Crop Growth Models with Fewer Cultivar-Specific Inputs to Enhance Use in Research and Decision Support

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Outline

- Genotype-Specific Coefficients (GSCs)
- Evaluation
- Applications

This presentation is available online at: soysim.unl.edu/cropmodels.pdf
Genotype-specific inputs (minimum req.)

- **Photo-thermal coeffs**
  - EM to R1,
  - R1 to R3,
  - R1 to R5,
  - R5 to R7,
  - R1 to end of leaf exp.,
  - seed filing duration,
  - pod filling duration

- **Critical short daylength**

- **Photoperiod sensitivity**

- **Specific leaf area (cm² g⁻¹)**

- **Max. leaf Ps (mg CO₂ m⁻² s⁻¹)**

- **Max. leaf size (cm²)**

- **Max. seed weight**,

- **Average seed per pod**

- **Thermal time coeffs**
  - EM to end of juvenile,
  - R1 to R6,
  - phyllochron

- **Photoperiod sensitivity for silking**

- **Maximum kernels per plant (G2)**

- **Potential grain filling rate (G5)**

**Genotype-specific Coefficients**

- **Hybrid-Maize**
  - Thermal time (EM to R6)

- **SoySim**
  - Maturity group
  - Stem termination type

- **Ceres-Maize**
  - Hybrid-Maize
  - SoySim
    - Setiyono et al., (2010)
  - CERES-Maize*
    - Jones & Kiniry (1986)
  - CROPGRO-Soybean*
    - Boote et al., (1998)

* in DSSAT 4.0.2.0

[soysim.unl.edu/cropmodels.pdf](soysim.unl.edu/cropmodels.pdf)
Genotype-specific inputs (minimum req.)

**Hybrid-Maize**
- Thermal time (EM to R6)

**SoySim**
- Maturity group
- Stem termination type

**Ceres-Maize**
- Thermal time coeffs (● EM to end of juvenile, ● R1 to R6, ● phyllochron)
  - Photoperiod sensitivity for silking
  - Maximum kernels per plant (G2)
  - Potential grain filling rate (G5)

**CROPGRO-Soybean**
- Photo-thermal coeffs (● EM to R1,
  - R1 to R3, ● R1 to R5, ● R5 to R7,
  - R1 to end of leaf exp., ● seed filing duration, ● pod filling duration)
  - Critical short daylength
  - Photoperiod sensitivity
  - Specific leaf area (cm² g⁻¹)
  - Max. leaf Ps (mg CO₂ m⁻² s⁻¹)
  - Max. leaf size (cm²)
  - Max. seed weight,
  - Average seed per pod

**Number of Genotype-specific coefficients**

- Hybrid-Maize: 1
- SoySim: 2
- CERES-Maize: 6
- CROPGRO-Soybean: 15
Simulated phenology is for P33P67 (1517°Cdays) and P93M11 (MG 3.1) in Lincoln, NE (2001) May-5 emergence

Phenology & Genotype-Specific Coefficients

EM = Seedling emergence, V1 = First leaf, VF = Final V-Stage

Maize
EJ = End of juvenile
TI = Tassel initiation
R1 = Silking
SD = Beginning grain filling
R6 = Physiological maturity

Soybean
R0 = Fully induced
R1 = First flower
R3 = First pod
R5 = Beginning seed
R7 = Physiological maturity

Simulated phenology is for P33P67 (1517°Cdays) and P93M11 (MG 3.1) in Lincoln, NE (2001) May-5 emergence
Avoiding GSCs: SoySim Example

---------- 20 cultivars (MG I to IV) ----------

SoySim, developer version

GSCs as inputs (20 x 7 coeffs) 1-set of GSCs applied to all cultivars

SoySim MG as input

Observed Phenology (Day of Year) Simulated Phenology (Day of Year)

Residual (d) Residual (d) Residual (d)

-30 -15 0 15 30

120 150 180 210 240 270 300

V1(55) R1(59) R3(69) R5(67) R7(66)

RMSE (d) RMSE (d) RMSE (d)

3.3 7.0 3.6

from Setiyono et al., (2007) Field Crop Res. 100, 257-271

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Genotype-Specific Coefficients
Avoiding GSCs: Hybrid-Maize Example

\[ GDD_{\text{silking}} = 0.41 \, GDD_{\text{total}} + 145.4 \quad (r^2 = 0.78) \]

\[ GDD_{\text{tassel to silking}} = 0.46 \, GDD_{\text{silking}} + 155.83 \]

Resp. coeffs are not cultivar-specific (Katsura et al. 2009, Field Crop Res. 87, 131-154)

From Yang et al., (2004)
Field Crop Res. 87, 131-154
<table>
<thead>
<tr>
<th>Aspects</th>
<th>Maize</th>
<th>Soybean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planting Date</td>
<td>4/20-5/20</td>
<td>3/27-6/14</td>
</tr>
<tr>
<td>Pop. (plants m(^{-2}))</td>
<td>3.7-10.4</td>
<td>13-56</td>
</tr>
<tr>
<td>Obs. Yield (Mg ha(^{-1}))</td>
<td>3.8-17.3</td>
<td>2.4-6.4</td>
</tr>
<tr>
<td>Obs. Yield (bu A(^{-1}))</td>
<td>61-276</td>
<td>36-95</td>
</tr>
<tr>
<td># Observations (n)</td>
<td>36</td>
<td>144</td>
</tr>
</tbody>
</table>

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Evaluation: Maize

Ceres-Maize
- RMSE: 3.1 Mg ha\(^{-1}\)
- ME: -1.1 Mg ha\(^{-1}\)
- \(y = 0.89x + 1.84\)
- \(R^2 = 0.83\)

Hybrid-Maize
- RMSE: 1.6 Mg ha\(^{-1}\)
- ME: 0.5 Mg ha\(^{-1}\)
- \(y = 1.12x - 2.58\)
- \(R^2 = 0.65\)

\(R^2 = 0.52\) (n=51)

in Jones & Kiniri (1986)

CERES-Maize:
A Simulation Model for Maize Growth and Dev.

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Evaluation: Soybean

Observed Yield (bu A⁻¹)

CROPGRO-Soybean
- RMSE: 0.72 Mg ha⁻¹
- ME: 0.06 Mg ha⁻¹
- y = 0.26x + 3.28
- R² = 0.20

SoySim
- RMSE: 0.46 Mg ha⁻¹
- ME: 0.03 Mg ha⁻¹
- y = 0.94x + 0.29
- R² = 0.67

CROPGRO results are similar to the exp.by Pedersen et al. (2004) in upper Midwest (Agron. J. 96, 556-564)

Applications: Decision Supports

- Hybrid-Maize:
  - Estimating maize N fertilizer requirements (Maize-N)
  - Evaluating maize productivity and water use in western corn-belt (Grassini et al., 2009, Agric. Forrest. Meteorol. 149, 1254-1265)

- SoySim:
  - Soybean Irrigation Scheduling for Nebraska

EONR = Economically optimum N rate
RMSE = Root Mean Square Error
ME = Mean Error
Yield response to climate change (CO₂), simulation study using SoySim

Hist. yield increase from CO₂
6 kg year⁻¹ (Simulated)
5 kg year⁻¹ (Specht et al., 1999)

From 315 to 630 μmol mol⁻¹ CO₂
30% increase in yield (SoySim)
24 % (Ainsworth et al., 2002, Global Change Biol., 8, 695-709)
35 % (Allen & Boote, 2000, In Reddy & Hodges, Climate Change & Global Climate Crop Productivity)
51% increase in ADM (SoySim)
Decrease in HI (Allen et al., 1991, Agron, J., 83,875-883)

24-year simulation for MG 3.1 in Lincoln, NE with 30 plants m⁻²
Applications: Hybrid-Maize

Warm night temperature & the drop in Oct 2010 yield forecast for Iowa

October’s corn yield forecast for Iowa dropped to 169 bushels per acre, a significant reduction from the August and September forecasts of 179 bushels per acre (see October USDA-NASS forecast). If realized, 2010 yields will rank 6th among the last seven years - higher only than the yields of 2005 (166 bushels per acre). Numerous yield reports substantiate lower than expected yields this year.

We’ve talked a lot this year about 2010 conditions and the possibility of reduced yields resulting from rapid crop development following silking. Statewide Growing Degree Day (GDD) accumulations were 116% of normal during most of the seed fill period - silk to dent - this year (see my September 10th and 15th postings).

Remember that cool night temperatures after silking in 2009 resulted in the highest average yield ever recorded in Iowa: 182 bushels per acre. In contrast, warm night temperatures after silking typically reduce yields.

Above: Crop consultant Jerry Mulliken uses the Hybrid-Maize model to monitor corn-yield potential through the growing season.
Summary
Genotype-Specific Inputs can be minimized in crop simulation models

- Reasonable phenology predictions
- Allow robust simulation of yield
- Enhance effective use for decision support and in research

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References


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## Crop Models

<table>
<thead>
<tr>
<th>Crop</th>
<th>Model</th>
<th>Version</th>
<th>Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>CERES-Maize (Jones &amp; Kiniry, 1986)</td>
<td>3.0 RUE</td>
<td>DSSAT 4.0.2.0 (Jones et al., 2003)</td>
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<td>Soybean</td>
<td>CROPGRO-Soybean (Boote et al., 1998)</td>
<td>2004 Phs, Resp</td>
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<td>Hybrid-Maize (Yang et al., 2006)</td>
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</tr>
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</table>

### Calibration Datasets:
Maize: Lincoln NE (2001)

CERES, Crop-Environment Resource Synthesis
DSSAT, Decision Support System for Agrotechnology Transfer
RUE, Radiation Use Efficiency; Phs, Photosynthesis; Resp, Respiration
Soybean Yield vs. Year

- **Slope**: 36 kg ha\(^{-1}\)
- **Slope**: 23 kg ha\(^{-1}\)

![Graph of Soybean Yield vs. Year]

- **Lines**:
  - NE Irrigated
  - NE Rainfed
  - USA
  - Contest Yield Winner
  - Field Exp. Lincoln, NE
  - Simulated (Lincoln, NE)

- **Legend**:
  - **NE Irrigated**
  - **NE Rainfed**
  - **USA**
  - **Contest Yield Winner**
  - **Field Exp. Lincoln, NE**
  - **Simulated (Lincoln, NE)**

- **Axes**:
  - **Yield (Mg ha\(^{-1}\))**
  - **Yield (bu A\(^{-1}\))**

- **Year**:
  - 1970
  - 1978
  - 1986
  - 1994
  - 2002
  - 2010

- **SoySim**
References, Detailed


References, Detailed (cont’d)


