# California Avocado Research Symposium 2006

*November 4, 2006*
*University of California, Riverside*

California Avocado Commission
Production Research Committee

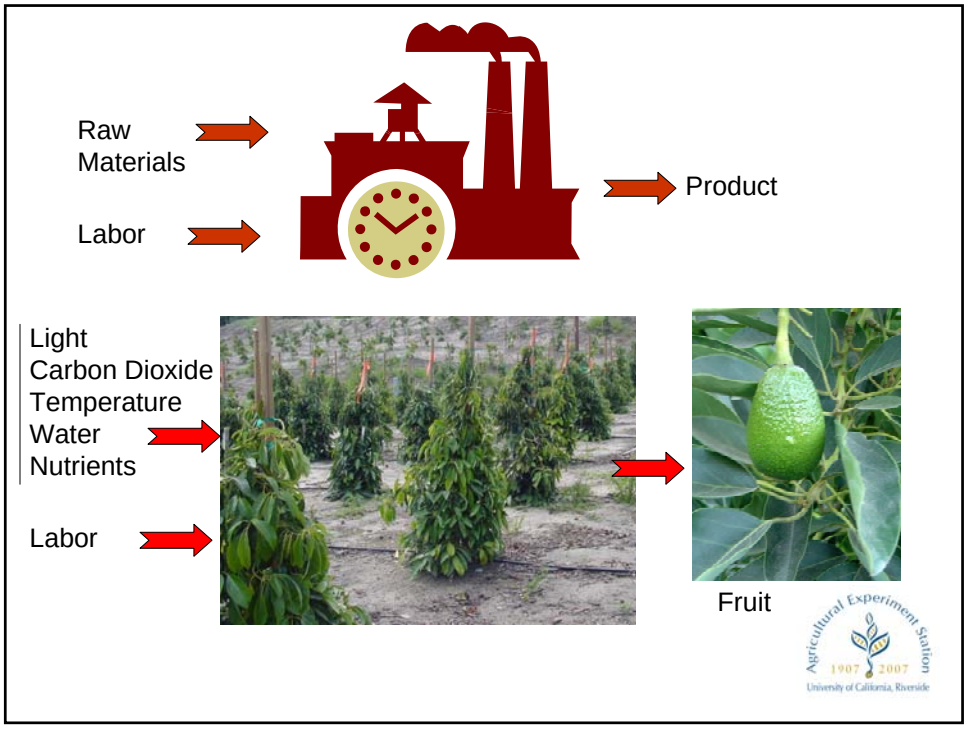
***Our Mission: To provide California Avocado Growers a means to achieve optimum profitability, now and in the future, through focused research, global collaboration, and effective communication of results***

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

# Avocado Tree Physiology – Understanding the Basis of Productivity

R. L. Heath, M. L. Arpaia
UC, Riverside

M. V. Mickelbart
Purdue University

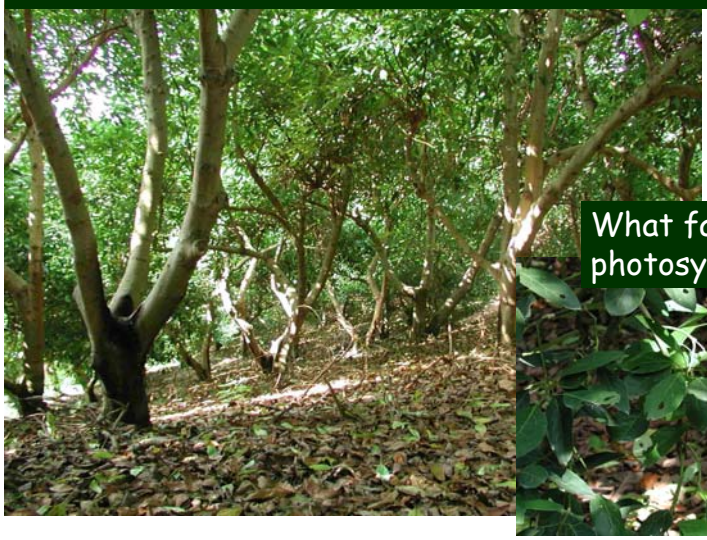



# Research priorities addressed

- 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?

## Problem: Lowered Productivity in California

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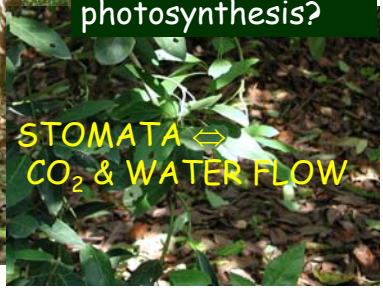
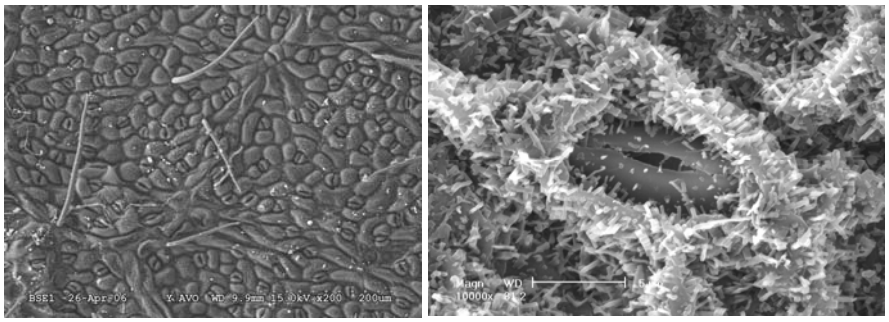
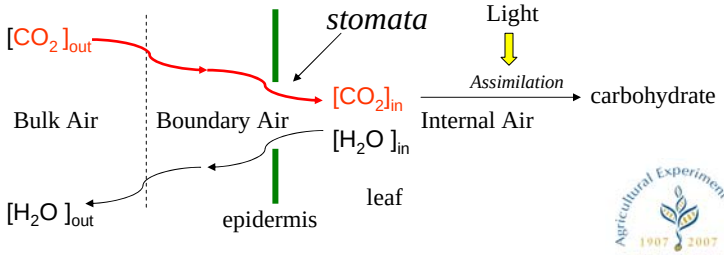


What factors limit photosynthesis?

STOMATA ⇔
$CO_2$ & WATER FLOW



**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

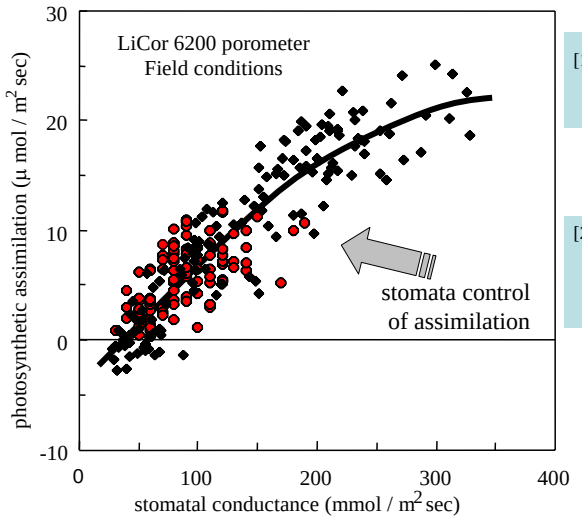
## Potential solutions:

[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

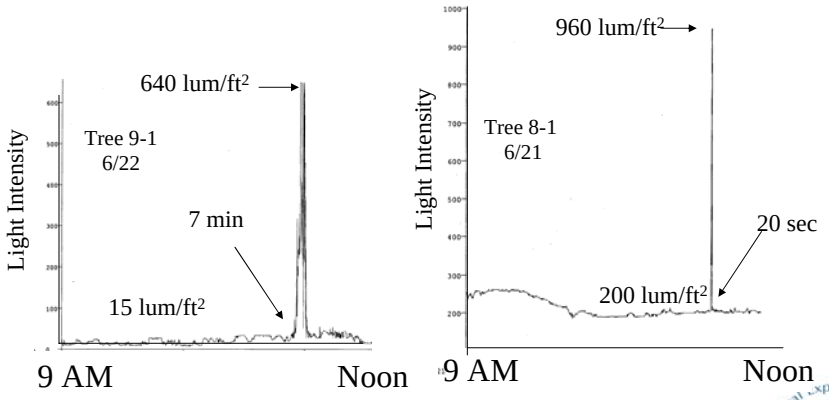
From Mickelbart (● & Xuan (▲)

# Accomplishments to date

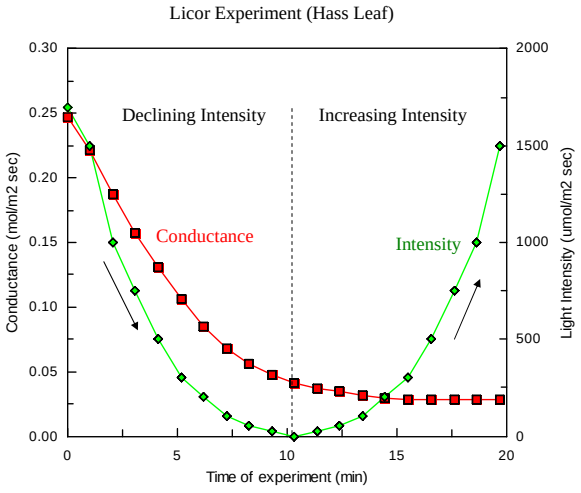
- Light Flecks
- Leaf area
- Leaf processes
  - Light intensity and assimilation
  - Model of productivity
- Sap flow

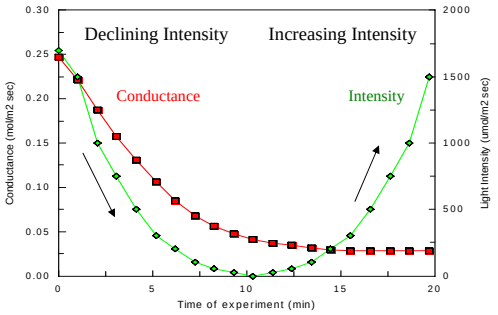
# Light "Flecks" inside canopy

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




# Speed of stomata change





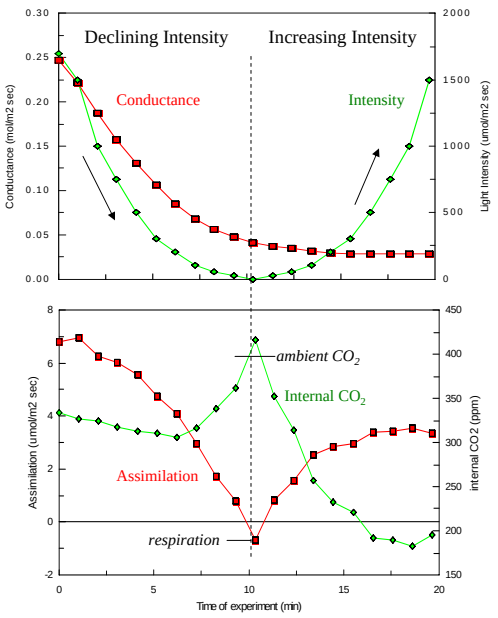

Licor Experiment (Hass Leaf)

## Decline

Lower intensity = closed stomata

Lower intensity & closed stomata = lower assimilation

Lower assimilation & closed stomata = higher internal $CO_2$

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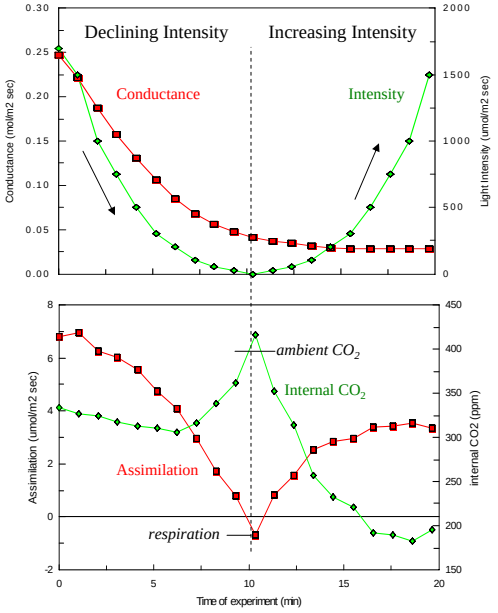


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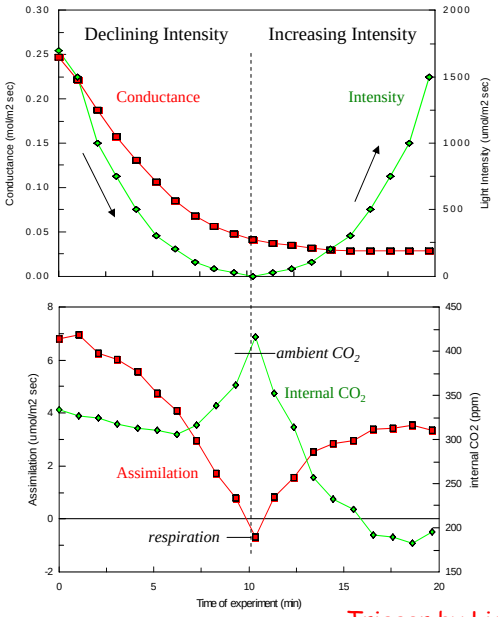
## Increase

Higher intensity = higher assimilation

Higher assimilation & closed stomata = lower internal $CO_2$

Lower internal $CO_2$ = opening of stomata

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Higher assimilation & closed stomata = lower internal $CO_2$

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)

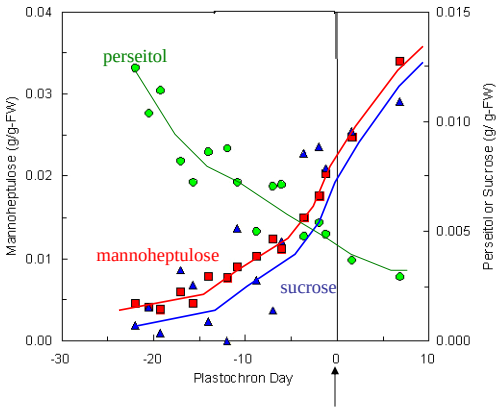
# Leaf area

- 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

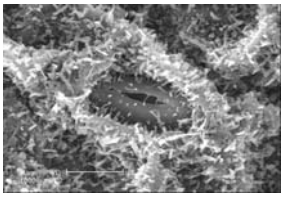
The amount of carbohydrate as related to 'Hass' leaf age




Day zero = 50% of maximum leaf size



Stomata (regulated opening in leaf)



$CO_2$ Transport from air to inside leaf

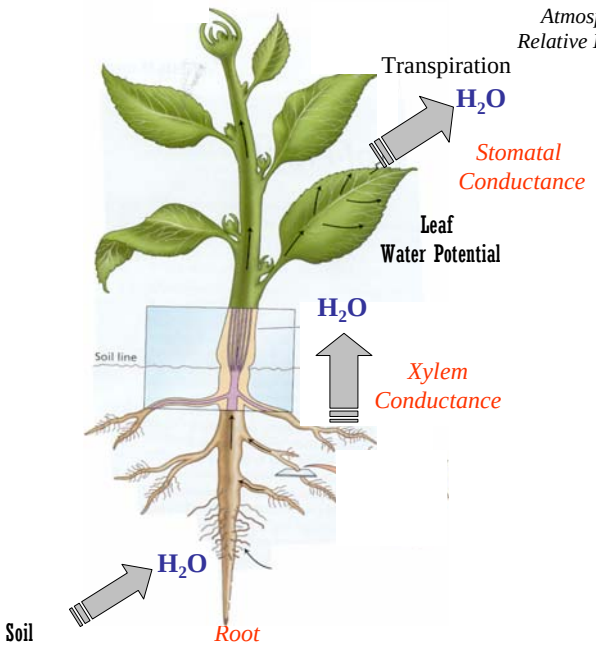
\-

$H_2O$ Transport from inside leaf to air

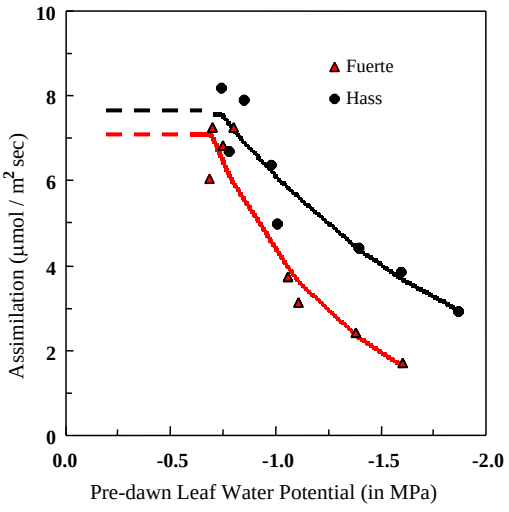
$CO_2$ Assimilation [Photosynthesis]

$H_2O$ Loss From Leaf ------→ Loss of Leaf

Carbohydrate / Oil Production

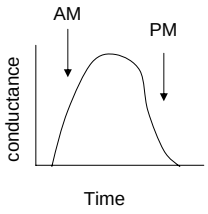



Water Flow Within The Plant




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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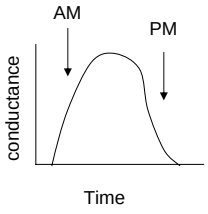


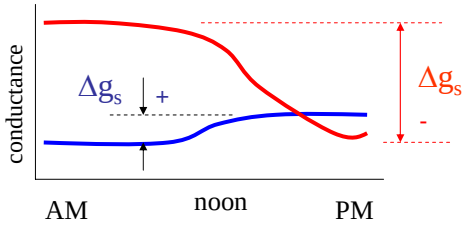

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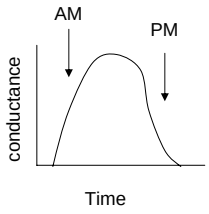
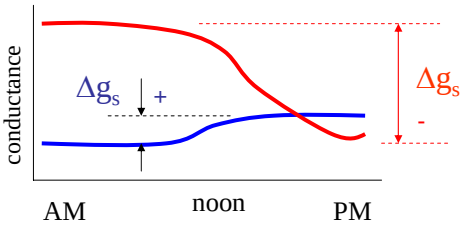
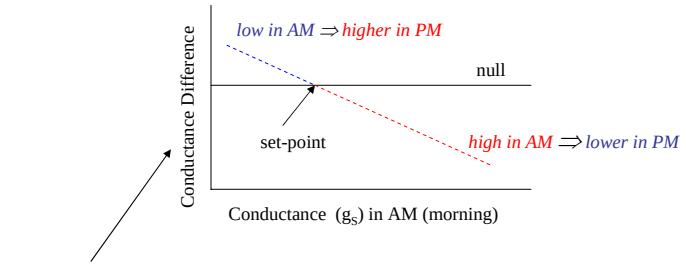
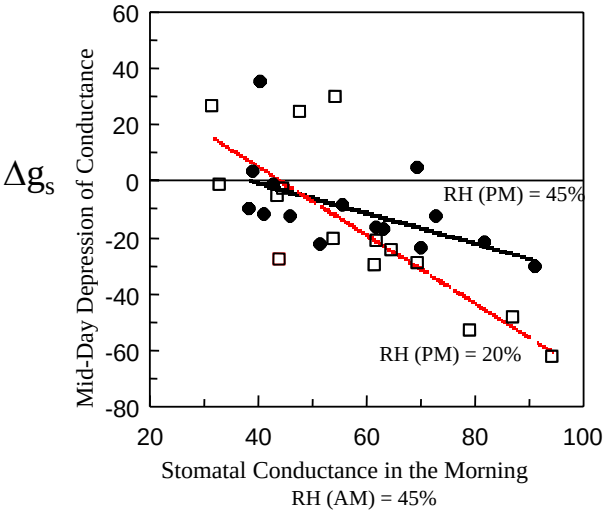




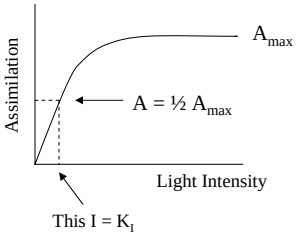



Measurements made with LiCor Porometer on one leaf at a time.

*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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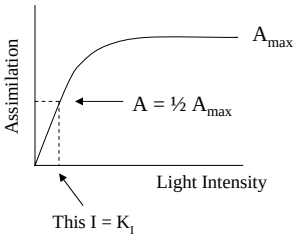


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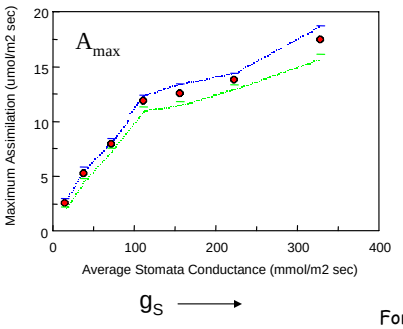
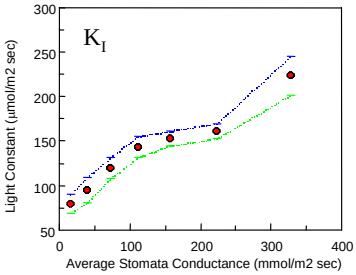



$g_S$ ⟶

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

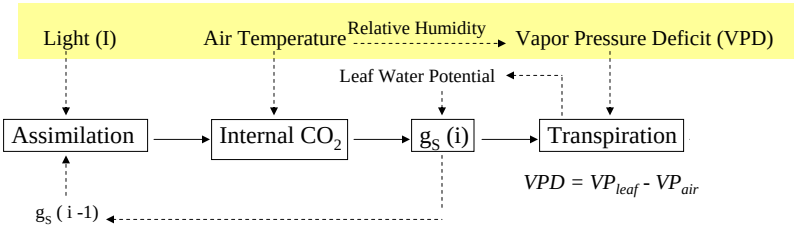
✓Water loss due to transpiration changes stomata but..
Transpiration is less for high relative humidity
Soil water can mitigate this leaf water loss

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)

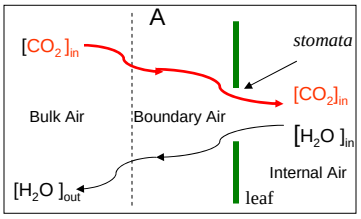
*All in the house that Jack built!*




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

*We still need soil water*

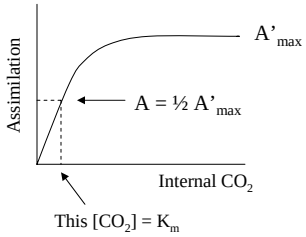
*FINALLY* Internal $CO_2$ Controls Conductance



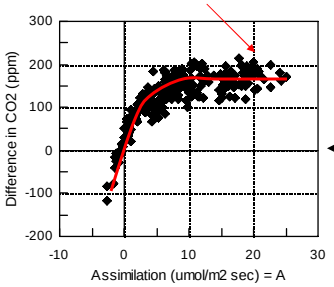

Difference in $CO_2$ = $[CO_2]_{outside} - [CO_2]_{inside}$

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

Movement of $CO_2$ limits assimilation




This $[CO_2] = K_m$



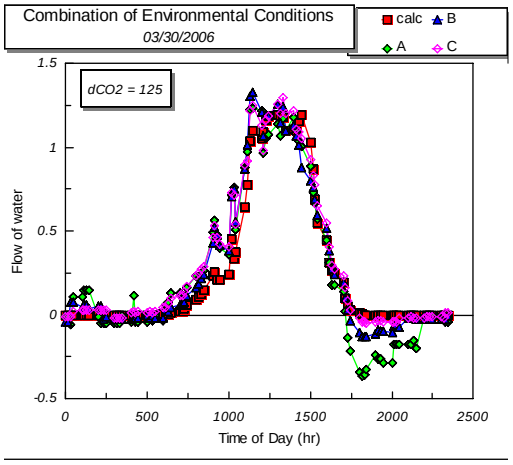

Air $CO_2$

Validation of model: How do you measure transpiration continuously ?

Validation of model: How do you measure transpiration continuously ?

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

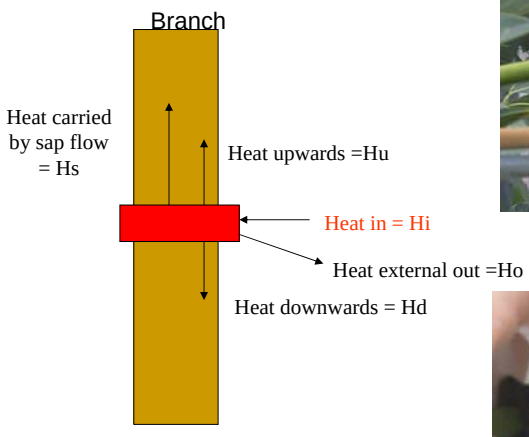
Three Zutano Trees (A, B, C) in Green House




Comparison between the Model and the Actual Sap Flow.

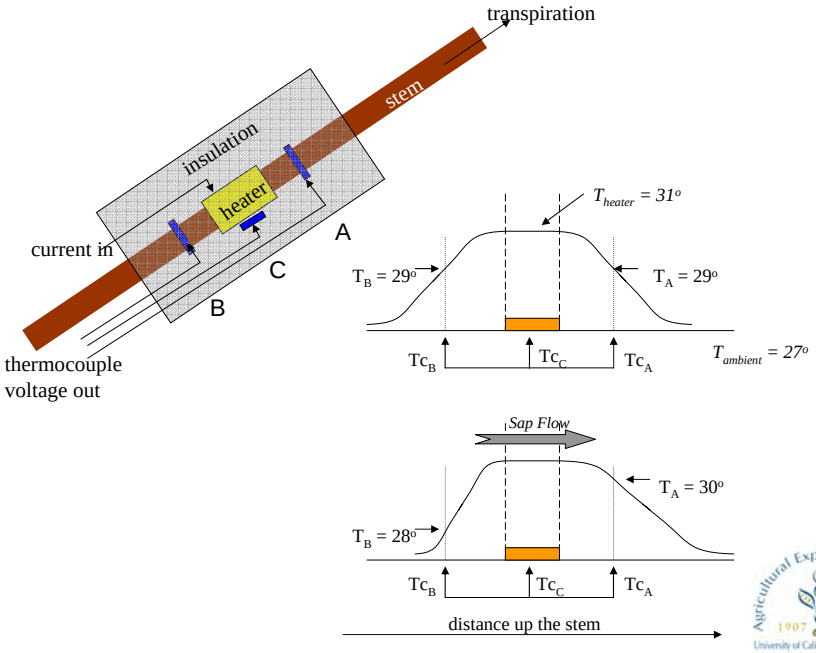
Three trees (zutano) were used in the green house to monitor sap flow (transpiration) and environmental parameters were also monitored. These values were used to calculate the transpiration and that was expanded to sap flow by the known of total leaf area on the branch.

## Sap Flow Measurement

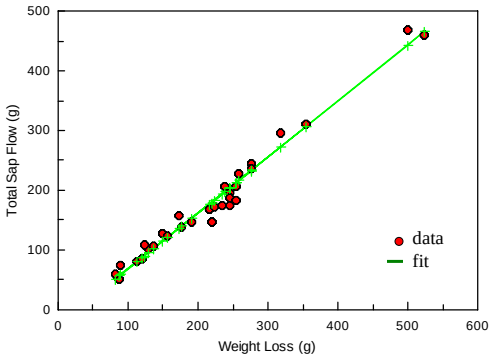



Heat Balance

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

| | | |
|---|---|---|
| rooted | rooted | clonal |
| rooted | pollinizer | clonal |
| rooted | clonal | clonal |

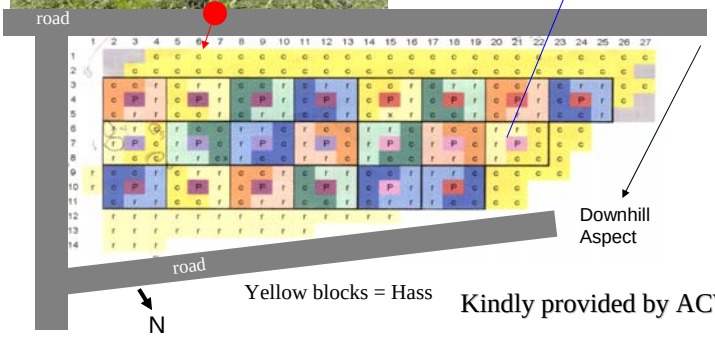
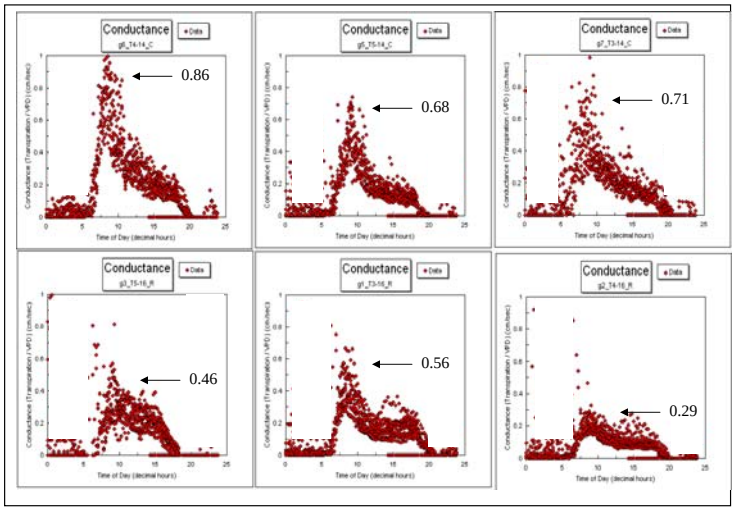



**Figure 1**

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*

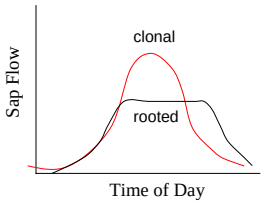
Afternoon / Morning

| | 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 |

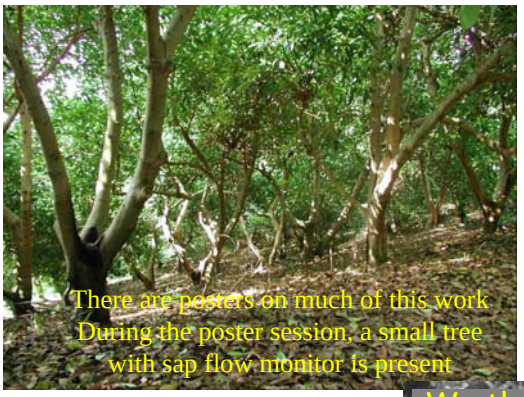
Morning = 7AM – 10AM
Afternoon = 3PM – 6PM

Hass Trees




Clonal compared with rooted
higher peak
afternoon fall-off

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



There are posters on much of this work. During the poster session, a small tree with sap flow monitor is present

We three thank you for your continued support!