Optimization theories for saline environments

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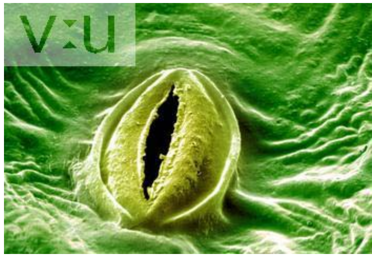
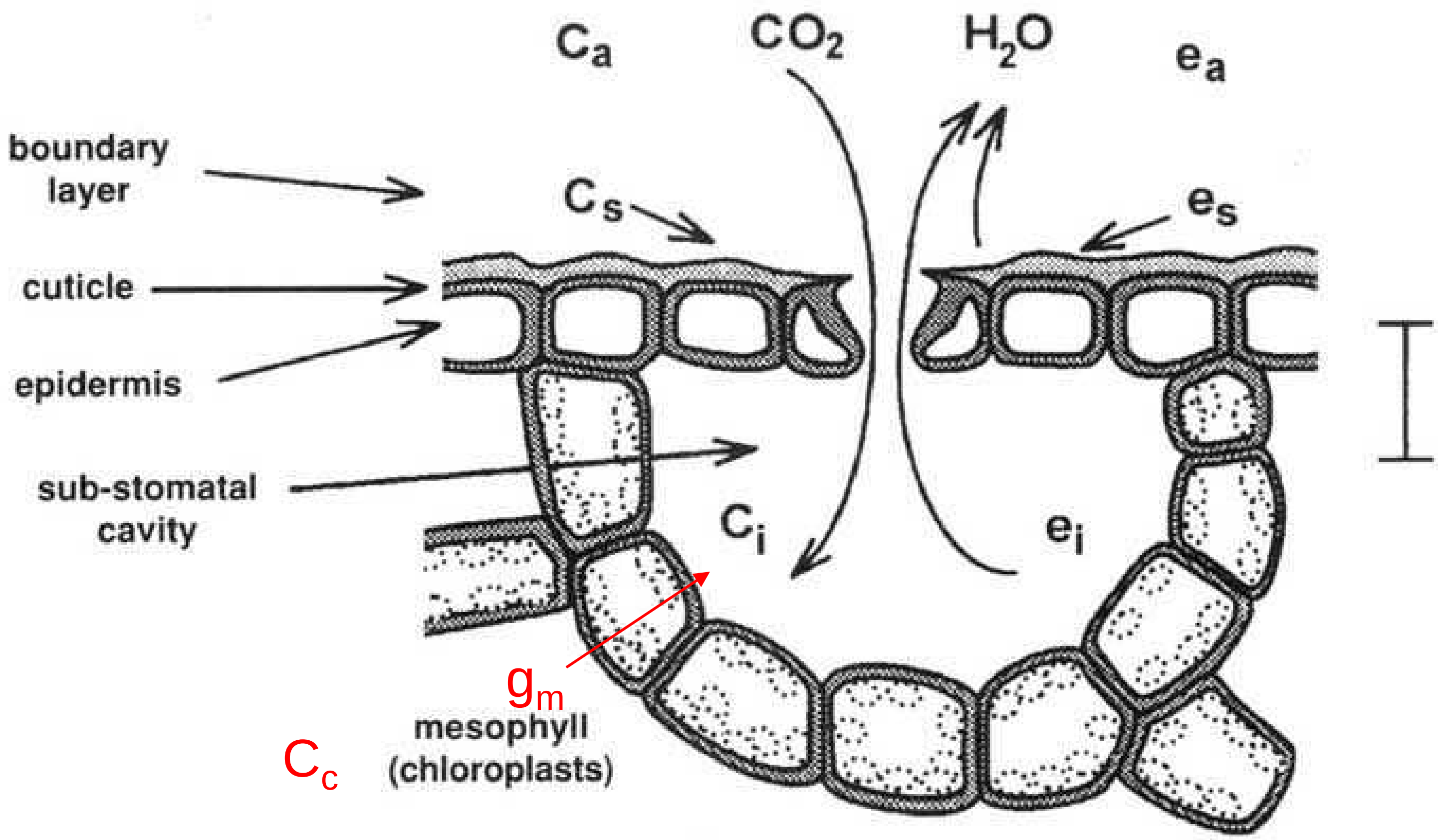
Motivations

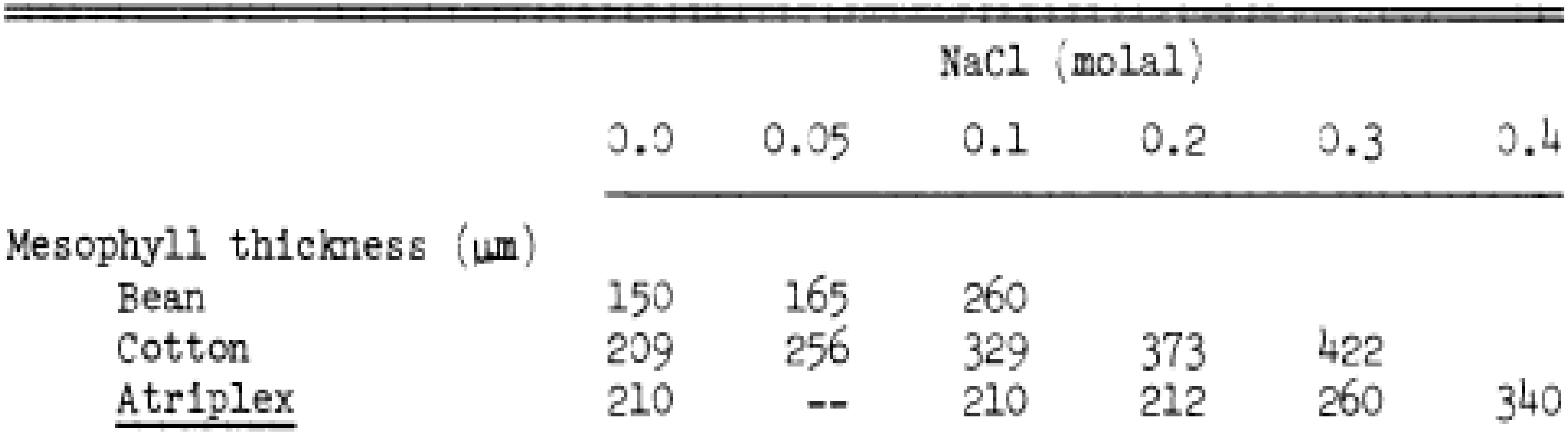
- It has long been suggested that, at the leaf scale, natural selection may have operated to provide increasingly efficient means of controlling the tradeoffs between water vapor loss and carbon gains.
- How does **salinity** modify this picture?



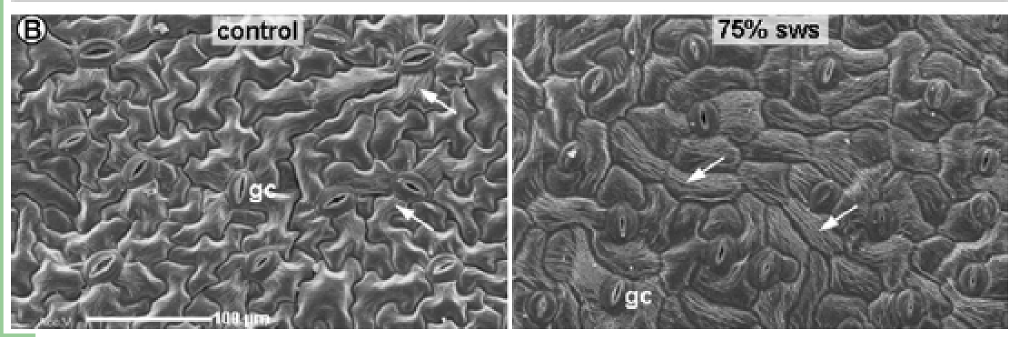
Photosynthesis - Transpiration

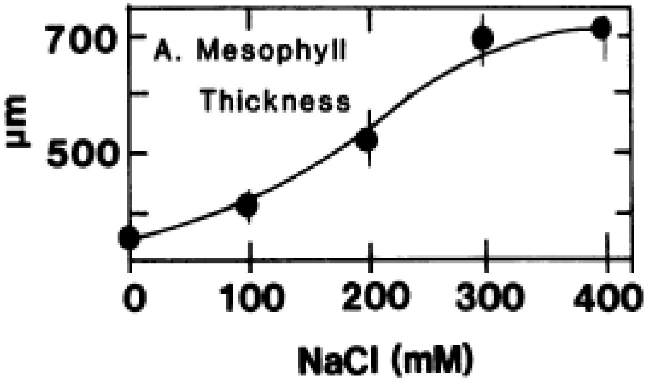


Structural modifications



	NaCl (molal)					
	0.0	0.05	0.1	0.2	0.3	0.4
Mesophyll thickness (µm)						
Bean	150	165	260			
Cotton	209	256	329	373	422	
Atriplex	210	--	210	212	260	340



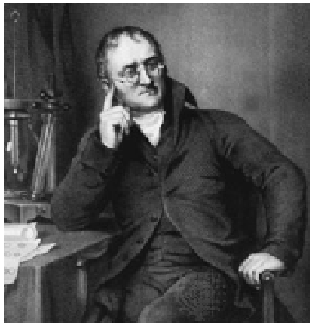


Optimization model (no mesophyll limitations)

Define the instantaneous:

$$\text{Carbon Gain} = f_c$$

$$\boxed{\text{Water Loss} = f_e \approx a\, g_s\, D}$$



John Dalton

OBJECTIVE FUNCTION

Lagrange Multiplier

$$f(g_s) = f_c(g_s) - \lambda f_e(g_s)$$

Leaves are autonomous and attempt to maximize their own carbon gain for a given amount of water loss.

Basic equations:

	Without Salinity	With Salinity
Transport Equation:	$f_c = g_s(C_a - C_i)$	$f_c = g_{eff}(c_a - c_c); \quad g_{eff} = \frac{g_c g_m}{g_c + g_m}$
Biochemical Demand:	$f_c = \frac{\alpha_1 \left(C_i - \Gamma^*\right)}{C_i + \alpha_2}$	$C_i \longrightarrow C_c$

Optimality Rule:

$$\frac{\partial\left(f_c(g_s) - \lambda f_e(g_s)\right)}{\partial g_s} = 0$$

Three equations with 4 unknowns (f_c, C_c, g_s, g_m) – mathematically unclosed

Optimization models (linear form) With mesophyll conductance

- Upon differentiating f(g_c) and setting it to zero:

$$f_c = \frac{a_1 g_m (c_a - c_p)}{a_1 + g_m (a_2 + s c_a)} \left[1 - \sqrt{\frac{a \lambda D}{c_a - c_p}} \right]$$

$$g_c = \frac{a_1 g_m}{\left(a_1 + g_m (a_2 + s c_a)\right)} \left(-1 + \sqrt{\frac{c_a - c_p}{a \lambda D}} \right)$$

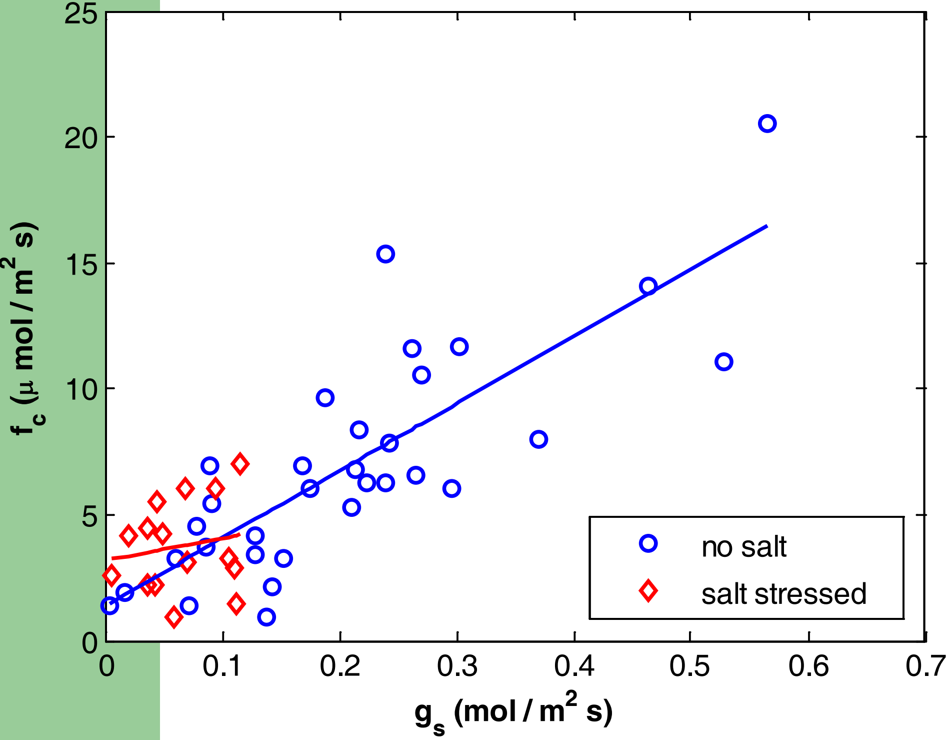
$$\frac{c_i}{c_a} = \frac{c_p}{c_a} + \frac{(c_a - c_p)}{c_a} \left[1 - \sqrt{\frac{(a \lambda D)}{(c_a - c_p)}} \right]$$

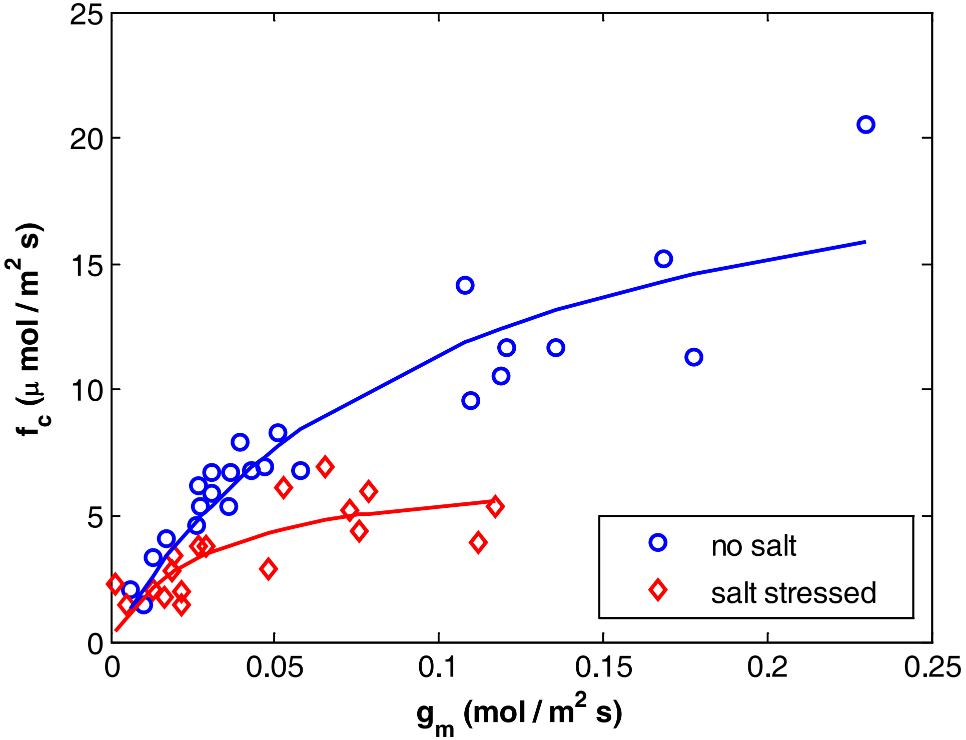
Preliminary Results (1)

- Olives (Loreto et al., 2003)

$$f_c = g_c(c_a - c_p)\left[\sqrt{\frac{a\lambda D}{(c_a - c_p)}}\right] = g_c\left[\sqrt{a\lambda D(c_a - c_p)}\right]$$

$$f_c = \frac{a_1 g_m(c_a - c_p)}{a_1 + g_m(a_2 + sc_a)}\left[1 - \sqrt{\frac{a\lambda D}{c_a - c_p}}\right]$$

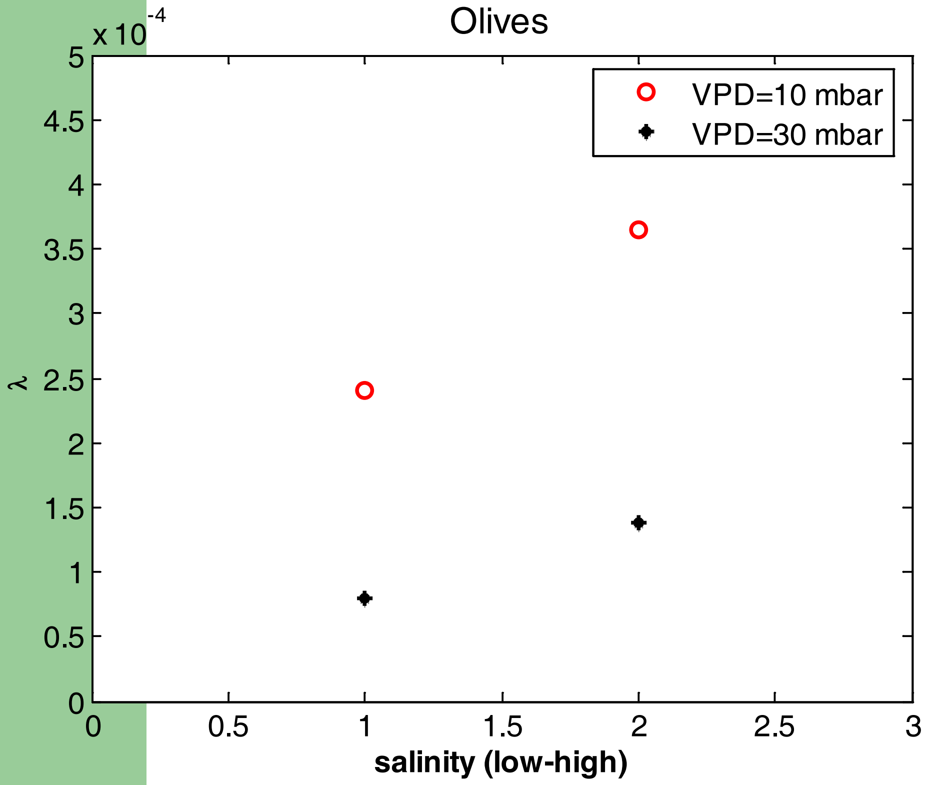




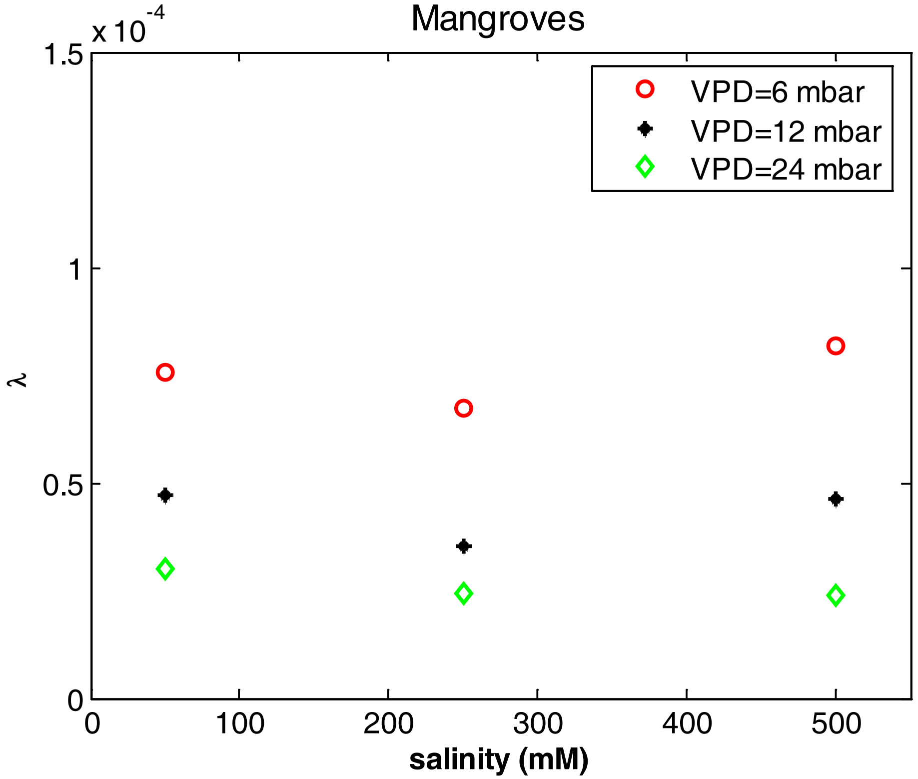
Preliminary Results (2)

$$\frac{c_i}{c_a}=\frac{c_p}{c_a}+\frac{(c_a-c_p)}{c_a}\left[1-\sqrt{\frac{(a\lambda D)}{(c_a-c_p)}}\right]$$

Bongi and Loreto, 1989



Ball and Farquhar, 1984



Preliminary conclusions

- 2 time scales of stomata response to increasing salinity:
  - FAST t.s.: stomatal conductance
  - SLOW t.s.: mesophyll conductance
- Optimization theory consistent with datasets analyzed
- Three parameters were used to analyze salt tolerance by different species (olives-mangroves):

  - g_m: changes in all species

  -λ: changes only for salt-intolerant species

  - a_1: changes for the olive case

Futher work

- Short Term: literature review to assess how salinity affects the optimization theory parameters for different species

- Long Term: integrate this results with on-going work on hydrologic models of the soil-plant system to assess how climate change (e.g. CO2, VPD, T) affects plant productivity in salt environments

References

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