Enhancing the Uptake of Weathered Persistent Organic Pollutants by *Cucurbita pepo*

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DIRTY DOZEN (plus PAHs)

Aldrin	Chlordane	DDT/DDE
Dieldrin	Dioxins	Endrin
Furans	Heptachlor	Lindane
Mirex	PCBs	Toxaphene

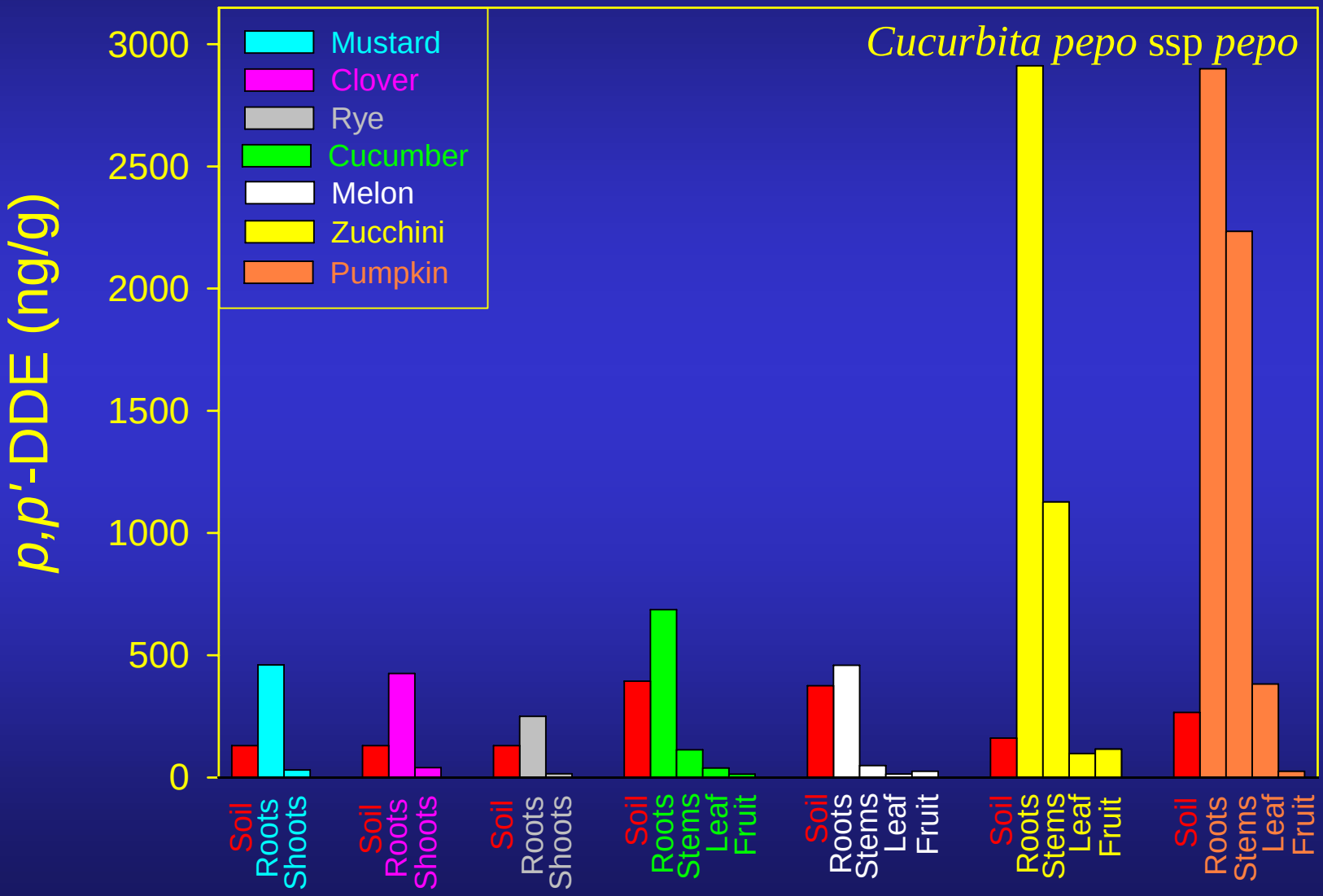
Why look at Persistent Organic Pollutants?

- They persist for decades
- Likely mutagenic, estrogenic, carcinogenic effects
- Bioaccumulation, biomagnification
- Other remediation strategies are ineffective due to high degree of sequestration

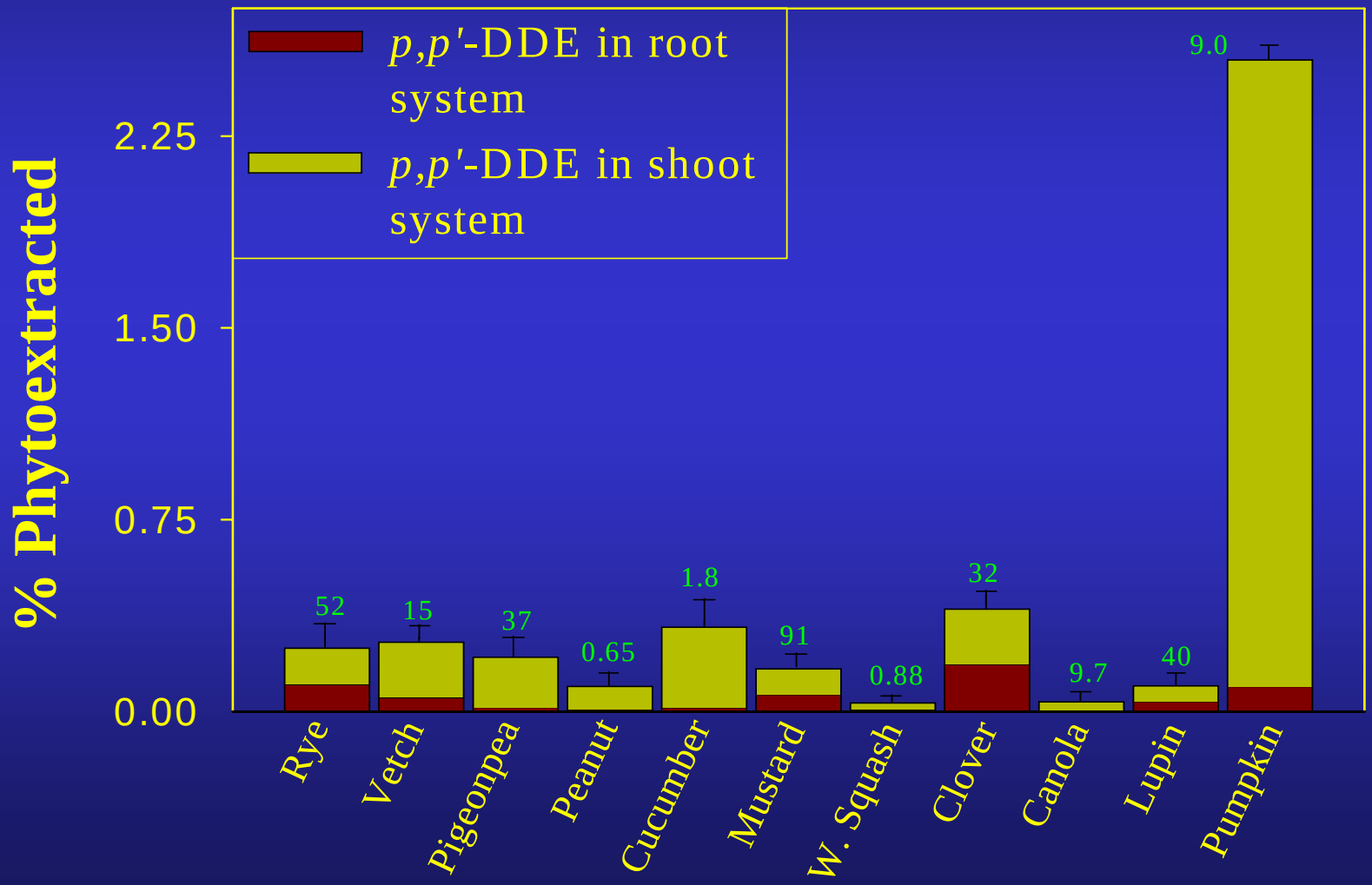
Most plants are unable to remove weathered POPs from soil (non-accumulators)

- **Plants shown to remove minimal amounts of DDE from soil**
  - Rye, alfalfa, vetch, clover, mustard, cucumber (3), bean, melon (3), winter squash (2), some summer squash (11), lupins (3), peanut, canola, pigeonpea, certain pumpkins (2)
- **Plants shown to remove minimal amounts of chlordane from soil**
  - Corn, pepper, tomato, potato, cucumber (2), lupins (3), some summer squash

Uptake and translocation of weathered *p,p'*-DDE by selected plant species



Phytoextraction (% removal) of weathered *p,p'*-DDE by plant species. Numbers in green indicate mass ratio of root to soil (values are 10^{-4})



Cucurbita pepo ssp *pepo*- true zucchini and some pumpkins

The *C. pepo* ssp *pepo* system

- **Similar (but variable) accumulation of:**

  Dioxins (Hülster et al., 1994)

  Chlordane (CAES work)

  PCBs (Dr.s Zeeb & Reimer at the RMC, CAES)

  PAHs (CAES work)

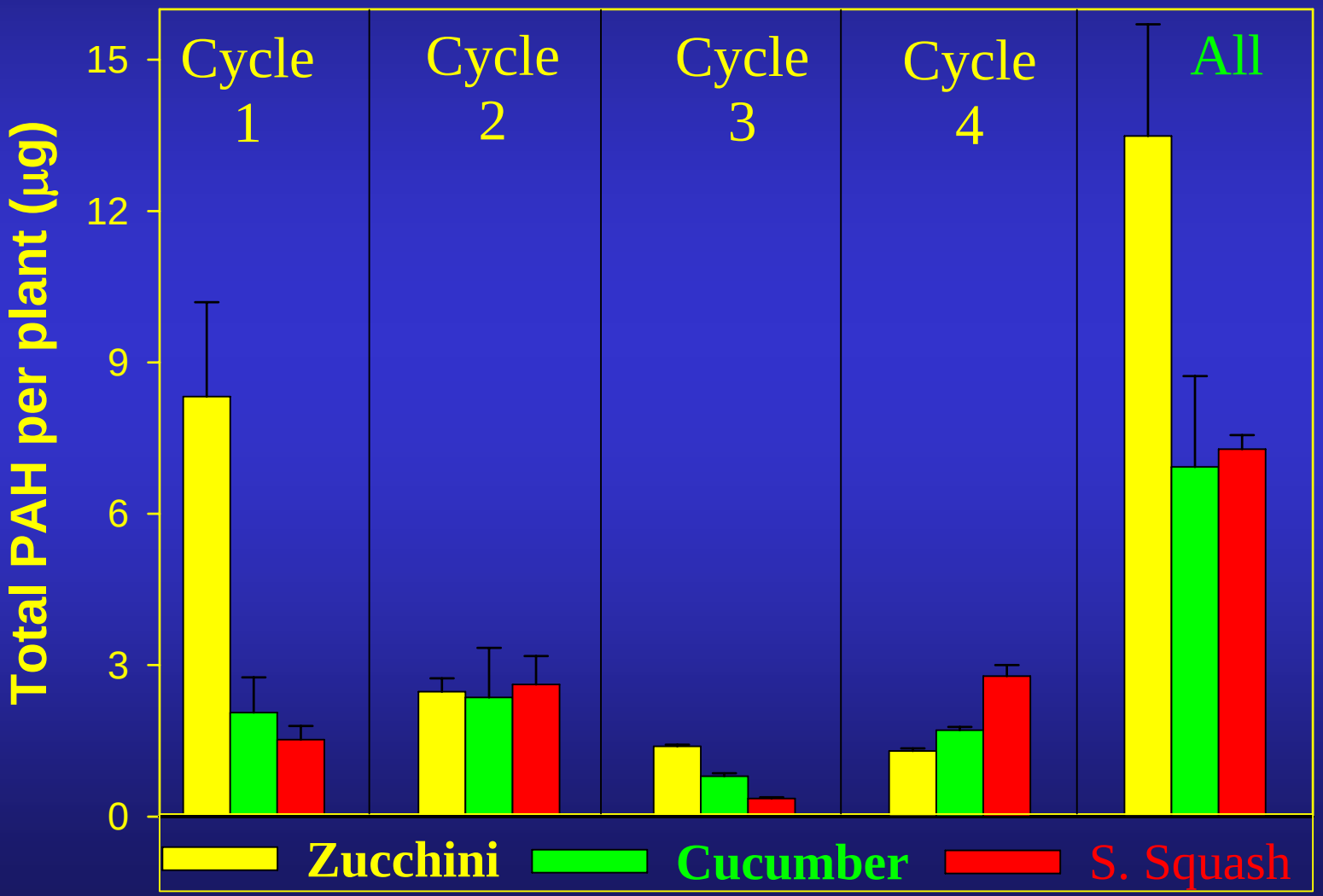
- **A unique two-part mechanism**

  1. Extraction of weathered hydrophobic residues to soil (function of unique nutrient acquisition mechanisms)

  2. Translocation of hydrophobic compounds from roots to shoots

- **For more on mechanisms, follow me after the break to 2A**

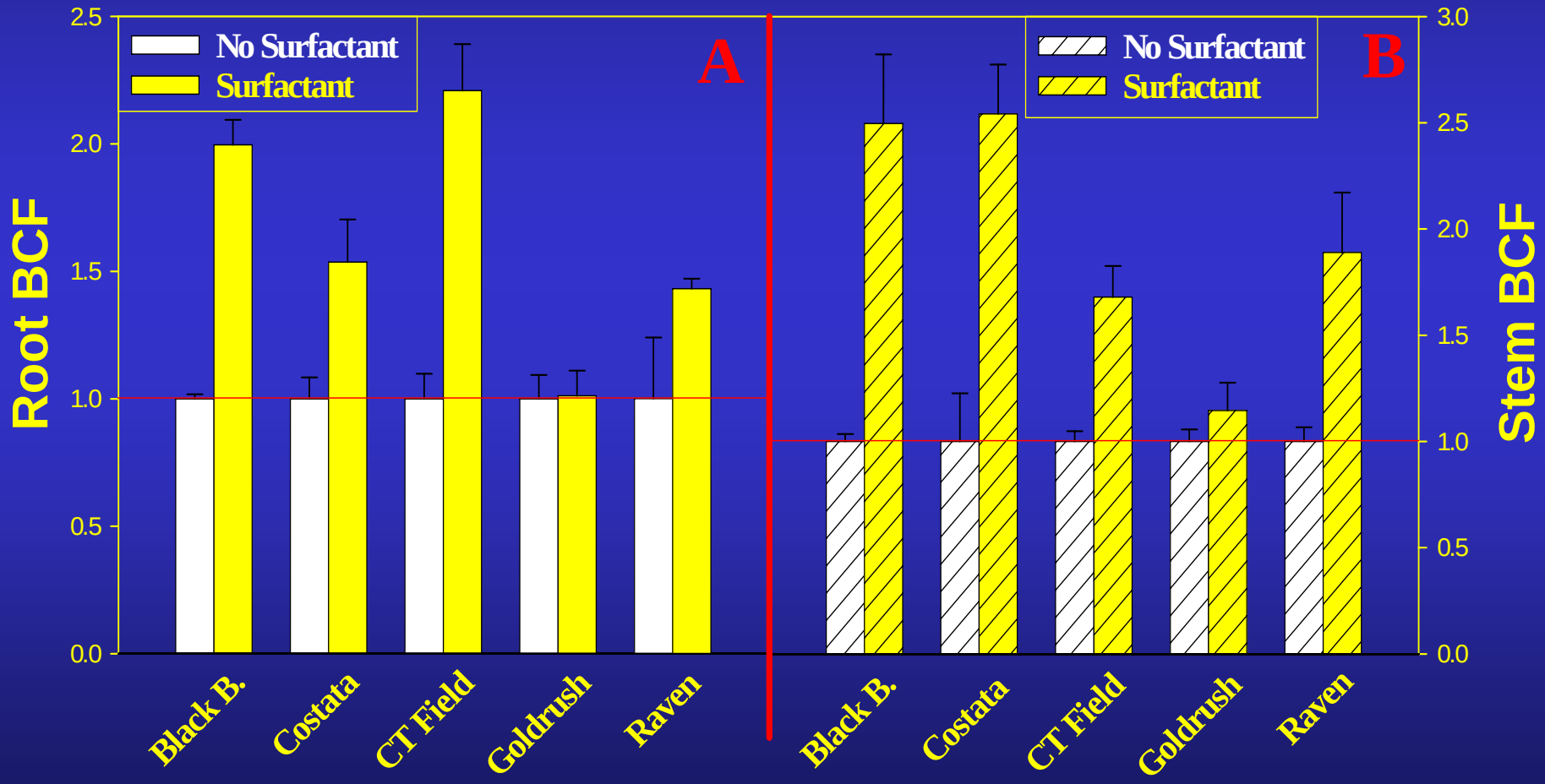
Uptake of 12 PAHs by 3 plant species from a MGP soil (37 mg/kg). Plants were cultivated in same soils for 4 consecutive growing periods (30-60 days)



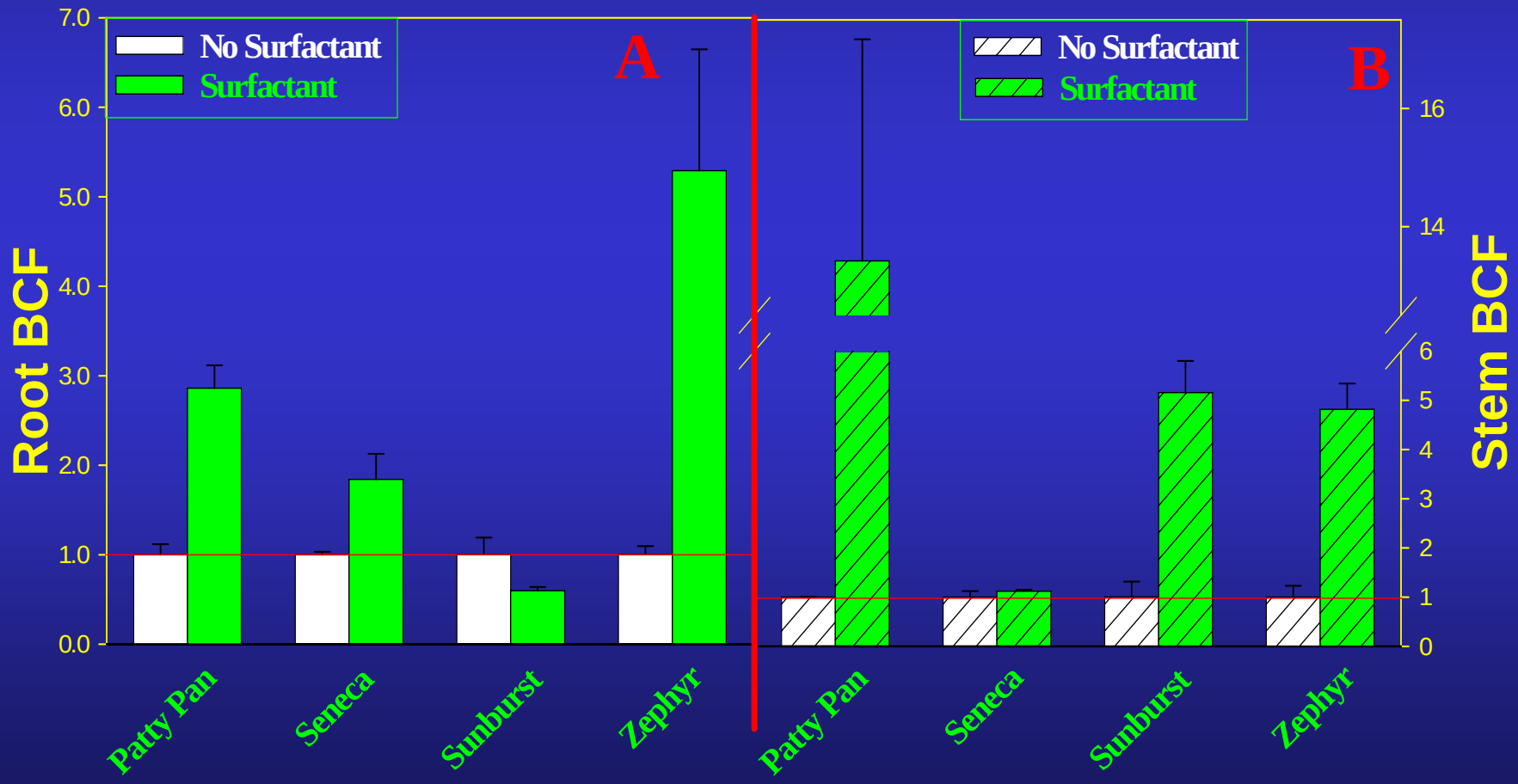
DDE 2004 Field Season- Can we further enhance the *C. pepo* ssp *pepo* system?

- **9 cultivars of *C. pepo***
    1. 5 of ssp *pepo* (4 zucchini and 1 pumpkin)
    2. 4 of ssp *ovifera* (summer squash)
- **Treatments included:**
    1. Rhamnolipid biosurfactant added to soil
    2. Mycorrhizal inoculum added to rhizosphere
    3. Intercropping (*ovifera* surrounded by *pepo*)
- **Monitor tissue DDE Bioconcentration factors (BCFs), translocation factors (TFs), and overall percent removal (% phytoextracted)**

Effect of a rhamnolipid biosurfactant on the root and stem BCFs of *C. pepo* ssp *pepo* cultivars. Each cultivar's control value is normalized to 1.0 and the surfactant-amended value is adjusted accordingly



Effect of a rhamnolipid biosurfactant on the root and stem BCFs of *C. pepo* ssp *ovifera* cultivars. Each cultivar's control value is normalized to 1.0 and the surfactant-amended value is adjusted accordingly



Effect of biosurfactant ammendment on the accumulation of *p,p'*-DDE by *Cucurbita pepo* subspecies.

Biosurfactant amendment:

1. Significantly increased root BCFs; ssp *pepo* by 1.6 times and ssp *ovifera* by 2.7 times
2. Significantly increased stem BCFs; ssp *pepo* by 2.0 times and ssp *ovifera* by 6.1 times
3. Significantly increased leaf BCFs; ssp *pepo* by 6.1 times and ssp *ovifera* by 3.4 times
4. Significantly decreased the biomass of *ssp ovifera* by 61%, no effect on % phytoextracted
4. Had no effect on ssp *pepo* biomass and significantly increased % phytoextracted (1.8 times)

Effect of fungal inoculation on *p,p'*-DDE accumulation of by *Cucurbita pepo*. Standard deviations are in parentheses.

ssp *pepo*	Treatment	Root BCF	Stem BCF	% Removed
Black B.	**Control**	6.7 (0.12)	4.2 (0.15)	0.54 (0.01)
	Fungi	18 (2.2)	11 (2.6)	0.98 (0.03)
Costata	**Control**	7.0 (0.59)	4.7 (0.59)	0.62 (0.11)
	Fungi	14 (0.56)	8.4 (0.63)	1.1 (0.01)
CT Field	**Control**	3.9 (0.38)	2.9 (0.14)	0.87 (0.03)
	Fungi	33 (3.8)	24 (1.8)	6.0 (0.17)
Goldrush	**Control**	14 (1.3)	6.0 (0.34)	0.75 (0.03)
	Fungi	15 (0.80)	6.8 (1.2)	0.58 (0.05)
Raven	**Control**	12 (2.8)	8.0 (0.53)	0.81 (0.04)
	Fungi	18 (1.3)	19 (2.5)	1.4 (0.02)
ssp *ovifera*				
Patty Pan	**Control**	1.2 (0.14)	0.01 (0.00)	0.01 (0.00)
	Fungi	3.8 (1.3)	0.12 (0.08)	0.02 (0.00)
Seneca	**Control**	7.2 (0.24)	0.87 (0.11)	0.16 (0.01)
	Fungi	17 (0.77)	2.9 (0.31)	0.36 (0.02)
Sunburst	**Control**	13 (2.5)	0.37 (0.12)	0.05 (0.00)
	Fungi	28 (0.47)	1.2 (0.14)	0.15 (0.00)
Zephyr	**Control**	3.7 (0.35)	0.26 (0.06)	0.35 (0.03)
	Fungi	13 (0.51)	1.8 (0.22)	0.24 (0.01)

Effect of mycorrhizal inoculation on the accumulation of *p,p'*-DDE by *Cucurbita pepo* subspecies. Fungal inoculation:

1. Significantly increased root BCFs; ssp *pepo* by 3.2 times and ssp *ovifera* by 2.8 times
2. Significantly increased stem BCFs; ssp *pepo* by 3.3 times and ssp *ovifera* by 6.8 times
3. Significantly decreased the biomass of *ssp ovifera* by 38%, no effect of % phytoextracted
4. Had no effect on ssp *pepo* biomass and significantly increased % phytoextracted (doubled). Inoculated CT Field removed 6.0% of the DDE.

Effect of intercropping 3 ssp *pepo* around 1 ssp *ovifera* cultivar on DDE accumulation. Combinations were Black Beauty/Patty pan, Goldrush/Zephyr, Costata/Sunburst, and Raven/Seneca

Plant type	Root BCF	Stem BCF	Leaf BCF	Fruit BCF
C. pepo ssp *pepo*				
Alone	**8.6** A	**5.2** A	**0.07** A	**0.23** A
Intercropped	**20** B	**20** B	**0.75** B	**2.4** B
C. pepo ssp *ovifera*				
Alone	**6.3** A	**0.38** A	**0.12** A	**0.48** A
Intercropped	**25** B	**2.1** B	**0.94** B	**0.74** B

Conclusions

- *C. pepo* ssp *pepo* uniquely phytoextracts significant quantities of weathered POPs
- The mechanisms are somewhat non-specific, as widely different contaminants are accumulated
- This is not a specifically evolved ability; POPs are entering on pre-existing physiological systems (nutrient acquisition)
- The mechanism of intra-plant translocation of hydrophobic organic compounds is under investigation
- POP availability in soil is a limiting factor, even for *C. pepo* ssp *pepo*
- Soil amendments that enhance POP availability can increase contaminant removal by *C. pepo* ssp *pepo*

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