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Predicting Wheat Growth
Using the CSM-Cropsim-CERES Wheat Crop Model

Mike Ottman
University of Arizona

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M. J. Ottman

Summary

CSM-Cropsim-CERES -Wheat is a crop growth model that predicts crop development stages, among other things, using genetic coefficients for vernalization and photoperiod. We used this model to predict flowering date for 12 durum varieties seeded in trials at Maricopa and Yuma from 1998 to 2006. The difference between simulated and measured flowering date averaged 4 days without genetic coefficients and improved to 3.5 days if genetic coefficients for flowering and vernalization were included for each variety.

Introduction

Computer models of the development of small grains are used to predict when the crop reaches various stages of development. The small grain advisory uses a model based on temperature developed at Maricopa. This model works well at Maricopa but adjustments are required at other locations. A model that may predict crop growth stages in Arizona more accurately is CSM-Cropsim-CERES Wheat. This model predicts crop development using a physiologically more complete approach that includes effects of photoperiod and vernalization (cold requirement for flowering) and considers differences in comparative earliness or lateness of cultivars.

Procedure

The ability of CSM-Cropsim-CERES Wheat v.4.5 (hereafter refered to as CERES Wheat) to predict flowering date was tested using existing data from Arizona. Flowering dates for 12 durum varieties were obtained or estimated from small grain variety evaluations at Maricopa and Yuma. These studies were conducted by the University of Arizona, Western Plant Breeders (WPB), and World Wide Wheat (WWW). Flowering dates were estimated by adding 7 days to heading date for the studies conducted by WPB and WWW. Weather from the nearest AZMET station and crop production data was entered into the CERES-Wheat program.

Genetic coefficients for vernalization (P1V) and photoperiod (P1D) were estimated using GenCalc2 (Table 1), a tool within the Decision Support System for Agtotechnology Transfer (DSSAT, version 4.5), while keeping the ecotype coefficients constant (see Table 2). Genetic coefficients adjust for differences in variety response to vernalization and day length. Ecotype coefficients adjust for heat units among growth phases in different growing regions. Generic genetic coefficients for P1V and P1D were obtained by averaging these coefficients over varieties.

The model was then tested under three conditions: 1) No genetic coefficients, or strictly a heat unit approach, where P1V and P1D were set to 0, and adjusting the ecotype coefficients until the mean simulated and measured flowering dates were nearly equivalent, 2) Generic genetic coefficients, where P1V and P1D were equal for all varieties, and the ecotype coefficients were adjusted until the mean simulated and measured flowering dates were nearly equivalent, and 3) Genetic coefficients, P1V and P1D, were used for each variety.

CERES-Wheat calculates heat units using the mean daily temperature with 0 and 26° C as base and ceiling

temperatures, respectively. These threshold temperatures are used when the average daily temperature is above or below the thresholds. More specifically, the minimum and maximum daily heat unit accumulation is 0° and 26° C day. In this exercise, we averaged the maximum and minimum temperature from AZMET to obtain average daily temperature.

Discussion

Genetic coefficients for vernalization and photoperiod for 12 durum varieties is presented in Table 1. The genetic coefficients for vernalization vary from about 18 to 24 and for photoperiod vary from 49 to 58. These coefficients are a bit higher than what may be expected for spring wheat, but certainly within the realm of possibilities. Spring wheat supposedly has no vernalization requirement, but most spring wheat respond to cold weather by heading somewhat earlier. Photoperiod sensitivity is also relatively low in spring wheat because of shuttle breeding, that is, selecting in a low latitude location in the winter/spring and a high latitude location in the spring/summer. Nevertheless, development rate is slowed somewhat by photoperiods shorter than the threshold, which is assumed to be 20 hours by CERES-Wheat.

CERES-Wheat was run with no genetic coefficients for vernalization or photoperiod, with generic genetic coefficients, and with genetic coefficients specific to each durum variety (Table 3 and A1). When the model was run with no or generic genetic coefficients, the average error, or difference between simulated and measued days after planting to flower, was about 4 days. The inclusion of genetic coefficients specific to each variety decreased the error by about half a day, to 3.5 days. The improvement in the ability of the model to predict flowering date by including genetic coefficients for each variety is not great for three reasons, possibly. First, the durum varieties tested do not differ much. The range in flowering dates for these varieties averages about 7 days. The range in flowering dates for barley varieties grown in the state ranges about 1 month. Second, the range in planting dates is relatively small for the data tested, about 1 month for each location. Under commercial conditions, the range of planting times may differ by 2 months. Third, the environmental conditions between Maricopa and Yuma do not differ as much as between Arizona other states in the US and the Mediterranean area, where some of these varieties may also be grown.

Some bias in the model exists in prediction of flowering time at Maricopa and Yuma. The model overestimates the time to flowering at Maricopa by 0.6 to 1.4 days, and underestimates the time to flowering at Yuma by 1.2 to 1.4 days. Using genetic coefficients narrows the sum of the bias over locations from 2.8 to 1.8 days.

One of the advantages of CERES-Wheat over other models may be that method it uses to calculate heat units. In this model, heat units are calculated simply from an average temperature. Other models adjust minimum and maximum temperatures relative to temperature thresholds, while CERES-Wheat makes adjustments based on mean temperature which rarely approach the threshold. So, heat units may be over- or under-estimated depending on method of calculation.

In conclusion, using genetic coefficients in CERES-Wheat improved the prediction of days to flowering in the data tested, but the improvement was not great. We expect that the improvement would have been greater if a wider range of planting dates and locations had been used in this analysis. We will continue testing the model for use in Arizona and expect to use the model for future reporting on wheat development.

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Table 1. Genetic coefficients for vernalization and photoperiod for 12 durum varieties generated using GenCalc2 in CERES-Wheat. The ecotype coefficients were set as follows: P1 = 400, P2 = 285, P3 = 240, P4 = 300 (Table 2). These coefficients were generated from Maricopa and Yuma data from 1998-2007 (Table 3).

Variety	Vernalization coefficient (P1V)	Photoperiod coefficient (P1D)
Alamo	23.56	50.21
Crown	22.57	58.34
Duraking	23.69	56.05
Kofa	21.12	49.28
Kronos	18.37	53.25
Matt	22.73	49.28
Mohawk	21.12	49.28
Ocotillo	22.88	51.80
Orita	24.42	59.62
Platinum	22.66	55.74
Sky	22.51	52.97
WPB881	24.47	51.47
AVG	22.51	53.11

Table 2. Ecotype and genetic coefficients used when running CERES-Wheat with no genetic coefficients, generic or average genetic coefficients, and genetic coefficients specific to each variety. When the model was run with no or generic genetic coefficients, the ecotype coefficients were generated using suggested coefficients in CERES-Wheat and adjusting these coefficients until there was no bias in prediction of days to flowering. When the model was run with genetic coefficients specific to each variety, ecotype coefficients suggested by the model were used, and genetic coefficients were generated with GenCalc2, a tool within CERES-Wheat.

Coefficient	Definition	No genetic coefficients	Generic genetic coefficients	Genetic coefficients
	Ecotype (specific to region)			
P1	End juvenile to double ridges (^{o}C.d)	425	400	400
P2	Double ridges to end leaf growth (^{o}C.d)	310	285	285
P3	End leaf growth to end spike growth (^{o}C.d)	270	240	240
P4	End spike growth to end grain fill lag (^{o}C.d)	330	330	300
	Genetic (specific to varieties)			
P1V	Vernalization - days at optimum vernalizing temperature required to complete vernalization	0	22.51	Variety specific (see Table 1)
P1D	Photoperiod - % reduction in development rate in a photoperiod 10 hour shorter than the threshold relative to that at the threshold	0	53.11	Variety specific (see Table 1)
PHINT	Phyllochron interval - interval between successive leaf tip appearances (^{o}C.d)	95	95	95

Table 3. Mean days after planting (DAP) for flowering of durum varieties as measured and averaged at various locations and years, and as simulated by CERES-Wheat using no genetic coefficients in the model (P1V and P1D set to 0), generic or average coefficients for all varieties, and genetic coefficients specific to each variety. The error is the absolute error, or the difference between simulated and measured DAP for flowering. The data in this table is averaged from Table A1.

		No genetic coefficients		Generic genetic coefficients		Genetic coefficients	
	Measure flower	Simulate flower	Error	Simulate flower	Error	Simulate flower	Error
	DAP	----- DAP -----		----- DAP -----		----- DAP -----	
Mean (DAP)	112.25	112.31	0.06	112.21	-0.04	111.95	-0.30
Absolute error (DAP)			3.96		3.95		3.52
Root mean square error (DAP)			4.33		4.34		3.90
Root mean square error (% of measured DAP)			4.87		4.87		4.37

Appendix

Table A1. Days after planting (DAP) for flowering of durum varieties as measured at various locations and years, and as simulated by CERES-Wheat using no genetic coefficients in the model (P1V and P1D set to 0), generic or average coefficients for all varieties, and genetic coefficients specific to each variety. The error is the absolute error, or the difference between simulated and measured DAP for flowering.

						No genetic coefficients		Generic genetic coefficients		Genetic coefficients	
Location	Harvest year	Variety	Planting date	Measure flower	Measure flower	Simulate flower	Error	Simulate flower	Error	Simulate flower	Error
					DAP	----- DAP -----		----- DAP -----		----- DAP -----	
Maricopa	1998	Crown	11/21	04/03	133	130	-3	128	-5	132	-1
		Duraking	11/21	03/31	130	130	0	128	-2	130	0
		Kofa	11/21	03/27	126	130	4	128	2	125	-1
		Kronos	11/21	03/26	125	130	5	128	3	126	1
		Mohawk	11/21	03/25	124	130	6	128	4	125	1
		Ocotillo	11/21	03/29	128	130	2	128	0	127	-1
		Platinum	11/21	03/30	129	130	1	128	-1	130	1
		WPB881	11/21	03/25	124	130	6	128	4	127	3
Maricopa	1998	Crown	12/17	04/13	117	118	1	117	0	120	3
		Duraking	12/17	04/12	116	118	2	117	1	118	2
		Kofa	12/17	04/07	111	118	7	117	6	114	3
		Kronos	12/17	04/10	114	118	4	117	3	115	1
		Mohawk	12/17	04/09	113	118	5	117	4	114	1
		Ocotillo	12/17	04/10	114	118	4	117	3	116	2
		Platinum	12/17	04/13	117	118	1	117	0	118	1
		WPB881	12/17	04/10	114	118	4	117	3	116	2
Maricopa	2002	Crown	11/29	04/01	123	123	0	122	-1	124	1
		Duraking	11/29	03/29	120	123	3	122	2	123	3
		Kofa	11/29	03/29	120	123	3	122	2	120	0
		Kronos	11/29	03/29	120	123	3	122	2	121	1
		Matt	11/29	03/28	119	123	4	122	3	120	1
		Mohawk	11/29	03/25	116	123	7	122	6	120	4
		Ocotillo	11/29	03/27	118	123	5	122	4	121	3
		Orita	11/29	04/01	123	123	0	122	-1	125	2
		Platinum	11/29	04/01	123	123	0	122	-1	123	0
		Sky	11/29	03/27	118	123	5	122	4	122	4
		WPB881	11/29	03/30	121	123	2	122	1	122	1
Maricopa	2003	Alamo	11/26	03/22	116	118	2	118	2	116	0
		Crown	11/26	03/23	117	118	1	118	1	120	3
		Duraking	11/26	03/22	116	118	2	118	2	119	3
		Kofa	11/26	03/22	116	118	2	118	2	115	-1
		Kronos	11/26	03/19	113	118	5	118	5	116	3
		Matt	11/26	03/22	116	118	2	118	2	116	0
		Mohawk	11/26	03/22	116	118	2	118	2	115	-1

		Ocotillo	11/26	03/21	115	118	3	118	3	117	2
		Orita	11/26	03/24	118	118	0	118	0	122	4
		Platinum	11/26	03/22	116	118	2	118	2	119	3
		Sky	11/26	03/21	115	118	3	118	3	117	2
		WPB881	11/26	03/23	117	118	1	118	1	118	1
Maricopa	2003	Duraking	11/28	03/29	121	117	-4	117	-4	118	-3
		Kofa	11/28	03/29	121	117	-4	117	-4	114	-7
		Kronos	11/28	03/27	119	117	-2	117	-2	115	-4
		Matt	11/28	03/24	116	117	1	117	1	115	-1
		Mohawk	11/28	03/28	120	117	-3	117	-3	114	-6
		Ocotillo	11/28	03/26	118	117	-1	117	-1	116	-2
		Orita	11/28	03/31	123	117	-6	117	-6	121	-2
		Platinum	11/28	03/29	121	117	-4	117	-4	118	-3
		Sky	11/28	03/29	121	117	-4	117	-4	117	-4
		WPB881	11/28	03/26	118	117	-1	117	-1	117	-1
Maricopa	2004	Alamo	11/30	03/24	115	116	1	116	1	115	0
		Crown	11/30	03/23	114	116	2	116	2	117	3
		Duraking	11/30	03/31	122	116	-6	116	-6	117	-5
		Kofa	11/30	03/29	120	116	-4	116	-4	114	-6
		Kronos	11/30	03/28	119	116	-3	116	-3	114	-5
		Mohawk	11/30	03/24	115	116	1	116	1	114	-1
		Ocotillo	11/30	03/28	119	116	-3	116	-3	115	-4
		Orita	11/30	03/27	118	116	-2	116	-2	119	1
		Platinum	11/30	03/26	117	116	-1	116	-1	116	-1
		Sky	11/30	03/24	115	116	1	116	1	115	0
		WPB881	11/30	03/26	117	116	-1	116	-1	116	-1
Maricopa	2004	Alamo	12/03	03/19	107	114	7	114	7	113	6
		Crown	12/03	03/20	108	114	6	114	6	115	7
		Duraking	12/03	03/20	108	114	6	114	6	115	7
		Kofa	12/03	03/19	107	114	7	114	7	111	4
		Kronos	12/03	03/21	109	114	5	114	5	112	3
		Mohawk	12/03	03/19	107	114	7	114	7	111	4
		Ocotillo	12/03	03/20	108	114	6	114	6	113	5
		Orita	12/03	03/24	112	114	2	114	2	117	5
		Platinum	12/03	03/20	108	114	6	114	6	114	6
		Sky	12/03	03/20	108	114	6	114	6	113	5
		WPB881	12/03	03/19	107	114	7	114	7	113	6
Maricopa	2005	Alamo	11/20	03/19	119	118	-1	117	-2	116	-3
		Crown	11/20	03/23	123	118	-5	117	-6	121	-2
		Duraking	11/20	03/21	121	118	-3	117	-4	120	-1
		Kofa	11/20	03/17	117	118	1	117	0	114	-3
		Kronos	11/20	03/12	112	118	6	117	5	115	3
		Matt	11/20	03/17	117	118	1	117	0	115	-2
		Mohawk	11/20	03/16	116	118	2	117	1	114	-2
		Ocotillo	11/20	03/20	120	118	-2	117	-3	116	-4
		Orita	11/20	03/31	131	118	-13	117	-14	122	-9

		Platinum	11/20	03/20	120	118	-2	117	-3	119	-1
		Sky	11/20	03/18	118	118	0	117	-1	117	-1
		WPB881	11/20	03/19	119	118	-1	117	-2	117	-2
Maricopa	2005	Alamo	12/02	03/21	109	114	5	114	5	112	3
		Crown	12/02	03/25	113	114	1	114	1	117	4
		Duraking	12/02	03/24	112	114	2	114	2	116	4
		Kofa	12/02	03/20	108	114	6	114	6	110	2
		Kronos	12/02	03/16	104	114	10	114	10	112	8
		Matt	12/02	03/18	106	114	8	114	8	111	5
		Mohawk	12/02	03/20	108	114	6	114	6	110	2
		Ocotillo	12/02	03/25	113	114	1	114	1	113	0
		Orita	12/02	04/06	125	114	-11	114	-11	119	-6
		Platinum	12/02	03/23	111	114	3	114	3	115	4
		Sky	12/02	03/24	112	114	2	114	2	113	1
		WPB881	12/02	03/22	110	114	4	114	4	114	4
Maricopa	2006	Alamo	12/02	03/29	117	118	1	118	1	116	-1
		Crown	12/02	04/03	122	118	-4	118	-4	120	-2
		Duraking	12/02	04/01	120	118	-2	118	-2	119	-1
		Kofa	12/02	03/29	117	118	1	118	1	115	-2
		Kronos	12/02	03/28	116	118	2	118	2	116	0
		Matt	12/02	03/30	118	118	0	118	0	116	-2
		Mohawk	12/02	03/27	115	118	3	118	3	115	0
		Orita	12/02	04/01	120	118	-2	118	-2	121	1
		Platinum	12/02	04/01	120	118	-2	118	-2	119	-1
		Sky	12/02	03/29	117	118	1	118	1	117	0
		WPB881	12/02	03/29	117	118	1	118	1	117	0
Yuma	1998	Alamo	12/04	04/04	121	112	-9	112	-9	112	-9
		Crown	12/04	04/06	123	112	-11	112	-11	115	-8
		Duraking	12/04	04/06	123	112	-11	112	-11	115	-8
		Kofa	12/04	04/03	120	112	-8	112	-8	110	-10
		Kronos	12/04	04/01	118	112	-6	112	-6	110	-8
		Mohawk	12/04	04/02	119	112	-7	112	-7	110	-9
		Ocotillo	12/04	04/02	119	112	-7	112	-7	112	-7
		Platinum	12/04	04/05	122	112	-10	112	-10	113	-9
		WPB881	12/04	04/02	119	112	-7	112	-7	113	-6
Yuma	1999	Crown	01/06	04/13	97	105	8	105	8	107	10
		Duraking	01/06	04/14	98	105	7	105	7	108	10
		Kofa	01/06	04/11	95	105	10	105	10	102	7
		Kronos	01/06	04/07	91	105	14	105	14	101	10
		Mohawk	01/06	04/10	94	105	11	105	11	102	8
		Ocotillo	01/06	04/12	96	105	9	105	9	105	9
		Orita	01/06	04/16	100	105	5	105	5	110	10
		Platinum	01/06	04/12	96	105	9	105	9	106	10
Wellton	2001	Crown	12/16	04/06	111	109	-2	108	-3	110	-1
		Duraking	12/16	04/07	112	109	-3	108	-4	109	-3

		Kofa	12/16	04/04	109	109	0	108	-1	106	-3
		Kronos	12/16	03/30	104	109	5	108	4	106	2
		Matt	12/16	04/03	108	109	1	108	0	106	-2
		Mohawk	12/16	04/04	109	109	0	108	-1	106	-3
		Ocotillo	12/16	04/01	106	109	3	108	2	107	1
		Orita	12/16	04/05	110	109	-1	108	-2	111	1
		Platinum	12/16	04/06	111	109	-2	108	-3	108	-3
		Sky	12/16	04/01	106	109	3	108	2	107	1
Yuma	2002	Crown	12/07	04/02	116	109	-7	109	-7	111	-5
		Duraking	12/07	04/01	115	109	-6	109	-6	110	-5
		Kofa	12/07	03/31	114	109	-5	109	-5	106	-8
		Kronos	12/07	03/31	114	109	-5	109	-5	106	-8
		Matt	12/07	04/01	115	109	-6	109	-6	107	-8
		Mohawk	12/07	03/31	114	109	-5	109	-5	106	-8
		Ocotillo	12/07	03/31	114	109	-5	109	-5	108	-6
		Orita	12/07	04/01	115	109	-6	109	-6	113	-2
		Platinum	12/07	03/31	114	109	-5	109	-5	110	-4
		Sky	12/07	04/01	115	109	-6	109	-6	108	-7
		WPB881	12/07	04/01	115	109	-6	109	-6	109	-6
Yuma	2003	Alamo	12/12	03/29	107	106	-1	107	0	106	-1
		Crown	12/12	04/01	110	106	-4	107	-3	109	-1
		Duraking	12/12	03/30	108	106	-2	107	-1	109	1
		Kofa	12/12	03/30	108	106	-2	107	-1	103	-5
		Kronos	12/12	03/28	106	106	0	107	1	103	-3
		Matt	12/12	03/28	106	106	0	107	1	105	-1
		Mohawk	12/12	03/28	106	106	0	107	1	103	-3
		Ocotillo	12/12	03/28	106	106	0	107	1	106	0
		Orita	12/12	04/04	113	106	-7	107	-6	112	-1
		Platinum	12/12	03/30	108	106	-2	107	-1	108	0
		Sky	12/12	03/29	107	106	-1	107	0	106	-1
		WPB881	12/12	03/30	108	106	-2	107	-1	108	0
Yuma	2004	Alamo	12/14	03/30	107	103	-4	103	-4	103	-4
		Crown	12/14	04/01	109	103	-6	103	-6	105	-4
		Duraking	12/14	04/01	109	103	-6	103	-6	105	-4
		Kofa	12/14	03/30	107	103	-4	103	-4	101	-6
		Kronos	12/14	03/28	105	103	-2	103	-2	101	-4
		Mohawk	12/14	03/31	108	103	-5	103	-5	101	-7
		Ocotillo	12/14	03/30	107	103	-4	103	-4	103	-4
		Orita	12/14	04/03	111	103	-8	103	-8	107	-4
		Platinum	12/14	04/02	110	103	-7	103	-7	104	-6
		Sky	12/14	03/31	108	103	-5	103	-5	103	-5
		WPB881	12/14	03/30	107	103	-4	103	-4	104	-3
Yuma	2005	Alamo	12/23	03/31	98	103	5	104	6	103	5
		Crown	12/23	04/04	102	103	1	104	2	106	4
		Duraking	12/23	04/04	102	103	1	104	2	106	4
		Kofa	12/23	03/31	98	103	5	104	6	100	2

		Kronos	12/23	03/28	95	103	8	104	9	99	4
		Matt	12/23	03/29	96	103	7	104	8	102	6
		Mohawk	12/23	03/30	97	103	6	104	7	100	3
		Ocotillo	12/23	04/03	101	103	2	104	3	103	2
		Orita	12/23	04/09	107	103	-4	104	-3	109	2
		Platinum	12/23	04/03	101	103	2	104	3	105	4
		Sky	12/23	03/31	98	103	5	104	6	103	5
		WPB881	12/23	03/30	97	103	6	104	7	105	8
Yuma	2006	Alamo	12/26	04/09	104	106	2	107	3	107	3
		Crown	12/26	04/13	108	106	-2	107	-1	109	1
		Duraking	12/26	04/13	108	106	-2	107	-1	109	1
		Kofa	12/26	04/08	103	106	3	107	4	104	1
		Kronos	12/26	04/03	98	106	8	107	9	103	5
		Matt	12/26	04/07	102	106	4	107	5	105	3
		Mohawk	12/26	04/07	102	106	4	107	5	104	2
		Ocotillo	12/26	04/15	110	106	-4	107	-3	107	-3
		Orita	12/26	04/10	105	106	1	107	2	112	7
		Platinum	12/26	04/12	107	106	-1	107	0	108	1
		Sky	12/26	04/09	104	106	2	107	3	107	3
		WPB881	12/26	04/09	104	106	2	107	3	108	4
Yuma	2007	Alamo	12/24	04/06	103	99	-4	99	-4	99	-4
		Crown	12/24	04/11	108	99	-9	99	-9	101	-7
		Duraking	12/24	04/08	105	99	-6	99	-6	101	-4
		Kronos	12/24	04/04	101	99	-2	99	-2	96	-5
		Matt	12/24	04/04	101	99	-2	99	-2	98	-3
		Ocotillo	12/24	04/06	103	99	-4	99	-4	99	-4
		Orita	12/24	04/13	110	99	-11	99	-11	102	-8
		Platinum	12/24	04/12	109	99	-10	99	-10	100	-9
		Sky	12/24	04/06	103	99	-4	99	-4	99	-4
		WPB881	12/24	04/09	106	99	-7	99	-7	100	-6
Mean (DAP)					112.25	112.31	0.06	112.21	-0.04	111.95	-0.30
Absolute error (DAP)							3.96		3.95		3.52
Root mean square error (DAP)							4.33		4.34		3.90
Root mean square error (% of measured DAP)							4.87		4.87		4.37