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Adapting the CROPGRO model to predict growth and perennial nature of bahiagrass

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Introduction The objective of this research was to modify an existing crop growth model for ability to predict growth and composition of bahiagrass (*Paspalm notatum* Flügge) in response to daily weather and management inputs. The CROPGRO–CSM cropping systems model has a generic, process-oriented structure that allows inclusion of new species and simulating cropping sequences and crop rotations. An early adaptation of CROPGRO-CSM “species files” for bahiagrass over-predicted growth during late fall through early spring, and totally failed in re-growth if all foliage was lost from freeze damage. Revised species parameters and use of “pest damage” offered only a partial solution. Three processes, absent from the annual CROPGRO-CSM model, contributed to prediction of excessive cool-season growth: (1) no provision for storage (reserve) structures, (2) lack of winter dormancy, and 3) freeze damage killed all leaves at once and resulted in crop death. In addition, the model lacked the CO_2-concentrating effect of C_4 photosynthesis in the leaf photosynthesis routines. Therefore, we modified the source code of CROPGRO to include these processes to improve biological accuracy of re-growth patterns and prediction of seasonal patterns of growth (Rymph *et al.*, 2004).

Materials and methods A new plant organ (STOR) was added to simulate stolons, thereby serving as a perenniating sink and source for storing carbohydrate and N. Partitioning of new growth among leaves, stems, roots, and STOR is assumed to shift toward STOR with increasing vegetative maturity. New functions were added to promote re-growth after harvest and in the spring. These include increasing the mobilisation of N and carbohydrate (CH_2O) from STOR progressively more rapidly as LAI falls below 3.0 and more rapidly as whole-plant N status increases from 30 to 70% of potential N-status. Functions for dormancy were added to regulate the degree of partitioning to STOR versus leaf and stem, and to regulate rate of mobilisation of CH_2O and N from STOR. Dormancy is initiated when day-length is <12.5 h, becoming progressively stronger (maximum) as day-length reaches 10.5 h. The strength of this dormancy signal acts to increase partitioning to STOR, decrease mobilisation of N and CH_2O from STOR and roots, and reduces herbage and root growth (because of partitioning shift). As day-length increases above 10.5 h in spring, the process is reversed.

The freeze damage process was modified to use a “death constant” that reduces leaf and stem mass 5% for each degree of minimum daily temperature <-5°C. A lethal freezing temperature threshold was defined as the low temperature required to kill the STOR organ.

A “CO_2-concentrating factor” was added to the leaf-level photosynthesis code to simulate C_4 photosynthesis, accounting for effect of high CO_2 concentrations in bundle sheath chloroplasts of C_4 plants. This factor reduces sensitivities of quantum efficiency and leaf photosynthetic rate to atmospheric CO_2 concentration.

Results Five experiments from Texas and Florida were simulated with the modified version of CROPGRO. Predicted herbage mass, herbage N concentration, and herbage N mass were compared to measured values (303 observations). Seasonal patterns of growth were more accurately predicted to mimic low leaf and stem growth during winter, and increase in STOR mass during fall through early spring. STOR mass is used (depleted) to support re-growth in spring and after each harvest. The crop now survives winter freeze events that kill all green foliage. Performance of the new model version was improved with better index of agreement (d-index) values for predicted herbage mass of 0.81 and 0.82 (out of a possible 1.0) using leaf-level and daily canopy photosynthesis options, respectively, compared to 0.71 and 0.73 for the older CSM version (slope, intercept, and r^2 were also improved). Prediction of herbage N concentration was similarly improved. Predicted leaf-level photosynthetic response to elevated CO_2 was of the same magnitude as observed in phytotron measurements. Predicted N-stress in the model is excessive, but the cause has not been identified. Additional work is needed on N-related parameters of the crop and soil to reduce the predicted N stress and refine model response to N.

Conclusions The modified forage version of CROPGRO marks a significant step in adapting this model to more accurately reflect the perennial and seasonal patterns of organ growth of bahiagrass. Summer vs. winter patterns of herbage production, herbage N concentration, leaf, stem, root, and stolon growth are more accurately predicted. Sensitivity analyses show reasonable leaf growth and stolon storage dynamics after cutting harvest.

References

Rymph S.J. (2004). Modeling growth and composition of tropical perennial forage grasses. Ph.D. diss. University of Florida, Gainesville.