Improving Parameters in the CROPGRO-Tomato model for Predicting Growth and Dry Matter Accumulation

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Outline

- **CROPGRO-Tomato model overview.**
- **Changing parameters in CG-Tomato model. Justification**
- **Examples of some outputs: different locations, seasons and cultivars.**
- **Predicting fruit fresh weight and size coupled to the C balance. Brief reference.**

CROPGRO-Tomato Model Overview

- **One of the DSSAT Mechanistic Models. Simulates C, N and water balance. Predicts growth and development of many crops.**

- **Specific relationships for each genotype through specie, cultivar and ecotype files.**

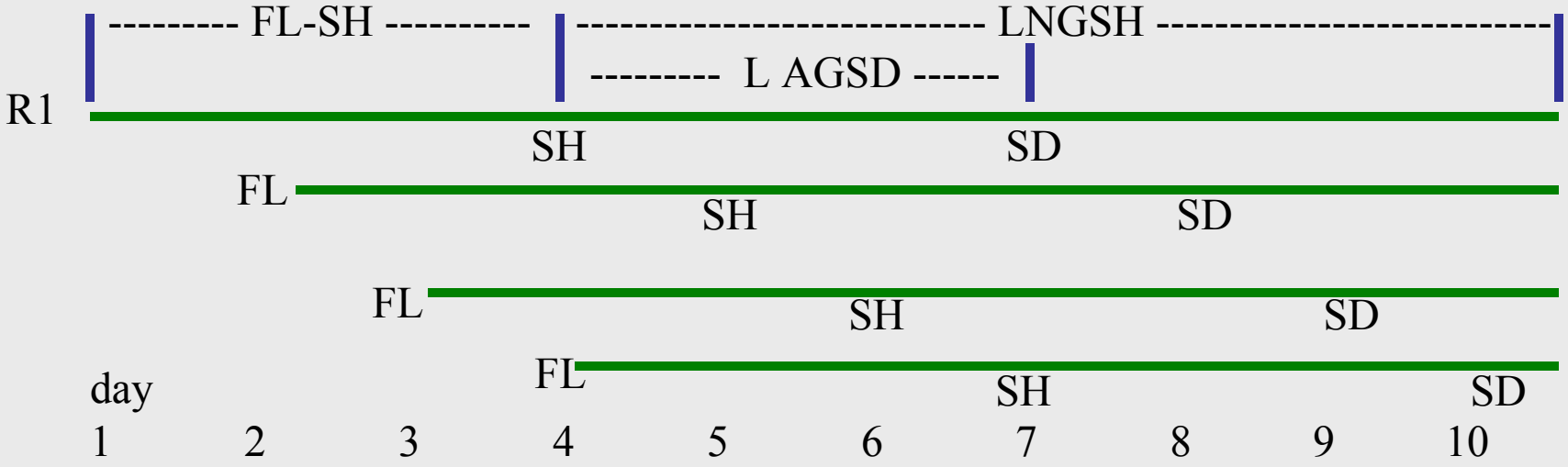
- **Species file:** Defines sensitivity of crop processes to environmental factors, such as temperature, solar radiation, CO_2 and photoperiod. Defines plant composition, initializations, other functions and parameters.
- **Ecotype file:** Defines coefficients for groups of cultivars that show similar behavior.
- **Cultivar file:** Cultivar-specific coefficients, such as photothermal days to flowering & maturity, sensitivity to photoperiod, determinacy, fruit and seed growth rates.

Crop Processes Simulated

- Crop Development
- Photosynthesis
- Maintenance Respiration
- Growth Conversion Efficiency
- Assimilate Partitioning
- Fruit/Seed Addition/fruit Growth
- Leaf Senescence
- Water Uptake and Transpiration
- Nitrogen Uptake

How does the model simulate fruit addition and fruit growth?

- Each day's group of flowers forms fruits (shells), and then seeds dependent on photo thermal day (ptd) accumulators for that cohort of flowers.



- Fruits begin FL-SH ptd after flower appears and grow for LNGSH days. After LAGSD ptd, then seeds are set in these fruits at SDPDVR seeds per fruit if PG is sufficient.
- Early vs late cohorts see different source:sink and envir.
- Tomato fruits have long LNGSH and small seed (low thresh).

Some Growth Processes in CROPGRO Dependent on Temperature

- V-stage (leaf appearance) rate
- R-stage progression
- Photosynthesis
- Maintenance respiration
- Rate of root depth progression
- Leaf expansion & Internode length
- Fruit addition rate
- Fruit (pod) growth rate
- Seed growth rate

Temperature dependence of the rate of development and other processes :

Cardinal Temperatures:

- **T_{base} – Base temperature, below which rate is zero**
- **T_{opt1} – 1st optimum temperature, at which rate is most rapid.**
- **T_{opt2} – 2nd optimum temperature, highest temperature at which rate is still at its maximum.**
- **T_{max} –Maximum temperature, at which rate is zero.**

Procedure followed to improve "Species" parameters

- Review published literature on process sensitivity to
  - Cardinal temperatures.
  - Update of parameters (in specie file) that represent temperature dependence of the process.
- Calibration with growth data (field)
  - Order: phenology 1st, early DM growth, yield traits
  - Determine RMSE, d-index, slope, intercept

Adapted from Boote et al., 2002.

Parameters represent temperature dependence of tomato phenology, shell and seed growth. Default V3.5 values (black) and updated (blue) in specie file: ***[New values from Adams et al., 2001b]***

Parameter	Tb °C	Top_1 °C	Top_2 °C	Tmax °C
Rate of leaf or truss app. (Vegetative dev.)	10 →7	28→22	**28**	55 → 48
Rate of progress to anthesis /truss app. (Early reprod. growth)	10 →7.2	28→22	**28**	55 → 48
Rate of fruit dev. and maturation. Late reprod. growth)	10 →5.7	28 →26	**28**	55 → 48
Relative effect of Temp. on rate of fruit addition and pollination. FNDPT	6 →7.2	8 →22	28 →25.5	30→32
Relative effect of Temp. on rate of indiv seed/fruit growth. FNSDT	6	8 →22	25.5 →25	32

Other updated Temperature Functions in CROPGRO (SPE. File) influencing photosynthesis, default values (**black**) and updated (**blue**)

Parameter	Tb °C	$Topt_1$ °C	$Topt_2$ °C	Tmax °C		
Canopy level Photosynthesis (C vers) FNPGT	5	27 →**22**	24 →**30**	48→**54**		
Leaf level Photosynthesis (L vers) XLMAXT	8→**7**	25→**26**	28 →**30**	48		
Effect of night Temp. on Ps rate next day (L ver.) FNPGL	0→**-1**	5 →**18**	----	----		

Boote & Scholberg. 2006. Acta Hort. 718:23.

Cultivar coefficients in CROPGRO-Tomato model, default and calibrated values after updating the cardinal temperatures in SPE file. Cultivar: Sunny

Name	Current Value	Modified value	Cultivar Coefficients Definition
EM-FL	23.00	35.00	Time from plant emergence to flower appearance (pd).
FL-SH	8.00	9.8	Time between first flower and first pod (pd).
FL-SD	17.00	22.00	Time between first flower and first seed. (pd).
SD-PM	50.00	55.00	Time between first seed and physiological maturity (pd).
FL-LF	50.00	62.00	Time between first flower and end of leaf expansion (pd).
LFMAX	1.36	1.20	Maximum leaf photosynthesis rate at 30 ºC and 350 ppm CO2 and high light (mg CO2 m^{-2} s^{-1}).
SLAVR	350	350	Specific leaf area of cultivar under standard growth conditions (cm^{-2} g^{-1}).
SIZLF	300	300	Maximum size of full leaf (cm^{-2}).
XFRT	0.75	0.74	Max fraction of daily growth partitioned to fruits
WTPSD	0.004	0.004	Max weight per seed (g).
SFDUR	25.00	23.00	Seed filling duration for pod cohort (pd).
SDPDV	300	300	Seed per pod at standard growth condition (# pod-1).
PODUR	42.00	47.00	Duration of pod addition (pd).

Pd = Photothermal day.

Cultivar coefficients in CROPGRO-Tomato model, default and calibrated values after update cardinal temperatures in SPE file. Cultivar: Agriset

Name	Current Value	Modified value	Cultivar Coefficients Definition
EM-FL	23.00	35.50	Time from plant emergence to flower appearance (pd).
FL-SH	8.00	9.9	Time between first flower and first pod (pd).
FL-SD	17.00	22.50	Time between first flower and first seed. (pd).
SD-PM	50.00	55.00	Time between first seed and physiological maturity (pd).
FL-LF	50.00	62.00	Time between first flower and end of leaf expansion (pd).
LFMAX	1.36	1.20	Maximum leaf photosynthesis rate at 30 ºC and 350 ppm CO2 and high light (mg CO_2 m^{-2} s^{-1}).
SLAVR	350	350	Specific leaf area of cultivar under standard growth conditions (cm^{-2} g^{-1}).
SIZLF	300	300	Maximum size of full leaf (cm^{-2}).
XFRT	0.75	0.75	Max fraction of daily growth partitioned to fruits
WTPSD	0.004	0.004	Max weight per seed (g).
SFDUR	25.00	26.00	Seed filling duration for pod cohort (pd).
SDPDV	300	300	Seed per pod at standard growth condition (# pod-1).
PODUR	42.00	46.00	Duration of pod addition (pd).

Pd = Photothermal day.

Cultivar coefficients in CROPGRO-Tomato model, default and calibrated values after update cardinal temperatures in SPE file. Cultivar: Solarset

Name	Current Value	Modified value	Cultivar Coefficients Definition
EM-FL	23.00	35.00	Time from plant emergence to flower appearance (pd).
FL-SH	8.00	9.8	Time between first flower and first pod (pd).
FL-SD	17.00	22.00	Time between first flower and first seed. (pd).
SD-PM	50.00	55.00	Time between first seed and physiological maturity (pd).
FL-LF	50.00	62.00	Time between first flower and end of leaf expansion (pd).
LFMAX	1.36	1.20	Maximum leaf photosynthesis rate at 30 ºC and 350 ppm CO2 and high light (mg CO_2 m^{-2} s^{-1}).
SLAVR	350	350	Specific leaf area of cultivar under standard growth conditions (cm^{-2} g^{-1}).
SIZLF	300	300	Maximum size of full leaf (cm^{-2}).
XFRT	0.75	0.72	Max fraction of daily growth partitioned to fruits
WTPSD	0.004	0.004	Max weight per seed (g).
SFDUR	25.00	25.00	Seed filling duration for pod cohort (pd).
SDPDV	300	300	Seed per pod at standard growth condition (# pod-1).
PODUR	42.00	46.00	Duration of pod addition (pd).

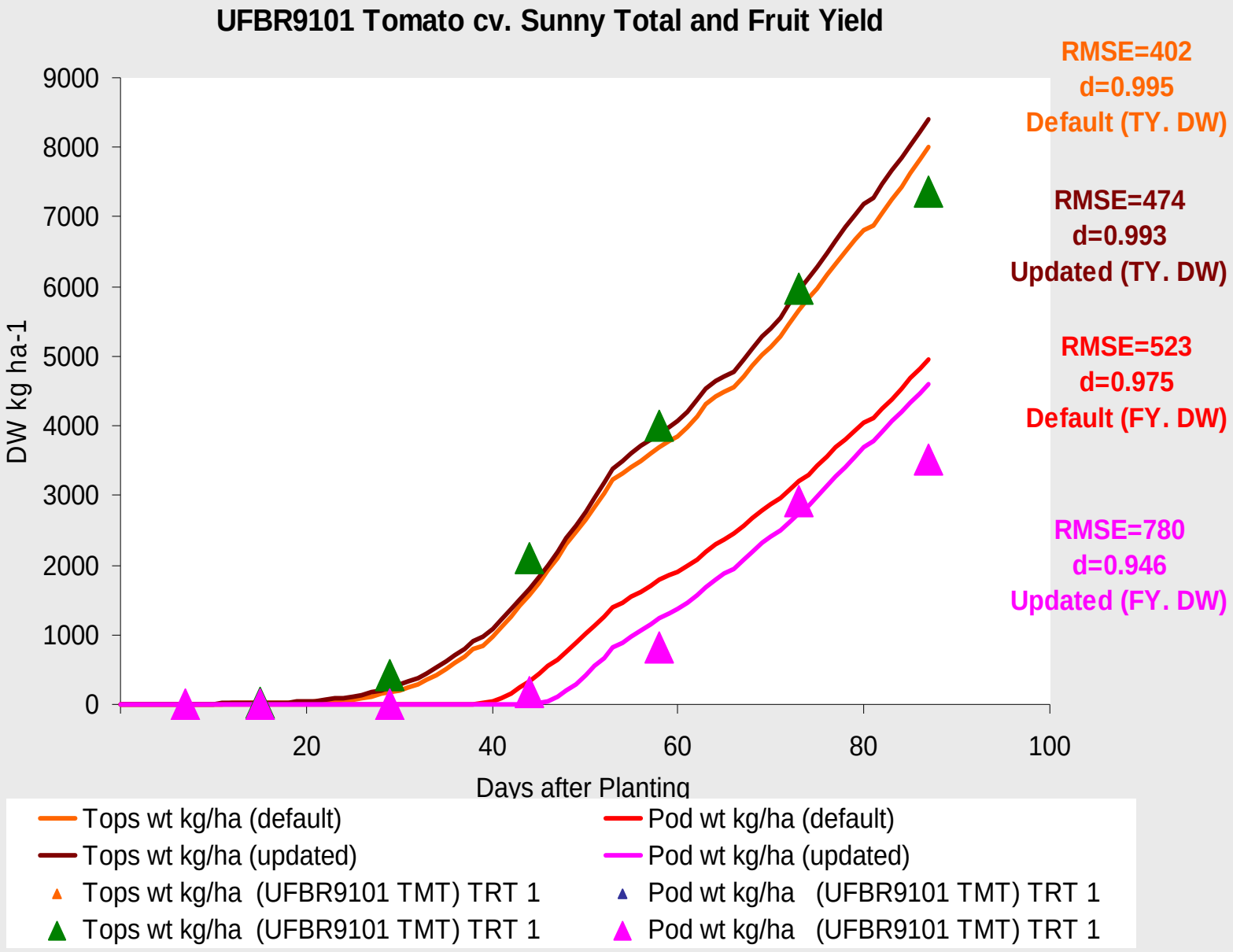
Pd = Photothermal day.

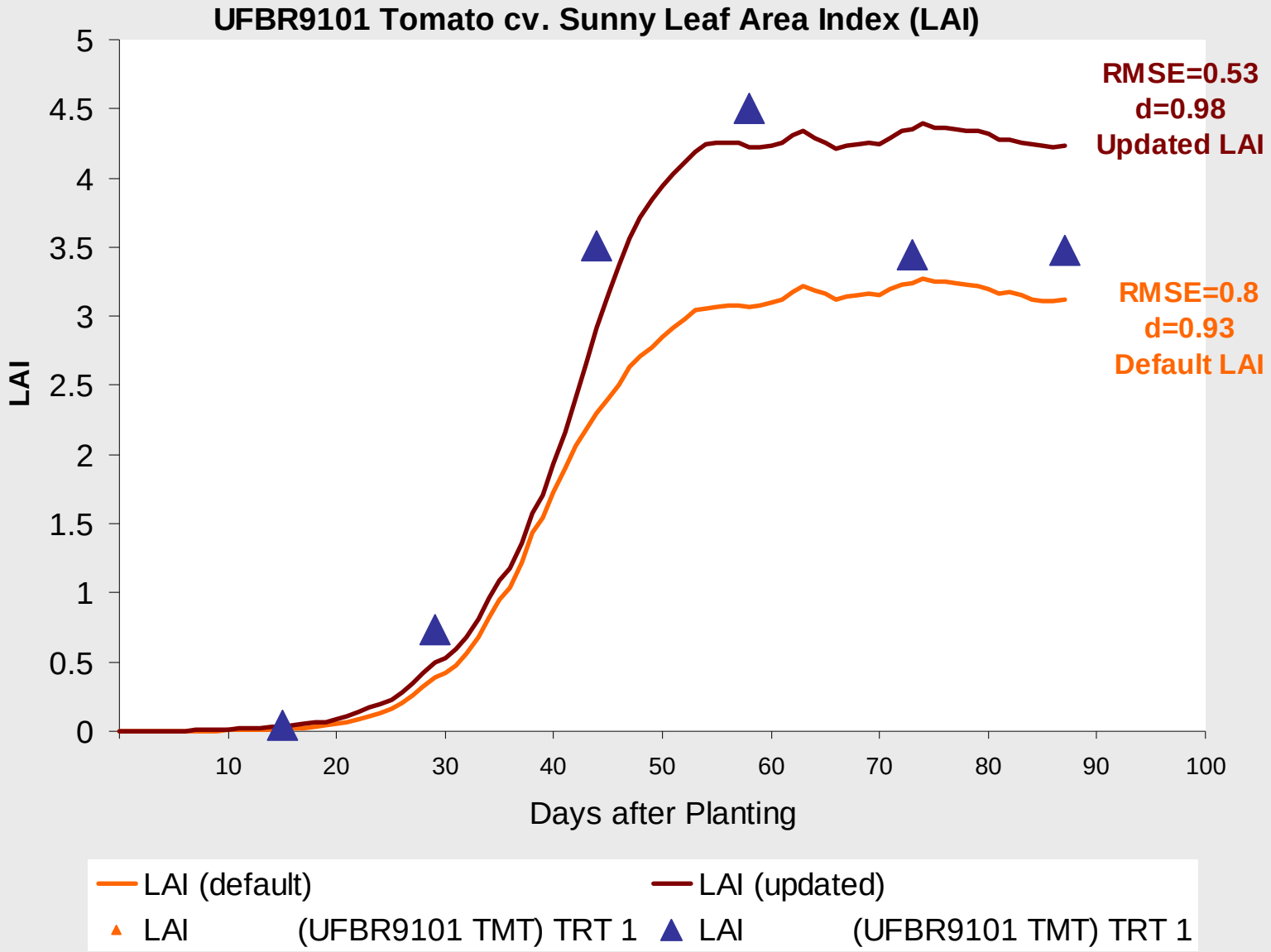
Additional changes (ecotype parameters)

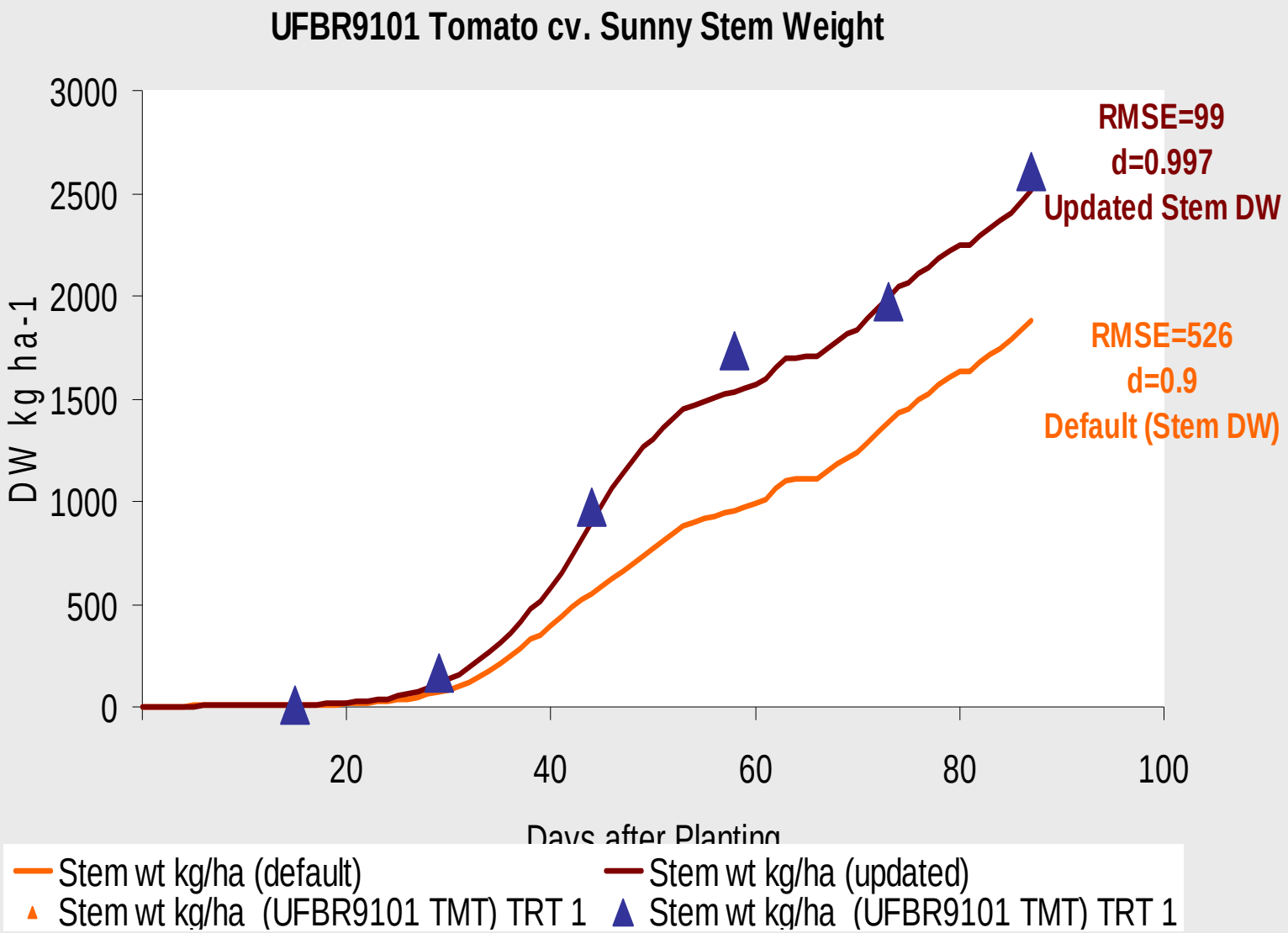
Parameter	Black (default values) Blue (updated values)
Rate of leaf appearance on main stem, TRIFL	0.52 → 0.5
Time from first flower to last leaf on main stem, FL-VS	18 → 22
Time required for growth of individual shell, LNGSH	35 → 38

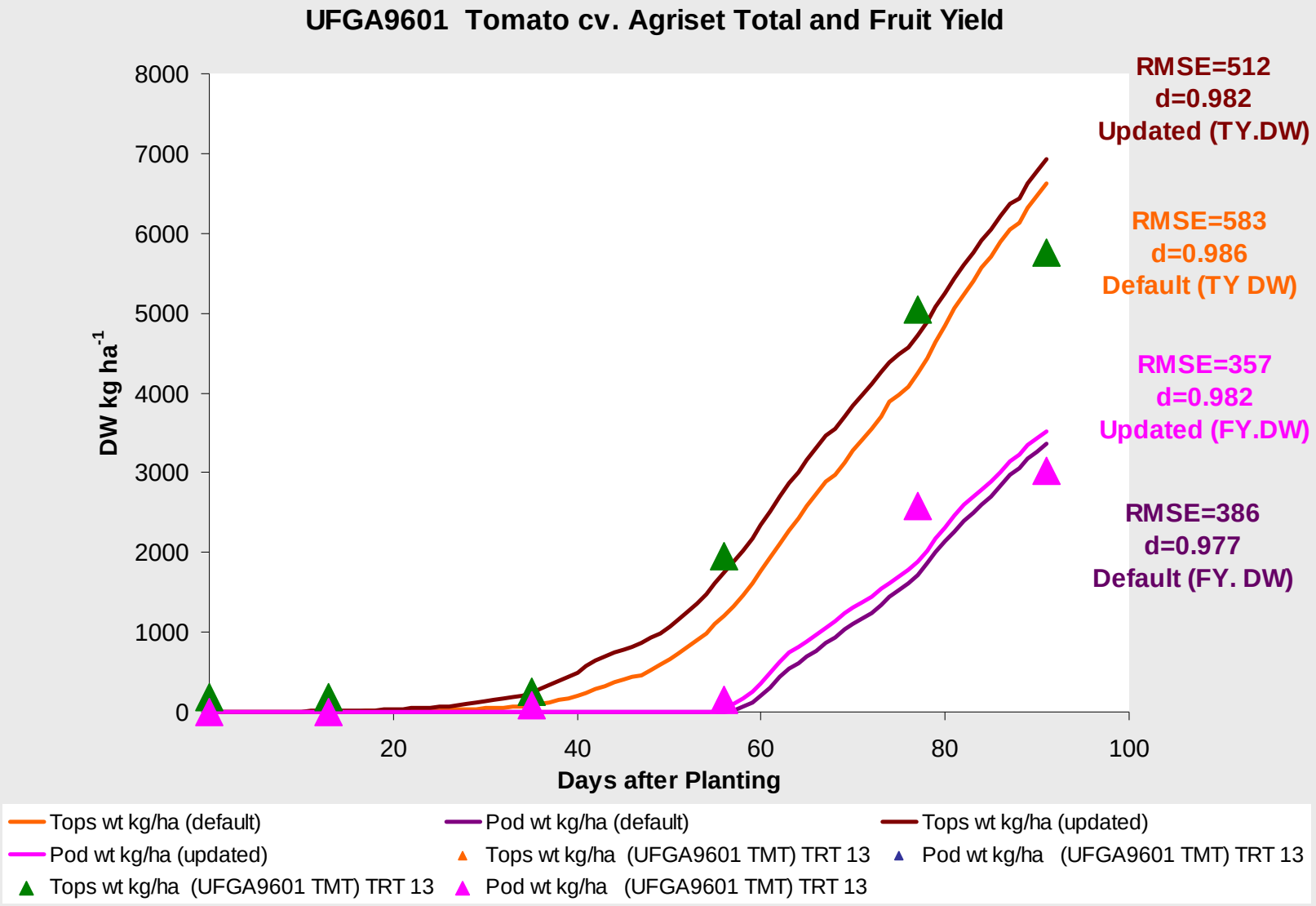
Additional changes: Transplant age

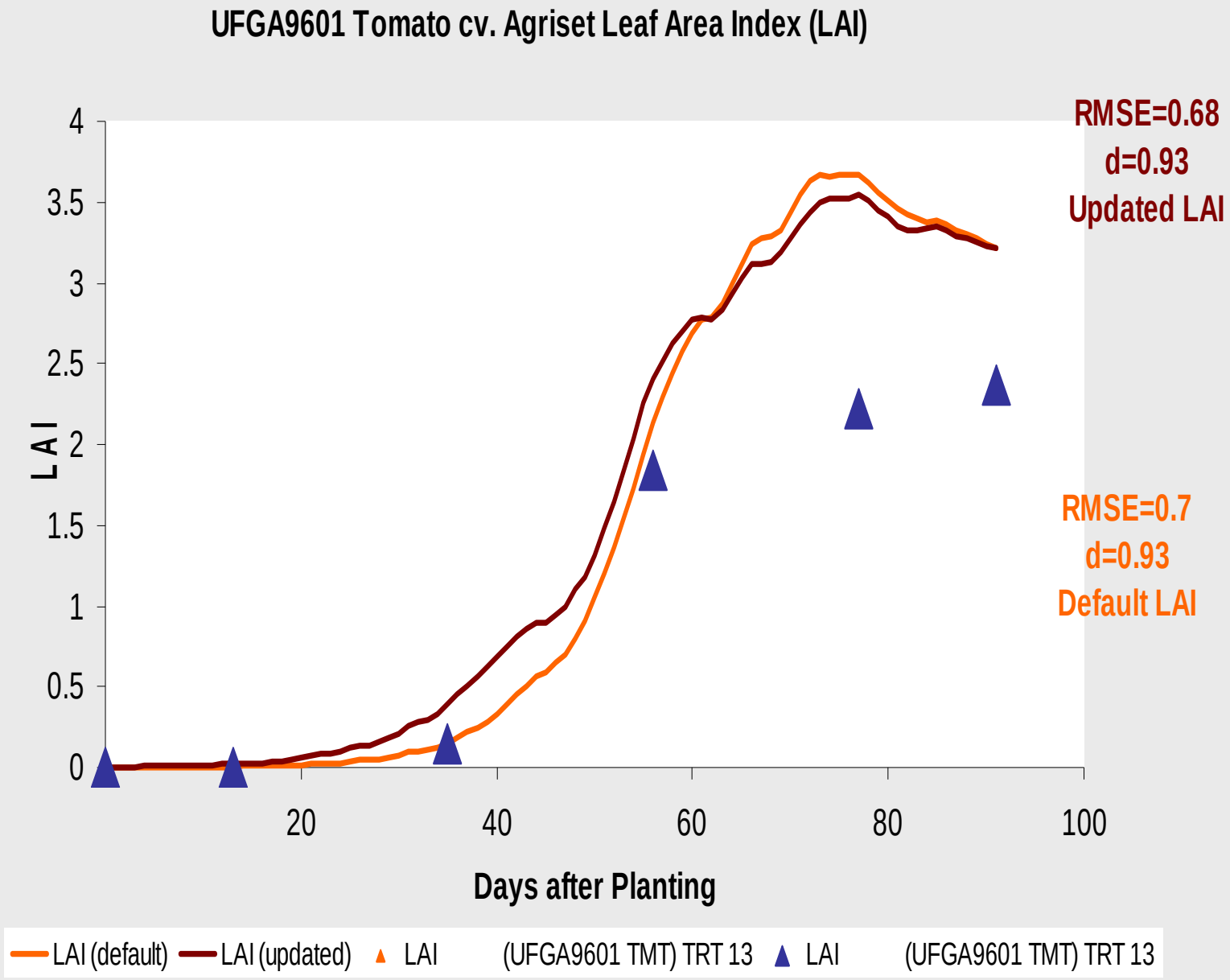
Examples


UFBR9101 Tomato cv. Sunny Total and Fruit Yield
RMSE=402
d=0.995
Default (TY. DW)
RMSE=474
d=0.993
Updated (TY. DW)
RMSE=523
d=0.975
Default (FY. DW)
RMSE=780
d=0.946
Updated (FY. DW)
DW kg ha-1
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
20
40
60
80
100
Days after Planting
Tops wt kg/ha (default)
Tops wt kg/ha (updated)
Tops wt kg/ha (UFBR9101 TMT) TRT 1
Tops wt kg/ha (UFBR9101 TMT) TRT 1
Pod wt kg/ha (default)
Pod wt kg/ha (updated)
Pod wt kg/ha (UFBR9101 TMT) TRT 1
Pod wt kg/ha (UFBR9101 TMT) TRT 1

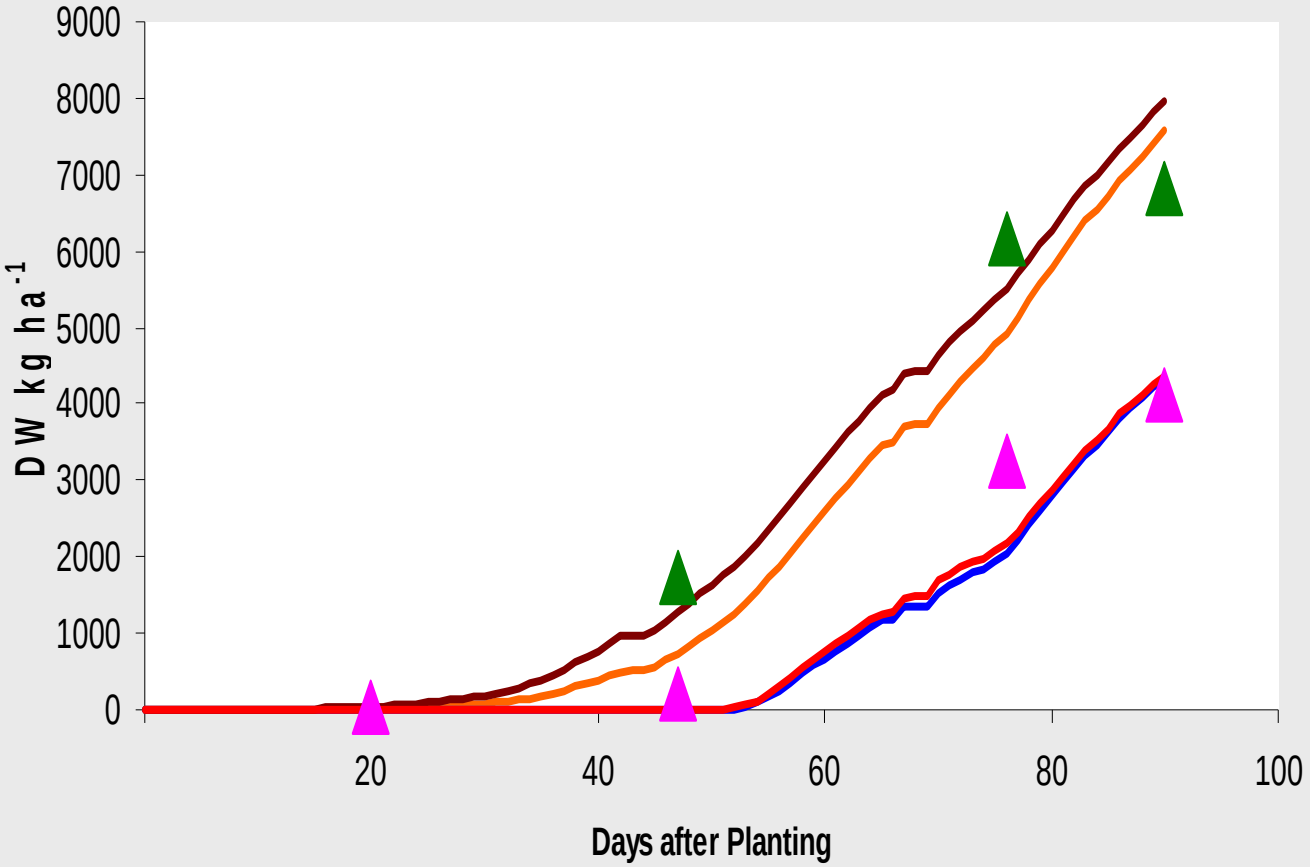

UFBR9101 Tomato cv. Sunny Leaf Area Index (LAI)
LAI
Days after Planting
RMSE=0.53
d=0.98
Updated LAI
RMSE=0.8
d=0.93
Default LAI
LAI (default)
LAI (updated)
LAI (UFBR9101 TMT) TRT 1
LAI (UFBR9101 TMT) TRT 1


UFBR9101 Tomato cv. Sunny Stem Weight
3000
2500
2000
1500
1000
500
0
DW kg ha-1
20
40
60
80
100
Days after Planting
RMSE=99
d=0.997
Updated Stem DW
RMSE=526
d=0.9
Default (Stem DW)
Stem wt kg/ha (default)
Stem wt kg/ha (updated)
Stem wt kg/ha (UFBR9101 TMT) TRT 1
Stem wt kg/ha (UFBR9101 TMT) TRT 1


UFGA9601 Tomato cv. Agriset Total and Fruit Yield
DW kg ha-1
8000
7000
6000
5000
4000
3000
2000
1000
0
20
40
60
80
100
Days after Planting
RMSE=512
d=0.982
Updated (TY.DW)
RMSE=583
d=0.986
Default (TY DW)
RMSE=357
d=0.982
Updated (FY.DW)
RMSE=386
d=0.977
Default (FY. DW)
Tops wt kg/ha (default)
Pod wt kg/ha (default)
Tops wt kg/ha (updated)
Pod wt kg/ha (updated)
Tops wt kg/ha (UFGA9601 TMT) TRT 13
Pod wt kg/ha (UFGA9601 TMT) TRT 13
Tops wt kg/ha (UFGA9601 TMT) TRT 13
Pod wt kg/ha (UFGA9601 TMT) TRT 13


UFGA9601 Tomato cv. Agriset Leaf Area Index (LAI)
RMSE=0.68
d=0.93
Updated LAI
RMSE=0.7
d=0.93
Default LAI
LAI
Days after Planting
0
0.5
1
1.5
2
2.5
3
3.5
4
20
40
60
80
100
LAI (default)
LAI (updated)
LAI (UFGA9601 TMT) TRT 13
LAI (UFGA9601 TMT) TRT 13

UFQU9501 Tomato cv. Agriset Total and Fruit Yield (Spring)



RMSE=701
d=0.99
Updated (TY. DW)

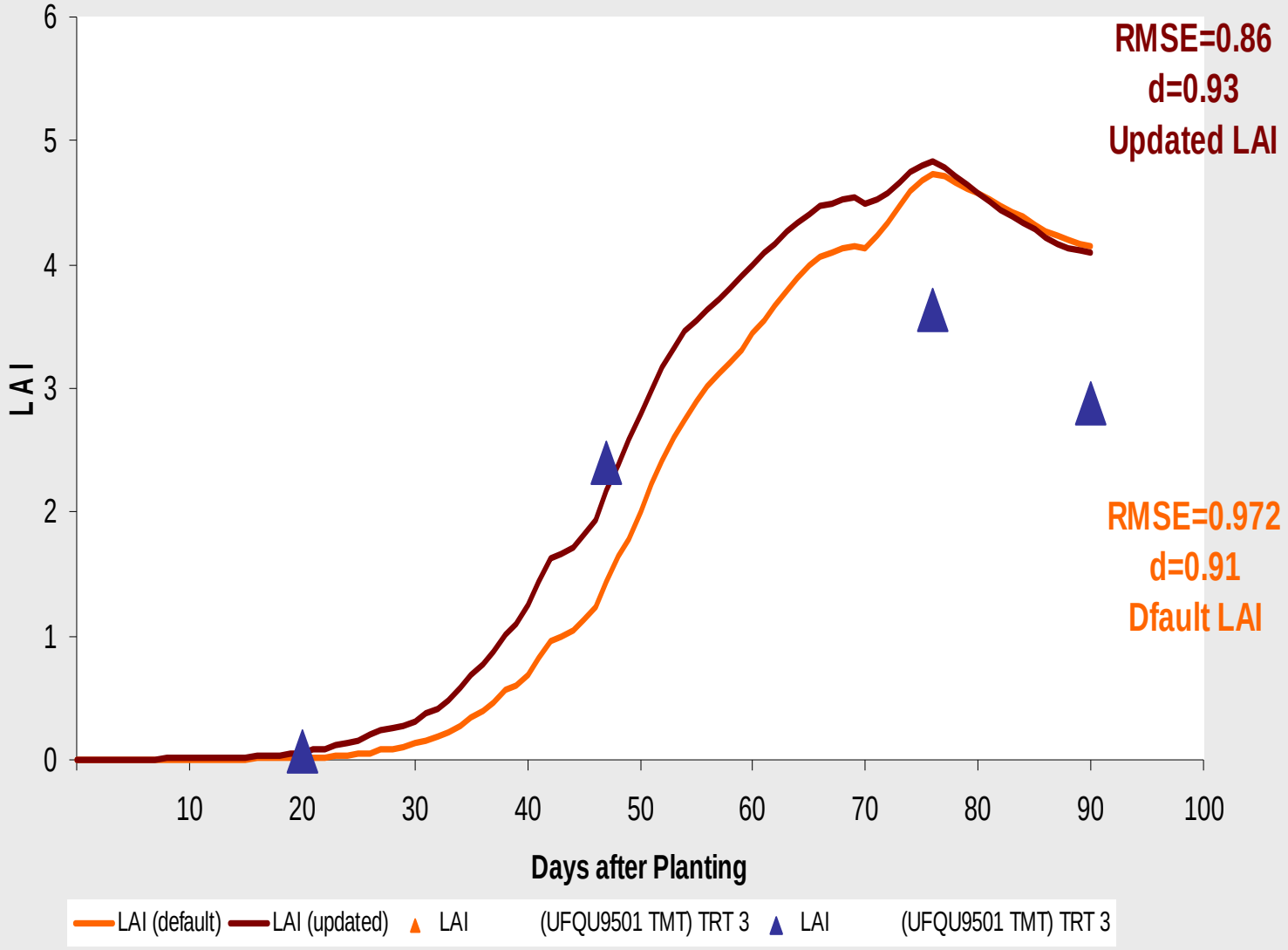
RMSE=886
d=0.98
Default (TY. DW)

RMSE=563
d=0.975
Updated (FY. DW)

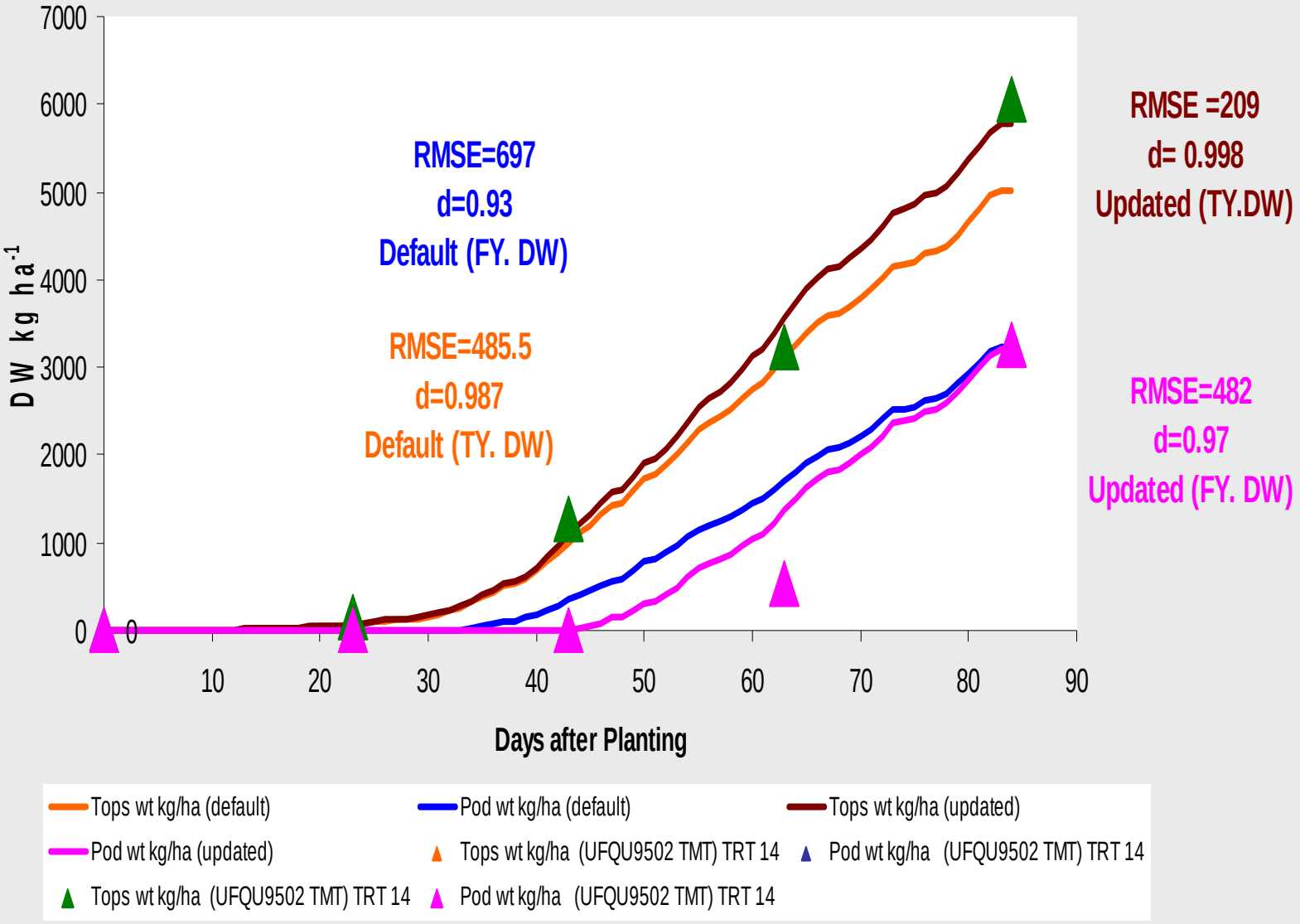
RMSE=698
d=0.97
Default (FY. DW)

Tops wt kg/ha (default)
Tops wt kg/ha (updated)
Tops wt kg/ha (UFQU9501 TMT) TRT 3
Tops wt kg/ha (UFQU9501 TMT) TRT 3
Pod wt kg/ha (default)
Pod wt kg/ha (updated)
Pod wt kg/ha (UFQU9501 TMT) TRT 3
Pod wt kg/ha (UFQU9501 TMT) TRT 3

UFQU9501 Tomato cv. Agriset Leaf Area Index (LAI) (Spring)



UFQU9102 Tomato cv. Solarest Total and Fruit Yield (Fall)



Summary

- Overall the modification of parameters in CROPGRO Tomato model improves the prediction of total and fruit dry matter accumulation and gives a better adjustment of the life cycle phase durations.

- Because the new cardinal temperature values are considered reliable as they come from recent published experiments conducted in controlled-temperature environments, we recommend updating the values of the genetic coefficients to the ones presented here for the current version of CROPGRO-Tomato model. The proposed adaptation should improve the accuracy of predictions of tomato dry weight and yield and reduce efforts in future model calibrations and evaluations.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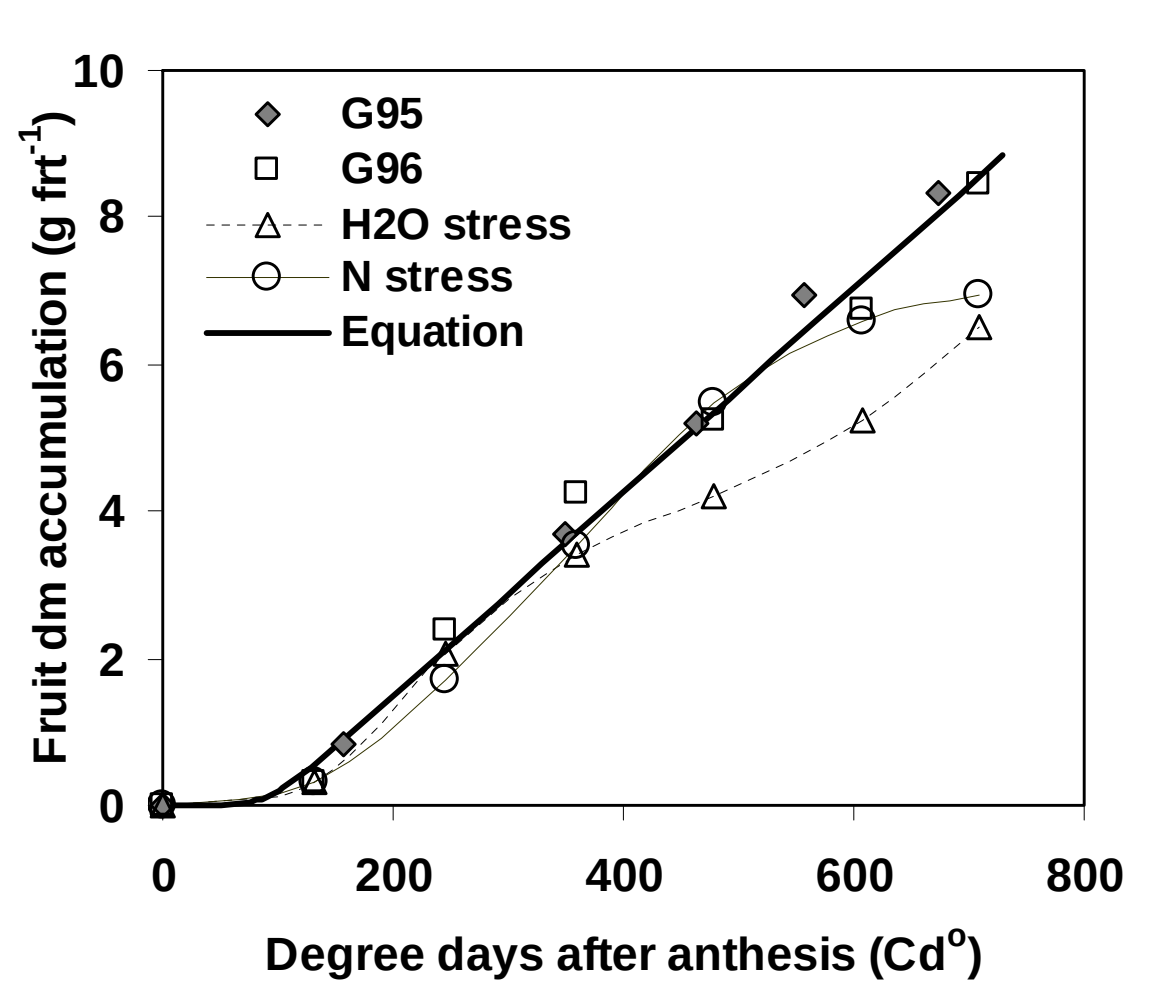
Predicting Tomato Fresh Weight & Size

We propose equations for predicting tomato fruit growth dynamics in terms of fresh weight and size, starting from C balance.

CROPGRO predicts fruit numbers added each day, and their respective fruit growth rates over time. As each individual cohort of fruits is added, each has its dry matter growth rate that is dependent on temperature and assimilate supply.

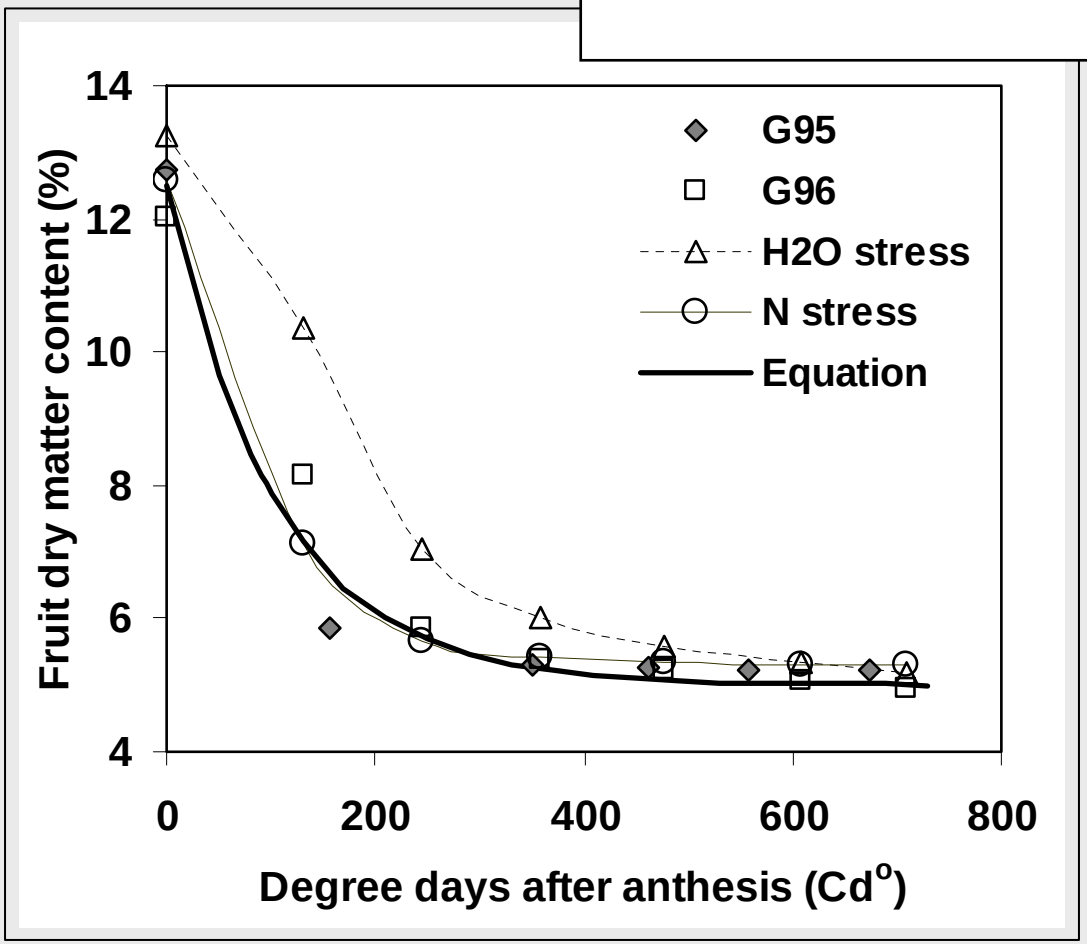
Dry matter accumulation of tomato fruits as a function of degree days after anthesis, for four treatments (Scholberg, 1997).



Growth in CROPGRO, although temp-dependent, is <u>not</u> a function of Cd °

Dry matter concn. of tomato fruits vs. degree days after anthesis, until maturity at 750 Cd°

$$DMP(Cd) = DMP_{\min} + a\left(\exp - b\frac{Cd}{Cd_{\max}}\right)$$



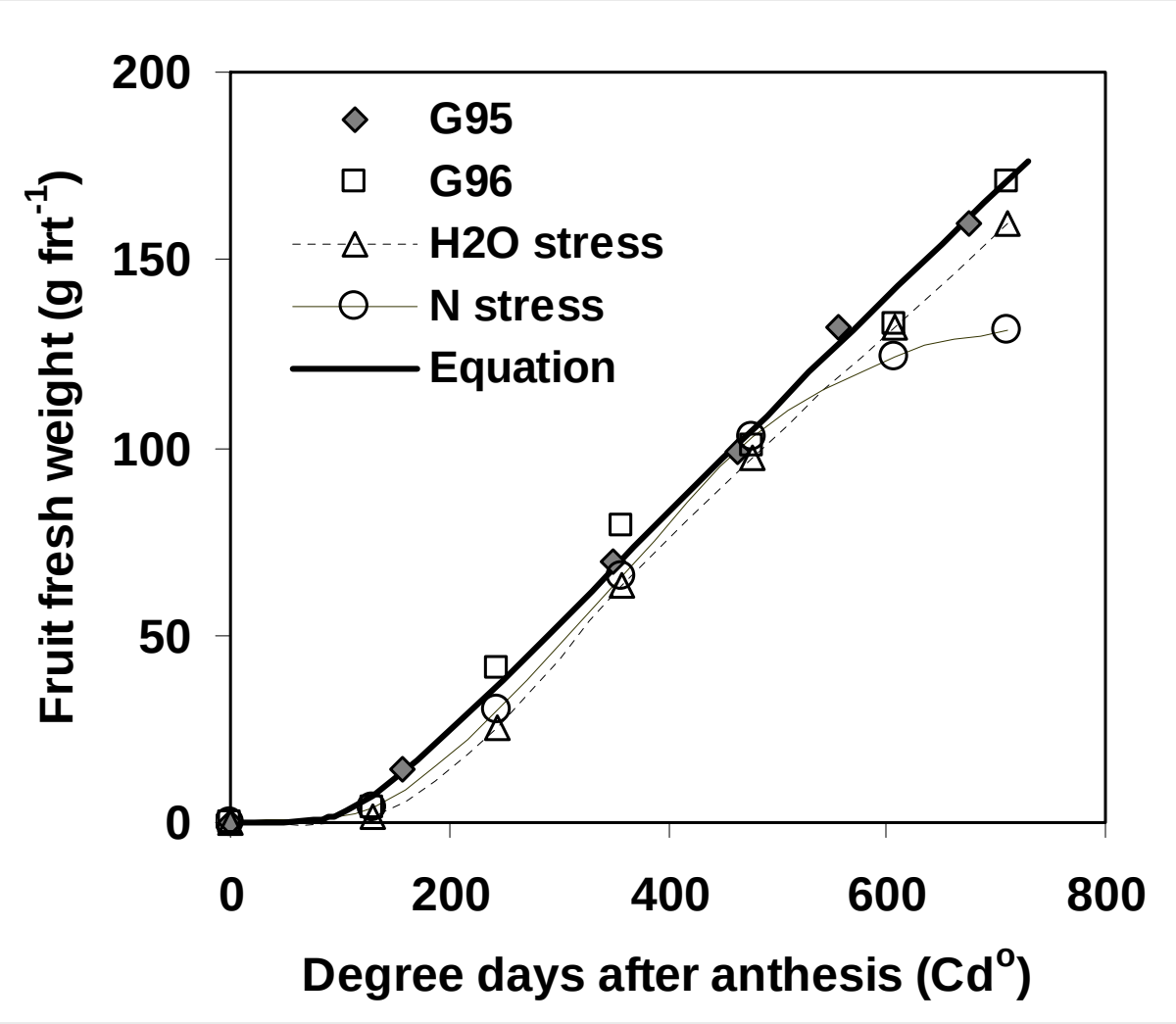
DMP min = 5%
a = 7.2
b = 7.5
Cd max = 750 C°d

Source: Scholberg 1997

To convert dry mass per fruit (Dw) to fresh mass per fruit (Fw):

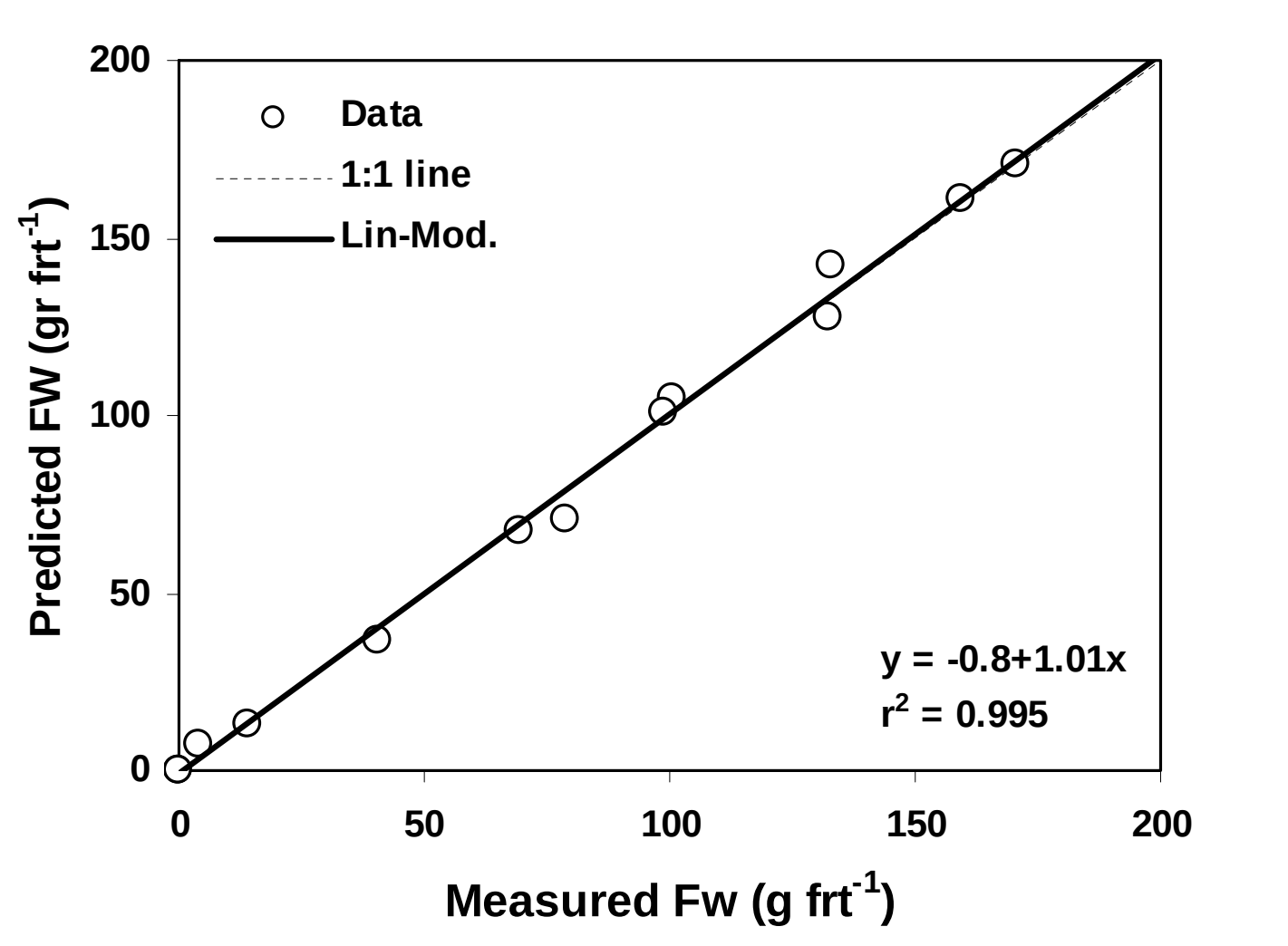
$$Fw\ (Cd\ ) = \frac{Dw}{DMC\ (Cd\ )}$$

Predicted fresh weight per fruit (based on dry weight & DMC) vs. degree days after anthesis



Source: Scholberg 1997

Predicted versus observed fresh weight per fruit (predictions used dry weight growth & DM/DMC)



Source: Scholberg 1997

Diameter as a function of fresh weight:

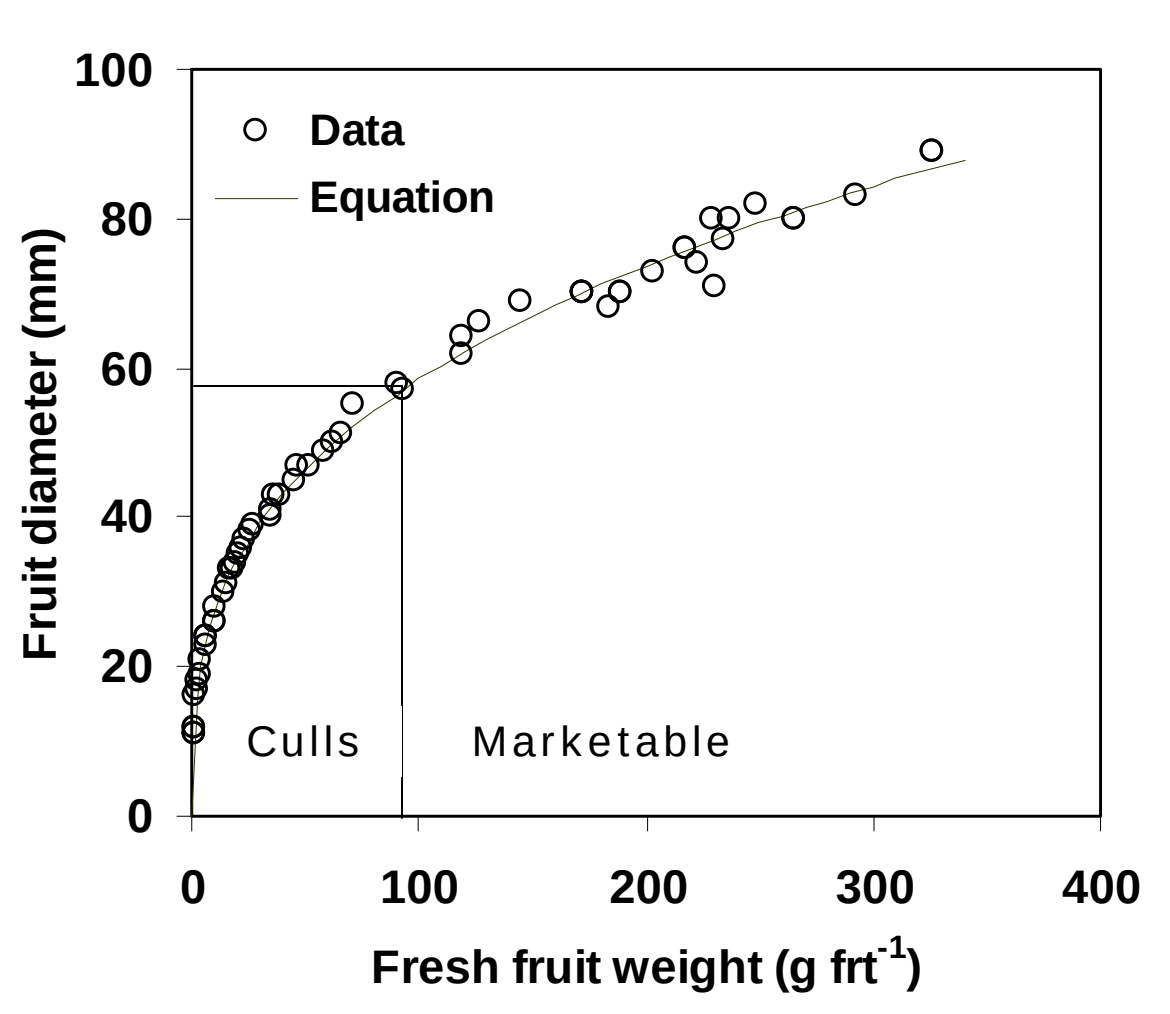
$$Diam\ (Fw) = 20 * \left(3 * \frac{Fw}{FC * 4} \right)^{\frac{1}{3}}$$

FC = 0.95 round fruits

FC = 1.05 oblong fruits

FC = 0.9 flat fruits

Size of tagged tomato fruits as a function of fruit fresh weight



Source: Scholberg 1997