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Validating CERES-wheat under North-German environmental conditions

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Abstract

The predictive quality of CERES-wheat was tested under contrasting nitrogen management and temperate-maritime climate conditions of North-Germany. Field data from 9 years of observations were used in this study. The magnitudes of the genetic parameters of the local wheat cultivar "Orestis" were strongly influenced by seasonal weather fluctuations. For predicted yield and harvest biomass, the root mean square error was 2.2 t/ha and 3.2 t/ha, respectively. These errors were too large to permit a practical application of the CERES-wheat model for optimizing fertilizer management under the production conditions of North-Germany. The results of this study suggest that the model needs to be considerably improved with respect to the simulation of soil and plant water-relations, as well as the interaction between water and nitrogen uptake which were found to be inconsistent.

Keywords: CERES; DSSAT; Wheat; Crop modelling; Simulation; Decision support; Validation; Temperate-maritime climate; Nitrogen management; North-Germany

1. Introduction

Wheat production in North-Germany takes place under temperate-maritime climate conditions. Actual wheat yields typically reach 10 t/ha of grain in this region which are promoted by long day-lengths, moderate temperature regimes and non-limiting soil water availabilities under average weather conditions (Hühn, 2003; Sieling et al., 2005). Inadequate nitrogen fertilization and the resulting leaching of soil nitrate into the groundwater is a frequently observed problem in North-Germany (Sieling et al., 1997). It is caused by considerable variabilities in precipitation and soil conditions, which prevent accurate estimations of crop fertilizer requirements under practical conditions (Wagner, 1998; Griepentrog and Kyhn, 2000; Treue, 2003).

The decision support system for agricultural technology transfer (DSSAT) was developed to reduce time, uncertainties and human resources required for analysing complex alternative management decisions in agricultural practice (Tsuji et al., 1998; Jones et al., 2003). Due to these characteristics we decided to use DSSAT as a decision making tool for optimizing nitrogen management under the soil and weather conditions of Schleswig–Holstein in North-Germany (Hanus, 2000). Our study focussed on the validation of CERES-wheat, which is a component model of the DSSAT system, has a long development history (Ritchie et al., 1998; Jones et al., 2003) and was applied in various parts of the world (Jones and Kiniry, 1986; Otter-Nacke et al., 1986; Ritchie et al., 1988; Porter et al., 1993; Jamieson et al., 1998; Tsuji et al., 1998; Asseng et al., 2000; Ghaffari et al., 2001; Jones et al., 2003; Rinaldi, 2004; Wessolek and Asseng, 2006; Timsina and Humphreys, 2006). The successful performance of this model under a wide range

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of environmental and management conditions provided confidence in its predictive quality (Matthews and Blackmore, 1997).

The validation study was carried out in three successive steps: The genetic coefficients of CERES-wheat were first calibrated with development and growth data from a wheat-cultivar which is commonly grown in North-Germany (cv. Orestis). The calibration mechanism is included in version 3.5 of this model to facilitate its global application (Hunt et al., 1993; Jones et al., 2003). We specifically analyzed the influence of seasonal weather variations on the variability of genetic parameterization. Carefully constructed sets of genetic coefficients were then used to drive the model with inputs from optimum managed wheat trials. The aim of this second step was to quantify the predictive quality of the model under optimum management but variable weather conditions. The third part of the validation study was carried out with field data from contrasting nitrogen fertilization experiments under the full range of common weather conditions to test the applicability of the model as a decision support tool for optimizing nitrogen management.

2. Material and methods

2.1. Environmental conditions

The experiment was carried out from 1990 until 1999 at the experimental farm of the University of Kiel (Hohenschulen – Geographical coordinates: 54° 19′ 0″ North, 9° 59′ 0″ East). Stagnic luvisols, gleysols and cambisols are heterogeneously deposited on debris marl at this location. Sand contents are higher than 50%. Bulk densities range between 1.4 g/cm^3 within the upper 30 cm soil layer and 1.8 g/cm^3 at 1 m depth. The main soil physical characteristics of the experimental site are given in Table 1.

The climate of Hohenschulen is temperate-maritime. During the study period the average daily temperature varied between 0.5 °C in winter and 18.5 °C in summer. Short-term temperature changes were generally small (Fig. 1), because the adjoining seas of Schleswig–Holstein (Baltic and North seas) acted as strong thermal buffers. North-west and south-west are the main wind directions. Rapid sequences of alternating cold and warm fronts caused high short-term variations in solar radiation and rainfall conditions (Fig. 1). These variations were occasionally interrupted during summers when high-pressure zones originating from Eastern-Europe stabilized the weather of Schleswig–Holstein. Rainfall events were evenly distributed during the growing seasons. There were no extensive dry periods except during summer 1996. The amount of rainfall between seeding and harvest varied considerably between 274 mm and 850 mm. The annual trends of the most

Table 1
Textures and physical soil properties of the soils at the experimental site

	Soil depth		
	30 cm	50 cm	100 cm
Sand (%)	57.8 ± 3.2	56.1 ± 3.5	56.0 ± 4.8
Silt (%)	26.1 ± 3.9	27.4 ± 2.7	27.6 ± 2.2
Clay (%)	16.1 ± 2.0	16.5 ± 2.1	16.4 ± 4.1
SBDM (g cm^{-3})	1.55 ± 0.11	1.68 ± 0.07	1.73 ± 0.11
SLLL (%)	0.12 ± 0.01	0.13 ± 0.02	0.13 ± 0.02
SDUL (%)	0.32 ± 0.03	0.30 ± 0.03	0.30 ± 0.03
SSAT (%)	0.37 ± 0.03	0.35 ± 0.02	0.35 ± 0.05

SBDM = soil bulk density, SLLL = drainage lower limit, SDUL = drainage upper limit, SSAT = drainage saturation limit.

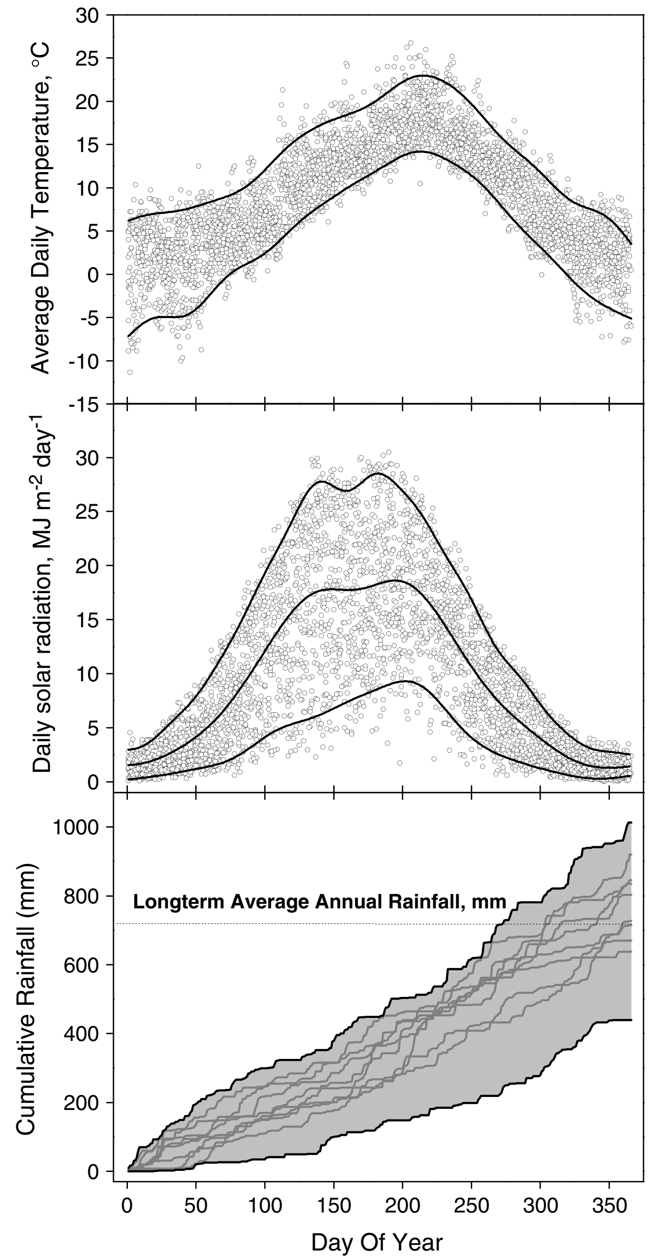

Fig. 1. Average daily temperature (top graph – symbols are daily values. Lines are smoothed maximum and minimum temperatures), daily solar radiation (center graph – symbols are daily values. Lines are smoothed maximum, average and minimum daily solar radiation) and cumulative rainfall (bottom graph – variability of cumulative annual rainfall) during the study period between 1990 and 1999 (experimental farm of the University of Kiel at Hohenschulen, Germany – Geographical coordinates: 54° 19′ 0″ North, 9° 59′ 0″ East).