Testing CERES-Maize versions to estimate maize production in a cool environment

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Introduction

- CERES-Maize is a simple deterministic crop model
- World wide used since its release in 1986 (Kiniry & Jones)

Introduction

Under non-limiting growing conditions the outputs depend on:

- SR, Tmax, Tmin, and to a lesser extent photoperiod
- Cultivar specific factors (5 genetic coefficients)
- Management practices (sowing date, plant density)

Introduction

Applications:

- Test theoretical consequences of varying management practices or cultivars characteristics
- Decision support

Introduction

- The multiple calibration, validation and adaptation processes have led to numerous different versions, differing slightly from the original model and not always well described in the literature.
- Due to its simplicity, this phenomenon is especially sensible in CERES-Maize

Introduction

- In addition to these unofficial versions:

CERES-maize has been modified and supposedly improved by model developers: Kiniry, Ritchie and successors.

Introduction

We highlight three of these recent versions:

CERES-Maize-2003 (CERES-2003) J.R. Kiniry

• CERES-3.5 (included in DSSAT 3.5)

• CERES-4.0 (included in DSSAT 4.0)

Not extensively tested under cool environment

Introduction

RUE driven model

PCARB = RUE * IPAR/PLTPOP [1]

IPAR = PAR * [1 – exp(-EXT * LAI)] [2]

CARBO = PCARB * min(PRFT, 1) [3]

Introduction

The model establishes the number of kernels per plant (GPP):

• as a function of average daily biomass growth rate between silking and beginning grain filling.

Introduction

Finally, the model computes daily reproductive growth:

If insufficient assimilates are available (DM can be remobilized from stems)

$$RGROWTH = GPP * G3 * RGFILL \quad [4]$$

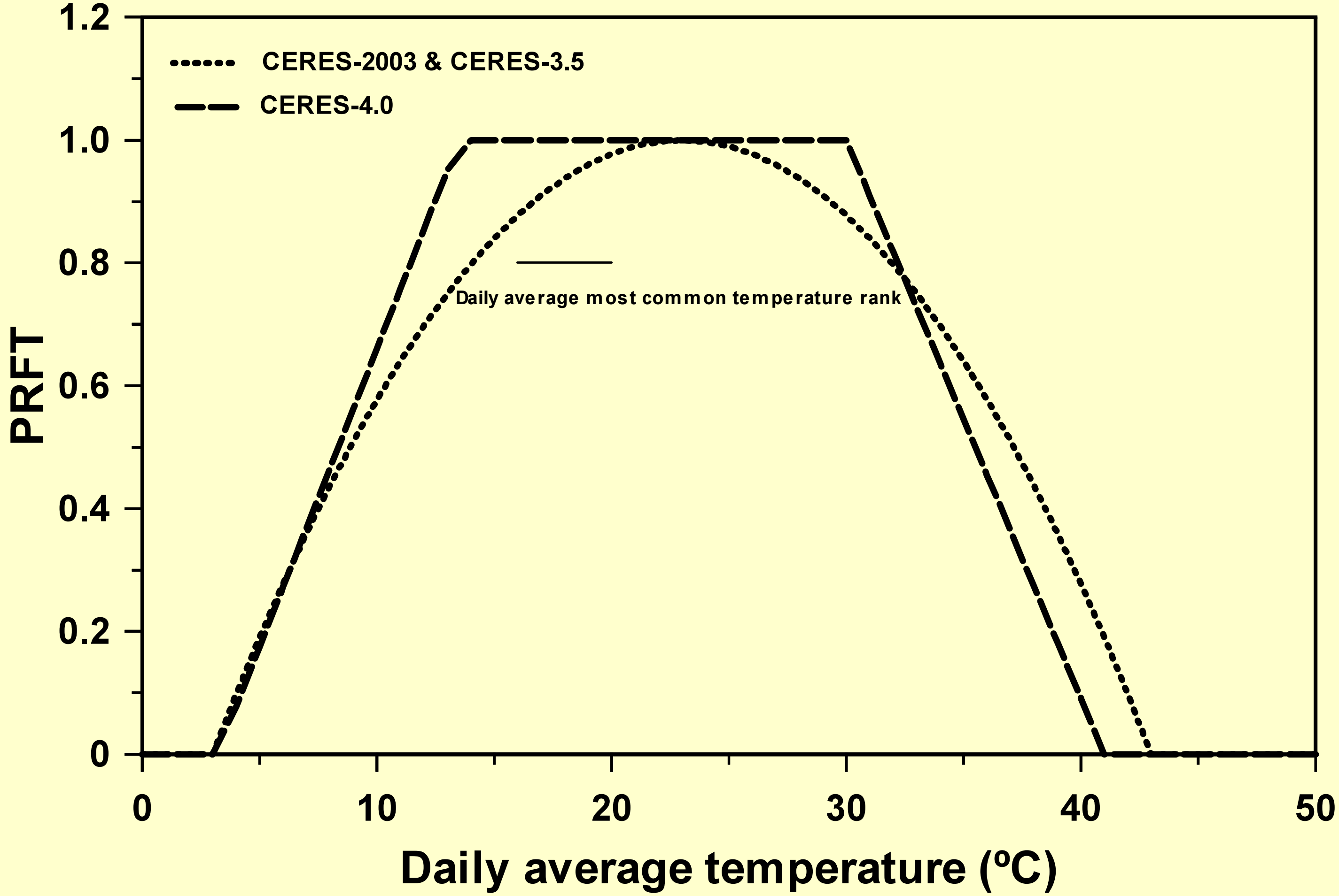
G3: potential kernel growth (opt. environment)
RGFIL: temperature function (0-1)

Introduction

Main differences between CERES-Maize versions

1. PFRT

- **CERES-2003 and CERES-3.5 share the same**
- **PRFT of CERES-4.0 is different**

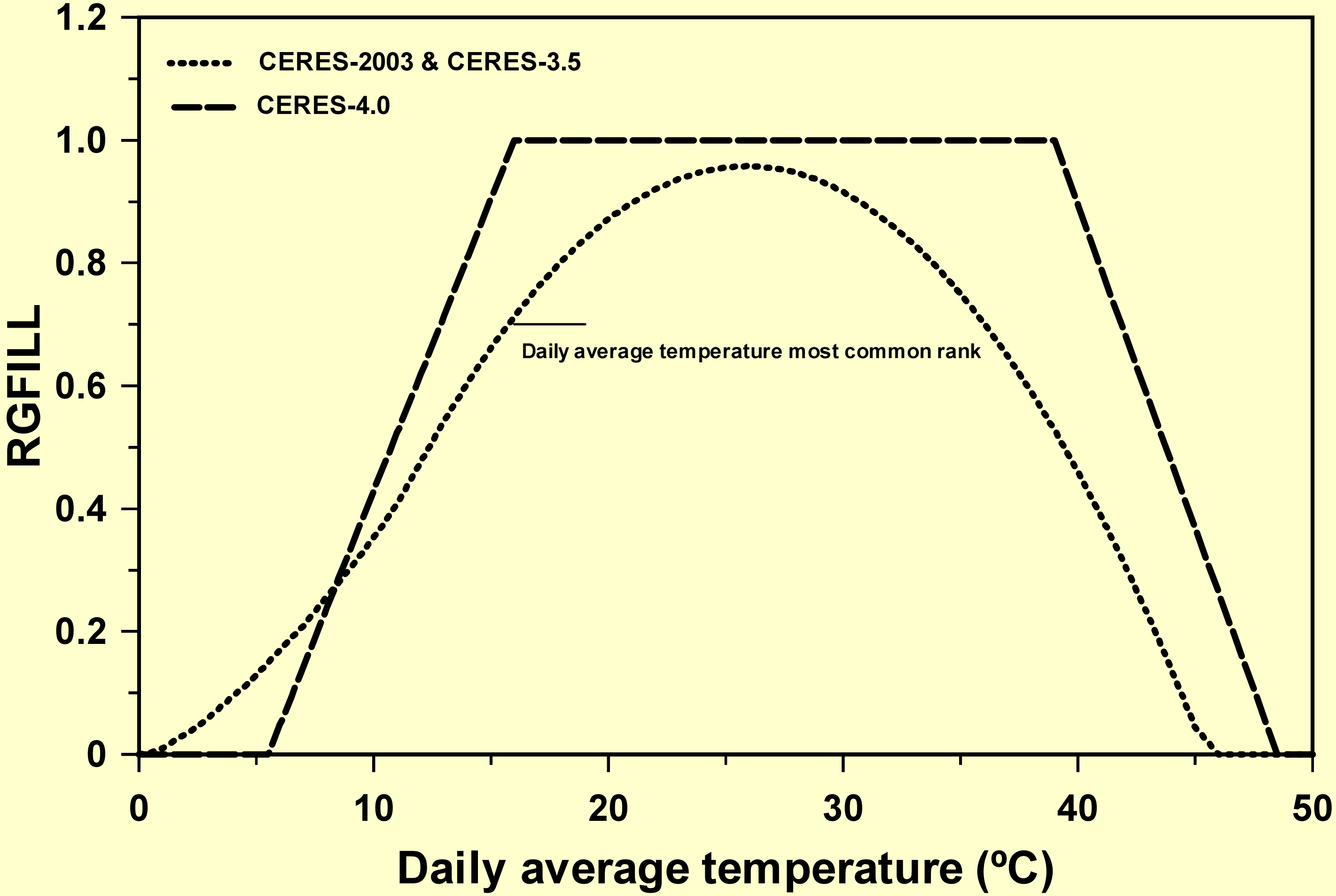

PRFT
1.2
1.0
0.8
0.6
0.4
0.2
0
CERES-2003 & CERES-3.5
CERES-4.0
Daily average most common temperature rank
0
10
20
30
40
50
Daily average temperature (ºC)

Introduction

Main differences between CERES-Maize versions

2. RGFILL

- CERES-2003 and CERES-3.5 share the same RGFILL
- RGFILL of CERES-4.0 is different



1.2
1.0
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RGFILL
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Introduction

Main differences between CERES-Maize versions

3. RUE

- In CERES-4.0 and CERES-3.5, RUE = 4.2 g $MJ(PAR)^{-1}$

- In CERES-2003, RUE is VPD dependent:

IF VPD<1 kPa, RUE = 4.33 g $MJ(PAR)^{-1}$ [5]

IF VPD>=1 kPa, RUE = 5.05-0.72 VPD g $MJ(PAR)^{-1}$ [6]

Introduction

Main differences between CERES-Maize versions

4. Extinction coefficient (EXT)

- In CERES-4.0 and CERES-3.5,

  EXT = f(Pl. density and row spacing)

- In CERES-2003,

  EXT = 0.65

Introduction

Main differences between CERES-Maize versions

5. Efficiency of conversion of mobilized vegetative dry matter to grain

The model starts mobilizing dry matter to grain when daily biomass production per plant (CARBO) is smaller than grain growth (GROGRN)

- In CERES-4.0 and CERES-3.5, 1.0 g of stem loss allows an increase of 1.0 g of grain weight

- In CERES-2003, 1.0 g of stem loss = 0.36 g increase in grain weight.

Introduction

Main differences between CERES-Maize versions

6. Grains per plant (GPP) and LAI computation

- In CERES-4.0 and CERES-3.5: identical equations

- In CERES-2003: slightly different eqs.

Objectives

- Evaluate the performance of 3 recent versions of CERES-maize:

  1. CERES-2003 (the most recent v. proposed by J.R. Kiniry)

  2. CERES-3.5 (DSSAT3.5)

  3. CERES4.0 (DSSAT4.0)

- **Predictions were compared to growth and yield data from field exps. (1998 - 2002; northwest Spain) with one short season cultivar grown at different sowing dates, under a cool environment, water and nutrients are fully available.**

Materials and Methods

1. Experiments

Soil: sandy-loam texture

Ph = 5.6

ample amounts of N, P, K fertilizers

Management: drip irrigation to avoid any water limitations

(tensiometers monitoring)

Treatments and years

Treatments	Sow. Date	Pl. density (pl. m^{-2})	Total N (kg N ha^{-1})
1998-1st	May 14	9.8	320
1988-2nd	June 4	10.0	320
1999-1st	May 24	9.9	345
1999-2nd	June 7	10.0	390
2000-1st	May 18	9.7	345
2000-2nd	June 8	9.7	390
2001	May 19	9.8	345
2002	May 8	8.6	345

Materials and Methods

2. Dry matter sampling

- **Samples of 0.5 m^2 at 15-day intervals**
- **separated into leaf blades, stem and grain (oven dried at 70ºC)**
- **Specific leaf area (SLA) was evaluated, in order to estimate LAI**
- **Crop phenology was observed three times per week (growth staging described by Kiniry and Jones (1986).**
- **At final harvest, 6 m^2 were hand harvested : yield and yield components determined**

Materials and Methods

3. Determination of the genetic coefficients of cv. Clarica

- A low density (4.8 pl. m^{-2}) sowing was established in 1999 (1st sow. Date 1999)
- Temperature is supposed to be above 20ºC
- Method proposed by Ritchie et al. (1986) to establish experimentally G2 & G3
- G2: Potential kernel number per plant
- G3: Potential kernel growth rate (mg $seed^{-1}$ d^{-1})

Materials and Methods

4. Model runs

- Water balance switched on (Priestley Taylor option)
- Nitrogen balance switched off

Materials and Methods

5. Statistical and grafical procedure to evaluate the different model versions

- intercept (a) and slope (b) values of linear regression between predicted and observed values (biomass, grain weight, LAI)
- root mean square error of these variables (RMSE)
- an index of agreement (d; Wilmott, 1982)
- predicted time series graphs of biomass, grain, and LAI were also compared visually, with measurements

Results and Discussion

1. Phenology prediction

- P2 (sensibility to photoperiod) was set to zero
- The others genetic coefficients were established as described in Mat. & Meth.

P1 = 175 GDD (from seedling emergence to the end of juvenile phase)

P5 = 630 GDD (from 75% silking to physiological maturity)

G2 = 936 (potential kernel number per plant)

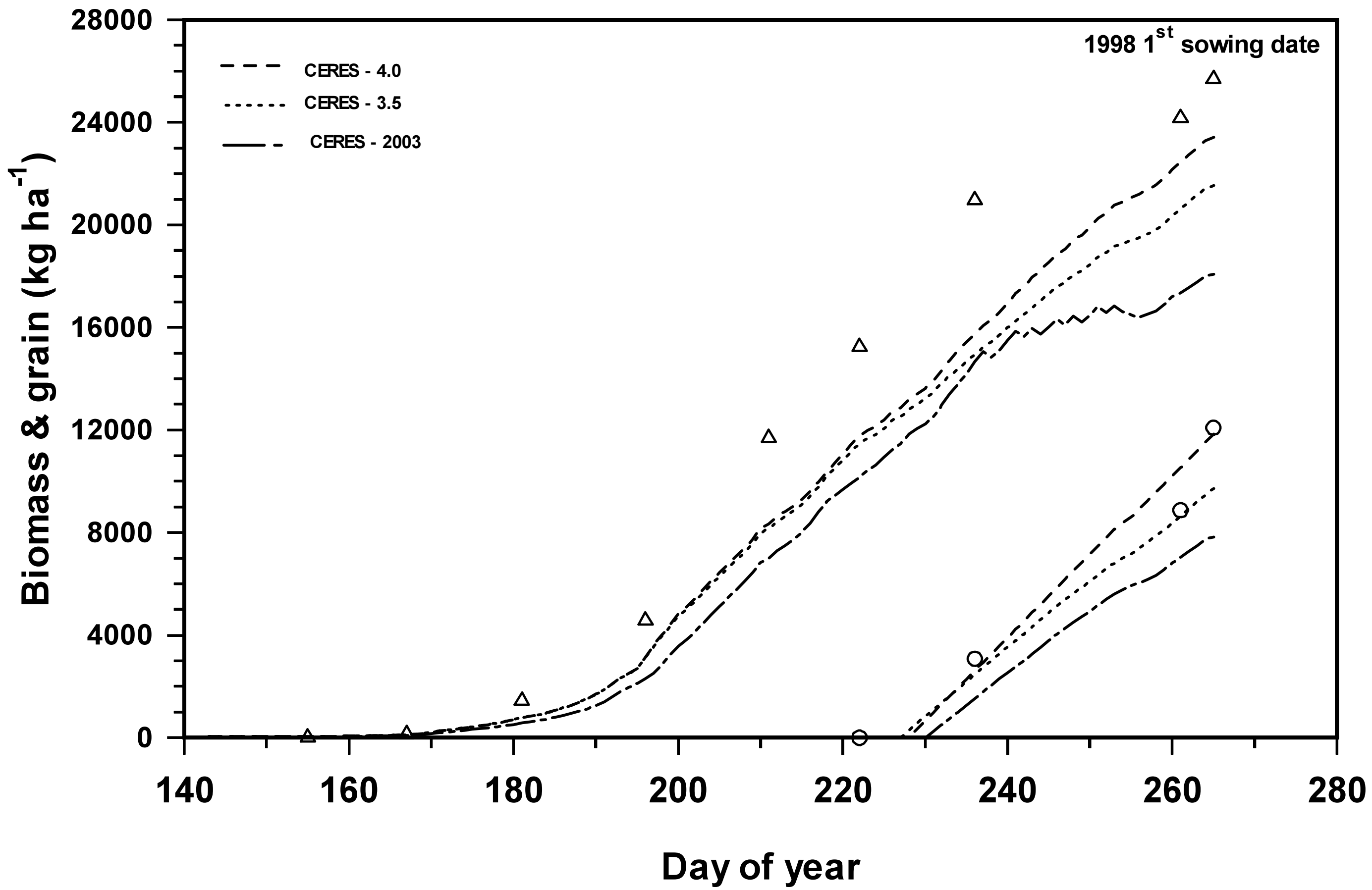
G3 = 8.0 (mg $seed^{-1}$ d^{-1})

Results and Discussion

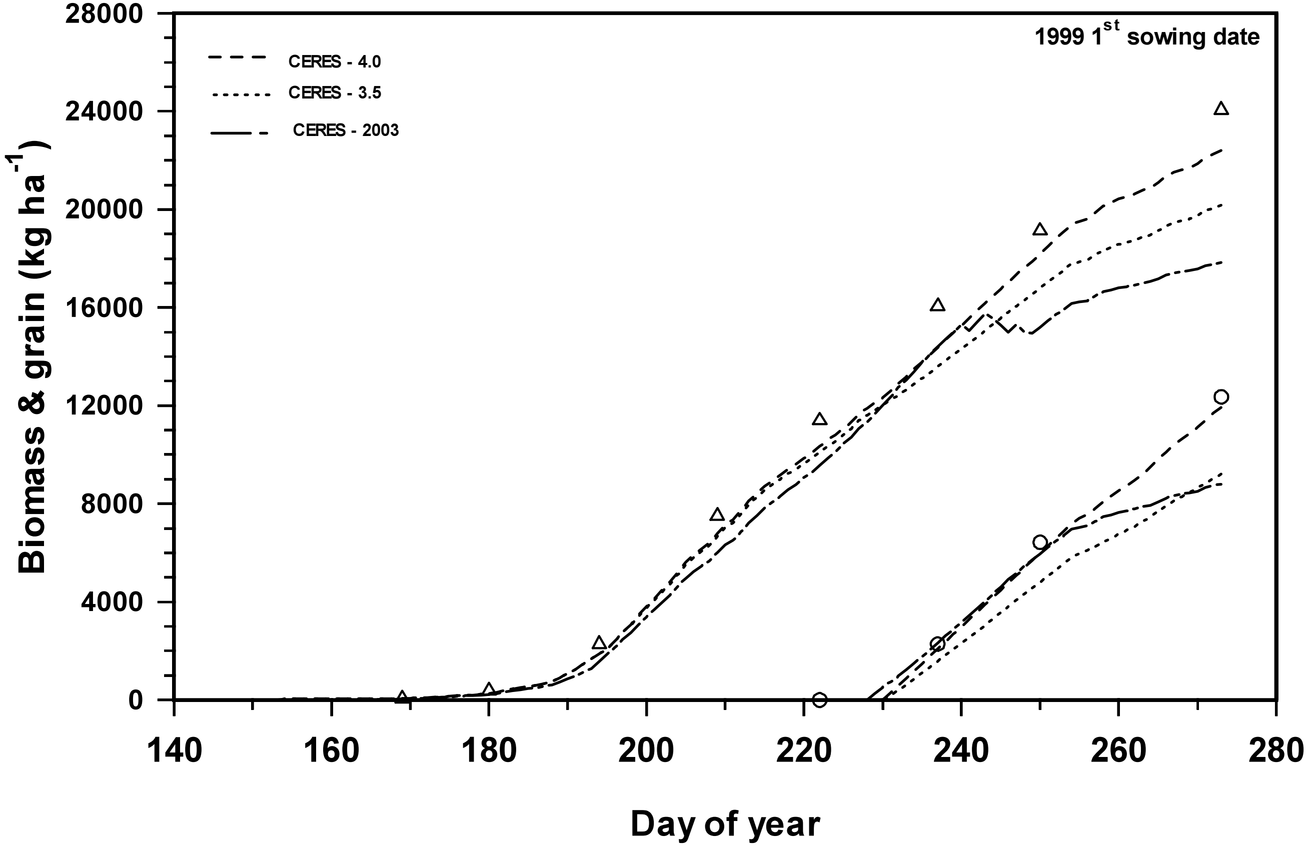
With this genetic coefficients all three models were able to simulate correctly phenology:

- Max RMSE for emergence: 2.6
- Max RMSE for 75% silking: 3.2

The accuracy of models for phenology prediction can be considered equivalent



1998 1st sowing date
CERES - 4.0
CERES - 3.5
CERES - 2003
Biomass & grain (kg ha-1)
Day of year
0
4000
8000
12000
16000
20000
24000
28000
140
160
180
200
220
240
260
280



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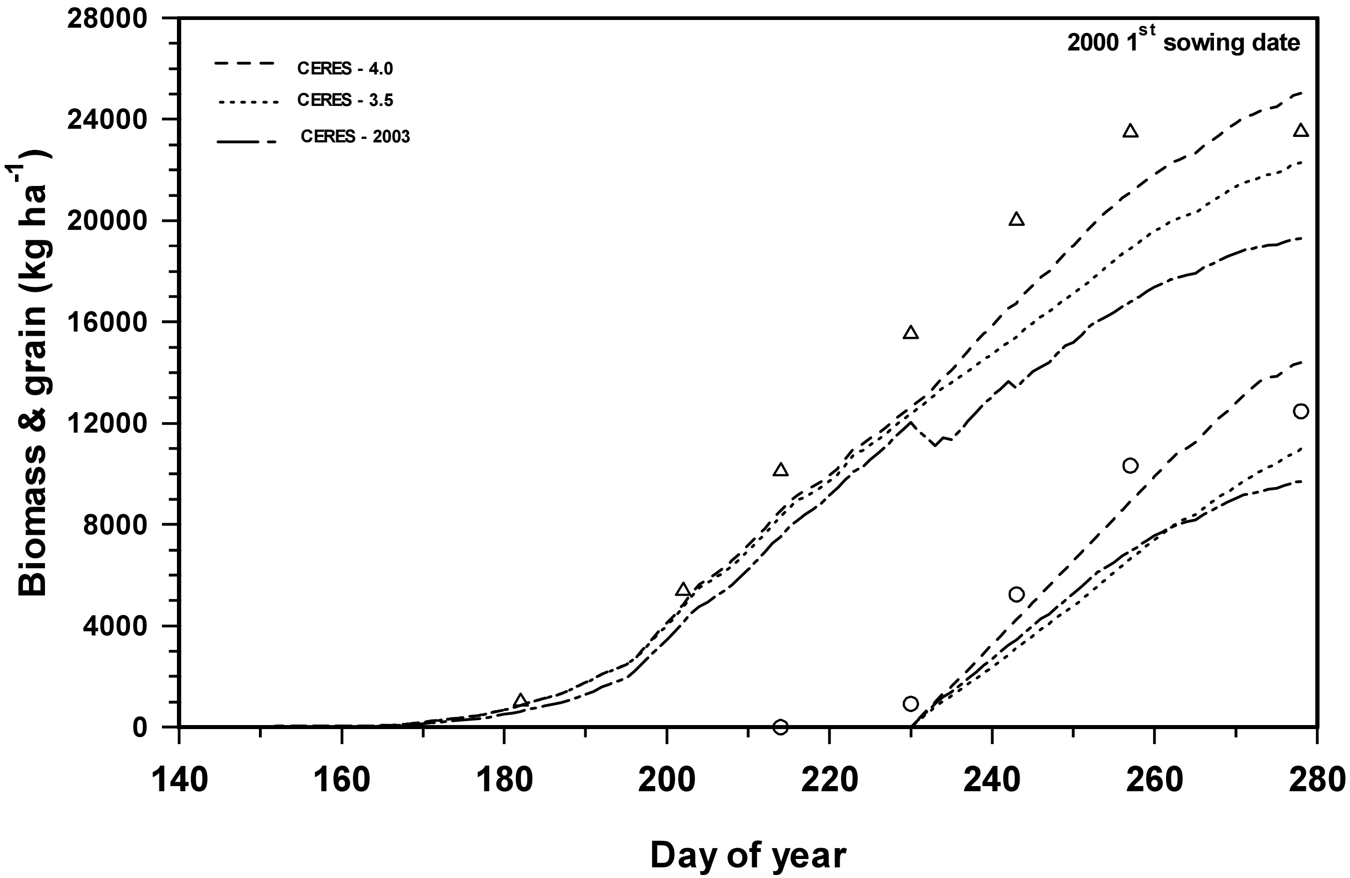

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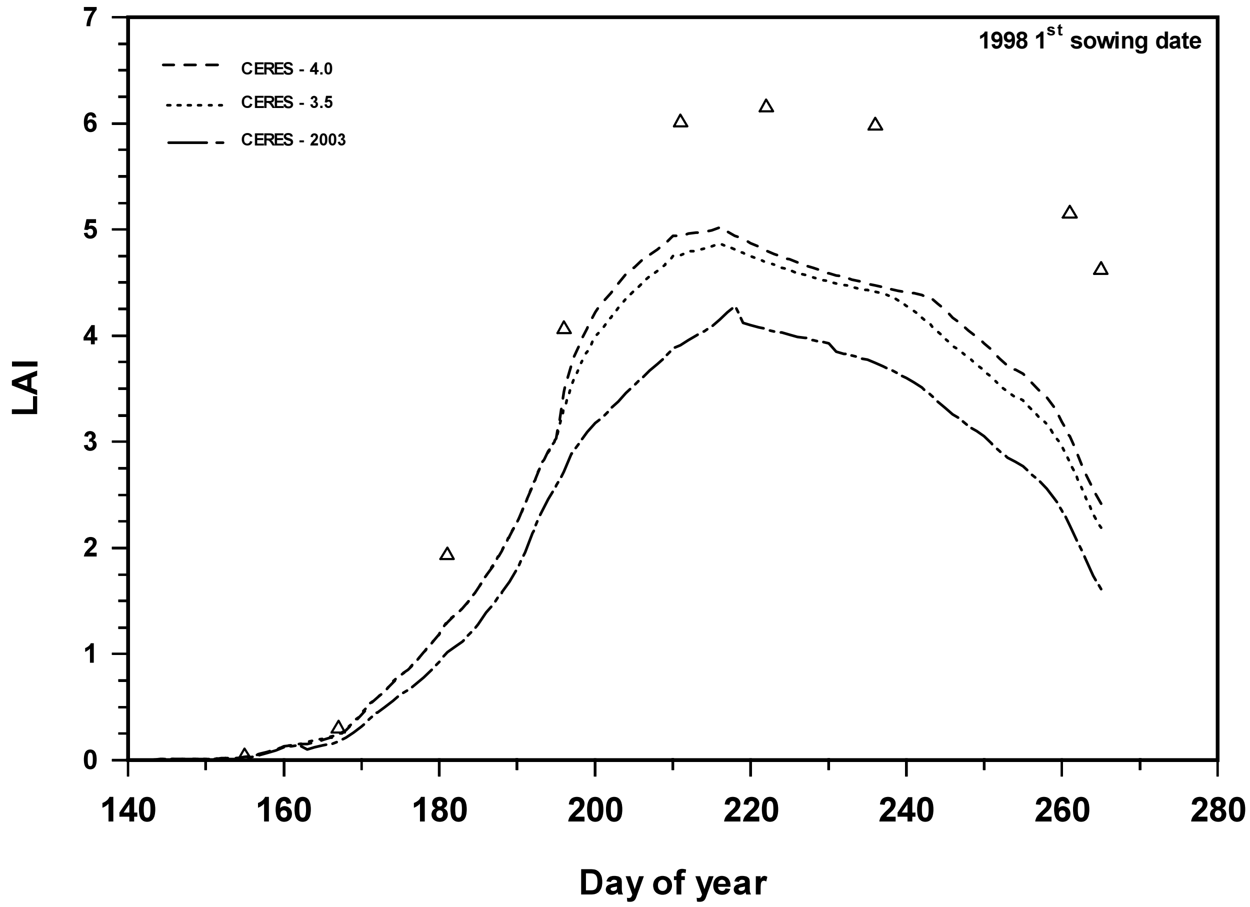


1998 1st sowing date
CERES - 4.0
CERES - 3.5
CERES - 2003
LAI
Day of year
0
1
2
3
4
5
6
7
140
160
180
200
220
240
260
280

TIME SERIES STATISTICS

Model	Variable	a	b	RMSE	*d*
CERES-4.0	Biom.	-3.9	0.902	2202	0.982
CERES-3.5	Biom.	312.0	0.828	2729	0.970
CERES-2003	Biom	297.8	0.740	3909	0.935
CERES-4.0	Grain	-253.0	1.055	1315	0.980
CERES-3.5	Grain	-134.0	0.825	1785	0.954
CERES-2003	Grain	40.0	0.730	2194	0.924
CERES-4.0	LAI	0.29	0.694	1.211	0.875
CERES-3.5	LAI	0.25	0.672	1.328	0.852
CERES-2003	LAI	0.08	0.542	1996	0.720

Model	Variable	Simulated	RMSE	*d*
CERES-4.0	Biom. (kg ha^{-1})	22584	1974	0.637
CERES-3.5	Biom. (kg ha^{-1})	20107	2527	0.600
CERES-2003	Biom (kg ha^{-1})	17732	4863	0.360
Measured	Biom (kg ha^{-1})	22185		
CERES-4.0	Grain (kg ha^{-1})	12137	1472	0.611
CERES-3.5	Grain (kg ha^{-1})	9527	1954	0.474
CERES-2003	Grain (kg ha^{-1})	8410	2942	0.393
Measured	Grain (kg ha^{-1})	11148		
CERES-4.0	LAI	4.5	0.93	0.541
CERES-3.5	LAI	4.3	1.04	0.583
CERES-2003	LAI	3.5	1.86	0.418
Measured	LAI	5.2		

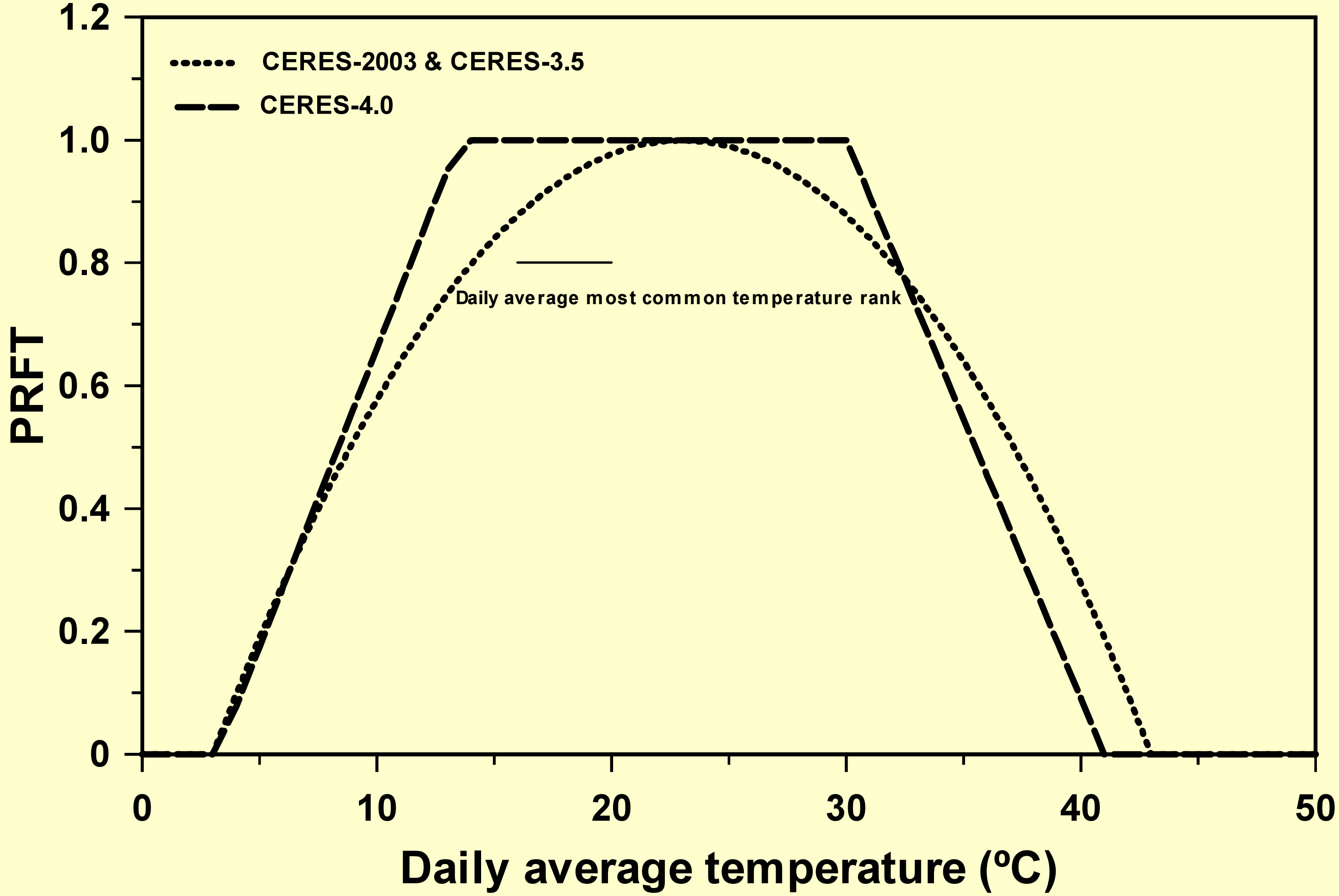
HARVEST DATA STAT

Results and Discussion

•Temperature during the growing season is relatively cool: Tavg. = 16.5-18ºC

From “emergence to anthesis”: Tavg. = 16.1-18.9 ºC

During “grain filling”: Tavg. = 15.2-19.1 ºC



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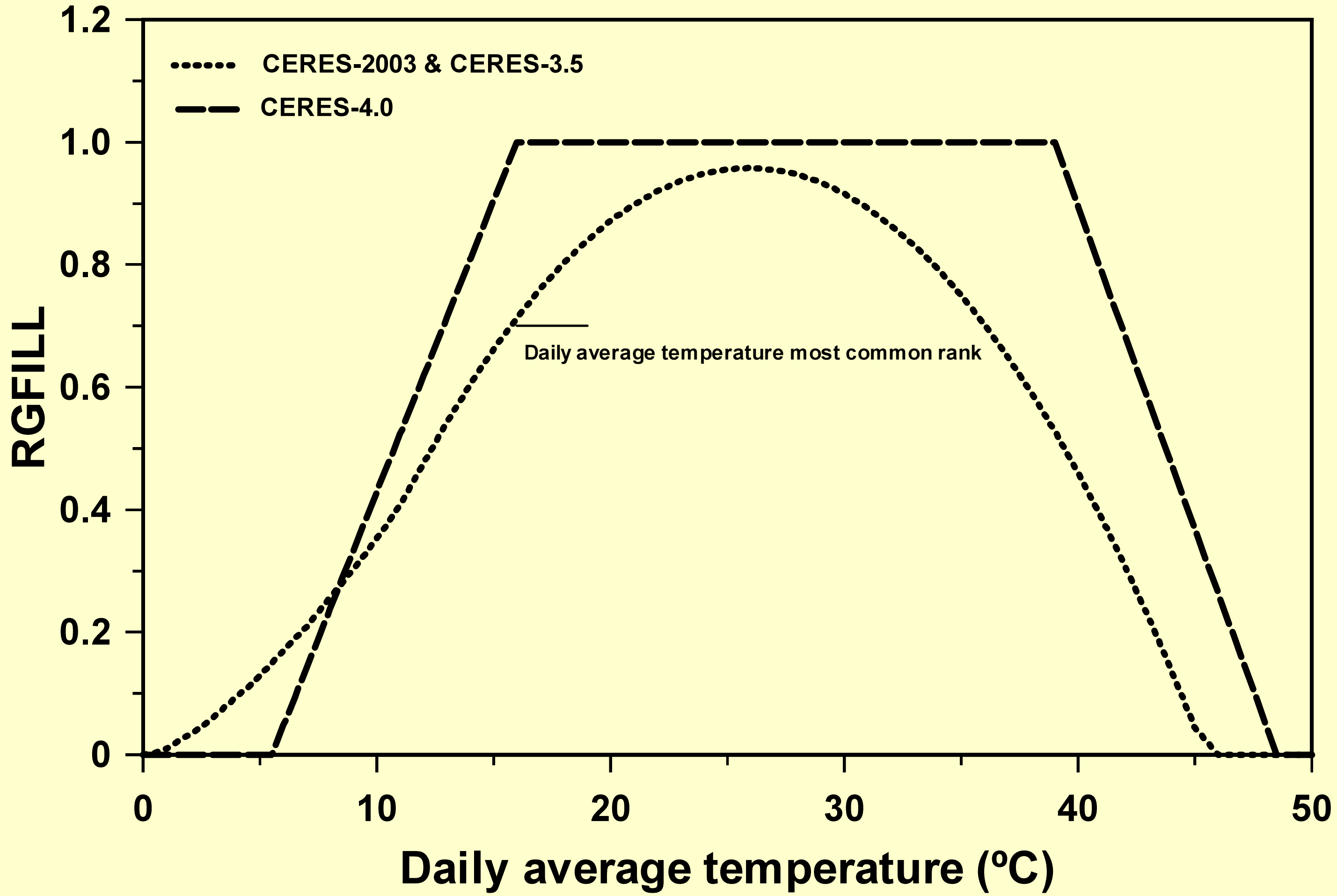

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Results and Discussion

• If we insert CERES-4.0 PRFT function in the CERES-3.5 code, that accounts for 41 and 20% of the difference in biomass and grain yield, respectively, caused by V4.0.

• If we insert CERES-4.0 RGFILL function in the CERES-3.5 code: that accounts for 44 and 68% of the difference in biomass and grain yield, respectively, caused by V4.0.

•If we insert CERES-4.0 both PRFT & RGFILL functions in the CERES-3.5 code: that accounts for 92 and 100% of the difference in biomass and grain yield, respectively, caused by V4.0.

•This confirms that the difference between the two versions is almost exclusively, PRFT & RGFILL.

Results and Discussion

• If we insert in CERES-2003, the translocation function of CERES-3.5 and CERES-4.0: biomass and grain yield predicted increases 12 & 18%, respectively, and the unexpected bumps in the growth curves disappear.

• If we insert in CERES-2003, the LAI functions of CERES-3.5 and CERES-4.0: biomass and grain yield predicted increases 5 & 9%, respectively.

• RUE change (to a fixed RUE independent from VPD) causes a tiny increase in predictions, while EXT change (from 0.65 to 0.59) generates a slight decrease in predictions.

Conclusions

- CERES-4.0 predicts most closely the biomass and grain yield under this cool environment.
- CERES-2003 showed the poorest performance.
- Reasons for CERES-4.0 advantadge are related to the new look-up functions for PRFT and RGFILL that create less sensitivity to temperature. Is this correct for all environments.