2004

In-season Prediction of Attainable Maize Yield Using the Hybrid-Maize Model

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Poster presented in the VIII ESA Congress: European Agriculture in A Global Context. KVL, Copenhagen, Danmark, 11-15 July 2004.

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The Hybrid-Maize Model

Hybrid-Maize simulates the growth of a maize crop under non-limiting or water-limiting (rainfed or irrigated) conditions based on daily weather data. This new maize model was developed by combining the strengths of two modeling approaches (Yang et al., 2004): (i) growth and development functions in used in CERES-Maize (Jones and Kiniry, 1986), and (ii) mechanistic formulations of light interception, photosynthesis and respiration used in generic crop models such as INTERCOM or WOFOST (van Ittersum et al., 2003).

Hybrid-Maize features temperature-driven maize phenological development, vertical canopy integration of photosynthesis, organ-specific growth respiration, and temperature-sensitive maintenance respiration. The new model requires fewer genotype-specific parameters without sacrificing prediction accuracy. A linear relationship between growing degree-days (GDD) from emergence to silking and GDD from emergence to physiological maturity is used for prediction of day of silking. Field validation under high-yielding growth conditions indicated close agreement between simulated and measured values for leaf area, dry matter accumulation (Fig. 1), final grain and stover yields, and harvest index (Yang et al., 2004).

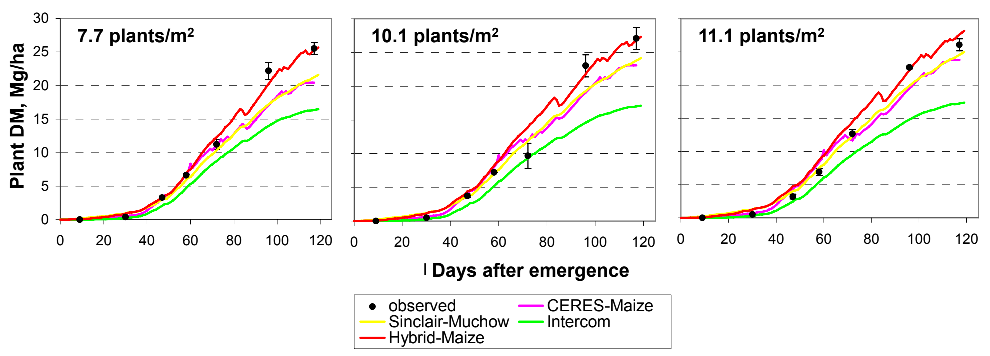
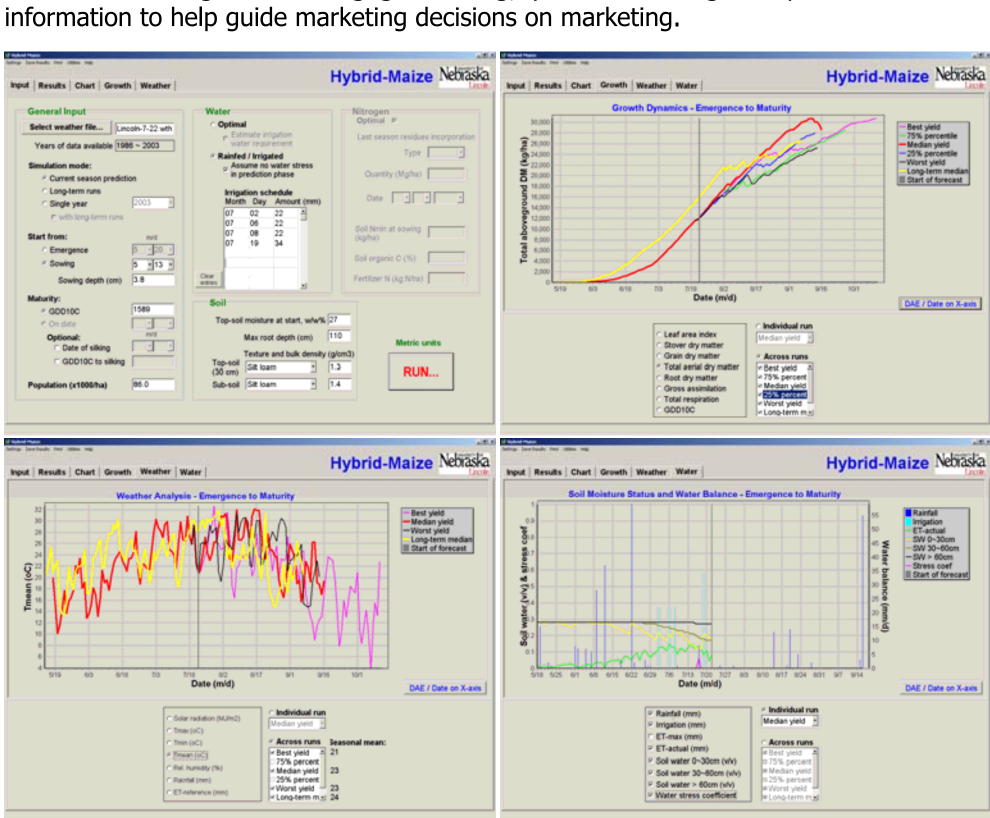


Figure 1. Observed and predicted aboveground dry matter accumulation of irrigated maize at Lincoln, Nebraska, 2001.

Real-time Simulation and Yield Forecasting

Hybrid-Maize allows the user to (i) assess the overall site yield potential and its variability, (ii) evaluate changes in attainable yield using different choices of planting date, maize hybrid, and plant density, (iii) analyze maize growth in specific years, (iv) explore options for irrigation water management, and (v) conduct in-season simulations to evaluate actual growth and forecast final yield at different growth stages.

In *Current season prediction* mode, model simulations are based on the up-to-date weather data of the current growing season, supplemented by the previously collected historical weather data for forecasting of all possible outcomes for the remainder of the season. This results in a range of forecasted scenarios, which are ranked based on the predicted final yield (Fig. 2). Management decisions could include adjusting the yield goal in comparison with normal years and making subsequent adjustments in fertilizer amounts and irrigation. During grain filling, yield forecasting can provide additional information to help guide marketing decisions on marketing.



Rank	GrainY	GrainDM	StoverDM	TotalDM	HI	vDays	rDays	V+R	tSola	Tmin	Tmax	Tmean	vTmean	rTmean	ETref	tRain
Best yield	21.5	18.2	12.6	30.7	0.59	65	82	147	2955	14	27	21	22	20	5.4	474
75% percentile	19.0	16.1	12.4	28.5	0.56	65	68	133	2728	16	28	22	22	22	5.6	442
Median yield	**17.4**	**14.7**	**14.0**	**28.6**	**0.51**	**65**	**57**	**122**	**2694**	**17**	**30**	**23**	**22**	**25**	**6.5**	**283**
25% percentile	15.7	13.3	14.7	28.0	0.47	65	54	119	2552	17	30	23	22	25	6.1	272
Worst yield	15.0	12.7	12.6	25.2	0.50	65	55	120	2437	17	29	23	22	25	5.8	263
Long-term median	**16.7**	**14.1**	**12.5**	**26.6**	**0.53**	**59**	**57**	**116**	**2558**	**18**	**30**	**24**	**23**	**24**	**6**	**350**

The ranking is based on GRAIN yield.
GrainY is grain yield at 15.5% moisture content, GrainDM, StoverDM, and TotalDM are all dry matter basis; the unit for all is Mg/ha.
Except for Long-term median, each run is based on this year's up-to-date weather date, supplemented with historical individual year data.
For Long-term median, only historical weather data prior to this year were used.
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 (MJ/m2)
tRain : total rainfall from emergence to maturity (mm)
Tmin, Tmax, Tmean and ETref : mean daily Tmin, Tmax, Tmean, and ET-reference, respectively, from emergence to maturity (oC)
vTmean, rTmean : mean daily Tmean from emergence to silking (i.e., vegetative phase) and from silking to maturity (i.e., reproductive phase), respectively (oC)

Figure 2. Hybrid-Maize model user interface and examples of model outputs for a real-time simulation and yield forecast made on July 22, 2003 at Lincoln, Nebraska.

Case Study 1: Irrigated Maize, Lincoln, Nebraska

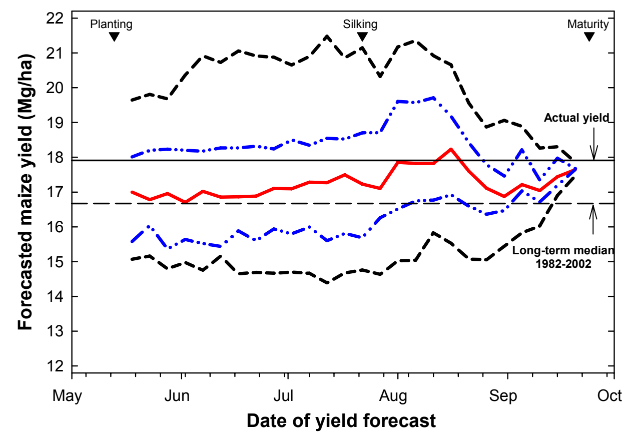


Figure 3. Forecasted and observed grain yield of irrigated maize grown at Lincoln, Nebraska, 2003.

Maize was grown near yield potential levels, i.e., with full irrigation, optimal nutrient supply, and at a density of 8.6 plants m^{-2}. Actual and historical daily weather data were used for yield forecasting in intervals of 5 days. Early in the season, yield forecasts mainly relied on historical weather data so that the median predicted yield was close to the long-term median. As the season progressed, more actual weather data were used, indicating above-normal growth conditions. Shortly after silking, predicted median yield approached the final measured grain yield of 17.9 Mg ha^{-1}. With progressing grain filling, the range of predicted yields gradually decreased.

Case Study 2: Rainfed Maize, Oliveros, Argentina

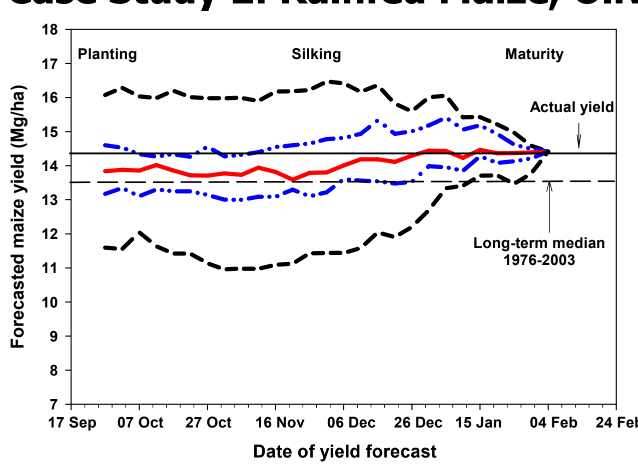


Figure 4. Forecasted and observed grain yield of rainfed maize grown with no water limitations at Oliveros, Argentina, 2004 (Data provided by F. Salvagiotti, INTA).

Rainfed maize was grown at 7 plants m^{-2} in a favorable season with no water stress. Shortly after silking, predicted median yield approached the final measured grain yield of 14.4 Mg ha^{-1}. With progressing grain filling, the range of predicted yields decreased.

Case Study 3: Rainfed Maize, Mead, Nebraska

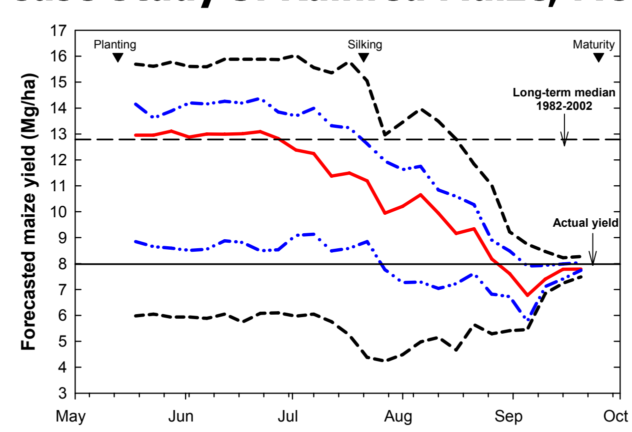


Figure 5. Forecasted and observed grain yield of rainfed maize grown under drought stress at Mead, Nebraska, 2003.

Rainfed maize was grown at 5.9 plants m^{-2}. Early in the season, median predicted yield was close to the long-term median. Little rain fell in July and August. As the season progressed, drought evolved and the predicted median yield decreased well below the long-term median, approaching the final measured grain yield of 8.0 Mg ha^{-1}. Median predictions were close to the final yield about one month before maturity.

Conclusions

Hybrid-Maize offers promising potential for in-season simulation and forecasting of maize biomass and grain yield. At sites with no water limitations, the final yield was accurately predicted shortly after silking stage. Greater variation in yield predictions may occur at rainfed sites under drought stress, but relative deviations from normal growth were detected early enough in both environments.

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Acknowledgements: Financial supported for developing Hybrid-Maize was provided by the Agricultural Research Division of the University of Nebraska-Lincoln, the Potash and Phosphate Institute through the Foundation for Agronomic Research, the Fluid Fertilizer Foundation, the Nebraska Corn Board, and by USDA-CSREES through the Consortium for Agricultural Soil Mitigation of Greenhouse Gases.