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Maximizing wheat grain yield in irrigated mega-environments: Targeting optimal flowering period by selecting optimal sowing date and genotype with appropriate phenological development pattern

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Abstract: Maximizing the grain yield of wheat requires flowering to coincide with the optimal flowering period (OFP). Identifying OFP for a specific environment is crucial for realizing yield potential while minimizing the risk of abiotic stresses (e.g. frost and heat stress) on reproductive development (e.g. determination of grain number). The OFP of wheat is largely determined by location-specific climate (e.g. temperature and frost and heat risk) rather than wheat genotypes with different phenological durations to flower (i.e. pre-flowering). The regulation of flowering time to coincide with OFP therefore can be achieved by selecting optimal sowing date and wheat genotype. However, wheat genotypes sharing the same duration of pre-flowering may differ in phenological development patterns of pre-flowering phases, including the relative durations of the vegetative phase from emergence to floral initiation, early reproductive phase from floral initiation to terminal spikelet initiation and late reproductive phase (LRP) from terminal spikelet to anthesis. The LRP is particularly critical as it coincides with the rapid growth of spikes and the development processes of florets while stem internodes elongate, which determine the survival of floret primordia to be fertile during anthesis and hence the final grain number. The duration of LRP is a major determinant of yield potential (YP), optimizing the phenological development pattern of pre-flowering (without altering flowering time) through tuning the onset of LRP (i.e. terminal spikelet) may contribute to increasing grain number and then rising YP.

This global study conducted a comprehensive modelling analysis of genotype, environment, and management to identify the OFPs for sites in irrigated mega-environments (MEs) of spring wheat where the crop matures during a period of increasing temperatures. We used a gene-based phenology model to conduct long-term simulation analysis with parameterized elite benchmark genotypes to identify OFPs and optimal sowing dates for sites in irrigated MEs, considering the impacts of frost and heat stress on yield. The long-term simulations indicated that frost and heat stress significantly advanced or delayed OFPs and shrank the durations of OFPs in irrigated MEs when compared with OFPs where the model excluded frost and heat stress impacts.

Using the known optimal flowering and sowing date of current elite benchmark genotypes, we further analysed yield-related variables of all potential germplasm with the same duration of flowering as the benchmark genotypes. These diverse genotypes had the same duration to anthesis but varying LRP duration. Lengthening LRP increased YP and harvest index by increasing grain number to some extent. However, an excessively long LRP reduced YP due to reduced time for canopy construction for high biomass production of pre-flowering phase. Genotypes with a ratio of the duration of LRP to pre-flowering phase of about 0.42 ensured high yields (≥95% of YP) with their optimal sowing and flowering dates.

These results provided an interpretation of the regulation of wheat flowering to the OFP by the selection of sowing date and cultivar to achieve higher yields in irrigated MEs.

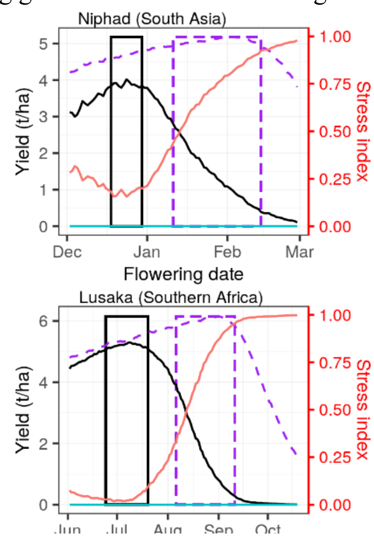

Figure 1. Examples of relationships of long-term mean simulated potential yields (purple dashed line refers to left axis), frost- and heat- limited yields (black solid line refers to left axis), the mean frost (blue line refers to right axis) and heat (red line refers to right axis) stress index

Keywords: *Crop model, phenology, yield potential, mega-environment, spring wheat*