Modeling the Implications of Variation in Phenology and Leaf Canopy Development for Wheat Adaptation to Climate Change

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Background

Crop phenology and leaf canopy development play a crucial role in the dynamics of resource use (water and nitrogen [N] uptake). The parameterization level of crop models for representing these processes may significantly affect the simulated impact of climate change on yield formation.
In this study we present two contrasting levels of APSIM (Agricultural Production Systems sIMulator, www.apsim.info) parameterization based on a comprehensive field dataset. The implications of these parameterization levels for simulating phenology, N use, and grain yield were then explored for climate change impact on wheat.

Figure 1. Wheat field experiment at Raasdorf, east of Vienna (June 2014).

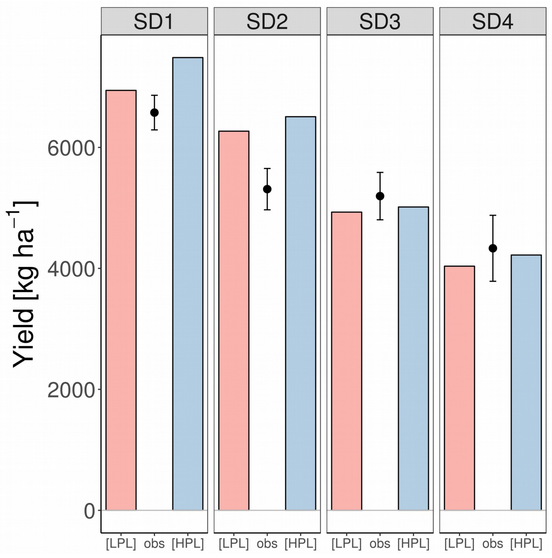

Figure 2. Simulated (bars) vs. observed (points) wheat yields for cv. *Xenos*, 2013/14, with low [LPL] and high [HPL] param. levels.

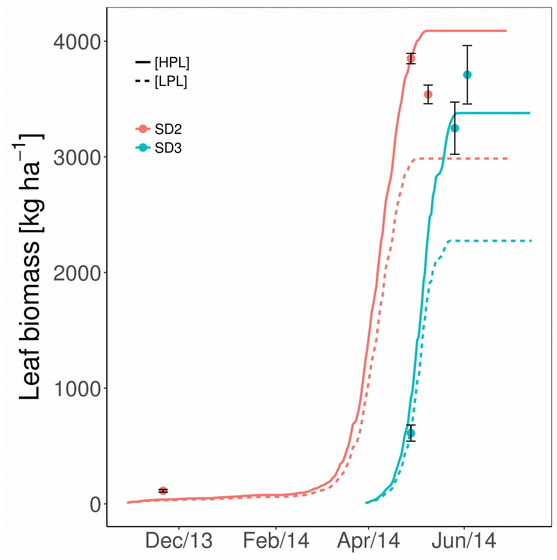

Figure 3. Simulated (lines) vs. observed (points) leaf biomass for [LPL] (dashed) and [HPL] (line) (*Xenos*, 2013/14).

Materials & Methods

For the two parameterization levels of APSIM we used a comprehensive eastern Austrian wheat field data set with 4 sowing dates (Sep. 26, Oct. 17 in 2013, and Mar. 4, Apr. 1 in 2014 [SD1-SD4, resp.]) and a facultative wheat cultivar (*Xenos*) (**Figure 1**).
The two parameterization levels were:

- **Low parameterization level [LPL]:** parameters for anthesis date, leaf and grain N conc.
- **High parameterization level [HPL]:** same as [LPL], plus: start of stem elongation date, leaf canopy parameters (mainly specific leaf area, leaf biomass fraction, and phyllochron)

We assessed the impact of these different parameterization levels on wheat performance for current climate (**BL**, 1981-2010) and a high emissions climate change scenario (**A1B** by IPCM4, 2035-65) for eastern Austria. Three sowing dates (Sep. 20, Oct. 20, Nov. 20) and 4 N fertilization levels (80, 120, 160, 200 kg N ha^{-1}) were simulated.

Results

The [HPL] simulations of APSIM showed slightly higher yields (**Figure 2**) and substantially improved final leaf biomass compared to [LPL] (**Figure 3**). Differences in model parameterization resulted in changes in pre vs. post anthesis and total N uptake (**Figure 4**). This was caused by intensified early leaf growth and canopy development. The total water uptake was not affected.

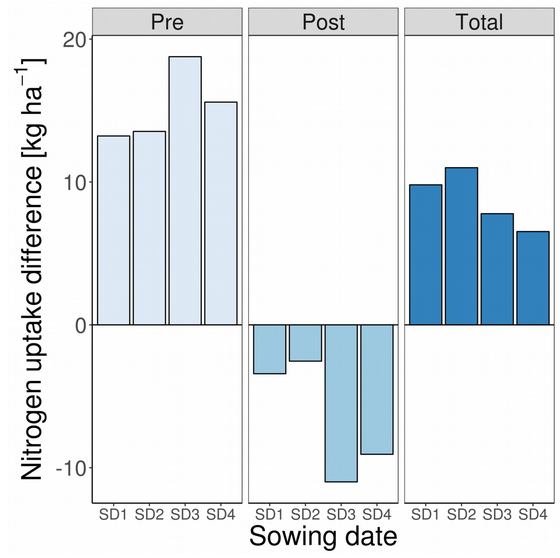

Figure 4. Pre/post anthesis and total N uptake change for the [HPL] compared to [LPL], *Xenos* wheat, 2013/14.

In the baseline (BL) climate scenario, simulated wheat yields ranged from 1410 to 6300 kg ha^{-1} for [LPL] and 1360 to 6870 for [HPL]. Compared to BL, yields were reduced by 45% [LPL] and 43% [HPL] in the A1B scenario.
[HPL] resulted in higher yields in all sowing dates and N fertilization rates except for N80 (**Figure 5a**). With very late sown crops (Nov. 20), the positive effect of N decreased with increasing fertilization rates. The yield advantage of [HPL] was largely due to increased N uptake during the pre anthesis phase as a consequence of improved canopy development (**Figure 5b**).

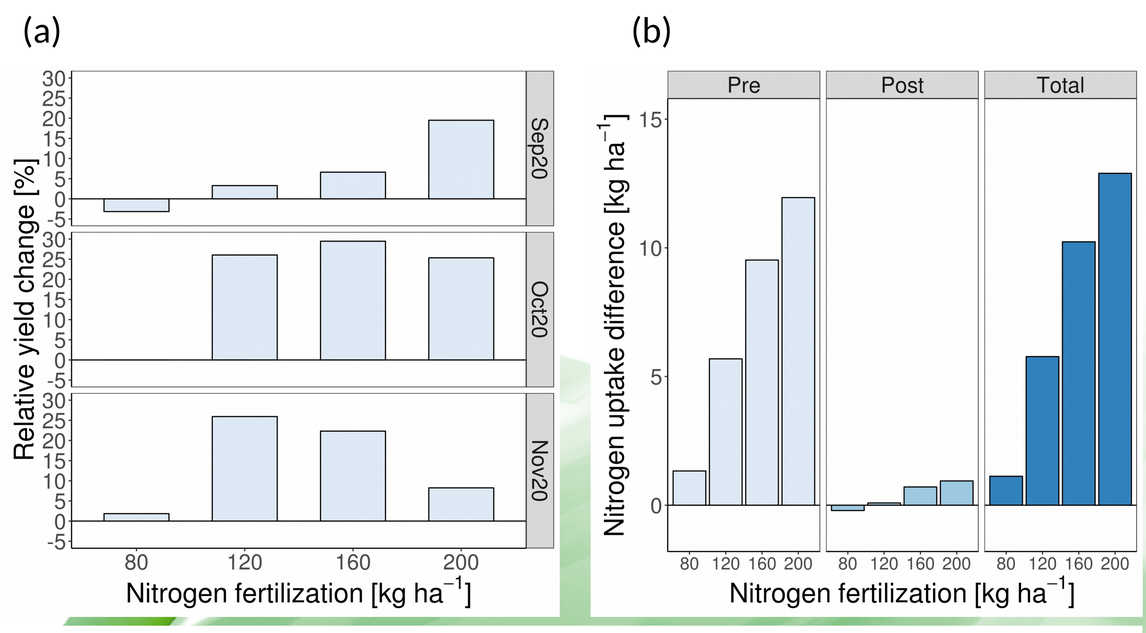

Figure 5. Changes in yield (a) and pre/post anthesis and total N uptake (b) for the [HPL] compared with the [LPL] for A1B climate scenario.

Conclusions

Our findings suggest that differences in the level of model parameterization for phenology and canopy development, [LPL] vs. [HPL], have a considerable impact on wheat N uptake, water use and, thus, yield formation.
For eastern Austria, the [HPL] resulted in higher yields due to improved canopy development and N uptake.
Furthermore, under drier weather conditions (A1B climate scenario), the positive effect of [HPL] on yield was stronger because plants took up more N in the pre anthesis phase which possibly enabled them to escape terminal drought stress.