Benchmark data set for wheat growth models: field experiments and AgMIP multi-model simulations

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Abstract: The data set includes a current representative management treatment from detailed, quality-tested sentinel field experiments with wheat from four contrasting environments including Australia, The Netherlands, India and Argentina. Measurements include local daily climate data (solar radiation, maximum and minimum temperature, precipitation, surface wind, dew point temperature, relative humidity, and vapor pressure), soil characteristics, frequent growth, nitrogen in crop and soil, crop and soil water and yield components. Simulations include results from 27 wheat models and a sensitivity analysis with 26 models and 30 years (1981-2010) for each location, for elevated atmospheric CO_2 and temperature changes, a heat stress sensitivity analysis at anthesis, and a sensitivity analysis with soil and crop management variations and a Global Climate Model end-century scenario.

Keywords: wheat, field experimental data, simulations, sensitivity analysis, climate change impact

1 ORIGINAL PURPOSE: The original purpose of this data set was a model intercomparison of the AgMIP-Wheat Pilot as part of the Agricultural Model Intercomparison and Improvement project (http://www.agmip.org/). The field experimental data were selected from local representative, high-quality field experimental data sets with a grain yield range from 2 to 8 t ha^{-1}. The original experiments were for specific agronomic studies and included measurements of crop-model-ready single treatments of wheat experiments at four contrasting locations, including a location in The Netherlands (Wageningen (Groot and Willigen 1991)), Argentina (Balcarce (Travasso, Rodriguez and Grondona 1995)), India (New Delhi (Naveen 1986)), and Australia (Wongan Hills (Asseng et al. 1998)) representing a wide range of growing conditions. The data were quality-checked and considered high-quality sentinel sites. The experimental data were used in observation-model comparisons and as the foundation for a sensitivity and uncertainty analysis for climate change impact assessments. The study was published by Asseng et al. (2013) and Martre et al. (2014). Details of the field and simulated experimental design are supplied in the Supplementary of Asseng et al. (2013) and Martre et al. (2014). A subset of the data was also published by Challinor et al. (2014). Observed variables include grain yield (t ha^{-1}), anthesis date (DOY); maturity date (DOY), grain N (kg N ha^{-1}); grains per square meter (# m^{-2}); cumulative evapotranspiration (mm); cumulative N mineralization (kg N ha^{-1}); plant available soil water to maximum rooting depth (mm); soil mineral N to maximum rooting depth (kg N ha^{-1}). Note, that not all measurements were available across all four experiments.

2 SIMULATION OF FIELD EXPERIMENTS: Simulations for the four experiments were carried out by 27 wheat models (see Supplementary of Asseng et al. (2013)). The annual simulation outputs included: grain yield (t ha^{-1}); above-ground biomass at anthesis (kg ha^{-1}); above-ground biomass at maturity (kg ha^{-1}); maximum leaf area index (LAI, m^2 m^{-2}); anthesis date (DOY); maturity date (DOY); cumulative soil N leaching (kg N ha^{-1}); cumulative soil water loss (mm); total above-ground N at anthesis (kg N ha^{-1}); total above-ground N at maturity (kg N ha^{-1}); grain N (kg N ha^{-1}); number of grains per square meter (# m^{-2}); cumulative evapotranspiration (mm); cumulative N mineralization (kg N ha^{-1}); cumulative N volatilization (kg N ha^{-1}); cumulative N immobilization (kg N ha^{-1}); cumulative N denitrification (kg N ha^{-1}); plant available soil water to maximum rooting depth (mm); soil mineral N to maximum rooting depth (kg N ha^{-1}).

Table 1. Layout of the field experiments. Modified after Asseng et al. (2013).

	Experiment			
Country	The Netherlands	Argentina	India	Australia
Location	Wageningen	Balcarce	New Delhi	Wongan Hills
Latitude (°)	51.97	-37.5	28.38	-30.89
Longitude (°)	5.63	-58.3	77.12	116.72
Environment	high-yielding long-season	high/medium-yielding medium-season	irrigated short-season	low-yielding rain-fed short-season
Mean growing season	Nov.-July	Jun.-Dec.	Nov.-April	May-Dec.
Soil type	Silty clay loam	Clay loam	Sandy loam	Loamy sand
Cultivar name	Arminda	Oasis	HD 2009	Gamenya
Experimental year	1982/83	1992	1984/85	1984
Mean growing season temperature (°C)	8.8	13.7	17.3	14.0
Mean growing season precipitation (mm)	595	336	383*	164

* Includes 383 mm of irrigation.

Each of the 27 wheat models was used to simulate the field experiments in two separate steps: 1) with limited in-season information from the experiments being made available to the modelers (partial calibration or 'blind' simulations), and 2) all available information being made available to the modelers (full calibration). Simulations with partially calibrated models were included to allow a more objective model assessment. For the partial calibration or 'blind model test', modelers had no access to measurements of grain yield, biomass, and crop water and N dynamics, receiving information only on soil characteristics, initial soil-water conditions, daily weather data, crop management, and flowering and maturity dates. For full calibration, modelers had access to all available measurements, including within-season and final biomass, water and N uptake, soil water and soil N, grain yield and yield components.

3 MODEL SENSITIVITY ANALYSIS: In addition to simulations of the single-year experiments, simulations were carried out with long-term measured daily climate data (solar radiation, maximum and minimum temperature, precipitation, surface wind, dew point temperature, relative humidity, and vapor pressure) using measured soil characteristics, measured initial soil water and soil N contents, crop management, measured anthesis and maturity dates from the single-year-experiments. For the baseline, daily climate data for the period 1980-2010 were used for all locations (31 years of climate data are required to simulate 30 years of yields in The Netherlands and India). For the location in India, solar radiation was obtained from the NASA/POWER dataset that extends back to 1983 (http://power.larc.nasa.gov). Missing data for 1980 to 1983 were filled in using the Weatherman tool included in DSSAT 4.5. In addition, 2-meter wind speed (km d^{-1}), dew point temperature (ºC), vapor pressure (hPa), and relative humidity (%) were estimated for each location from the NASA Modern Era Retrospective-Analysis for Research and Applications (MERRA). For the location in The Netherlands, measured wind speed and vapor pressure were available. In the sensitivity analysis, daily temperatures were changed in steps of 3°C from -3 to +9°C and atmospheric CO_2 concentrations were changed in steps of 90 ppm from 360 to 720 ppm. In addition, a sensitivity analysis of heat stress impact was carried out with the 1981-2010 climate data by introducing seven days of maximum temperature of 35°C starting at the measured anthesis day for each location. In a sensitivity analysis on variations in soil and crop management, at each location, the plant-available water-holding capacity of the local soil was varied by +/- 20%, the crop sowing date was varied by +/- 20 days and N-fertiliser applications were varied by +/- 50% and simulated with the baseline (1981-2010) and a Global Climate Model end-century scenario.

Table 2. Layout of the AgMIP Pilot simulations

Simulation steps	Description	Model output	Simulation file name
Experimental year, low information	Simulation of the four single treatment experiments with low prior information (limited calibration)	Daily and summary	1.1_experiment_years_(annual summary_low_and_all_info).txt 1.2_experiment_years_(dynamics_low_and_all_information).txt
Baseline 30-years simulation, low information	30-years simulations with baseline (past) weather data and low prior information (limited calibration	Summary	2_30_years_simulations_(low_and_all_information).txt
Experimental year, all information	Simulation of the four single treatment experiments with all prior information (full calibration)	Daily and summary	1.1_experiment_years_(annual summary_low_and_all_info).txt 1.2_experiment_years_(dynamics_low_and_all_information).txt
Baseline 30-years simulation, all information	30-years simulations with baseline (past) weather data and all prior information (full calibration)	Summary	2_30_years_simulations_(low_and_all_information).txt
Limited factors sensitivity analysis, all information	Factorial manipulation of CO_2 (360, 450, 540, 630, 720 ppm) , temperature (-3, 0, 3, 6, 9°C) N (-50%,100% and 150% of experiment), factors for 30 years of baseline weather	Summary	3_SA_limited_factors_(all_information).txt
Special factor sensitivity analysis, all information	Baseline (360 ppm CO_2) and end-of-century (single A2 scenario; 734 ppm CO_2) weather with either 7 days with 35°C maximum daily temperature starting at observed anthesis date, ± 50% N fertilizer rate (for end-of-century only), ± 20 days in sowing date, or ± 20% in plant available soil water (changed drained lower limit)	Summary	4_SA_special_factors_(all_information).txt

Model input (cultivar information and crop management), soil description and initial conditions data for simulation set up are in Excel spreadsheets provided with the data. All simulation results are in text files (tab delimited). The file name and variable names are explained in Excel spreadsheets as part of the data set.

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