How Increasing Temperatures Have Reduced Yields and Quality of Californian Tree Fruit in Warm Years

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While much of the climate change discussion is focused on log-term effects of global warming on general factors influencing crop production like photosynthesis, water use and availability, etc., recent experience in California indicates that problems related to tree fruit production may be more specific and immediate.

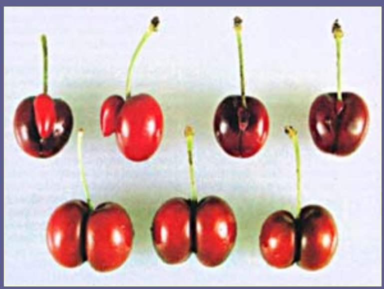
Many of these are related to developmental processes rather than assimilatory processes and will be more difficult to deal with in perennial crops than in annual crops.

Importance of Developmental Processes

- Developmental processes don't only drive organ growth and biomass yield.
- They influence whether there is a crop and the quality of the crop.
- In tree crops, crop quality is probably as much of an issue today as crop quantity.
- So first I will remind us about how climate change could affect developmental processes and crop quality.

Floral initiation and differentiation

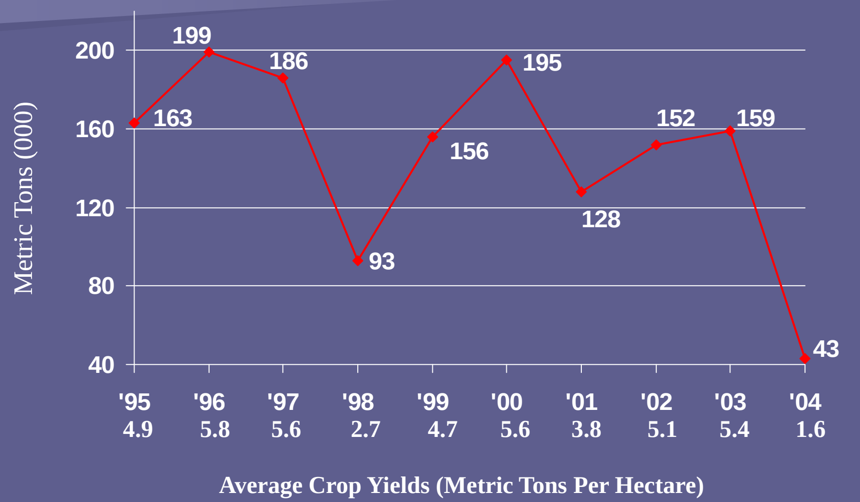
- Floral initiation and differentiation occurs during the summer and fall of the year prior to bloom.
- It is well documented that high heat and/or water stress during summer and early fall can cause fruit defects such as double fruits or deep sutures in cherries, peaches and prunes in the subsequent year due to developmental abnormalities.



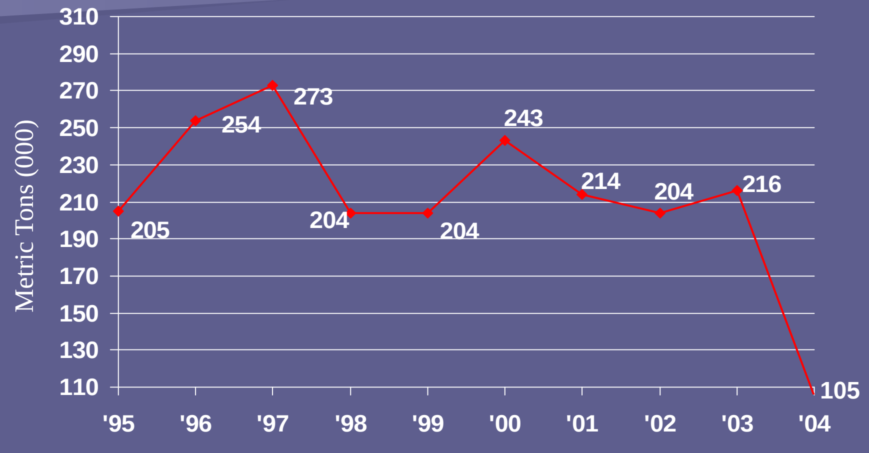
Flowering and fruit set

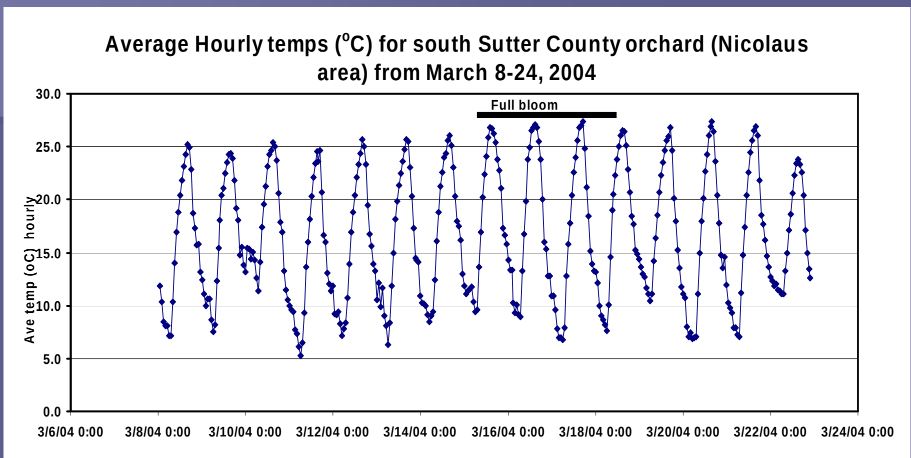
- Flowering date and characteristics of bloom are strongly affected by winter chilling (cumulative temp. 0 – 7 C) and post-rest heat accumulation.
- The central valley of California is generally considered a moderate to high chill region. Winter chilling in central valley is strongly affected by an insulating fog layer. Climate change will likely decrease the incidence of fog and winter chilling.
- Decreased winter chilling results in late and straggled bloom and can influence pollination, fruit set (+/-) or cause poor fruit quality.
- Some crops such as apricots and cherries are known to drop flower buds or not set any crop in extremely low chill years.

Fruit set of prunes is very negatively affected by high temperatures and dry winds during bloom.

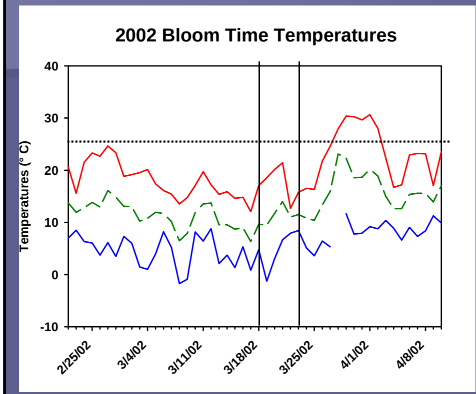


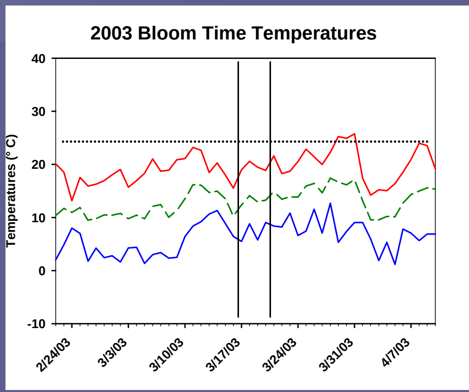
Natural Condition Supply





Spring Temperatures





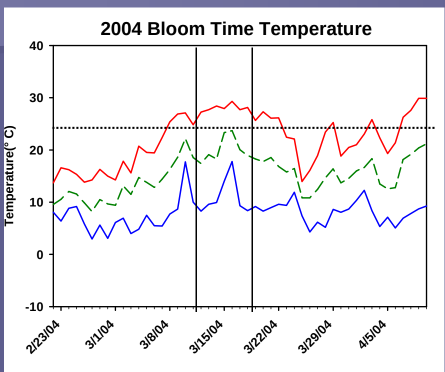
2002 French bloom
from 3/18 to 3/23

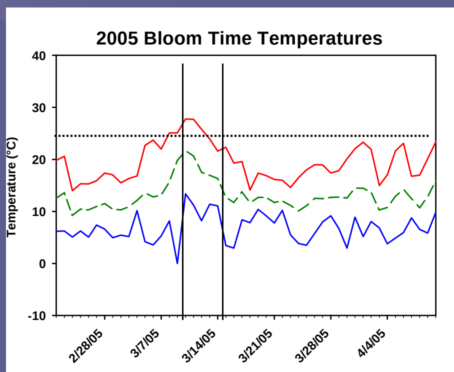
128,935 Net Metric Tons

2003 French bloom
from 3/17 to 3/21

152,712 Net Metric Tons

Spring Temperatures





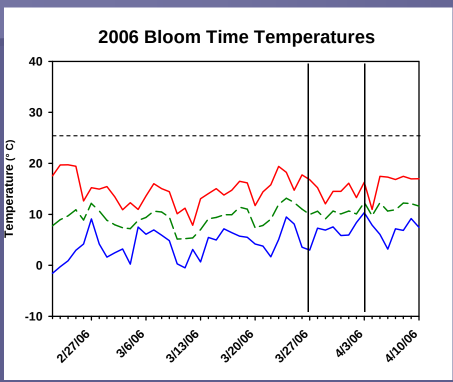
2004 French bloom from
3/11 to3/18

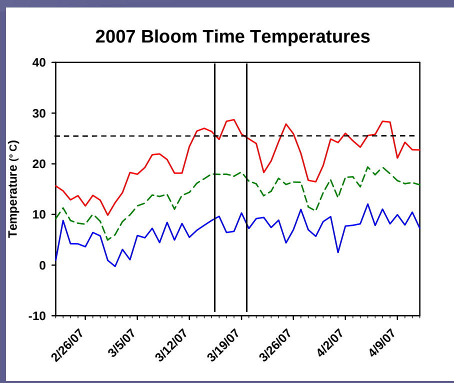
43,313 Net Metric Tons

2005 French bloom from
3/10 to 3/14

84,753 Net Metric Tons

Spring Temperatures





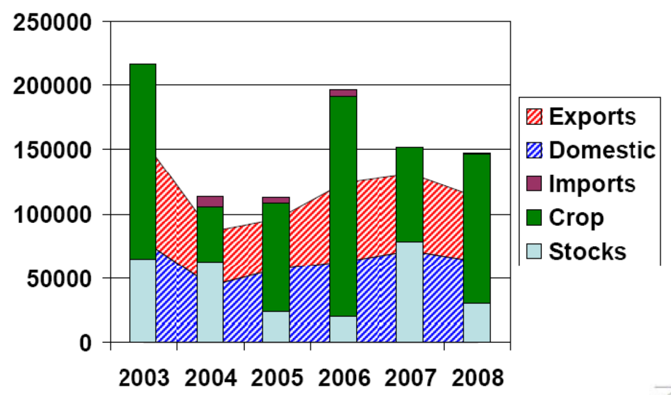
2006 French bloom from
3/27 to 4/6

171,250 Net Metric Tons

2007 French bloom from
3/16 to 3/20

86,167 Net Metric Tons

California



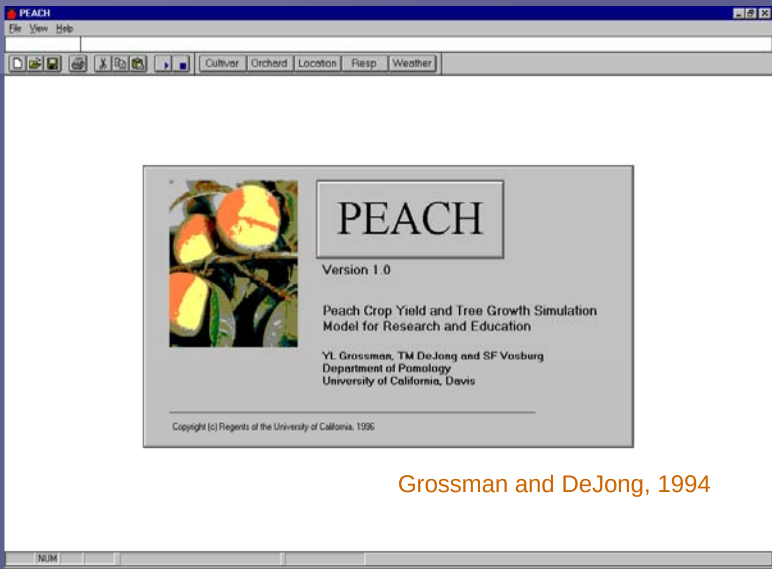
Inclement weather during harvest

- Rain near or during harvest increases the incidence of fruit brown rot and other fruit and nut diseases.
- Rain can also cause fruit cracking and destroy the crop.
- If climate change brings more variable weather, especially more late spring and summer rains it will have a major effect on tree fruit and nut quality and production.

What can crop models tell us about the likely general effects of warmer temperatures of fruit size and yield?

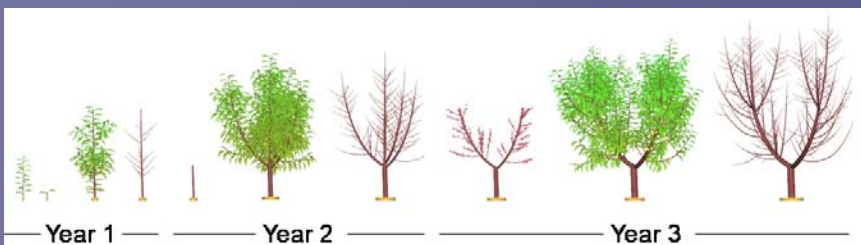
- Crop modeling is good for integrating assimilatory and developmental processes.
- Assimilation processes (determine the **supply** of carbohydrates and nutrients available to support growth and development)
- Developmental processes (drive organ initiation and rates of development and **demand** for carbohydrates and nutrients)

Simulation Model of Fruit and Tree Growth



Grossman and DeJong, 1994

Using the L-Peach Model to Study and Develop an Integrated Understanding of Tree Crop Physiology.



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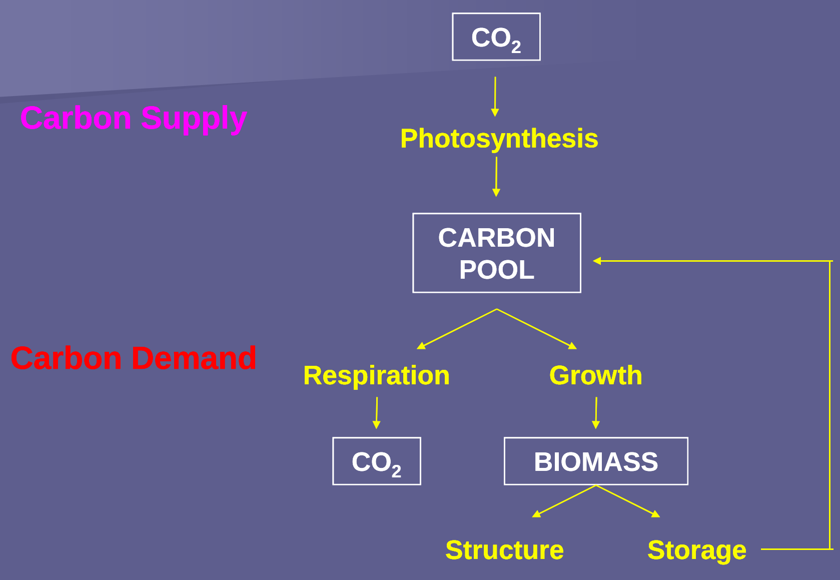
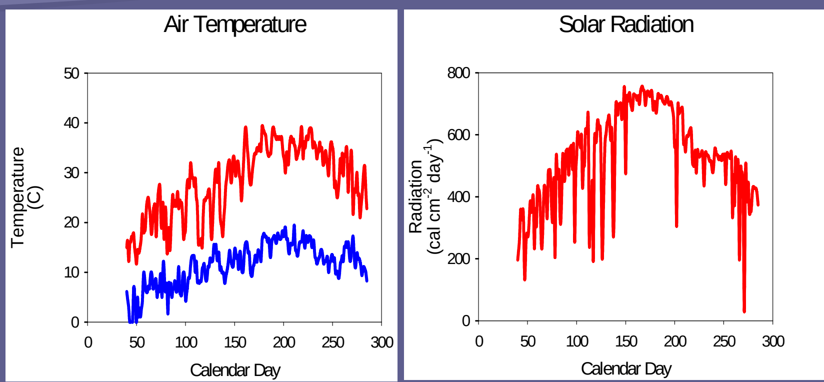
Carbon Budget

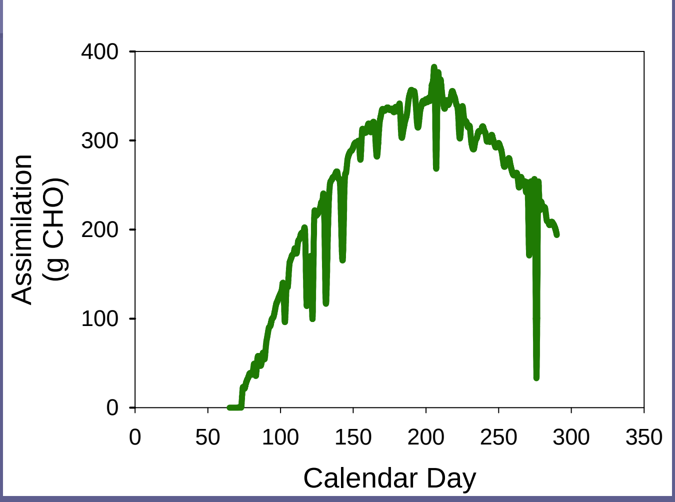


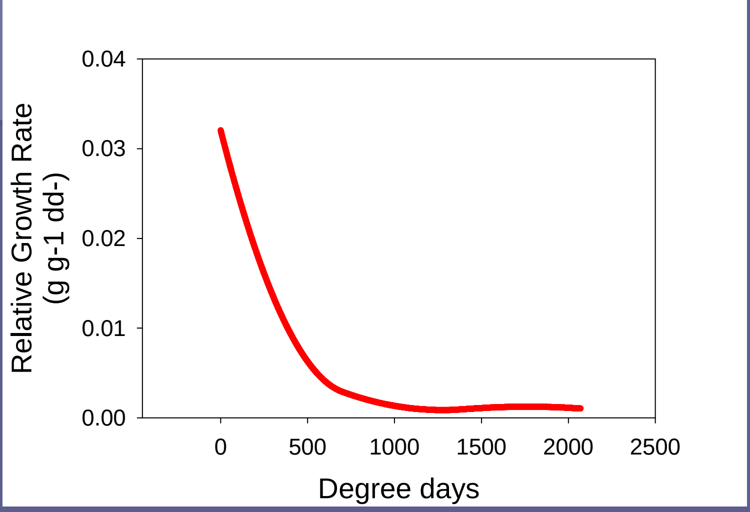
Environmental Parameters



Kearney Agricultural Center, 1994

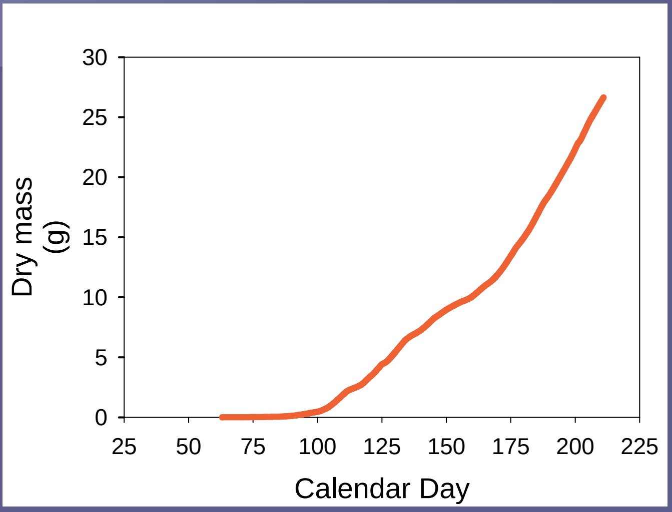
Simulated Carbon Supply: Daily Assimilation



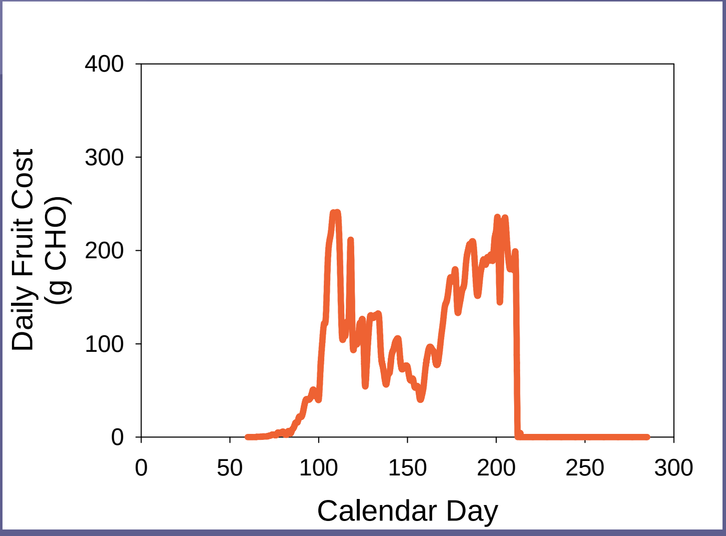


Grossman and DeJong 1995.
Annals of Botany 75:553-560.

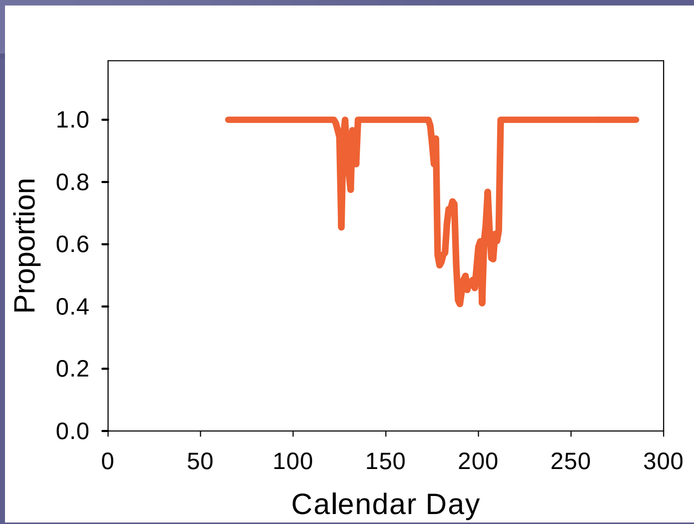
Individual Fruit Growth



Daily Carbohydrate Used for Fruit Growth / Tree

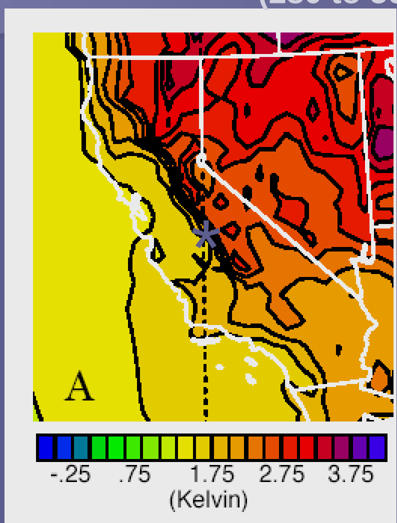


Fraction of Fruit Growth Allowed (periods of CHO limitation)



Increase in average temperature caused by doubling CO_2

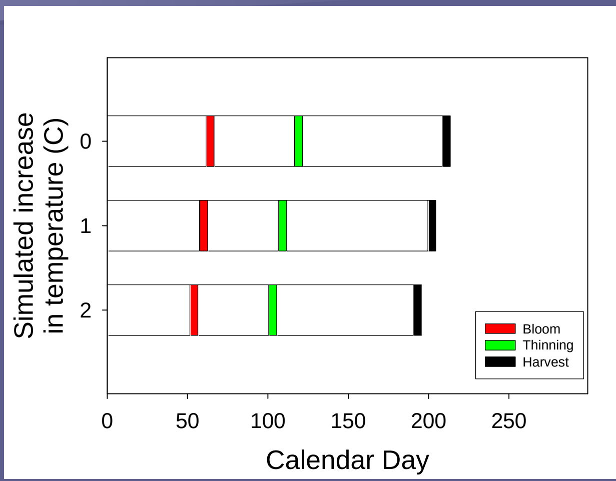
(280 to 560 ppm)



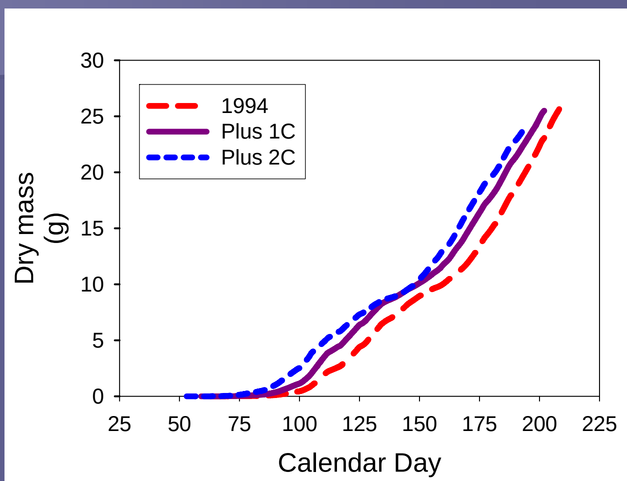
Kearney Agricultural Center

Simulations run by Y.L. Grossman, based on climate data by Snyder et al. 2002 http://es.ucsc.edu/~lcsloan/

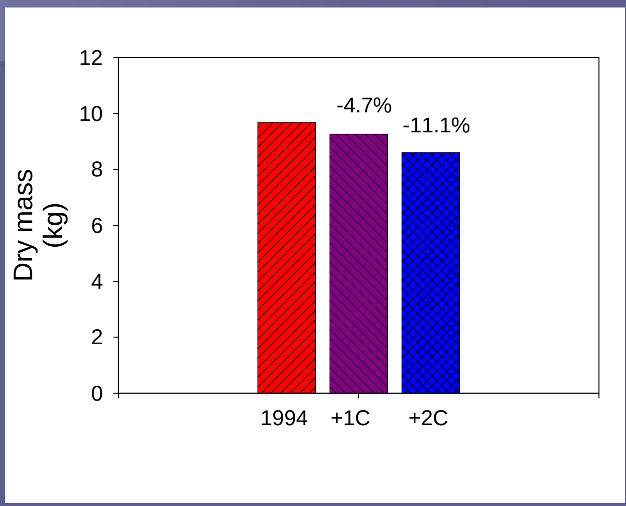
Peach Phenology: Bloom date and Fruit development rate depends on temperature



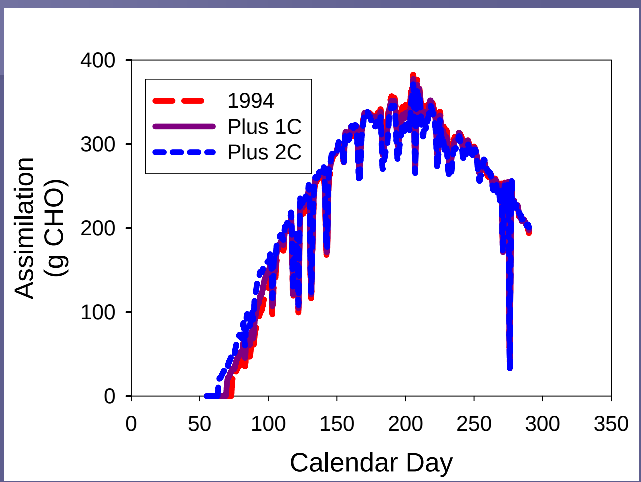
Individual Fruit Mass



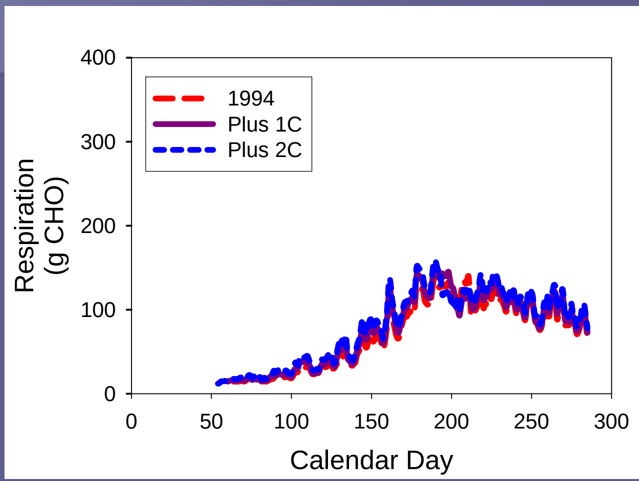
Crop Dry Mass at Harvest



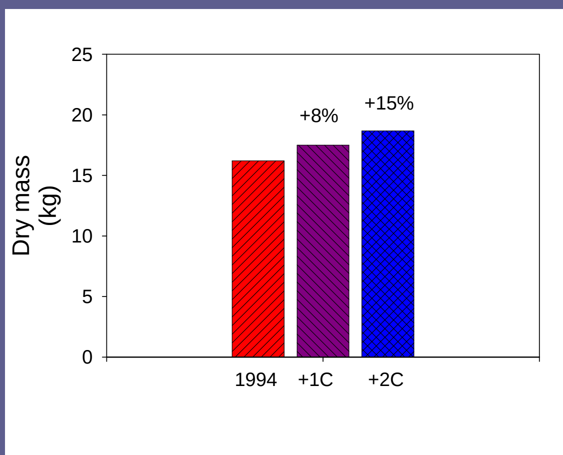
Daily Assimilation



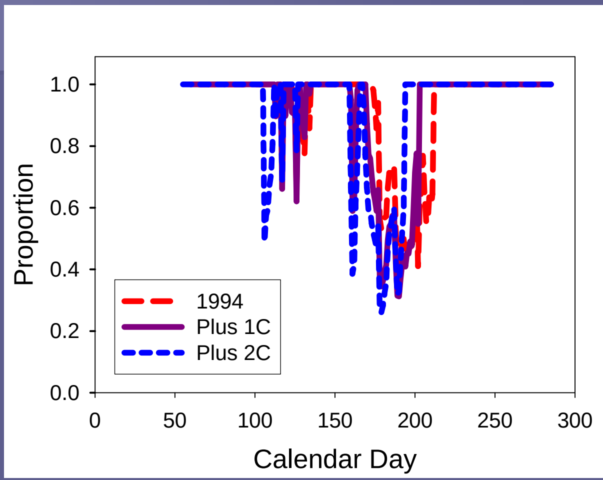
Daily Maintenance Respiration



Cumulative Maintenance Respiration



Proportion of Carbon Required for Growth that is Unavailable

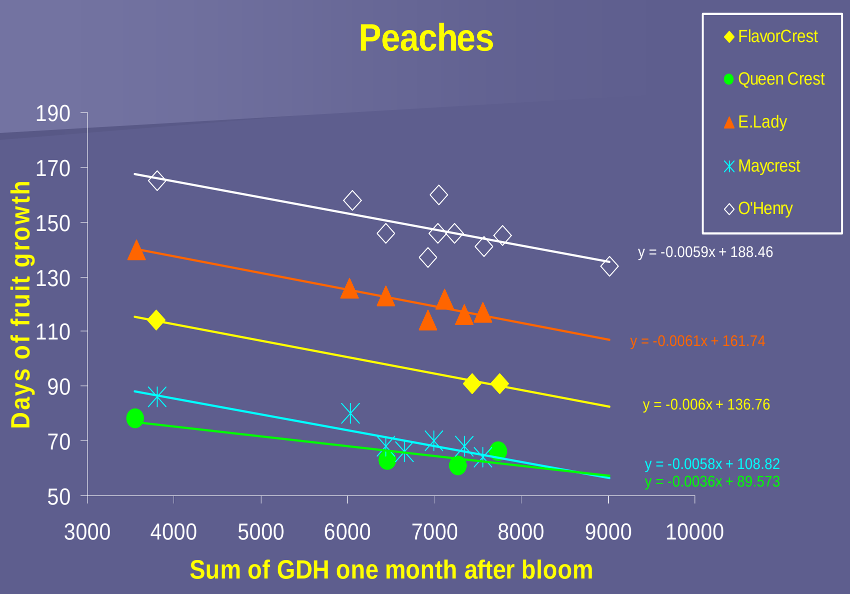


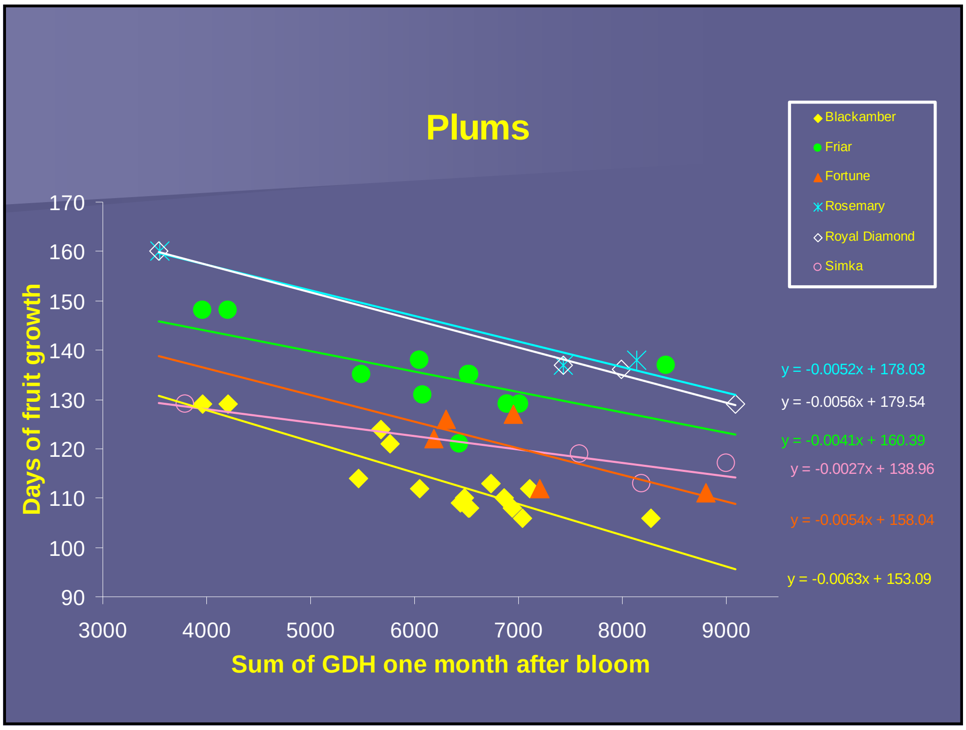
General Modeling Results

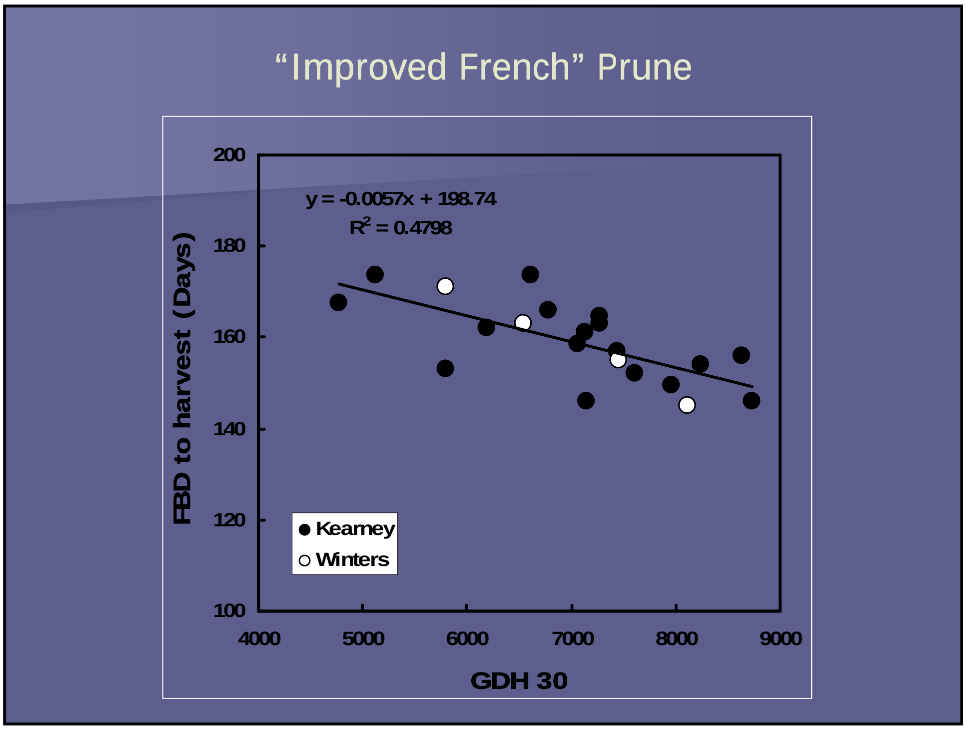
- Cumulative assimilation relatively unchanged with temp ↑
- Cumulative maintenance respiration ↑ with temp ↑
- Fruit development period ↓ with temp ↑
- Fruit size ↓ with temp ↑

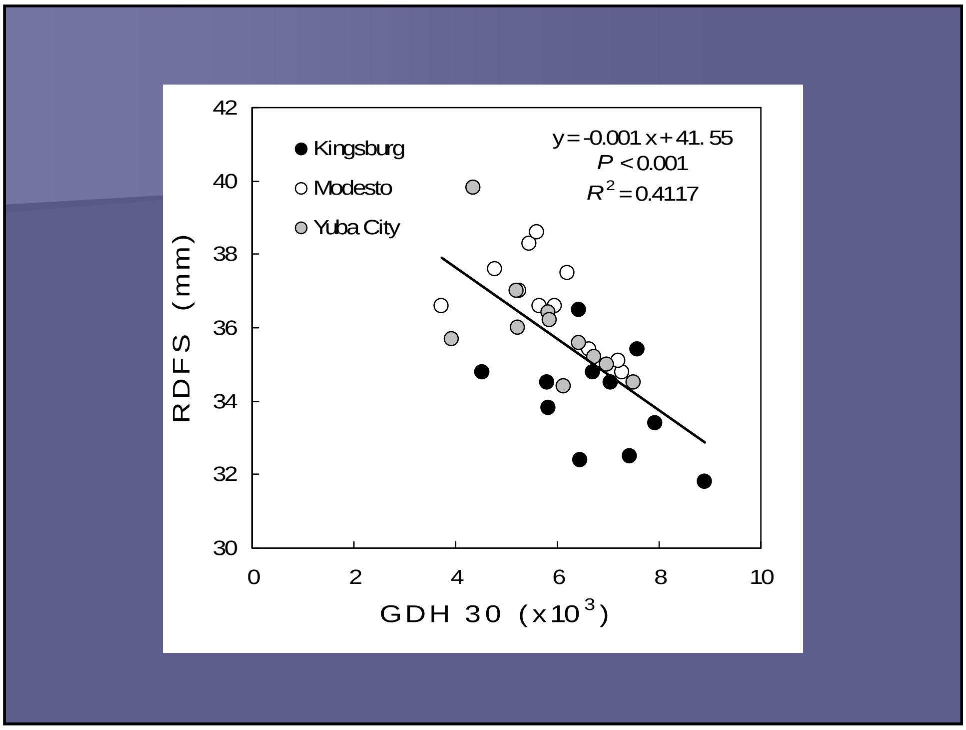
Temperature has a large effect on fruit developmental processes?

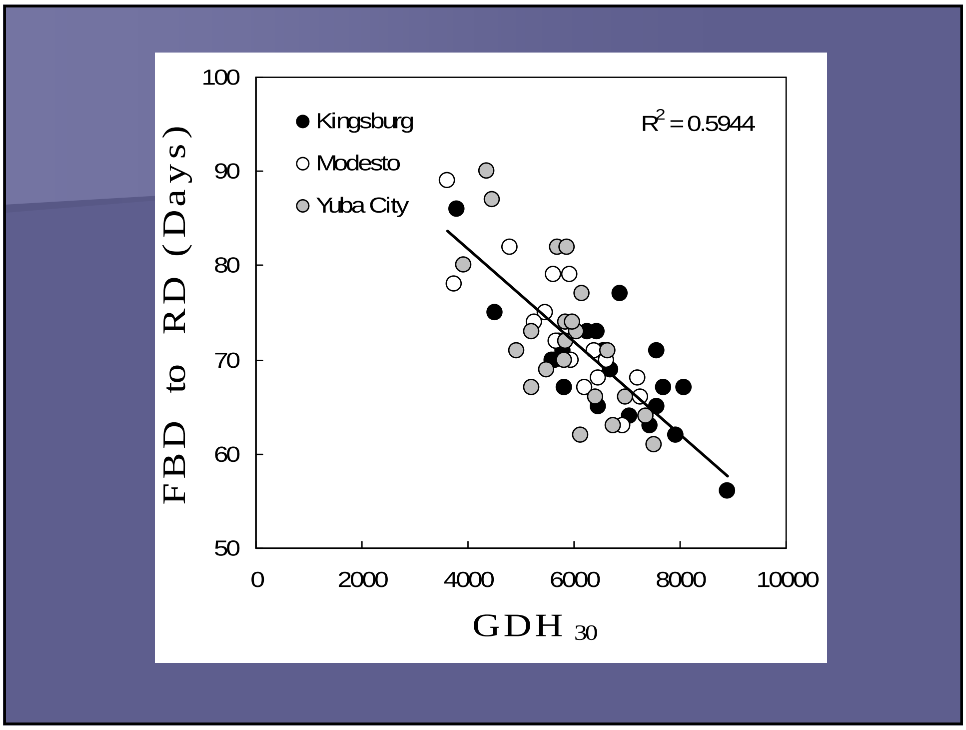
- Since this general modeling research was done we have discovered that rates of fruit maturity (time between bloom and harvest) are strongly controlled by **heat unit accumulation** between bloom and 30 days after bloom in stone fruits.

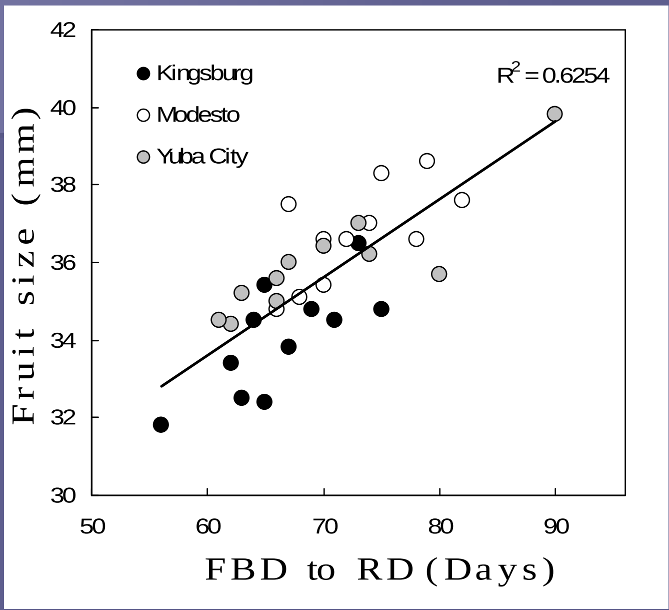



Plums
Blackamber
Friar
Fortune
Rosemary
Royal Diamond
Simka
Days of fruit growth
170
160
150
140
130
120
110
100
90
3000
4000
5000
6000
7000
8000
9000
Sum of GDH one month after bloom
y = -0.0052x + 178.03
y = -0.0056x + 179.54
y = -0.0041x + 160.39
y = -0.0027x + 138.96
y = -0.0054x + 158.04
y = -0.0063x + 153.09

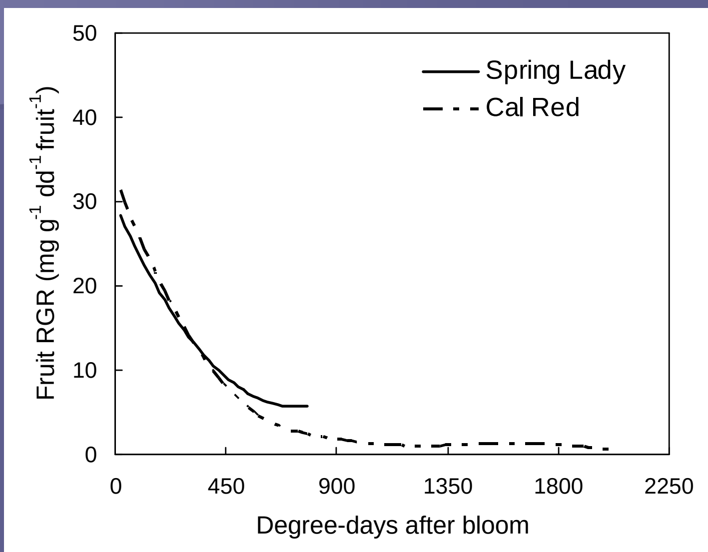

"Improved French" Prune
y = -0.0057x + 198.74
R2 = 0.4798
FBD to harvest (Days)
200
180
160
140
120
100
4000
5000
6000
7000
8000
9000
GDH 30
Kearney
Winters


Kingsburg
Modesto
Yuba City
y = -0.001 x + 41. 55
P < 0.001
R2 = 0.4117
RDFS (mm)
GDH 30 (x10 3)
42
40
38
36
34
32
30
0
2
4
6
8
10

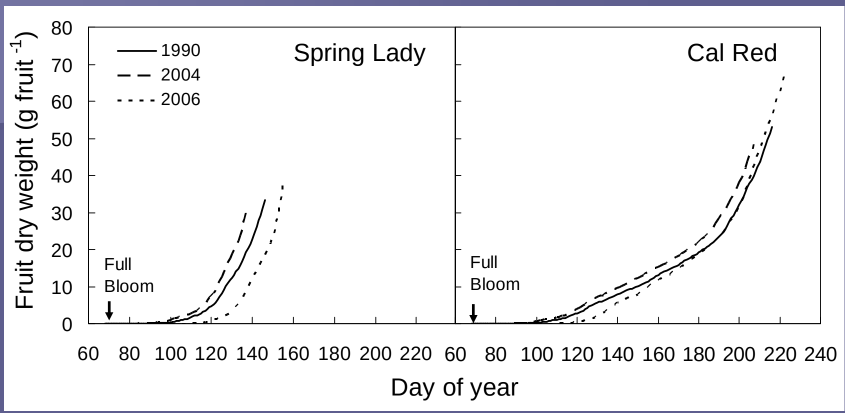

Kingsburg
Modesto
Yuba City
R2 = 0.5944
FBD to RD (Days)
GDH 30
100
90
80
70
60
50
0
2000
4000
6000
8000
10000



To understand why warm springs can cause small fruit we can use RGR models of fruit growth to predict rates of fruit carbohydrate demand in different years.



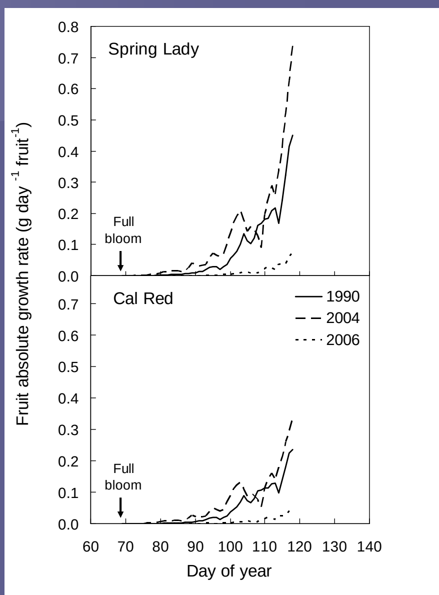
From Grossman and DeJong 1995



If we use the RGR functions shown on the previous slide to project potential fruit dry weight growth for three contrasting seasons we see substantial differences in the timing of potential fruit sink demands for carbon.

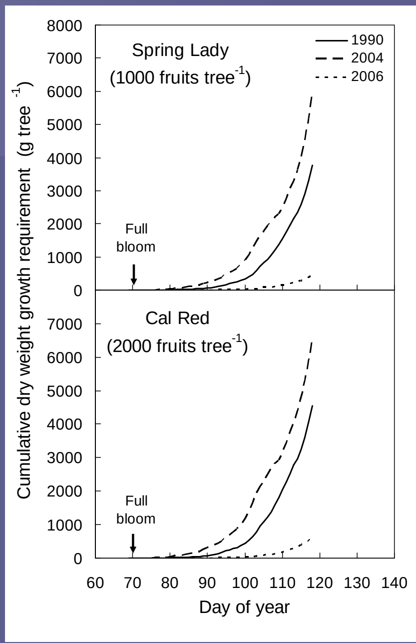
Lopez et al. 2009, Acta Hort in press

The differences between seasons is even more apparent when potential absolute fruit growth rates of individual fruits are calculated for the first 50 days after bloom.



Lopez et al. 2009, Acta Hort in press

When the individual fruit growth demands are compounded by pre-thinning crop loads during the first 50 days after bloom, the differences in potential carbon demand by the fruit among years is really apparent.



Lopez et al. 2009, Acta Hort in press

Using a critical value of 6000 for GDH 30 we would predict substantial sizing problems in 2 out of the 6 past years; near normal sizes in three of the 6 years and large sizes in 1 year.

Experience tells us that peach fruit sizes were small in 2004 and were also a problem in 2007. Fruit sizes were exceptionally large in 2006.

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Harvest Prediction Module for Peaches, Plums, and Nectarines
CIMIS weather station: Parlier (#039 - Fresno County)
How to interpret the data in the table, below

Days after Bloom	Bloom Date					
	Mar 5 2007	Mar 6 2006	Feb 28 2005	Mar 8 2004	Mar 3 2003	Mar 5 2002
	Accumulated Growing Degree Hours (GDH)					
1	548	250	373	613	256	370
2	845	328	536	954	385	536
3	1,062	444	728	1,282	562	593
4	1,258	473	956	1,601	743	755
5	1,460	483	1,148	1,915	933	943
	. . . .					
25	6,545	3,012	5,733	7,522	5,575	4,391
26	6,832	3,174	5,912	7,867	5,854	4,678
27	7,153	3,374	6,179	8,157	6,125	4,947
28	7,464	3,620	6,344	8,401	6,418	5,245
29	7,767	3,835	6,492	8,669	6,650	5,581
30	8,095	3,931	6,625	9,001	6,749	5,852

Summary

- Fruit and nut production and profitability could be in jeopardy if climate change brings more variable and higher temperatures and alters summer rainfall patterns.
- The most immediate issues for prune growing in California appear to be:
  - high temperatures during bloom that reduce fruit set
  - high spring temperatures for 30 days after bloom that shorten the fruit development period and thus decrease fruit size
- Due to their perennial nature (long-lived plantings and slow breeding times) adapting these crops to climate change will be more difficult than with annual crops.

Thanks for you attention

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