Use of the Hybrid-Maize model to improve management decisions

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Daniel Walters
Kenneth Cassman

Digital Agronomy for Increased Yield and Profit
- Yield potential and yield gaps
- Basic structure of Hybrid-Maize
- Model inputs
- Model applications
- Validation, uncertainties & future improvements
Yield potential and yield gaps

Yield potential

CO₂
Solar radiation
Temperature
Genotype
Plant density

Water-limited yield potential

Attainable yield with available water supply:
soil
rainfall
irrigation

Actual yield

Other limiting factors:
Nutrients
Weeds
Pests
Others
Crop simulation model: = a set of mathematical equations, which describe major processes of plant development and growth as a function of time, climate, and other factors

- Simulation of crop development: phenology & prediction of growth stages in vegetative and reproductive phases (e.g., emergence, leaf development, flowering, leaf senescence)
- Simulation of crop growth: gross and net dry matter accumulation in different plant organs (light interception, photosynthesis, growth and maintenance respiration, partitioning)
- With or without considering the influence of other factors on crop development and growth (water, nutrients)
- Most crop models operate on a daily time scale.

Crop simulation models
A simple crop-soil water model

Porter et al., 1999. An approach for modular crop model development
http://www.icasa.net/modular/index.html
Vegetative phase:
- Leaf number increase is calculated based on a maximum rate and actual temperature.
- Continues until the plant reaches a genetically determined maximum leaf number.
- Assimilates are partitioned between canopy and roots.

Reproductive phase:
- The difference between daily mean temperature and a base temperature is used to calculate the rate of plant development.
- All growth occurs in the grain.
- All whole plant weight increases are converted to area based values by multiplying by the plant density.

Porter et al., 1999. An approach for modular crop model development
http://www.icasa.net/modular/growth.html
Simulates growth and development of maize for **yield potential** and **water-limited yield potential**

Combined two previous modeling approaches:
- T-driven growth and development (CERES/DSSAT)
- Mechanistic descriptions of light interception, photosynthesis and organ-specific respiration from generic models (Dutch school of modeling)

General:
Weather file  
Simulation mode  
Start mode and date  
Hybrid/maturity settings  
Plant population

Water:
Optimal  
or  
Rainfed/Irrigated

Soil:
Texture  
Bulk density  
Initial moisture

Inputs
Read & check inputs, parameters
From emergence?
Yes
Maturity by GDD?
No
GDD to silking?
Yes
In-season?
No
Initiate daily growth simulation

No
Estimate date of emergence

Yes
Estimate total GDD from date of maturity

Yes
Estimate GDD to silking from date of silking or total GDD

Yes
Combine current weather data with historical records

No
Estimate GDD to silking from date of silking or total GDD

No
Estimate: root distribution soil moisture crop water stress

Optimal water?
No

Yes

Outputs
Numerical output
Bar charts
Graphs of growth dynamics
Graphs of weather data
Graphs of soil moisture

Compute GDD accumulation, phenology leaf area expansion/senescence, light capture, gross assimilation, growth and maintenance respiration, net dry matter production and allocation to organs. Write results to output files.

End (crop matures or dies of frost damage)
- **Daily** weather data: solar radiation, max. and min. temperature, rainfall
- Crop management: date of planting, seed depth, corn hybrid or GDD to silking/maturity, plant density
- For simulating water-limited yield: max. rooting depth, texture class and bulk density in topsoil and subsoil
- **Optional:** change model parameters
  - Hybrid-specific crop coefficients
  - General model coefficients describing crop growth and development
  - Soil physical properties for different soil texture classes
Inputs: general options
<table>
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<tr>
<th>Management</th>
<th>Crop growth</th>
<th>Resp &amp; Photosyn</th>
<th>Hybrid-specific</th>
<th>Soil</th>
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**Texture-specific parameters**

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<th>Ksat</th>
<th>Alfa</th>
<th>AK</th>
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</table>

Porosity: total pore fraction in soil.
GAM: texture-specific constant, cm-2.
PSimax: texture-specific constant, cm.
Ksat: saturated hydraulic conductivity, cm/d.
Alfa: texture-specific geometry constant, cm^-1.
AK: texture-specific empirical constant, cm^-2.4 d^-1.

Refer to User’s Manual for more information about the parameters on this page.

Inputs: parameter settings
- Standard version includes long-term daily climate data for 15 sites
- Purchase Expanded Weather Database from estore.adec.edu (137 sites in 10 states of the Corn Belt), $25
- Subscribe to High Plains Regional Climate Center for online access to daily weather data (both long-term data and real-time data for the ongoing growing season), hprcc.unl.edu

Inputs: weather data
HPRCC supports a three-tiered national climate services support program. The partners include:

National Climatic Data Center, Regional Climate Centers, and State Climate Offices.

About HPRCC
(mission, objectives, activities, highlights, personnel)

Climate Data
(online, full service, AWDC, NWS, digital, hardcopy)

Climate Products
(current maps, normals, atlas, historical, national)

Research Projects
(NE soil moisture, crop coefficients, wind energy)

Publications
(articles, books, reports, extension)

Weather and Climate Links
(state climatologists, government, education)

High Plains Regional Climate Center
University of Nebraska
236 L.W. Chase Hall, Lincoln, NE 68583-0728
Phone: 402-472-6706, Fax: 402-472-6614
Sites with automatic weather stations and long-term daily climate records, including solar radiation.
Search for, and Select a Station

Current Station List: NORTH PLATTE WSD ARP, NE 1/1/1948 to 4/15/2002

Click Here to Blank the Current List

Click Here to Add the Highlighted Station(s) to the Current List

Hold down Ctrl-key while clicking to select multiple stations

Identify a State: Nebraska

Identify a Station Network: National Weather Service & Cooperative Observer Network

Click Here to Search for a Station

Visit the Automated Weather Data Network (AWDN) home for detailed information on AWDN station location, period of record, data available, and more.

Visit the HPRCC Archive of National Weather Service Surface Observations home for detailed information on NWS station location, period of record, data available, and more.

Note: These sites are not a part of the HPRCC Online System, and following either link will open a new browser window.
## Downloaded raw weather data (HPRCC format)

**Inputs:** weather data

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<th>Date/Time</th>
<th>T-High</th>
<th>T-Low</th>
<th>Rel Hum</th>
<th>Soil Temp</th>
<th>Wind Spd</th>
<th>Solar</th>
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### Converted weather data (Hybrid-Maize format)

**Inputs: weather data**
Predicted by Hybrid-Maize or entered by user

- **VE**: Emergence
- **R1**: Silking, >50% silks are visible outside the husks
- **R6**: Physiological maturity (blacklayer), all kernels on the ear have attained their maximum dry matter accumulation. Average kernel moisture content is 30-35%.
- **H**: Harvestable maturity, after dry-down. Kernel moisture content is below 20%.

**Inputs: key growth stages**
Choices:

- Actual dates of VE, R1, and/or R6 observed
- Model-predicted dates based on hybrid-specific GDD values (GDD to silking and physiol. maturity)
- Model-predicted dates based on brand-specific or generic functions. Inputs can be:
  - GDD to blacklayer (R6), or
  - Crop relative maturity rating (RM)

Inputs: key growth stages
Fig. 4.2. Relationship of GDD-to-silking to total GDD for four commercial maize seed brands. The GDD values refer to °C.

Inputs: total GDD
Fig. 4.1. Relationship of total GDD with relative maturity (RM, in days) for 12 commercial maize brands. The black line and the equation represent the regression of the pooled data. The GDD values refer to °C.

Inputs: relative maturity
Yield potential and yield gaps
Basic structure of Hybrid-Maize
Model inputs
Model applications
  - Analyze yield potential and/or water requirements for regional or site-specific decision making (before planting)
  - In-season yield forecasting and decision-making
  - Post-season analysis: what happened?
  - Validation, uncertainties & future improvements

Model applications
Using historical, long-term climate data for a site:

- Assess long-term yield potential and its variation among years (irrigated and non-irrigated).
- Assess change in yield potential due to varying planting date, hybrid choice, plant density, and/or water availability.
- Estimate irrigation requirements.
- Management decisions:
  - set adequate yield goals
  - determine optimal planting date (window)
  - identify most suitable hybrids
  - optimal plant density
  - evaluate economics and risks of various scenarios.

**Yield potential analysis**
General Input

Weather file... North Platte, NE wth
Years of data available 1982 ~ 2004

Simulation mode
- Current season prediction
- Long-term runs
- Single year

Start from
- Emergence
- Planting

Seed depth (inch) 1.8

Seed brand Pioneer

Maturity
- GDD50F 2850

Optional:
- Date of silking (m/d)
- GDD50F to silking * 1375

Population (x1000/acre) 32.0

Water

- Optimal Estimate irrigation water requirement
- Rainfed / Irrigated Assume no water stress in prediction phase

Irrigation schedule
- Month
- Day
- Amount (inch)

Nitrogen

- Optimal
- Last season residues incorporation
- Type
- Quantity (Mg/ha)
- Date

Soil

- Top-soil moisture at start, w/w% 25
- Max root depth (inch) 39.4
- Texture and bulk density (g/cm³)
  - Top-soil Loam 1.3
  - Sub-soil Loam 1.4

English units

RUN...
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<tr>
<th>Run</th>
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**Outputs:** results for each year
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<td>246.3</td>
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<td>8.23</td>
<td>14.06</td>
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<td></td>
<td>1990</td>
<td>242.9</td>
<td>5.75</td>
<td>7.09</td>
<td>12.84</td>
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<td>1982</td>
<td>241.9</td>
<td>5.73</td>
<td>6.74</td>
<td>12.47</td>
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<td></td>
<td>1984</td>
<td>241.8</td>
<td>5.73</td>
<td>7.23</td>
<td>12.95</td>
<td>0.44</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>2003</td>
<td>241.6</td>
<td>5.72</td>
<td>7.80</td>
<td>13.52</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td>1983</td>
<td>240.4</td>
<td>5.69</td>
<td>6.72</td>
<td>12.41</td>
<td>0.46</td>
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<td>2001</td>
<td>238.7</td>
<td>5.65</td>
<td>7.14</td>
<td>12.79</td>
<td>0.44</td>
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<td>1991</td>
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<td>5.53</td>
<td>7.74</td>
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<td>1992</td>
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<td>5.40</td>
<td>6.26</td>
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<td>0.46</td>
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<tr>
<td><strong>25% percentile</strong></td>
<td>2002</td>
<td>223.0</td>
<td>5.28</td>
<td>6.67</td>
<td>11.95</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>207.6</td>
<td>4.92</td>
<td>8.10</td>
<td>13.02</td>
<td>0.38</td>
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<td>1993</td>
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<td>4.79</td>
<td>5.83</td>
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<td>1998</td>
<td>197.9</td>
<td>4.69</td>
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<td>0.37</td>
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<tr>
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<td>11.33</td>
<td>0.41</td>
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<td>1985</td>
<td>174.4</td>
<td>4.13</td>
<td>7.13</td>
<td>11.26</td>
<td>0.37</td>
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<tr>
<td><strong>Worst</strong></td>
<td>1989</td>
<td>156.5</td>
<td>3.71</td>
<td>6.68</td>
<td>10.39</td>
<td>0.36</td>
</tr>
<tr>
<td><strong>Long-term mean</strong></td>
<td>238.2</td>
<td>5.64</td>
<td>6.81</td>
<td>12.45</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td><strong>CV%</strong></td>
<td></td>
<td>16.0</td>
<td>16.0</td>
<td>11.7</td>
<td>7.7</td>
<td>12.6</td>
</tr>
</tbody>
</table>

Outputs: yield-based ranking of results
Simulations using long-term historical weather data from 1982 to 2004

<table>
<thead>
<tr>
<th>Rank</th>
<th>Year</th>
<th>Or. Y</th>
<th>Gr. DM</th>
<th>Stover</th>
<th>tDM</th>
<th>HI</th>
<th>vDays</th>
<th>rDays</th>
<th>V+R</th>
<th>tSola</th>
<th>Tmin</th>
<th>Tmax</th>
<th>tMean</th>
<th>vMean</th>
<th>rTr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best yield</td>
<td>1987</td>
<td>304.4</td>
<td>7.21</td>
<td>6.55</td>
<td>13.76</td>
<td>0.52</td>
<td>71</td>
<td>76</td>
<td>147</td>
<td>77612</td>
<td>52.4</td>
<td>83.1</td>
<td>67.7</td>
<td>68.5</td>
<td>67.</td>
</tr>
<tr>
<td>75% percentile</td>
<td>1994</td>
<td>250.8</td>
<td>6.18</td>
<td>6.18</td>
<td>12.36</td>
<td>0.50</td>
<td>66</td>
<td>62</td>
<td>128</td>
<td>67297</td>
<td>56.2</td>
<td>84.3</td>
<td>70.2</td>
<td>69.8</td>
<td>70.</td>
</tr>
<tr>
<td>Median yield</td>
<td>2003</td>
<td>241.6</td>
<td>5.72</td>
<td>7.80</td>
<td>13.52</td>
<td>0.42</td>
<td>60</td>
<td>59</td>
<td>128</td>
<td>60638</td>
<td>65.5</td>
<td>84.6</td>
<td>70.1</td>
<td>60.1</td>
<td>71.</td>
</tr>
<tr>
<td>25% percentile</td>
<td>2002</td>
<td>223.0</td>
<td>5.28</td>
<td>6.67</td>
<td>11.35</td>
<td>0.44</td>
<td>61</td>
<td>48</td>
<td>103</td>
<td>61870</td>
<td>59.1</td>
<td>87.9</td>
<td>73.5</td>
<td>71.6</td>
<td>75.</td>
</tr>
<tr>
<td>Worst yield</td>
<td>1989</td>
<td>156.5</td>
<td>3.71</td>
<td>6.68</td>
<td>10.39</td>
<td>0.36</td>
<td>79</td>
<td>46</td>
<td>125</td>
<td>64013</td>
<td>52.1</td>
<td>81.6</td>
<td>66.9</td>
<td>66.7</td>
<td>67.</td>
</tr>
</tbody>
</table>

Long-term mean: 238.2, 5.64, 6.81, 12.45, 0.45, 73, 65, 138, 69741, 54.1, 82.3, 68.2, 68.2, 68.

Long-term CV, %: 15, 16, 12, 8, 13, 9, 21, 13, 8, 5, 4, 4, 2, 7

Among the five years above, frost damage during grain filling occurred in: 1989

Overall probability of frost occurrence during grain filling (%) : 39

Note:
The ranking is based on GRAIN yield. Gr.Y is grain yield in bu/acre at 15.5% moisture content, Gr. DM, Stover and tDM are dry matter for grain, stover and total aboveground biomass in short ton/acre. The long-term means are the numerical averages of all years.

Abbreviations:
HI: harvest index, i.e., the ratio of grain dry matter to total aboveground dry matter
vDays: days from emergence to silking (i.e., vegetative phase)
rDays: days from silking to maturity (i.e., reproductive phase)
V+R: days from emergence to maturity
tSola: total solar radiation from emergence to maturity (Langley)
Irain: total rainfall from emergence to maturity (inches)
Tmin, Tmax, Tmean and ETRef: mean daily Tmin, Tmax, Tmean, and ET-reference, respectively, from emergence to maturity (F)
vTmean, rTmean: mean daily Tmean from emergence to silking (i.e., vegetative phase) and from silking to maturity (i.e., reproductive phase), respectively (F)

User-specified inputs:
Weather file: North Platte, NE.wth
Weather Analysis - Emergence to Maturity

Seasonal weather statistics:

<table>
<thead>
<tr>
<th></th>
<th>Before silk...</th>
<th>After silk...</th>
<th>Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Tmax (F)</td>
<td>82.7</td>
<td>88.2</td>
<td>85.1</td>
</tr>
<tr>
<td>Mean Tmin (F)</td>
<td>55.2</td>
<td>59.0</td>
<td>56.9</td>
</tr>
<tr>
<td>Total Rainfall (in)</td>
<td>3.2</td>
<td>8.8</td>
<td>12.0</td>
</tr>
<tr>
<td>Mean ET-reference</td>
<td>0.27</td>
<td>0.27</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Individual run
- Solar radiation (Langley)
- Tmax (F)
- Tmin (F)
- Tmean (F)
- Rel. Humidity (%)
- Rainfall (inch)
- ET-reference (inch)

Across runs
- Best yield
- 75% percentile
- Median yield
- 25% percentile
- Worst yield

Date (m/d)

Temperature

Rainfall & ET-reference
Corn yield potential in the Corn Belt

80 locations within Lat 32.7-42.7 N; Long 88-102 W; Elev. 130 – 1390 m
Hybrid-Maize simulated yield potential for corn:
Hybrid: 2650 GDU (110 d CRM); Planting date: May 1, 40,000 plants/acre
Management: no limitations by water or nutrients
Mean temperature during the growing season (°F)

Mean yield potential (bu/acre)

Akron, CO
Monmouth, IL
Arthur, NE
O’Neill, NE
Hutchinson, KS
Lincoln, NE

Hybrid-Maize simulated yield potential for corn:
Hybrid: 2650 GDU (110 d CRM); Planting date: May 1, 40,000 plants/acre
Management: no limitations by water or nutrients

80 locations within Lat 32.7-42.7 N; Long 88-102 W; Elev. 130 – 1390 m

Corn yield potential in the Corn Belt
80 locations within Lat 32.7-42.7 N; Long 88-102 W; Elev. 130 – 1390 m
Hybrid-Maize simulated yield potential for corn:
Hybrid: 2650 GDU (110 d CRM); Planting date: May 1, 40,000 plants/acre
Management: no limitations by water or nutrients

Corn yield potential in the Corn Belt
Cumulative solar radiation VE to R6 (MJ/m²)

Mean yield potential (bu/acre)

2000 2200 2400 2600 2800 3000 3200 3400

220 230 240 250 260 270 280 290 300 310 320

80 locations within Lat 32.7-42.7 N; Long 88-102 W; Elev. 130 – 1390 m
Hybrid-Maize simulated yield potential for corn:
Hybrid: 2650 GDU (110 d CRM); Planting date: May 1, 40,000 plants/acre
Management: no limitations by water or nutrients

Corn yield potential in the Corn Belt
Yield potential of >280 bu/acre:

- Long growing season & high solar radiation (>2500 MJ/m² from emergence to maturity)
- Cool environment (mean air T <73 F from emergence to maturity)
- Warm during vegetative growth (large veg. biomass) & cool during grain filling (>60 days grain filling period)
- High plant density (varies by hybrid: 30-40k/acre)
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Arthur, NE</td>
<td>41.4</td>
<td>101.3</td>
<td>1097</td>
<td>269</td>
<td>360</td>
<td>171</td>
<td>91</td>
<td>65.7</td>
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<tr>
<td>O'Neill, Nebraska</td>
<td>42.3</td>
<td>98.5</td>
<td>625</td>
<td>275</td>
<td>346</td>
<td>183</td>
<td>60</td>
<td>67.5</td>
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<tr>
<td>Akron, CO</td>
<td>40.1</td>
<td>103.1</td>
<td>1384</td>
<td>305</td>
<td>409</td>
<td>197</td>
<td>55</td>
<td>67.6</td>
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<td>Monmouth, IL</td>
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<td>90.7</td>
<td>229</td>
<td>318</td>
<td>360</td>
<td>291</td>
<td>14</td>
<td>68.4</td>
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<tr>
<td>Ames, IA</td>
<td>42.0</td>
<td>93.5</td>
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<td>287</td>
<td>347</td>
<td>226</td>
<td>16</td>
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<td>552</td>
<td>286</td>
<td>336</td>
<td>218</td>
<td>17</td>
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<td>291</td>
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<td>251</td>
<td>0</td>
<td>71.2</td>
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<td>Carbondale, IL</td>
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<td>277</td>
<td>366</td>
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<td>72.3</td>
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<td>Lincoln, NE</td>
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<td>357</td>
<td>248</td>
<td>291</td>
<td>213</td>
<td>0</td>
<td>73.4</td>
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<tr>
<td>Hutchinson, KS</td>
<td>37.6</td>
<td>98.0</td>
<td>477</td>
<td>230</td>
<td>265</td>
<td>192</td>
<td>0</td>
<td>75.6</td>
</tr>
</tbody>
</table>

Hybrid-Maize simulated yield potential for corn:
Hybrid: 2650 GDU (110 d CRM); Planting date: May 1, 40,000 plants/acre
Management: no limitations by water or nutrients

Yield potential analysis for Lincoln, NE
Lincoln, NE: At this site, high night temperatures during grain filling may cause early maturity of corn. Delaying planting or choosing a longer season hybrid could move grain filling into a period with lower night temperatures.


Yield potential analysis for Lincoln, NE
<table>
<thead>
<tr>
<th>Hybrid GDU</th>
<th>Planting date</th>
<th>Yield potential (bu/acre)</th>
<th>Maturity Emerg. to silking Silking to maturity Risk of frost (F)</th>
<th>Avg. T</th>
<th>Avg. T</th>
<th>%</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2650</td>
<td>April 25</td>
<td>248</td>
<td>late Aug</td>
<td>64</td>
<td>70</td>
<td>52</td>
<td>77</td>
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<tr>
<td>2650</td>
<td>May 15</td>
<td>255</td>
<td>early Sep</td>
<td>56</td>
<td>73</td>
<td>55</td>
<td>75</td>
</tr>
<tr>
<td>2850</td>
<td>April 25</td>
<td>276</td>
<td>early Sep</td>
<td>67</td>
<td>71</td>
<td>59</td>
<td>76</td>
</tr>
<tr>
<td>2850</td>
<td>May 15</td>
<td>285</td>
<td>late Sep</td>
<td>59</td>
<td>73</td>
<td>63</td>
<td>74</td>
</tr>
</tbody>
</table>

- Average yield potential simulated with the Hybrid-Maize model
- Daily climate data 1986-2004 (T, radiation, rainfall, humidity)
- Hybrids: 2650 GDD = 110 d CRM; 2850 GDD = 119 d CRM
- 40,000 plants/acre, full irrigation, optimal management

Yield potential analysis for Lincoln, NE
Site: Champion, southwest NE (semi-arid)
Climate data: 1982 to 2004
Variable rainfall, <4 to >20” during the growing season
Planting: Hybrid with GDD 2650, planted on May 1 @ 30,000/acre
Soil: Loam, topsoil moisture at planting 25 vol.%, deep (>40”)

Dryland corn yield potential
Average: 138 bu/a
Range: 68-261 bu/a

Irrigated corn yield potential
Average: 239 bu/a
Range: 178-316 bu/a

Analysis of water requirements
Irrigation required
Average: 12”
Range: 8-15”
Using real-time climate data for a growing season:

- Estimate actual yield potential or water-limited yield potential based on actual + historical daily records of solar radiation, temperature, and rainfall.
- Decision aid for:
  - comparing growth with normal years/other years.
  - adjusting yield goal and making adjustments in fertilizer amounts (sidedress, fertigation)
  - evaluating soil moisture and making decisions on irrigation
  - marketing decisions (farmers)
  - grain purchasing decisions (feedlots, ethanol plants)
  - overall corn production forecasts (policy makers, crop insurance, markets, etc.)

In-season yield forecasting
In-season yield forecasting

Weather data:
- Historical (01/01/85 to 12/31/03)

Weather data:
- Current year (01/01 to 07/25/04)

Other model inputs:
- Hybrid
- Planting/emergence
- Maturity/silking
- Population
- Soil
- Water (rainfed, irrigations)

Long-term yield potential
simulated for each year (1985-2003)

Current-season yield potential
actual weather until 07/25/04 + all possible scenarios of past weather data (1985-2003) from then onward

Reference:
- median yield year
- “normal” weather + growth

Actual growth until 07/25/04
- Growth scenarios to maturity

Predicted yields:
- (min., 25%, median, 75%, max.)

Example: July 25, 2004
Irrigated corn in Nebraska: yield potential prediction made on August 03, 2004.

Average predicted yield potential (irrigated, 10 sites):

- 2003: 241 bu/a
- 2004: 260 bu/a (+8%)

State average corn yield (dryland + irrigated):

- 2003: 146 bu/a
- 2004: 166 bu/a (+14%)
Post-season analysis
7 irrigations 06/22-07/28, predicted grain yield: 201 bu/acre
7 irrigations 06/30-08/15, predicted grain yield: 223 bu/acre
<table>
<thead>
<tr>
<th>Crop model</th>
<th>Grain</th>
<th>Stover</th>
<th>Total biomass</th>
<th>HI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured</td>
<td>13.2</td>
<td>13.2</td>
<td>26.4</td>
<td>0.50</td>
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<tr>
<td>Ceres-Maize</td>
<td>12.4</td>
<td>11.0</td>
<td>23.4</td>
<td>0.53</td>
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<tr>
<td>Muchow-Sinclair</td>
<td>11.4</td>
<td>11.4</td>
<td>22.8</td>
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<tr>
<td>Intercom</td>
<td>9.7</td>
<td>9.0</td>
<td>18.7</td>
<td>0.52</td>
</tr>
<tr>
<td>Hybrid-Maize</td>
<td>13.1</td>
<td>13.2</td>
<td>26.3</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Lincoln, NE, high-yield experiment, corn after soybean, 37,000 plants/acre, intensive nutrient management, averages of 1999-2001.
Total aboveground crop biomass during the growing season.
Manchester: Francis Childs farm, 2002, Pioneer 33P67, 34,000 plants/acre
Lincoln: High-yield experiment, 2002, Pioneer 33P67, 38,000 plants/acre

Validation
Lincoln, NE, high-yield experiment, corn following soybean, intensive nutrient management, 2001.

Validation
Yield potential: simulated with Hybrid-Maize model for actual emergence and maturity dates and final plant stands in each year.

Actual yields: EI experiment, corn following soybean, high plant population (37-43k), intensive nutrient management
Lincoln EI, 2004, 30k/a

Maturity: 09/30/04

Measured yield: 264 bu/a
<table>
<thead>
<tr>
<th>Location - treatment</th>
<th>Grain yield (bu/acre)</th>
<th>Measured</th>
<th>Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lincoln, NE – siL, corn following soybean, 35,000 pl./a, irrigated, 223 lbs N/acre, 4-way split, +P and K</td>
<td>285</td>
<td>287</td>
<td></td>
</tr>
<tr>
<td>Bellwood, NE – IS, continuous corn, 31000 pl./a, irrigated, 335 lbs N/acre, 5-way split, +P and K</td>
<td>268</td>
<td>273</td>
<td></td>
</tr>
<tr>
<td>Cairo, NE – siL, continuous corn, 32500 pl./a, irrigated, 300 lbs N/acre, 2-way split, +P and K</td>
<td>276</td>
<td>275</td>
<td></td>
</tr>
<tr>
<td>Paxton, NE – IS, continuous corn, 31800 pl./a, irrigated, 300 lbs N/acre, 3-way split, +P and K</td>
<td>258</td>
<td>257</td>
<td></td>
</tr>
<tr>
<td>Brunswick, NE – siL, corn following soybean, 35000 pl./a, irrigated, 259 lbs N/acre, 3-way split, +P and K</td>
<td>277</td>
<td>279</td>
<td></td>
</tr>
<tr>
<td>Scandia, KS - 28000 pl./a, irrigated, 300 lbs N/acre, 4-way split, +P, K, and S</td>
<td>223</td>
<td>219</td>
<td></td>
</tr>
<tr>
<td>Scandia, KS - 42000 pl./a, irrigated, 230 lbs N/acre, 4-way split, +P, K, and S</td>
<td>251</td>
<td>252</td>
<td></td>
</tr>
<tr>
<td>Champaign, IL, corn/oats/hay rotation, rainfed corn, lime plus fertilizer (Morrow Plots long-term experiment)</td>
<td>261</td>
<td>286</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2001</td>
<td>2003</td>
<td></td>
</tr>
<tr>
<td>------------------------------</td>
<td>-------</td>
<td>-------</td>
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<tr>
<td>Hybrid</td>
<td>P 33B51</td>
<td>P 33B51</td>
<td></td>
</tr>
<tr>
<td>Planting</td>
<td>14-May</td>
<td>13-May</td>
<td></td>
</tr>
<tr>
<td>Maturity (R6)</td>
<td>12-Sep</td>
<td>5-Sep</td>
<td></td>
</tr>
<tr>
<td>Final population</td>
<td>22,000/a</td>
<td>23,000/a</td>
<td></td>
</tr>
<tr>
<td>Measured yield</td>
<td>Combine (160 acres)</td>
<td>139</td>
<td>123</td>
</tr>
<tr>
<td>(bu/acre)</td>
<td>Hand-harvest (24 locations)</td>
<td>154</td>
<td>127</td>
</tr>
<tr>
<td>Simulated yield</td>
<td>Planting date - hybrid GDD</td>
<td>145</td>
<td>138</td>
</tr>
<tr>
<td>(bu/acre)</td>
<td>Estimated date of maturity</td>
<td>7-Sep</td>
<td>16-Sep</td>
</tr>
<tr>
<td></td>
<td>Planting date - maturity date</td>
<td>158</td>
<td>125</td>
</tr>
</tbody>
</table>

Dryland corn, Mead, NE, CSP site 3

Validation
- Sensitive to dates of growth stages entered or predicted (silking and physiological maturity).
- Mostly tested with plant populations ranging from 25,000 to 45,000 plants/acre.
- Does not account for different row spacing.
- Interactive effects of plant density and temperature on growth are not well understood.
- Limited validation for water-limited conditions. Performance under extreme dryland conditions with low plant populations is uncertain.
- Default soil physical properties for different soil texture may not represent actual properties.
- Validation & possibly modification of the water balance module for simulating dryland and irrigated cropping
- Alternatives for entering soil moisture at the beginning of the growing season
- Revision of functions describing response to plant density
- Module for making NPK management decisions
- Module for simulating carbon and nitrogen turnover from crop residues and short- as well as long-term changes in soil C and N
- Grain dry-down prediction

Possible future improvements
Hybrid-maize represents the current scientific understanding of corn growth and development on a dynamic and mechanistic basis.

Hybrid-Maize allows evaluating options for corn management and making decision before, during, and after the growing season.

Hybrid-Maize can contribute to better exploiting the climatic-genetic site yield potential, leading to more efficient use of resources and higher profit.

Hybrid-Maize also has a great educational value: understand what drives crop growth in the field.

Summary
Hybrid-Maize

A simulation model for corn growth and yield

What does the Hybrid-Maize model do?

Hybrid-Maize is a computer program that simulates the growth of a corn crop (Zea mays L.) under non-limiting or water-limited (rainfed or irrigated) conditions based on daily weather data. Specifically, it allows the user to:

- Assess the overall site yield potential and its variability based on historical weather data;
- Evaluate changes in attainable yield using different combinations of planting date, hybrid maturity, and plant density;
- Analyze corn yield in relation to the timing of silking and maturity in specific years;
- Explore options for optimal irrigation management;
- Conduct in-season simulations to evaluate actual growth up to the current date based on real-time weather data, and to forecast final yield scenarios based on historical weather data for the remainder of the growing season.

Hybrid-Maize does NOT allow assessment of different options for nutrient management nor does it account for yield losses due to weeds, insects, diseases, lodging, and other stresses.

Hybrid-Maize has been evaluated primarily in rainfed and irrigated maize systems of the US Corn Belt. Caution should be exercised when applying this model to other environments as this may require changes in some of the default model parameters.

As with all simulation models, Hybrid-Maize still represents a simplification of the ‘real-world’ system and, as such, model predictions may differ from actual outcomes. Therefore, the results of model simulations should be considered approximations and not taken as fact.

For questions, comments or suggestions, contact:

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