Oxidation of sediments by *Spartina* marsh grasses: Potential facilitation of pollutant degradation

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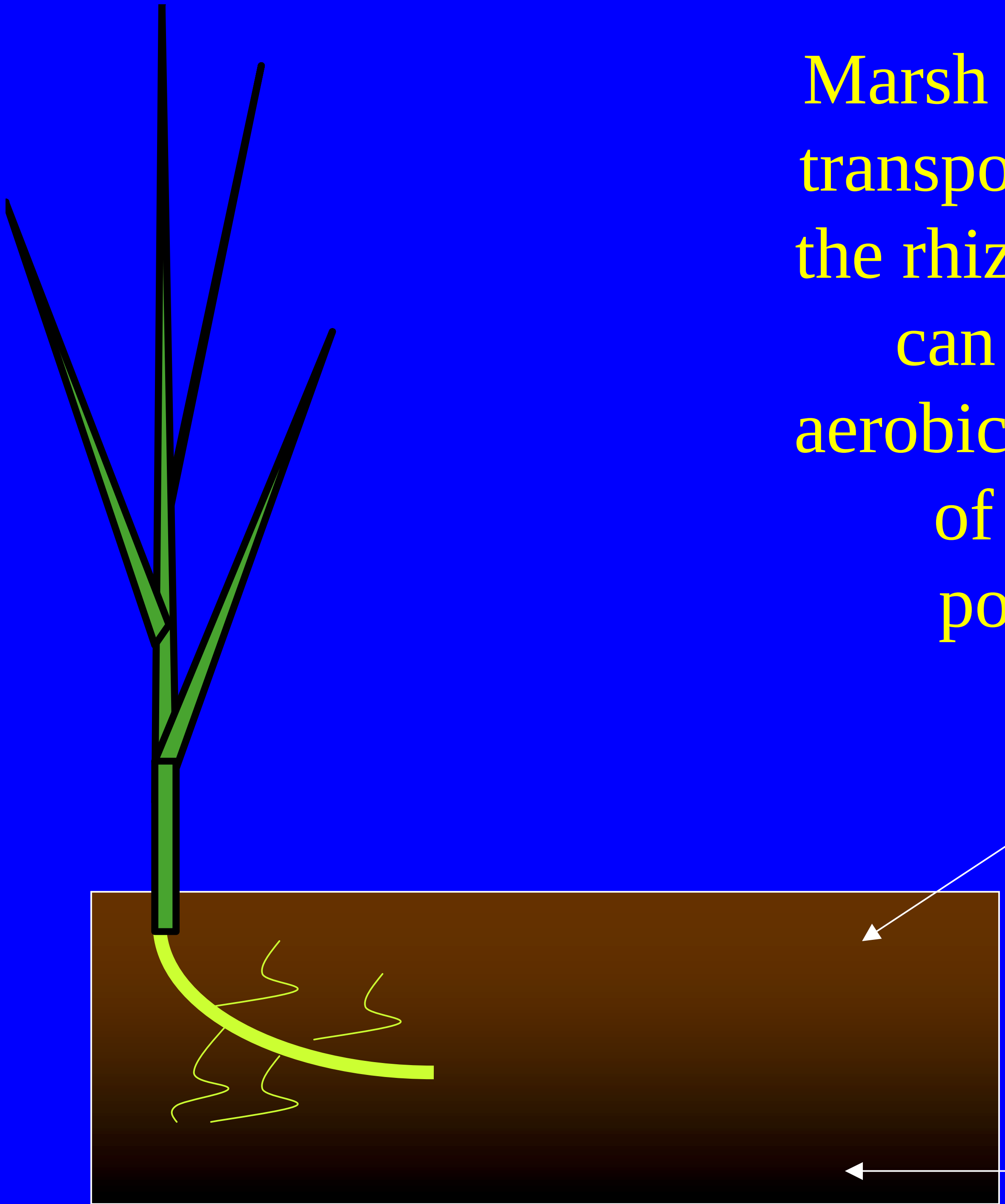
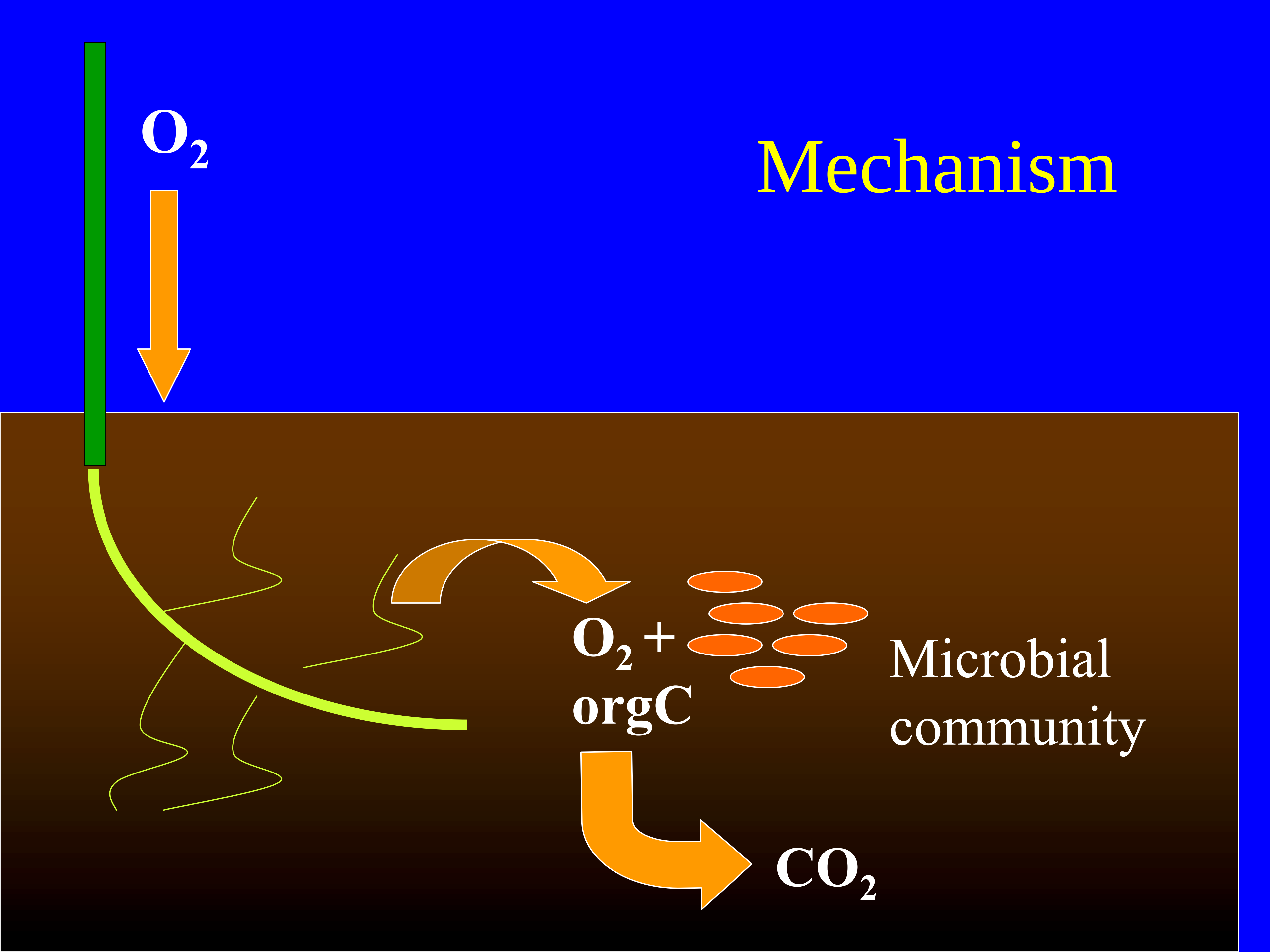
Marsh grasses may transport oxygen to the rhizosphere that can facilitate aerobic degradation of organic pollutants





Mechanism
O2
O2 +
orgC
Microbial
community
CO2

Oxidation of sediments by *Spartina* marsh grasses: Potential facilitation of pollutant degradation

- Introduction - a highly vigorous plant
- Gas conducting tissues
- Gas transport
- Testing for accelerated degradation

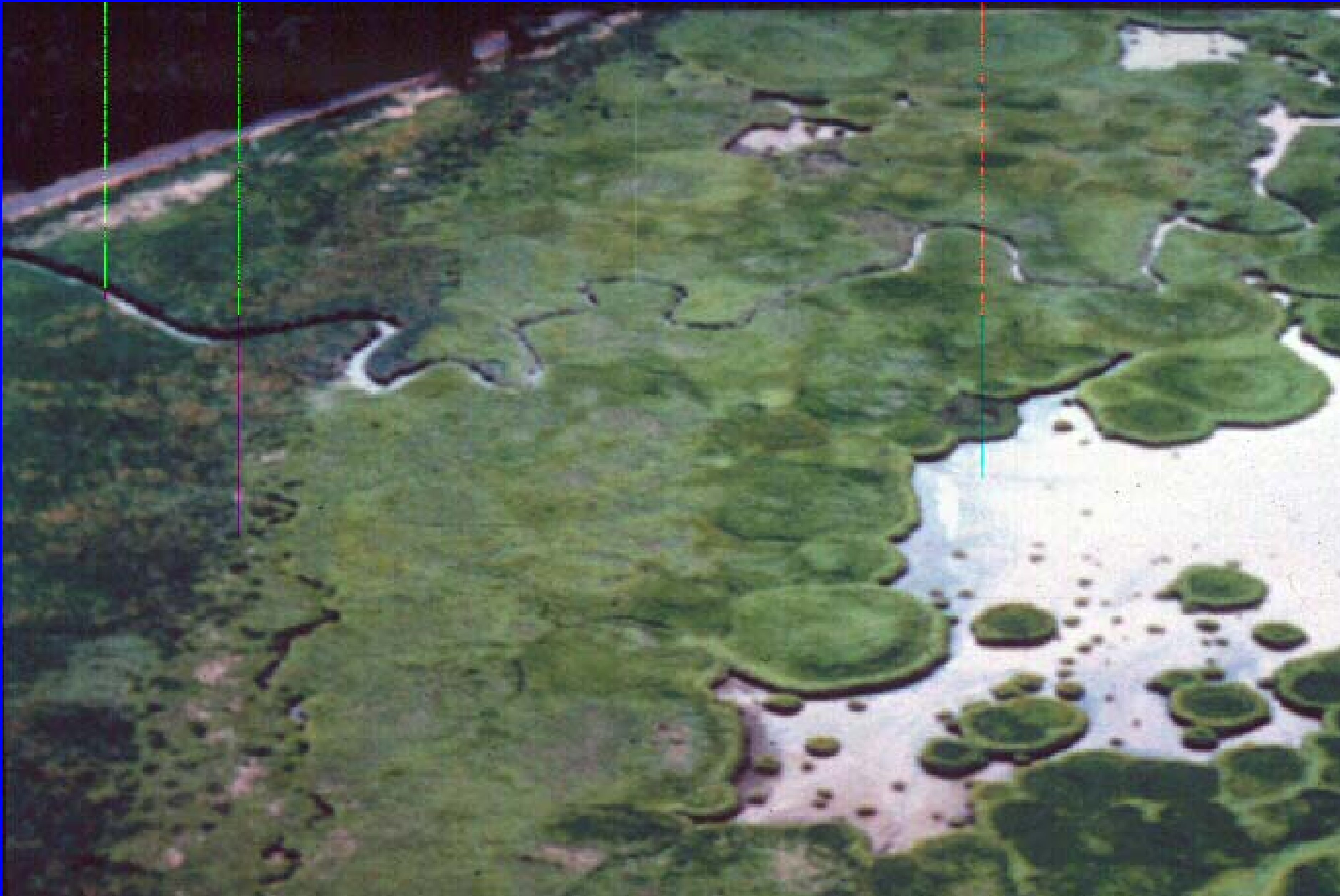
Spartina alterniflora and *Spartina anglica*

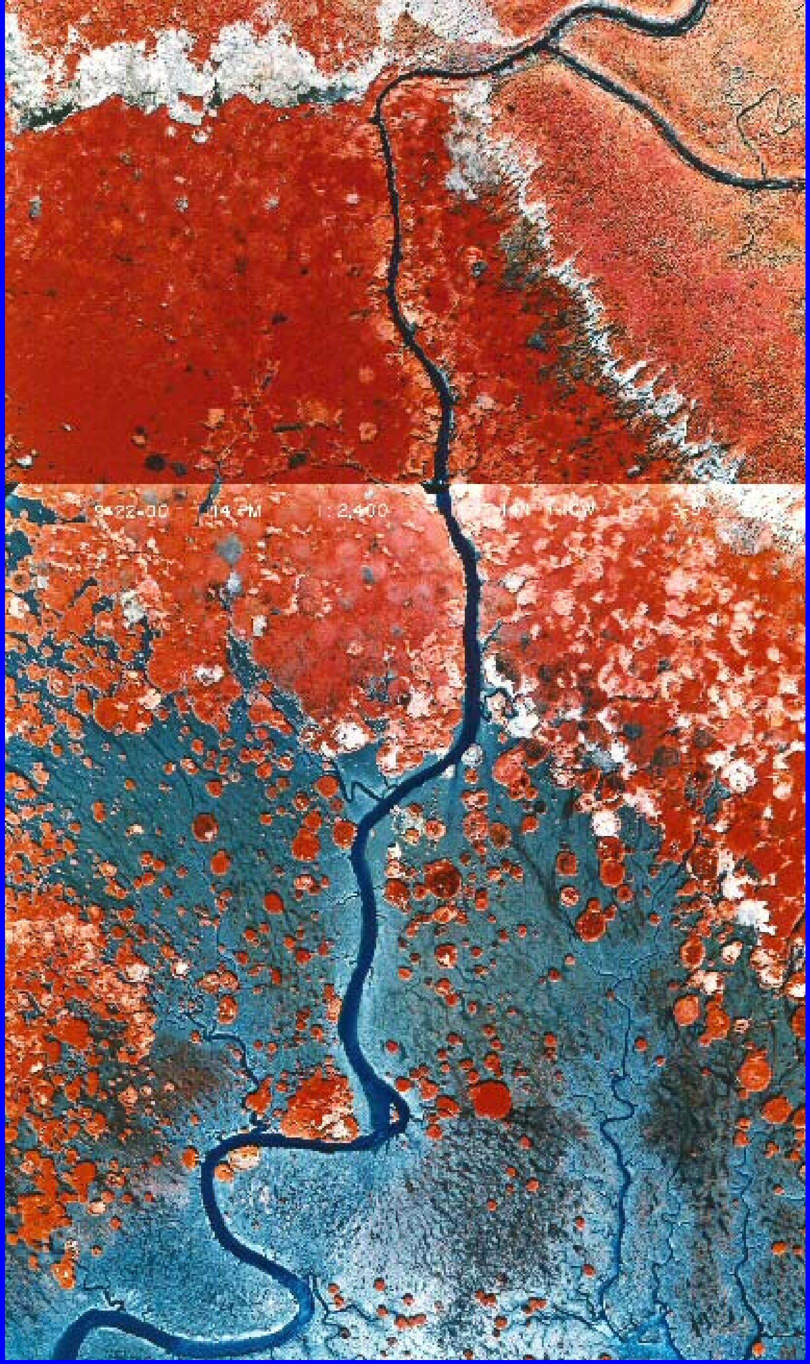
- Saltmarsh grasses native to the Eastern U.S. (*S. alterniflora*) and British Isles (*S. anglica*).
- Invasive species in Puget Sound and Willapa Bay in Washington State.

Spartina are physiologically resilient and vigorous

- Physiological tolerance
  - Wide range of salinities
  - Waterlogged soils
    - Anoxia
    - Hydrogen sulfide
- Fast rate of spread - average 10-20% per year (can be much greater)


One Year-old Seedling
Two Year-old Seedlings
Ten Year-old Meadow
Three to Four Year-old Clone



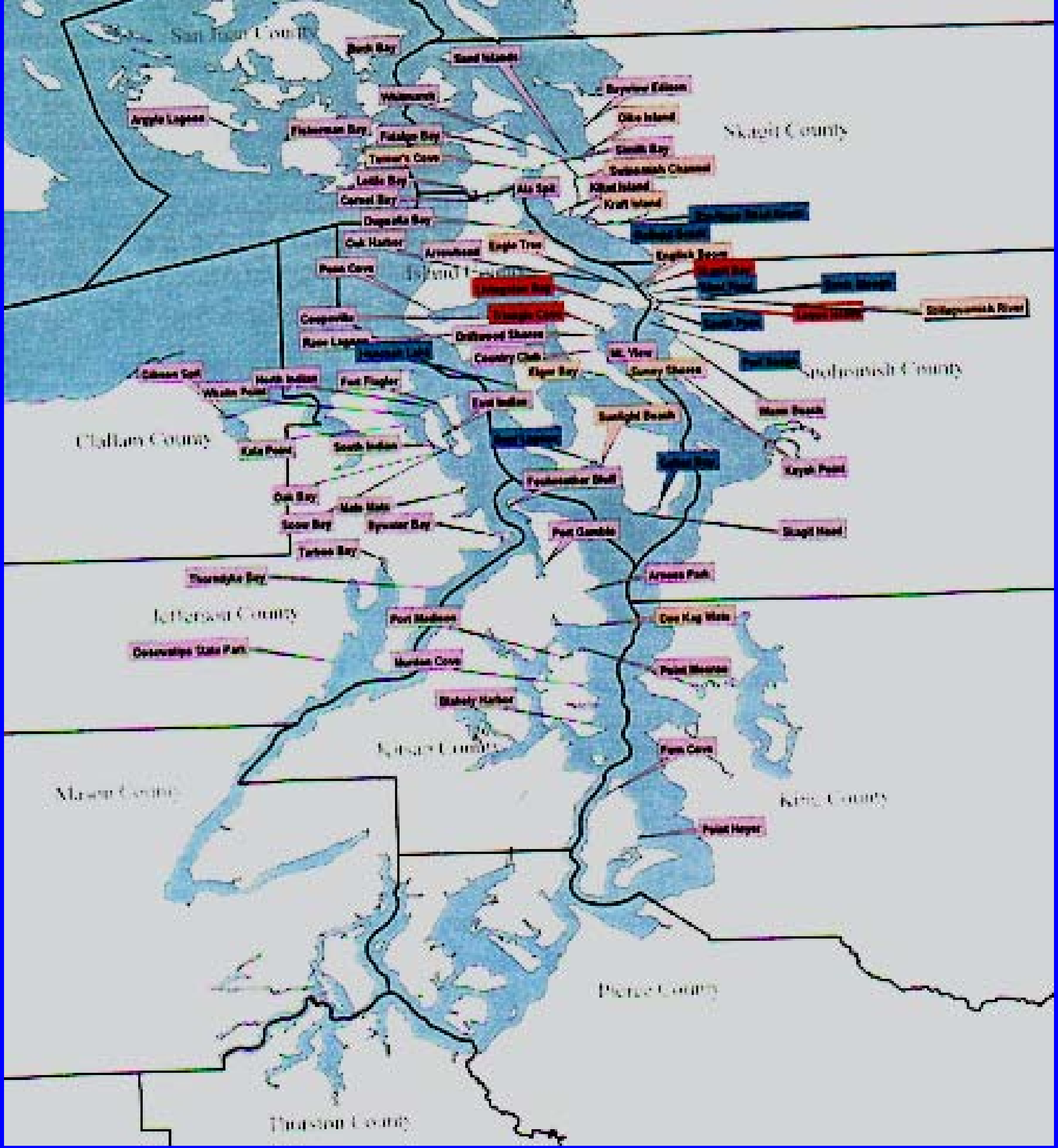


Willapa Bay

- *Spartina alterniflora*
- 10,000 to 25,000 acres affected
- Nearly 4000 solid acres

Puget Sound

- *Spartina anglica*
- ≈7000 acres affected
  - Solid acres:
    - Pink=<1
    - Peach= 1-5
    - Blue=6-100
    - Red=>100



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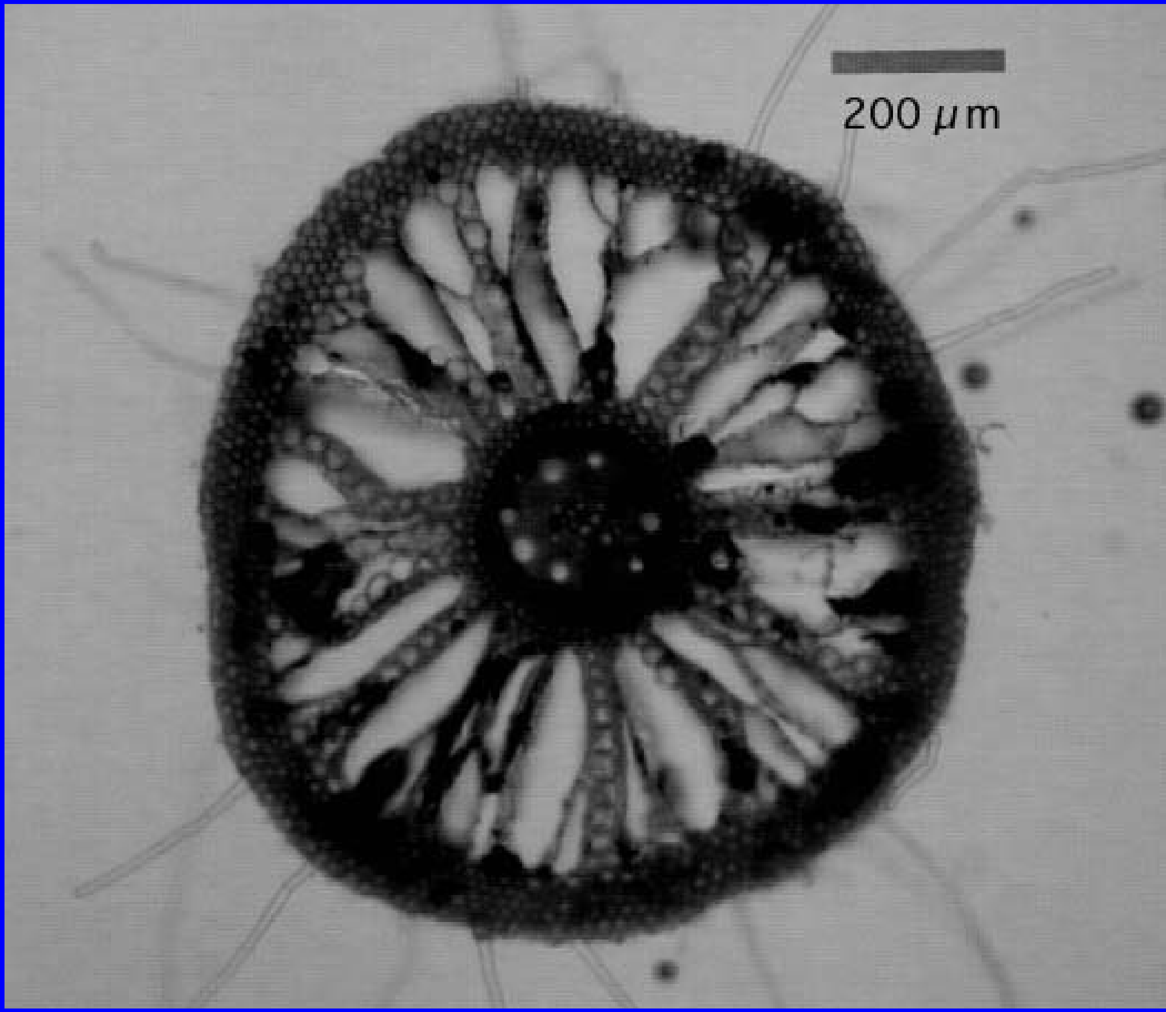
Quantification of gas conducting structures

Tolerating anoxic sediments

- Aerenchyma
- Anaerobic metabolism
  - Alcohol dehydrogenase
- Sulfide oxidation



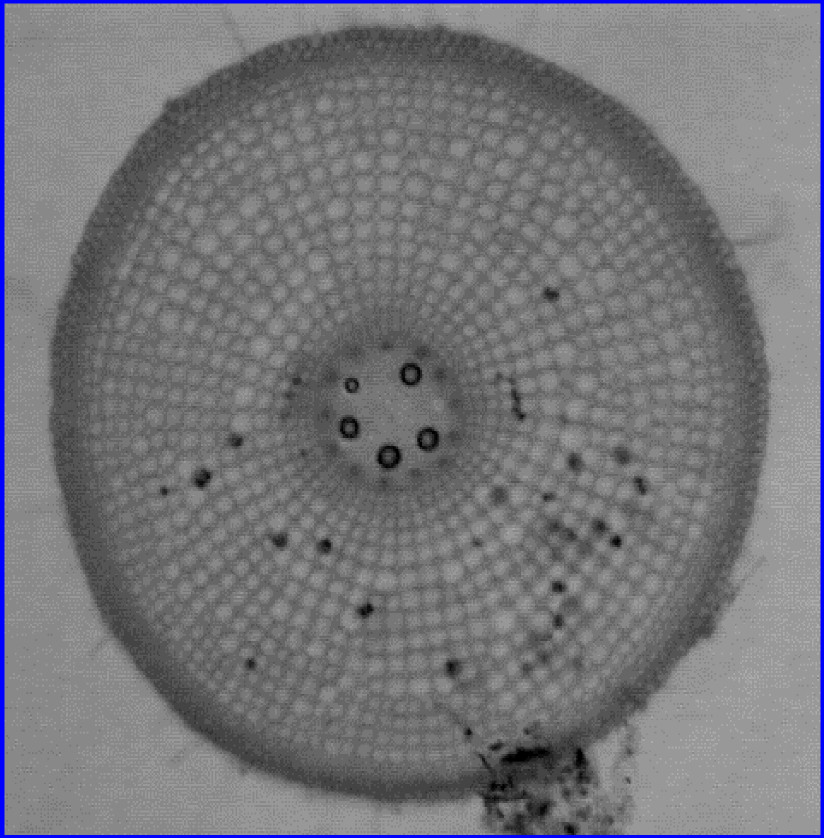
Spartina anglica root

Root Structure During Flooding

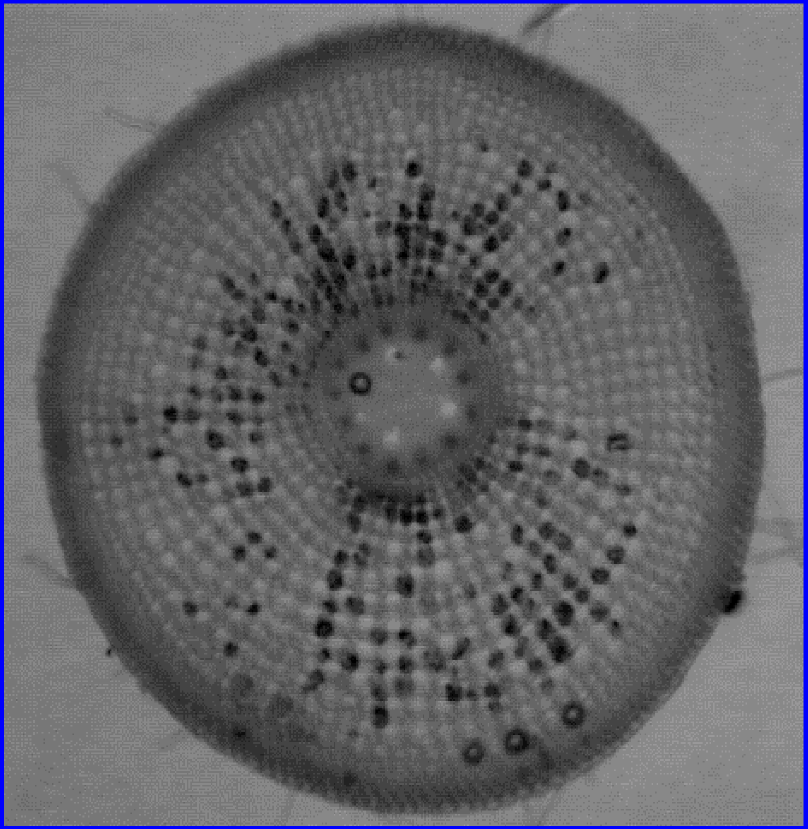
- During flooding roots are deprived of oxygen
- An aerenchyma system is developed to overcome deficiencies
- Root samples were taken from various treatments of plants, and fixed for microscopy
- Roots were sectioned serially, and examined by light microscopy

Spartina anglica Root Structure

1 cm from root tip

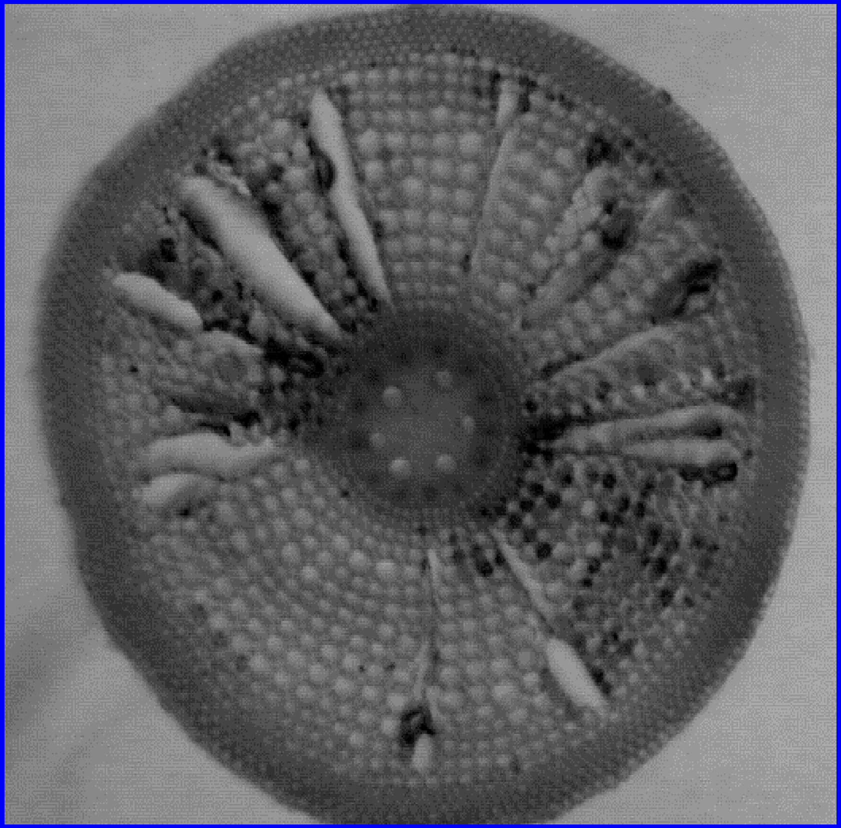


2 cm from root tip

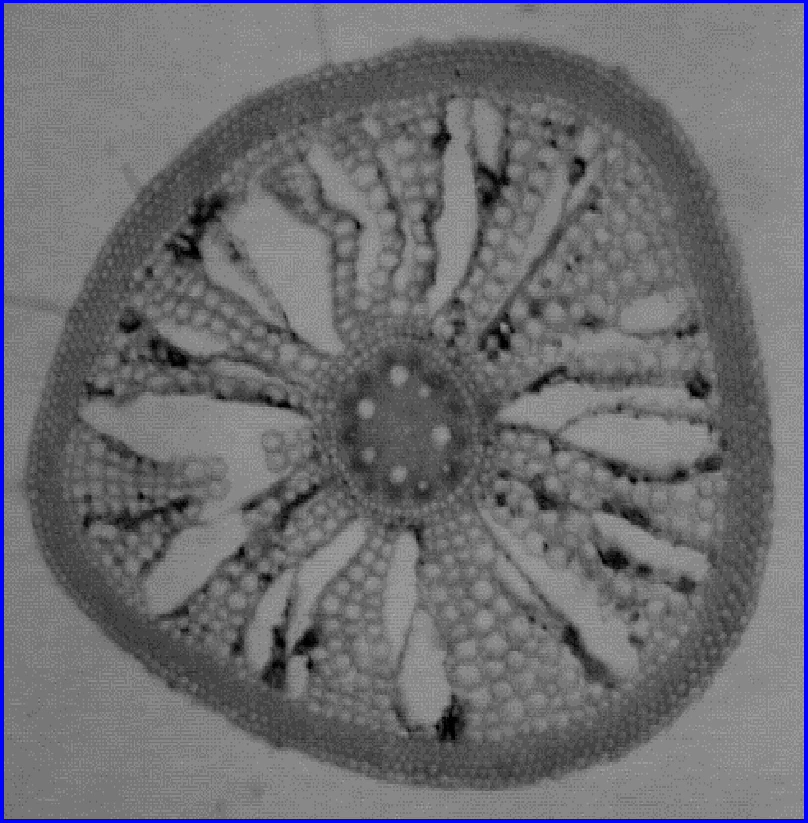


Spartina anglica Root Structure

4 cm from root tip

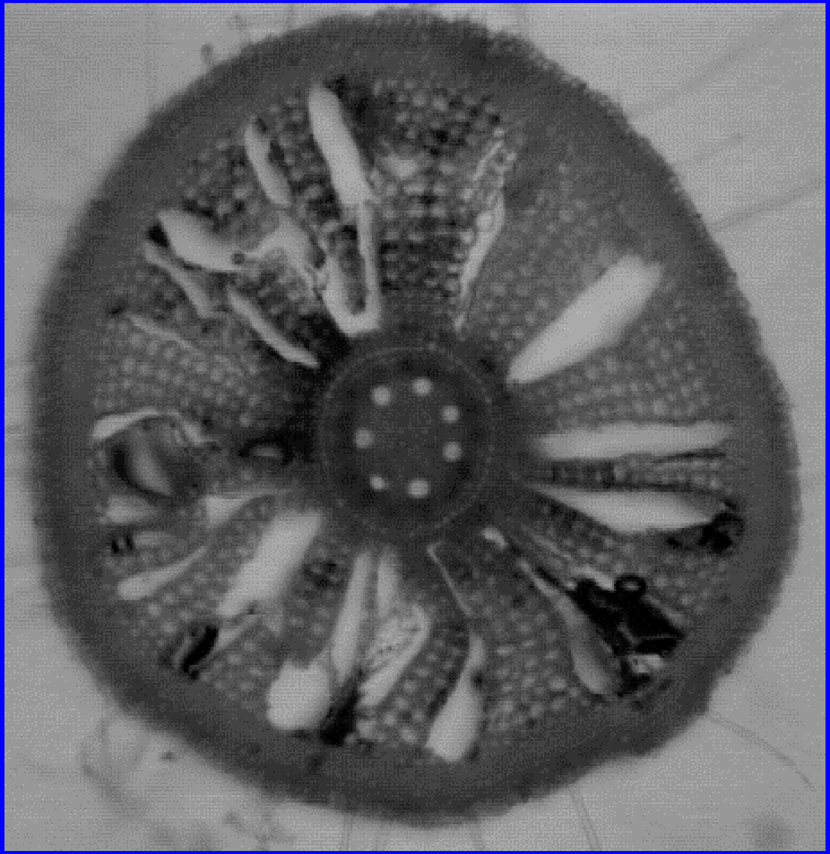


6 cm from root tip

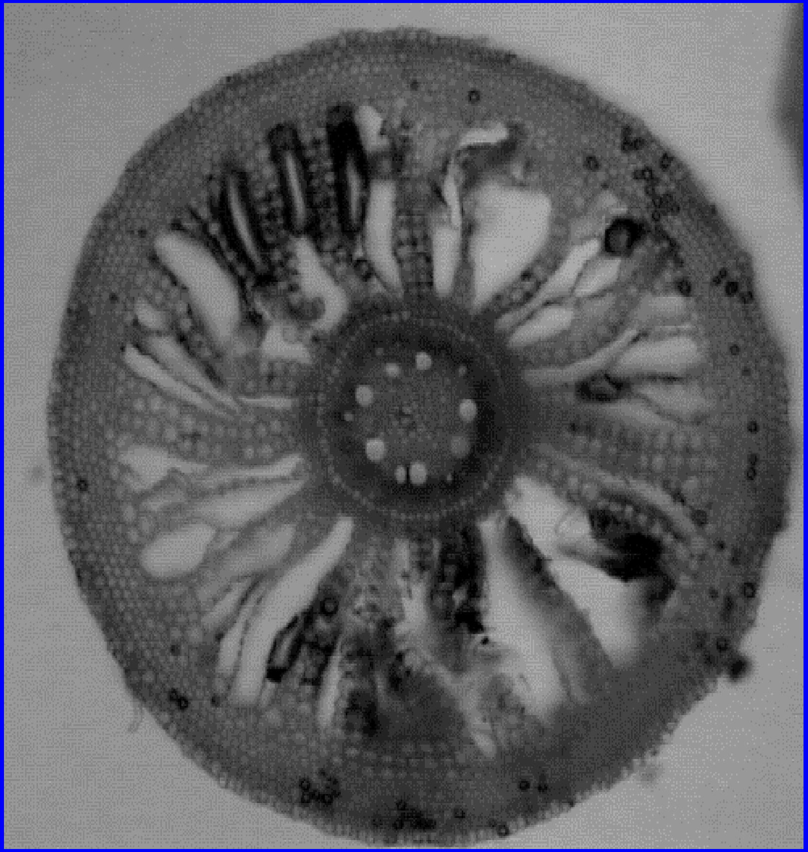


Spartina anglica Root Structure

8 cm from root tip

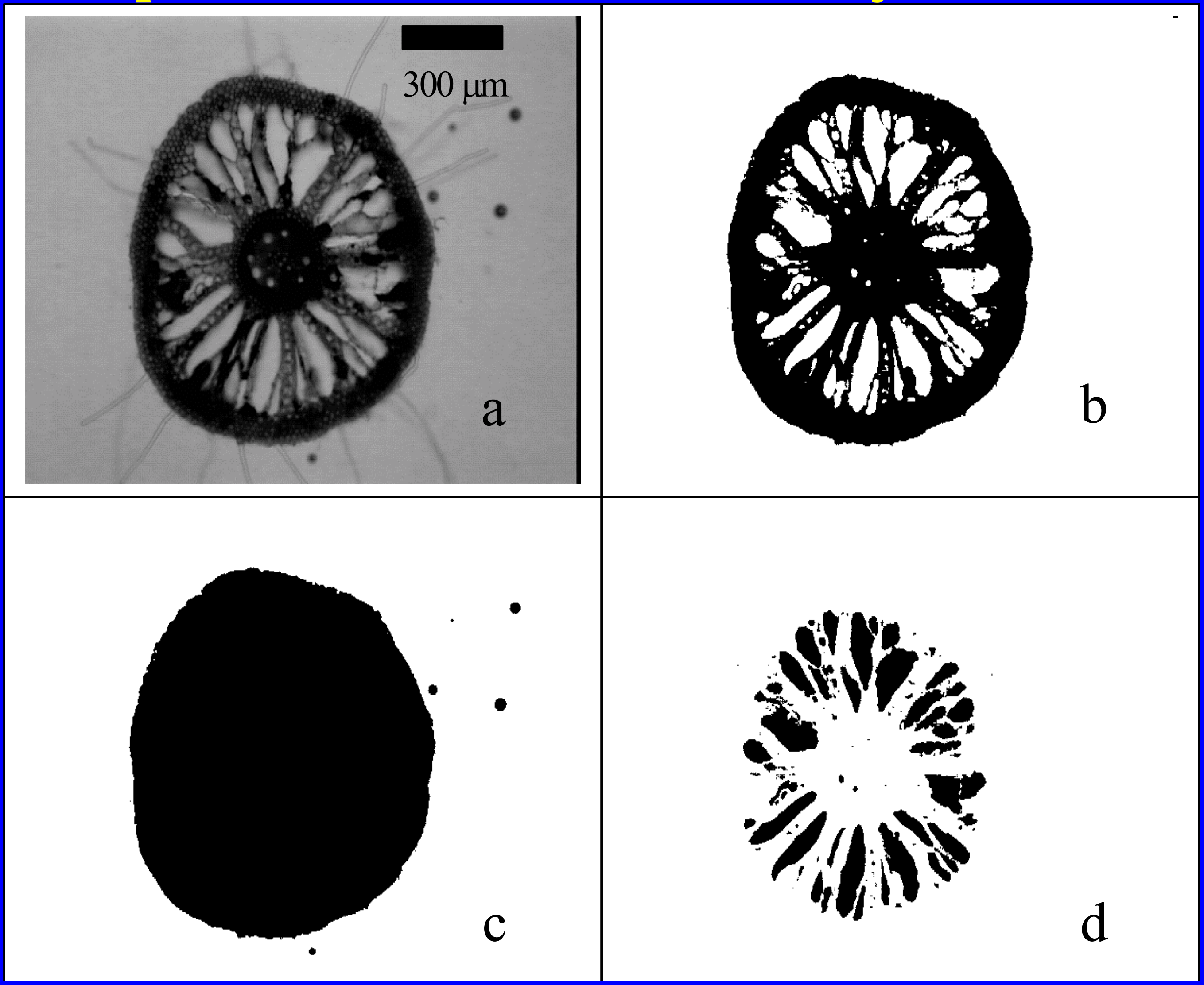


10 cm from root tip

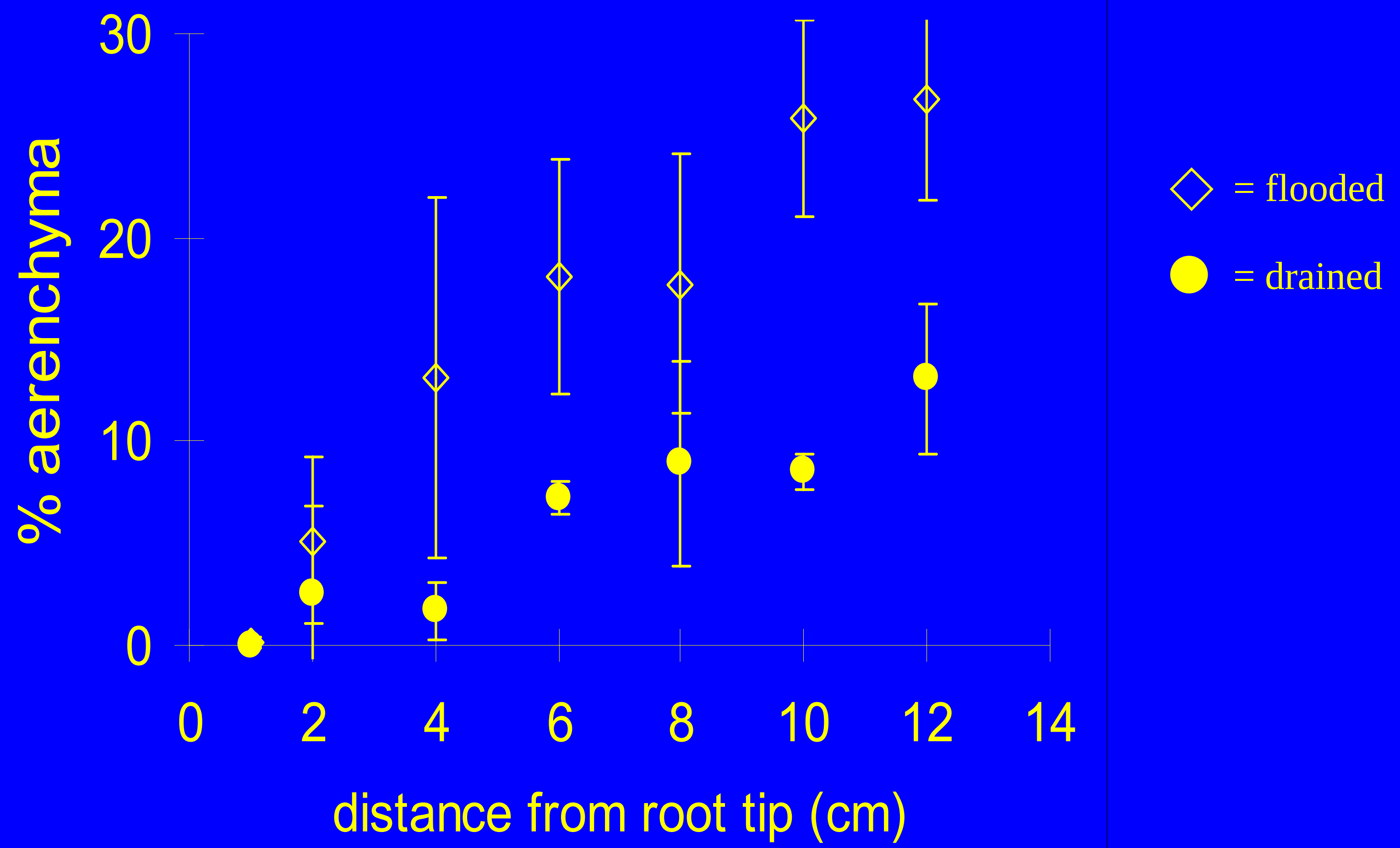


Digital quantification of aerenchyma

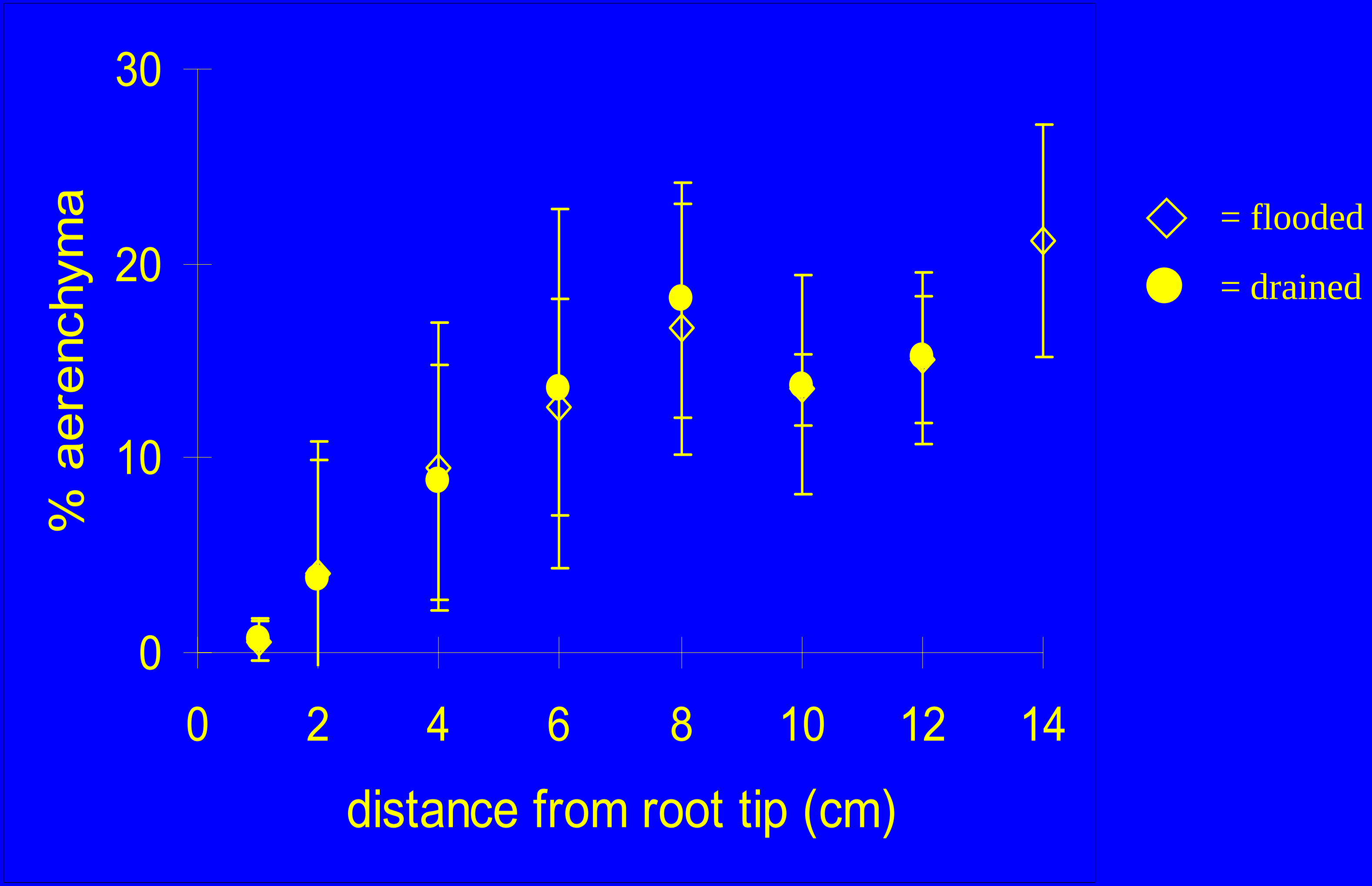
Percent aerenchyma equals the number of pixels in “d” divided by the number of pixels in “c.”



S. alterniflora develops more aerenchyma when flooded



S. anglica does not develop more aerenchyma when flooded



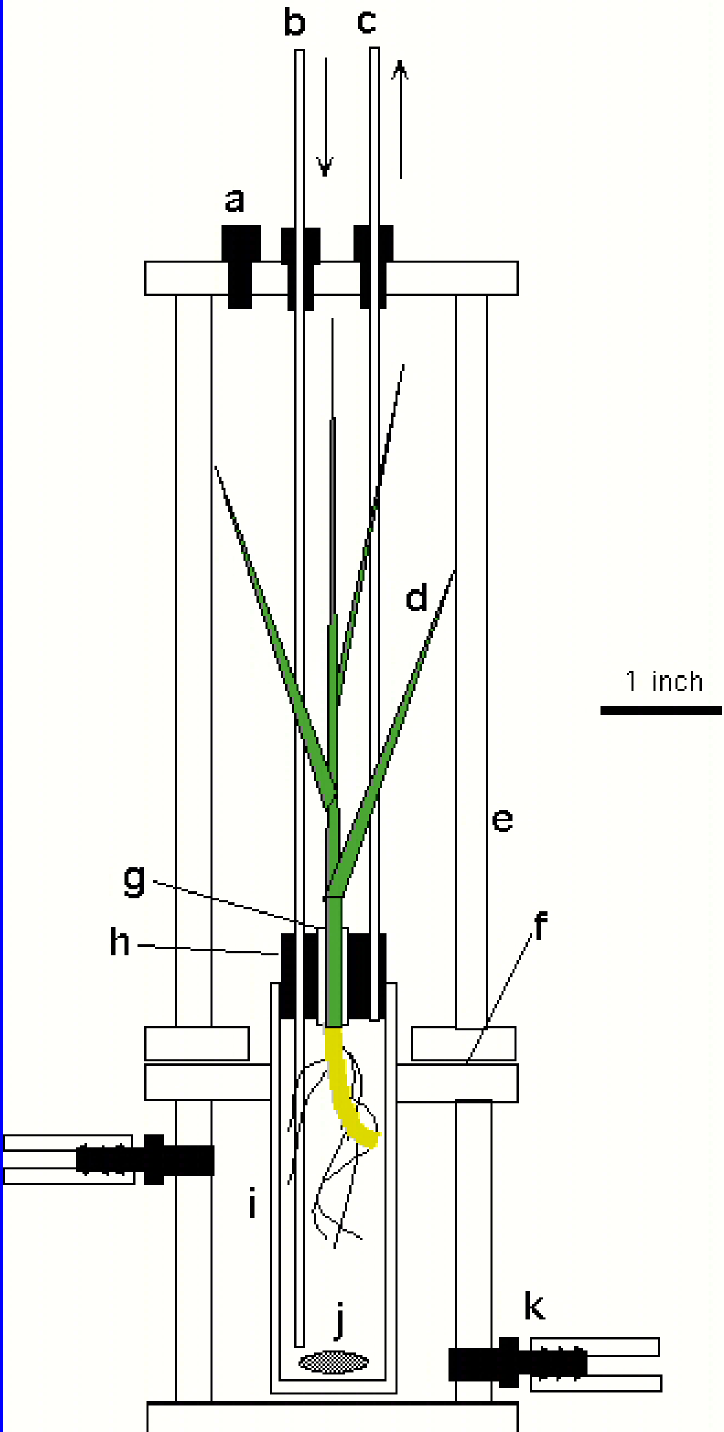
Root Structure Results

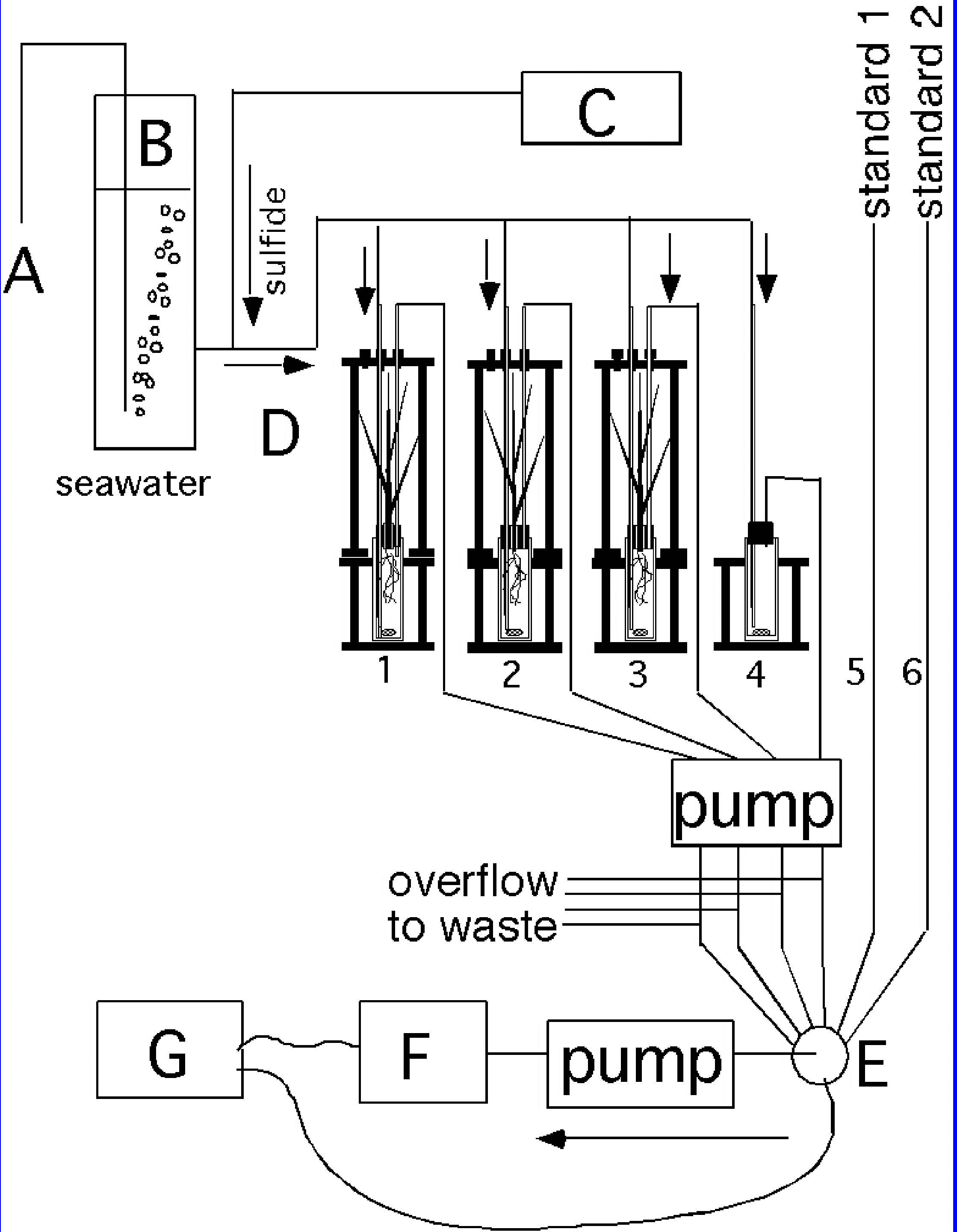
- *Spartina alterniflora* roots become stressed with the onset of flooding and form more aerenchyma.
- *Spartina anglica* plants were not stressed by flooding! They do not form aerenchyma even when confronted with flooding stress.

Quantifying oxygen transport

S. anglica respirometry experiments

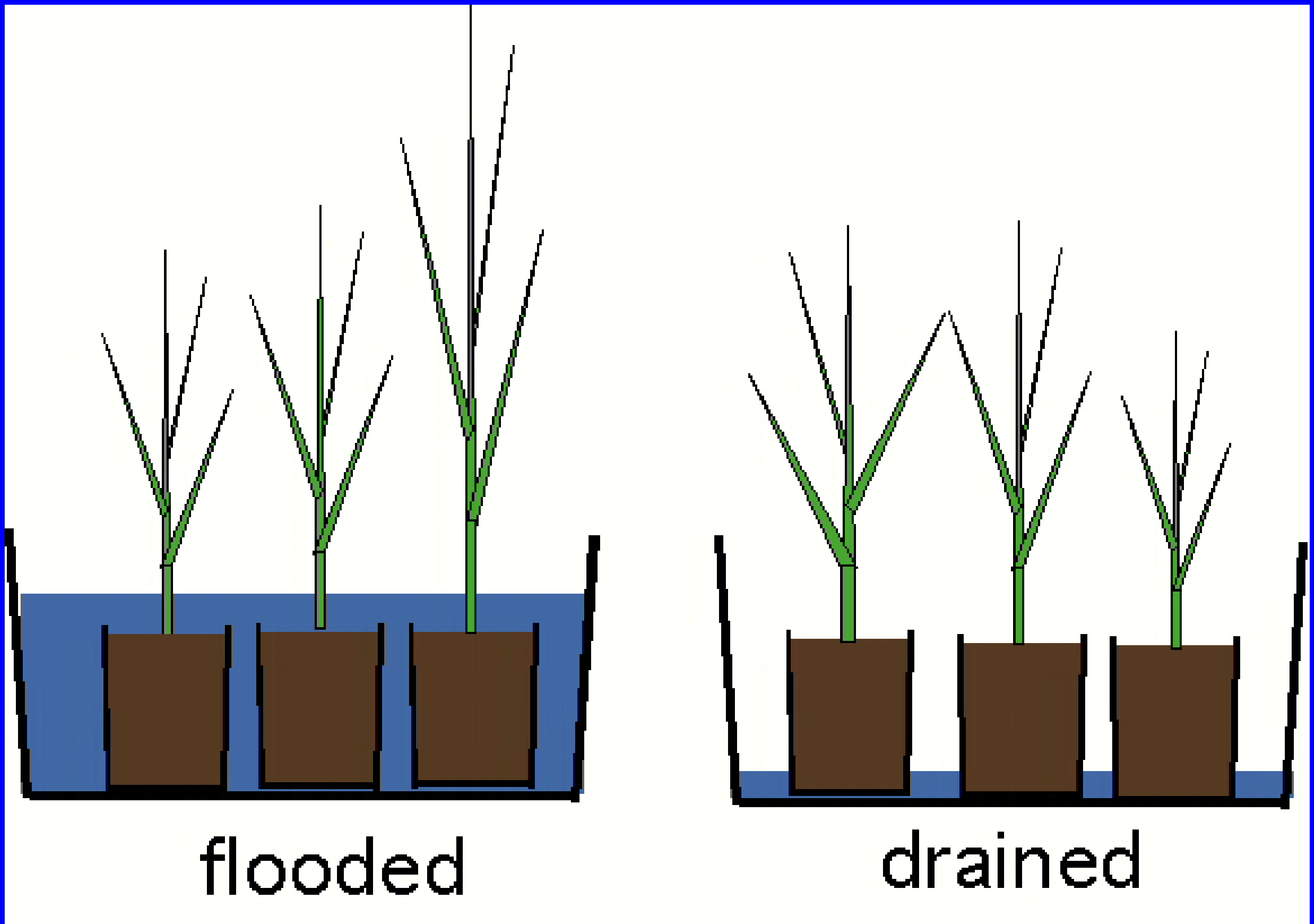
- Use automated flow-through respirometry system
- Quantify root O_2, H_2S, CO_2, NH_3 fluxes
- Aerenchyma gas transport
- Sulfide detoxification





Flow-through respirometry

Compare plants grown under different conditions

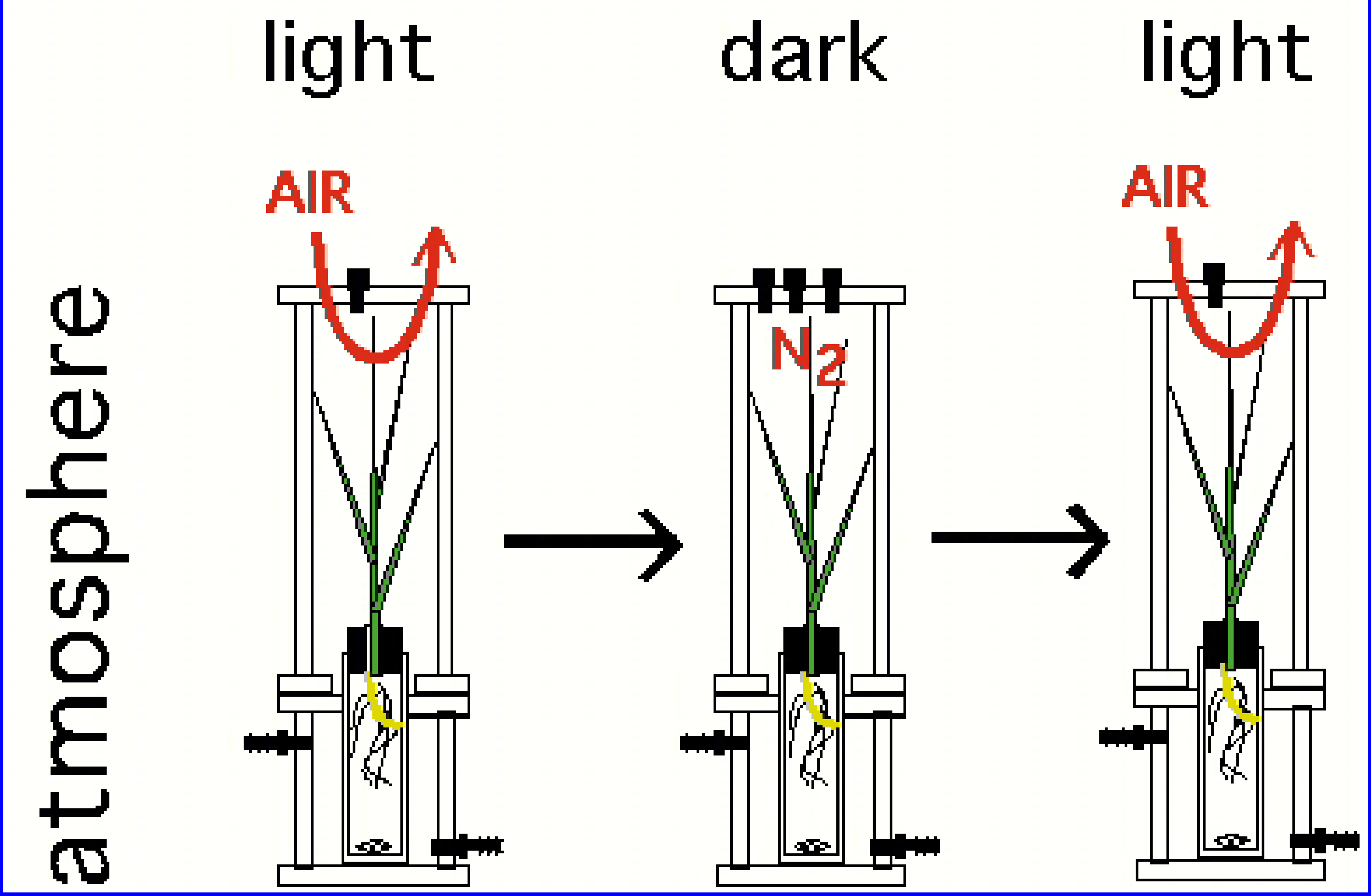


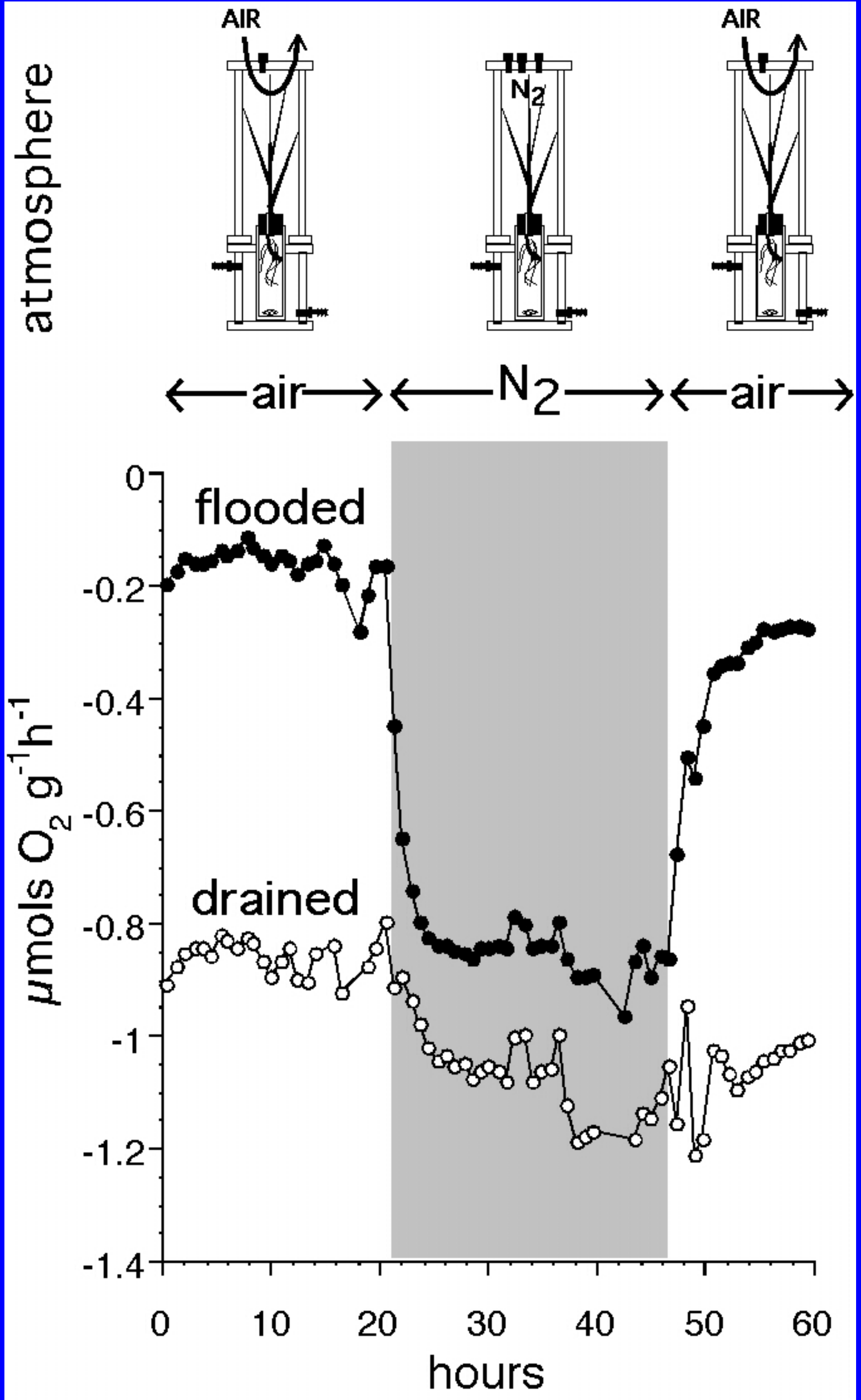
Flooded plants consume less oxygen from the medium

Rates of root oxygen flux in *Spartina anglica* grown under drained and flooded conditions. Negative fluxes denote uptake from the medium. Values given are mean ± SD (n).

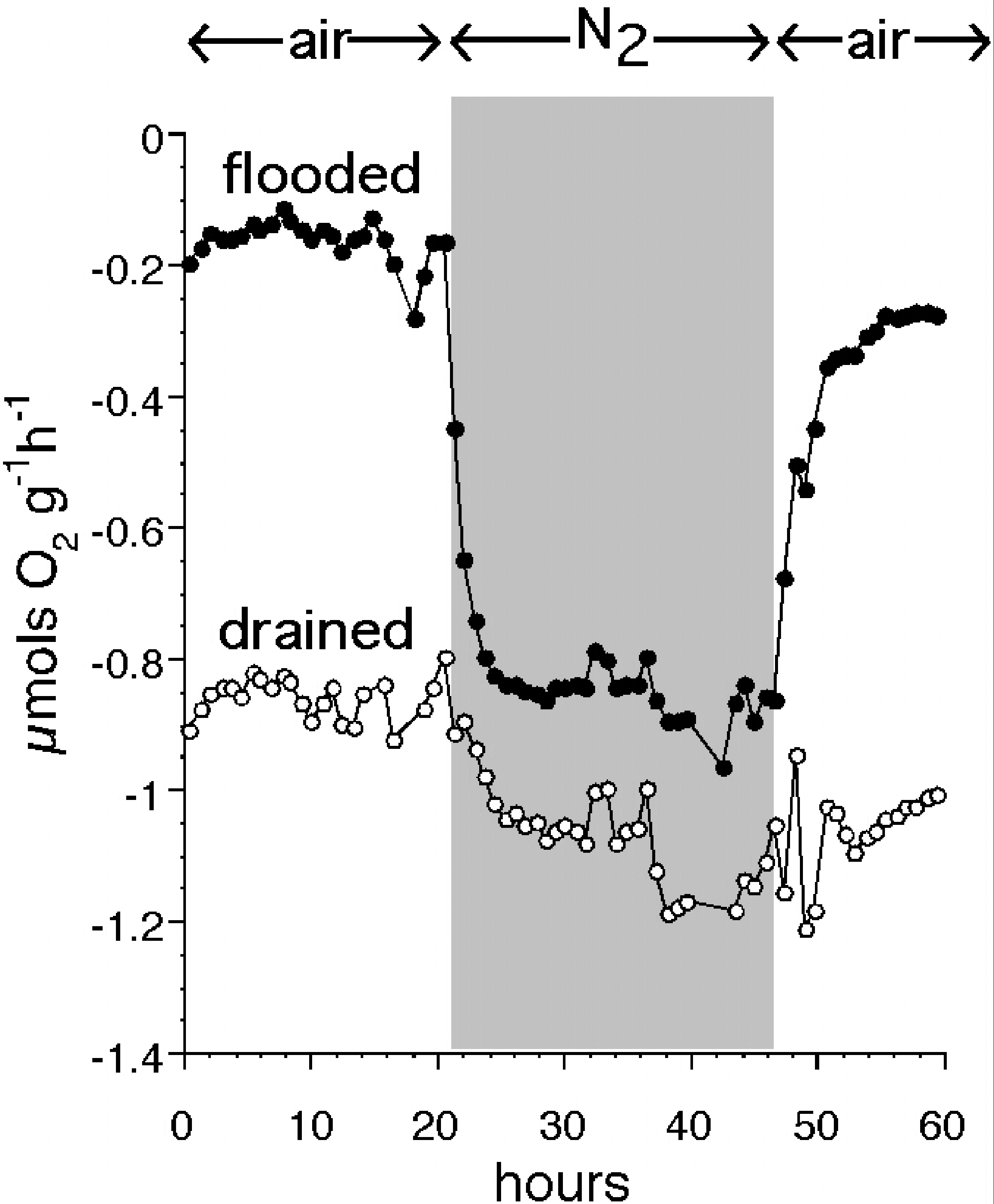
	O_2 flux (μmol g^{-1} h^{-1})
Flooded	Drained
-0.02 ± 0.49 (16)	**-0.70 ± 0.50 (8)**

Quantifying aerenchyma O_2 transport





atmosphere
AIR
N2
AIR
air
N2
air
flooded
drained
µmols O2 g-1h-1
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
0
10
20
30
40
50
60
hours



- Aerenchyma O_2 transport is high (0.6 μmols g^{-1} h^{-1}) in flooded plants and negligible in plants grown under drained conditions

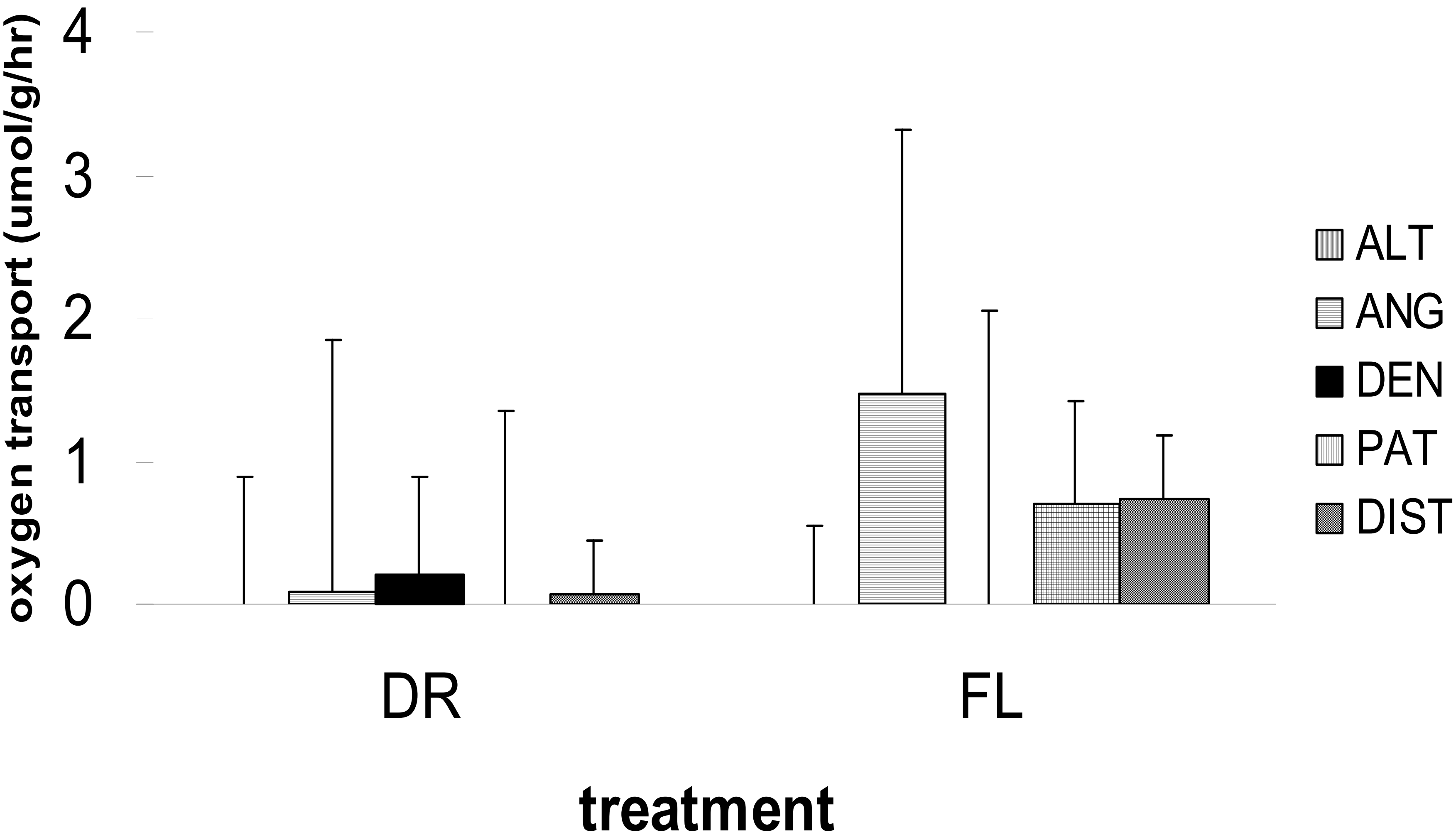
Summary of respirometry results

Species/Treatment	Gas Fluxes to the Rhizosphere* Air atmosphere (μmols g^{-1} h^{-1})	sealed N_2 atmosphere (μmols g^{-1} h^{-1})
O_2 flux		
Spartina anglica flooded	**0.110 ± 0.324 (13)**	**-0.830 ± 0.083 (3)**
Spartina anglica drained	**-0.523 ± 0.355 (5)**	**-0.826 ± 0.302 (4)**
Spartina alterniflora flooded	**-2.689 ± 1.512 (6)**	**-2.562 ± 1.612 (6)**

Oxygen transport appears to be more effective in *S. anglica* compared with *S. alterniflora*

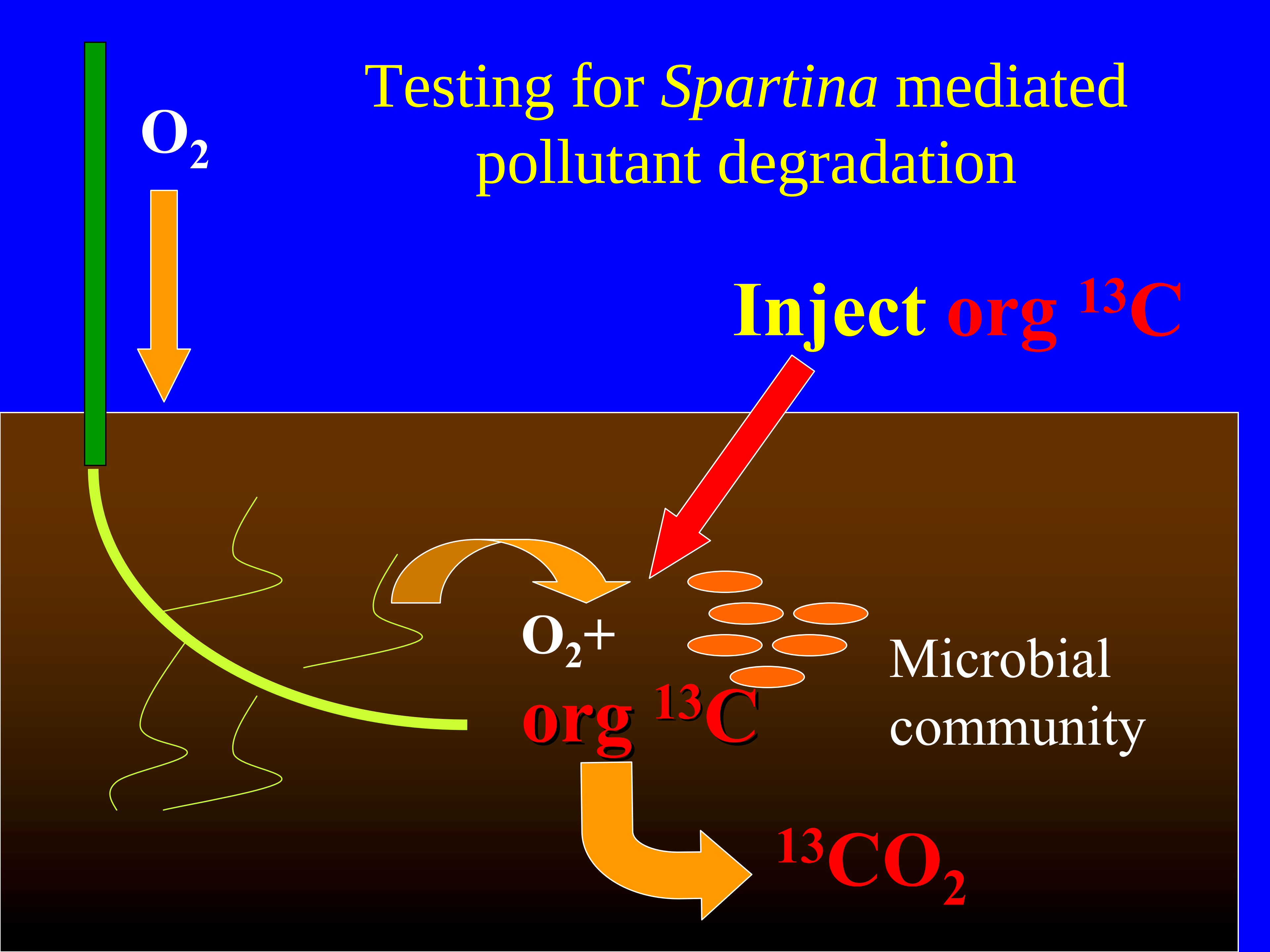
- *S. alterniflora* do not exhibit net release of oxygen to the medium (Howes and Teal, 1994)
- Possible implications for success of *S. anglica* as an invasive species?

Additional species vs. *S. anglica*



S. anglica sediment oxidation

Treatment/Habitat	Sediment Redox Potential (mV)	Porewater Sulfide (μM)
Intact *S. anglica*	-183.38 ± 170.82 (8)	643.55 ± 539.61 (10)
Bare Mudflat	-291.67 ± 56.61 (3)	737.14 ± 1296.50 (6)
Mowed to Mud	-326.00 ± 68.07 (5)	747.58 ± 473.03 (8)
Mowed to Stubble	-316.60 ± 27.63 (5)	2205.80 ± 975.20 (8)
Mowed Previous Year	-193.33 ± 232.41 (3)	1114.37 ± 766.46 (3)


Testing for *Spartina* mediated pollutant degradation
O_2
Inject org ^{13}C
O_2+
org ^{13}C
Microbial community
$^{13}CO_2$

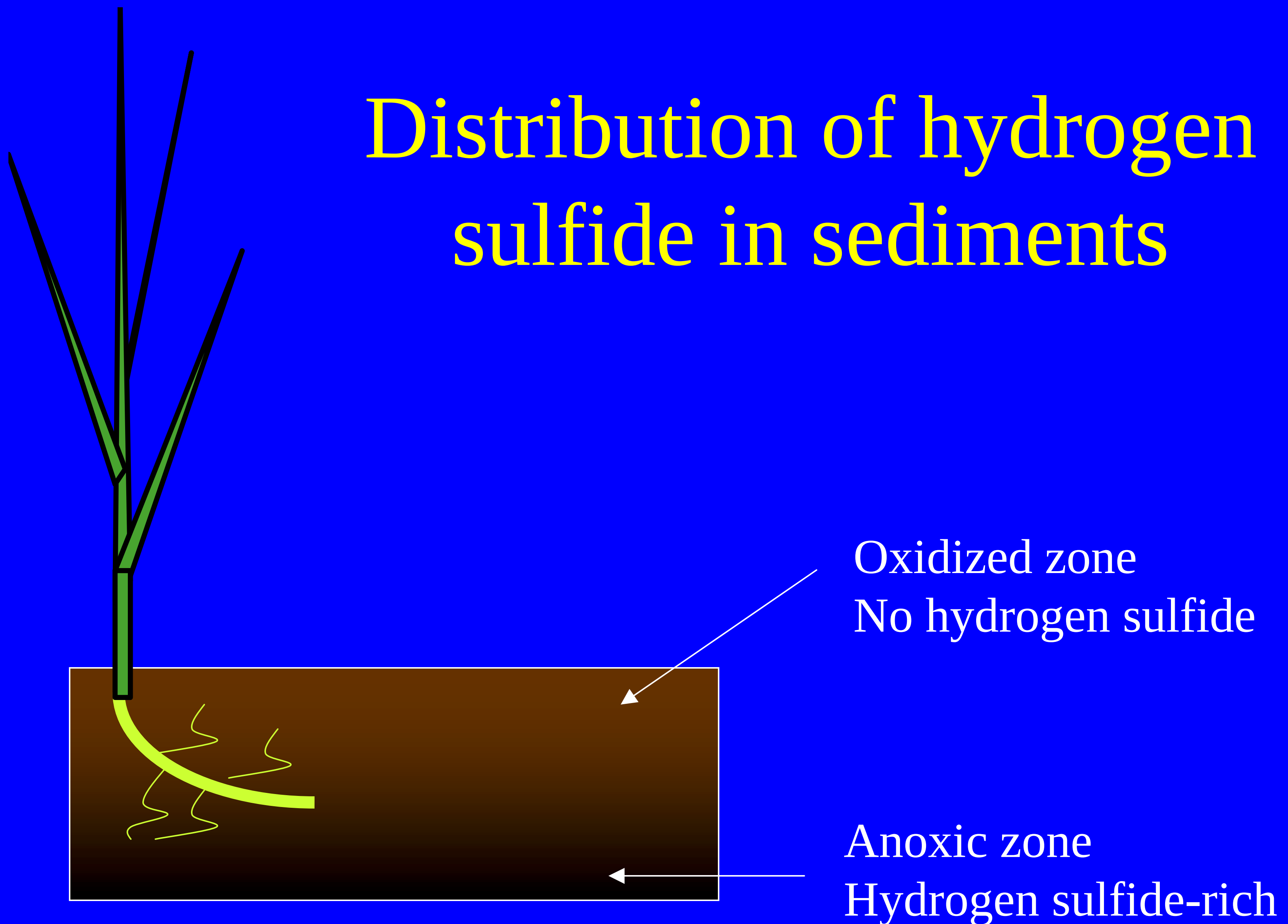
What substrate to use?

- Commercial availability of labeled compound
- Oxygen required for degradation
- low vapor pressure
- oxidation to carbon dioxide

Acknowledgments

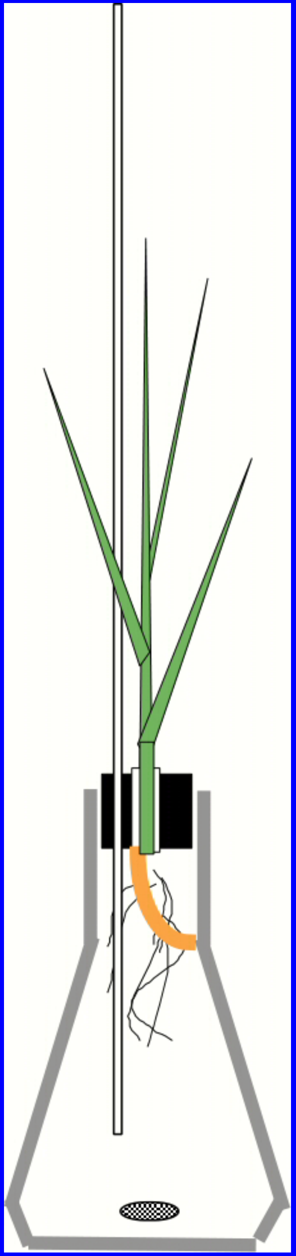
- Brian Maricle - Ph. D. student
  - aerenchyma measurements, some respirometry, environmental measurements
- EPA joint program in phytoremediation/Mitch Lasat
- NSF - development of respirometry system

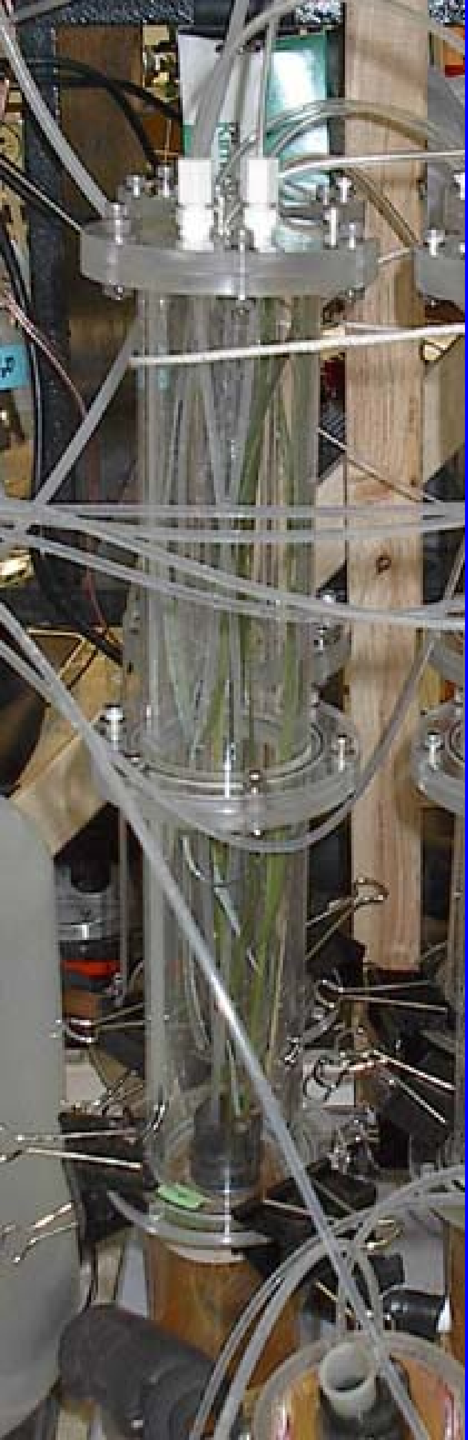
Distribution of hydrogen sulfide in sediments



Checking for oxygen transport

- A plant can be sealed into a flask of N_2-flushed water
- An oxygen-sensing probe can be used to monitor the water--any increase in O_2 must have come through the plant





Flow-through chambers

- Quantify O_2 consumption and transport
- Upper enclosure allows plant to be subjected to numerous conditions:
    - Normal air (~21% O_2)
    - N_2 gas (0% O_2)
    - Under water