Can We Predict the Time of Seedling Emergence of Spring Wheat?

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Introduction:

The timing of seedling emergence affects growth and yield of wheat (*Triticum aestivum* L.) greatly and a good growth model should predict it accurately. The Cropping System Model of The Decision Support System for Agrotechnology Transfer (DSSAT-CSM) is used worldwide for many different applications, but its simulation on the timing of seedling emergence of wheat is not satisfactory. In order to improve the prediction of seedling emergence, we incorporated a newly developed emergence model, Beta model, into DSSAT-CSM.

The objectives of this paper were 1) to investigate if incorporating the Beta model in DSSAT-CSM could improve the prediction of spring wheat seedling emergence and 2) to test if the model is improved by using hourly air or soil temperature as compared with using daily air temperature.

Materials and Methods:

Observation of seedling emergence

Simulation performances were tested using observations of spring wheat (cv. Thatcher) from 24 sites across North America (Figure 1) from 1930 to 1954 which totalled 244 location-years (Nuttonson 1955).

Because detailed information of this study were not provided, we assumed that 1) emergence was recorded when 50% of the plants had emerged from the soil, 2) management was fallow-wheat rotation under conventional till, 3) seeding depth was 5 cm, and 4) no fertilizer was added to the soil.

The models were run in sequence mode using two sequence files, odd year wheat and even year wheat for each site. This allowed wheat simulations under fallow-wheat rotations for each year. Simulations started two years before the years with emergence observations in order to reduce the error of inputs of initial soil conditions.

The Beta model

Jame and Cutforth (2004) separated the period between seeding and emergence of wheat into three consecutive processes: germination, subcrown internode elongation (if seeding depth > 2.5

cm), and coleoptile elongation. The rates (DR) of emergence (day-1) were calculated by the following beta function:

$$DR = EXP(\mu) \times (T - Tb)\alpha \times (Tc - T)\beta$$

where T is temperature in °C ($Tb < T < Tc$), Tb and Tc are base and upper critical temperatures, respectively, μ, α and β are the model parameters.

The base temperature was set as 0 oC by Jame and Cutforth (2004). We used 1 oC as Tb and changed Tc from 42 oC to 39 oC. The model was parameterized based on the data of Canadian cultivars using nonlinear regression analysis.

Incorporation with DSSAT-CSM and Model Evaluation

The Beta model was incorporated into DSSAT-CSM to simulate wheat emergence using daily air temperature, calculated hourly air temperature and calculated soil temperature at seeding depth separately in order to compare their performances.

Models were assessed and compared by their consistent errors (mean difference, M), associations (Pearson's correlation, *r*), and coincidences (root mean square errors (RMSE)) between simulated and measured values.

Results and Discussion:

Over all years and locations of this study, days from seeding to seedling emergence (DSE) ranged from 5 to 39 days and averaged 12.2 days. The unmodified DSSAT-CSM underestimated DSE in most cases (94% location years) and averaged 4.8 days less than observations (Figure 2).

The modified model using simulated daily soil temperature at seeding depth also improved simulation in terms of M and RMSE (Figure 2), but was not as good as the model using air temperatures. This is surprising, considering that soil temperature should better reflect seed environment than air temperature. Figure 3 showed that the model tended to overestimate soil temperature at seeding depth (5 cm). The relatively poor prediction of DSE by simulated soil temperature is associated with the inaccuracy of soil temperature simulation.

Although the modified model using simulated hourly air temperature was only slightly better than that using daily temperature (Figure 2), it is preferable because of the large diurnal variation in temperature and the nonlinear nature of the response of emergence process to temperature. Further work should include improving soil temperature and moisture simulations. Then, the model can use seedbed condition indicators to predict seedling emergence.

References:

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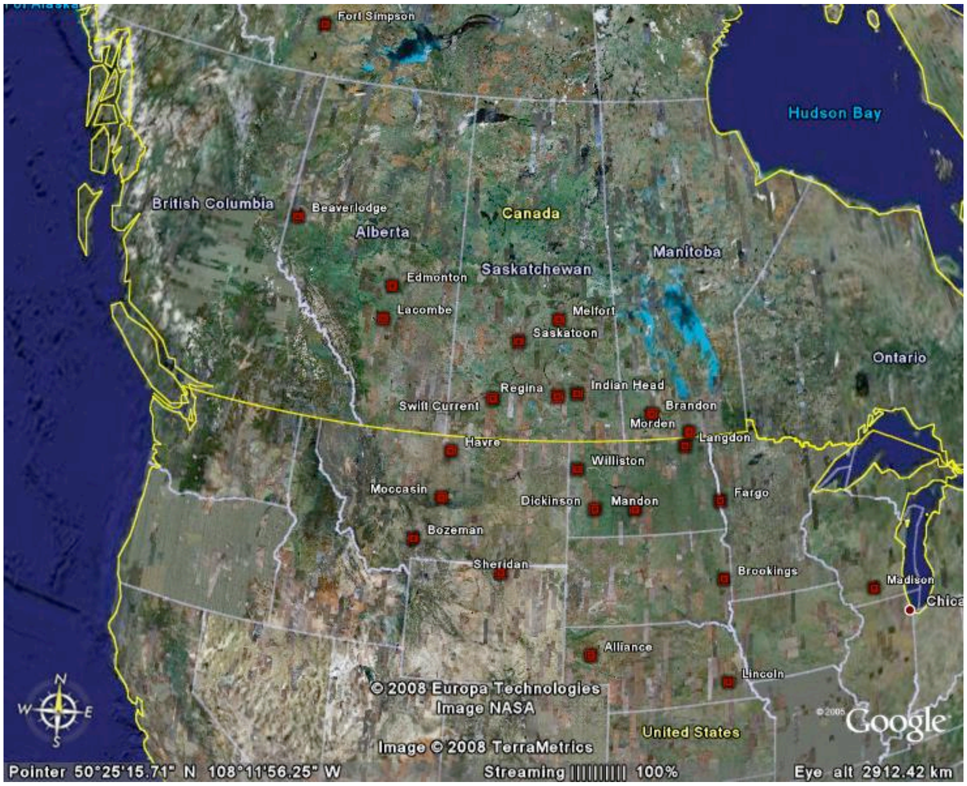

Figure 1. Canadian and American sites used for seedling emergence observations

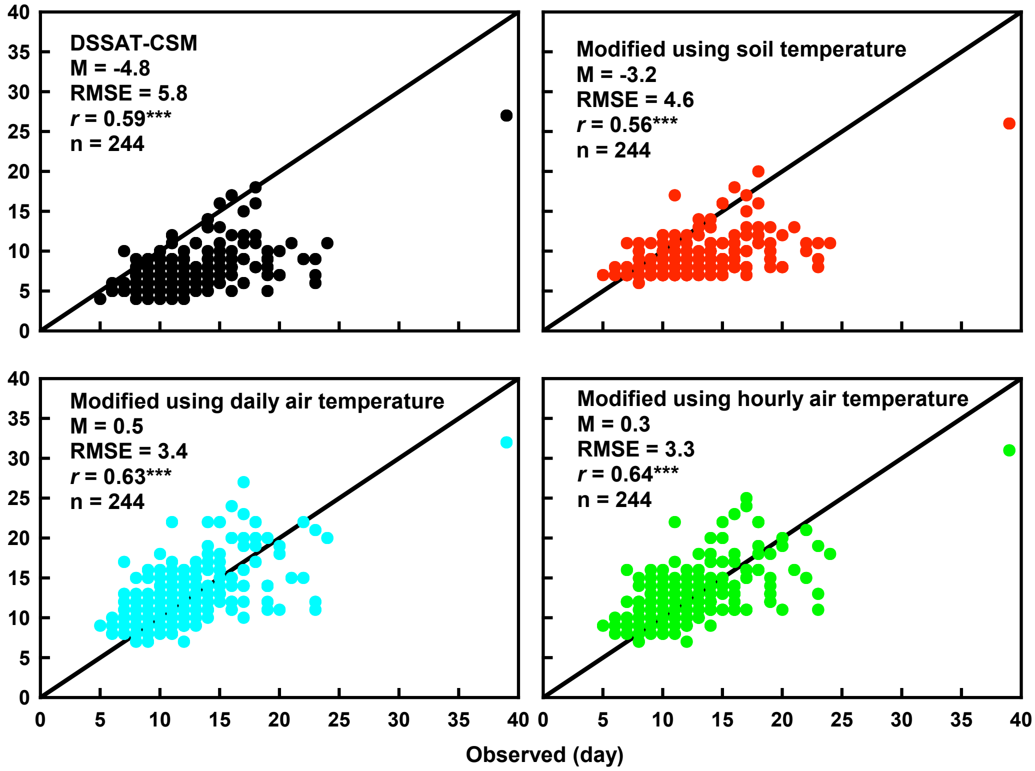

Figure 2. DSSAT-CSM model results for tested mergence models

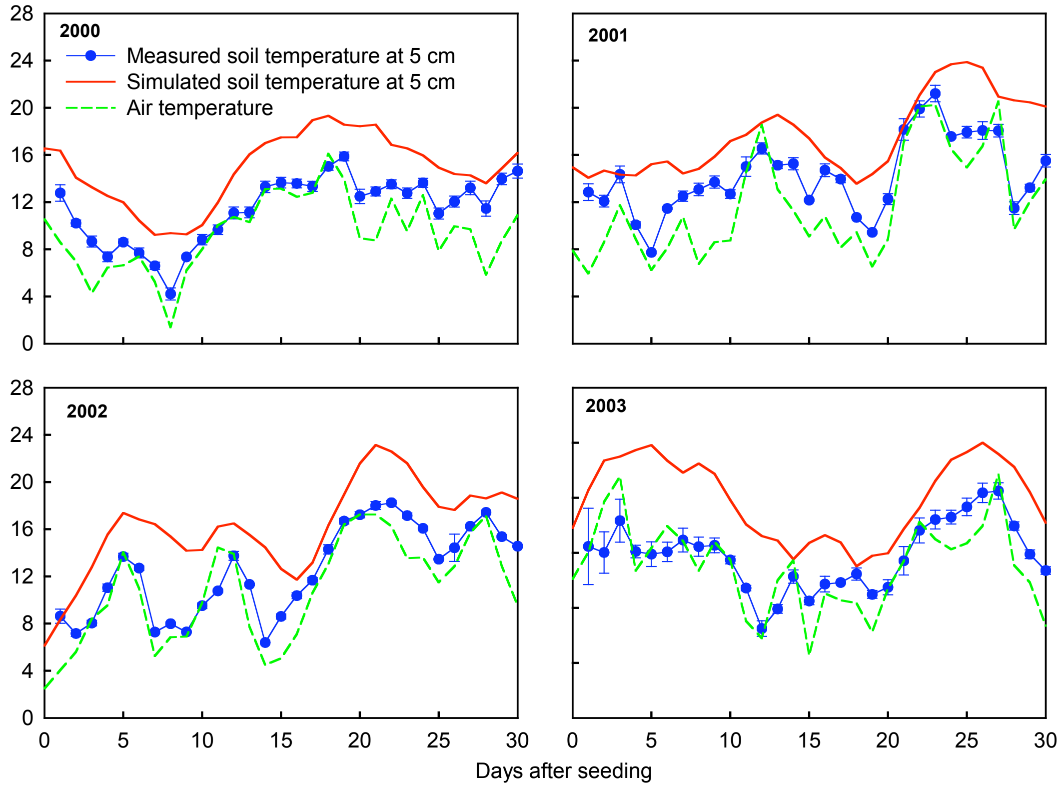

Fig. 3. Measured and simulated soil temperatures at 5 cm under conventional tillage with air temperature at Three Hills AB. Bars are standard errors of measured soil temperature