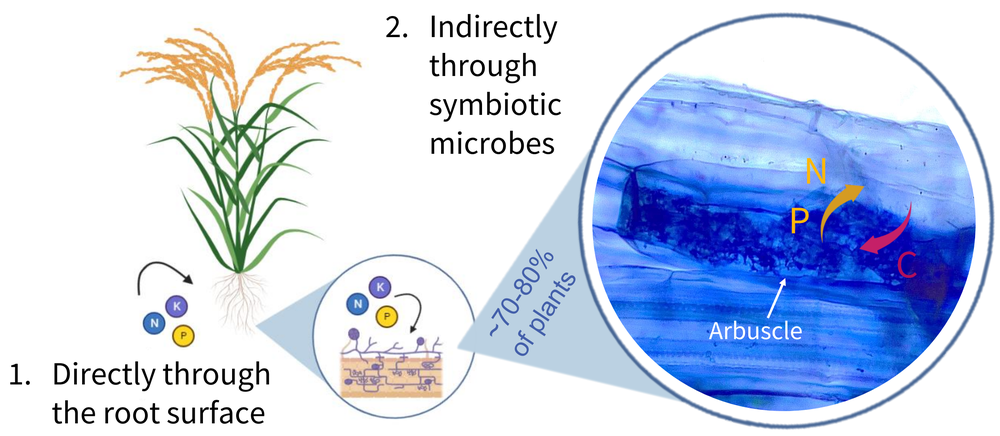
Overview

- Inorganic fertiliser use has revolutionised crop production; however, its use has caused economic burden and environmental damages
- There is a growing need to reduce the use of inorganic fertiliser while keeping yields high
- One strategy is the development of crop plants with improved nutrient use efficiency (NUE)

Plant nutrient uptake pathways



Arbuscular mycorrhizal (AM) symbiosis

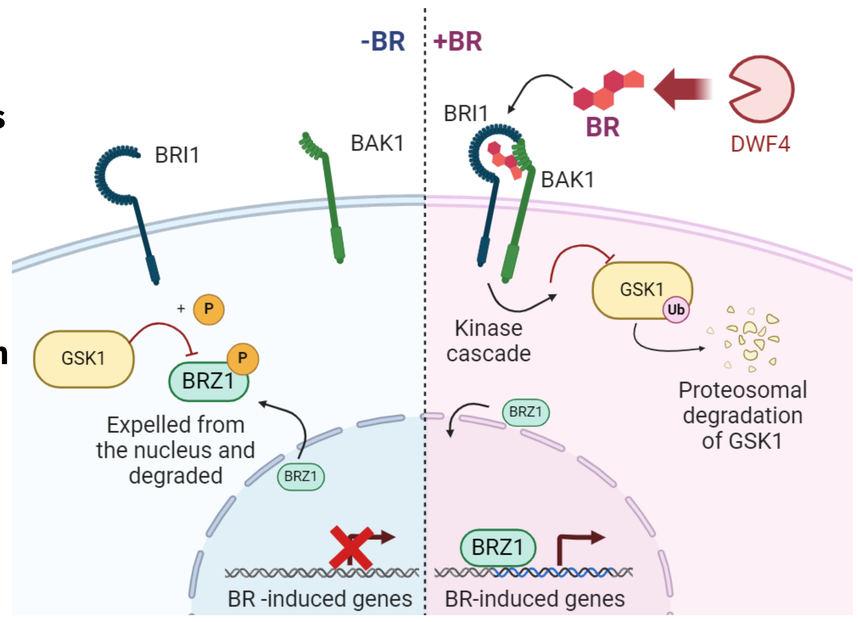
- Characterised by bidirectional exchange of nutrients between the plant and fungi via arbuscules

Plant response to phosphate limitation

- Plants invest more resources in root growth, shown by higher root to shoot ratios
- In low phosphate plants have increased AM colonisation, whereas high phosphate suppresses AM colonisation

Brassinosteroids (BRs) biosynthesis and signalling

BRs are plant hormones involved in regulating many processes, including growth, defence and NUE



Modified from Nolan *et al.,* 2020. by using BioRender

Project Aims

- Characterise the roles of the BRs in NUE
- Characterise the roles of BRs in AM symbiosis
- Use knowledge gained from this project to develop crops with higher NUE

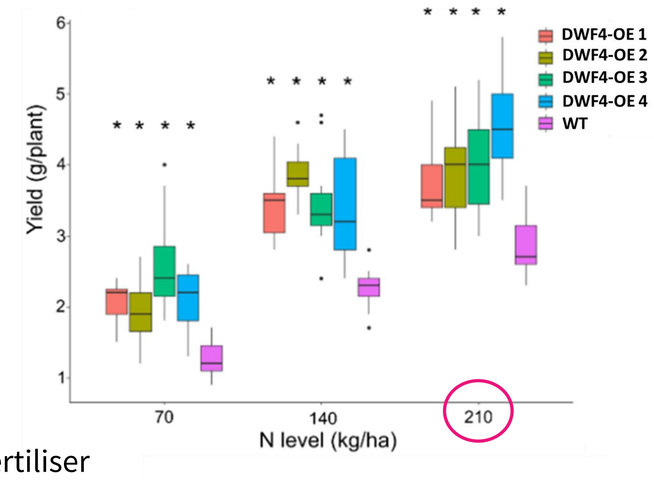
Previous research and plant materials

Previous research

- DWF4 is the enzyme encoding the rate limiting step in BR biosynthesis
- Wheat overexpressing (OE) *DWF4* had improved yields and nitrogen use efficiency (Milner et al., 2022)

DWF4-OE wheat yields > WT yields
At all N levels tested

DWF4-OE wheat yields at 140kg/ha > WT yields at 210 kg/ha



- Wheat *DWF4*-OE needs less fertiliser than WT without compromising yields

Nitrogen fertiliser input currently recommended in the UK

Wheat lines

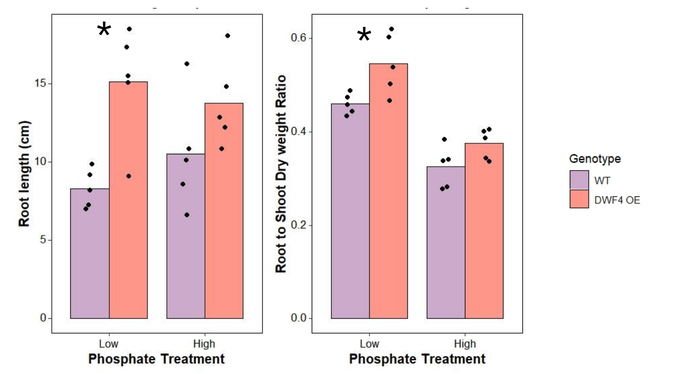
Genotype	Target	BR response	Growth condition
gsk1 (gene-edited)	Negative regulator of BR signaling	Increased	Field work
DWF4-OE	BR biosynthesis	Increased	Glasshouse

- All predicted to have improved NUE
- The *gsk1* line will be able to be grown in the field through the recent change in UK legislation, the Genetic Technology (Precision Breeding) Bill

Results

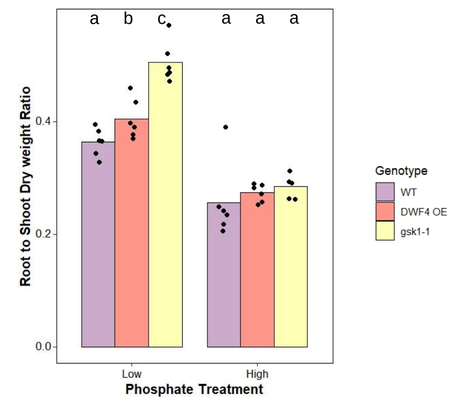
BRs altered low phosphate response in wheat *DWF4*OE

- The wheat *DWF4* -OE plants have longer roots and higher root to shoot ratios than WT when grown hydroponically in low phosphate solution



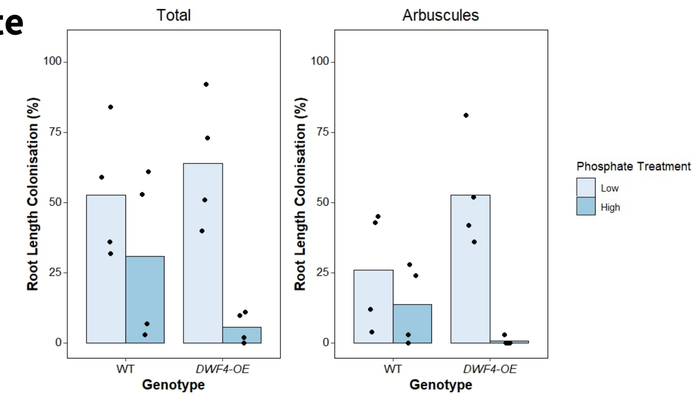
BRs altered low phosphate response in wheat *gsk1*

- Further hydroponic experiments show that *gsk1* plants also have higher root to shoot ratios like *DWF4*-OE when grown in low phosphate



AM fungi colonised *DWF4*-OE plants were hypersensitive to suppression by high phosphate

- High phosphate levels are known to suppress colonisation of plants by AM fungi
- *DWF4-OE* plants were hypersensitive to suppression of AM symbiosis by high phosphate



All graphs show the mean of each data set. Pairwise comparisons performed using the Students T test. * represents a significance of P<0.05. Multiple group comparisons performed using Kruskal Wallace analysis.

Outstanding questions

- How are BRs regulating differential response to nitrogen and phosphate availability?
- What are BRs involvement in AM colonisation?

Ongoing and future work

- Identifying mechanisms underpinning improved NUE using RNAseq
- Yield trials of *DWF4*-OE and *gsk1* in a range of P and N conditions
- AM symbiosis experiment with *gsk1* and *DWF4* overexpression wheat lines
- Microbiome analysis of BR mutants
- Field trials of *gsk1* wheat lines

Acronyms

BRs- Brassinosteroids
NUE- Nutrient Use Efficiency
DWF4- Dwarf 4
GSK1- Glycogen synthase kinase 1
BZR1- Brassinozole resistant 1

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References

- Milner, M. J. *et al.* Over-expression of TaDWF4 increases wheat productivity under low and sufficient nitrogen through enhanced carbon assimilation. *Communications Biology 2022 5:1* **5**, 1–12 (2022).
- Nolan, T. M *et al.* Brassinosteroids: Multidimensional Regulators of Plant Growth, Development, and Stress Responses. *Plant Cell* **32**, 295–318 (2020).