Linking papaya horticulture to its ecophysiology

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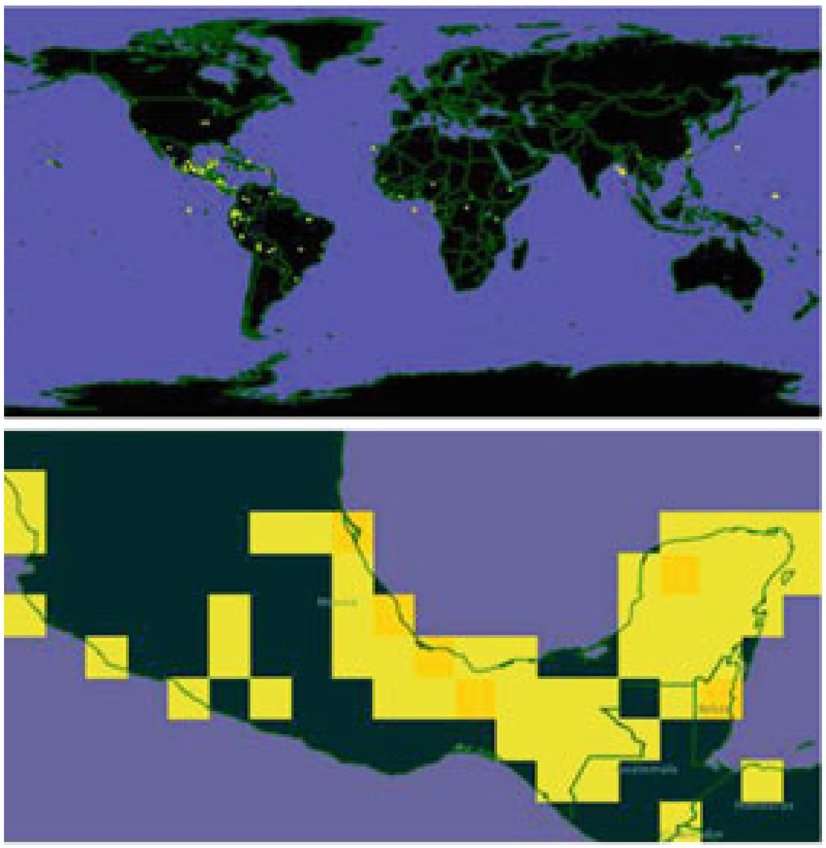
Interdisciplinary Ecology

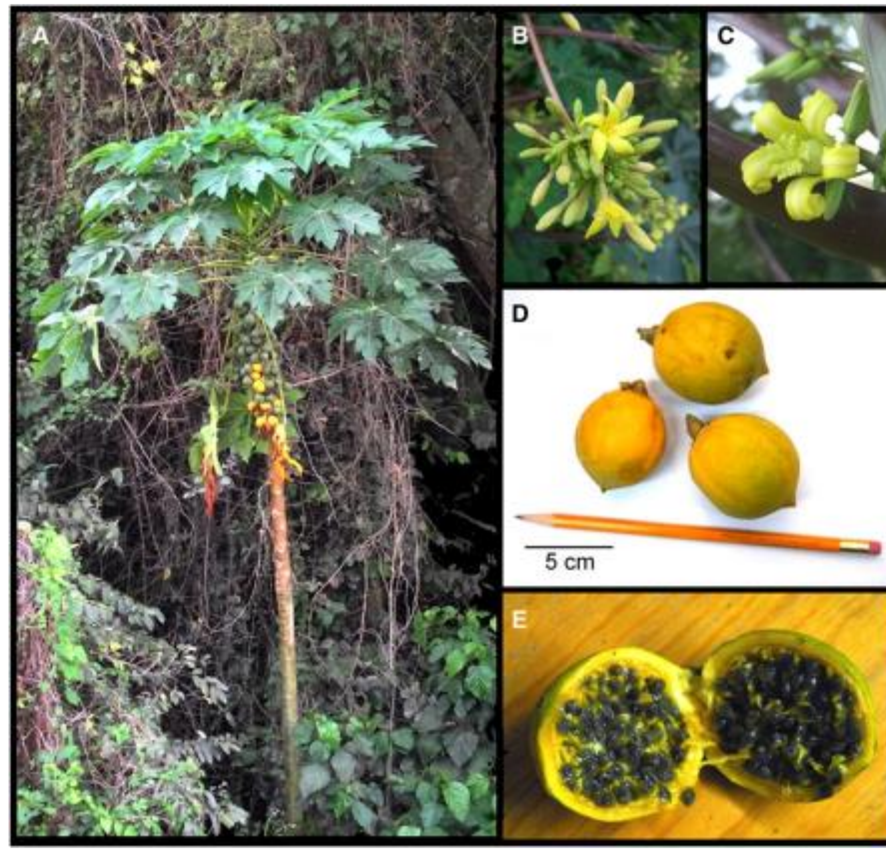
Preview

- *C. papaya* background
  - Ecology
  - Biology
- Fruit production
- Wind damage and stress
- Proposed new production methods
  - Sunn hemp
  - Priming
- Study 3: Sunn hemp intercrop
- Study 1: Soil dry-down
- Study 2: Shade-light transition and water-deficit priming
- Conclusions

Carica papaya L. origin



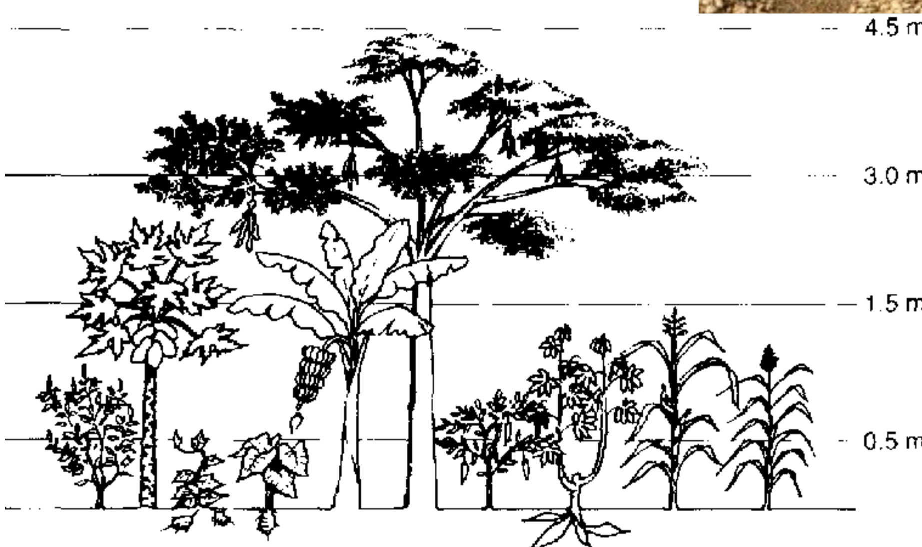
From: G. Fuentes & J.M. Santamaria (2014)



From: Chavez-Pesquera et al. (2014)

Papaya production

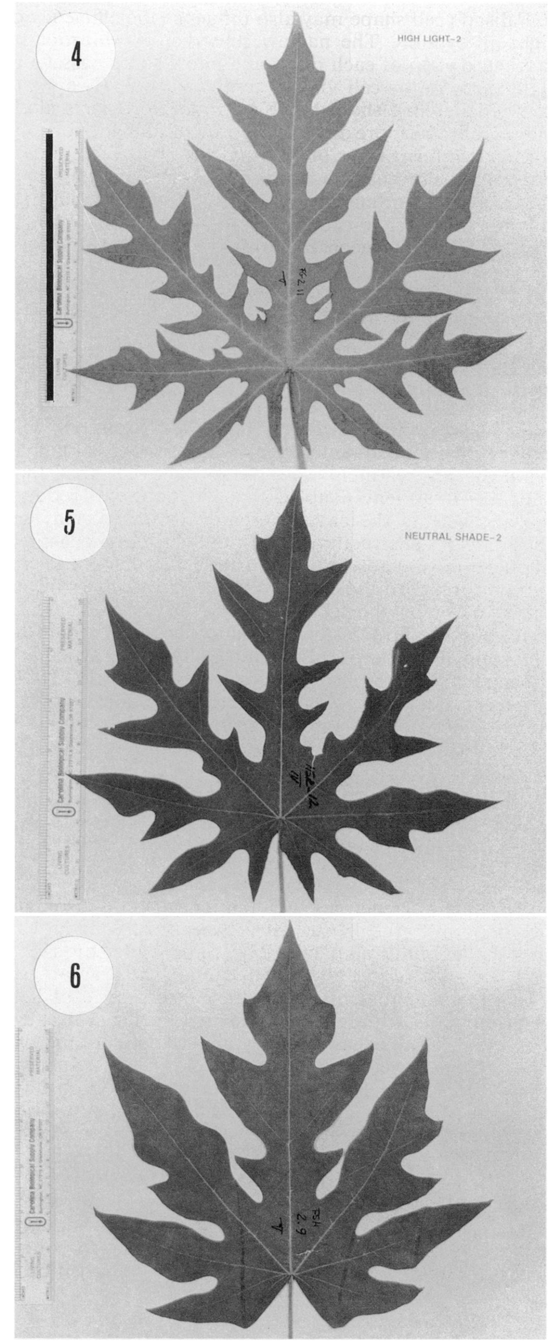
- 3rd global tropical fruit
- Carotenoids
- Large scale and smallholder



Acclimation

- VPD
- Wind
- Shade
  - Plasticity
  - Dynamics?

From Buisson & Lee (1993)



Figs. 4–6. Leaf shapes of papaya seedlings grown in different light treatments. **4.** High light (HL). **5.** Neutral shade (NS). **6.** Filtered shade (FS). Bar = 10 cm.

Wind damage

Photo by Kati Migliaccio

- Sensitive periods
- Constructed barriers costly

Sunn hemp

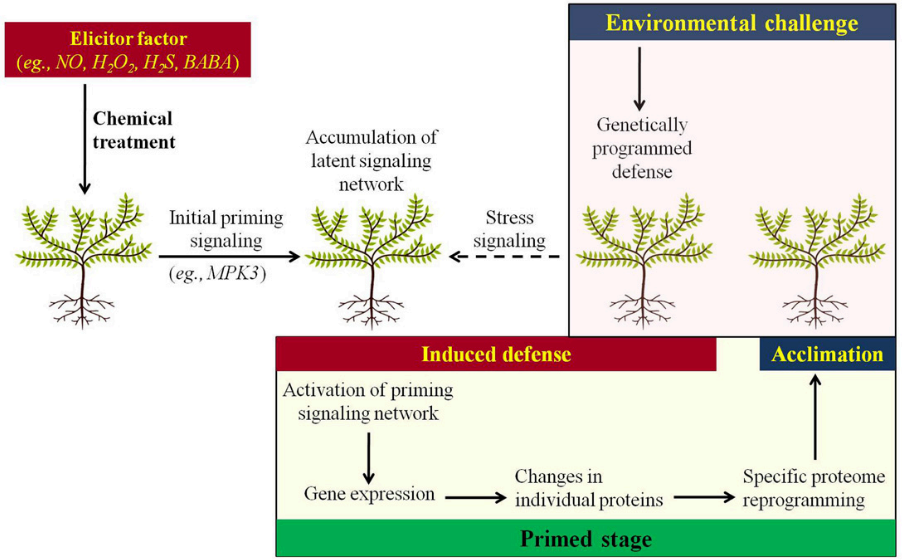
- *Crotalaria juncea* L.
- Legume
- Vigor
- Popular with growers

Intercrop wind mitigation

- Shade acclimation
- Mulch, green manure
- High-light stress

Priming

- Any treatment that elicits an improved response to subsequent challenges (pests, disease, salinity, water deficit)
- RDI priming in row crops
- Mechanisms
- Cross-priming?



Tanou et al. 2012. Front. Plant. Sci.

Cross-priming

- Cross-priming:
  - Effecting priming with a different type of stress
- Water-deficit priming to reduce high-light stress:
  - Photoprotection
  - Carotenoids
  - Antioxidants

Photos provided by Bruce Schaffer

Measuring plant stress

Research Objectives

- Test the use of an intercrop as a wind block and green manure for papaya production.
- Test the use of water-deficit priming in mitigating the impacts of shade to high-light transitions (cross-priming).

Studies

- Field study
  - Test sunn hemp intercrop-mulch system in production
  - Test priming for reducing high-light stress upon mowing sunn hemp
- Soil dry-down
  - Compare measurement variables
  - Set priming treatment
- Shade-Priming
  - Test cross-priming hypothesis

Sunn hemp intercrop

- Objectives:
  - Test the effect of sunn hemp intercrop and mulching system on papaya growth, yield, physiological variables, and agricultural water use.
  - Test the effect of timing of mowing-mulching, on the same.
  - Test the use of priming in the field.

Methods

- Treatments
  - SH-mown early (August 11)
  - SH-mown late (September 25)
  - No sunn hemp
- SH used as mulch
- Priming by withholding irrigation

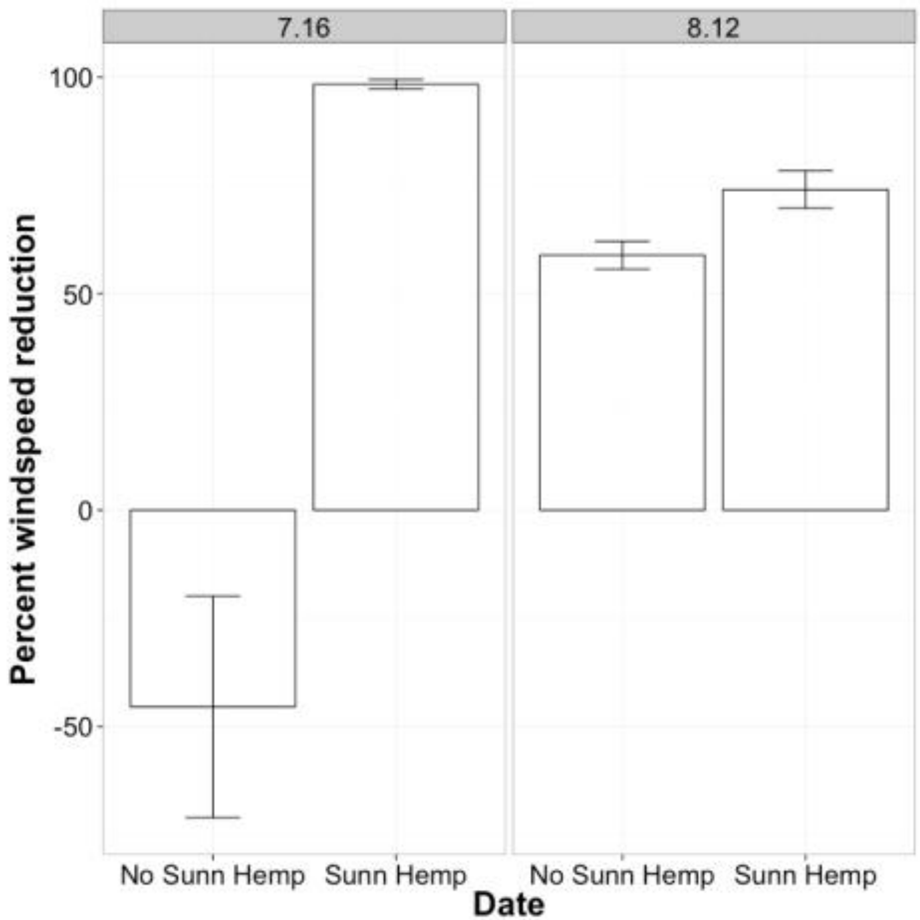
Methods

- Experimental design
  - Split-plot RCB
- Variables
  - Growth: stem diameter, stem length, others
  - Gas exchange
  - OJIP
  - Specific leaf weight
- Analysis
  - Linear models for single dates (anova)
  - Linear models (repeated measures) for multiple dates
  - nlme package in R

Wind

Percent reduction of wind speed relative to outside of planting of papaya with and without sunn hemp intercrop

Low wind speed day



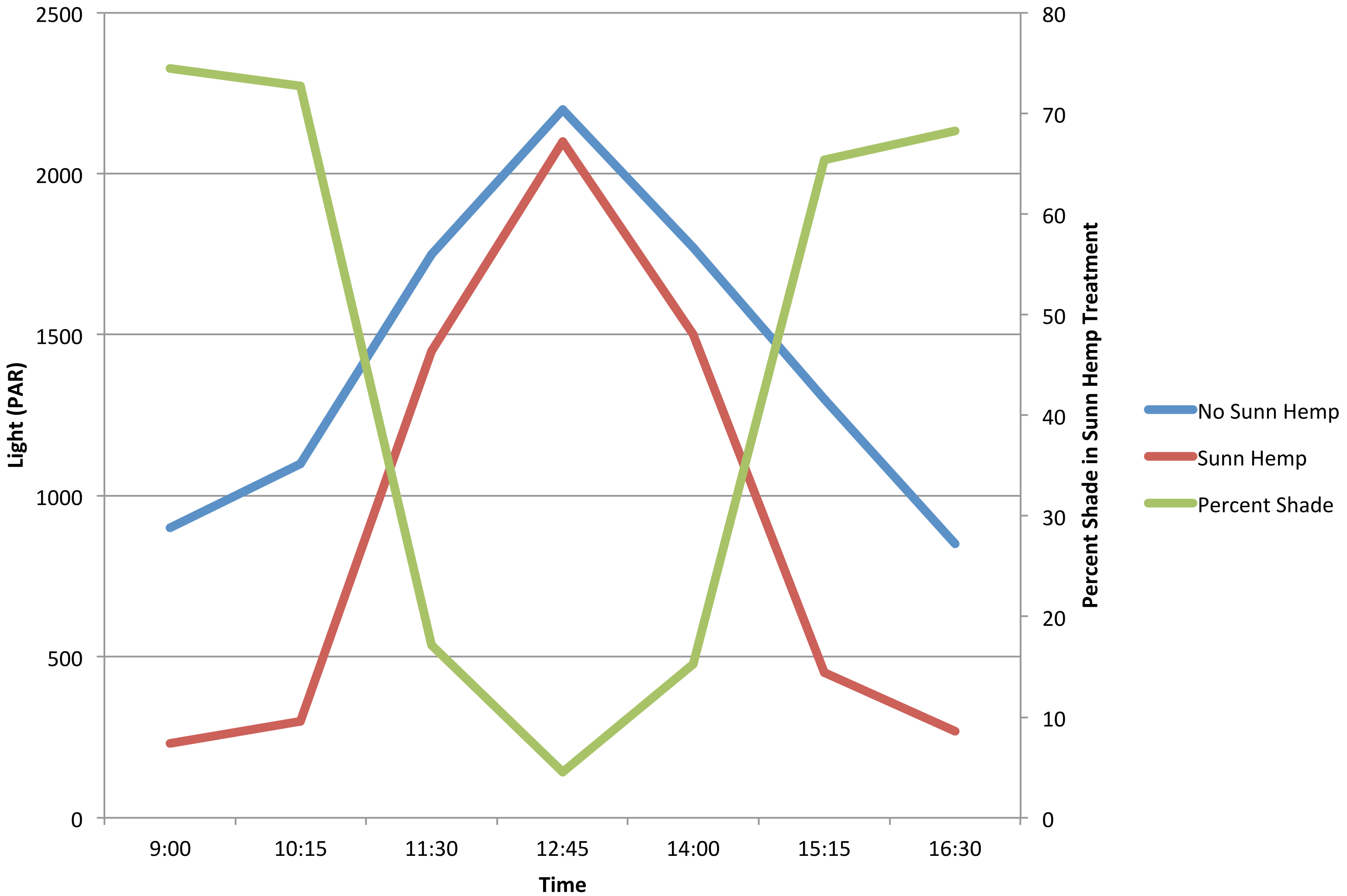
High wind speed day

Bars represent standard error.

Shade

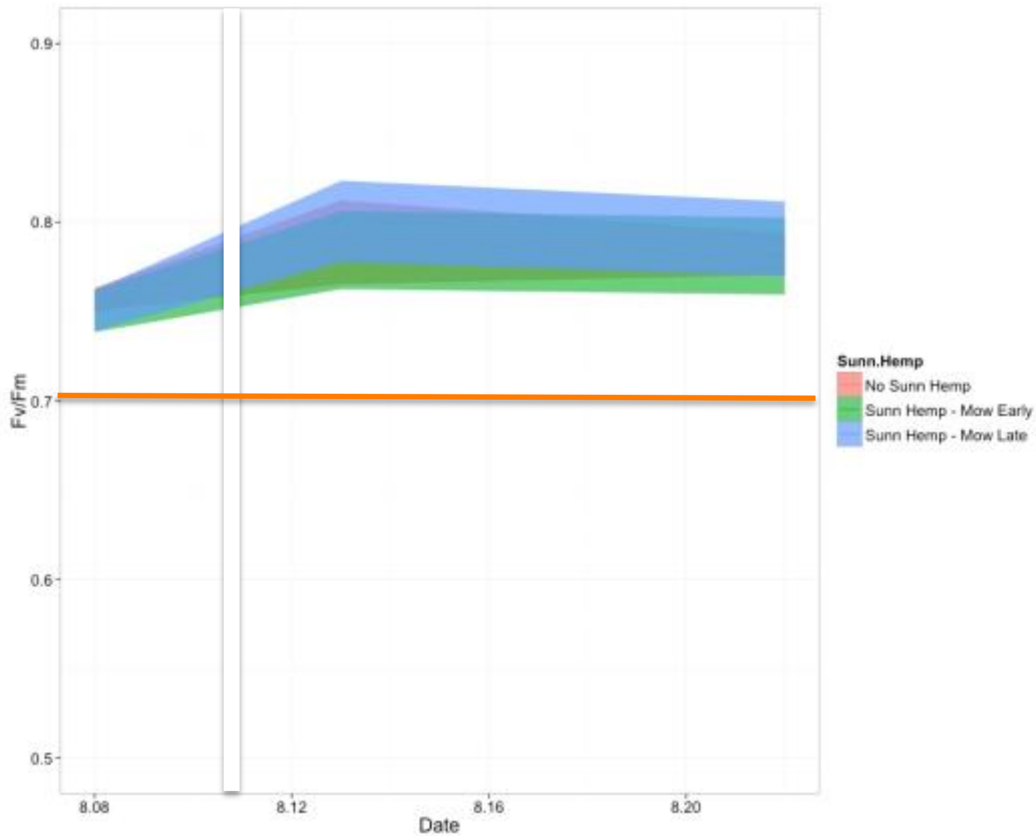
Sunn Hemp Intercrop

Shading



Sunn Hemp Intercrop

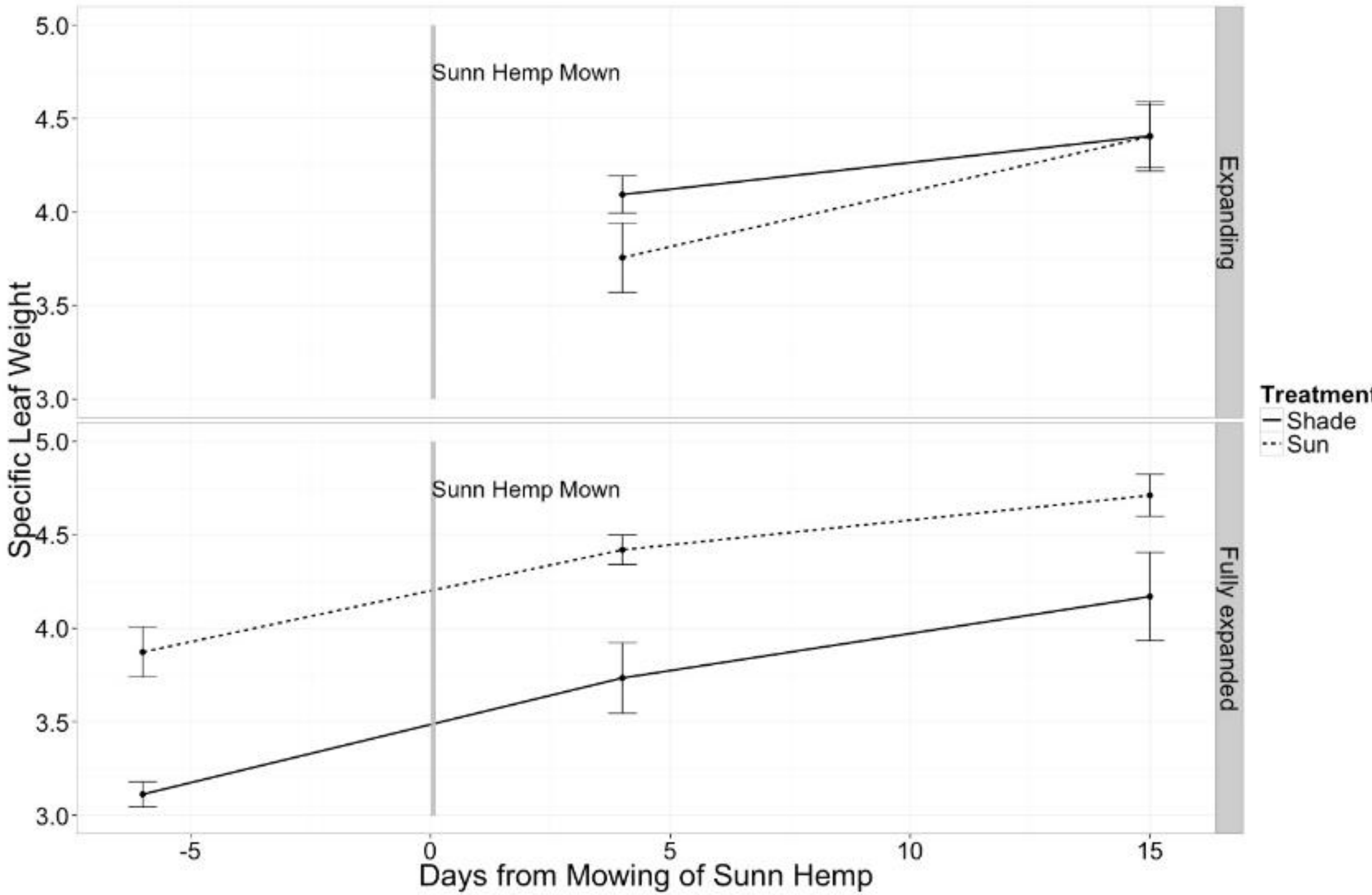
Yield of PSII (Fv/Fm) of 'Red Lady' papaya intercropped with sunn hemp, ML treatment sunn hemp mown on Aug. 11



Fluorescence Fv/Fm

Bands represent 95% confidence intervals.

Specific leaf weight (mg DW cm^{-2}) of 'Red Lady' papaya prior to and following mowing of shading sunn hemp intercrop



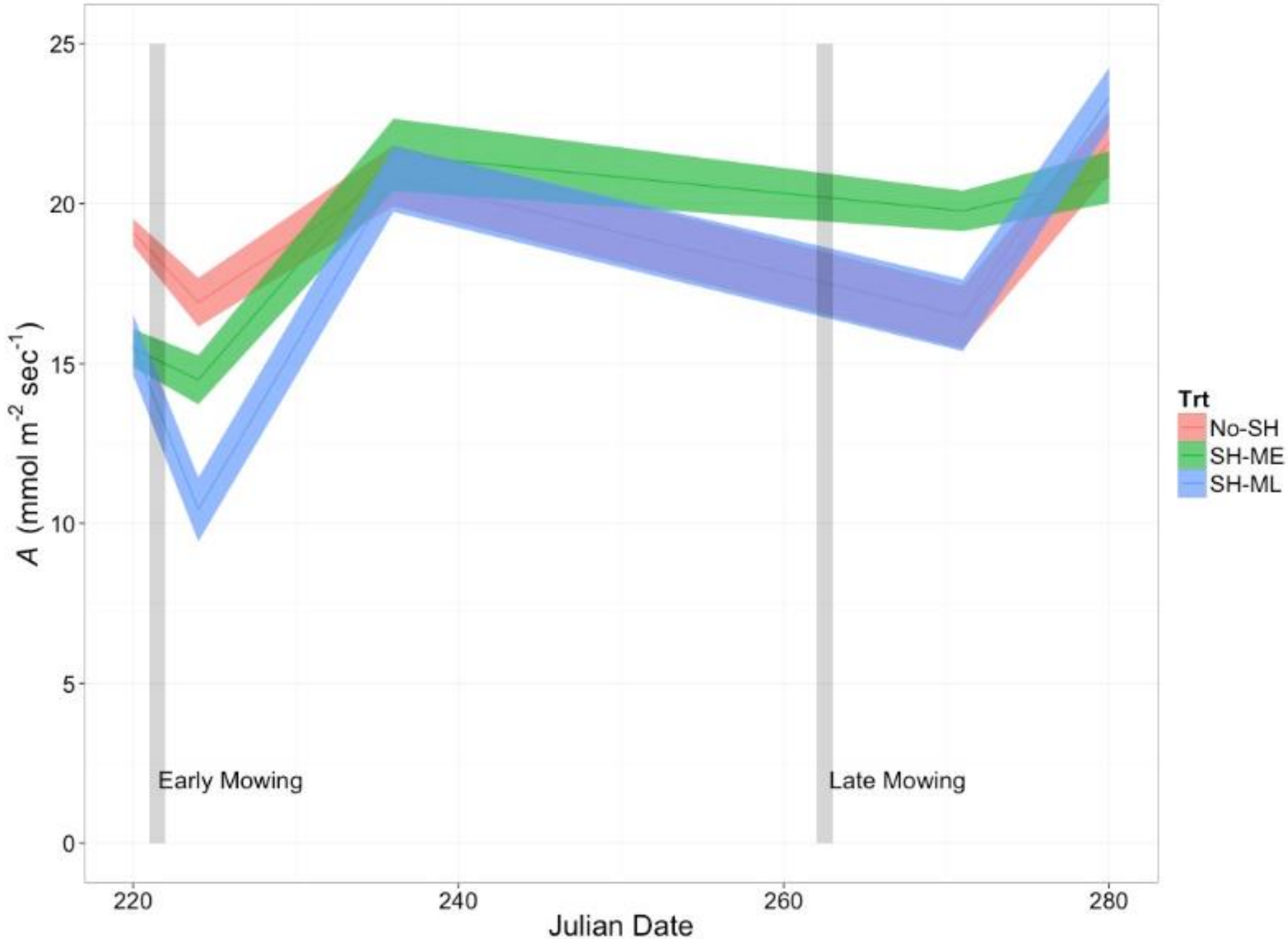
Bars represent SE. Gray vertical line marks date of sunn hemp mowing.

Sunn Hemp Intercrop

Growth

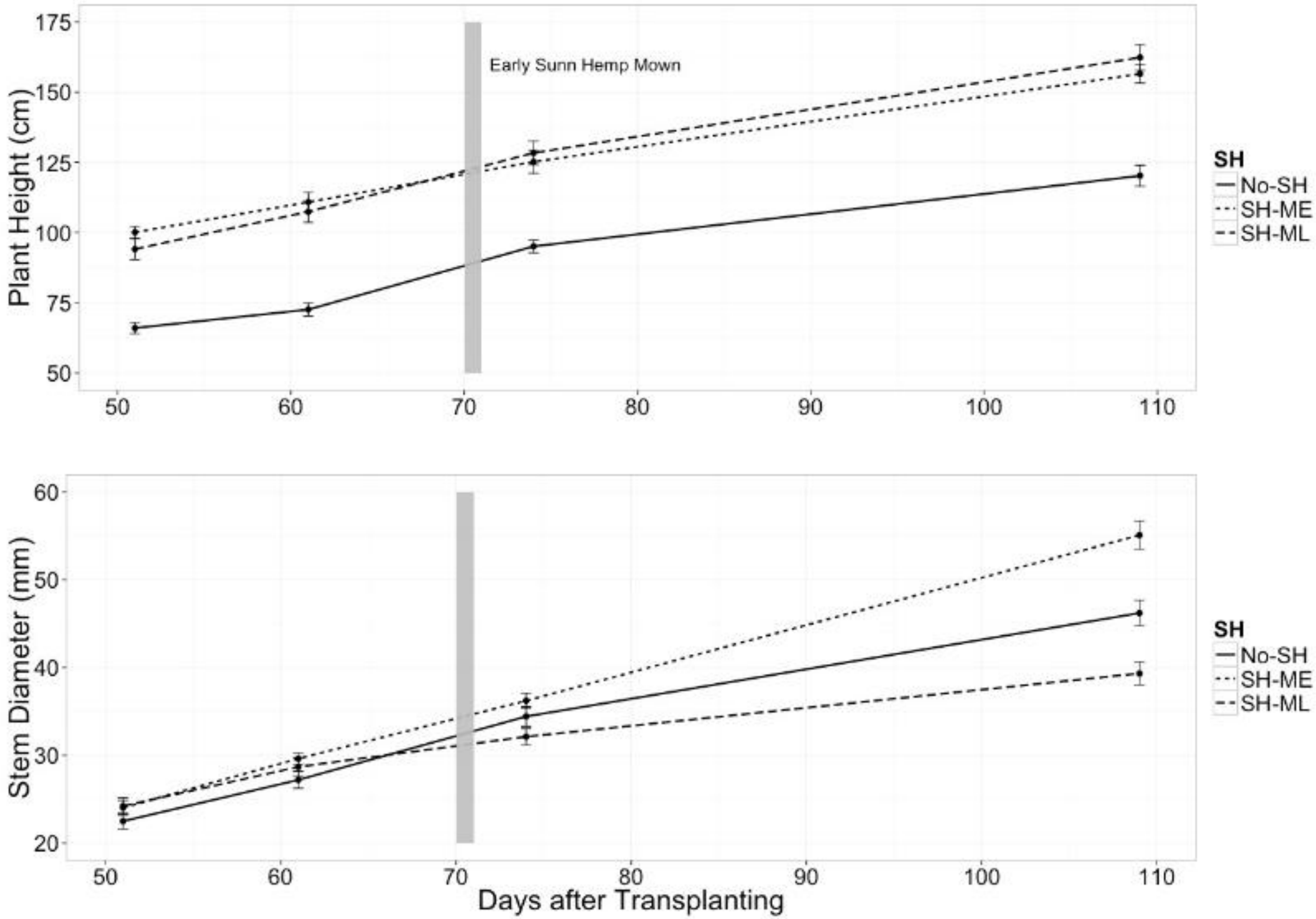
Sunn Hemp Intercrop

Net photosynthesis (*A*) of 'Red Lady' papaya intercropped with sunn hemp mown in August (ME) or September (ML)



Bands represent standard error.

Height and diameter of 'Red Lady' papaya prior to and following mowing of shading sunn hemp intercrop



Bars represent SE. Gray vertical line marks date of sunn hemp mowing.

Weeding time

Treatment	Weeding time (minutes per plot)
No Sunn Hemp	74.5 a
Sunn Hemp Mown Early	29.6 b
Sunn Hemp Mown Late	28.5 b

Means followed by different letters are significantly different at P=0.05 according to Bonferroni's LSD. Analyses performed on log transformed data, non-transformed data did not conform to assumptions of normality.

Conclusions

- Sunn hemp intercrop has potential to protect and improve papaya crop growth.
- If prolonged, sunn hemp intercrop shading of papaya reduces growth.
- Sunn hemp mulch improves subsequent growth.
- Papaya acclimated rapidly to shifting light environments, avoiding photo-oxidation.

Soil Dry-Down Study

- Goal:
  - Set level of water deficit for priming treatment in subsequent priming study.
- Objectives:
  - Determine most sensitive plant measurement to mild water deficits.
  - Determine the most moderate level of water deficit at which differences relative to well-watered plants could be determined.

Methods

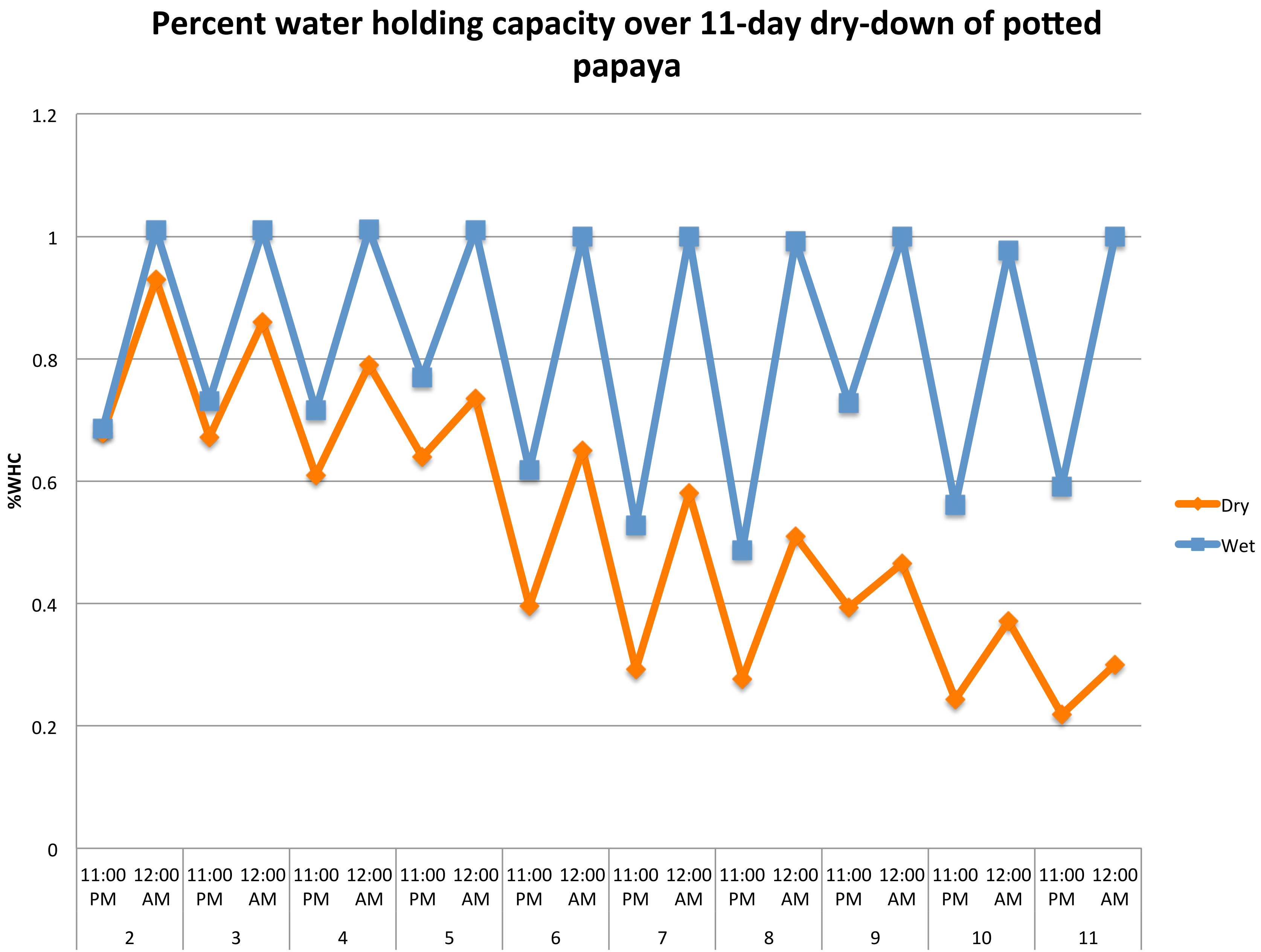
- 12 Days
- 'Red Lady' papaya in 2 gallon pots, Pro-Mix
- 10 reps
- 2 Treatments
  - Fully watered
  - Dry-down
- Progressive drying
  - Partial re-watering each day, 7% (WHC by weight) less each day than the previous day

Dry-down study

Methods

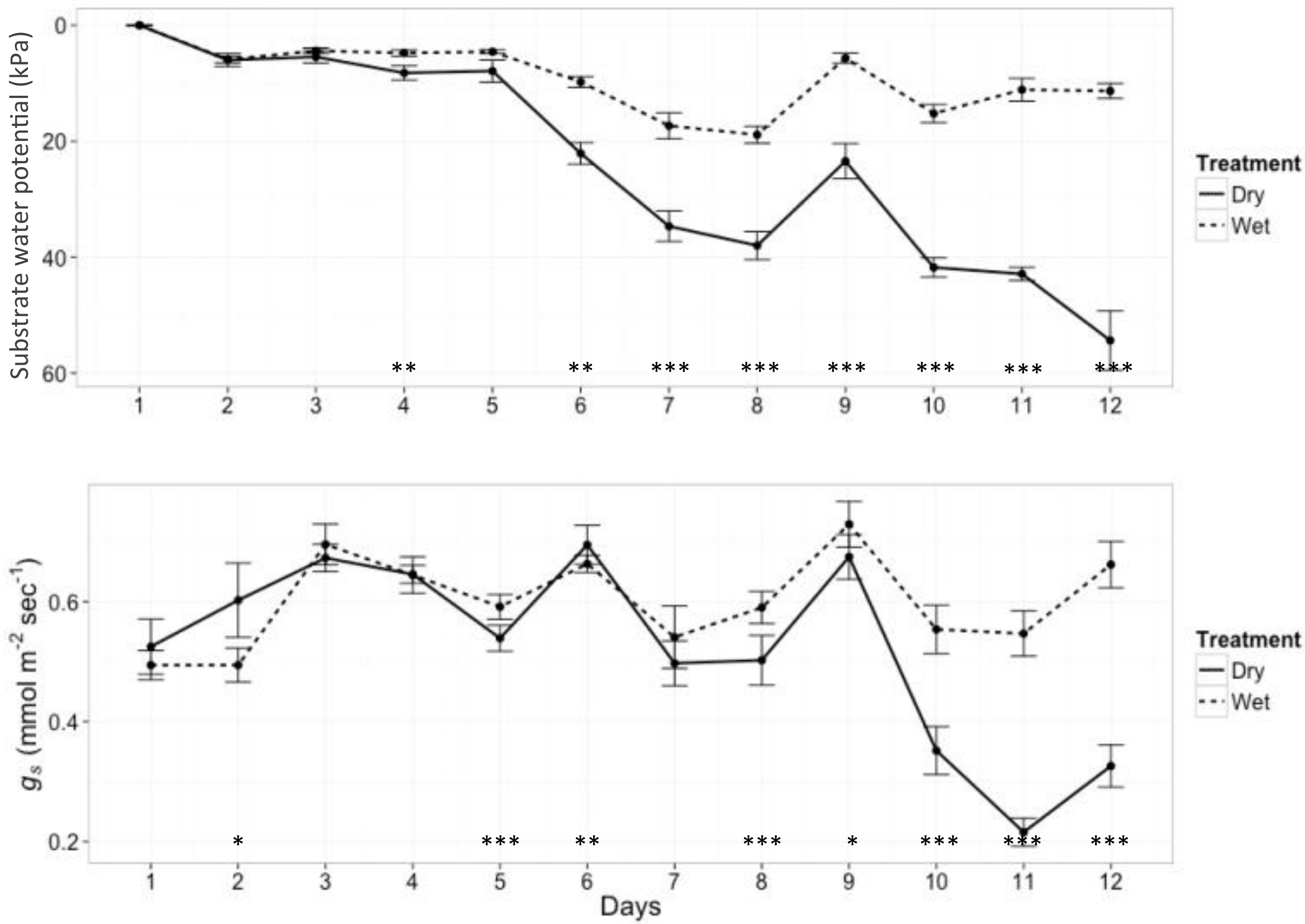
- Variables:
  - Chlorophyll fluorescence:
    - Daytime: F’, ϕ_{PSII}
    - Steady-state: F_v/F_m, NPQ, J
  - Leaf gas exchange from 9 am – 11 pm: g_s, A, WUE, iWUE
  - Leaf angle
  - SPAD
- Analysis
  - T-test for each day
  - Non-linear models for select variable responses

Dry-down study



Dry-down study

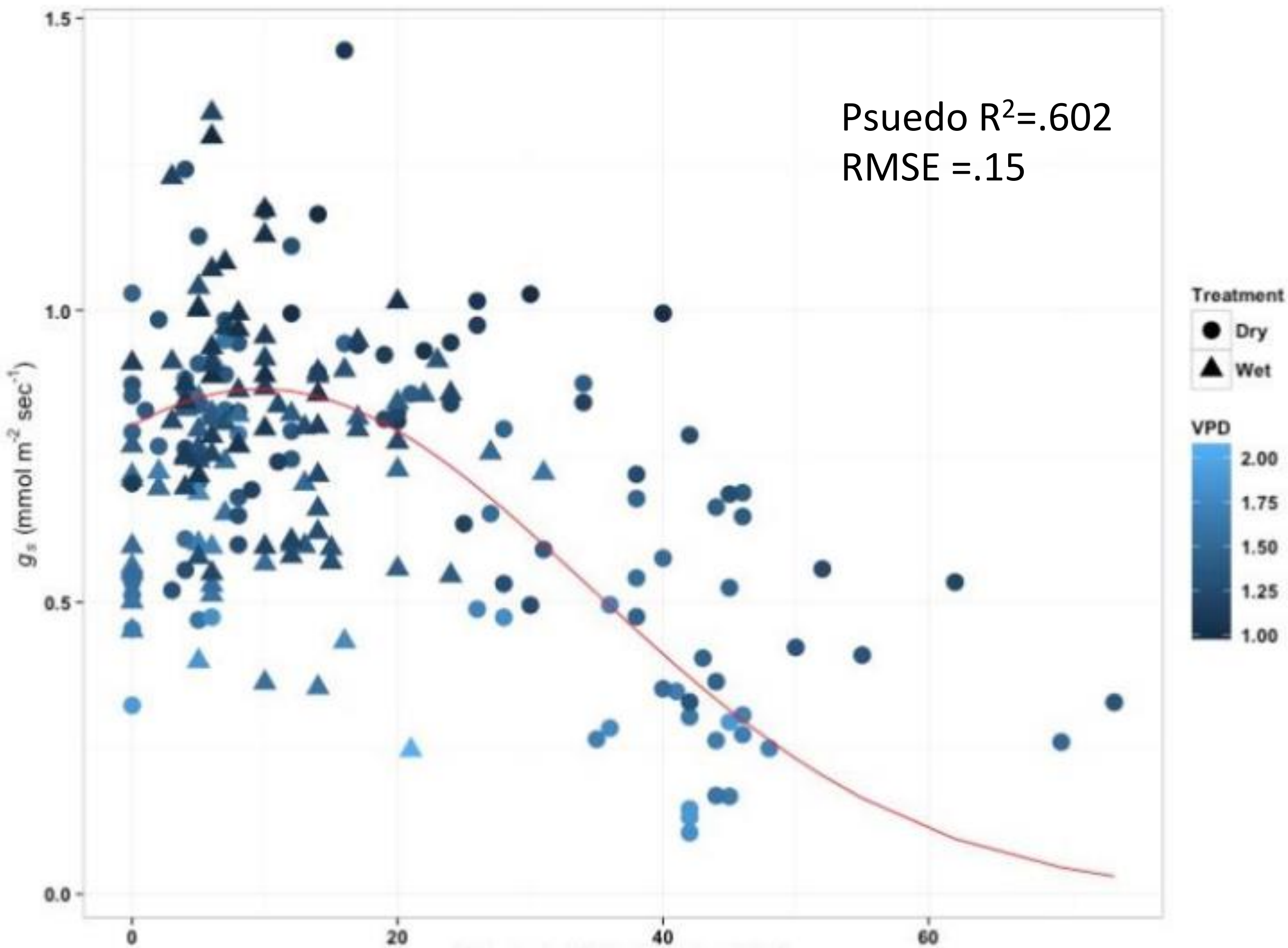
Substrate water tension and stomatal conductance (g_s) of 'Red Lady' papaya over a 12-day substrate dry-down period.



Bars represent standard error. Asterisks indicate p-value of difference between treatments: *,**,** represent P-values < .1, .05, .01 respectively, based on 1-way analysis of variance for each day.

Dry-down study

Stomatal conductance response of 'Red Lady' papaya to substrate water tension and leaf vapor pressure deficit (VPD)



Substrate water potential (kPa)

Line represents prediction of nonlinear model.

Dry-down study

Soil Dry-Down

Conclusions:

- Most variables are not sensitive to mild water deficit
- Stomatal conductance most sensitive
- -30 kPa selected as target substrate moisture for water-deficit priming

Shade-Priming

Objectives

- Test priming based on dry-down study
- Determine whether priming alleviates photo-oxidation when shade acclimated plants were exposed to full sunlight (cross-priming)
- Determine whether timing of priming impacts responses

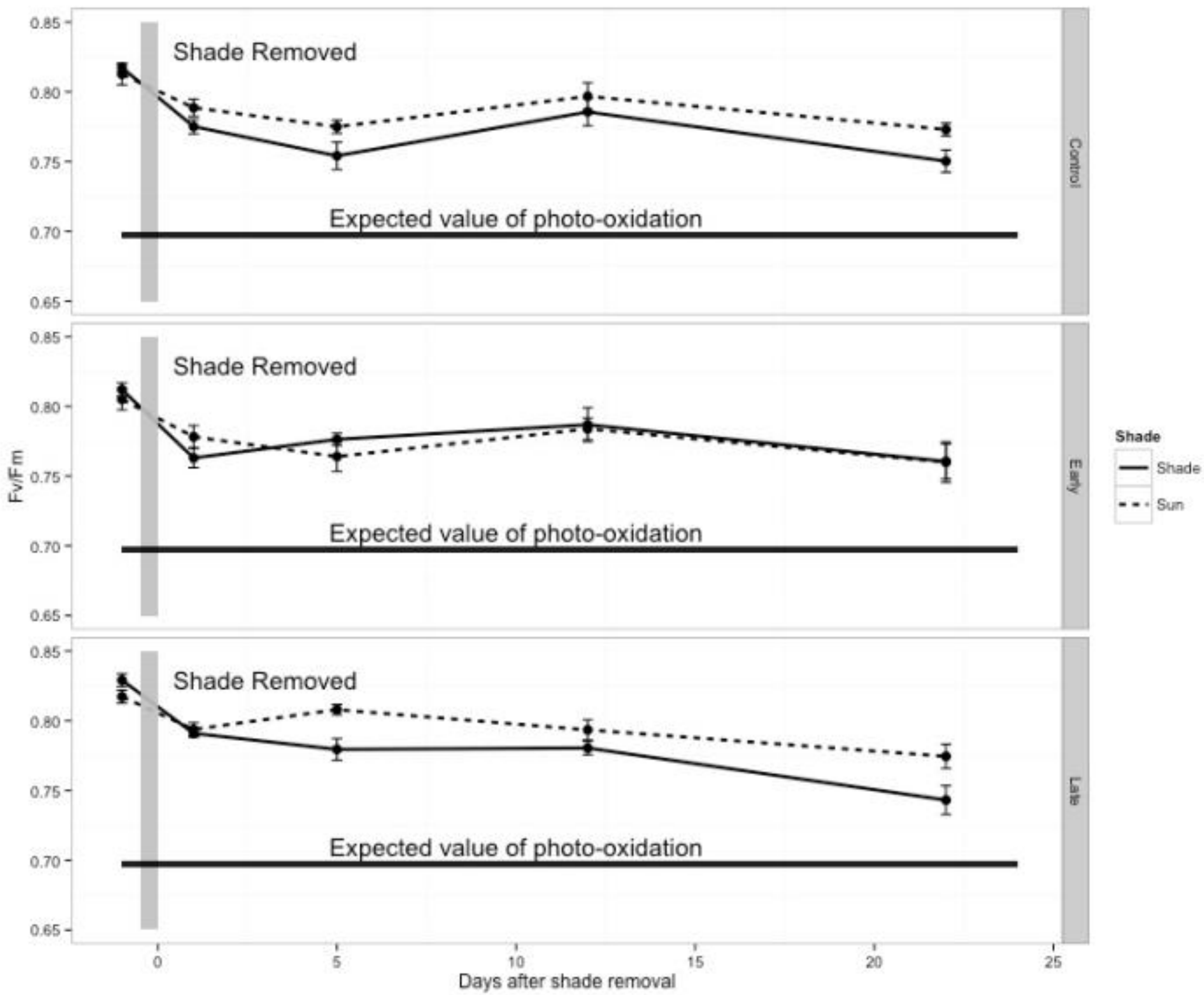
Methods

- Row-Column design
- 2x3 factorial, 6 reps
- Light
  - No shade
  - 40% Shade for 3 months, then removed (high-light stress)
- Water-deficit priming
  - No priming
  - Early priming: ending 1 mo before shade removal
  - Late priming: ending 2 d before shade removal
- Water-deficit priming: 3 weeks of daily watering at target of -30 kPa
- Study repeated 2x

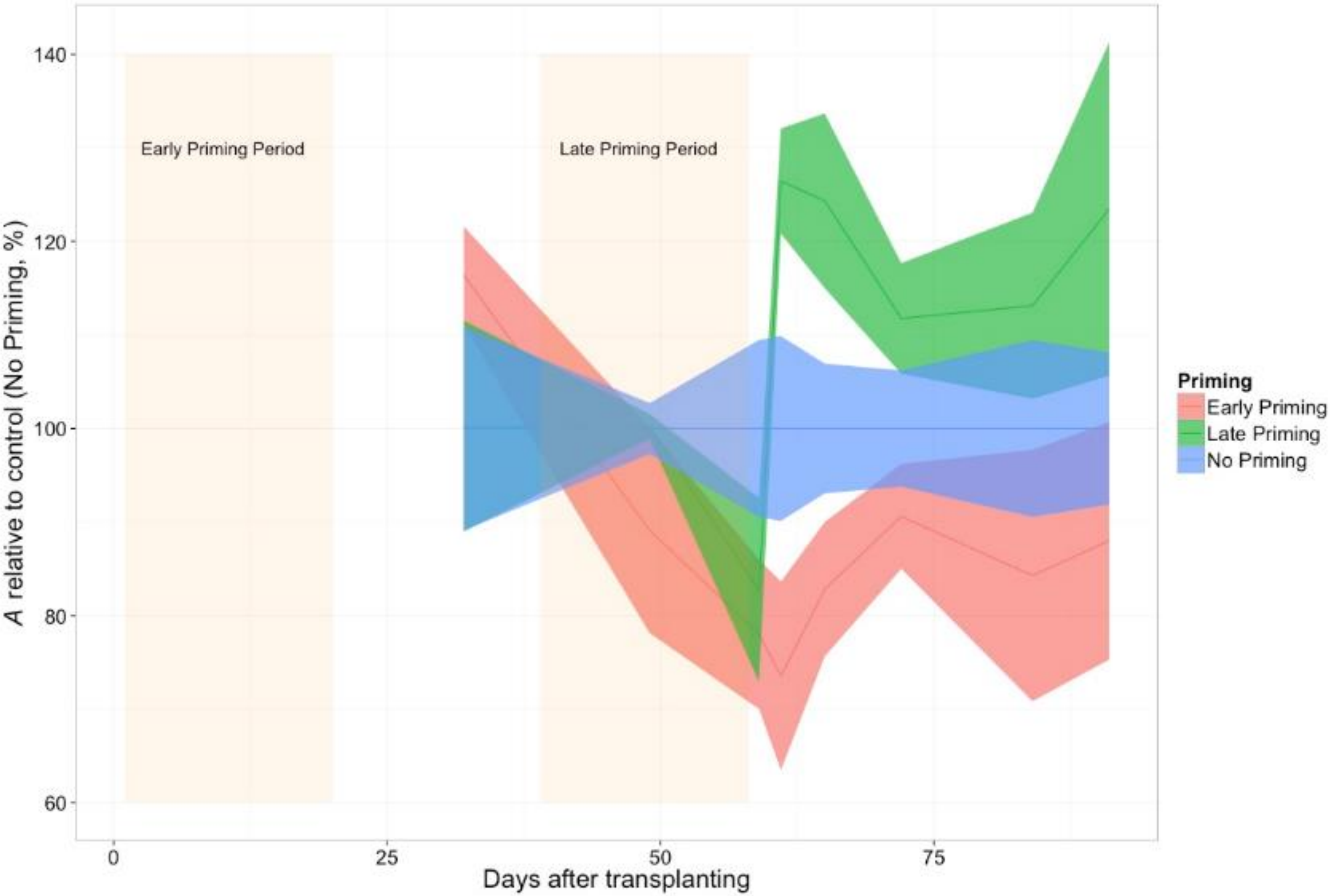
Measurements

	Days from shade removal						
Variable	**-1**		**1**	**5**	**10**	**20**	**30**
Chlorophyll fluorescence: Fv/Fm, OJIP	○	Shade removed	○	○	○	○	○
Leaf gas exchange: Maximum	○		○	○	○	○	○
Leaf gas exchange: Light curve	○				○		○
SPAD	○		○	○	○	○	○

Fv/Fm of 'Red Lady' papaya acclimated to 50% shade or full sun and water-deficit priming for one month after shade removal

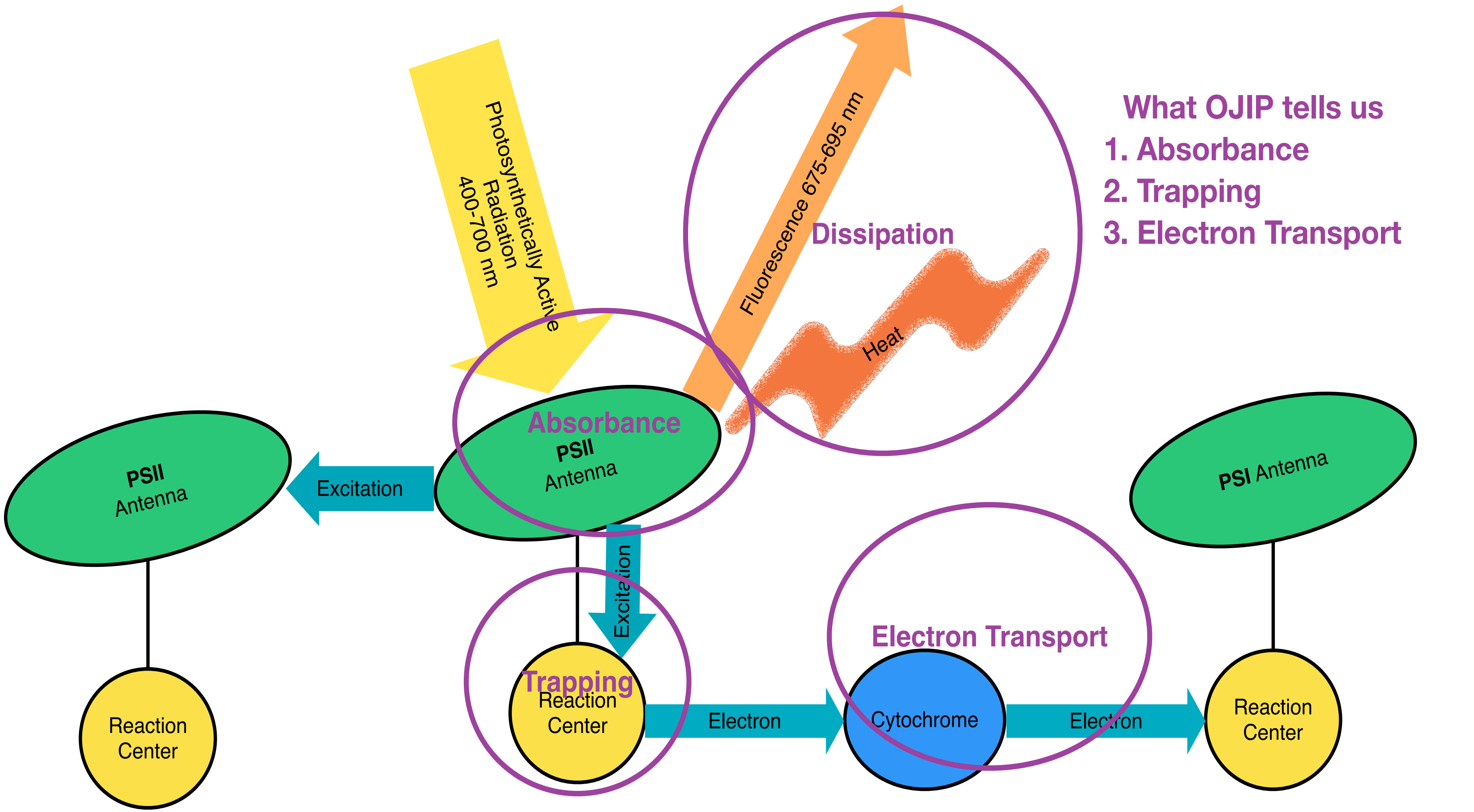


Relative net photosynthesis (% of control) of 'Red Lady' papaya subjected to different timings of water-deficit priming



Bands represent standard error.

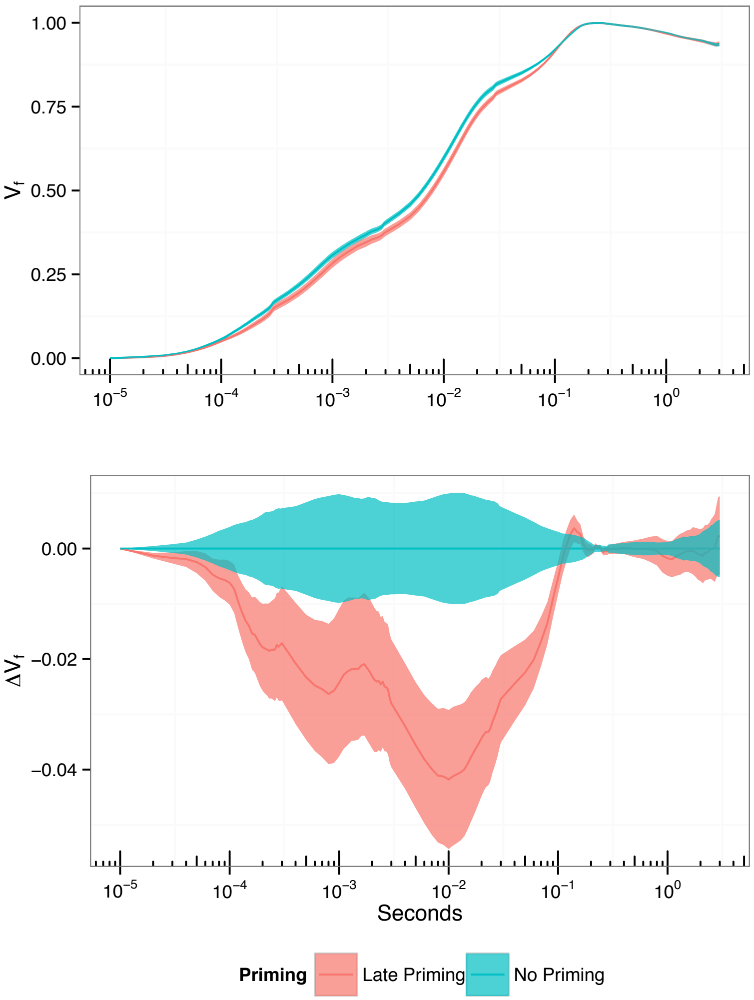
Shade-Priming


Photosynthetically Active Radiation 400-700 nm
Fluorescence 675-695 nm
Dissipation
Heat
What OJIP tells us
1. Absorbance
2. Trapping
3. Electron Transport
PSII Antenna
Excitation
Absorbance
PSII Antenna
Excitation
PSI Antenna
Trapping
Reaction Center
Reaction Center
Electron
Electron Transport
Cytochrome
Electron
Reaction Center
Shade-Priming

Water-deficit priming and OJIP

Increases in:

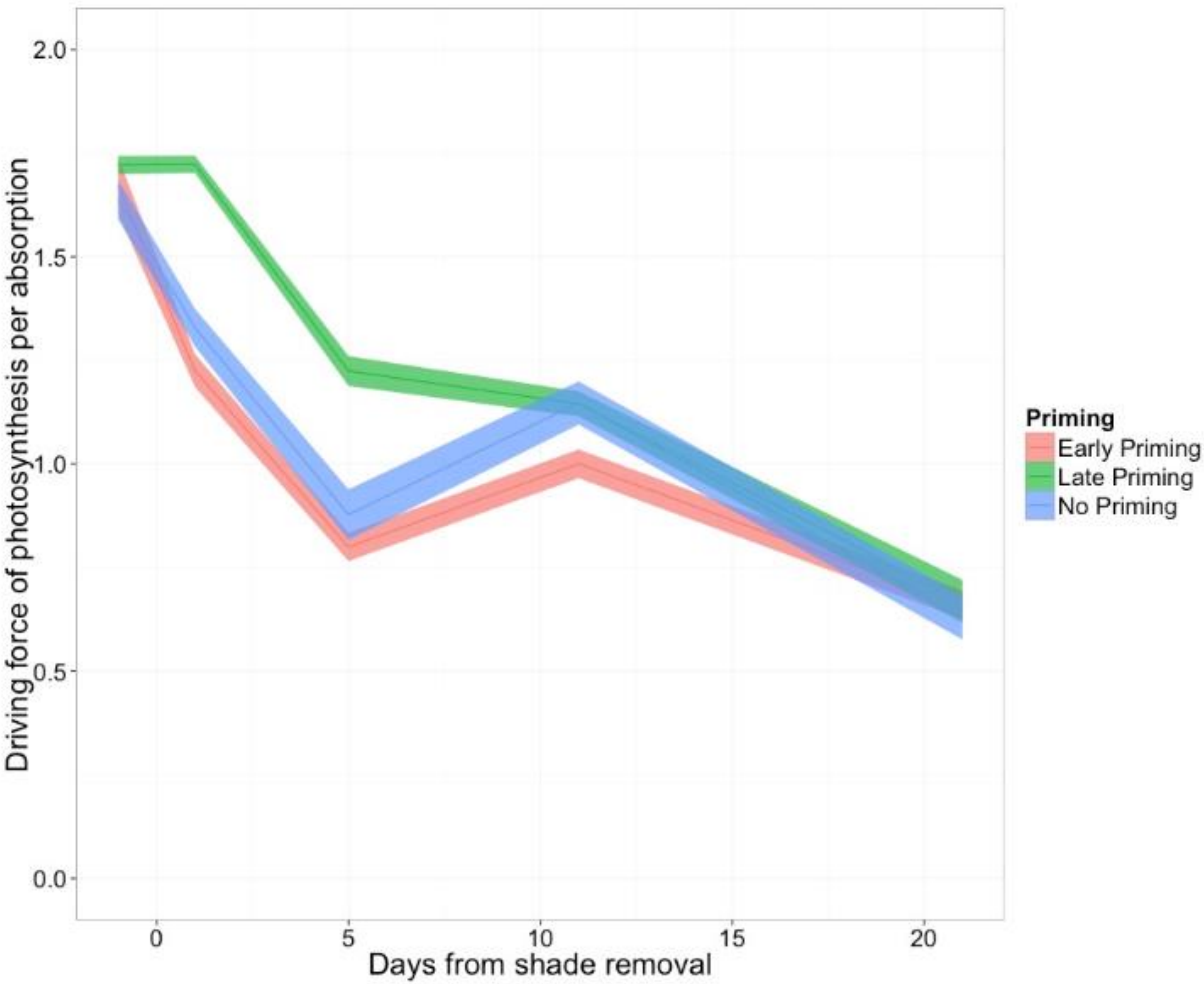
- Electron transport at J and I, leading to increases through Q_A, Q_B, and PSI
- Driving force
- Cross-priming?



Bands represent 95% confidence intervals.

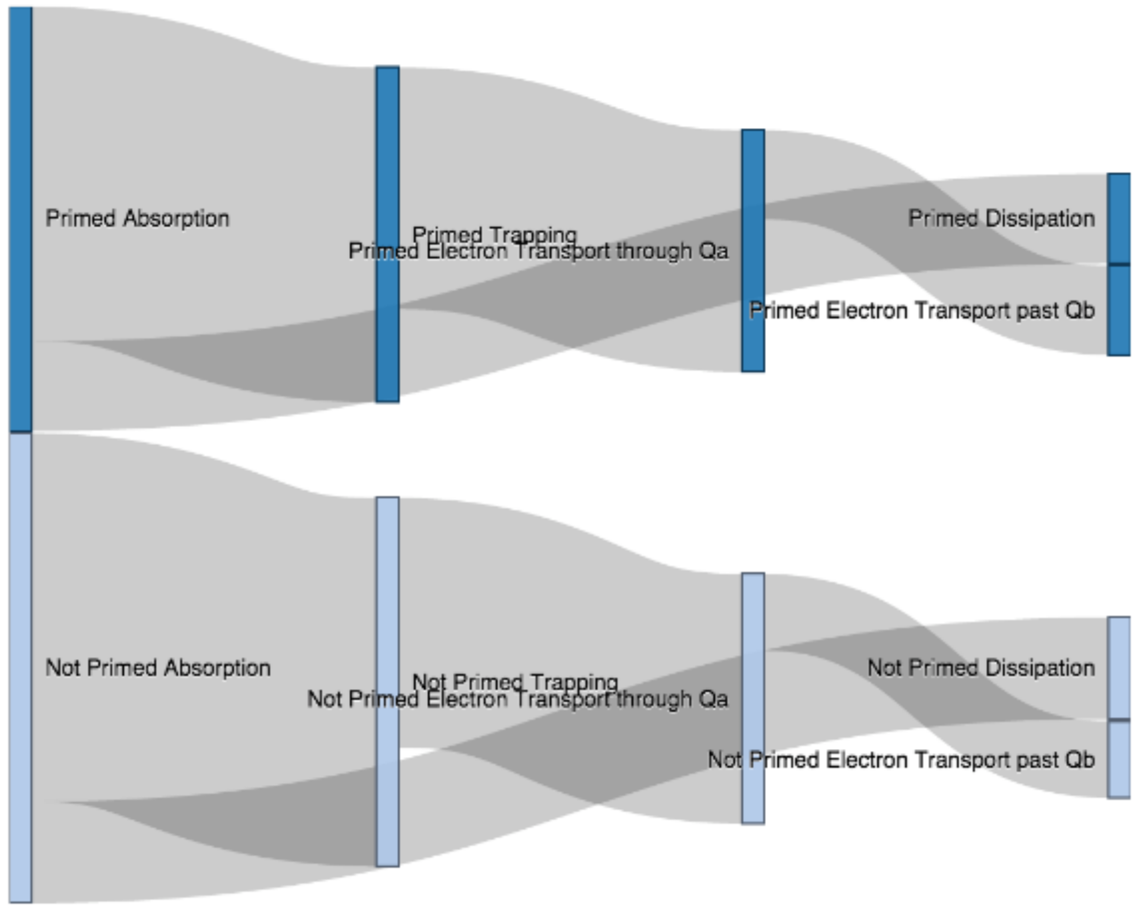
Shade-Priming

Driving force of photosynthesis per absorbance in 'Red Lady' papaya after exposure to different timings of priming treatment



Bands represent standard error.

Reaction centers per cross-section of 'Red Lady' papaya 4 days after end of priming treatment



Shade-Priming

Shade-Priming

Conclusions

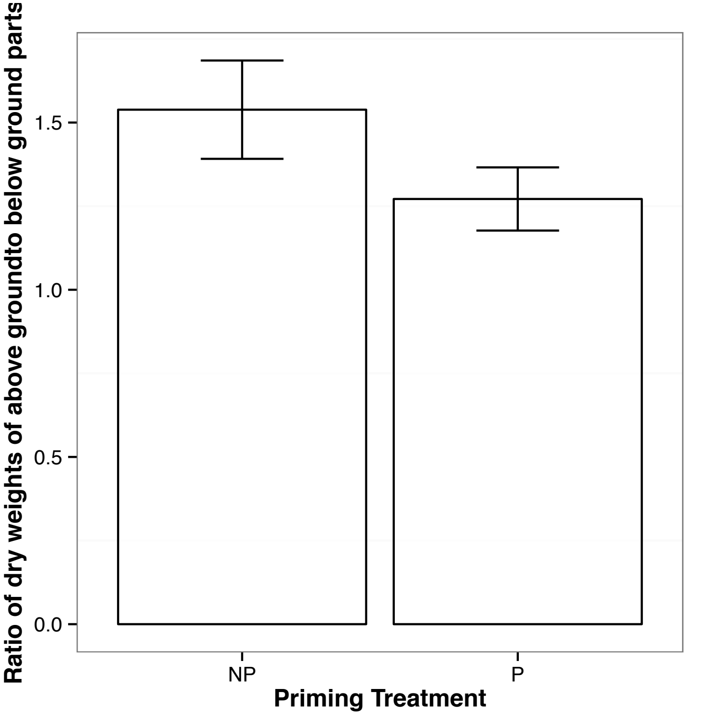
- Dry-down method set effective level to test priming
- Priming increases:
  - net photosynthesis
  - leaf chlorophyll content
  - photochemical driving force of photosynthesis
- Cross-priming?
- Acclimation to 50% shade is insufficient to induce photooxidation upon shade removal in papaya.
- How long does priming effect last?

Priming memory study in progress

- Test water-deficit priming with subsequent extreme water deficit
- Imposed stresses at approx: 2,6,10 wks after priming

Priming memory

- Apparent differences
  - Leaf greenness
  - Photosynthesis
- No significant difference in dry weight
- Change in shoot:root allocation



Bars represent 95% confidence intervals.

Overall Conclusions

- Sunn hemp intercrop has potential.
- Papaya plasticity is rapid. Mechanisms?
- Papaya ecological adaptation makes it uniquely suited for multiple-species systems.
  - Shade
  - Shade-removal
  - VPD
- Priming is possible:
  - Photosynthesis
  - Partitioning

Next Steps

- **Priming memory**
  - Just finished
  - Tests severe water-deficit responses
    - Anti-oxidants
    - Gas exchange
    - OJIP
- **Cross-Priming**
  - Shade removal to determine shade level for photo-inhibition
  - Possible mechanisms
    - Anti-oxidants
    - Non-photochemical quenching
    - Photochemical efficiency of CO_2 fixation
  - Describe physiology of acclimation from low to high light
- **Repeat sunn hemp field study**

Thank you