Winter wheat development and growth in The Netherlands: Using a detailed field trial to parametrize and improve WOFOST

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Introduction

Crop models are key tools for agricultural research in its broadest sense (van Ittersum et al., 2003). Despite the wide range of model applications and inter-comparisons, recently little attention has been paid to model calibration (Seidel et al., 2018). Detailed field trials are needed for this purpose but these are expensive and barely conducted, and as a consequence model parameters tend to become outdated. The objective of this study is to present an improved version of WOFOST alongside a model re-parametrization for winter wheat, using data from recent field trials conducted in The Netherlands.

Materials and methods

Two field trials were conducted in Wageningen to estimate the potential yield of winter wheat. The first was harvested in the summer 2014 and the second in 2015. The trials included three varieties (one old variety 'Ritmo' and two recent varieties 'Julius' and 'Tabasco') and three N levels (180, 240 and 300 kg N/ha) laid out in a split-plot design in four replicates. Ten intermediate samples were taken during the growing season to measure leaf area index (LAI), aboveground biomass of leaf (LVB), stem (STB) and grain (GRB) and final yield and yield components. Crop development was also recorded, including anthesis and maturity dates .

Data from 2014 were used to calibrate WOFOST and from 2015 to evaluate the model. Calibration consisted of: 1) optimization of thermal times to anthesis and maturity using observed phenological dates, 2) optimization of six parameters controlling leaf and biomass dynamics using measured LAI and total aboveground biomass (TAGP) and, 3) manual calibration of partitioning coefficients to approximate final yield. This was done for the original model version (de Wit et al., 2018) and for a modified version including reallocation of leaf and stem biomass to grain after anthesis. Simulations were done in *python* and a non-linear optimization algorithm minimizing the RMSE between simulated and observed data was used for calibration.

Results

Measured yields were between 10.31 and 12.52 t DM/ha in 2014 and between 10.53 and 13.06 t DM/ha in 2015. Wheat yields increased with N level and these effects were significant across years and varieties. In 2014, there were no significant yield differences between Julius and Tabasco and both outperformed Ritmo. In 2015, Tabasco obtained the greatest yield followed by Ritmo and Julius with differences between varieties being statistically significant.

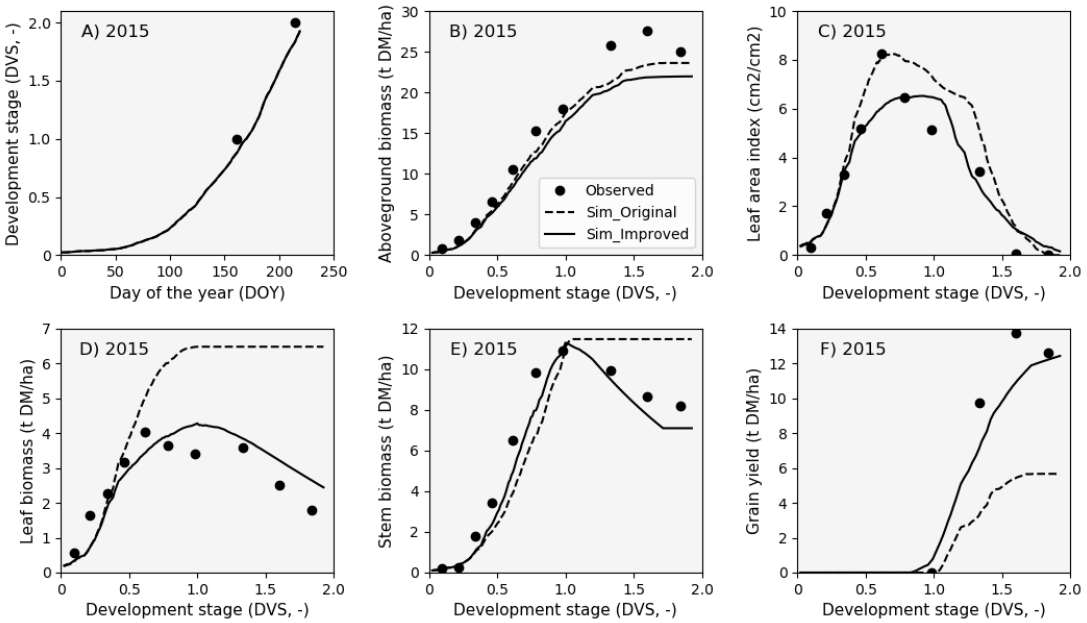

Figure 1. Simulated and observed data on A) development stage, B) aboveground biomass, C) leaf area index, D) leaf biomass, E) stem biomass and F) grain yield for the winter wheat variety Ritmo with 300 kg N ha^{-1} in year 2015 (used for model evaluation only). Simulated values were derived with the original and improved version of WOFOST, the latter considering reallocation of biomass from stems and leaves to grains.

The original version of WOFOST was able to reproduce development stage (DVS) fairly well but, it underestimated TAGP and GRB and overestimated LAI, LVB and STB especially towards the end of the growing season (Figure 1). The modified model improved the simulation of LAI, LVB, STB and final yield compared to the original model but underestimated TAGP and maximum LAI (Figure 1) .

Conclusion

Detailed field trials under potential production situations are needed for proper calibration of crop models. This study builds upon these to re-parametrize and improve WOFOST for winter wheat in The Netherlands. The model was sensitive to specific leaf area and was able to reproduce the high yields measured only when routines with reallocation of leaf and stem biomass to grain were added to the original model. Further research will focus on model calibration for other varieties and N levels and on fine-tuning the current crop parameters in the context of the feedback loops linking LAI, biomass production and partitioning.

Keywords: Yield potential; Biomass reallocation; Model calibration

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