Enhanced sustainable green revolution yield via nitrogen-responsive chromatin modulation in rice

With the support by the National Natural Science Foundation of China and the National Key Research and Development Program of China, the research team led by Prof. Fu XiangDong (傅向东) at the Institute of Genetics and Developmental Biology, Chinese Academy of Sciences, uncovered a previously unknown GA signaling that explains the increased yield and tillering of cereal Green Revolution Varieties (GRVs) that is a key component for future agricultural sustainability, which was published in *Science* (DOI: 10.1126/science.aaz2046), as a cover story.

The Green Revolution of the 1960s boosted crop yields in part through cultivation of semi-dwarf GRVs. The beneficial semi-dwarfism is respectively conferred in wheat and rice GRVs by mutant *Reduced height-1* (*Rht-1*) and *semi-dwarf1* (*sd1*) alleles, which cause the accumulation of growth-repressing DELLA proteins. Resultant semi-dwarf plants resisted lodging but required high nitrogen fertilizer inputs to maximize yield. Because environmentally degrading inorganic nitrogen fertilizer use underlies current worldwide cereal yields, future agricultural sustainability demands enhanced nitrogen use-efficiency (NUE). However, in-depth understanding of the molecular mechanisms underlying cereal NUE has until now remained largely elusive, thus preventing significant improvement.

Recently, Fu's group surveyed variations in nitrogen uptake rates of rice GRVs and identified that allelic variation at the *GROWTH-REGULATING FACTOR4* (*GRF4*) locus had major causal impact. They demonstrated that the GRF4-DELLA interaction balance enables homeostatic co-regulation of plant growth, carbon fixation, and nitrogen assimilation, increase of GRF4 abundance in GRVs substantially boosts GRV NUE and yield. GRF4-DELLA balance thus provides a relatively simple route for GRVs NUE, a trait whose genetic complexity had previously made improvements difficult to achieve. This finding was published in *Nature*, as a cover story.

More excitingly, they advanced understanding of the plant growth response to varying nitrogen supply, with a particular focus on the molecular mechanism via which nitrogen supply determines GRVs yield-enhancing tillering. They used genetic screening and identified a rice *ngr5* (nitrogen-mediated tiller growth response 5) mutant in which nitrogen-promotion of tillering is abolished, and hence molecularly discovered the rice APETALA2-domain transcription factor encoded by an *NGR5* allele that promotes tillering in response to varying nitrogen supply. They showed that nitrogen-responsive NGR5 recruits polycomb repressive complex 2 (PRC2) to genome-wide promotion of H3K27me3 histone modification. This is the first case that nitrogen promotes tillering via the nitrogen-promoted NGR5 repression of strigolactone signaling and other shoot-branching inhibitory genes via chromatin modification, thus reducing the inhibition of tiller outgrowth.

They demonstrated that NGR5 is a novel target of GA-GID1-SCF^{GID2} mediated proteasomal destruction. This is the first report of a non-DELLA protein being regulated by the GA-GID1-SCF^{GID2} mechanism. NGR5 and DELLA interact with one another and compete for interaction with the GA receptor GID1 explains for the first time why GRVs exhibit the enhanced tillering N-response. This study identifies an important but previously unknown alternative (non-DELLA) pathway of GA signaling, which adds to a growing understanding of how diverse modes of molecular and functional cross-talk between phytohormonal signaling and fertilizer use responses function in the environmentally adaptive regulation of plant growth and development. Finally, they demonstrated that increased NGR5 activity uncouples tillering from N-regulation, thus boosting GRVs tillering and yield at low N fertilizer levels. The manipulation of GID1-NGR5-DELLA-GRF4 regulatory module thus provides a novel breeding strategy for simultaneously ensuring global food security and environmental sustainability.

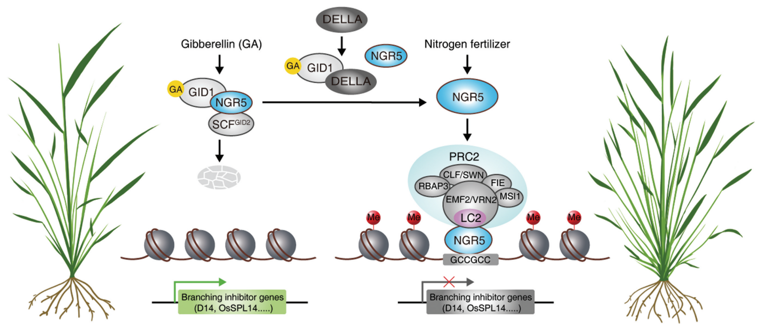

Figure Nitrogen- responsive chromatin modulation enhances rice tillering and yield.