TRENDS, CHALLENGES AND ADVANCES IN FRUIT CROP PRODUCTION IN CALIFORNIA

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California Crop Acreage Trends (2005-2014)

Apples	24000	15000
Apricots	12600	9500
Cherries	25000	**33000**
Figs	12000	7000
Kiwifruit	4500	3900
Nectarines	34000	21000
Olives	32000	**37000**
Peach (clingstone)	30400	20000
Peach (freestone)	33000	24000
Pears (Bartlett)	12000	8500
Pears (other)	4000	2600
Plums (fresh)	32000	18000
Plums (dried prunes)	67000	48000

CDFA 2015 Crop Statistics

California Crop Acreage Trends (2005-2014)

Nuts		
Almonds	590000	870000
Pecans	2800	2950
Pistachios	105000	221000
Walnuts	215000	290000
Others		
Blueberries	1900	4800
Mandarins (etc.)	13000	46000
Grapes (raisin)	240000	190000
Grapes (table)	83000	110000
Grapes (wine)	477000	565000

CDFA 2015 Crop Statistics

Note, just in case you are wondering:

California peach and nectarine growers have tried:

- White-fleshed sub acid
- White-fleshed normal acid
- Yellow-fleshed sub acid
- Flat (doughnut) shaped fruit

But today the majority of new plantings involve yellow-fleshed normal flavored varieties. Flavor and size of new early season cultivars has improved over past few years.

Challenges

- Droughts
- Changing Climate
  - Warmer winters (less chill)
  - Erratic/warmer springs
  - Warmer summers
- Increased N fertilizer regulations
- Rising labor costs/ shortages

Drought

In spite of what some “scientists” may tell you, there is no known plant biological answer for maintaining high levels of productivity while coping with drought.

Crop productivity is a direct function of crop light interception and the use of light energy to carry out photosynthesis.

Solar energy absorbed by chlorophyll

Photosynthesis →

Water + Carbon dioxide ⇌ Carbohydrates + Oxygen

(H_2O) (CO_2) $(CH_2O)_n$ (O_2)

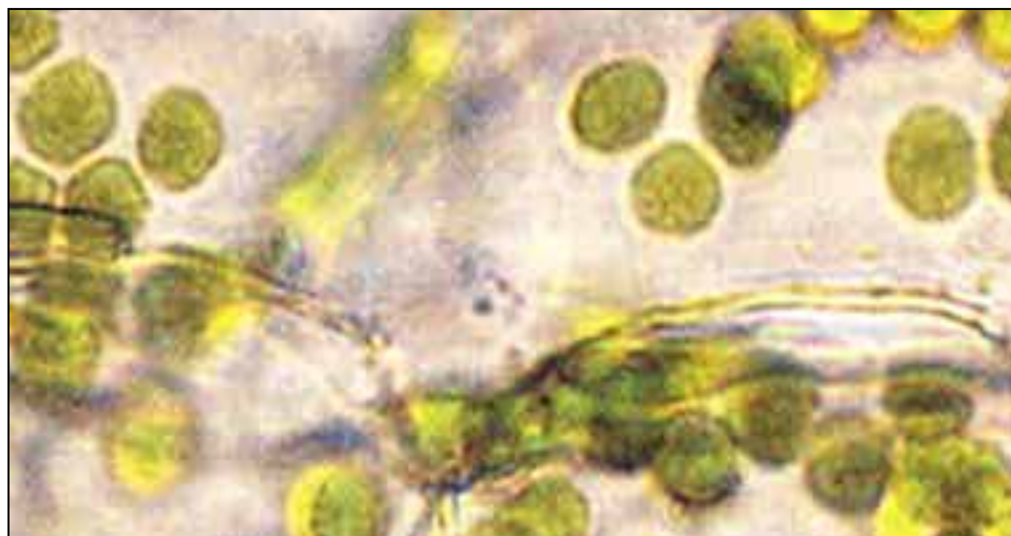
← Respiration

(O_2)

(O_2)

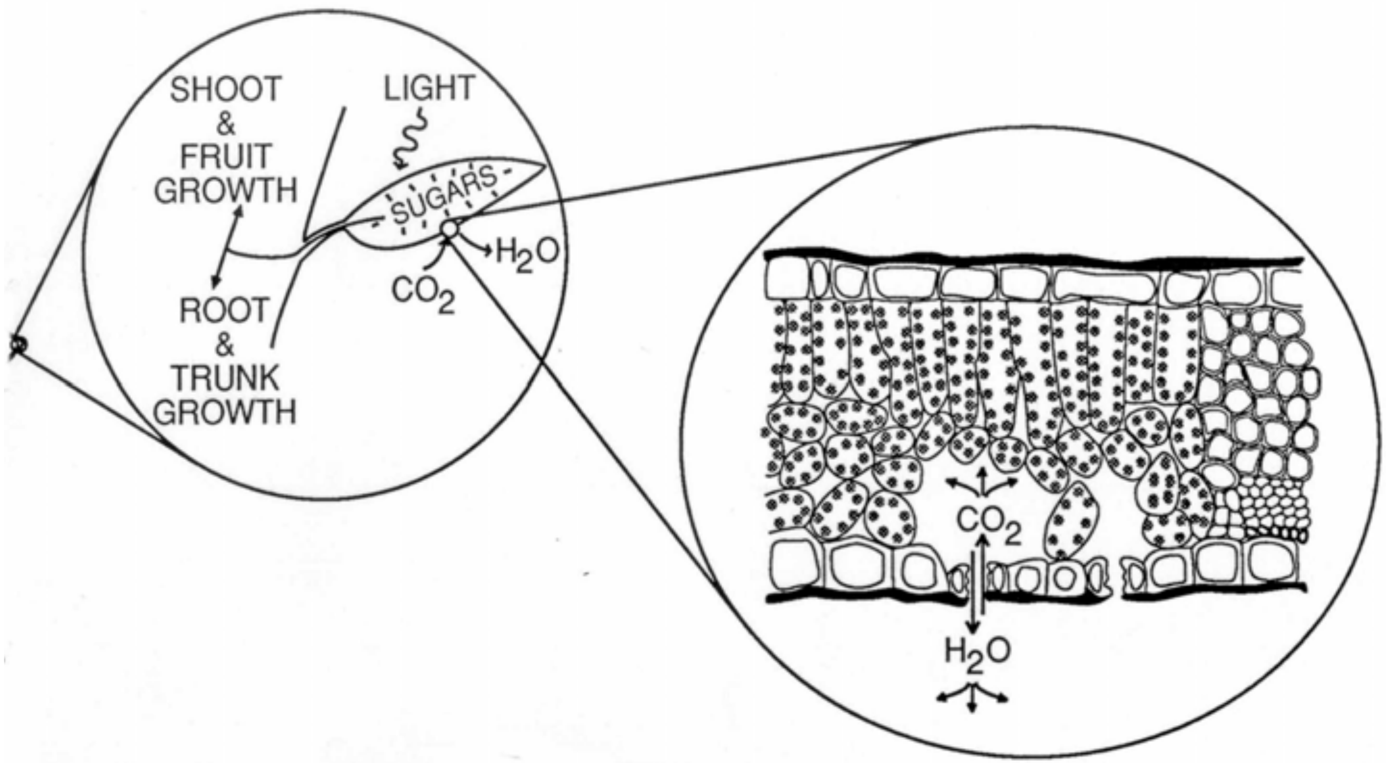
Chemical energy
To build and repair

Photosynthesis is done in the chloroplasts in leaf cells.

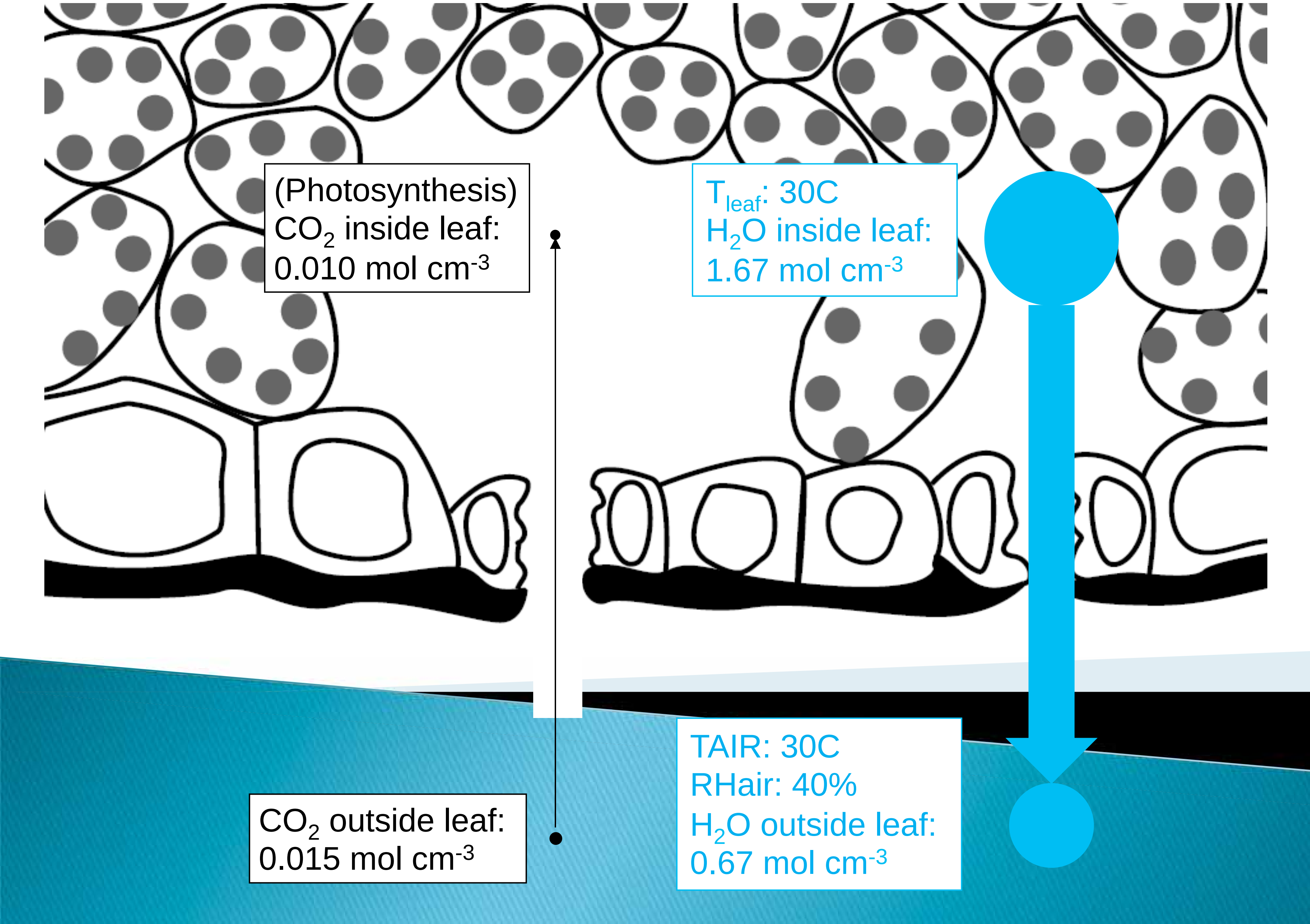


- The primary function of leaves is to house and display the **chloroplasts** for solar energy collection.
- Problem: **chloroplasts need an aqueous environment to function**, air is dry and CO_2 from air is required for photosynthesis.

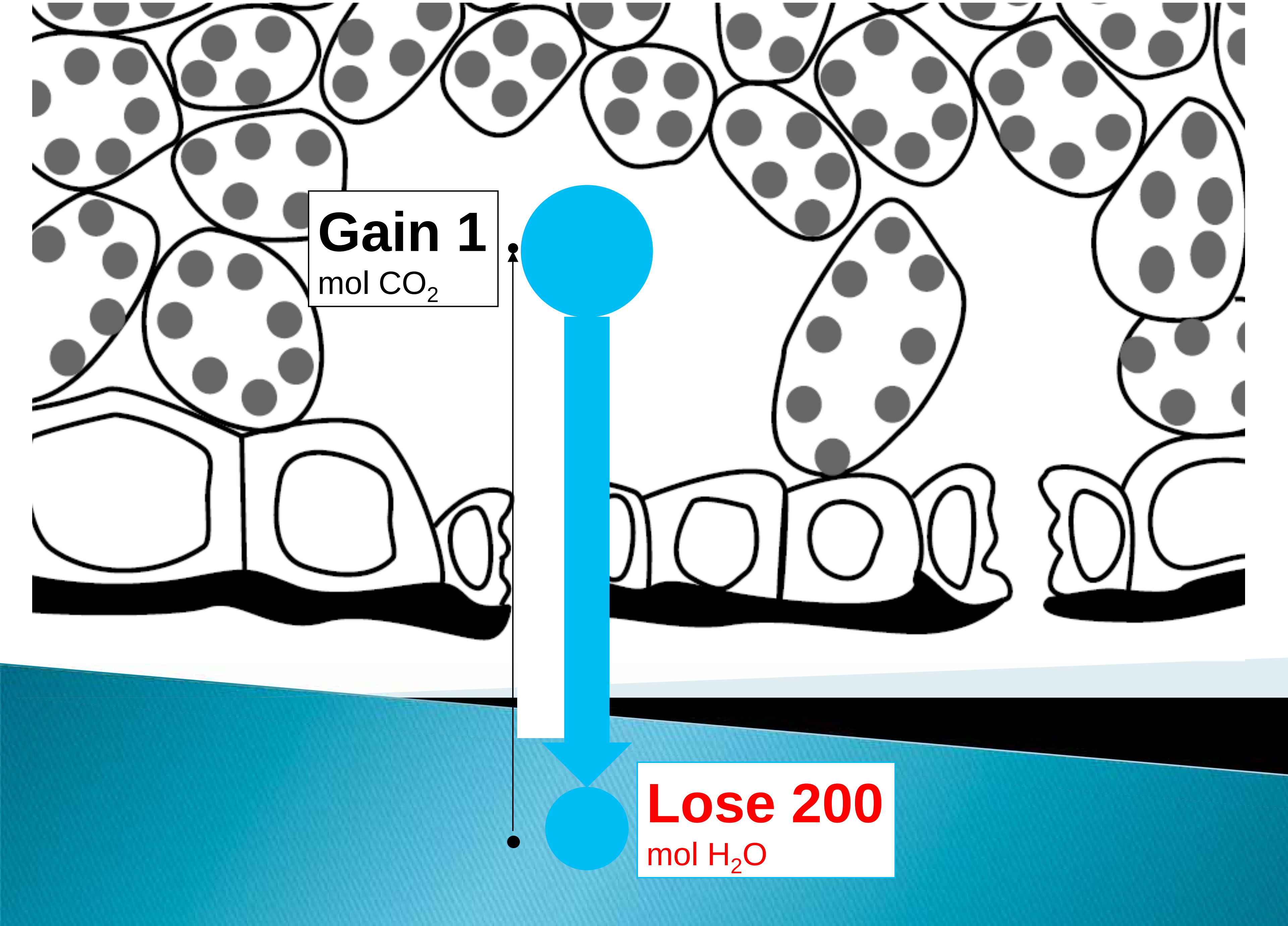
Stomata must remain open to allow CO_2 into the leaf for photosynthesis and sugar production.



But at the same time, they allow water to escape (evaporate). Water loss is the cost that the plant must pay to be productive.



(Photosynthesis)
CO_2 inside leaf:
0.010 mol cm^{-3}
T_{leaf}: 30C
H_2O inside leaf:
1.67 mol cm^{-3}
TAIR: 30C
RHair: 40%
H_2O outside leaf:
0.67 mol cm^{-3}
CO_2 outside leaf:
0.015 mol cm^{-3}


Gain 1
mol CO_2
Lose 200
mol H_2O

Drought

Is it reasonable to try to develop drought resistant rootstocks for fruit and nuts production?

No, tree survival during drought is not the problem. Drought resistant rootstocks do not address the fundamental photosynthesis-water loss problem.

Drought

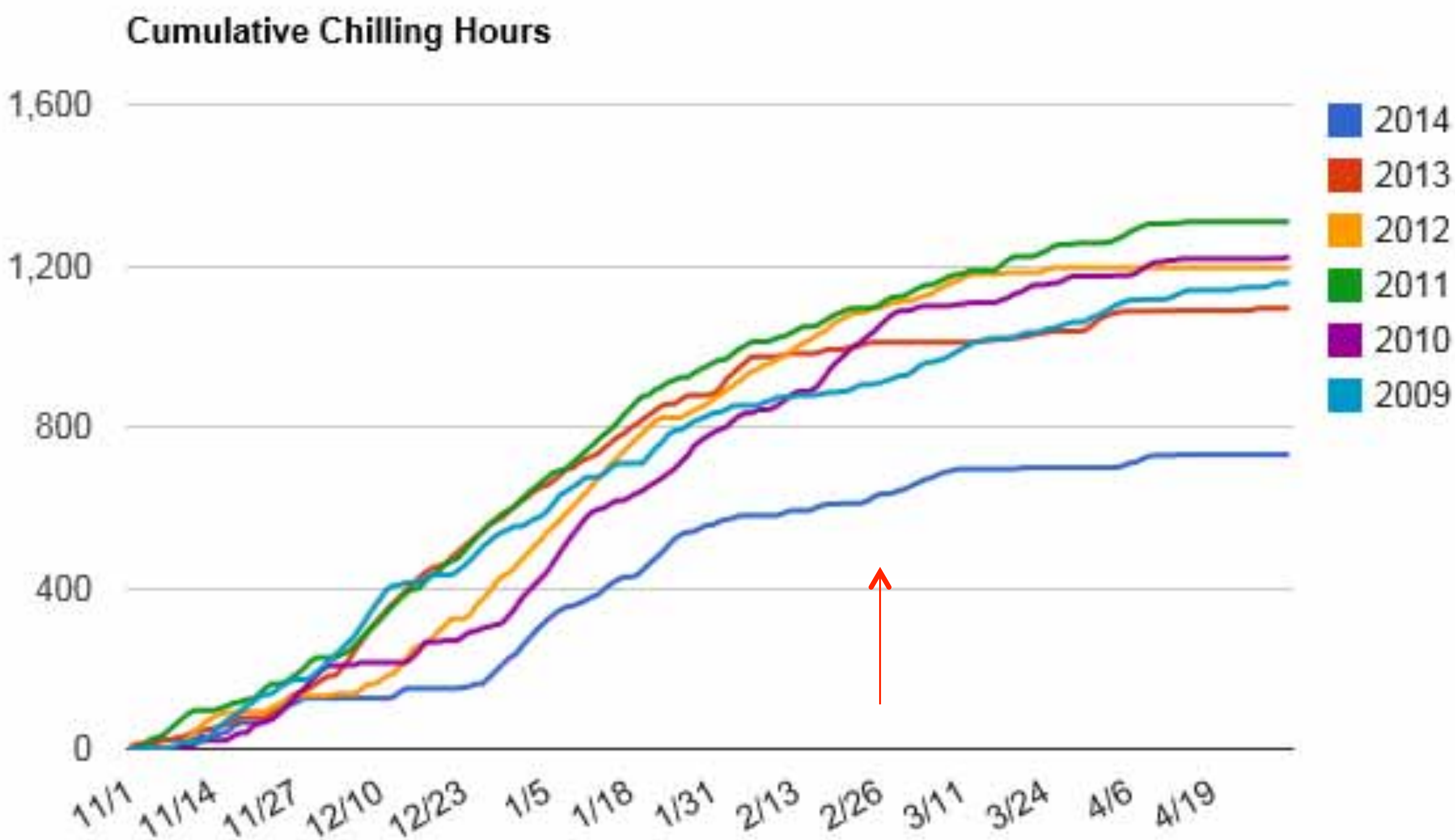
The only way to address drought is to optimize irrigation systems, scheduling and general practices and implement water conservation/regulated deficit irrigation where feasible.

http://ciwr.ucanr.edu/California_Drought_Expertise/Drought_information/

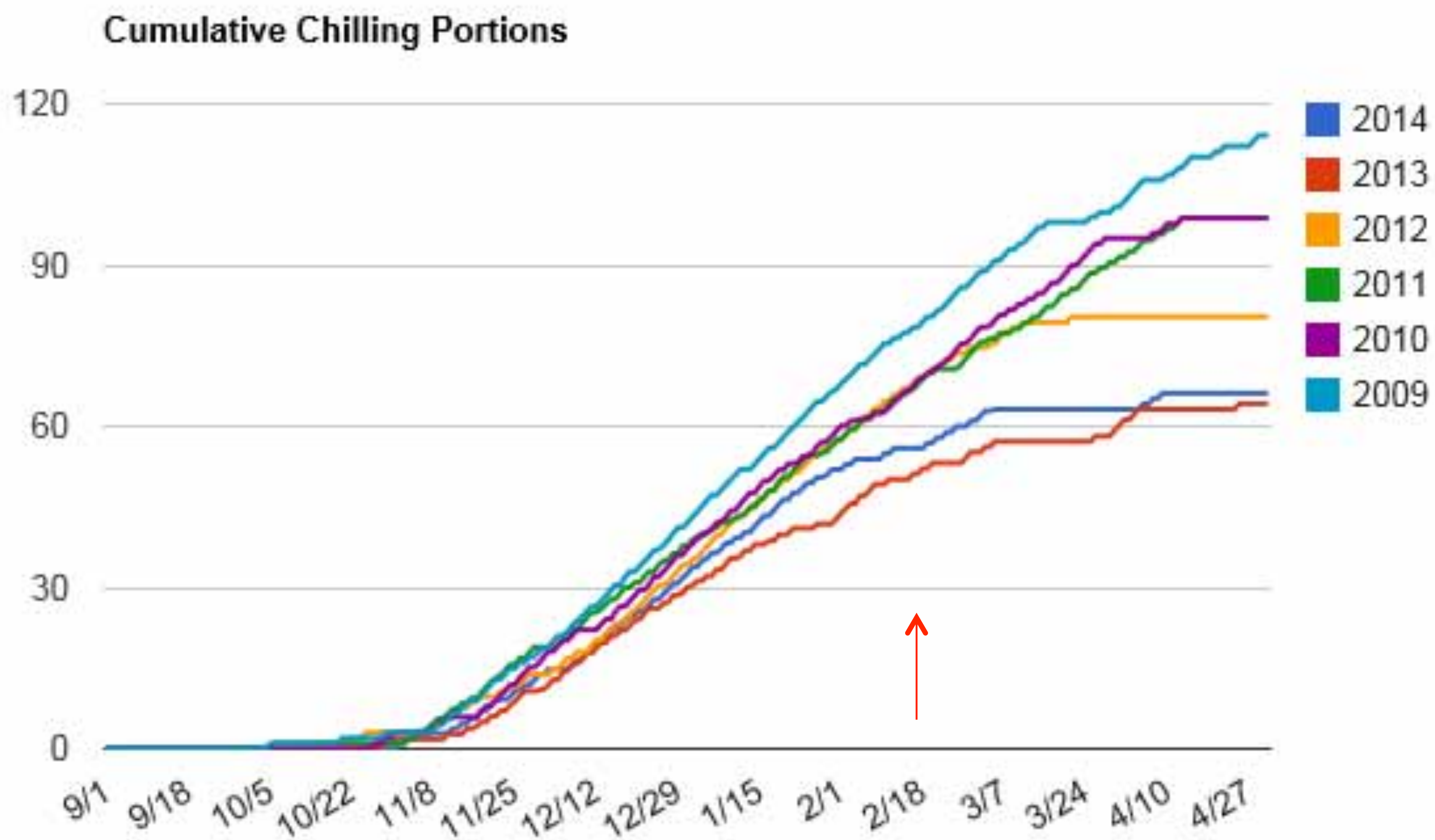
Changing climate – warmer winters

- Lack of chilling can primarily be dealt with by switching to lower chill requiring cultivars/crops.
- Dormancy breaking chemicals can work in some cases but they are really just a temporary solution.
- There is some recent research done by my colleagues at UCD that indicate that CHO metabolism is still very active during “dormancy” and that large day/night temperature fluctuations in winter may deplete CHO reserves and affect subsequent cropping.

According to traditional measures Californian Central Valley winter chill was particularly low in 2014.



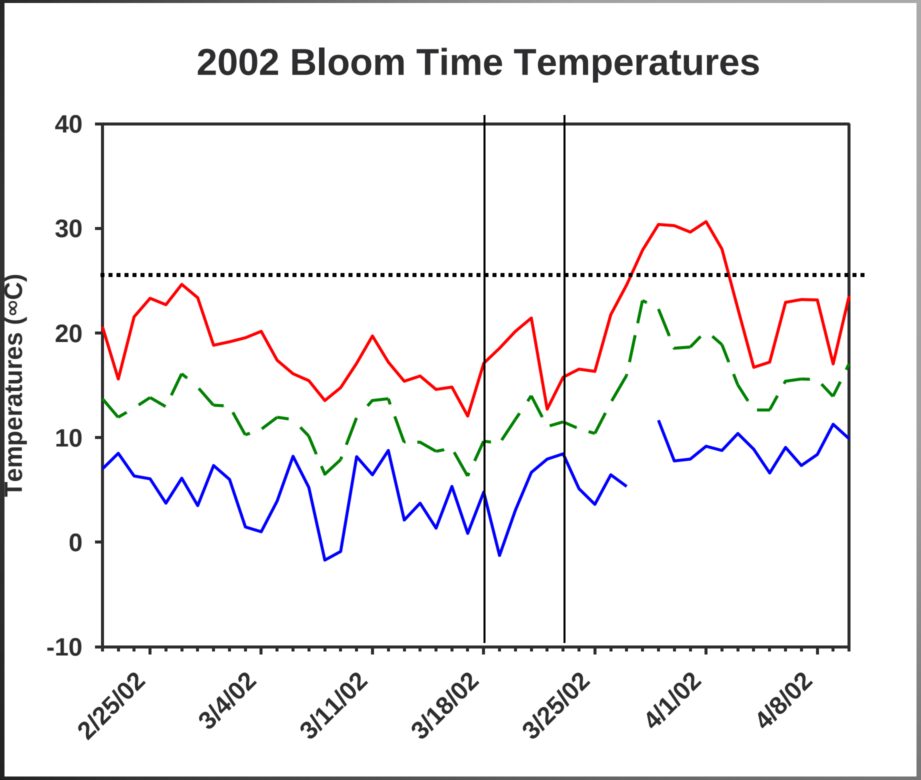
However, in 2013 trees also showed signs of lack of chill. The chill portion model is apparently giving results that better reflect how the trees react.

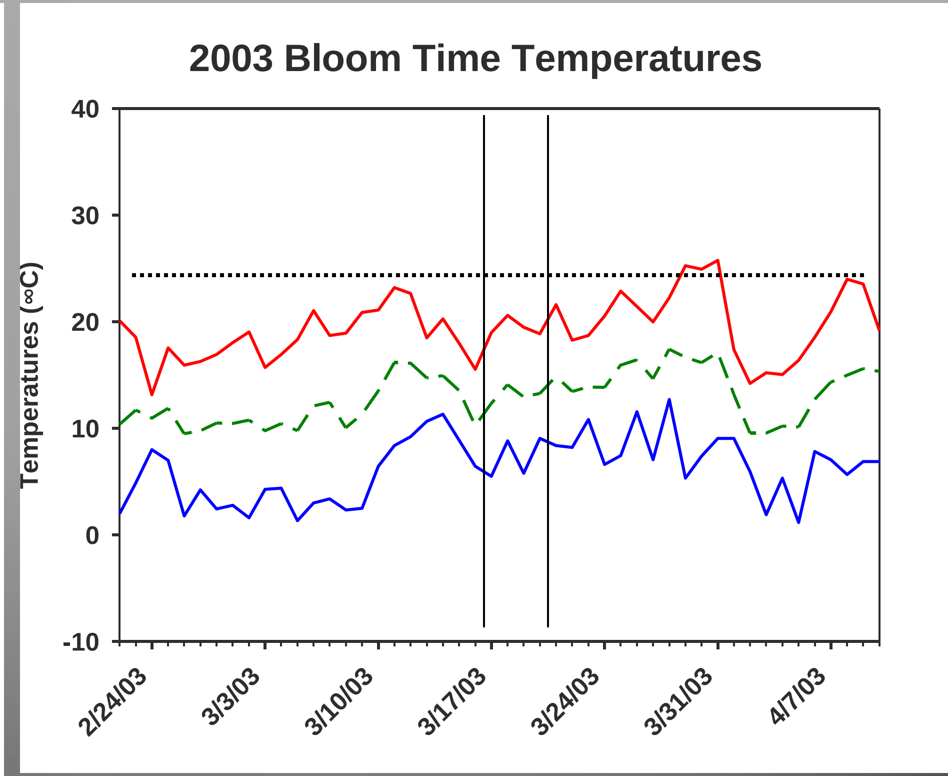


Changing climate – erratic springs

- California prune production is dependent on one cultivar, ‘Improved French’
- This cultivar does not set fruit when temperatures during bloom are > 25 ^{o}C
- Temperature spikes during bloom have caused reduced crops in prunes in 5 out of 12 years.

Spring Temperatures





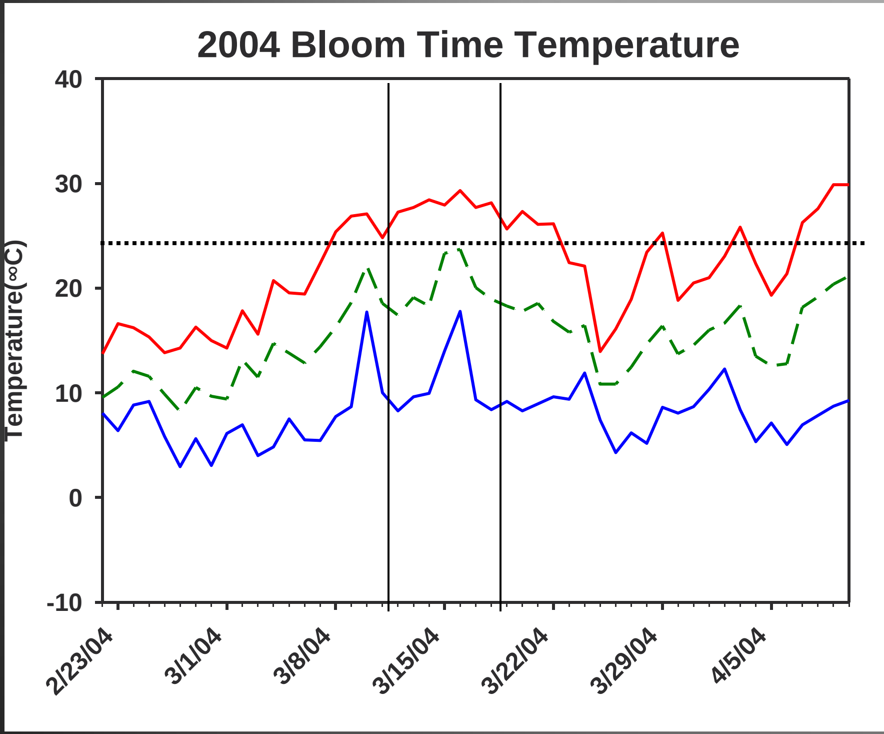
2002 French bloom
from 3/18 to 3/23

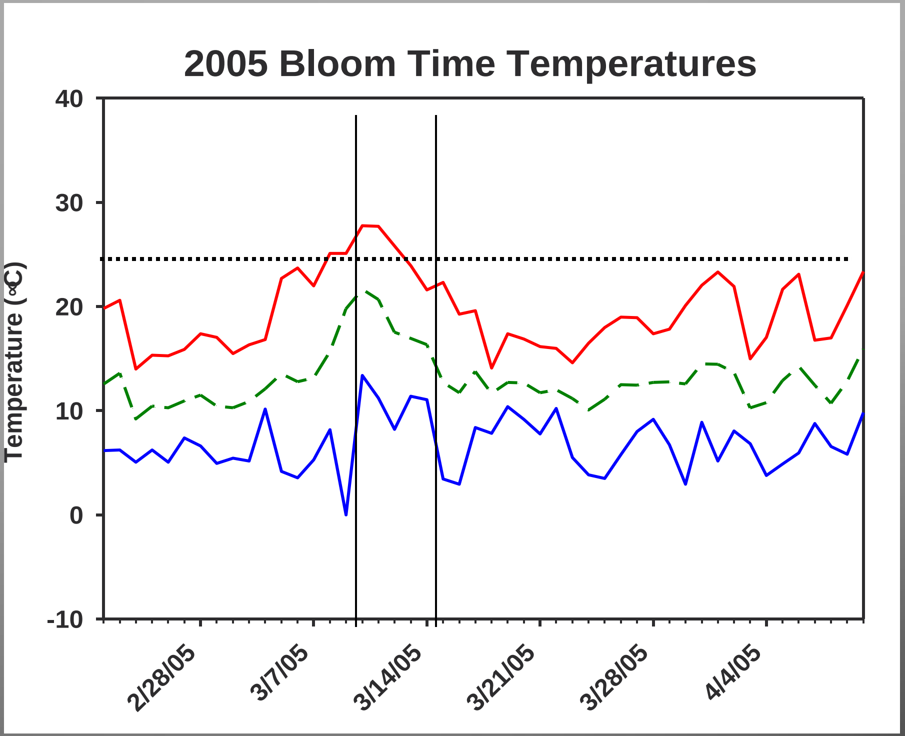
128,935 Net Metric Tons

2003 French bloom
from 3/17 to 3/21

152,712 Net Metric Tons

Spring Temperatures





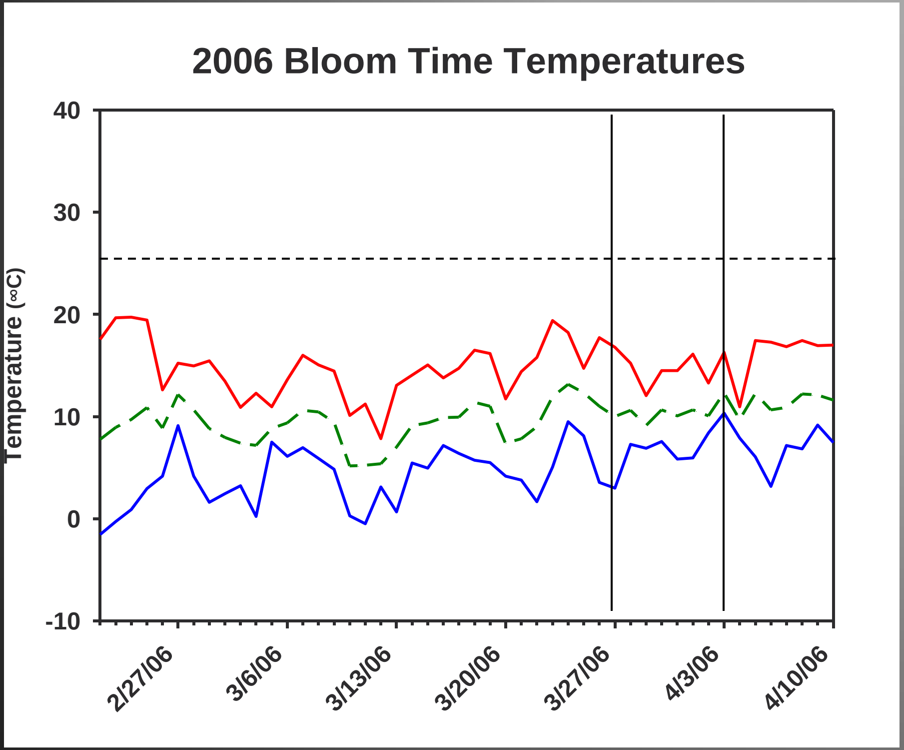
2004 French bloom from 3/11 to3/18

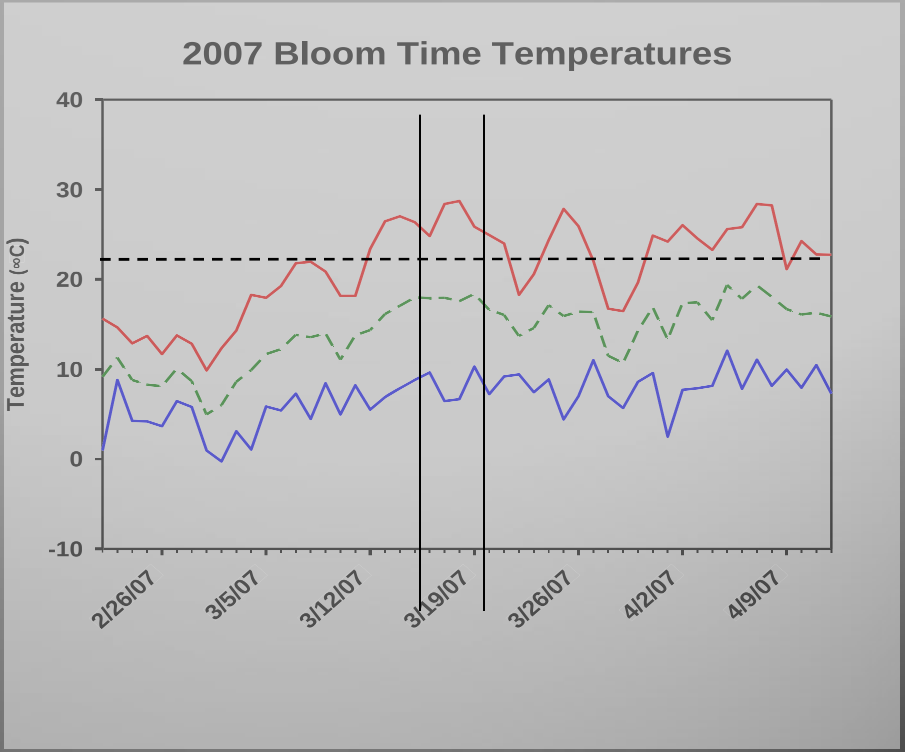
43,313 Net Metric Tons

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

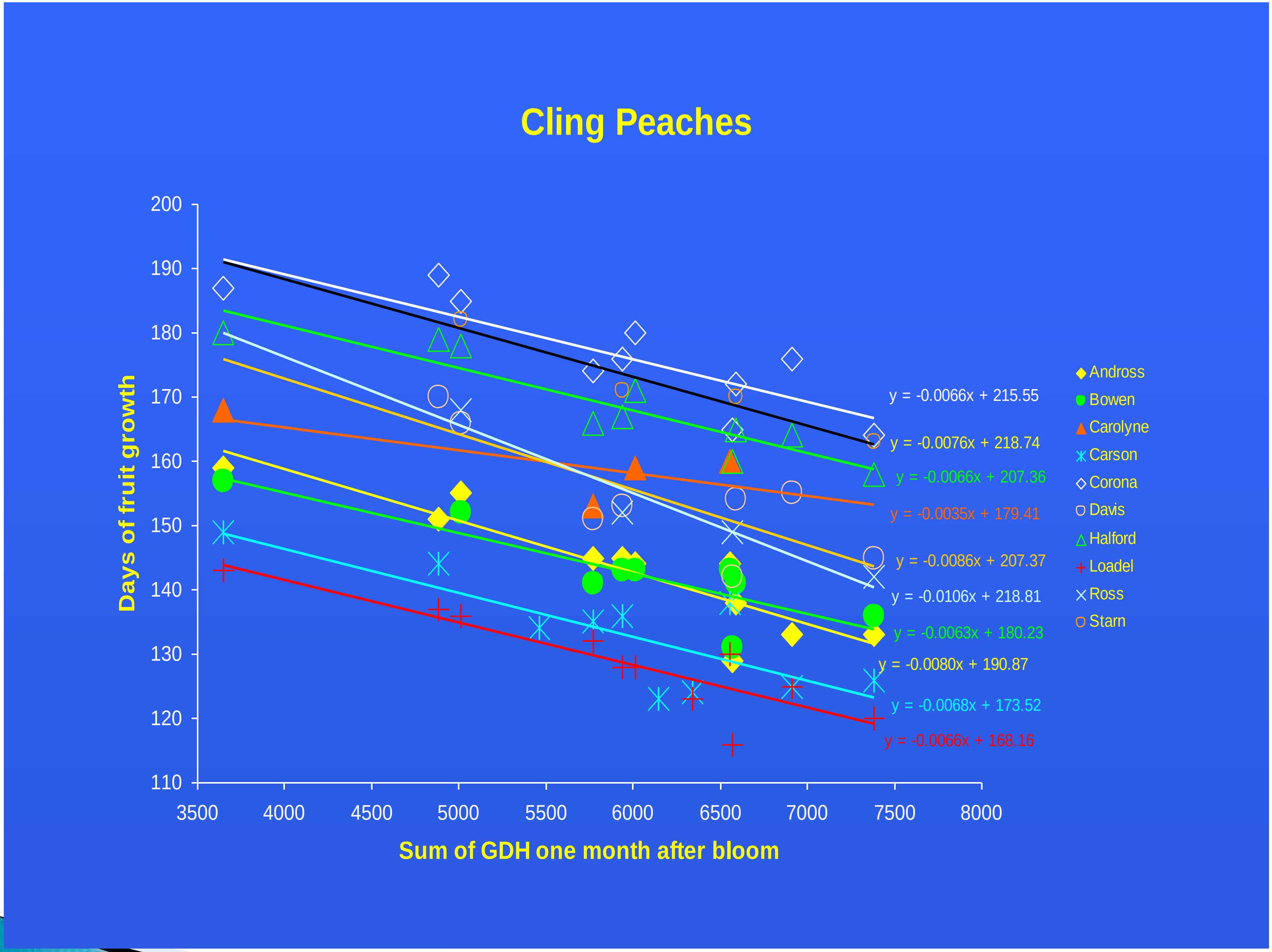
Changing climate – erratic springs

- California prune production is dependent on one cultivar, ‘Improved French’
- This cultivar does not set fruit when temperatures during bloom are > 25 ^{o}C
- Temperature spikes during bloom have caused reduced crops in prunes in 5 out of 12 years.

- **SOLUTION: new cultivars that spread the bloom and the risk. UC has a prune breeding program to address this problem.**

Changing climate – warmer springs

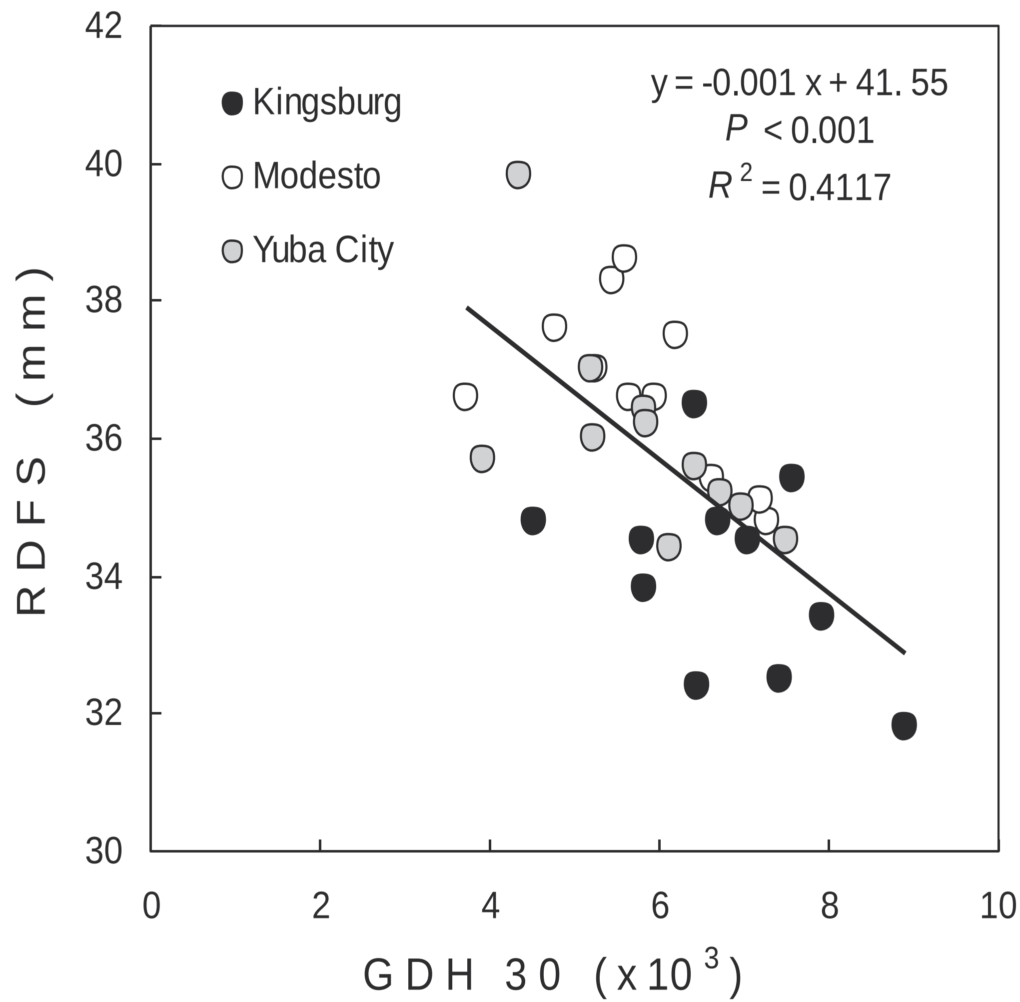
- Temperatures have a large effect on rate of fruit development and temperatures are normally limiting during spring time.
- Growing-degree-hour (heat) accumulation in the first 30 days after bloom strongly influences the rate of fruit development and harvest date for a given cultivar and year.
- High early spring temperatures can also have a strong tendency to negatively effect fruit size.
- To cope with this, growers must pay attention to early spring temperatures, thin earlier during warm springs and plan for earlier harvest.



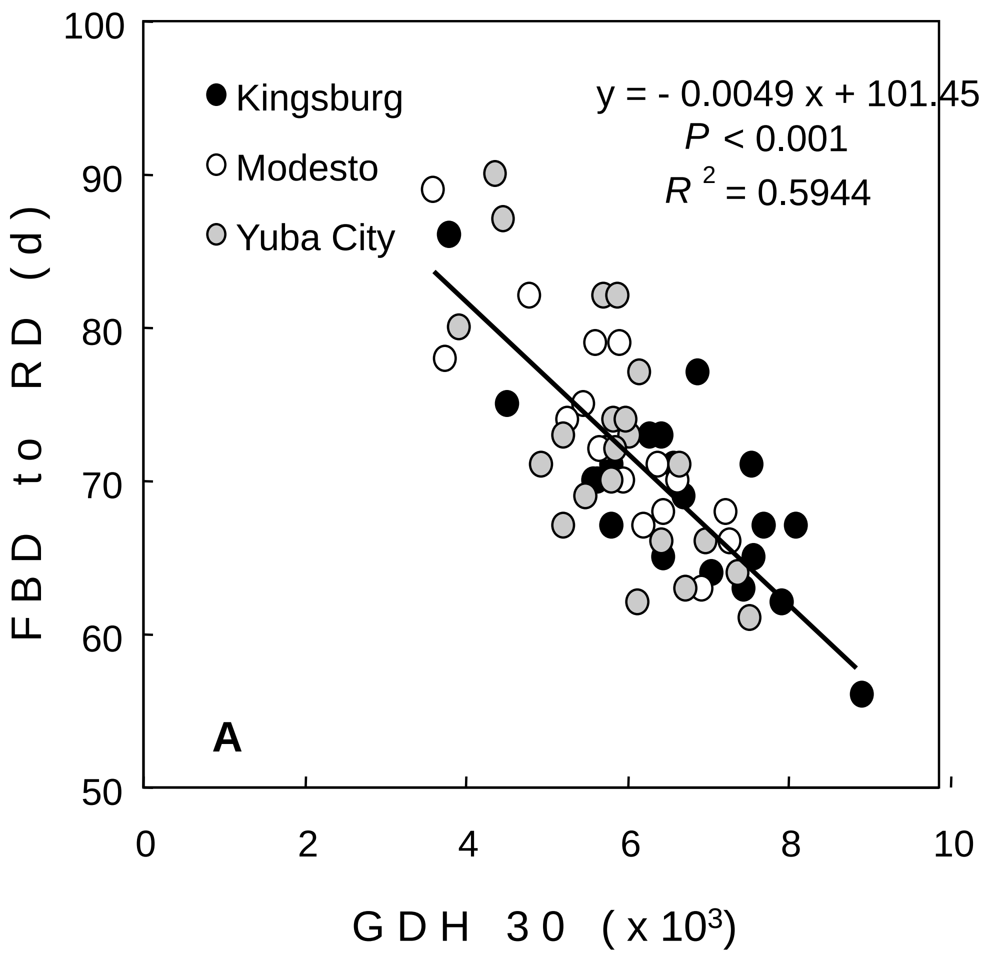
Cling Peaches
Days of fruit growth
Sum of GDH one month after bloom
200
190
180
170
160
150
140
130
120
110
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
y = -0.0066x + 215.55
y = -0.0076x + 218.74
y = -0.0066x + 207.36
y = -0.0035x + 179.41
y = -0.0086x + 207.37
y = -0.0106x + 218.81
y = -0.0063x + 180.23
y = -0.0080x + 190.87
y = -0.0068x + 173.52
y = -0.0066x + 168.16
Andross
Bowen
Carolyne
Carson
Corona
Davis
Halford
Loadel
Ross
Starn

High temperatures in early spring tend to reduce fruit size at reference date (at the end of Stage I of fruit growth). And because fruit grow according to a RGR function, average fruit size at harvest is also usually smaller, all other things being equal.

Why is fruit size at reference date negatively affected by early spring temperatures?



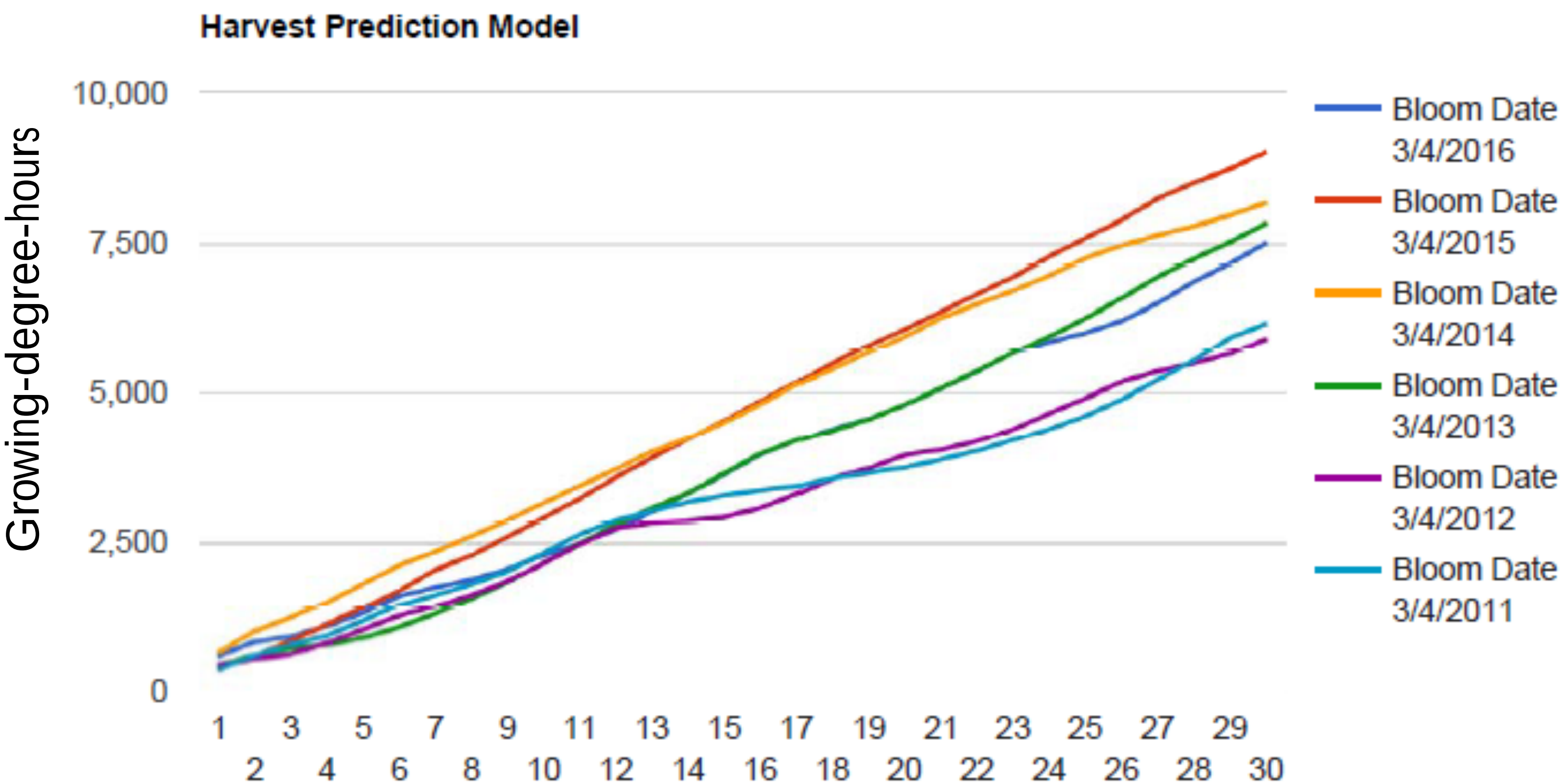
When spring temperatures are very warm, fruit development rates are faster than the ability of the plant to supply resources to support the potential fruit growth rate, and early fruit size differences are often carried through to harvest.



In California our growers can go to the UC Davis Fruit and Nut Center web site to get data on **accumulated winter chilling** (both chill hours and chill portions) and post-bloom heat accumulation (growing-degree-hours or days) from weather stations near their farms.

http://fruitsandnuts.ucdavis.edu/Weather_Services/chilling_accumulation_models/Chill_Calculators/index.cfm?type=harvest

Examples of spring heat accumulation differences for six recent years.



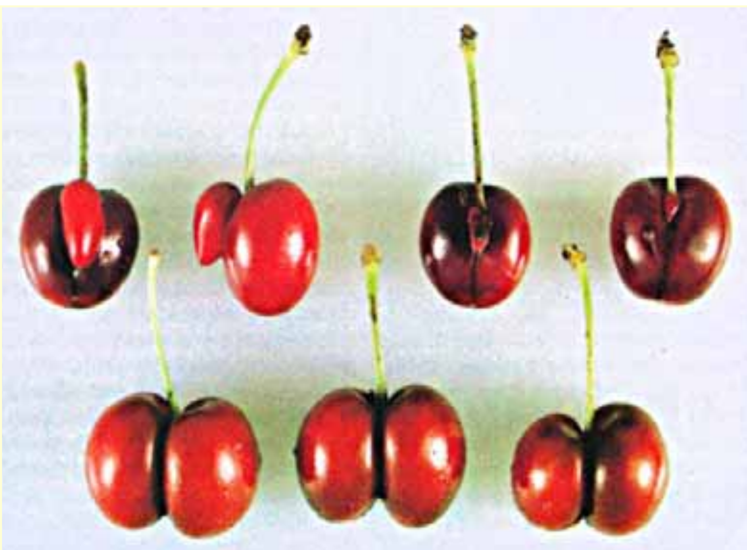
http://fruitsandnuts.ucdavis.edu/Weather_Services/chilling_accumulation_models/Chill_Calculators/index.cfm?type=harvest

Examples of spring heat accumulation differences for six recent years.

Days after Bloom	Mar 4 2016	Mar 4 2015	Mar 4 2014	Mar 4 2013	Mar 4 2012	Mar 4 2011
	Accumulated Growing Degree Hours (GDH)					
1	605	394	657	451	452	388
2	838	605	1,009	621	559	618
3	922	848	1,228	740	639	787
27	6,516	8,239	7,629	6,949	5,357	5,216
28	6,865	8,499	7,779	7,243	5,491	5,542
29	7,168	8,727	7,955	7,518	5,655	5,937
30	7,504	9,009	8,169	7,827	5,915	6,173

Changing climate – warmer summers

- Flower buds for the next season are formed during summer of current year.
- High temperatures during summer when accompanied by water stress cause double and deep sutured fruits.



Growers must insure that trees are well-watered in August (February for Chile)

Increased N fertilizer regulations

- Many wells in California agricultural production areas have high nitrate concentrations in the water.
- Current trend is to develop regulations for annual orchard N applications based on the amount of N removed in the crop plus a “fudge factor” for other N losses in the system.
- This may work for nut crops that can account for large amounts N in the crop but will likely be a challenge for some fruit crops that require high tree vigor to achieve good fruit sizes but the crop does not account for much N removal in the crop.

Increasing labor costs/shortages

- High labor costs and labor shortages have driven many growers to switch from crops requiring a lot of hand labor (fresh fruits) to crops that can be managed mechanically (nuts).

- Another solution is to develop orchards with shorter trees that don't require as much hand labor and ladder work. (This has already been partially achieved with rootstocks in apples but not for most stone fruits.)

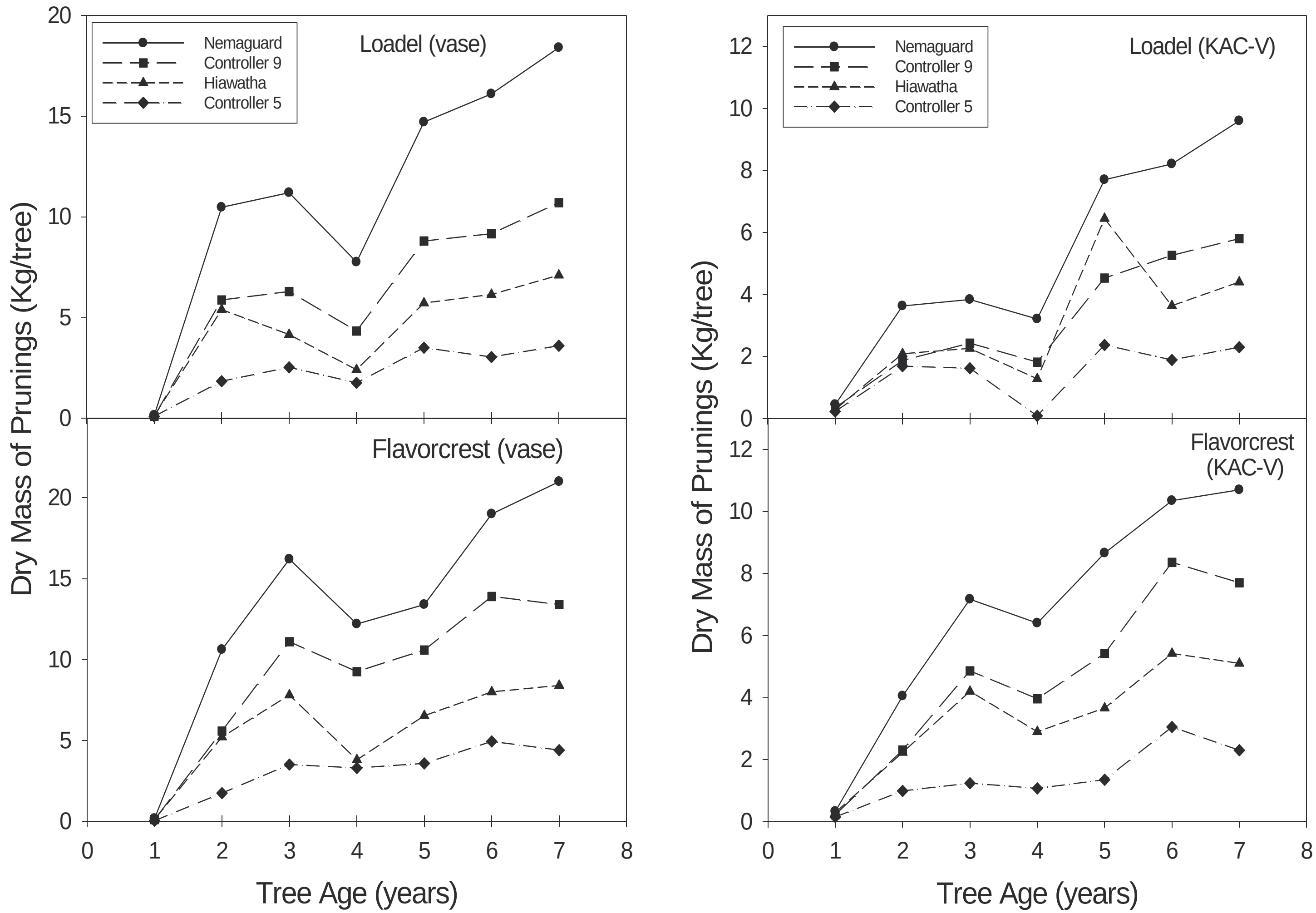
Development of size-controlling rootstocks for peaches

- Our goal is to develop peach orchards that can be managed from the ground ("pedestrian orchards") with minimal pruning.

“Controller^{TM}” rootstocks
from UC Davis and USDA-ARS Parlier

- Controller 9.5 (HBOK 50) root-knot resistant
- **Controller 9 (P30-135)**
- Controller 8 (HBOK 10) root-knot resistant
- Controller 7 (HBOK 32) root-knot resistant
- **Controller 6 (HBOK 27)** root-knot resistant

  Controller 5 (K146-43)

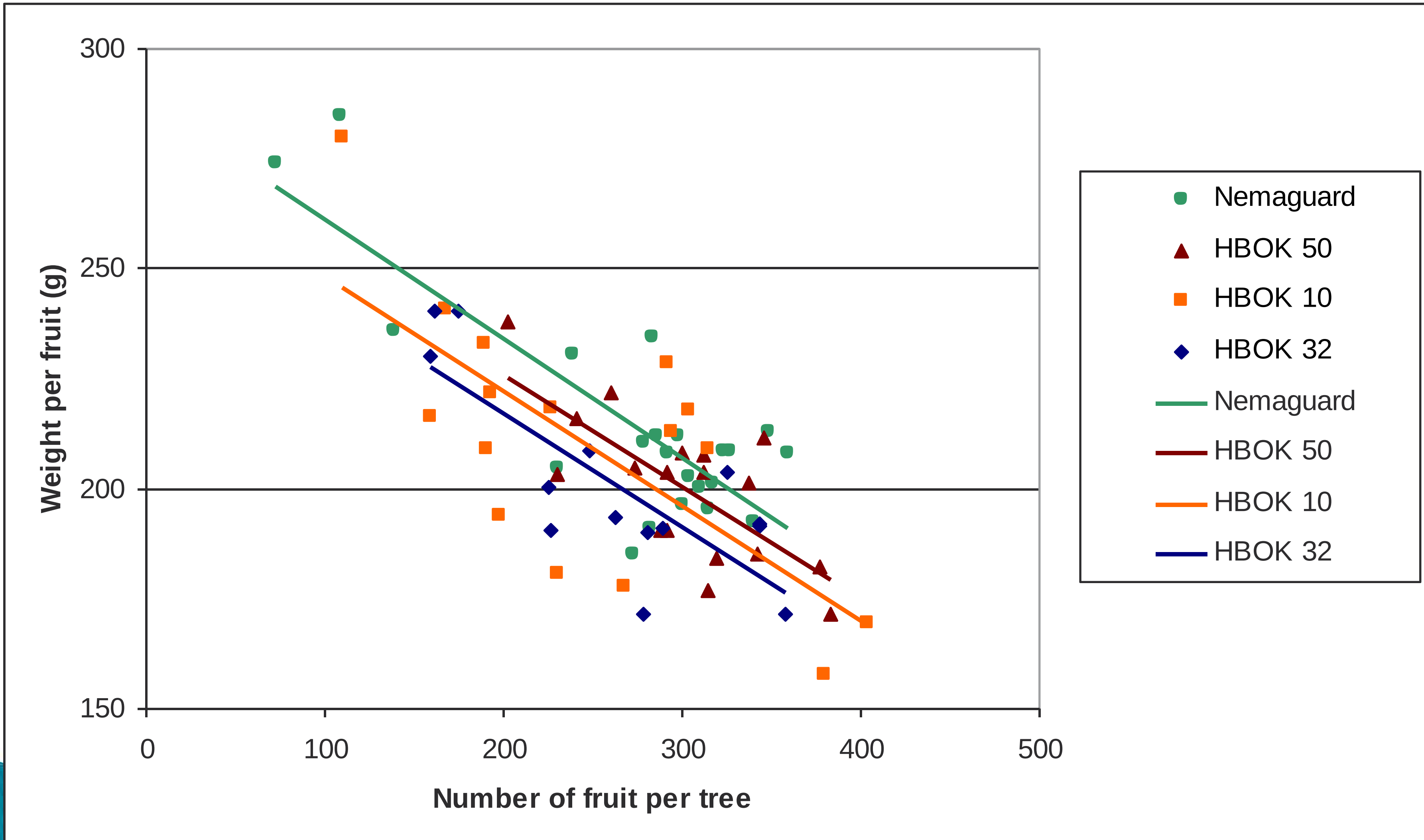


Differences in vegetative vigor (as reflected by pruning weights) among trees on different rootstocks were apparent very early in the trial and remained fairly consistent. The differences in vigor are essentially the selling points of the size-controlling rootstocks.

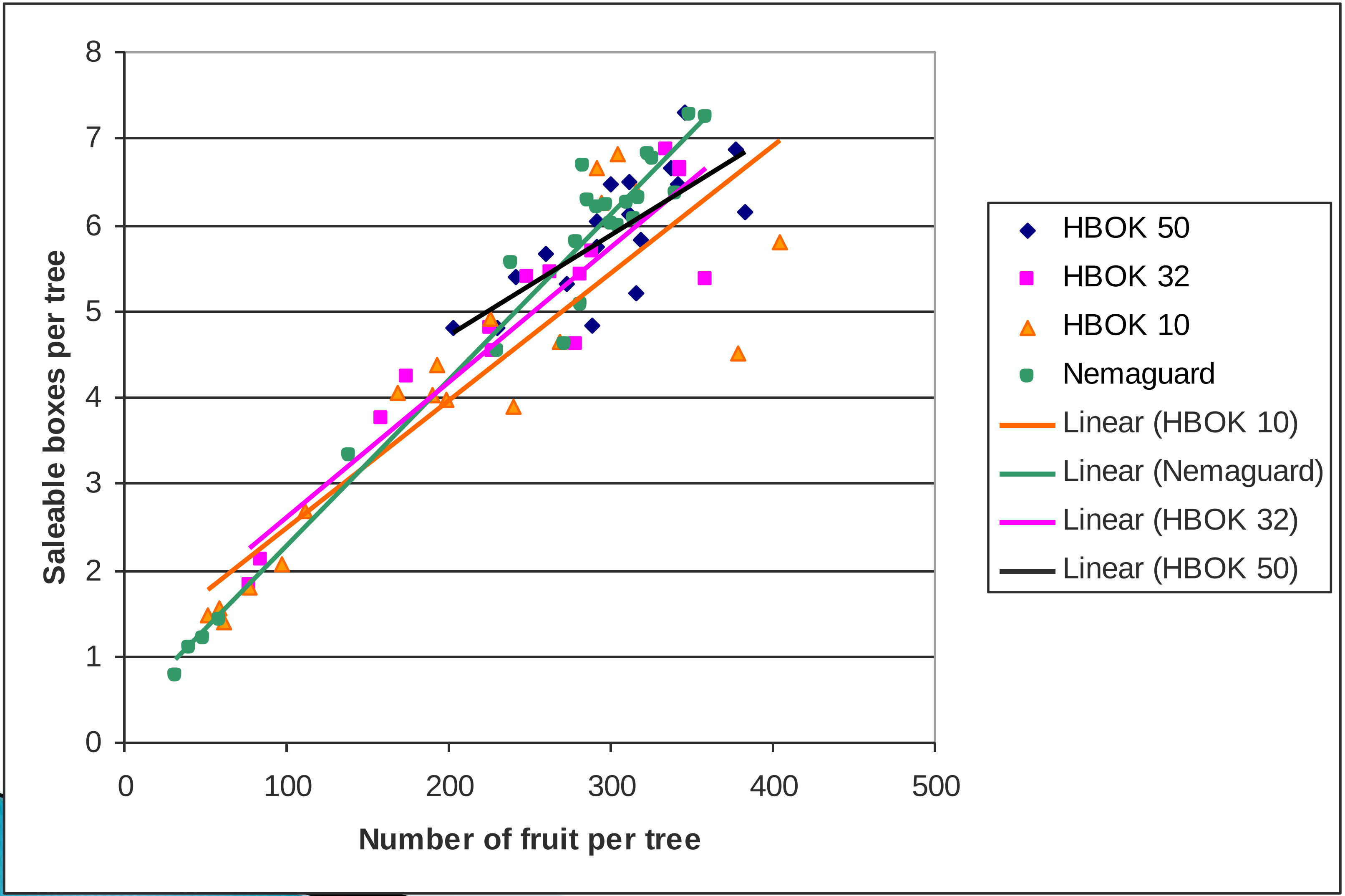
Vigor control of four rootstocks that have recently been developed.

Rootstock *'O'Henry' peach as scion*	TCA % of Control	Dormant pruning % of Control	Summer pruning % of Control
Nemaguard	100	100	100
Controller 9.5	93.1	78.7	124.6
Controller 8	69.6	65.2	76.9
Controller 7	61.1	49.2	46.2
Controller 6	59.2	44.4	34.5

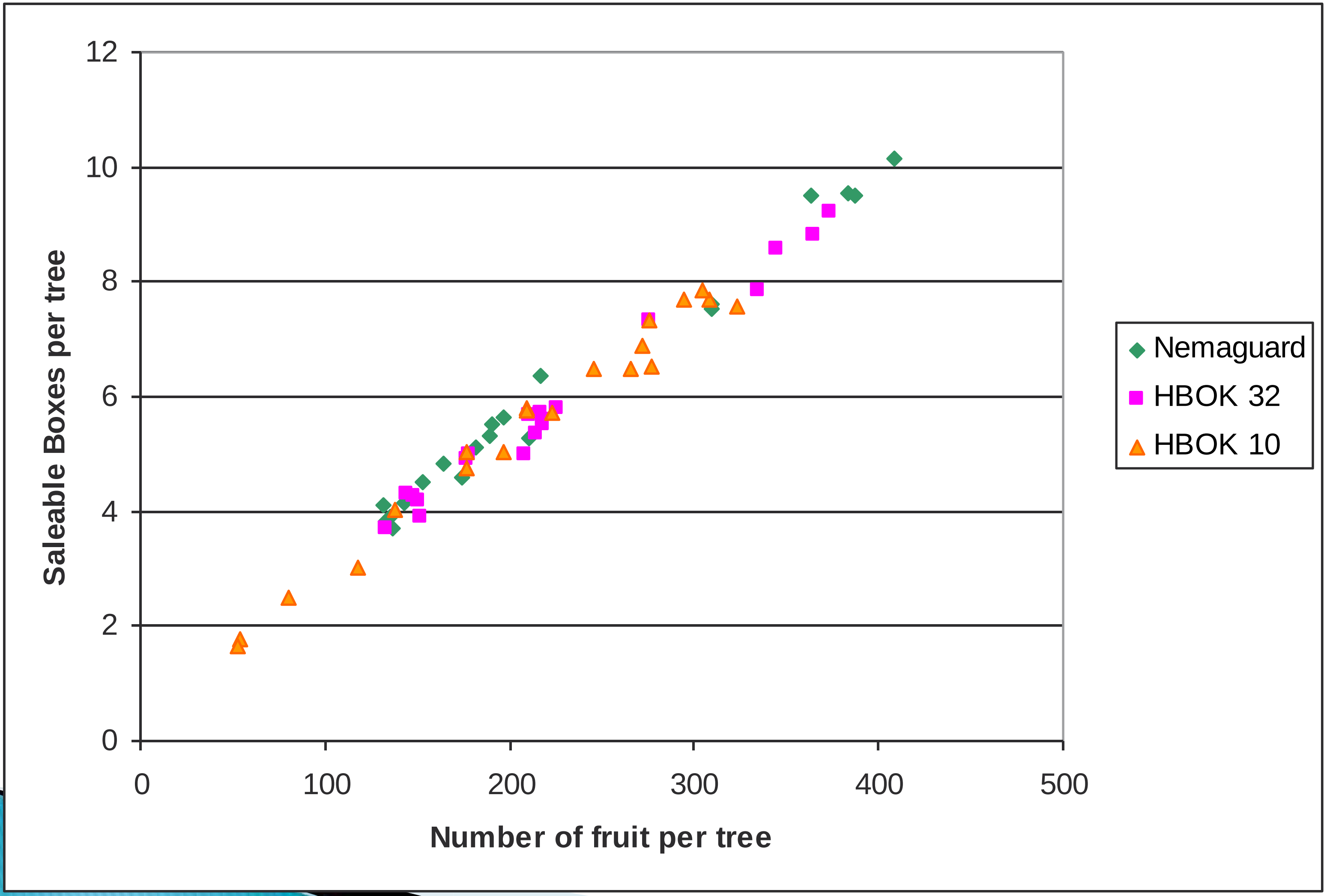
O'Henry Fruit Size

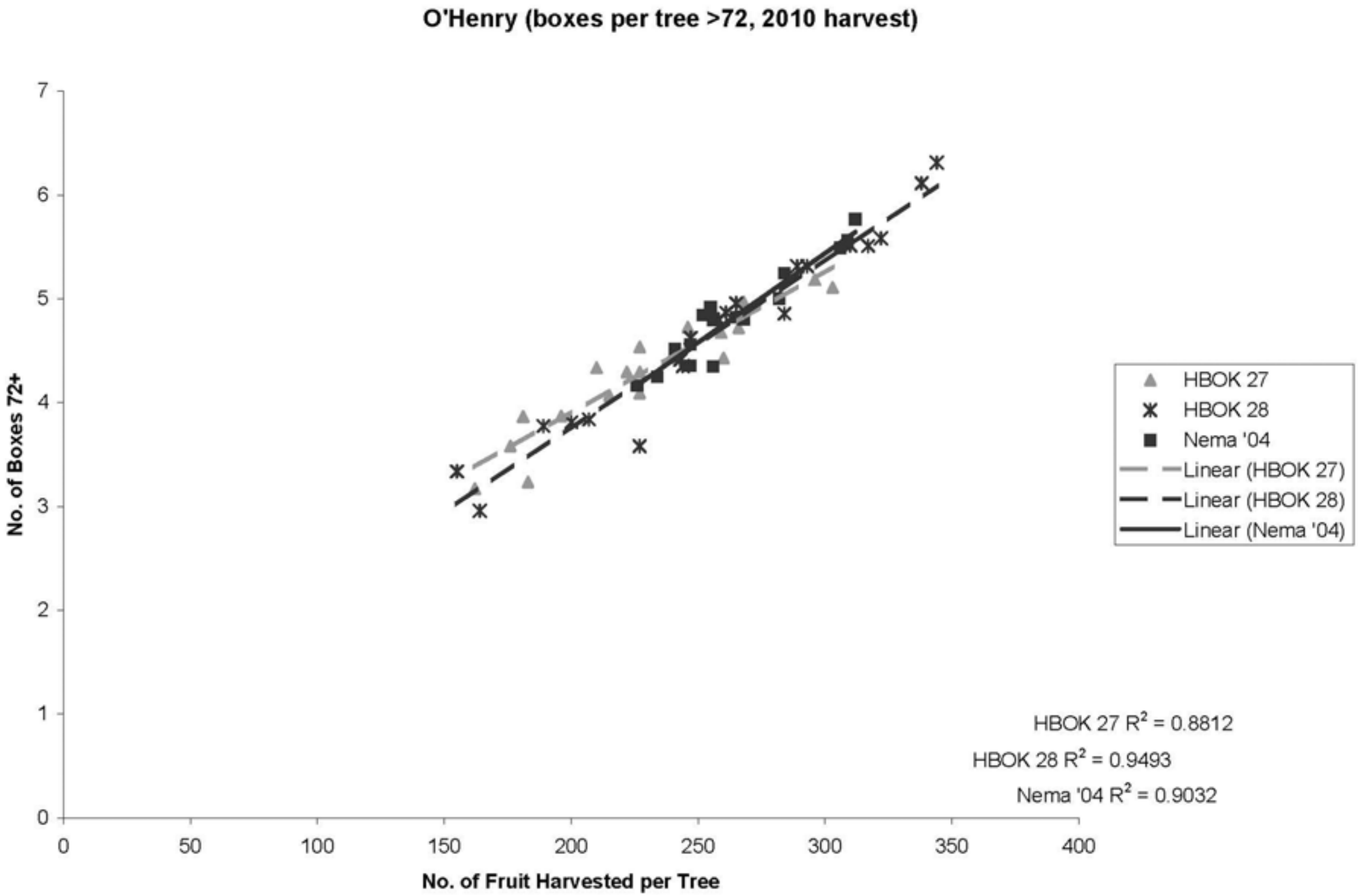


O’Henry boxes per tree
(56’s and larger)

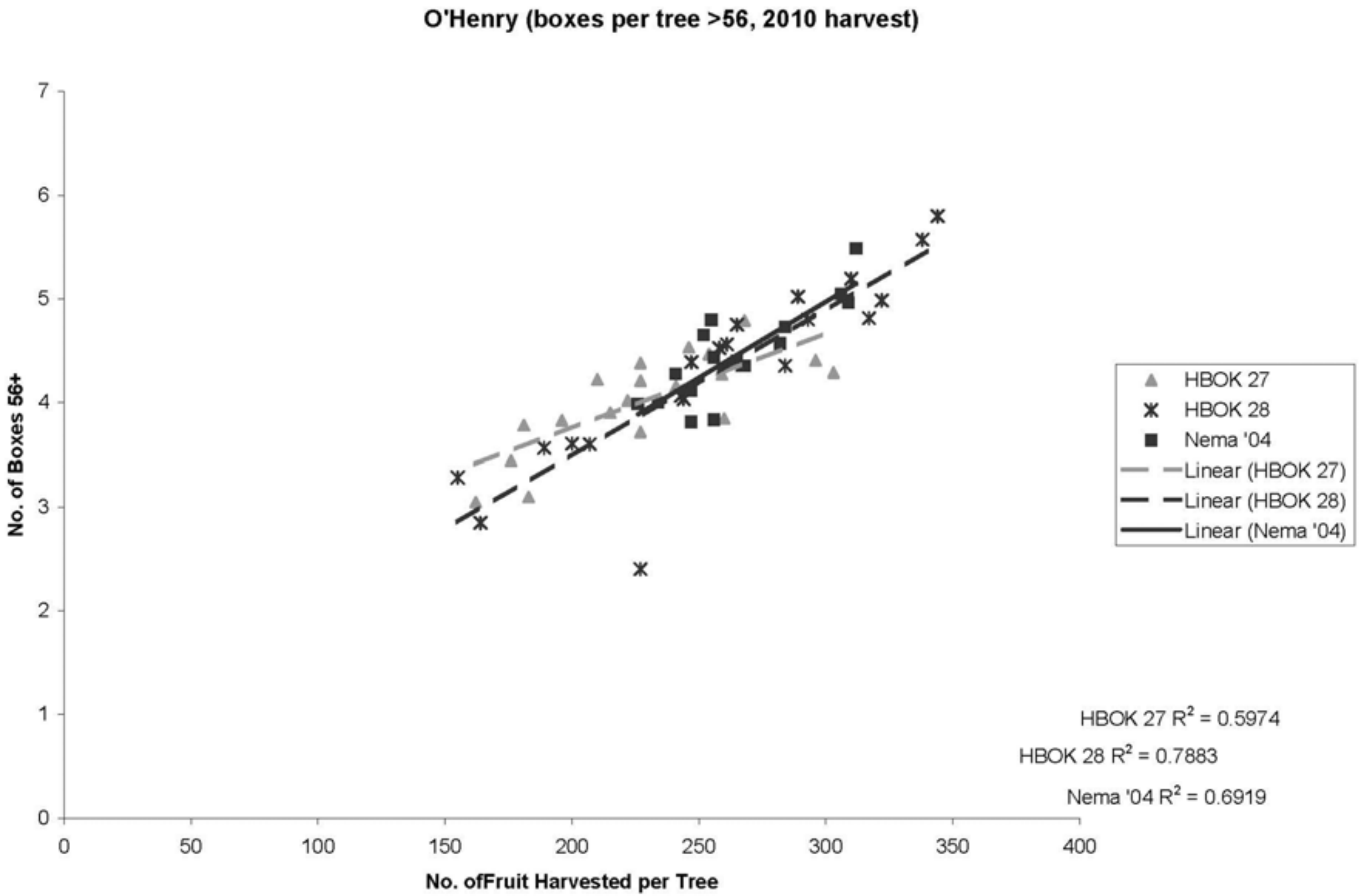


Summer Fire boxes per tree
(70's and larger)





O'Henry (boxes per tree >72, 2010 harvest)
No. of Boxes 72+
No. of Fruit Harvested per Tree
0
1
2
3
4
5
6
7
0
50
100
150
200
250
300
350
400
HBOK 27
HBOK 28
Nema '04
Linear (HBOK 27)
Linear (HBOK 28)
Linear (Nema '04)
HBOK 27 R^2 = 0.8812
HBOK 28 R^2 = 0.9493
Nema '04 R^2 = 0.9032



O'Henry (boxes per tree >56, 2010 harvest)
No. of Boxes 56+
No. ofFruit Harvested per Tree
0
1
2
3
4
5
6
7
0
50
100
150
200
250
300
350
400
HBOK 27
HBOK 28
Nema '04
Linear (HBOK 27)
Linear (HBOK 28)
Linear (Nema '04)
HBOK 27 R2 = 0.5974
HBOK 28 R2 = 0.7883
Nema '04 R2 = 0.6919

1st leaf on Controller 6 (finished trees)
2nd leaf on Controller 6 (grafted in place)

1st leaf on Controller 9 (grafted in place)
3rd leaf on Controller 9 (grafted in place)

Third leaf trees of a late peach on Controller 9 (>1500 boxes/acre)

So what is causing the size-controlling?

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- **Basile, B., J. Marsal, and T.M. DeJong. 2003.** Daily shoot extension growth of peach trees growing on rootstocks that reduce scion growth is related to daily dynamics of stem water potential. Tree Physiology 23:695-704.
- **Basile, B., J. Marsal, L.I. Solari, M.T. Tyree, D.R. Bryla, and T.M. DeJong. 2003.** Hydraulic conductance of peach trees grafted on rootstocks with differing size-controlling potentials. Journal of horticultural Science & Biotechnology 78 (5):768-774.
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- **Solari, L.I., S. Johnson and T.M. DeJong. 2006.** Relationship of water status to vegetative growth and leaf gas exchange of peach (*Prunus persica*) trees on different rootstocks. Tree Physiology 26:1333-1341.
- **Solari, L.I., S. Johnson and T.M. DeJong. 2006.** Hydraulic conductance characteristics of peach (*Prunus persica*) trees on different rootstocks are related to biomass production and distribution. Tree Physiology 26: 1343-1350.
- **Solari, L.I., F. Pernice and T.M. DeJong. 2006.** The relationship of hydraulic conductance to root system characteristics of peach (*Prunus persica*) rootstocks. Physiologia Plantarum 128:324-333.
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- **Tombesi , S., Johnson, R.S., Day K.R., DeJong, T.M. 2010.** Relationships between xylem vessel characteristics, calculated axial hydraulic conductance and size-controlling capacity of peach rootstocks. Annals of Botany 105, 327-331.
- **Tombesi, S., Johnson, R.S., Day, K.R. and DeJong, T.M. 2010.** Interactions between rootstock, inter-stem and scion xylem vessel characteristics of peach trees growing on rootstocks with differing size-controlling characteristics. AoB PLANTS 2010: plq013
- **Tombesi, S., Almehdi, A. and DeJong, T.M. 2010.** Phenotyping vigour control capacity of new peach rootstocks by xylem vessel analysis. Scientia Horticulturae 127:353-357.

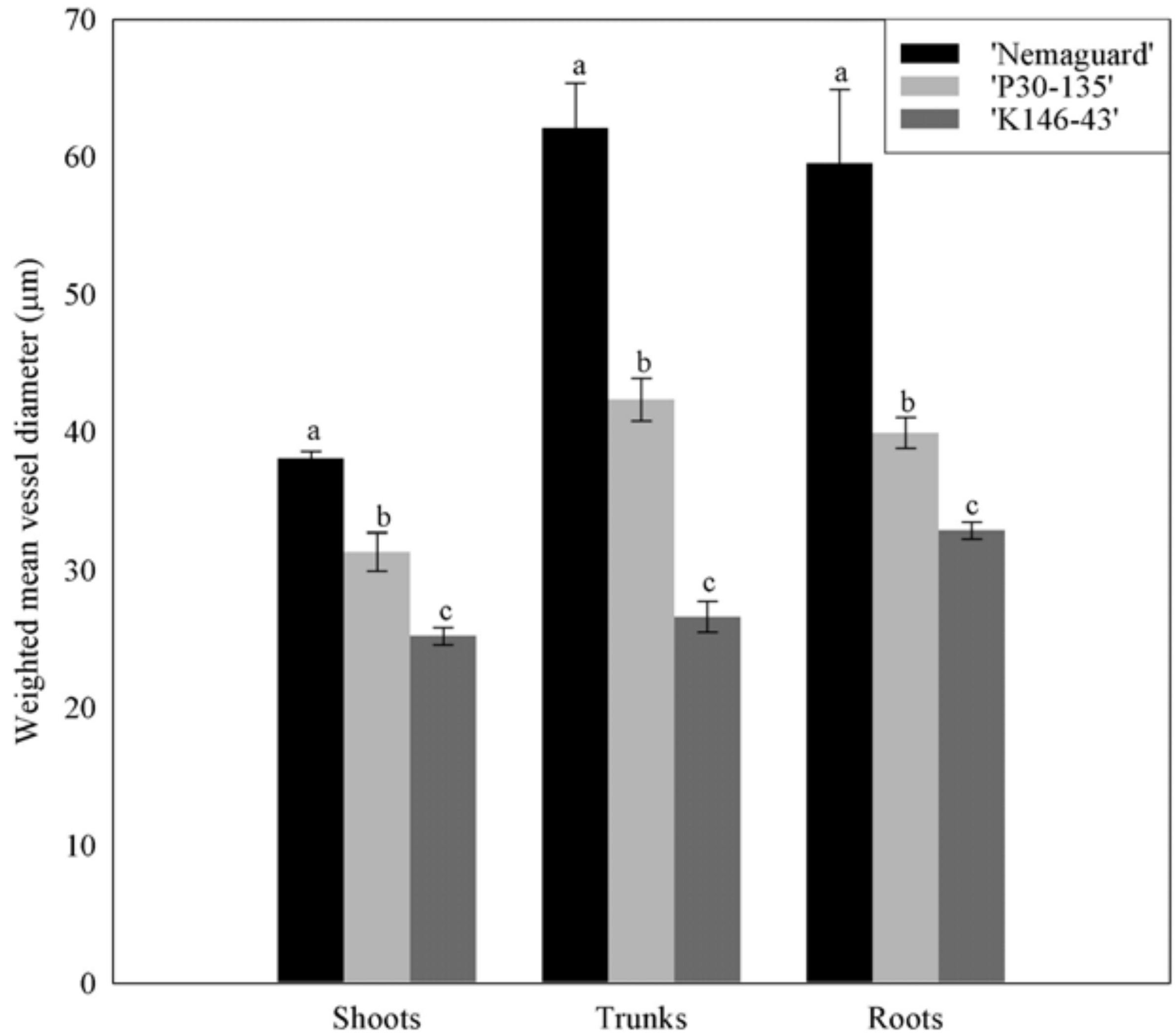
Peach trees have three types of shoots.

Proleptic (hangers)

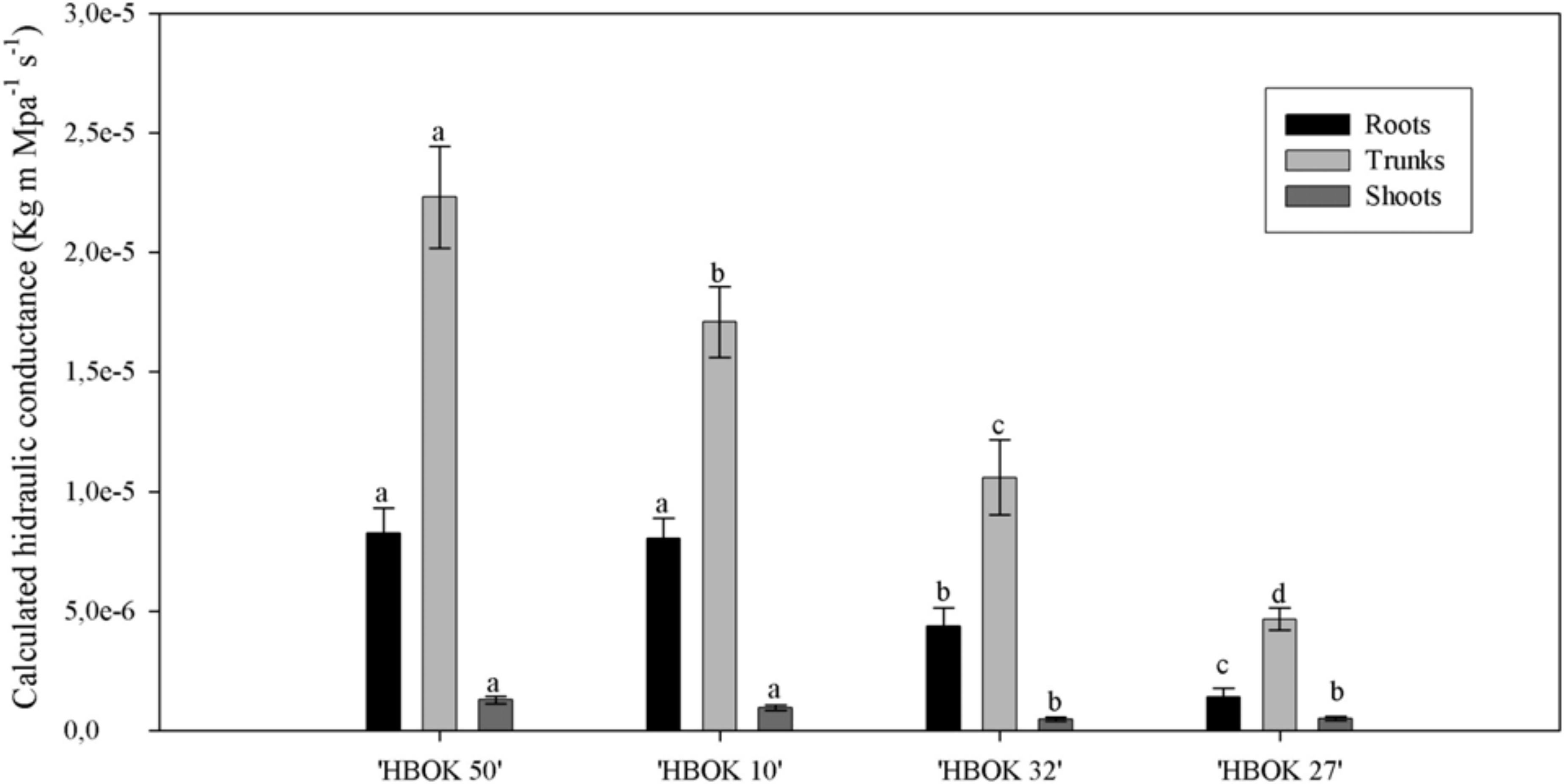
Epicormic (water sprouts)

Syleptic

Weighted mean vessel diameters in xylem tissue obtained from shoots, trunks and roots of three rootstock genotypes: ‘Nemaguard’ (vigorous), ‘P30-135’ (modestly dwarfing), ‘K146-43’ (dwarfing).



Xylem tissues of the HBOK rootstocks and their vessel characteristics appear to linked to rootstock vigor in a manner similar to Controller 5 and 9.



Controller 9.5 Controller 8 Controller 7 Controller 6

Summary of how dwarfing peach rootstocks work compared to Nemaguard rootstock

- Diameter of the water conducting (xylem) vessels of dwarfing rootstocks are smaller
- This causes the hydraulic conductance of the rootstock water conducting tissue (xylem) to be lower
- This causes the water availability (water potential) in the stems and leaves to be slightly lower
- This causes the elongation of stems to be slightly less and overall vigor of tree is decreased over time
- This decreases the amount of pruning needed
- Decreased pruning reduces the number of water sprouts and this decreases the need for pruning even more, etc.
- This also decreases internal canopy shading and thus increases shoot quality and flower bud development

Can we simulate it?

Rootstock effects were simulated by simply reducing the hydraulic conductance of the rootstock by 50% (which was similar to the reduction caused by Controller 8 rootstock).

This caused a 30% reduction in stem weight after the 4th simulated year and 29% reduction in dormant pruning weight after the 4th year in the field experiment.

Collaborators on rootstock work

- Controller 5 and 9
  - Dave Ramming, Scott Johnson, Kevin Day, Jim Doyle
- Controller 6, 7, 8, 9.5
  - Ali Almehdi, Fred Bliss, Lyndsey Grace, Kevin Day
- Physiology
  - Antonio Weibel, Boris Basile, Jordi Marsal, Luis Solari, Sergio Tombesi, Fulvio Pernice
- Modeling
  - David Da Silva, Romeo Favreau, Gerardo Lopez, Inigo Auzmendi,

California
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References: spring temperature influences

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DeJong, T.M. 2012. Fruit growth and development as it relates to crop load, thinning and climate change. Acta Hort. 962: 233-238

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