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New approaches for simulating germination and emergence in APSIM

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Abstract: Accurate simulation of crop establishment is critical for predicting wheat yield under diverse sowing conditions. In APSIM Next Generation (NG), wheat germination is assumed to occur in one day when air temperature is above zero and soil moisture in seed layer above lower limit, while emergence is modelled only as a function of sowing depth and air temperature. These simplified approaches do not account for variations in soil temperature, moisture and hardness, and are also unable to simulate the emergence of novel wheat varieties with varying coleoptile lengths sown to different depths. As a result, the model struggles to simulate dry and deep sowing scenarios and cannot adequately assess the success of emerging strategies such as early (Hunt et al, 2019) and deep sowing of novel wheat genotypes with long coleoptile length (Zhao et al, 2022), that are increasingly explored across Australia to mitigate climate risks. There is a critical need to enhance the physiological representation of crop establishment processes in APSIM NG.

We present an improved germination and emergence module for wheat integrated into APSIM NG, incorporating mechanistic responses to soil temperature, moisture, soil hardness, and genotypic variations in coleoptile length and early vigour. Germination is now driven by effective thermal time modulated by a water stress factor derived from controlled-environment experiments. The germination phase completes when accumulated thermal time reaches a threshold, with water stress effects varying in response to soil temperature and soil water content.

The emergence phase is modelled using a new approach, which simulates the elongation of coleoptile and the first leaf. Coleoptile elongation begins after a lag phase and is driven by soil temperature, soil moisture, soil hardness and a genotype-specific coleoptile elongation rate. The maximum rate of coleoptile elongation is determined by the presence (or absence) of different *Rht* genes (dwarfing genes), which also affects the elongation of the first leaf. The model assumes emergence occurs when shoot length equals or exceeds sowing depth, or when a maximum duration is reached. Emergence probability is calculated based on the ratio of sowing depth to coleoptile length, allowing partial emergence to be represented under limiting conditions.

Preliminary results based on calibration and testing for multiple wheat genotypes across a wide temperature range and soil moisture indicated that the model is able to capture variation in germination timing and coleoptile final length. The model is being further tested against data under contrasting field conditions. These enhancements have potential to improve APSIM NG's capacity to simulate early establishment of novel wheat varieties under variable field conditions, providing a platform for evaluating genotype × environment × management (G×E×M) interactions in early crop development and supporting the design of resilient cropping systems.

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