How Nutrients Interact with Stresses, such as Flooding and Salinity, to Affect Plant Growth and Leaf Tissue Chemistry

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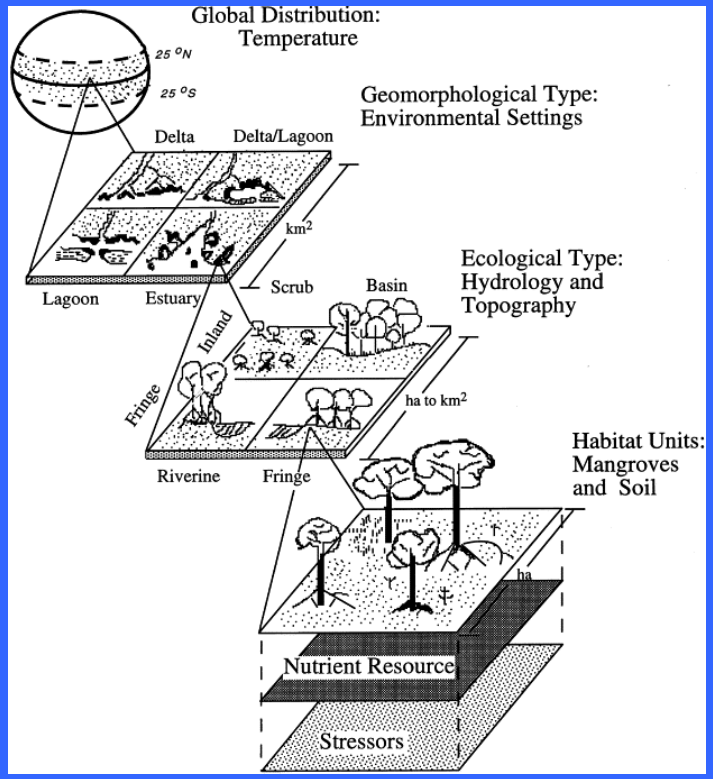
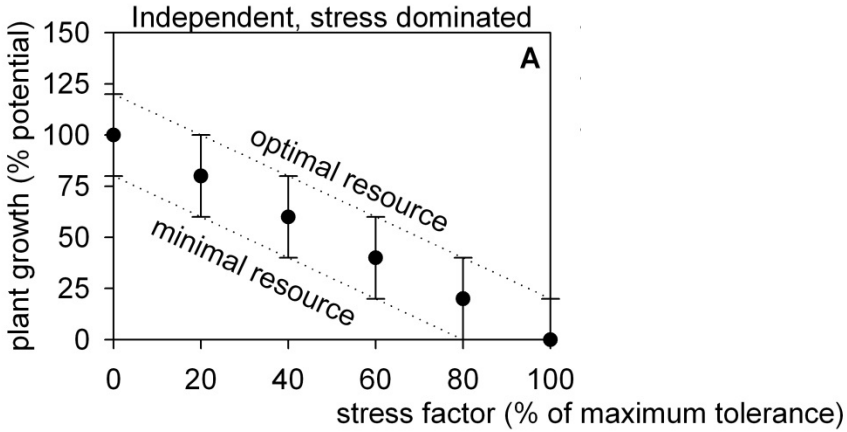
Acknowledgements: Dayna Huval (USGS), Joy Merino (NMFS), Vanessa Tobias Ph.D. (CDFW), etc.





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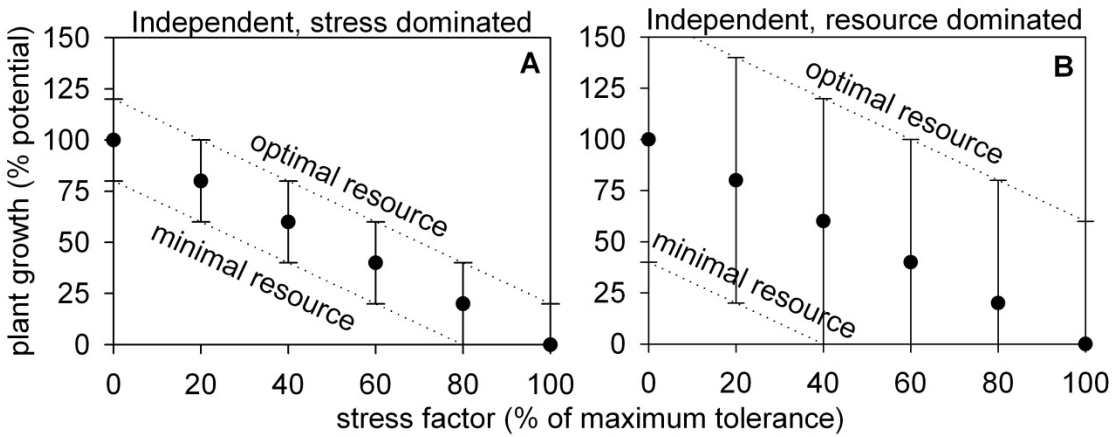

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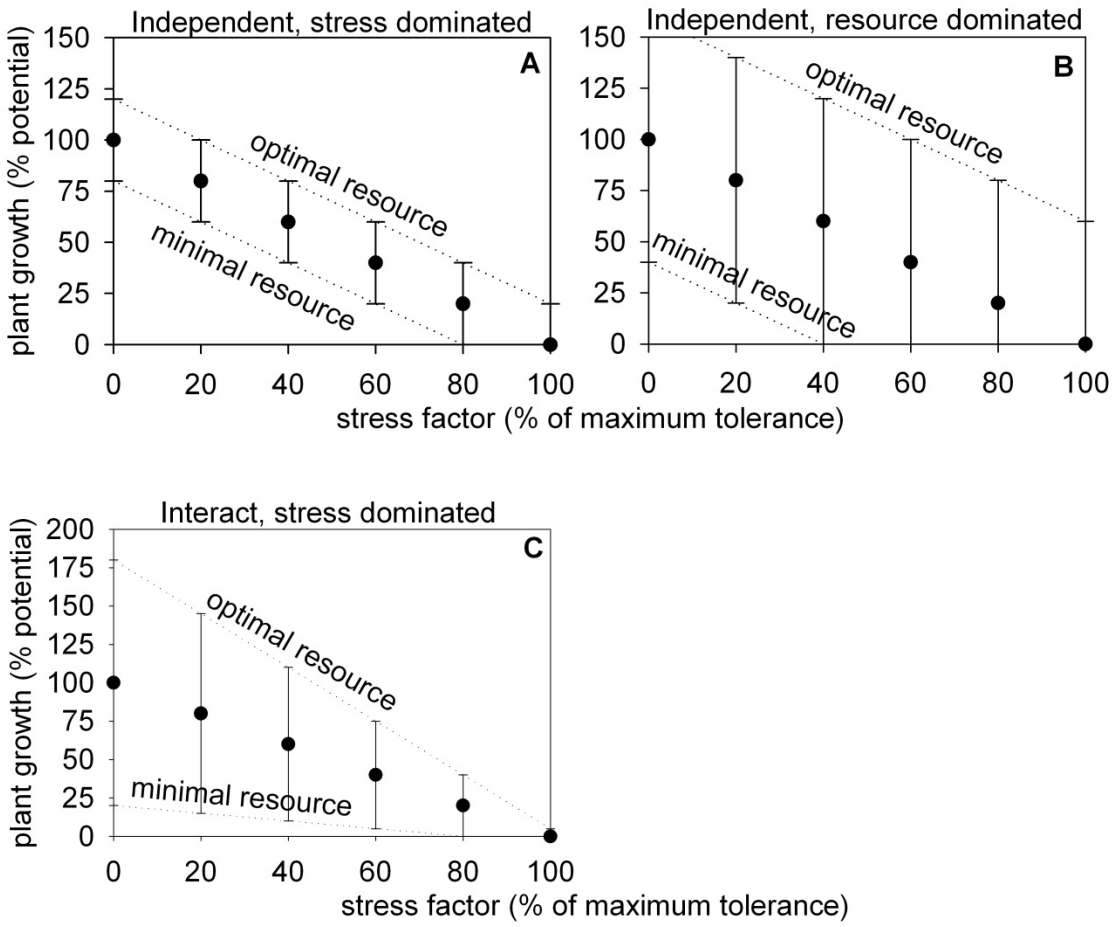

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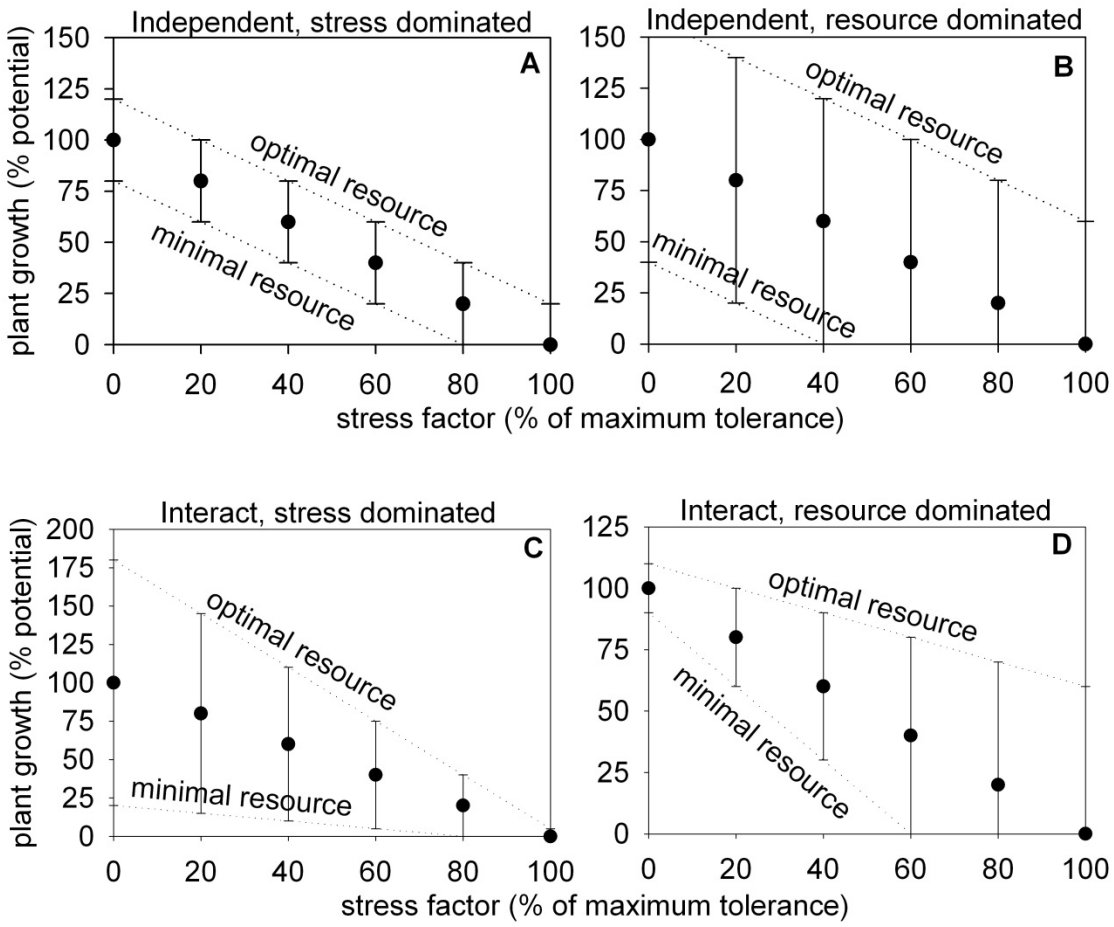

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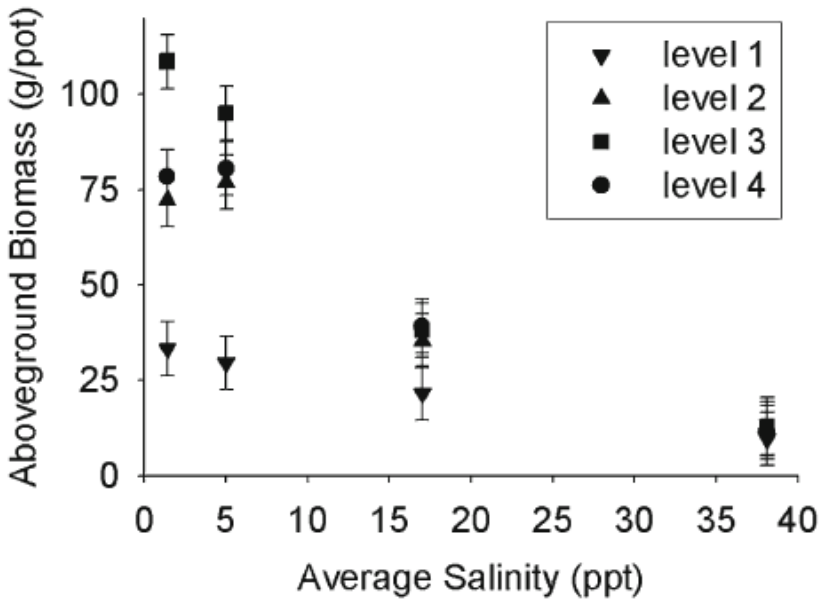
experiments

- *Spartina patens* experiment
  - nutrients and salinity stress
- *Taxodium distichum* experiment
  - nutrients and flooding stress



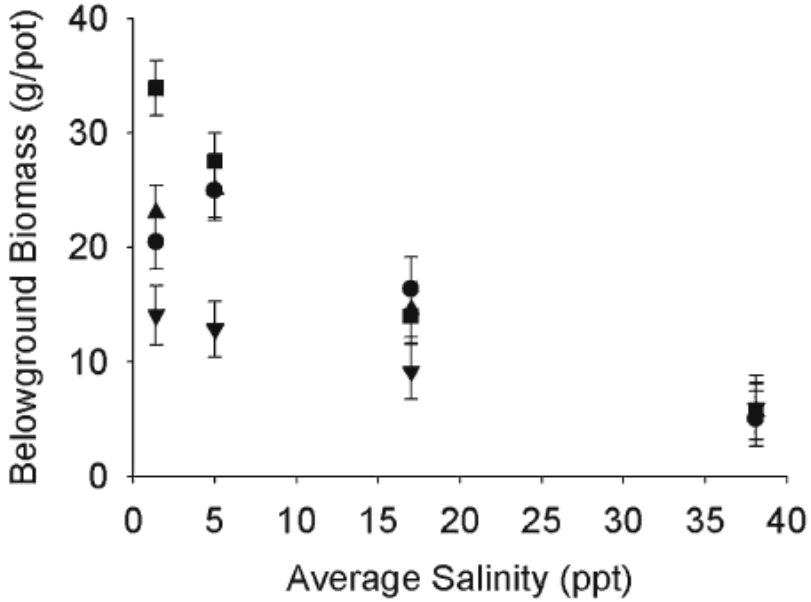
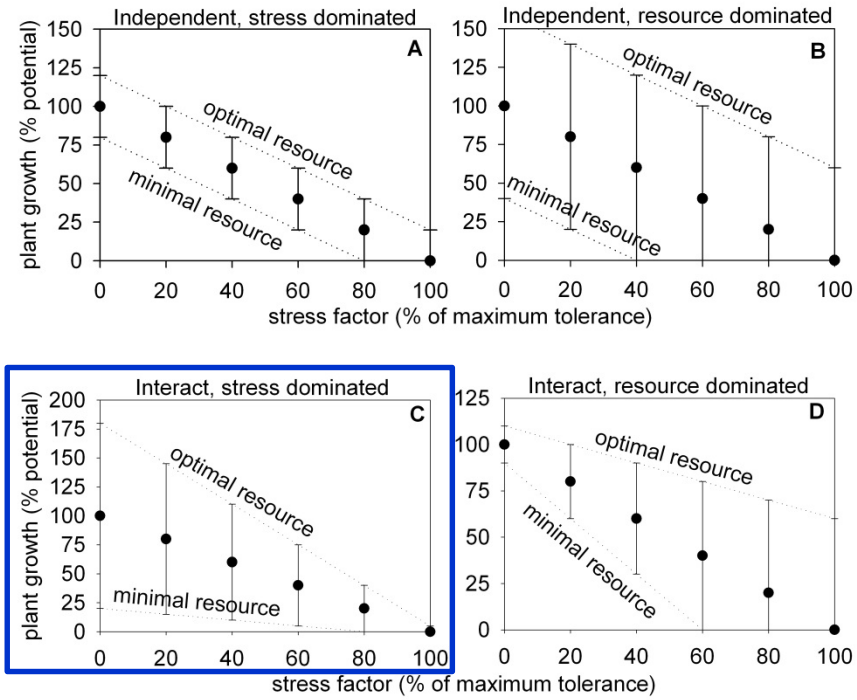


Fig. 1 The above- and belowground biomass of *Spartina patens* grown at different salinities and at different levels of nutrients, harvested after 144 days of treatment in a greenhouse. Nutrient levels were (1) 0.5 & 0.024, (2) 1.46 & 0.07, (3) 2.43 & 0.12, and (4) 3.89 & 0.19 mg N cm^{-3} & mg P cm^{-3} of soil, respectively. Modified from data in Merino et al. (2010)

Morris et al. 2013. Wetlands

- nutrient availability and flooding stress interacted with the interaction dominated by flooding stress.



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- Nutrient additions increase biomass of *Spartina patens* at high and low salinity (DeLaune et al. 2005).
- Nutrient additions increased biomass of *Spartina patens* at low salinity but not high salinity (Foret 2001).

optimum nutrient availability

average nutrient availability

minimum nutrient availability

potential biomass (%)

100

75

50

25

0

a

b

c

c

0 5 10 15 20 25 30 35 40

average water salinity

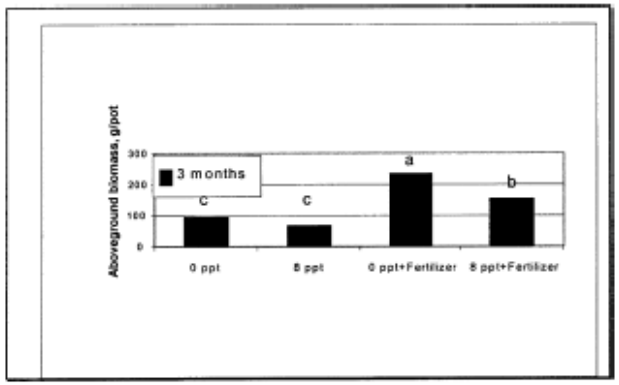

Figure 1. Effect of salinity level and nutrient addition on growth of *Spartina patens*. Means assigned the same letter are not significantly different at p≤0.05 using DMRT, n=6

DeLaune et al. 2005 Wetlands 25:155-161

optimum nutrient availability

average nutrient availability

minimum nutrient availability

potential biomass (%)

100

75

50

25

0

man+fert

man

ref+fert

ref

0 5 10 15 20 25 30 35 40

average water salinity

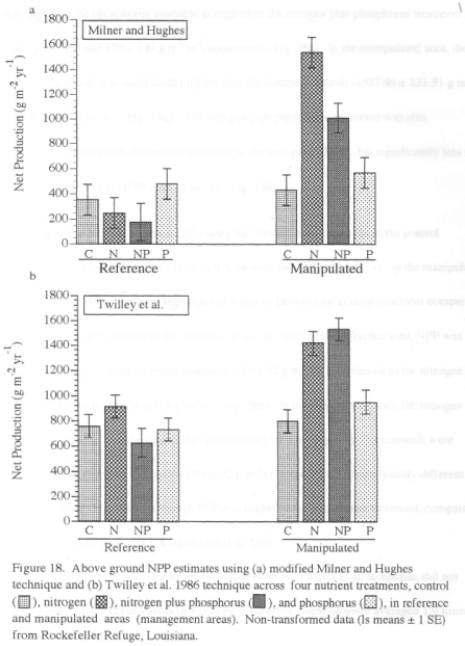

Figure 18. Above ground NPP estimates using (a) modified Milner and Hughes technique and (b) Twilley et al. 1986 technique across four nutrient treatments, control ( ), nitrogen ( ), nitrogen plus phosphorus ( ), and phosphorus ( ), in reference and manipulated areas (management areas). Non-transformed data (ls means ± 1 SE) from Rockefeller Refuge, Louisiana.

Foret. 2001. PhD Dissertation. University of Louisiana at Lafayette.

experiments

- *Spartina patens* experiment
  - nutrients and salinity stress
- *Taxodium distichum* experiment
  - nutrients and flooding stress

- Treatment #1 had no additional nutrients.
- Nutrient enhancement rates (g m^{-2}) in the remaining treatments were….

element	treatment #2	treatment #3	treatment #4
N	56.6	282.9	1,131.8
P	28.3	141.5	565.9
K	14.1	70.7	282.9
S	5.6	28.3	113.2
Fe	7.1	35.4	141.5
Mn	5.6	28.3	113.2
Mg	6.4	31.8	127.3
Zn	3.3	16.7	66.8

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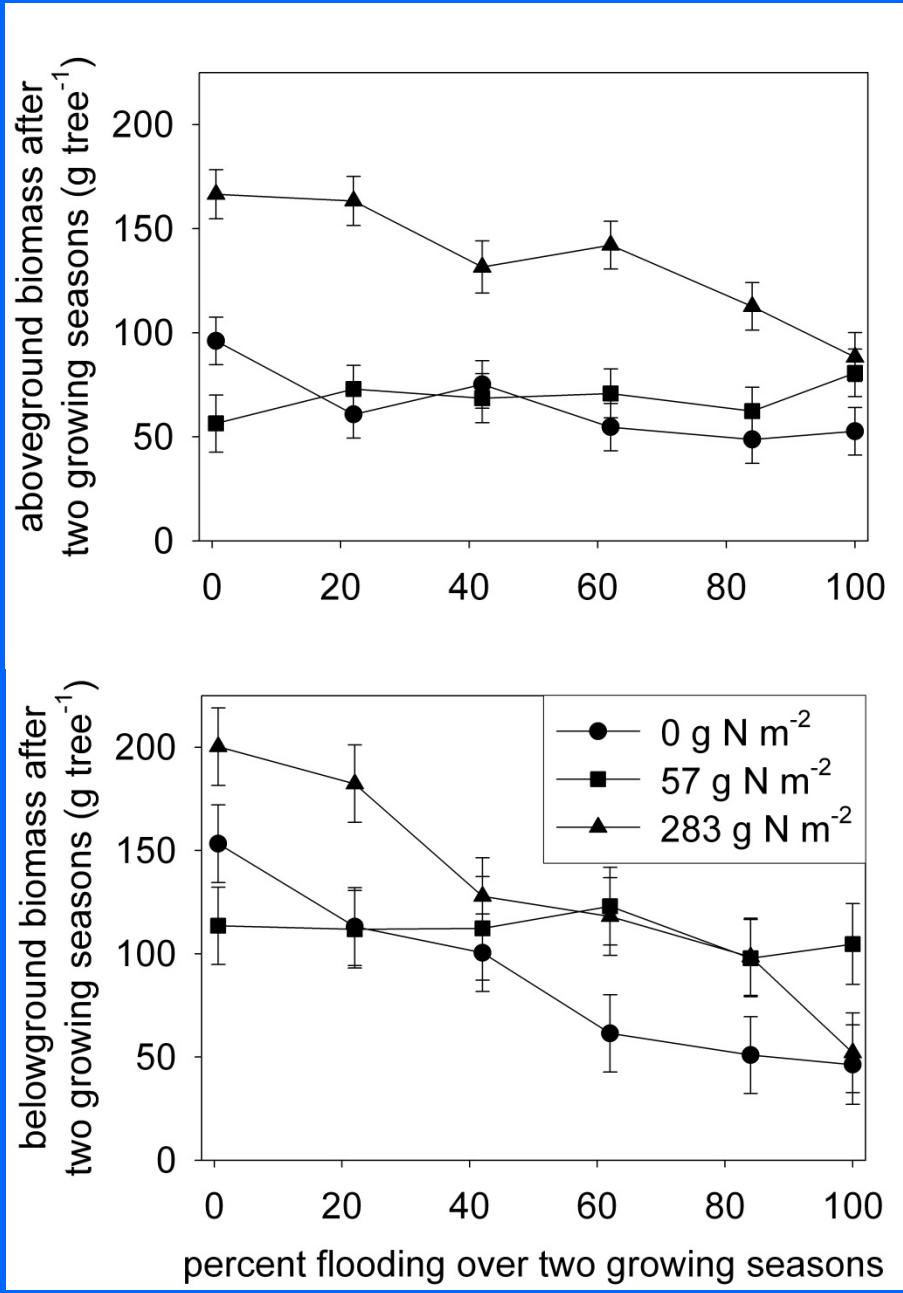

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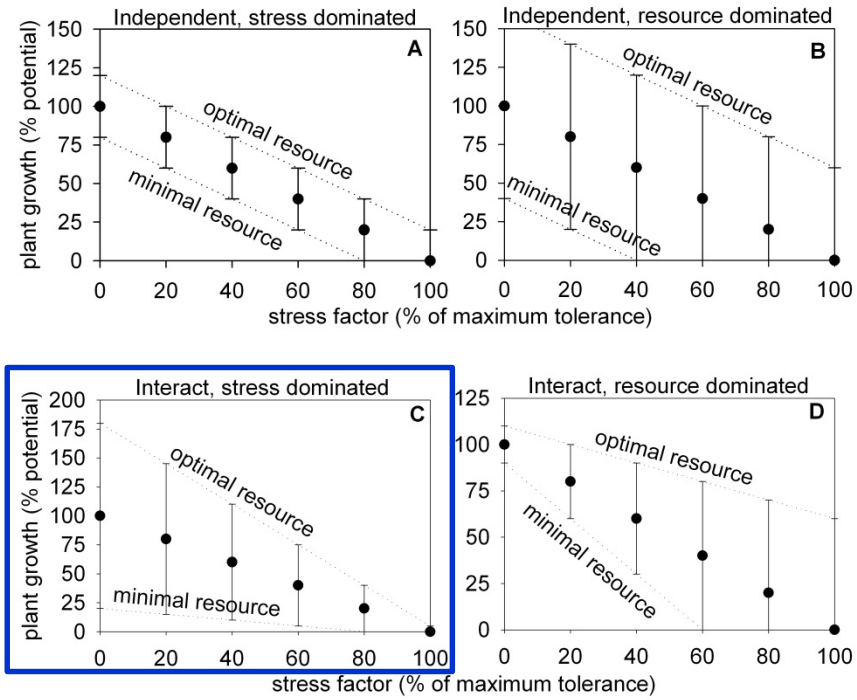
- nutrient availability and flooding stress interacted with the interaction dominated by flooding stress (Figure 1c).



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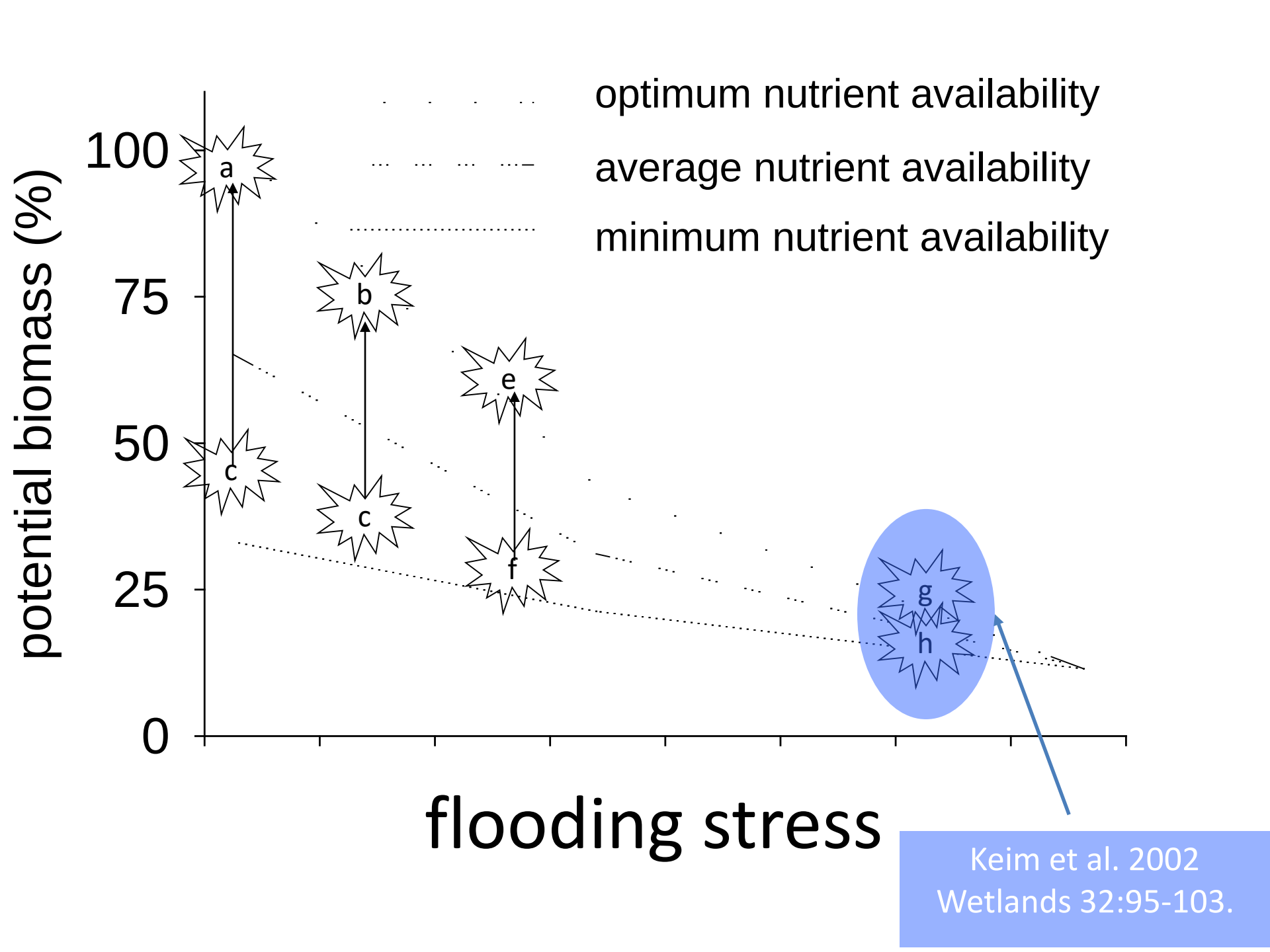
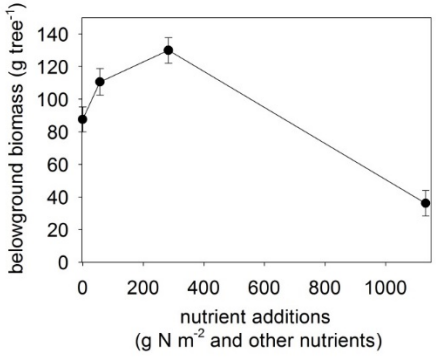
- Nutrients increase growth of *Taxodium distichum* (e.g.; Brown 1981, Shaffer et al. 2015).
- Nutrient additions failed to increase growth of *Taxodium distichum* (Keim et al. 2012).


optimum nutrient availability
average nutrient availability
minimum nutrient availability
potential biomass (%)
100
75
50
25
0
a
b
c
c
e
f
g
h
flooding stress
Keim et al. 2002
Wetlands 32:95-103.



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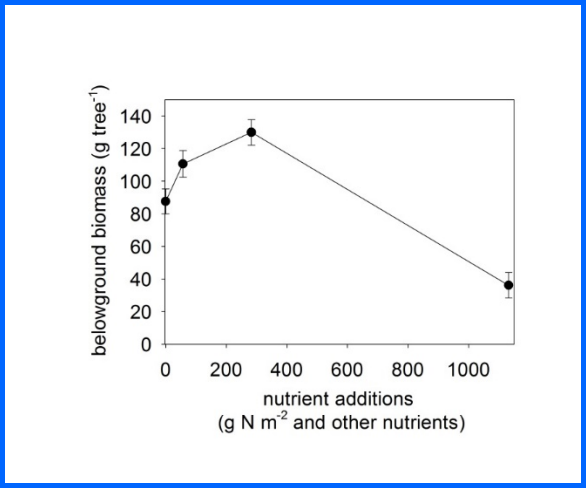

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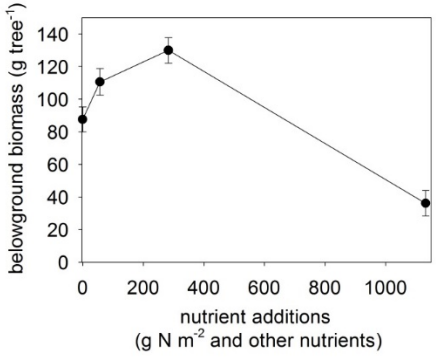
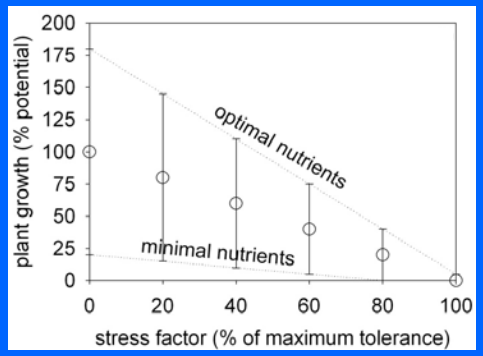
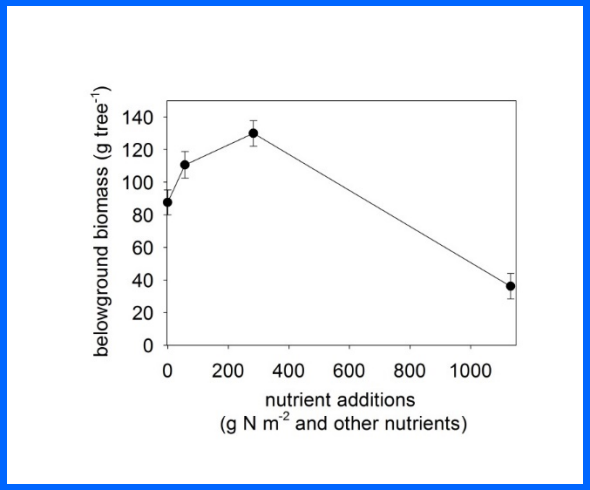
Mg	6.4	31.8	127.3
Zn	3.3	16.7	66.8
Rice Agriculture	~5x	~24x	~80x


belowground biomass (g tree^{-1})
0
20
40
60
80
100
120
140
0
200
400
600
800
1000
nutrient additions
(g N m^{-2} and other nutrients)


plant growth (% potential)
0
25
50
75
100
125
150
175
200
optimal nutrients
minimal nutrients
0
20
40
60
80
100
stress factor (% of maximum tolerance)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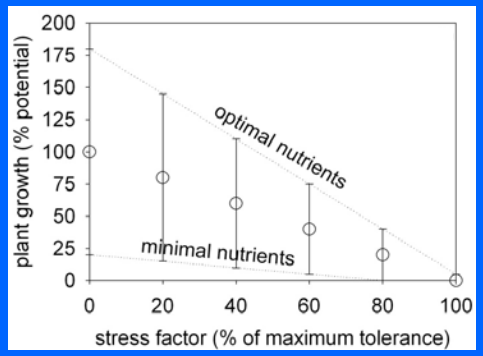
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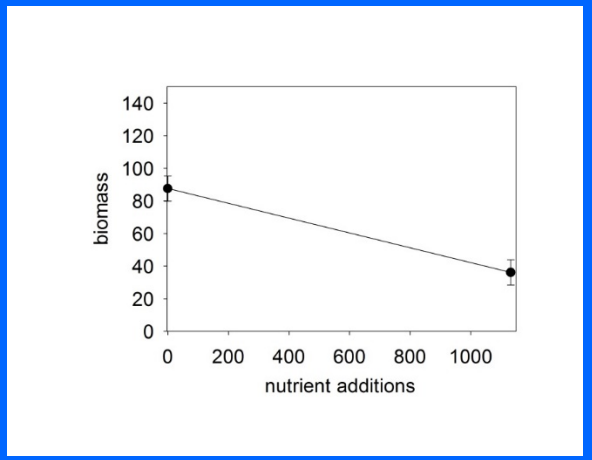
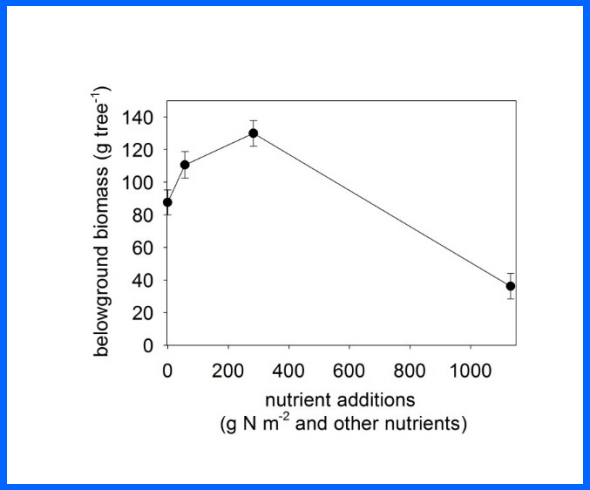
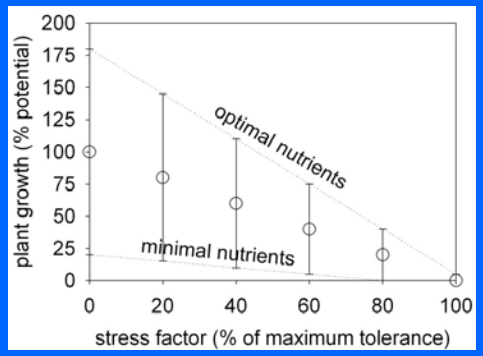
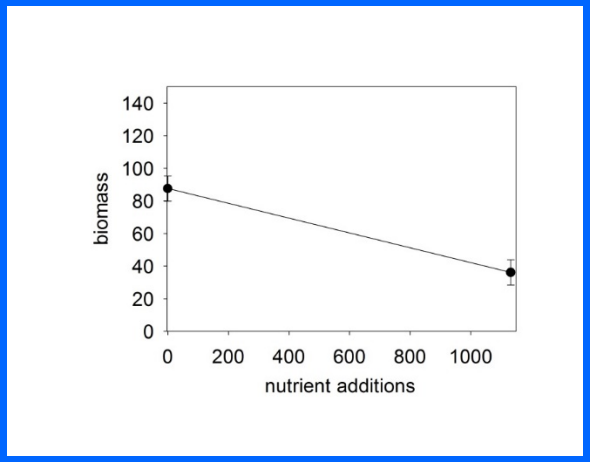

biomass
0
20
40
60
80
100
120
140
0
200
400
600
800
1000
nutrient additions

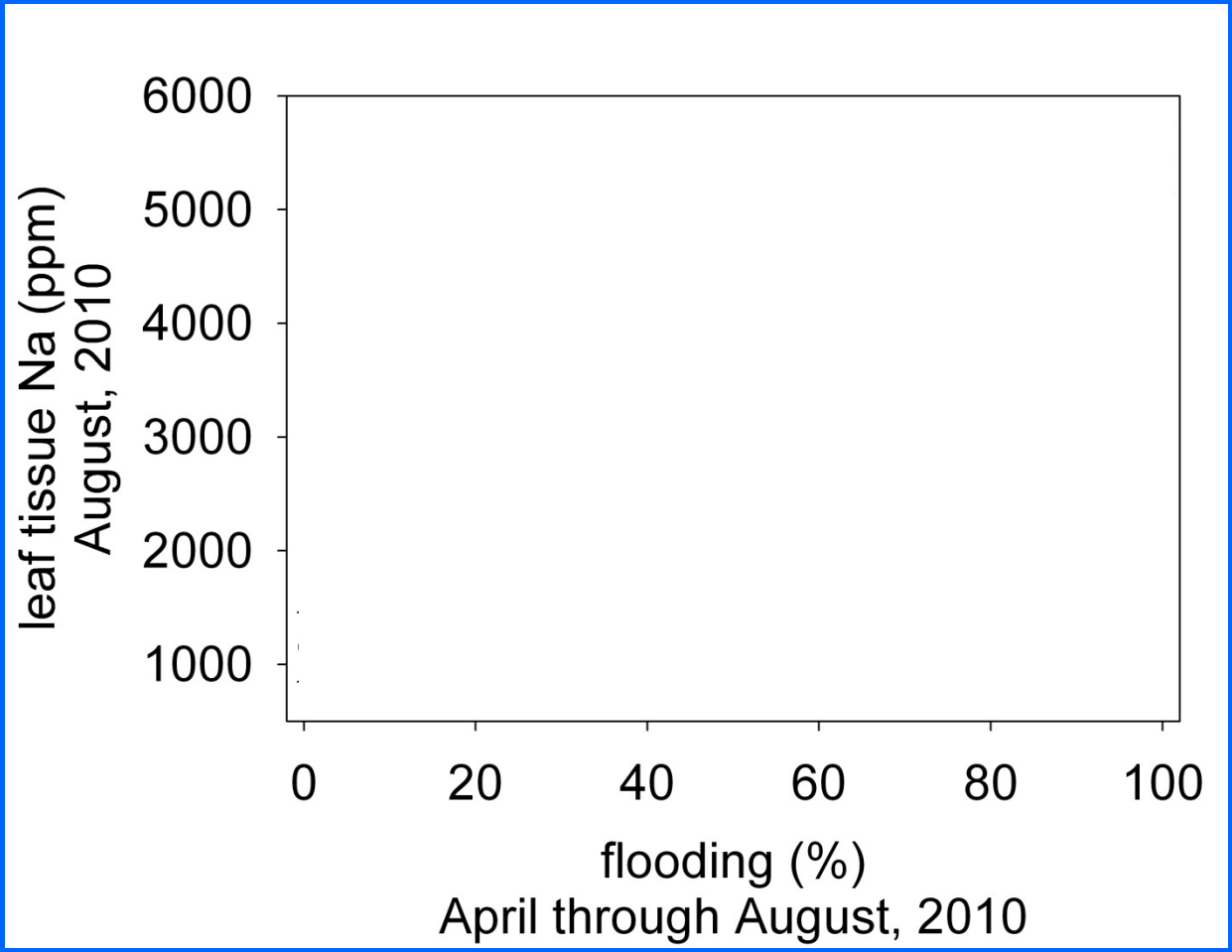






"… we were interested in determining whether there was a tipping point at which nutrient inputs would exceed the nutrient processing ability of the marsh ecosystem and degrade the system. By 1974, however, various measurements showed that we had not reached such a tipping point (Valiela and Teal 1974), so we added a third and higher dose of the mixed fertilizer, 90x the rates suggested for oats (XF)." Valiela (2015) Estuaries and Coasts 38:1099-1120.

T. distichum stoichiometry



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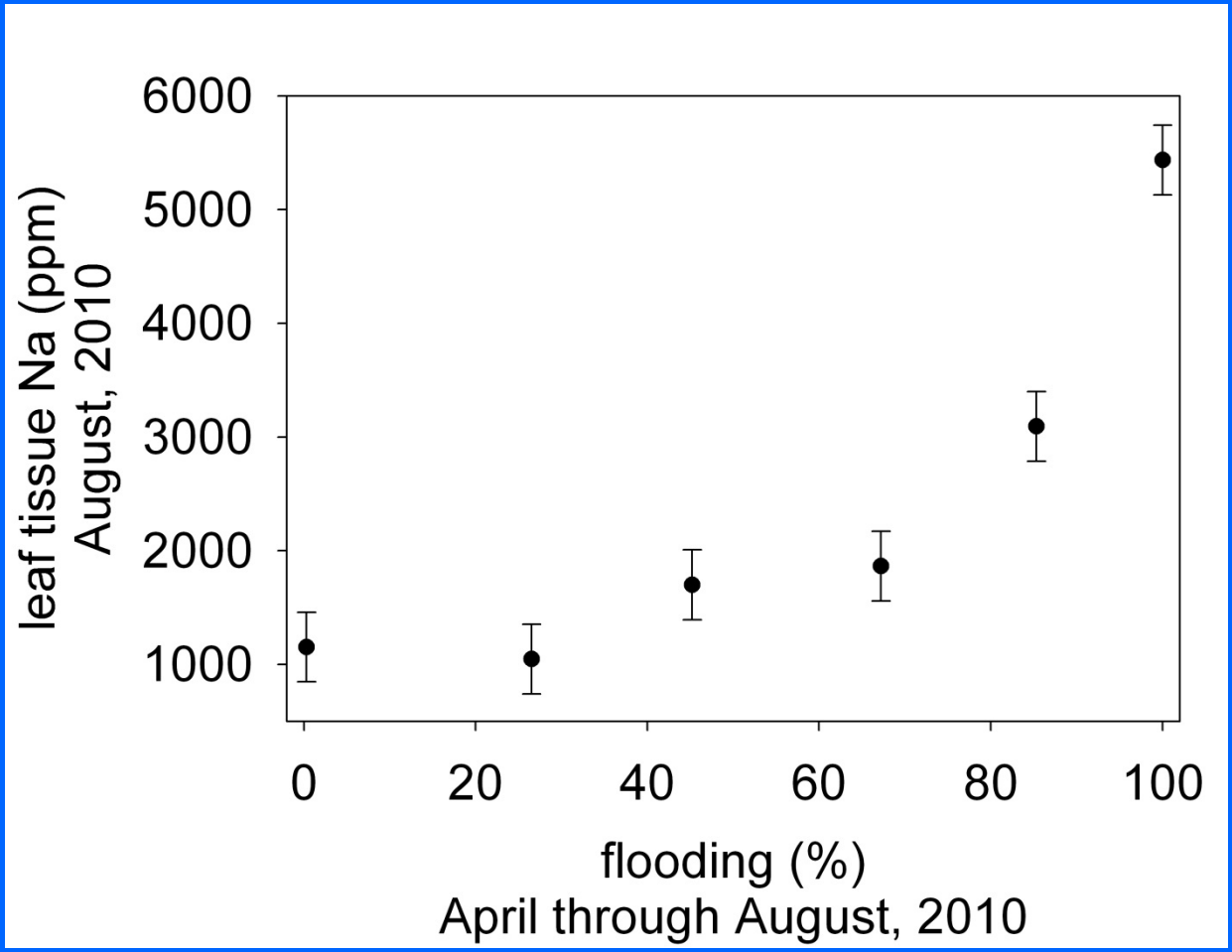

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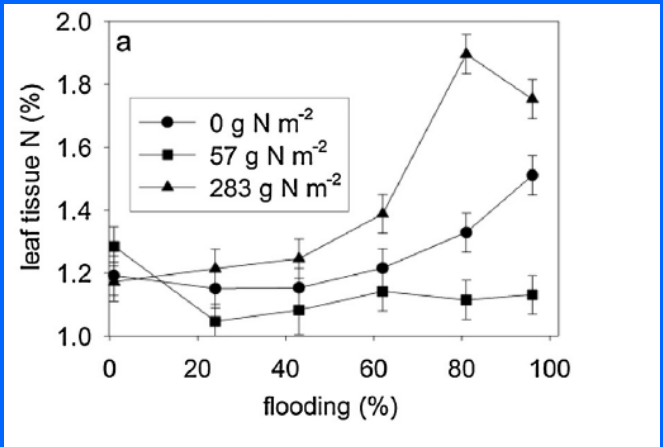

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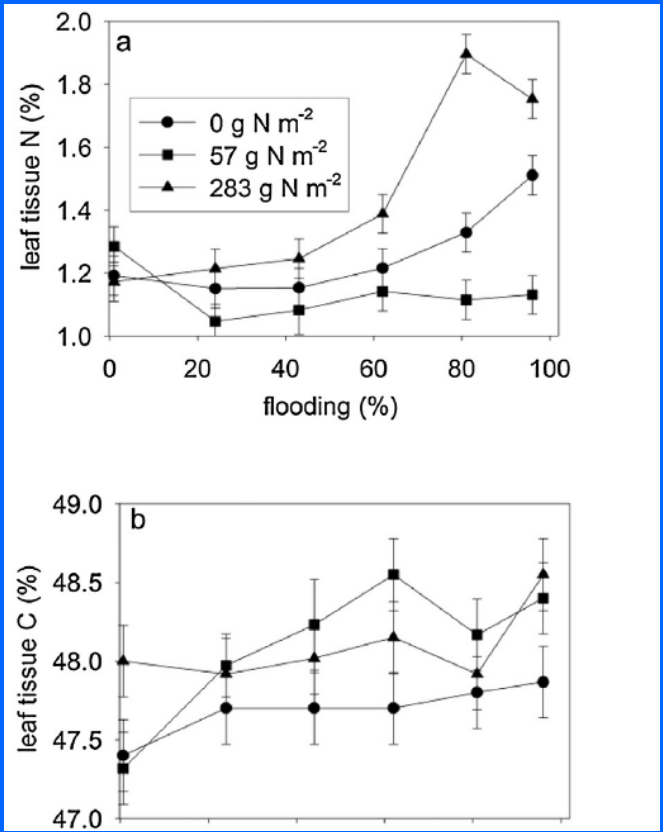

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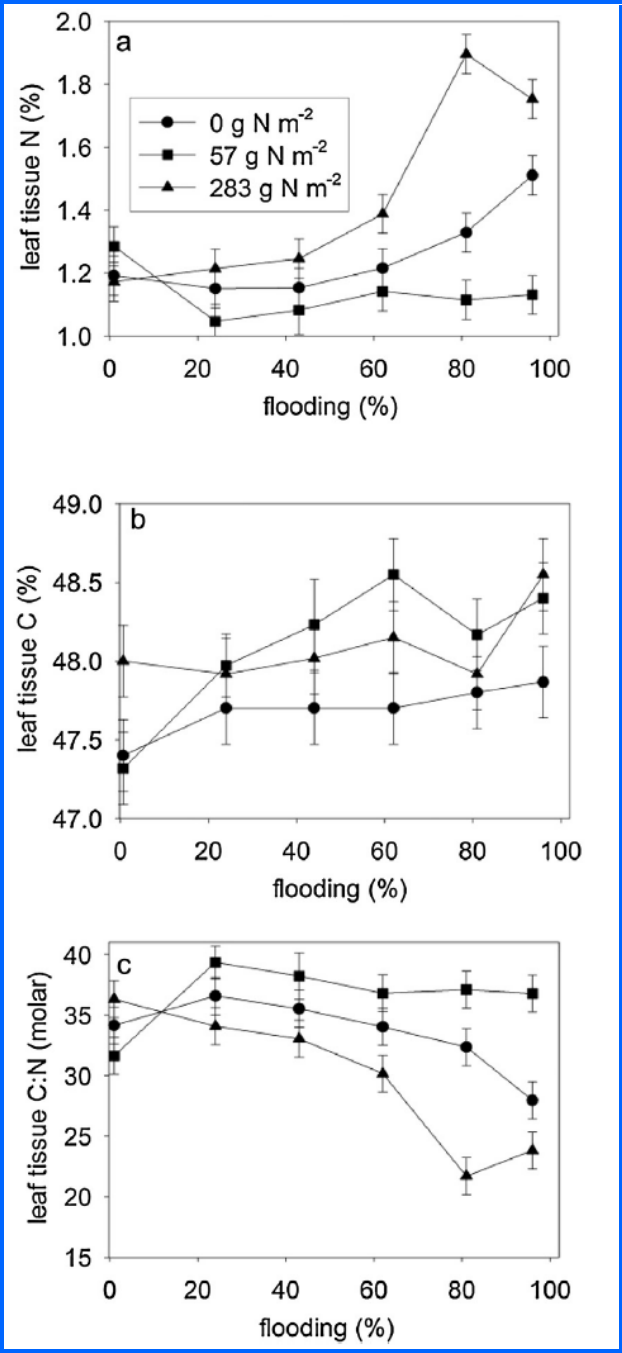

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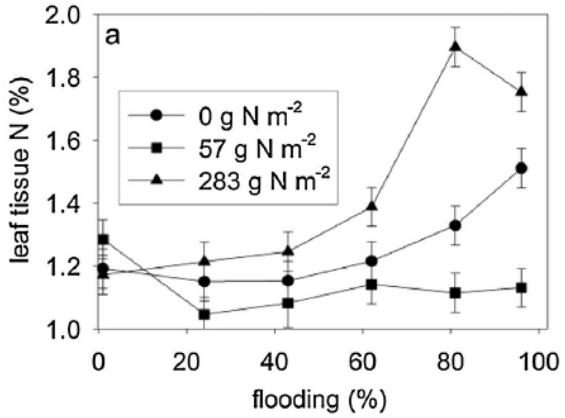

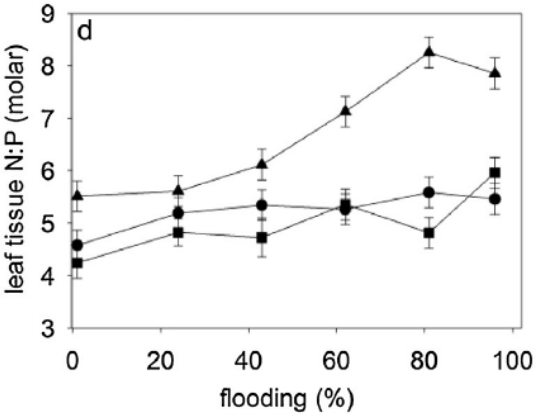

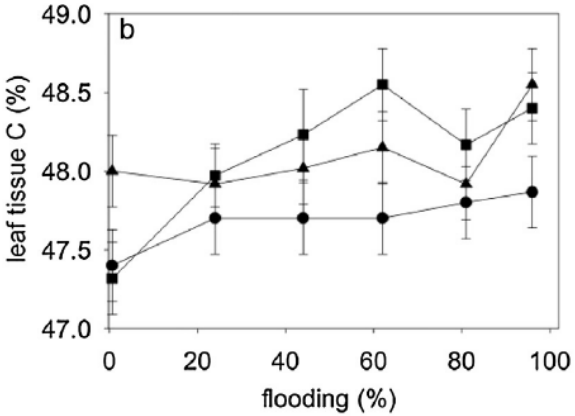

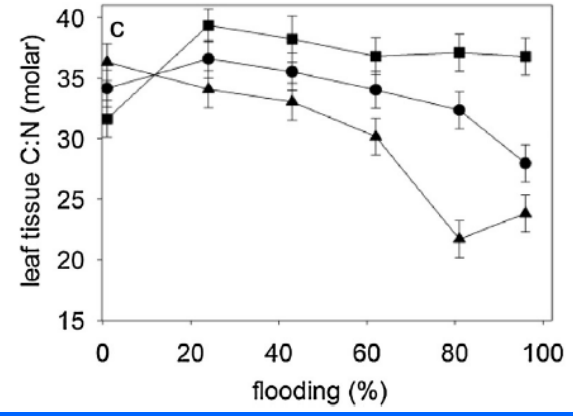

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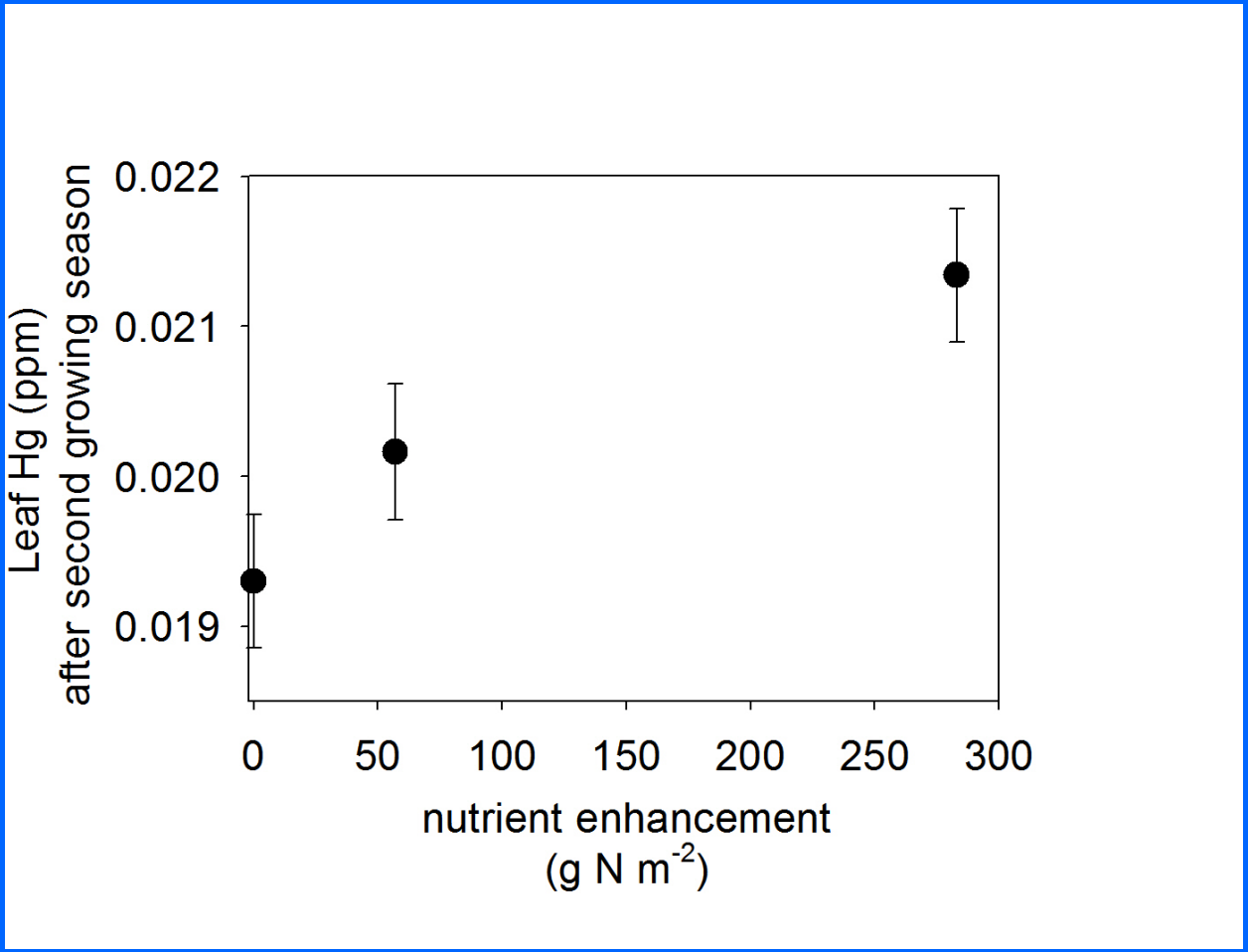

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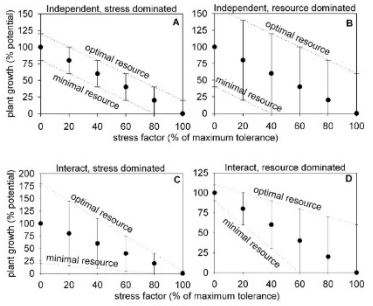
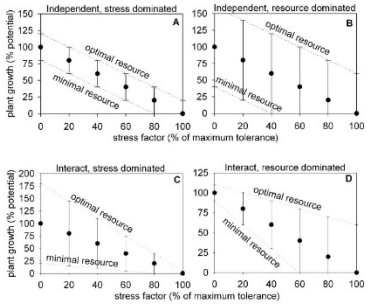
Conclusions

- The response of plants to nutrients reflects principles of ecology and toxicology:
  - Increasing availability of a limiting nutrient increases growth.
  - Everything, including nutrients, is a toxin; the dose determines whether or not something is toxic.
- Our research shows that when plant growth is limited by stress, the likely responses to nutrients are no-response or a toxic response.
  - This can look like a ecosystem tipping point if you are seeking one.



Conclusions

- Sodium concentrations in leaf tissue were affected by stress, which complicates using leaf tissue Na to infer salinity exposure to plants.
- Nutrient concentrations and ratios in leaf tissue were affected by stress, which complicates using leaf tissue nutrient ratios to infer the nutrient availability to plants.
- Nutrient availability increased leaf tissue Hg in *T. distichum.*



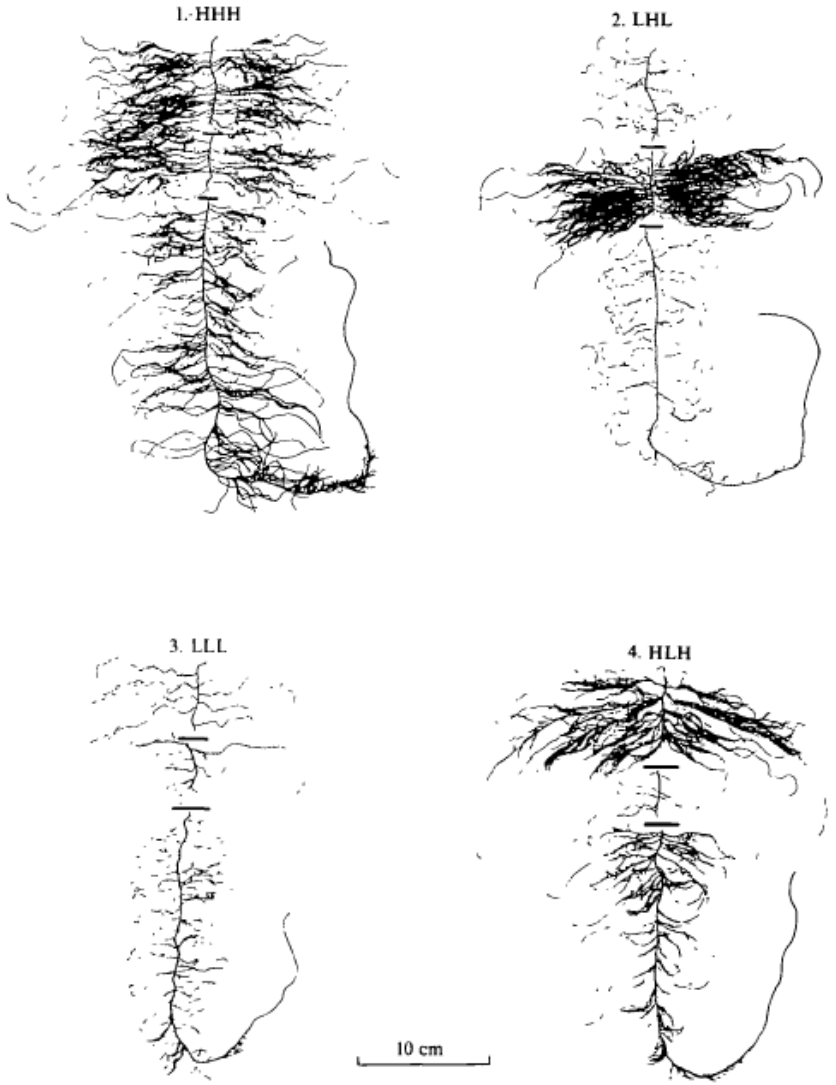


FIG. 2. The effect of nitrate supply on root growth. Nutrient solutions containing high (H, 1·0 mM) or low (L, 0·01 mM) concentrations of nitrate were supplied to three zones along the treated seminal axis (zones A–C, limits indicated by bars) using the apparatus illustrated in

Drew et al. 1973. Journal of Experimental Botany 1189-1201

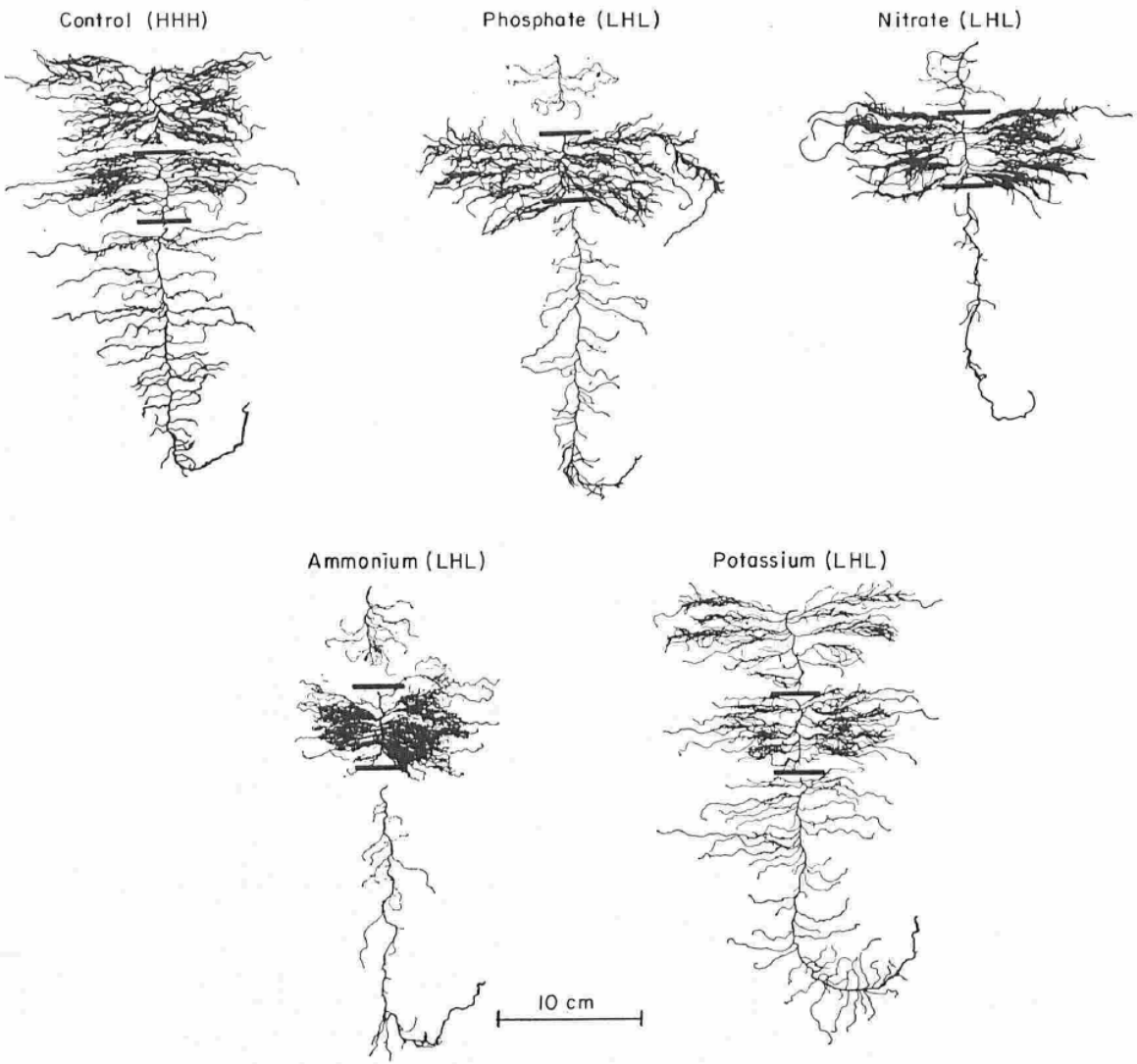


Fig. 4. Effect of a localized supply, of phosphate, nitrate, ammonium, and potassium on root form. Control plants (HHH) received the complete nutrient solution to all parts of the root system. The other roots (LHL) received the complete nutrient solution only in the middle zone, the top and bottom being supplied with a solution deficient in the specified nutrient. Note similarity between control and potassium treated roots.

Drew, M.C. 1975. New Phytologist 75:479-490.

$1\ g\ m^{-2} = 10\ kg\ ha^{-1}$

Table 6 Various types and rates of nitrogen deposition (grams per square meter per year)

Type	Rate ($g\ m^{-2}$)	Source
Atmospheric inorganic N deposition in USA	0–2 N	NADP undated
Caernarvon diversion:	0–8 N	Hyfield et al. (2008)
Rice farming	6–14 N	Saichuck et al. (2011)
Experiments with positive effects of nutrients on wetland plant roots		
Coastal salt marsh, MA, USA	18.2–157.2 N	Valiela et al. (1976)
Everglades, FL, USA	0–4.8 P[a]	Craft et al. (1995)
Everglades, FL, USA	0–<1 P	Daoust and Childers (2004)
Coastal salt marsh, CT, USA	2.7–7.5 N[a]	Anisfeld and Hill (2012)
Coastal salt marsh, WA, USA	80	Tyler et al. (2007)
Experiments with positive effects of nutrients on wetland elevation		
Coastal salt marsh, SC, USA	12.8 N[a]	Morris et al. (2002)
Coastal salt marsh, MA, USA	18.2–157.2 N	Fox et al. (2012)
Experiments with negative effects of nutrients on plant roots:		
Tidal freshwater marsh, GA, USA	50 N[a]	Ket et al. (2011)
Coastal salt marsh, LA, USA	74 N[a]	Darby and Turner (2008b)
Coastal salt marsh of the USA and Canada	224 N[a]	Darby and Turner (2008a)

See literature cited for full citations of all sources

[a] Other nutrients were added in addition to the nutrient that affected roots and/or elevation

Nyman 2013 Estuaries and Coasts 37:1490-1505