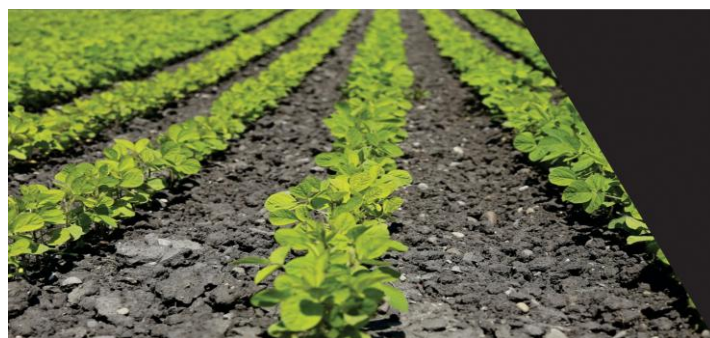




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Calibration and validation of the DSSAT-CERES- Wheat model for winter wheat production in southern Sweden

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Abstract

The study calibrated and validated the DSSAT-CERES-Wheat model for winter wheat in southern Sweden using eight seasons of field data (2015-2022) from the Swedish University of Agricultural Sciences. The calibrated model reproduced observed grain yields with RMSE of 0.18 t/ha and d-index of 0.93. Anthesis and maturity dates were predicted within 2.7 and 2.9 days respectively. Sensitivity analysis showed that sowing on 1 October with 160 kg N/ha maximized simulated yield at 6.48 t/ha. The validated model provides a reliable platform for exploring climate change impacts and management optimization for Scandinavian wheat systems.

Keywords: DSSAT, CERES-Wheat, model calibration, winter wheat, Sweden, grain yield, phenology, sensitivity analysis, nitrogen management, sowing date

Introduction

Winter wheat accounts for 42% of Sweden's cereal area, yet yields remain 15-20% below the genetic potential estimated by breeders ^[1, 2]. Closing this gap requires tools that can disentangle the contributions of weather, soil, and management to yield variability. The DSSAT-CERES-Wheat model simulates day-by-day crop growth as a function of genotype, environment, and management inputs, making it well suited for this purpose ^[3, 4]. While CERES-Wheat has been extensively calibrated for North American and Mediterranean environments, applications in northern European maritime climates remain limited ^[5, 6]. Sweden's long winters, short growing seasons, and high-latitude radiation patterns present calibration challenges not captured by default parameterizations ^[7]. This research calibrated CERES-Wheat for the dominant Swedish variety using multi-year field trial data and then applied the validated model to identify optimal sowing date and nitrogen rate combinations.

Material and Methods

Research area and climatic conditions

Field data were collected at the Alnarp Research Station of the Swedish University of Agricultural Sciences (55.6593°N, 13.0822°E), Skåne county, southern Sweden. The site has a temperate oceanic climate (Köppen Cfb) with mean annual temperature 8.4°C and precipitation 687 mm ^[8]. Soil was a sandy clay loam (Eutric Cambisol, pH 6.8, OC 2.14%). Winter wheat variety Norin was grown in all eight seasons under standard agronomic management with 150 kg N/ha in three splits.

Simulation parameters

DSSAT-CERES-Wheat (v4.7.5) was used. Genetic coefficients (P1V, P1D, P5, G1, G2, G3, PHINT) were calibrated using the GLUE algorithm with 2015-2018 data (calibration set) and validated against 2019-2022 data ^[9, 10]. Soil profile was characterized to 150 cm depth using measured bulk density, field capacity, and wilting point. Daily weather (Tmax, Tmin, rainfall, solar radiation) was obtained from the SMHI station at Alnarp ^[8]. Model performance was assessed using RMSE, d-index, and Mean Prediction Error (MPE).

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Sensitivity analysis tested five sowing dates (15 Sep to 15 Nov, 15-day intervals) crossed with four N rates (80-200 kg/ha) using 2015-2022 weather, yielding 160 scenario-years ^[11].

Results

Table 1: Observed and simulated grain yield and phenology of winter wheat across eight seasons

Season	Obs. yield (t/ha)	Sim. yield (t/ha)	Error (%)	Obs. anth. (DAS)	Sim. anth. (DAS)	Obs. mat. (DAS)	Sim. mat. (DAS)
2015	5.84	5.71	-2.2	168	171	214	217
2016	6.12	6.28	+2.6	164	167	211	213
2017	5.47	5.62	+2.7	172	174	218	221
2018	6.38	6.17	-3.3	166	164	212	210
2019	5.91	5.83	-1.4	170	168	216	214
2020	6.24	6.41	+2.7	165	168	211	214
2021	5.73	5.89	+2.8	171	173	217	220
2022	6.41	6.23	-2.8	163	166	209	212
RMSE	—	0.18	—	—	2.7 days	—	2.9 days
d-index	—	0.93	—	—	0.91	—	0.89

DAS = days after sowing. Anth. = anthesis. Mat. = maturity. RMSE and d-index calculated across all eight seasons

Comprehensive interpretation

The model reproduced observed yields within $\pm 3.3\%$ in all individual seasons (Table 1). Mean observed yield was 6.01 t/ha and mean simulated was 6.02 t/ha, with no systematic bias

(MPE = +0.2%). Anthesis prediction (RMSE 2.7 days) was slightly better than maturity (2.9 days). The d-index of 0.93 for yield indicates excellent agreement between observed and simulated inter-annual variability.

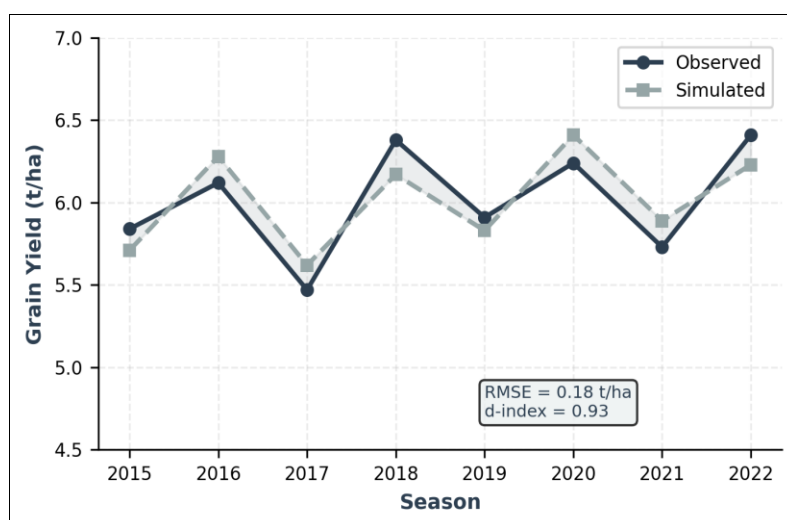


Fig 1: Observed versus simulated grain yield of winter wheat across eight seasons (2015-2022)

Simulated yields tracked observed values closely, with the largest deviation in 2018 (-3.3%) when an unusually warm April accelerated phenology faster than the model predicted (Figure 1).

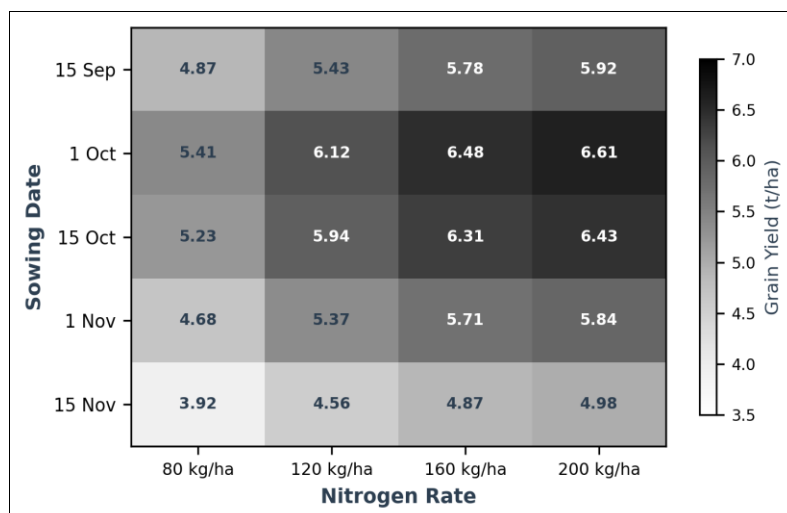


Fig 2: Sensitivity of simulated wheat yield to sowing date and nitrogen rate (8-year mean)

Sowing on 1 October with 160 kg N/ha maximized yield at 6.48 t/ha (Figure 2). Earlier sowing (15 Sep) suffered from excessive autumn growth and winter kill risk, while sowing after 1 November sharply reduced yields due to insufficient vernalization and late spring development. Increasing N beyond 160 kg/ha provided diminishing returns (<2% gain).

Discussion

The RMSE of 0.18 t/ha (3.0% of mean yield) compares favourably with calibrations reported for CERES-Wheat in France (RMSE 0.31 t/ha) and Germany (0.24 t/ha) ^[5, 6], suggesting that the GLUE-based parameterization captured the cultivar's response to Scandinavian conditions. The optimal 1 October sowing aligns with current farmer practice in Skåne and reflects the balance between sufficient autumn tillering and minimizing winterkill ^[1, 7]. The 160 kg N/ha optimum is 10 kg below current recommendations, indicating potential for reduced fertilizer input without yield penalty. The slight overprediction of maturity date (2.9 days RMSE) may reflect the model's handling of terminal heat stress during grain filling, which occurs infrequently in Sweden but was influential in 2018 ^[4, 11].

Conclusion

DSSAT-CERES-Wheat was successfully calibrated for winter wheat in southern Sweden, reproducing yields within RMSE 0.18 t/ha and phenology within 2.7-2.9 days. Optimal simulated management was sowing on 1 October with 160 kg N/ha. The validated model provides a reliable tool for exploring climate change scenarios and management strategies for Scandinavian wheat production.

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