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Research to Deliver Wheat for the Future

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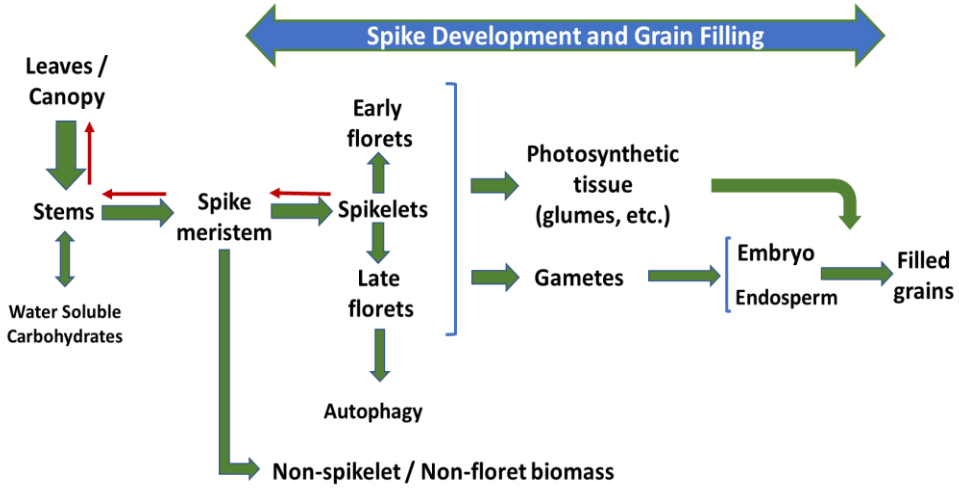
A Diagram of Nutrient Flow that Highlights Strategies for Yield Enhancement

IWYP-associated scientists have devised and published Wiring Diagrams to aid understanding of trait designs for higher yielding wheats (Reynolds et. al 2022 https://doi.org/10.1038/s43016-022-00512-z; Slafer et al 2023 https://doi.org/10.1093/jxb/erac410; Murchie et al 2023 https://doi.org/10.1093/jxb/erac415). These were created by linking, via "wires", different developmental stages in trait formation where variation is known to affect crop performance and yield. Other kinds of "wiring diagrams" can illustrate the flow of molecules within and between plant parts during tissue/organ development and maturation. Such diagrams can help predict the consequences of varying routes and rates of flow of molecules in, for example, spike development.

Large quantities of molecules including carbohydrates, proteins, hormones, water and ions flow from leaves and stems to build the mature spike through formation of spikelets, anthesis, fertilization and grain filling. The spike developmental program, in addition to environmental parameters, hormones and biochemical controls such as those regulated by Trehalose-6-Phosphate, determine the partitioning and utilization of the available nutrients.

The figure below is a high level diagram illustrating the flow of nutrients during spike development and growth up to and including grain filling. Additional granularity could be added to enhance understanding. Consideration of the arrows in the diagram, which depict nutrient flow, predicts that: (i) sustained flow of nutrients from leaves and stems is essential for optimal spike development and yield; (ii) the duration of spike development and grain maturation defines the total period available for nutrient flow and organ development; (iii) simultaneous growth of and accumulation of water soluble carbohydrates in the main stem compete with spike development for nutrients; (iv) growth of the main axis of the spike competes with growth of spikelets, florets and grains, (v) florets compete with each other for nutrients; and (vi) floral parts (glumes, palea, rachilla and awns) compete with ovule formation but provide carbon for grain filling by photosynthesis late in spike development.



These predictions have been validated by many of the genetic variants documented and reviewed in Slafer et al. 2023. The flow diagram can therefore be used to identify specific genetic variation for altering the absolute and relative sizes/biomass of spike parts to boost final grain mass. For example, reduction in the flow of nutrients and hormones through a specific branch in the diagram by knockout editing of genes preferentially controlling that branch should lead to increased flow through remaining branches and alter spike architecture and yield. Such opportunities for deterministic yield improvement illustrate the value of such flow-based wiring diagrams for identifying steps and subsequently genes that control nutrient and hormone translocation. The ideal ideotype is likely one that optimizes the balance of all the options and trade-offs in nutrient flow and utilization during the total time available between spike initiation and grain development to maturity.