Improving the intercropping version of the STICS model for simulating inter-specific competition

Rémi Vezy [1,2,3], Sebastian Munz[4], Noémie Gaudio[5], Marie Launay[6], Kirsten Paff[1,2], Patrice Lecharpentier[6], Dominique Ripoche[6], Eric Justes[2,7]*

[1] *SYSTEM, Univ Montpellier, CIRAD, INRA, IRD, Montpellier SupAgro, Montpellier, France*
[2] *INRA, UMR SYSTEM, Montpellier, France*
[3] *Current address: CIRAD, UMR AMAP, F-34398 Montpellier, France. remi.vezy@cirad.fr*
[4] *Institute of Crop Science, University of Hohenheim, Stuttgart, Germany*
[5] *Univ. Toulouse, INRAE, UMR AGIR, F-31320, Castanet-Tolosan, France*
[6] *INRA, US1116 AgroClim, Avignon, France*
[7] *CIRAD, Persyst department, Montpellier, France*

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Introduction

The STICS model has been previously adapted to simulate crops grown in bi-specific mixtures (Brisson et al., 2004; Launay et al., 2009), but the model evaluation showed inconsistencies regarding light interception, plant height, frost damage and leaf senescence for intercrops as partly already identified by Corre-Hellou et al. (2009). The main objective of our work was to update the intercrop version of STICS by fixing code issues and by adding new formalisms to integrate a computation of plant height and a new formalism of the equivalent plant density to better represent the competition between the two crops. A second objective was to evaluate the relevance of these changes compared to the previous version using a comprehensive dataset of field measurements.

Materials and Methods

The new computation of plant height uses an allometric equation from the aboveground biomass that enhances the range of possible relationships while being robust and parameter scarce. A new option was included for the equivalent plant density, a concept first included by Brisson et al. (2004) to consider the interspecific competition between two species. The code of the model was also revised to remove some bugs, mainly for the computation of frost damage and leaf senescence, that were found for the intercrop version. The model STICS was then evaluated using observations from durum wheat and winter pea grown either in sole crop or bi-specific intercrop in Auzeville (France) for three years in 2007, 2010 and 2011. The new parameters were calibrated using the sole crop data, except those only used for intercropping, for which two parameters were calibrated using data of intercrops. Then, the simulated leaf area index (LAI), aboveground biomass and plant height were compared to measurements at different growth stages for each species, either in the two sole crops or in intercrop, in order to evaluate the improvement with respect to the previous model version.

Results and discussion

The simulations from the new STICS-intercrop version were closer to the observations compared with the previous version of the model for the targeted output variables, i.e. LAI, aboveground biomass and plant height for the three wheat-pea intercrop experiments (Fig. 1). The RMSE was lower by 15.8 % on average for the two species and the three variables, and the model efficiency increased from -0.27 to 0.53 showing that the new formalisms improved the simulation of the intercropping system. The model is currently being tested more extensively using different N-treatments, species and pedoclimates to define its validity domain, with preliminary results presented in Paff et al. (2020). A new R package that uses the STICS intercrop version was designed and used to perform simulations and analysis (Vezy et al., 2019). See the SticsRPacks project for more information (Buis et al., 2020).

Conclusion

New formalisms were implemented in the STICS-intercrop version to model bi-specific intercrops with a relatively simple conceptual approach simulating competition for light capture between two intercropped species. The new version successfully simulated LAI, aboveground biomass and plant height for both wheat and pea grown either in sole- or in intercropping.

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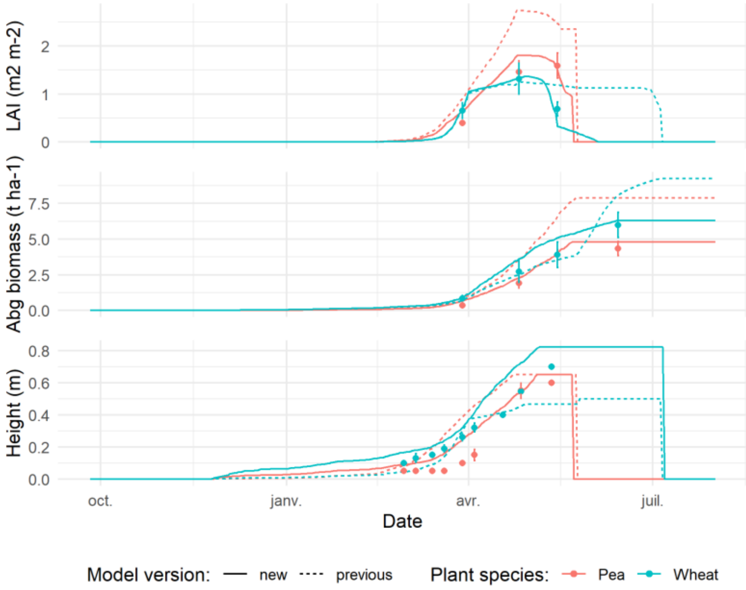

Figure 4. Simulated (lines) and observed (symbols) leaf area index (LAI), aboveground biomass, and plant height for pea (red) and wheat (blue) grown in mixture simulated with the previous (straight) and new (dotted) STICS-intercrop version.

References

Brisson, N., Bussière, F., Ozier-Lafontaine, H., Tournebize, R. and Sinoquet, H., 2004. Adaptation of the crop model STICS to intercropping. Theoretical basis and parameterisation. Agronomie, 24(6-7): 409-421.

Buis, S., Lecharpentier, P., Vezy, R. and Giner, M., 2020. SticsRpacks: a set of packages for managing Stics from R, STICS model workshop - side-event of ICROPM, Montpellier.

Corre-Hellou, G., Faure, M., Launay, M., Brisson, N. and Crozat, Y., 2009. Adaptation of the STICS intercrop model to simulate crop growth and N accumulation in pea–barley intercrops. Field Crops Research, 113(1): 72-81.

Launay, M. et al., 2009. Exploring options for managing strategies for pea–barley intercropping using a modeling approach. European Journal of Agronomy, 31(2): 85-98.

Paff, K. et al., 2020. Calibration and Evaluation of the STICS Intercrop Model for Two Cereal-Legume Mixtures, ICROPM, , 3-5 February 2020, Montpellier.

Vezy, R., 2019. VEZY/sticRs: Parameter optimization (Version 1.1.0). Zenodo. http://doi.org/10.5281/zenodo.3233968