PhD position

Laboratory : UMR 1095 Genetic, Diversity and Ecophysiology of Cereals (GDEC)

Host team : Quality of Grains (QualiGrain)
https://www6.clermont.inrae.fr/umr1095/Organisation/Equipes-de-recherche/Qualite-des-Grains

Genetic and molecular mechanisms of global warming tolerance in interaction with sulfur nutrition in bread wheat

Context

Bread wheat (*Triticum aestivum* L.) is the world's most important cereal crop in terms of harvested area and commercial exchange. It's mainly consumed after transformation and provides about 20% of the total calories and protein in the human diet. Its processing requires good technological quality, the main determinants of which are the content and composition of grain storage proteins (GSP) including glutenins and gliadins which are at the origin of the gluten network. This network corresponds to a macropolymer of disulfide-bonded glutenins, to which gliadins are attached. The balance between monomeric gliadins and polymeric glutenins, and more importantly, the molecular weight distribution of the latter, strongly influences the rheological properties of dough. Furthermore, the content of free asparagine (Asn) in the grain is the major determinant of acrylamide formation during cooking, a potential carcinogen.

In addition to the genotype, plant nitrogen (N) and sulfur (S) nutrition and environment modulate GSP synthesis and their polymerization. Indeed, the amount of N allocated to a given protein fraction is a function of the total amount of N in the grain. As GSP differ in their S-containing amino acids content, S deficiency decreases the concentration of S-rich proteins but increases the concentration of S-poor proteins, with the effect to modulate the ratio gliadins/glutenins and the size of glutenin polymers. Moreover, S-deficiency can lead to high Asn concentration in mature grain. Heat stress and its Reactive Oxygen Species (ROS) production, is one of the major abiotic stresses affectting production and quality of wheat. Technological quality decreases in heat-stressed wheat. Maintaining redox homeostasis under stressful conditions is therefore essential for plant survival and grain quality.

In recent years, research on the interaction between S nutrition and crop tolerance to abiotic stresses has received particular attention. Recent studies have demonstrated the beneficial effect of S application on grain yield when plants are exposed to moderate water deficit or heat stress during the reproductive period (Bonnot et al., 2023). Thiol-containing metabolites such as glutathione are well-known modulators of environmental responses. S could help to maintain the redox status of cells. Very limited information is available on the variety x temperature x S interaction and its impact on technological and health qualities. Moreover, the overall level of interaction and the mechanisms involved are not known.

Questions of research

In a context of climate change, including the increased prevalence of intense climatic events and soil S deficiency due to reduced atmospheric deposition, technological and health quality of wheat is expected to change. The project aims to assess the effects of S nutrition on the adaptation of bread wheat to global warming and the maintenance of its quality. **Its objective is to answer 3 questions** : **(i)** Can S nutrition mitigate the negative effects of heat stress on grain yield and grain quality (technological and health) ? **(ii)** What are the molecular mechanisms involved ? **(iii)** Is there genetic variability in the responses ?

Proposed approach

To assess the effect of S nutrition on the tolerance of bread wheat to global warming, two experiments will be carried out: one under controlled conditions (growth chambers, year 1) and the other in the field under semi-controlled conditions (UE PHACC, year 1). For each experiment, 2 varieties with contrasting quality stability will be tested. Six treatments with two stress application periods, with or without S supply at flowering, and corresponding controls are planned. (figure 1). Heat stress will be applied for 10 days, during the early stage of grain development (3 days after anthesis to avoid impacting the number of grains per ear), which is the most sensitive growth stage, followed by a later stage of grain filling (15 days after anthesis). In both cases, moderate thermal constraints, already tested in the unit, will be applied (29/23°C vs 21/15°C day/night under controlled conditions ; Girousse et al., 2018 ; Touzy et al., 2022).

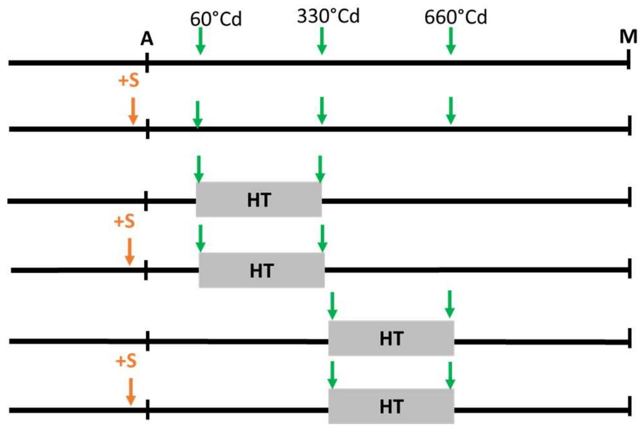

Figure 1: Experimental design
Heat stress (ST) is applied 3 or 15 days after anthesis. Grains will be harvested: (i) at maturity and (ii) during development at 60, 330 and 660°Cd corresponding to the stages before and after the 10 days of HT, depending on the treatment.

+S : sulfur supply, A: anthesis; M: maturity

Experiment under controlled conditions.

The effects of the stress and S nutrition, alone or in combination, will be evaluated at maturity by measuring the various components of the grain : weight, GSP content and composition (CNS, RP-HPLC), glutenin polymers size (SE-HPLC) and the starch content. About health quality, the free Asn contents in flour will be measured (Metabolome platform, Bordeaux).

Samples will also be harvested before and after stress periods to identify molecular actors and metabolic pathways impacted by stress and/or sulfur nutrition. To better understand the overall grain response, analysis of proteomics (Proteogen platform, University of Caen), transcriptomics, redox status (forms of glutathione, H_2O_2, trolox, Redox platform in Bordeaux), free amino acid content (Metabolome platform, Bordeaux) and hormones will be carried out. These data will be integrated using tools such as the R package mixOmics. A search for key regulators (genes, proteins, metabolites) will also be performed out by constructing of co-expression or co-accumulation networks using the RulNet tool developed by the team (Vincent et al., 2015; Bonnot et al., 2020).

Field experiments under semi-controlled conditions.

Semi-controlled conditions will be applied using mobile mini-tunnels to increase the temperature of a micro-parcel in order to simulate heat stress. An experiment in southern locations (e.g. UE DIASCOPE in Mauguio) will be considered with 2 or 4 genotypes (chosen in collaboration with Limagrain). We will also be able to benefit from trials set up in a southern network (around ten varieties in ten locations) as part of the FSOV project "Understanding the effect of global warming to improve the stability of wheat baking quality" (accepted).

The technological quality of flours obtained from mature grains will be assessed using indirect tests (farinograph, alveograph) and will be evaluated after processing into bread by carrying out bread-making test. Yield components such as thousand kernel weight, GSP content and composition, GSP polymer size, starch and free Asn content will also be evaluated.

Skills and training required

The PhD candidate must hold a Master degree or equivalent. He/She must have a good background in plant molecular physiology, biochemistry and molecular biology. To successfully complete this multidisciplinary project, the PhD student will need to be curious, rigorous and organized. The PhD student will be involved in field analysis and will perform analysis at Limagrain Ingredient under the supervision of Laurent Linossier (project partner). A good command in R and an experience in –omic data analysis would be appreciated.

Application and recruitment procedures

The candidate will be registered at the SVEA doctoral school of Clermont-Auvergne University. Funding for the PhD contract is acquired (UCA- Isite CAP20-25).
Starting date: october or november 2023 for 3 years

Localization : UMR 1095 GDEC (UCA-INRAE) ; the unit is located on 2 sites, one on the Cézeaux university campus (Aubière) and the other on the INRAE Crouël site (Clermont-Ferrand). The PhD will be carried out on the latter site.

Director and supervisor : Jacques Le Gouis & Julie Boudet.

Applications should be adressed by e-mail [application letter + CV ; names and e-mail for references; marks of M1 and M2] to jacques.le-gouis@inrae.fr & julie.boudet@uca.fr before **11th of August 2023**.

References

Bonnot T., Bachelet F., Boudet J., Le Signor C., Bancel E., Vernoud V., Ravel C., Gallardo K. (2023) Sulfur in determining seed protein composition: present status on its interaction with abiotic stresses and future directions. J Exp Bot. Mar 22:erad098. doi: 10.1093/jxb/erad098.

Bonnot T., Martre P., Hatte V., Dardevet M., Leroy P., Bénard C., Falagán N. Martin-Magniette M.L., Deborde C., Moing A., Gibon Y., Pailloux M., Bancel E., Ravel C. (2020) Omics Data Reveal Putative Regulators of Einkorn Grain Protein Composition under Sulfur Deficiency. Plant Physiol. Jun;183(2):501-516. doi: 10.1104/pp.19.00842.

Girousse C., Roche J., Guerin C., Le Gouis J., Balzegue S., Mouzeyar S., Bouzidi MF. (2018) Coexpression network and phenotypic analysis identify metabolic pathways associated with the effect of warming on grain yield components in wheat. Plos One 13:e0199434

Touzy G., Lafarge S., Redondo E., Lievin V., Decoopman X., Le Gouis J., Praud S. (2022) Identification of QTL affecting post-anthesis heat stress responses in bread wheat. Theoretical and Applied Genetics 135:947-964

Vincent J, Martre P, Gouriou B, Ravel C, Dai Z, Petit J-M, Pailloux M (2015) RulNet: A web-oriented platform for regulatory network inference, application to wheat -omics data. PLoS One 10: e0127127