【Workshop 2】Crop Production under Heat Stress

The GECROS Model and its Application for Assessing Impacts of Climate Change on Crop Production

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Crop growth relies on the functional balancing of contrasting components (e.g. shoots vs roots, sources vs sinks) or processes (e.g carbon metabolism vs nitrogen metabolism, assimilation vs dissimilation). In addition, like any other type of system process involving cybernetic mechanisms, crop growth is associated with many feedback features. An example of such a (negative) feedback is apparent reduced amount or down-regulation of Rubisco under conditions of high carbohydrate status such as at an elevated CO_2 condition. The consequences of these feedback and compensation mechanisms are those often reported generalities such as low yielding ability of cultivars having high protein concentration and low nitrogen (N) concentration of plants when grown at an elevated CO_2 level.

Some models use these emergent physiological generalities as input functions to guarantee model predictability over a certain domain, and therefore, may contain too many empirical trivialities. Similarly, the early prevailing model concept that demarcates crop production into potential, water-limited or N-limited levels, facilitating model development by focusing on one major factor at a time, cuts the internal link among processes and therefore may not help to model individual processes that interact. For example, leaves with high N levels transpire more than low-N leaves, because of the coupling of photosynthesis, stomatal conductance and transpiration. Thus, models considering water- and N-limited levels separately are not useful for environments whereby N and water may be co-limiting or limiting in tandem.

A relatively new Wageningen crop model, GECROS, was developed to overcome some of the weaknesses of earlier models. GECROS is able to capture elementary traits of genotype-specific responses to environment based on quantitative descriptions of complex traits related to phenology, root system development, photosynthesis and stomatal conductance, and stay-green traits, thereby suiting for analysis of a number of physiological processes in response to environmental stresses. The model can generate, in a phenomenological manner, some physiological observations, such as leaf photosynthetic acclimation to elevated CO_2. It predicts an accelerated leaf senescence of plants grown under elevated CO_2 conditions as often observed experimentally. It also predicts better the impact of stimulation of crop yield by elevated CO_2 as observed in a large-scale FACE (free-air CO_2 enrichment) experiment than existing crop models do. Some scientists expressed the concern that there are some quantitative differences in how crops respond to elevated CO_2 in FACE and chamber experiments given that current popular crop models parameterised from chamber experiments typically overestimate the CO_2 fertilization effect on crop yields. They indicated that controlled chamber environments clearly are not the best experimental facilities for estimating CO_2 response ratio of crop yield. It will be shown that the robust crop model GECROS largely allows a translation and extrapolation of input information at the leaf level in a short-time scale (usually from controlled-environment chamber studies) to the crop performance in a continuously changing field environment.