UC RIVERSIDE UNIVERSITY OF CALIFORNIA | College of Natural & Agricultural Sciences

Avocado Tree Physiology – Understanding the Basis of Productivity

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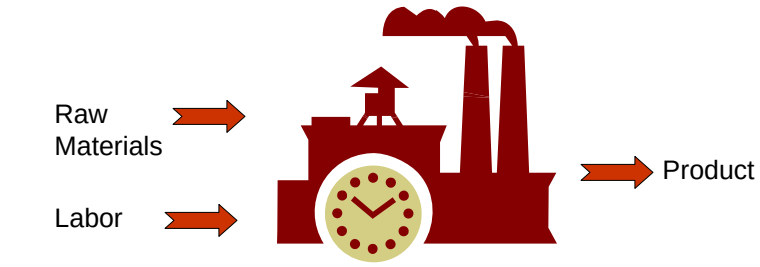
Purdue University

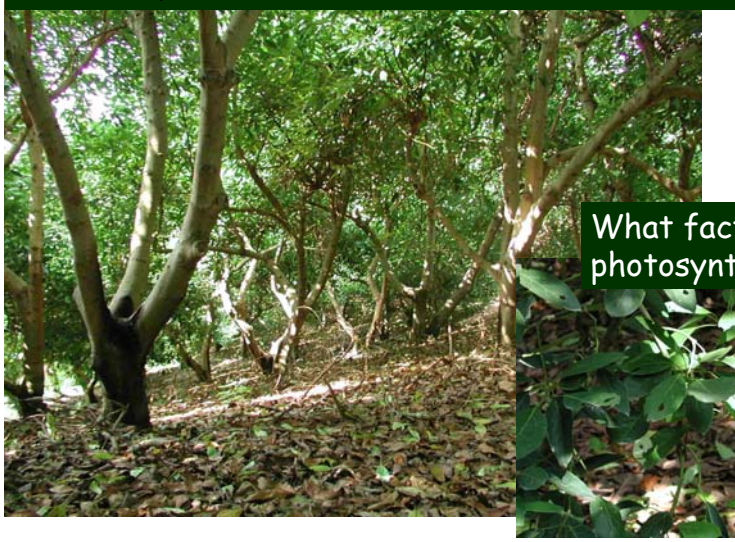


Research priorities addressed

- Canopy management, tree density, tree architecture
- Development and refinement of a model to predict phenological events for the avocado
- Innovative practices to increase efficiencies of grove operations and orchard profits

Problem: Lowered Productivity in California

Photosynthesis is the Production Line of the "Factory"



What factors limit photosynthesis?

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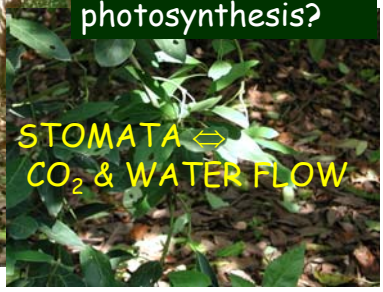
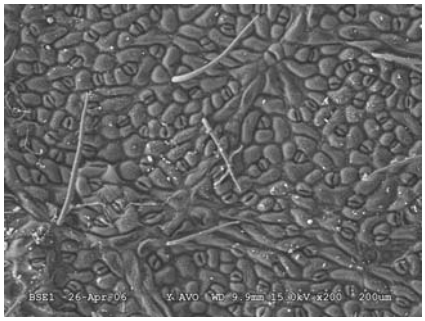
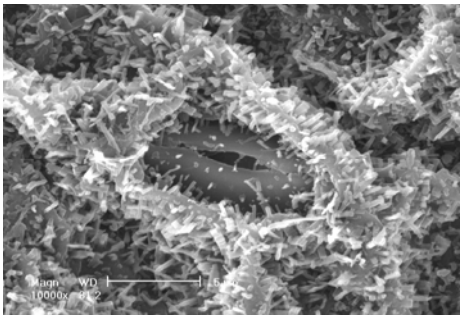
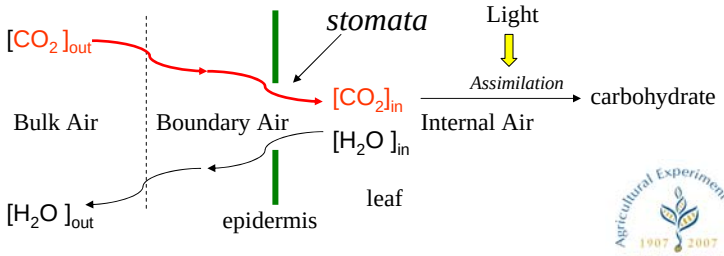






lower leaf surface of 'Hass' avocado leaf



Problem: Lowered Productivity in California

WHY? Several reasons BUT
[1] Stomata close-down "in error", lowering assimilation
Stomata conductance altered by water loss
[2] Light is limiting for assimilation, relative to size of canopy

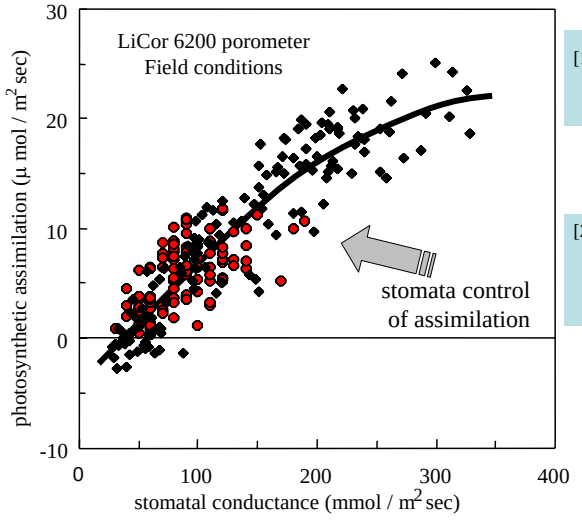
Potential solutions:

[1] Increase productivity through manipulation of air relative-humidity.
[2] Alter the canopy of the trees to change air flow & light absorption
Denser canopy to control water loss.

Research Plan:

[1] Determine the assimilation efficiency upon stomata conductance
[2] Determine the variation of conductance upon relative humidity.
[3] Build a simplified model of assimilation

One Limit to Productivity: Stomata



[1] During normal conditions assimilation governed by stomata conductance

[2] During most stress conditions stomata conductance declines but assimilation still governed by stomata conductance

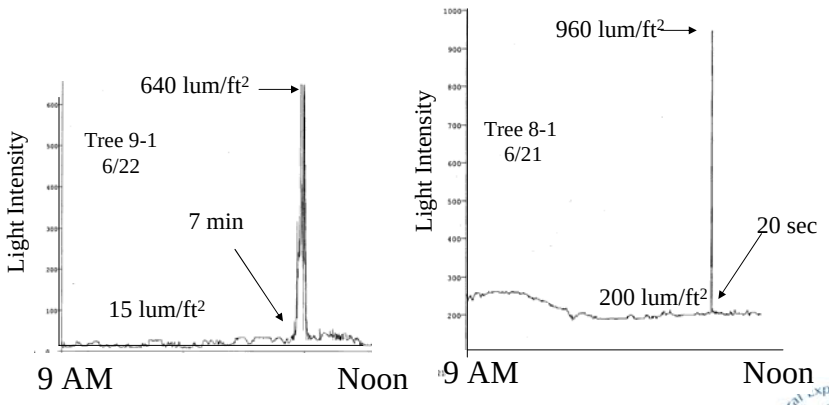
From Mickelbart (●) & Xuan (▲)

Accomplishments to date

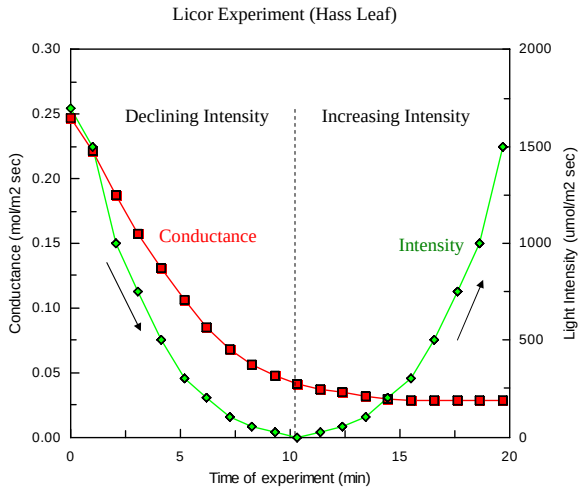
- Light Flecks
- Leaf area
- Leaf processes
  - Light intensity and assimilation
  - Model of productivity
- Sap flow

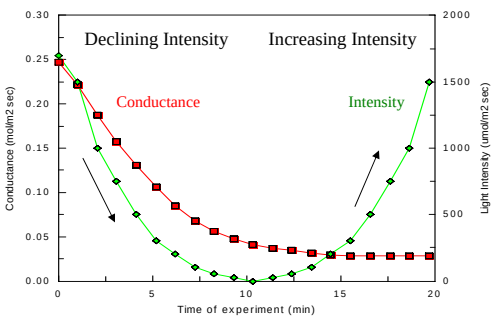
Light "Flecks" inside canopy

Field 10 (measured by light meter on east side, ½ way into canopy, 6 ft off ground)



Speed of stomata change





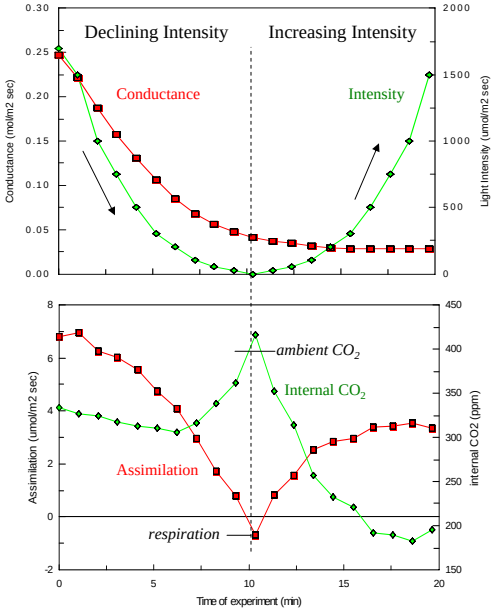
Licor Experiment (Hass Leaf)

Decline

Lower intensity = closed stomata

Lower intensity & closed stomata = lower assimilation

Lower assimilation & closed stomata = higher internal CO_2



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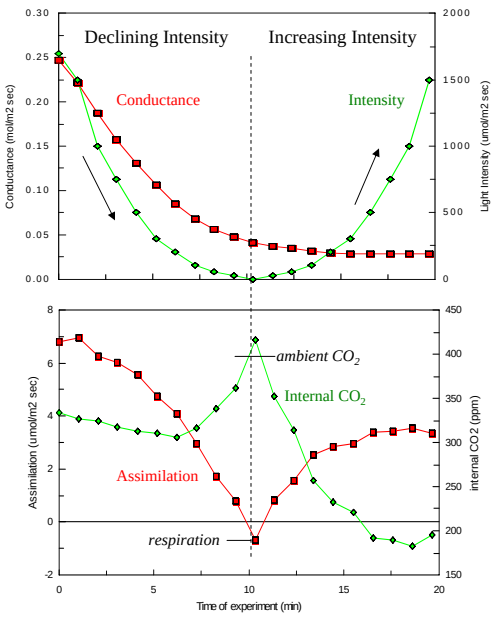

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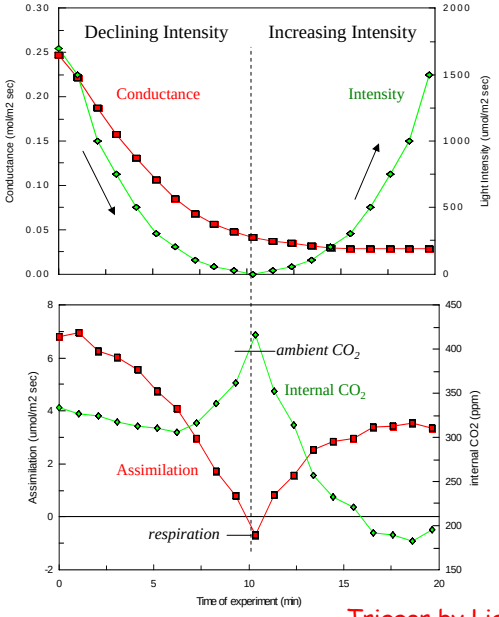
Increase

Higher intensity = higher assimilation

Higher assimilation & closed stomata
= lower internal CO_2

Lower internal CO_2
= opening of stomata



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Lower internal CO_2
= opening of stomata

Trigger by Light Different Speed than by CO_2

So Light Flecks are not especially useful, if high light is of short duration.

Windows in canopies must give enough duration of light to allow stomata response
(30+ minutes)

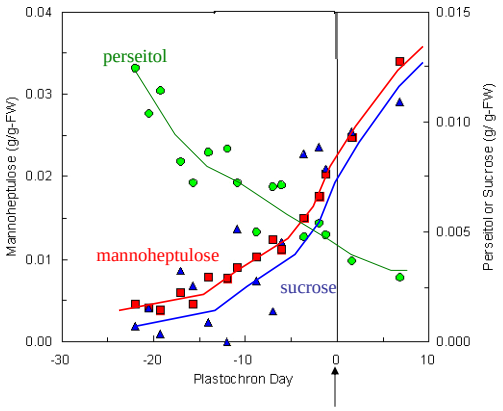
Leaf area

- Development of a plastochron index that can be used to describe the physiological age of each leaf
- Based on leaf area (*or even leaf length*)
- Development of an "easy-to-use" program for field measurement

Allows one to "standardize" measurements based on leaf age – critical to reduce data variability and to understand how flush growth influences whole tree physiology

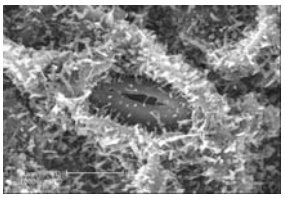
Plastochron Index application

The amount of carbohydrate as related to 'Hass' leaf age



Day zero = 50% of maximum leaf size

Stomata (regulated opening in leaf)



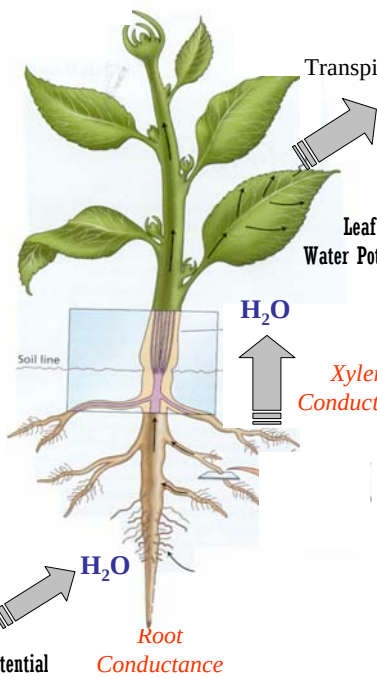
CO_2 Transport from air to inside leaf

H_2O Transport from inside leaf to air

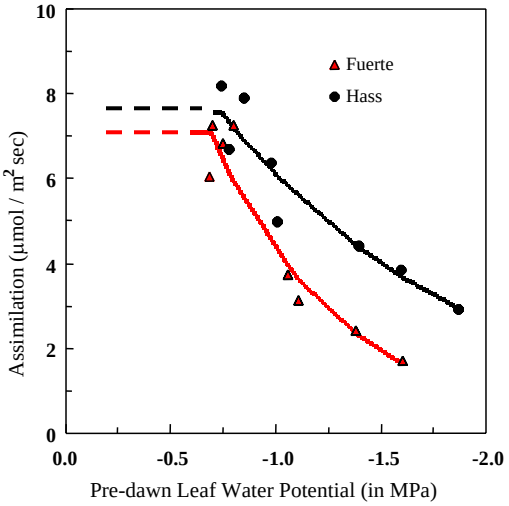
CO_2 Assimilation [Photosynthesis]

H_2O Loss From Leaf ------> Loss of Leaf

Carbohydrate / Oil Production



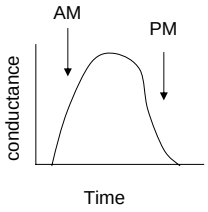
Water Flow Within The Plant



[water in soil]

Note that assimilation is falling because lower water potential induces more closed stomata and so lower conduction of both water and CO_2 flow.

California afternoon: higher temperature and lower relative humidity
if stomata are open, higher water loss from leaf
Can the soil provide the water?



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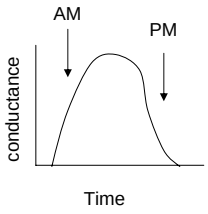

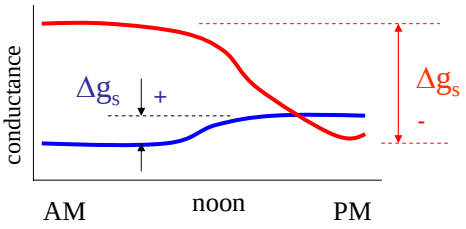

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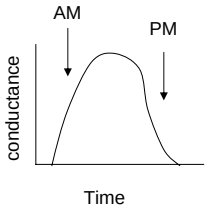
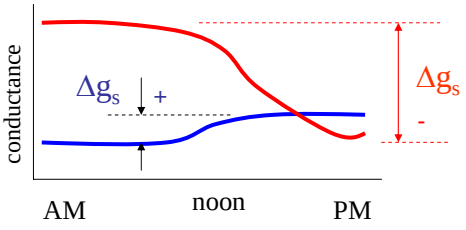
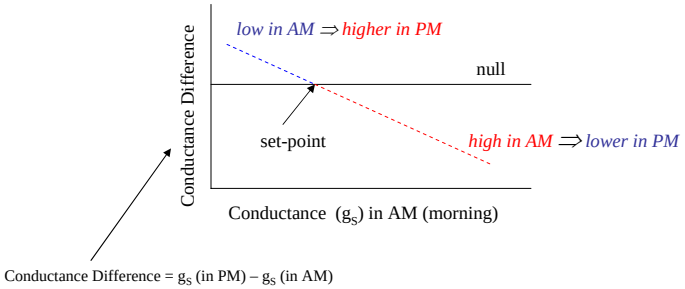
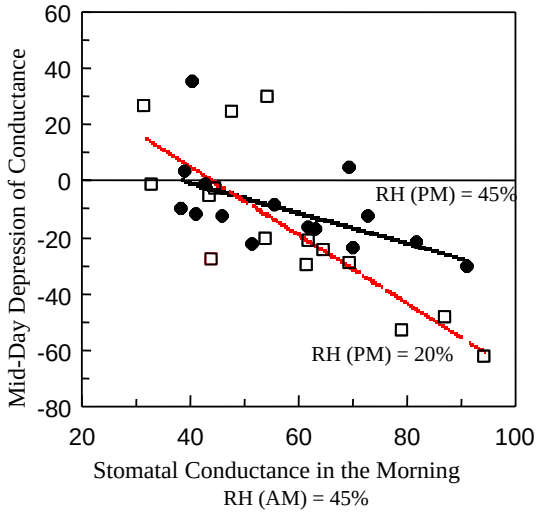






Δg_s

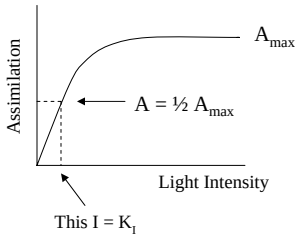


Measurements made with LiCor Porometer on one leaf at a time.

Conclusion: Lowering of conductance in PM made worse by low RH
But only if conductance in AM is high.

Assimilation Dependence Upon Light

Assimilation is Light-dependent CO_2 fixation



$$A = \frac{A_{max}\, I}{[\, K_m + I\,]}$$

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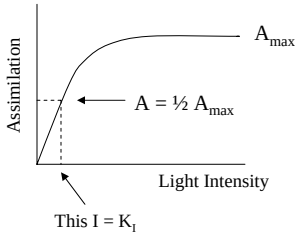

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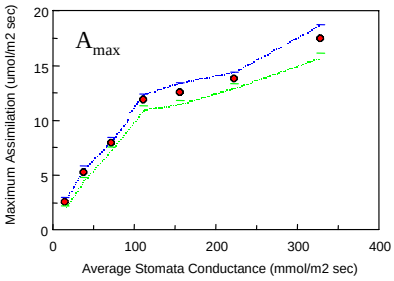
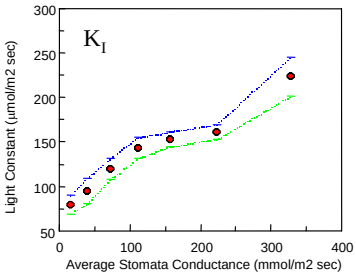




g_S ⟶

For Hass Avocado

What do we know?

✓Light governs assimilation but..
Stomata govern (in part) assimilation too

✓Assimilation reduces internal CO_2 but...
That low CO_2 opens stomata

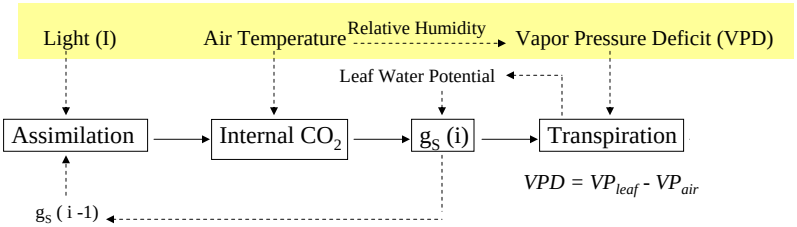
✓Water loss due to transpiration changes stomata but..
Transpiration is less for high relative humidity
Soil water can mitigate this leaf water loss

Can we use these facts for a model that depends only upon the environment?

Model Development: Expansion

Assimilation depends upon light
That changes internal CO_2
That alters the conductance
That changes Transpiration which is dependent upon vapor pressure deficit
(which is dependent upon air temperature and relative humidity)
That changes leaf water potential (which feedback upon conductance)

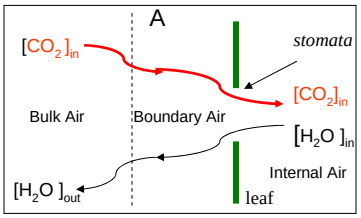
All in the house that Jack built!



$A = \frac{A_{max}\ I}{K_I + I}$ $\quad A = g_S\ (Co - Ci)$ $\quad Ts = g'_S\ VPD$

We still need soil water

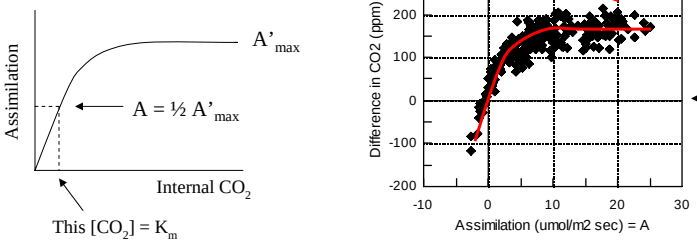
FINALLY Internal CO_2 Controls Conductance



Difference in $CO_2 = [CO_2]_{outside} - [CO_2]_{inside}$

Movement of CO_2 = {conductance} *x* {Difference in CO_2}

Movement of CO_2 limits assimilation



Validation of model: How do you measure transpiration continuously ?

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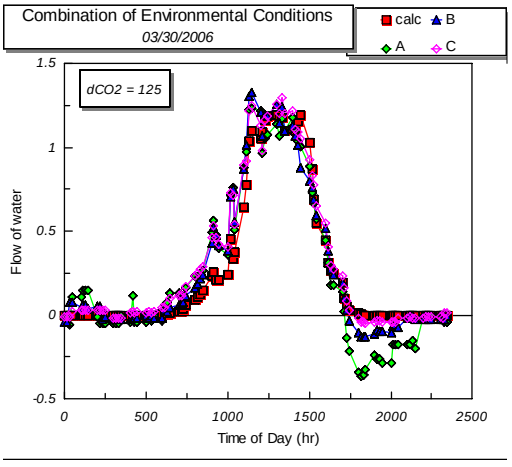
SAP FLOW *(continuous heat with insulated, non-invasive probes)*

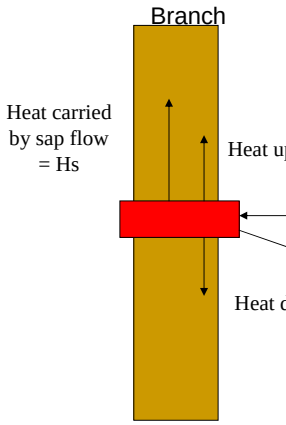
Three Zutano Trees (A, B, C) in Green House



Comparison between the Model and the Actual Sap Flow.

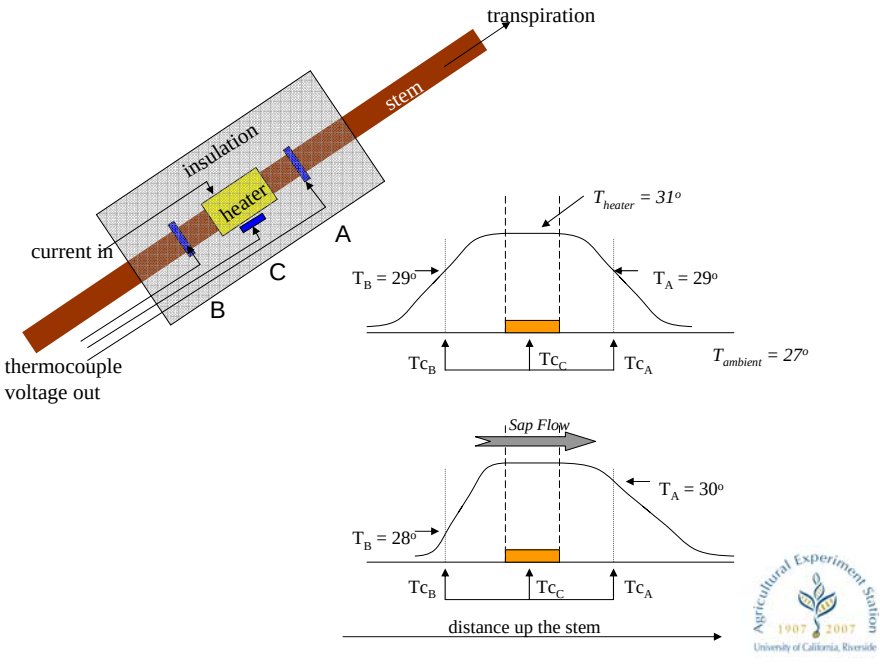
Three trees (zutano) were used in the green house to monitor sap flow (transpiration) and environmental parameters were also monitored. These values were used to calculate the transpiration and that was expanded to sap flow by the known of total leaf area on the branch.

Sap Flow Measurement

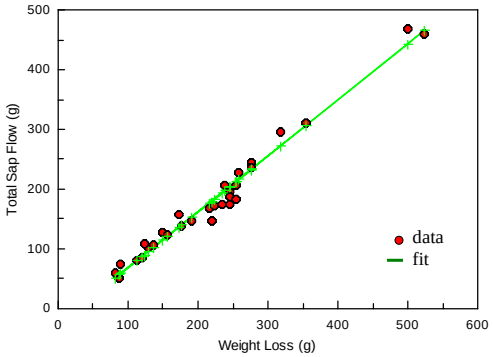


Heat Balance

Hi = Hu + Hd + Ho + Hs



Hass on Variety of Root Stocks (Duke 7 and Toro Canyon)
Young trees trimmed to only several branches; all open.
Data from Claudia Fassio, Summer 2006



Constant	-26.4
Std Err of Y Est	15.8
R Squared	**0.97609**
No. of Observations	30
X Coefficient(s)	0.938
Std Err of Coef.	0.028

Other Problems: Unequal illumination of leaves on branch being tested
Age Differences of Leaves on branch

Field Sap Flow Measurements – July 2006

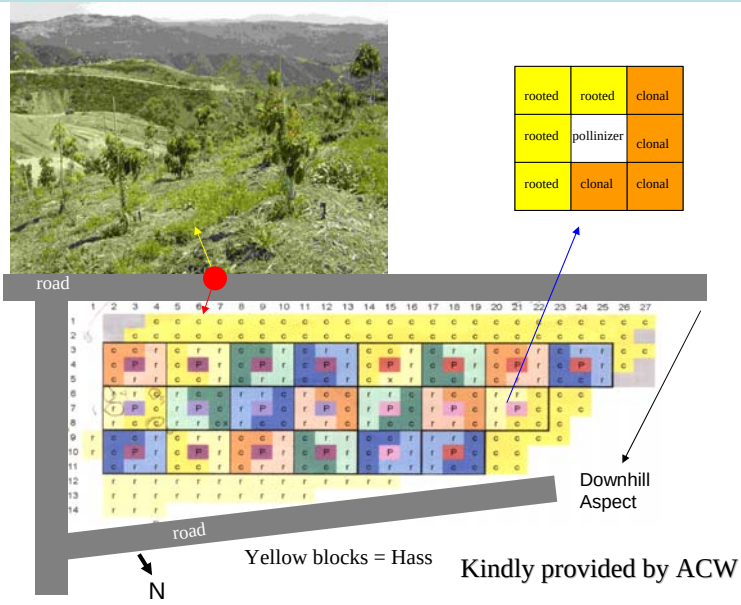
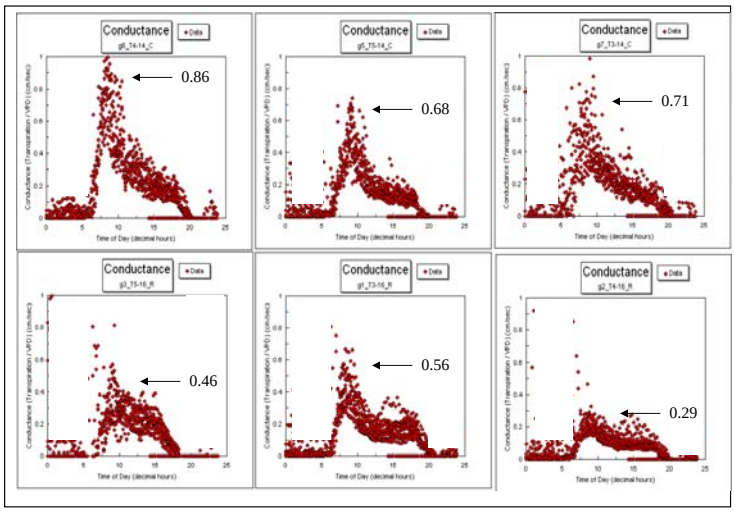


Figure 1

Yellow blocks = Hass

Kindly provided by ACW

Rooted vs Clonal (Duke 7)



Comparison of the Calculated Conductance between Rooted and Clonal Rootstock in the Field.

Sap flow (g/hr) converted by leaf area (m2) into transpiration (mmol/m^2 sec). Using VPD from relative humidity and air temperature, the transpiration is converted into conductance. These are total conductance, not those from LICOR measurements (which misses the boundary layer).
Data are from six trees planted at a field plot at ACW, Fallbrook, spaced by 10 feet from 7/6 to 7/17/06.

To obtain "standard" conductance multiply these numbers by 250 to obtain conductance as mmol/m^2 sec.

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Rooted trees maintain morning sap flow

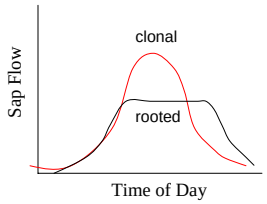
Afternoon / Morning

	Ratio of Sap Flow - PM / AM		
average	74%	108%	1.50
std. dev.	22%	24%	
t-test	0.4%		

	average PM / AM		
	clonal	rooted	rooted / clor
07/06	130.2%	150.3%	1.15
07/07	61.5%	106.2%	1.73
07/08	54.4%	86.0%	1.58
07/09	53.2%	84.1%	1.58
07/10	84.6%	109.9%	1.30
07/12	57.7%	84.6%	1.47
07/13	67.2%	76.8%	1.14
07/14	60.7%	111.4%	1.84
07/15	79.3%	122.7%	1.55
07/16	95.2%	149.2%	1.57
07/17	64.9%	101.7%	1.57

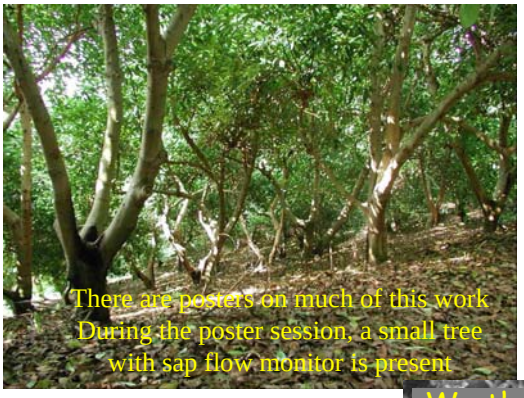
Morning = 7AM – 10AM
Afternoon = 3PM – 6PM

Hass Trees



Clonal compared with rooted
higher peak
afternoon fall-off

Less total water movement in rooted
= less total conductance in rooted



We three thank you for your continued support!