Italian Journal of Agronomy
Rivista di Agronomia

An International Journal of Agroecosystem Management

10th Congress of the European
Society for Agronomy
15-19 September 2008, Bologna, Italy

ESA

Multi-functional Agriculture
Agriculture as a Resource for Energy
and Environmental Preservation

The Official Journal of the
Italian Society of Agronomy

Evaluation of the CROPGRO/DSSAT Model Performance for Simulating Plant Growth and Grain Yield of Soybeans, Subjected to No-Tillage and Conventional Systems in the Subtropical Southern Brazil

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Introduction

During crop cycle, growth and phenological development are influenced by different factors such as weather conditions, genetic potential, soil fertility, and system management. Management practices influences soil water retention properties and consequently crop growth and yield. In Brazil, a paradigm change in soil management has lead conventional tillage system to give room to no-tillage system, due to impacts such as erosion processes and soil organic carbon losses. No-tillage is considered a conservationist system because it includes crop rotation, mulching and only minimum soil mobilization on the seeding line. Those practices promote higher soil water storage, which are attributed to improvement of mesoporosity and non-saturated soil hydraulic conductivity. Knowledge on soil-water-atmosphere system dynamics is required on modeling crop growth and yield for supporting decision systems. Among several options, the Decision Support System for Agrotecnology Transfer (DSSAT) seem to be the most suitable for practical application since it includes more than 18 different crops models tested worldwide. After model calibration against field data, it is possible to simulate realistic scenarios for decision-makers (farmers, managers, agricultural technicians and government), as well as to identify crop constraint for scientists defining research priorities. This study aimed to evaluate CROPGRO/DSSAT model performance to simulate soybean growth, development and crop yield under no-tillage and conventional tillage systems in subtropical climate conditions, in order to support decision making in soybean cropping of Brazil.

Methodology

CROPGRO model integrated to DSSAT Version 4.0 was used to simulate a soybean crop during 2003/04 cropping season, in Eldorado do Sul (30°05'S and 51°40'W and 46 m altitude), RS, Brazil. Simulations were compared with data from an experiment conducted in a area of 0,5 ha of a typical Argissolo Vermelho Distrófico. The area had been conducted under two soil management systems (no-tillage and conventional tillage) since 1995, with maize grown in summer and oat and vetches cultivated in winter. The experiment was conducted in a stripe design, with cultivar Fepagro RS-10 sown in November20th, 2003, in 0,40 m row spacing and 300,000 plants per hectare. The treatments were conventional tillage and no-tillage, with irrigation and no-irrigation. Soil water potential was measured with tensiometers to be used on the soil retention curves, determined experimentally, to obtain observed soil moisture. Evapotranspiration rates were measured in a weighing lysimeter and meteorological data were determined in an automatic weather station. Leaf area index (LAI) and dry biomass (leaves, stems, pods and seeds) were determined weekly. Model inputs included minimum and maximum air temperature (°C), precipitation (mm) and solar radiation (MJ m^{-2}). Soil inputs included soil classes, soil physical-hydraulic and chemical properties, in addition of crop management information (weed control, variety, planting date and irrigation). Calibration was performed using genetic coefficients of cultivar Fepagro RS-10, as described by Martorano (2007). Willmott et al. (1985) concordance index "d" was used to compare CROPGRO-Soybean estimates with observed data.

Results

Figure 1 shows high accuracy of CROPGRO-Soybean model to simulate crop phenological stages, as demonstrated by the low scattering of points around the 1:1 line, mostly for treatments with irrigation.

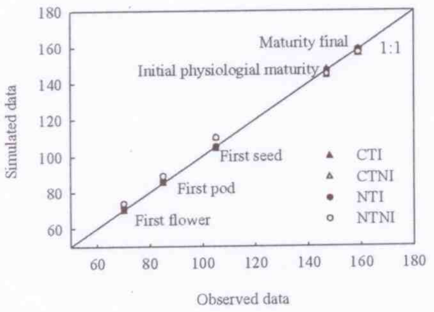

Figure 1. CROPGRO-Soybean model simulated and observed phenological stages (in days after sowing) for different treatments in Eldorado do Sul, RS, Brazil, 2003/04. CTI is conventional tillage irrigated, CTNI is conventional tillage non-irrigated, NTI is no-tillage irrigated and NTNI is no-tillage non-irrigated

The model was efficient to simulate the crop phenology (d ≈ 1) and to estimate the canopy biomass. Crop emergence occurred 8 days after sowing (DAS) and first flower appearance was about 71 DAS, with a difference of three days between irrigated and non-irrigated treatments. In conventional tillage with irrigation, comparison among simulated and observed data showed d values of 0.83 for LAI, 0.96 for plant height, 0.93 for leaf weight, 0.97 for total dry biomass, 0.90 for pod weight and 0.98 for seed weight. In no-tillage system with irrigation, d were 0.82, 0.87, 0.89, 0.94, 0.88 and 0.91, respectively. The model had lower accuracy under water deficit (non-irrigated treatments), especially in no-tillage system. Observed crop grain yields were 3,597 kg ha^{-1} (CTI), 3,816 kg ha^{-1} (NTI), 1,559 kg ha^{-1} (CTNI) and 1,894 kg ha^{-1} (NTNI), while simulated values were 3,108 kg ha^{-1} (CTI), 2,788 kg ha^{-1} (NTI), 824 kg ha^{-1} (CTNI) and 818 kg ha^{-1} (NTNI). Differences in crop grain yield between observed and simulated data of non-irrigated treatments suggest the necessity in adjusting soil water parameters in order to improve the performance of the model in simulating the crop growth and yield. Faria & Bowen (2003) after introduction of Darcy's equation to calculate soil water flux significantly improved soil moisture estimates.

Conclusions

CROPGRO-Soybean model presented higher performance to simulate phenological stages, growth variables and yield components under irrigated conditions than in non-irrigated treatments, especially in conventional tillage. Crop yield results for no-tillage system presented low accuracy, mostly for water deficit conditions (non-irrigated). Lower values of Willmot's test for agreement index "d" in no-tillage system than in conventional system suggest that adjusting model parameters is essential for applying CROPGRO/ DSSAT model in Brazil, where no-tillage system area is increasing significantly.

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