



# Phytoextraction of PCBs: A Case Study

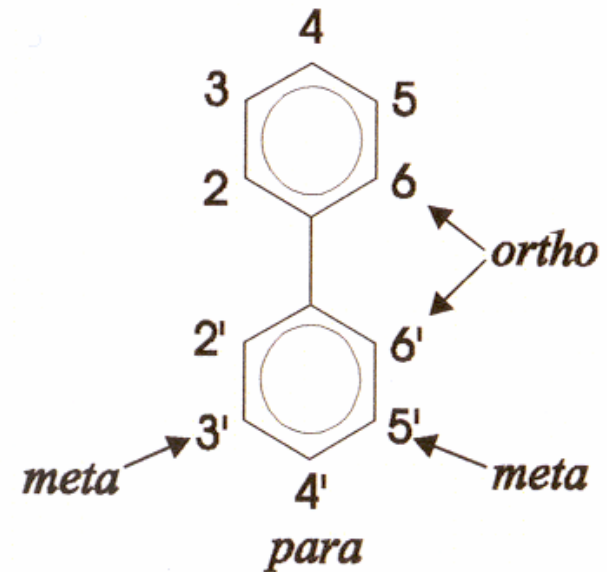
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# The PCB Problem

- Used in adhesives, flame retardants, paints, dielectric fluids for transformers and capacitors etc
- Persistent in environment
- Hydrophobic
- Numerous PCB contaminated sites remain in Canada and internationally

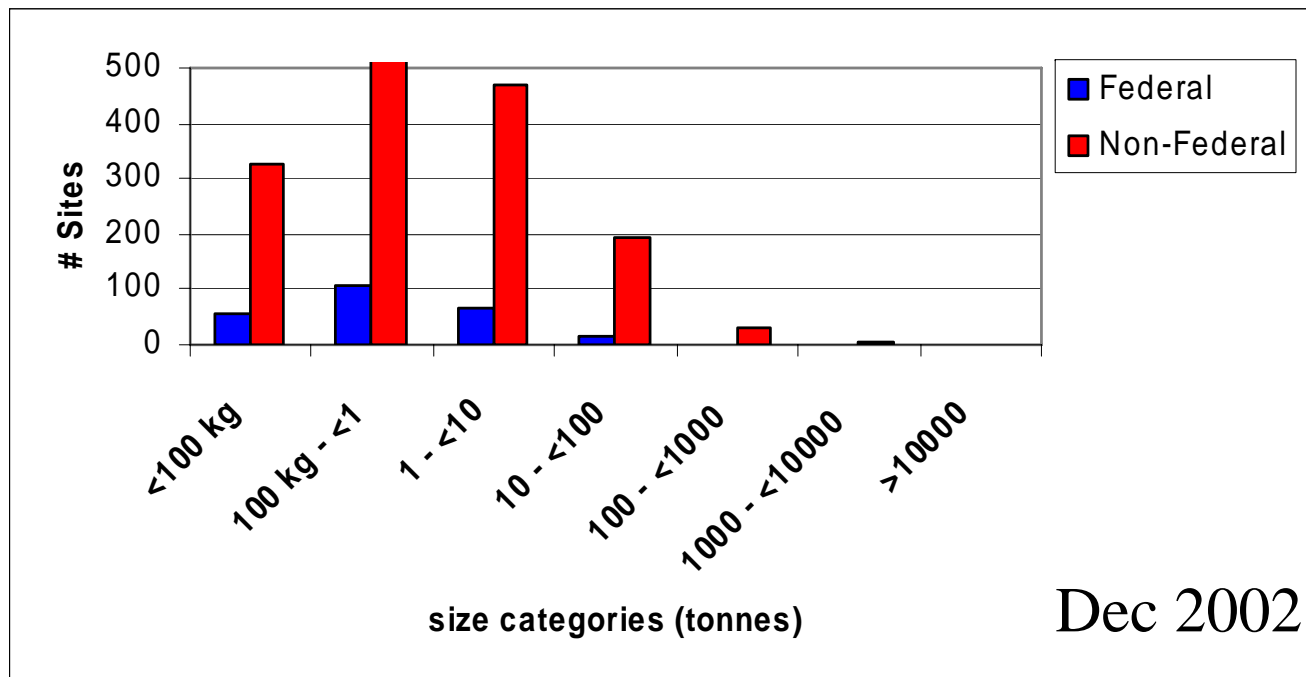


**209 possible congeners  
depending on chlorine  
substitution**



# PCB Storage in Canada

- Total of 1861 PCB waste storage sites in Canada (82 331 tonnes soil with >50ppm)
- Thousands more sites with PCBs <50ppm
  - Need for cost-effective remediation to improve property values





# Current Methods of Remediation

## Physical treatments

- On-site extraction by surfactants or solvents
- On-site dechlorination (uses high temperatures and basic conditions)
- On/off-site incineration

## Alternatives

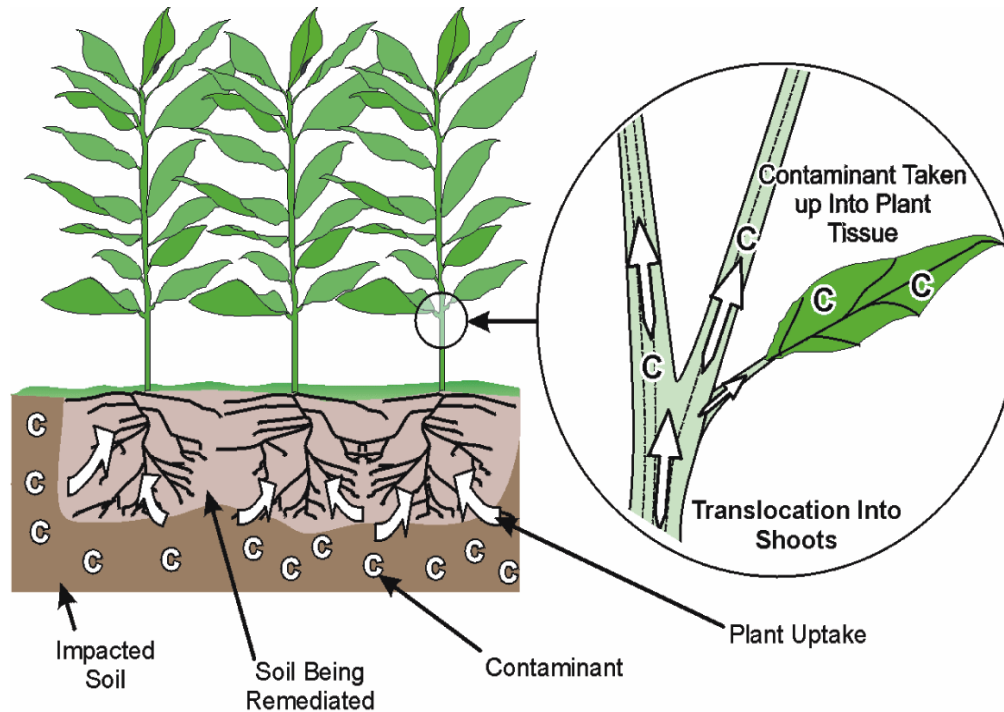
- Bioremediation (using bacteria)
- *Phytoremediation (using plants)*



**Figure 2:** PCB incinerator in St. Ambroise, QC (Kroeker, 2001)



# Phytoextraction



- Previously thought that hydrophobic organochlorines ( $\log K_{ow} > 5$ ) could not be extracted
- Now known that this is possible for compounds like DDT, PCBs



# Schneider Electric



- World leader in electrical distribution, industrial control and automation products, systems and services

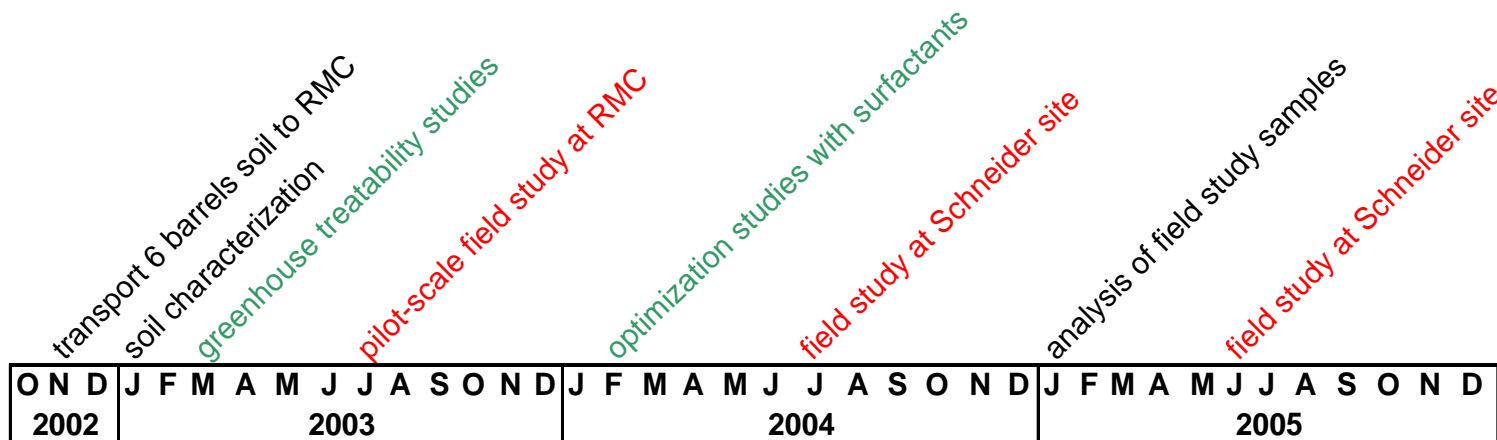


- Company acquired a PCB contaminated site in Etobicoke, Ontario, Canada
- Site is a Provincially registered & managed PCB Storage Facility
- Agreed to participate in a study of PCB phytoremediation



# Objectives & Timeline

1. To determine the efficacy of using phytoremediation as a strategy for remediating PCB-contaminated soil at the Schneider Electric site, and
2. To improve the marketability (through better knowledge of cost & regulatory factors) for using this technology in Canada.





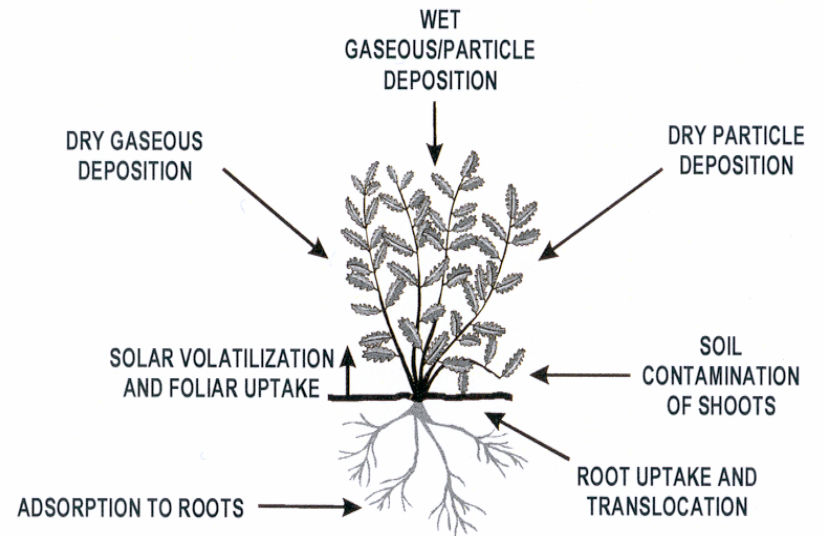
# Controlled GH Studies



To examine potential for PCB phytoextraction



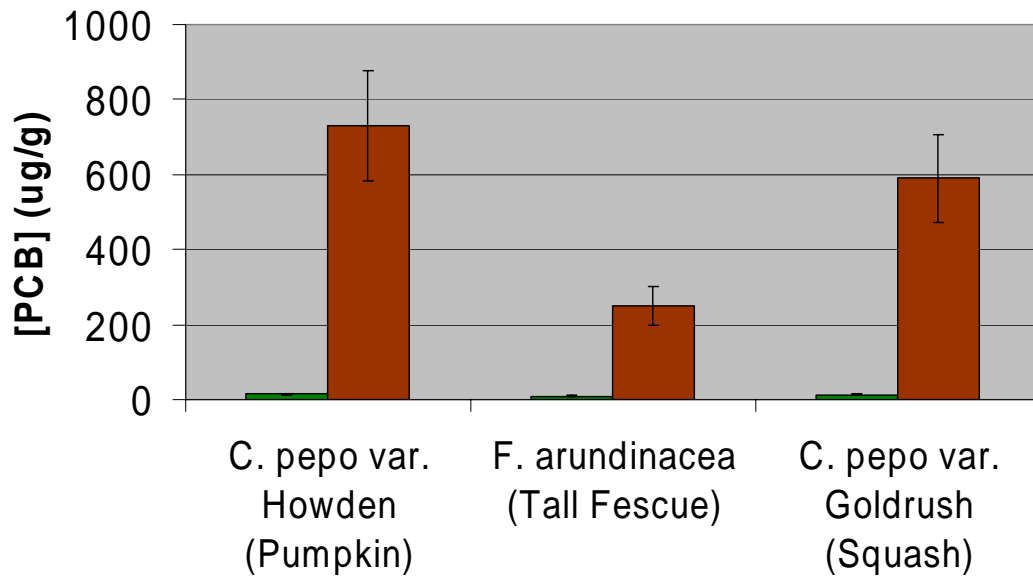
Parafilm seal between shoots & soils to eliminate direct contact pathways







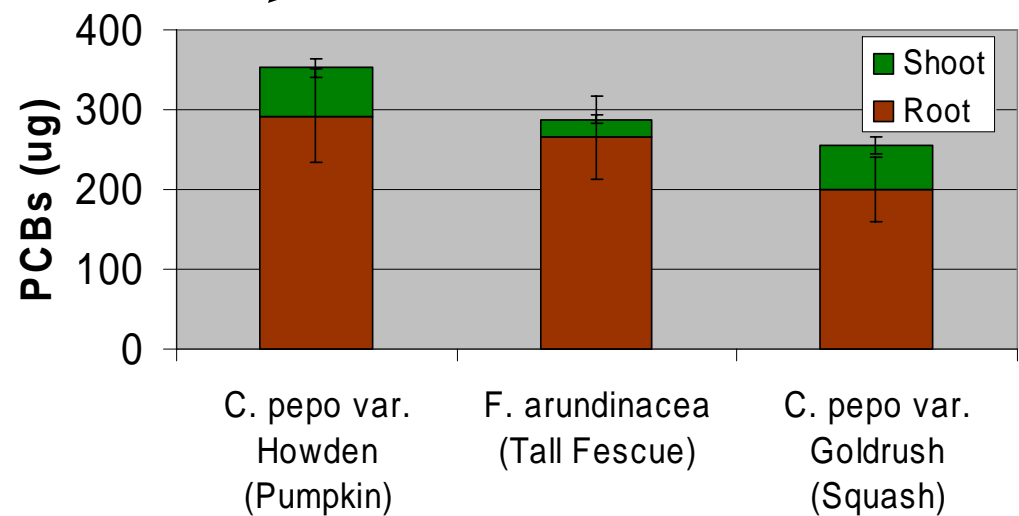
# Greenhouse Results



**PCB-Concentration  
(ug/g)**

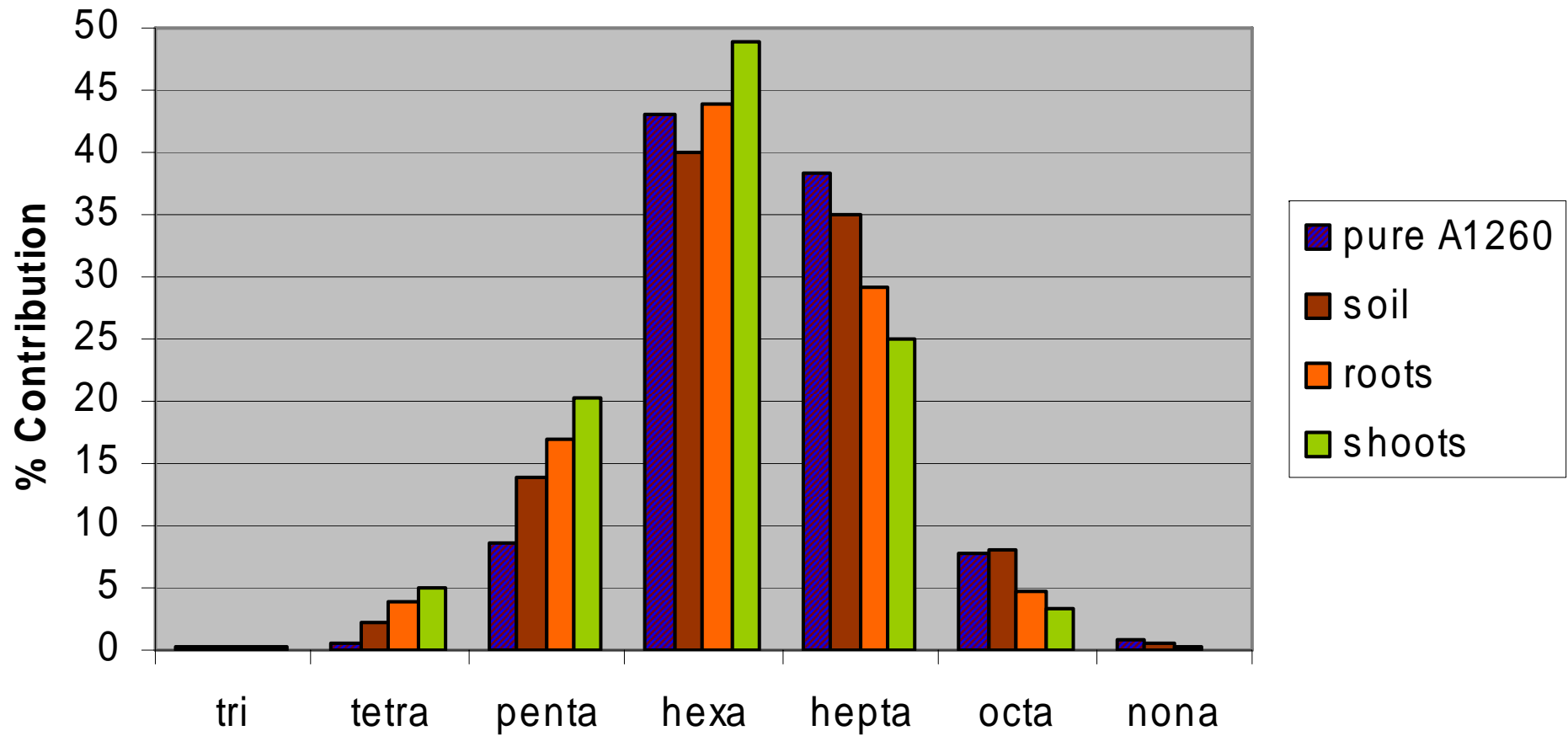
**vs.**

**PCB-Extraction  
(ug)**





# Homologue Distributions



# *Ex-Situ Field Plots*



Scaled-up, outdoor experiments

-same soil as greenhouse work

Safety considerations:

- Registered PCB storage facility
- Water collection and treatment
- Spill barrier
- Weekly air monitoring

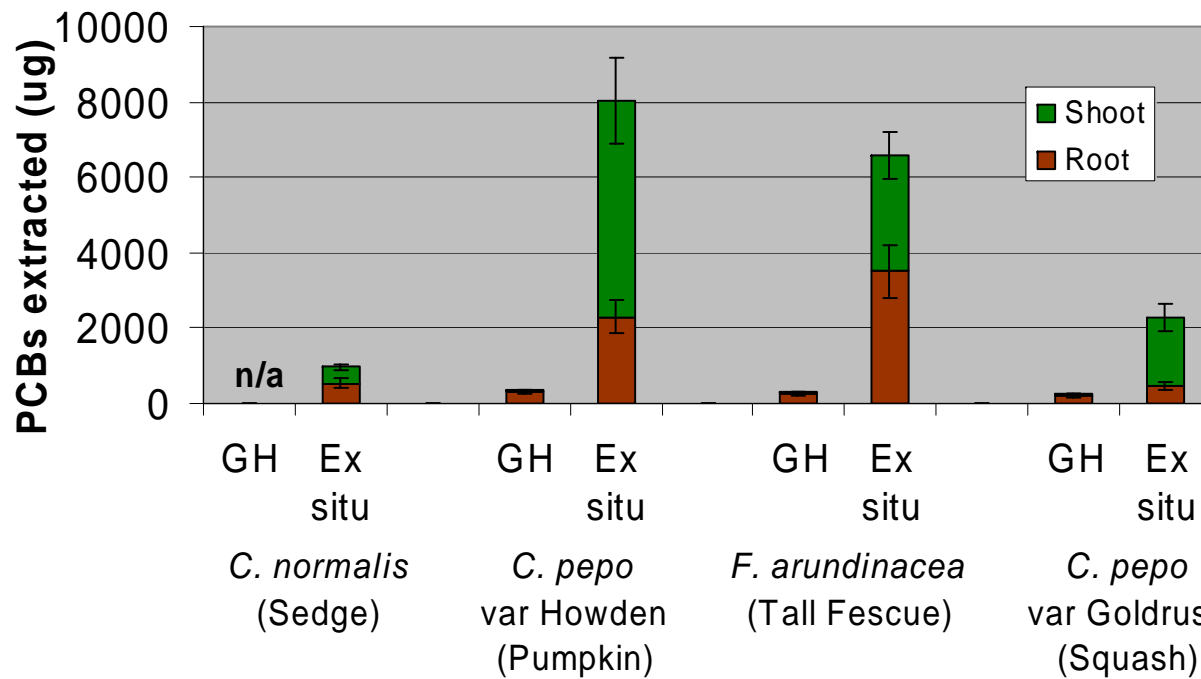
Species used:

- Pumpkin, Squash, Tall Fescue, and Sedge



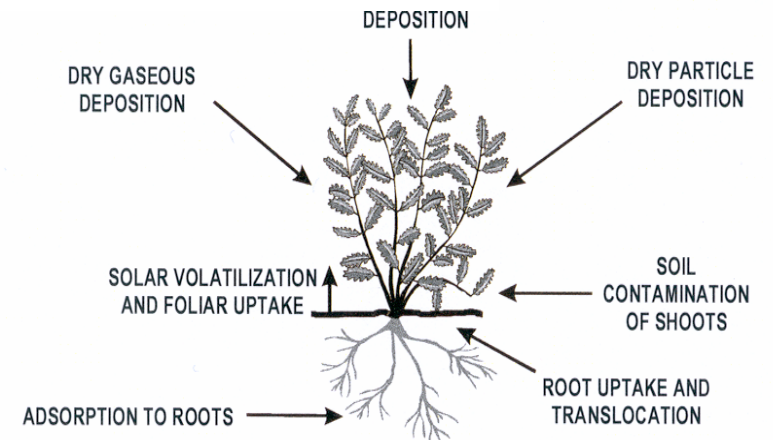


# Greenhouse vs. Ex situ Field Results



## PCB-Extraction (ug)

$[PCB]_{soil} = \sim 500 \text{ ug/g}$



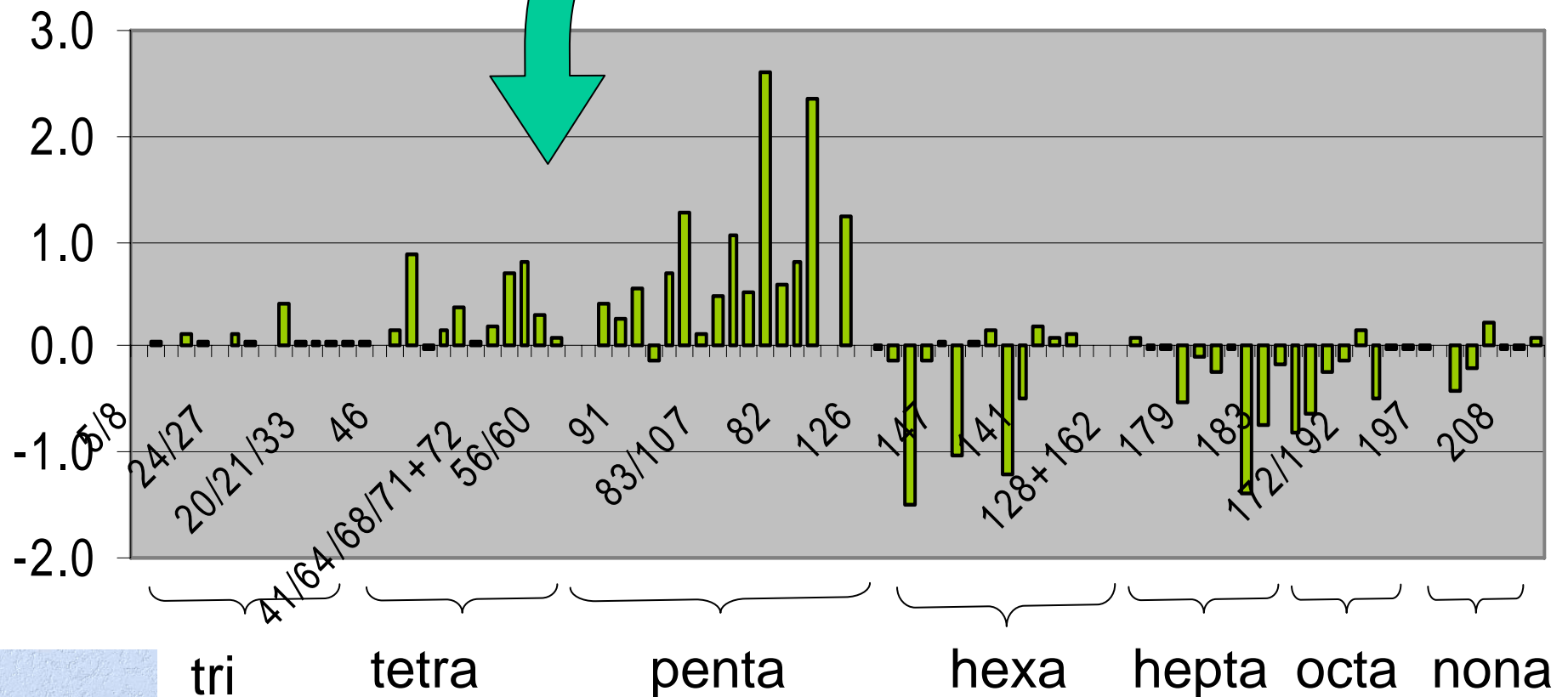


# Shoots

## *Ex Situ Field vs. Greenhouse*

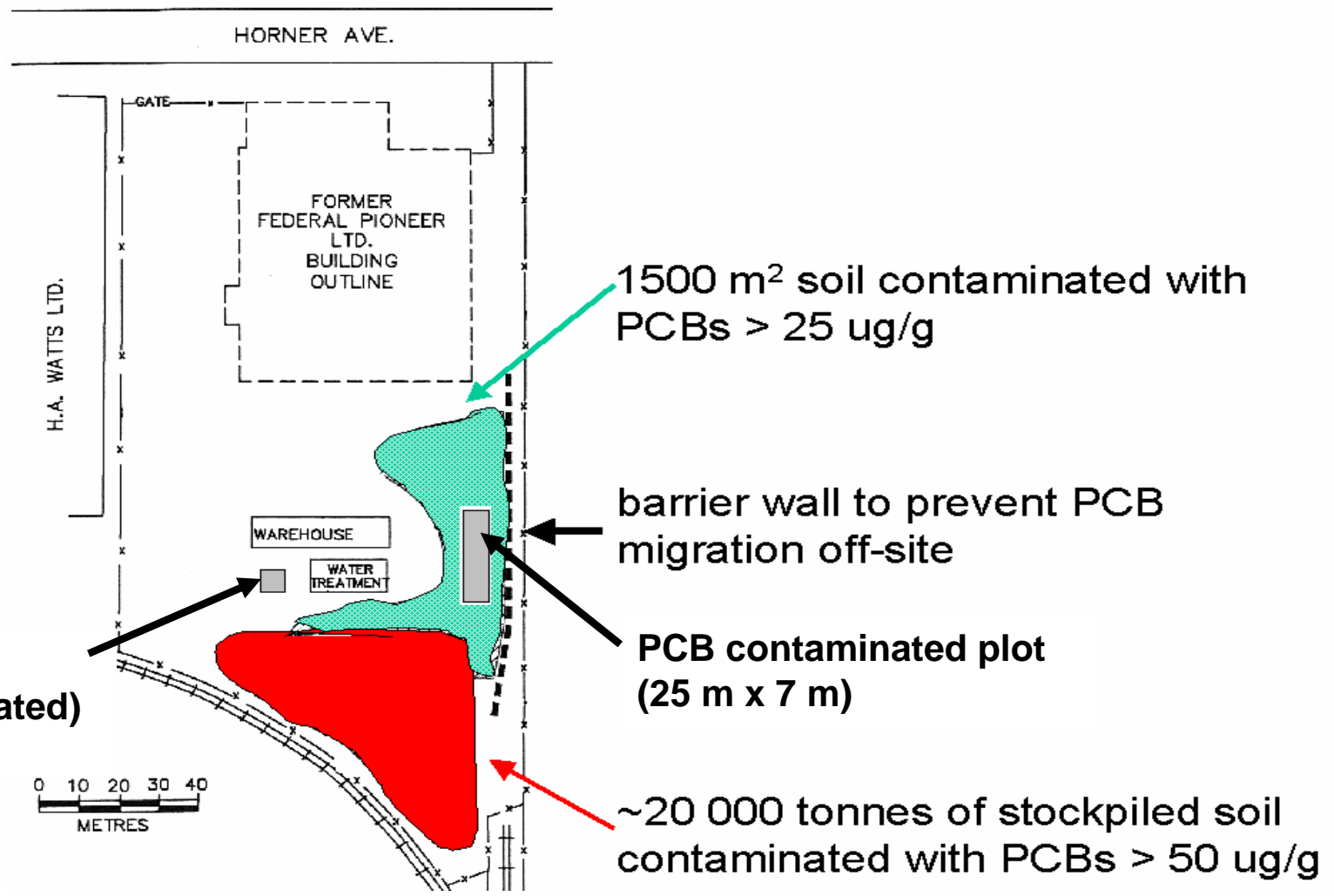
### T. Fescue Shoot

Enrichment of lower chlorinated congeners in *ex situ* field setting





# *In situ* Field Trial: July 22 – Oct 4, 2004





Location of  
Control Plot



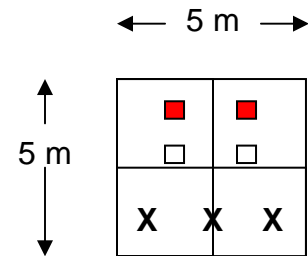
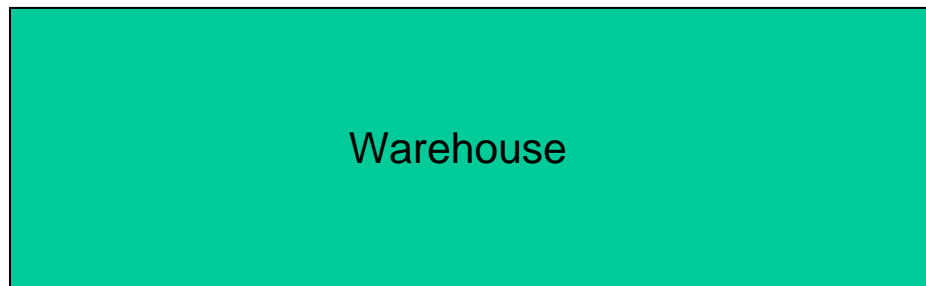
Location of  
PCB Plots



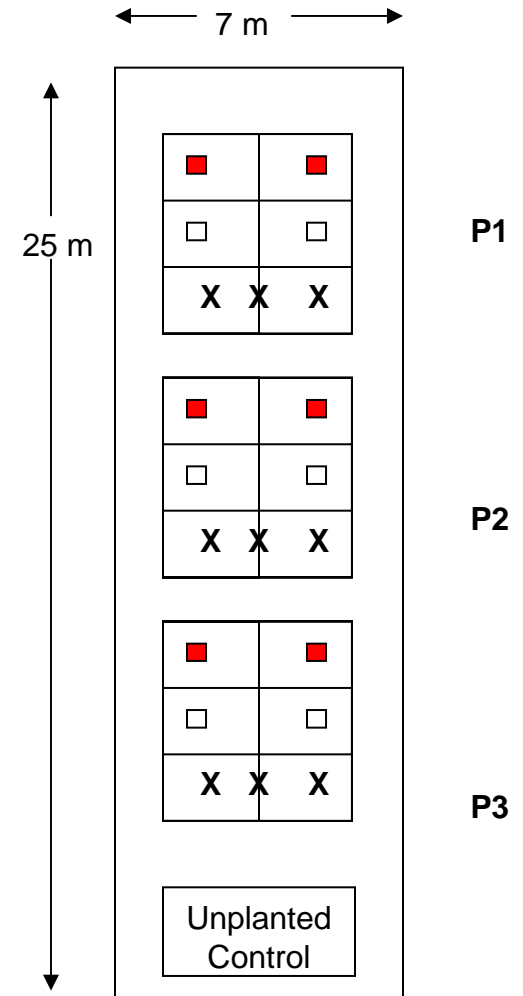
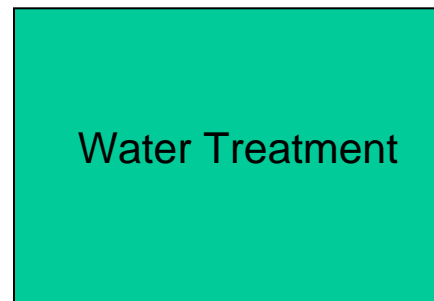
# Experimental Design

- X - Mound of 4-5 *Cucurbita pepo* cv. Howden plants
- - 0.5 m x 0.5 m plot of *Festuca arundinacea*
- - 0.5 m x 0.5 m plot of *Carex normalis*

↑  
Horner Ave



Control Plot (Clean Soil)  
"Plot C"



Contaminated Soil Plots  
"Plots P1, P2, P3"





# August 11



Tall Fescue



Sedge



Pumpkin



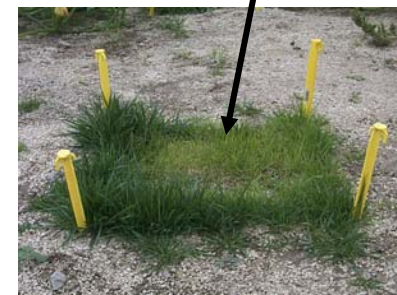
# September 17



Pumpkin



Sedge



Tall Fescue



# Harvesting, October 4



Tall Fescue



Sedge





# *Results*





# *Monitoring Results*

## **PCBs in air**

- All air samples taken at the site throughout the duration of the field trial returned non-detect levels of PCBs in air (i.e.  $<2800\text{mg/m}^3$ )

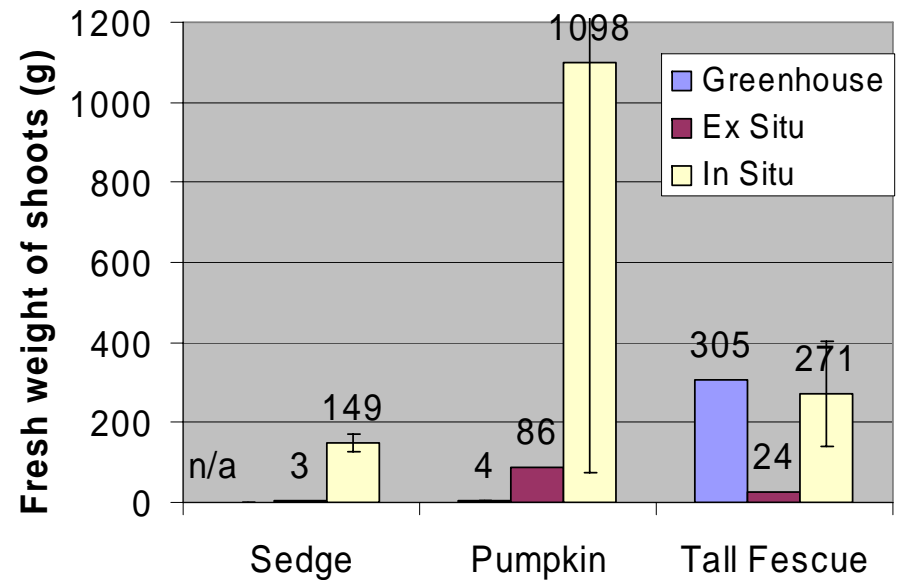
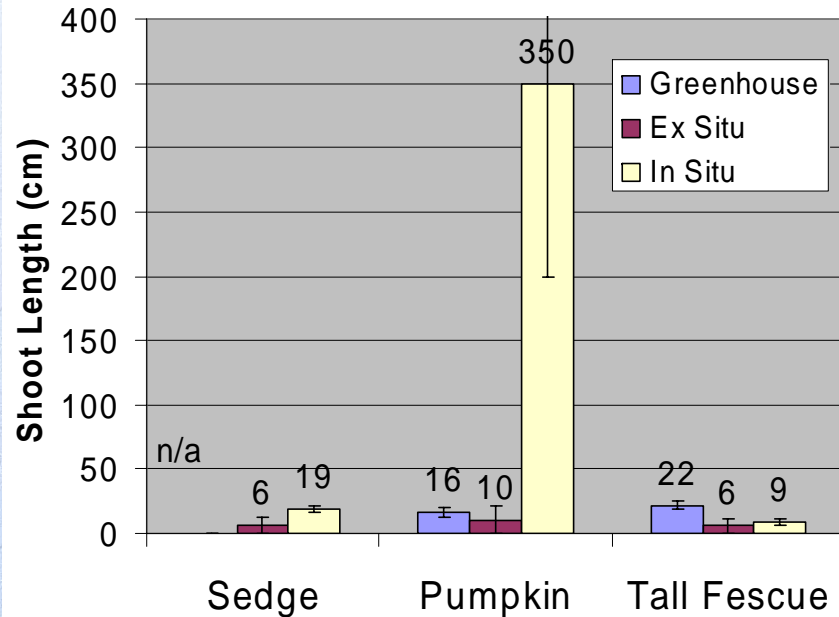
## **PCBs in groundwater**

- Groundwater passing through the field trial site was collected and treated on-site.
- Monthly testing of the discharge water revealed no changes in [PCB]. Water continued to meet safe discharge levels.



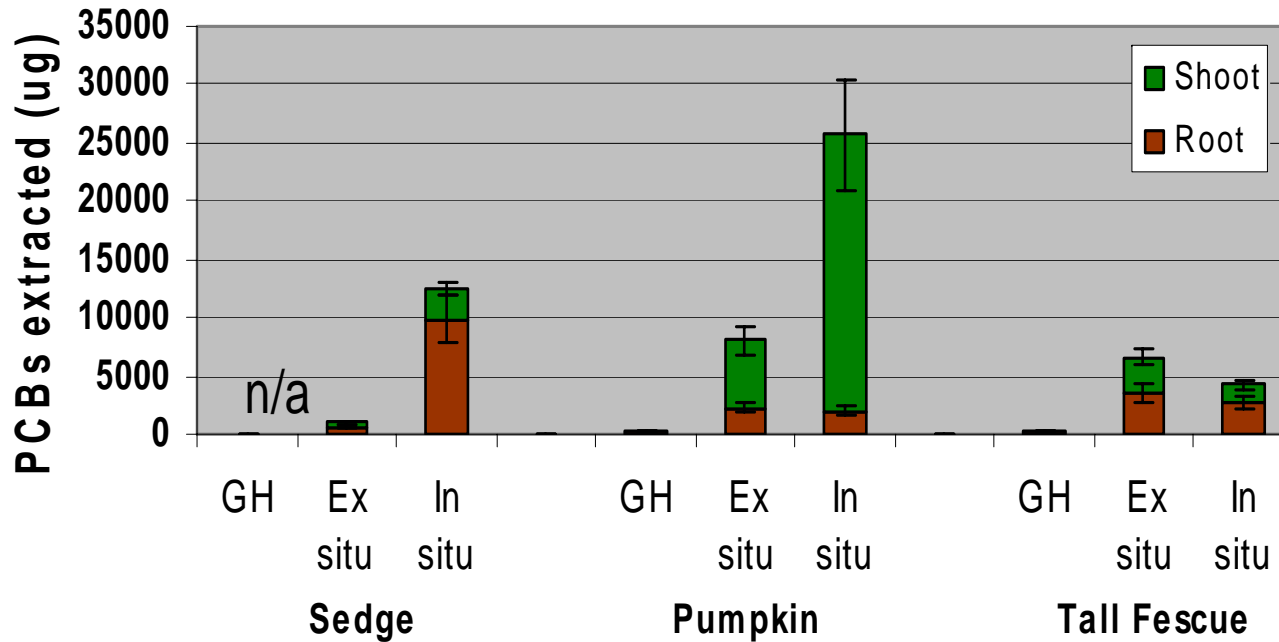
# Greenhouse vs. Ex situ Field vs. In situ Field

	Soil [PCB]	Aroclor
Greenhouse	120 – 390 ug/g, median 170 ug/g	1260
Ex situ	410 – 570 ug/g, median 520 ug/g	1260
In situ	2 – 210 ug/g, median 30 ug/g	1254/1260





# Greenhouse vs. Ex situ Field vs. In situ Field



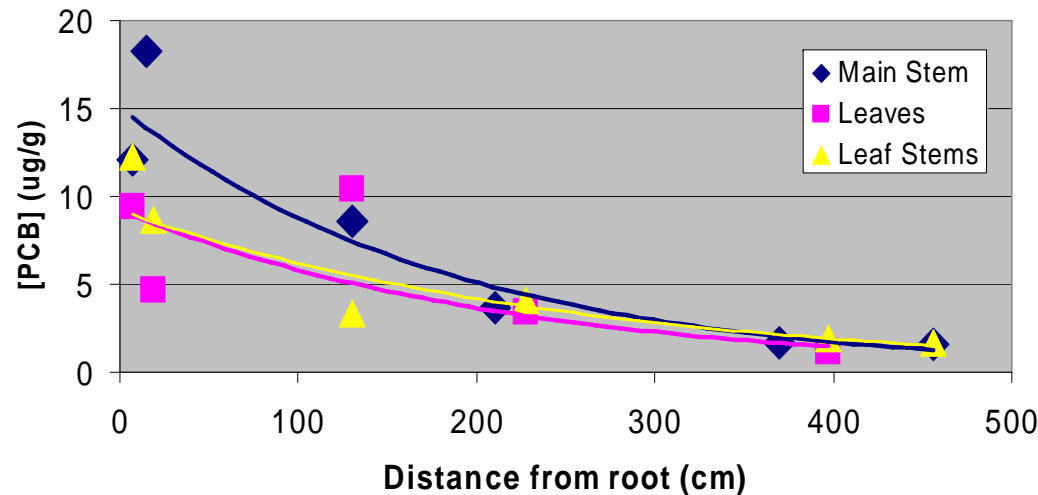
**PCB-Extraction  
(ug)**

- Increased biomass *in situ* resulted in large increases in total PCB uptake



# PCB Distribution in Pumpkins

PCB Concentration in pumpkin P3 HPb1



- Similar PCB concentrations found in various tissues
- Pumpkins themselves had the lowest concentrations – mainly found on the exterior surface
- Distance from root was the most important factor influencing PCB concentration



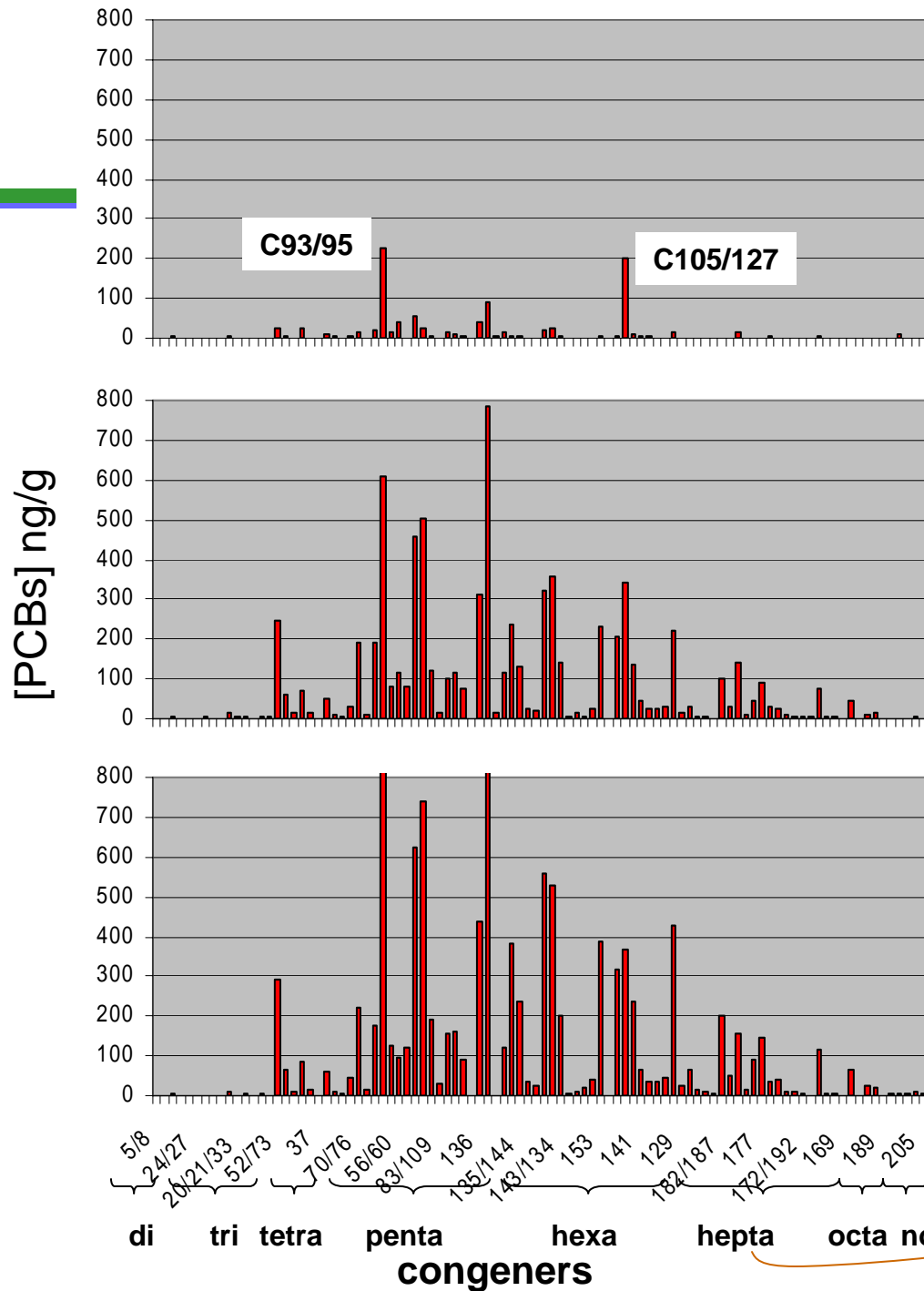




sum of congeners  
= 1 043 ng/g

sum of congeners  
= 7 723 ng/g

sum of congeners  
= 10 877 ng/g



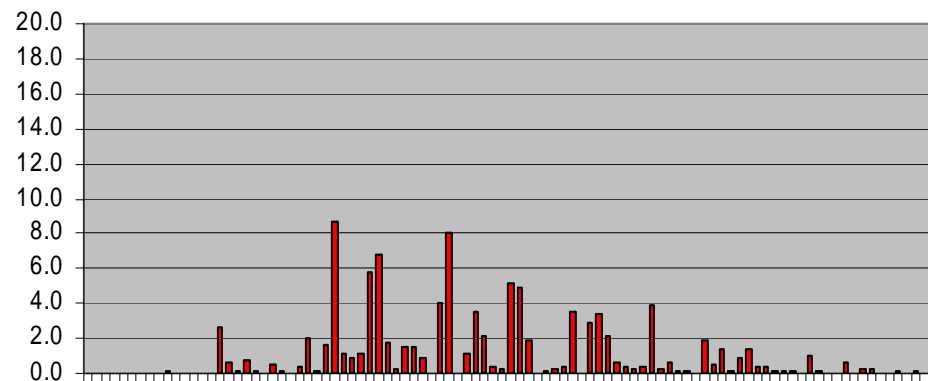
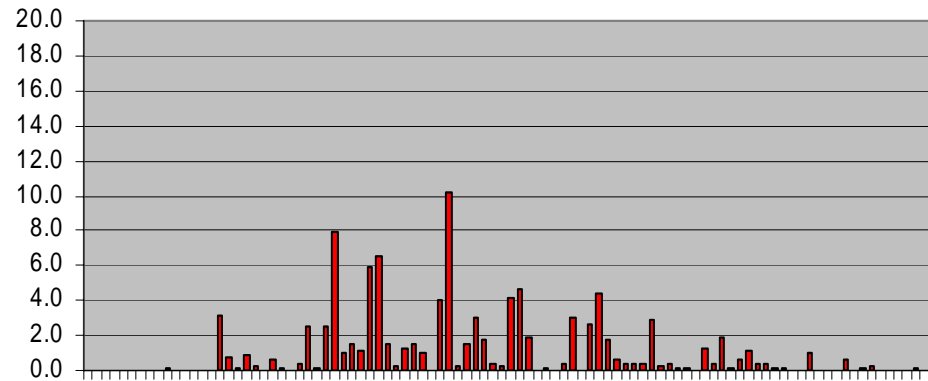
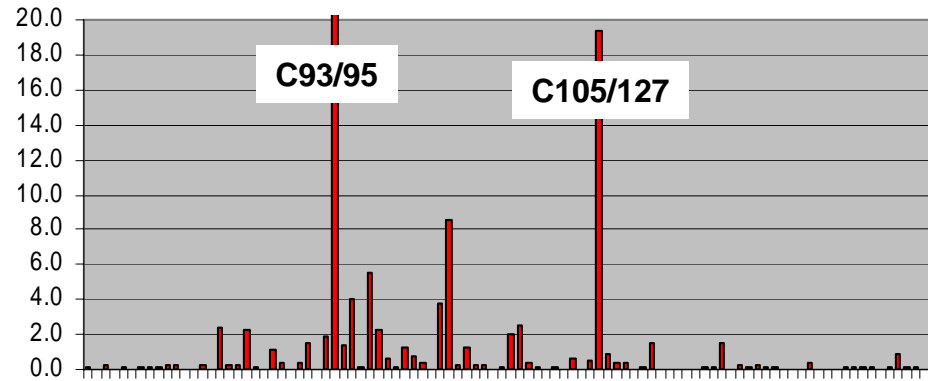
440-472 cm

120-140 cm

006-008 cm

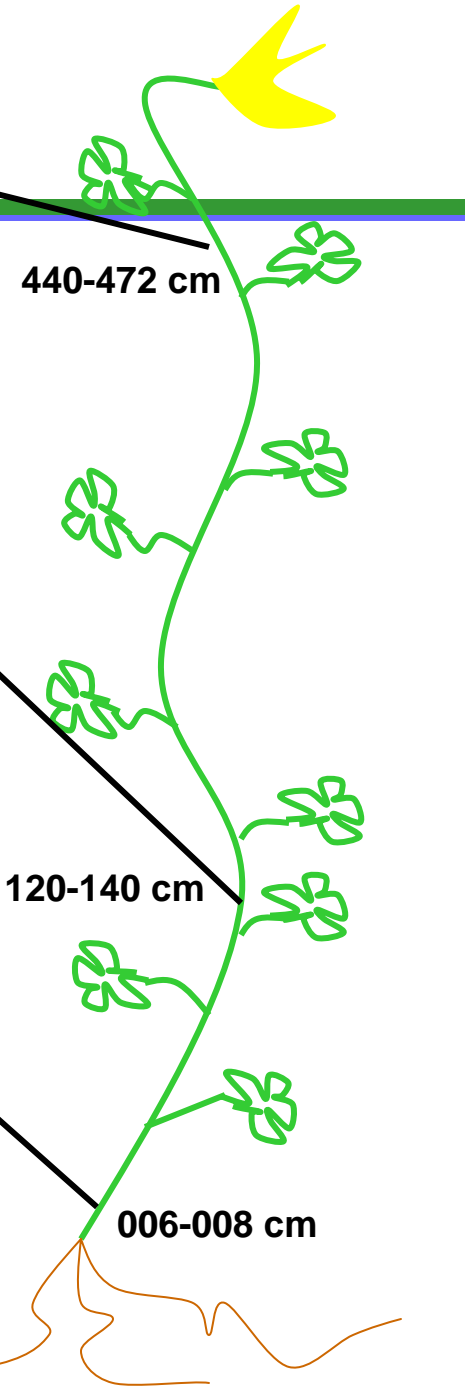


relative contribution of congeners



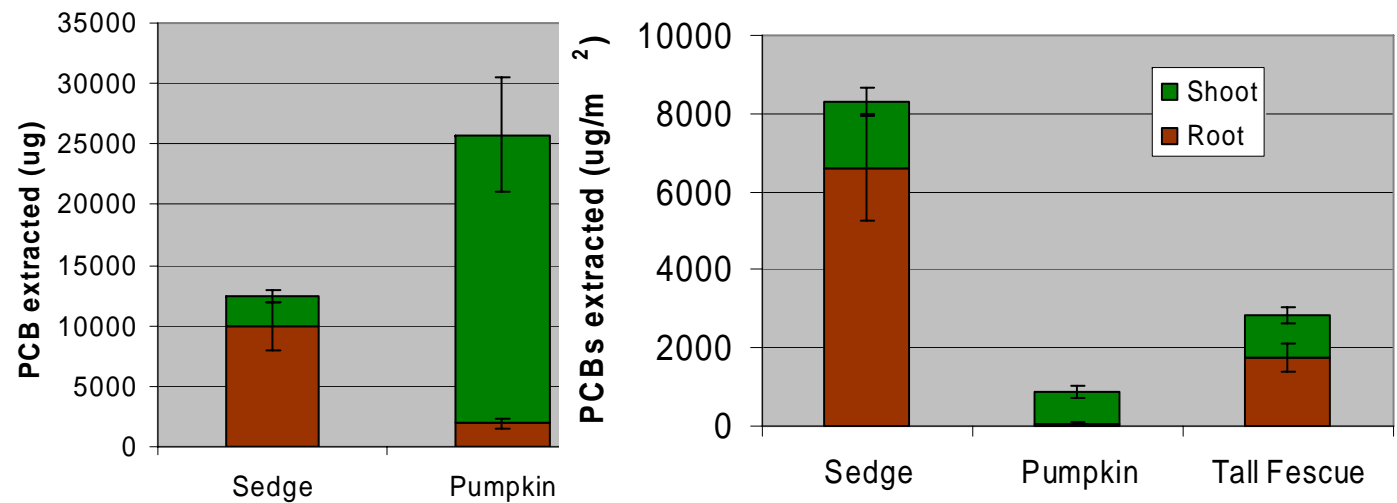
5/8  
24/27  
20/21/33  
52/73  
37  
70/76  
56/60  
83/109  
136  
135/144  
143/134  
153  
141  
129  
182/187  
177  
172/192  
169  
189  
205

congeners





# Results of In situ Field Trial





# Conclusions

- First *in situ* demonstration site of PCB phytoremediation in Canada
- No fugitive release of PCBs during field trial.
- Plants had high germination and success rates under *in situ* conditions
- Sedge, pumpkin and Tall Fescue show potential for PCB phytoextraction





# Next Steps: Field Season 2005

- Project funding confirmed
- Field season will begin in late June
- Soil will be homogenized before planting
- Increase plot sizes of Sedge and Tall Fescue
- Examine effect of shorter, more densely planted pumpkins



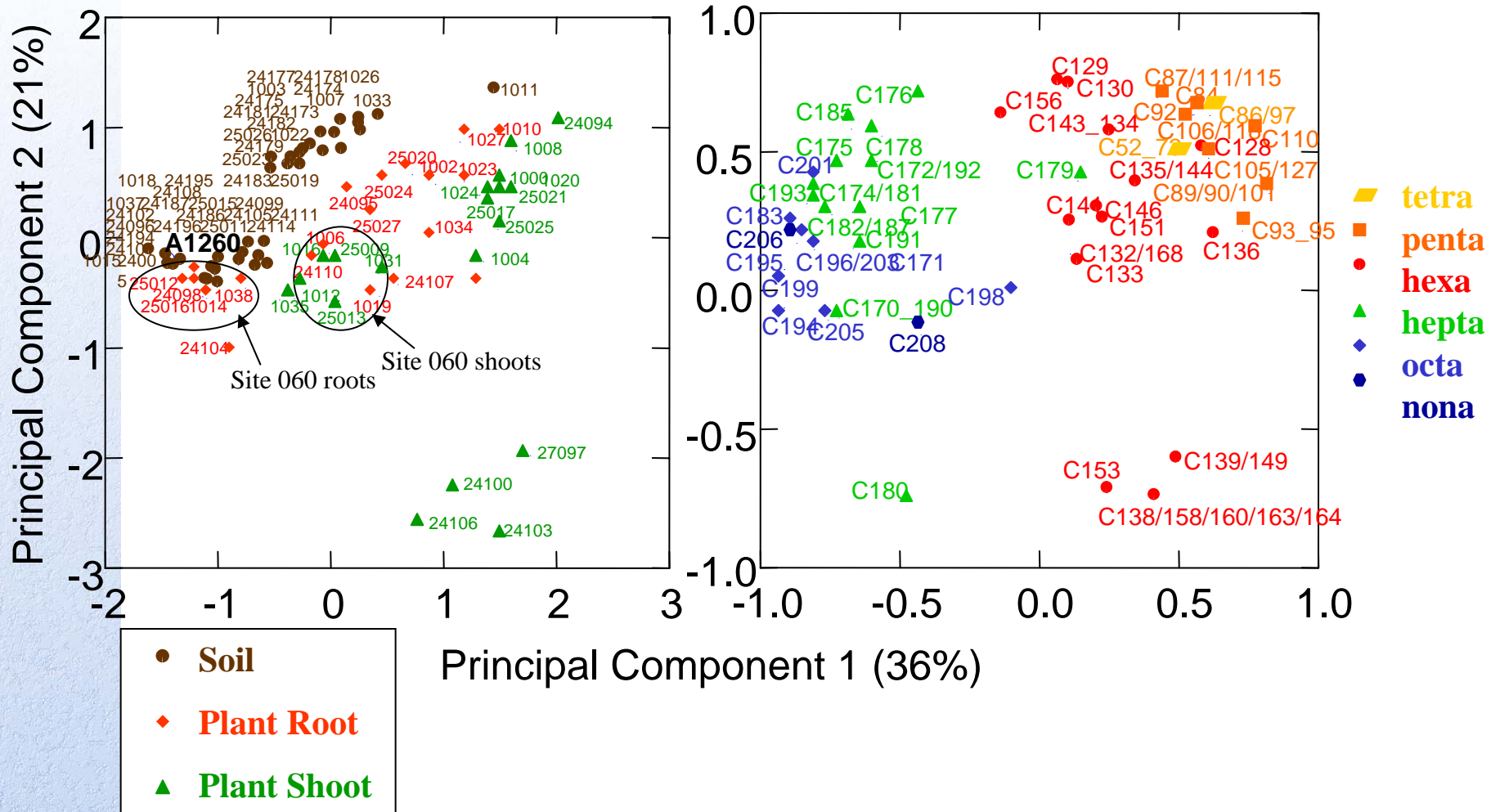


# QUESTIONS?



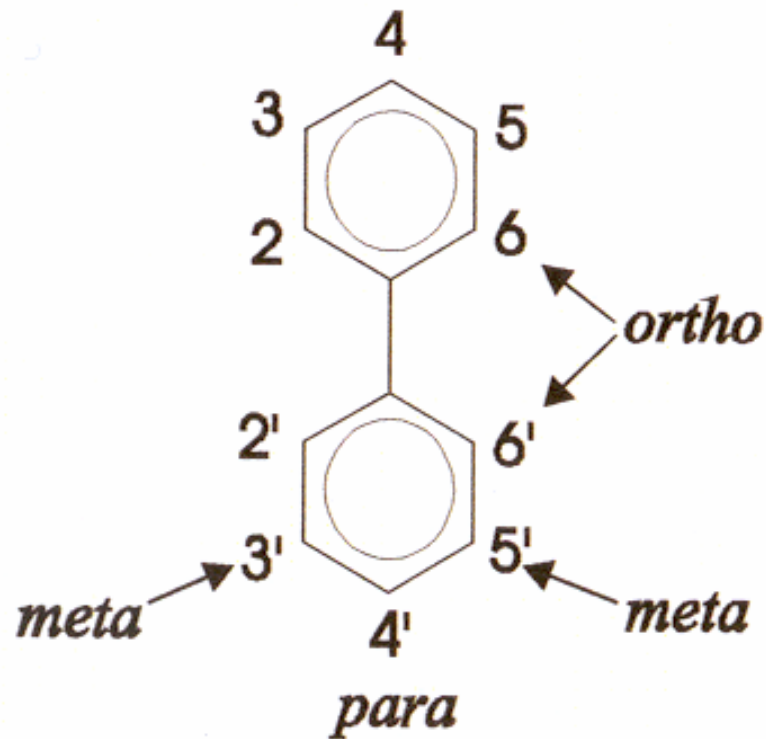


# PCA of soil and plant samples from PCB-contaminated soils





# PCB Molecular Shape



**209 congeners total**

- non- and mono-ortho substituted molecules are coplanar or semi-coplanar, and widely recognized as serious environmental pollutants

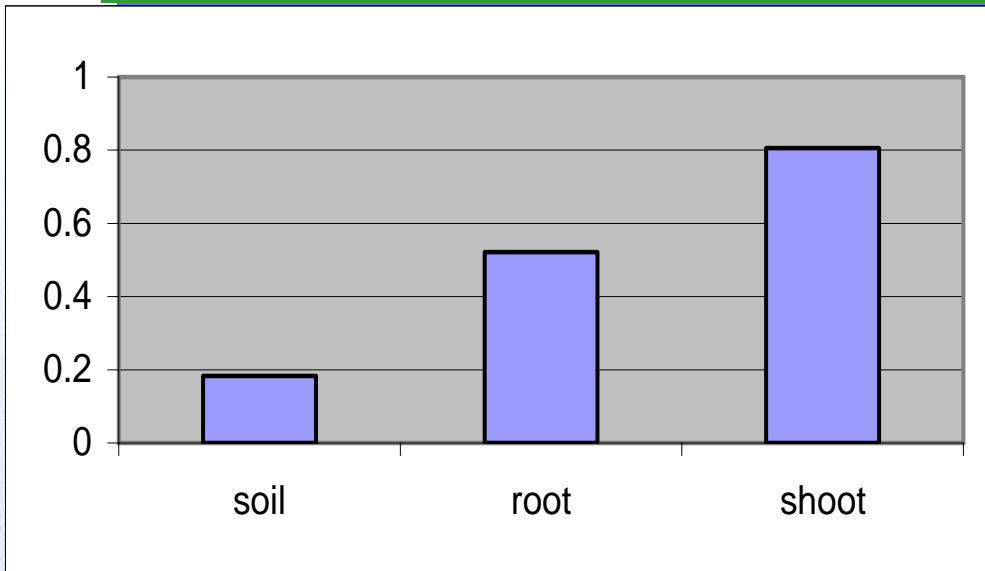
**3,3',4,4',5,5' hexa-chlorobiphenyl = congener 169 (coplanar) -  $\log K_{ow} = 7.1$**

**2,2',4,4',6,6' hexa-chlorobiphenyl = congener 155 (staggered) -  $\log K_{ow} = 6.4$**





# Molecular Geometry & Translocation



**non-ortho substituted congeners**

**multi-ortho substituted congeners**

