Linking a phosphorus module to CSM-CERES-Sorghum and evaluating it for West African conditions

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Introduction

Phosphorus (P) deficiency is a major constraint to sorghum productivity in West Africa with its highly weathered soils. Changes in P management are a much larger determinant of crop performance than climate change in the Sudanian zone, the principal sorghum production zone. The rapid agricultural intensification, decreased or abandoned fallowing, and variable access to and manner of P fertilization in this zone create both challenges and opportunities for farmers keen to increase sorghum productivity. Additionally, P and moisture availability interact with significant effects on plant phenology and growth. Yet in most mechanistic crop models, P has not been included for process simulation. In the Cropping System Model (CSM) of DSSAT (Jones et al., 2003), a soil and plant P module is active for CSM-CERES-Maize (Dzotsi et al., 2014) but not for CSM-CERES-Sorghum or CERES-Millet where it is greatly needed. The aim of this paper is to present the current efforts to develop a P-aware sorghum model within DSSAT (Hoogenboom et al., 2014).

Materials and Methods

To couple the P module to the sorghum CSM model, we first calibrated CSM-CERES-Sorghum for representative West African sorghum genotypes in non P-limiting conditions, then proceeded with key CSM source code modifications to couple the CSM Phosphorus module to CSM-CERES-Sorghum, and finally we establish the P response in selected genotypes from experimental data. For this, we collected data on phosphorus concentration in stems, leaves and grain in sorghum grown in a high and P deficient soils at ICRISAT-Mali on three cultivars of contrasting maturity and photoperiod sensitivity for calibration in DSSAT (PP sensitivities). Plant samples were collected at different crop stages and plant nutrient concentrations were determined. Soil analysis was performed to determine P Bray in soil. Field experiments are also conducted in Burkina Faso to extend the range of environments.

Results and Discussion

The model was first calibrated for three contrasting varieties representing the range of maturities for the West African Sudanian zone (Figure 1) and then coupled to the P module available within the CSM. We performed simulations with low P optimal concentration in plant organs as reported in data from Mali (P-concentration in shoot at mat = 0.89mg/g for CSM355) as well as information on soil-P content and yield response to P deficiency from Leiser et al., 2014 on a low-P (4.4 ppm Bray-1) soil with observed yield reductions of 38 to 57 %(all cultivars included). Data of P concentrations are still being collected to test the improved model against sorghum yields observed under high and low soil-P conditions,

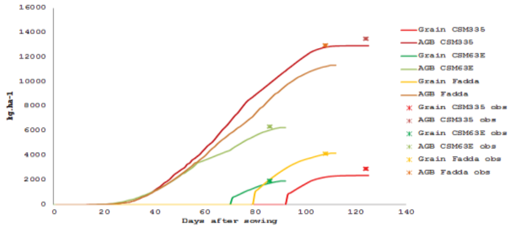

Figure 1. Simulated (lines) and observed (crosses) grain and aboveground biomass (ABG) productivity three contrasting sorghum varieties adapted to West African conditions

The coupling of the DSSAT Phosphorus module to CERES-Sorghum is now functional and we simulated a yield reduction for the sorghum CSM335 (cultivar adapted to the Koutiala, Mali) similar to the one observed by Leiser et al., 2014 (Table 1).

Table 1. Simulation of sorghum yield reduction due to phosphorus (P) deficiency

Grain yield CSM335 (kg/ha)	**Simulated**	**Observed**
Sorghum model (without P coupled)	2671	2210 (high P)
Sorghum model (with P coupled)	817	950 (low P)

On-going work is on calibration and evaluation of the P-aware sorghum model with P concentration data collected in Mali and Burkina Faso (2014-2015). Results of this work will be presented at the conference.

Conclusions

We achieved the technical coupling of the P module with the sorghum model in DSSAT-CSM, calibrated for Malian conditions. We are currently collecting P concentration data to calibrate and evaluate the P model and using the new data for additional evaluation. Further, we plan to improve the DSSAT sorghum model for leaf area dynamics and carbon partitioning.

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