The Role of Plant Root Exudates in the Phytoremediation of Weathered Persistent Organic Pollutants in Soil

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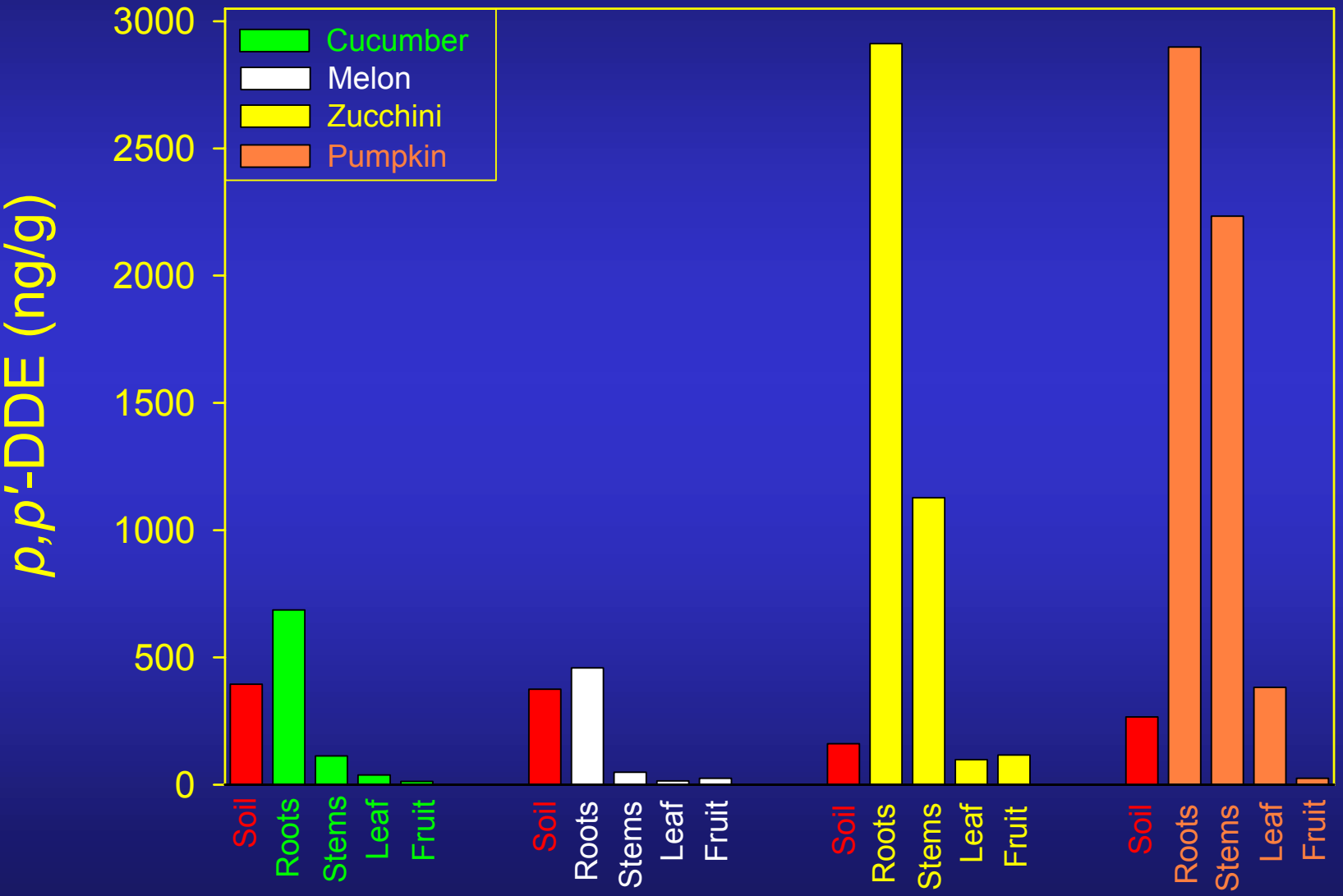
Chlordane, *p,p'*-DDE, and PAHs are Persistent Organic Pollutants (POPs)

- They persist for decades
- Likely mutagenic, estrogenic, carcinogenic effects
- Bioaccumulation, biomagnification
- High degree of sequestration complicates implementation of remediation strategies

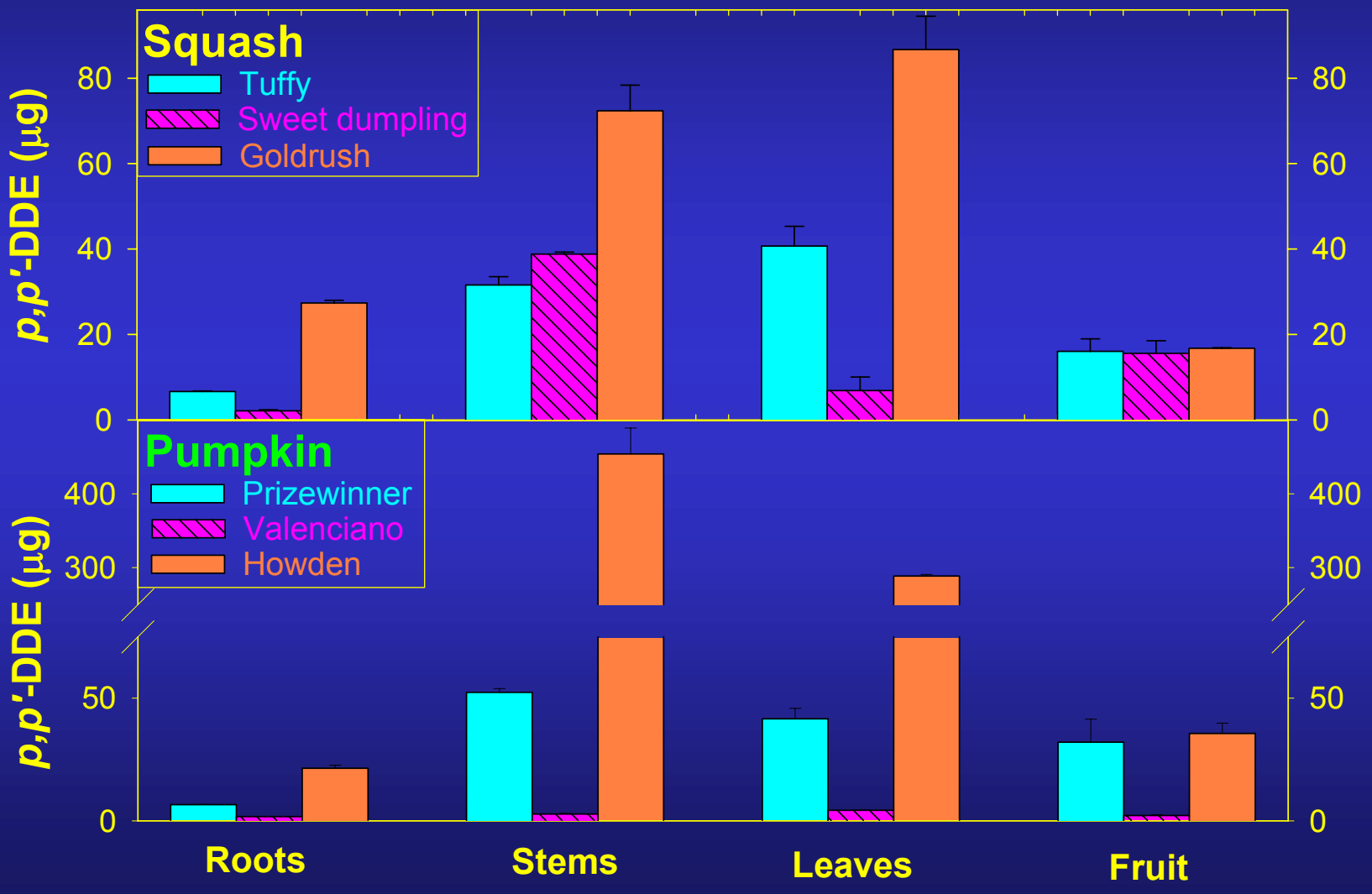
Most plants are unable to remove weathered POPs from soil (non-uptakers)

- **Plants shown to remove minimal amounts of DDE from soil**
  - Rye, alfalfa, vetch, clover, mustard, cucumber, bean, melon, winter squash, certain pumpkins
- **Plants shown to remove minimal amounts of chlordane from soil**
  - Corn, pepper, tomato, potato

Uptake and translocation of *p,p'*-DDE by plants in the *Cucumis* (non-upaker) and *Cucurbita* (uptaker) genera



Total amounts of *p,p'*-DDE in the vegetative tissues of cultivar varieties of *Cucurbita pepo* and *Cucurbita maxima* (Prizewinner and Valenciano)



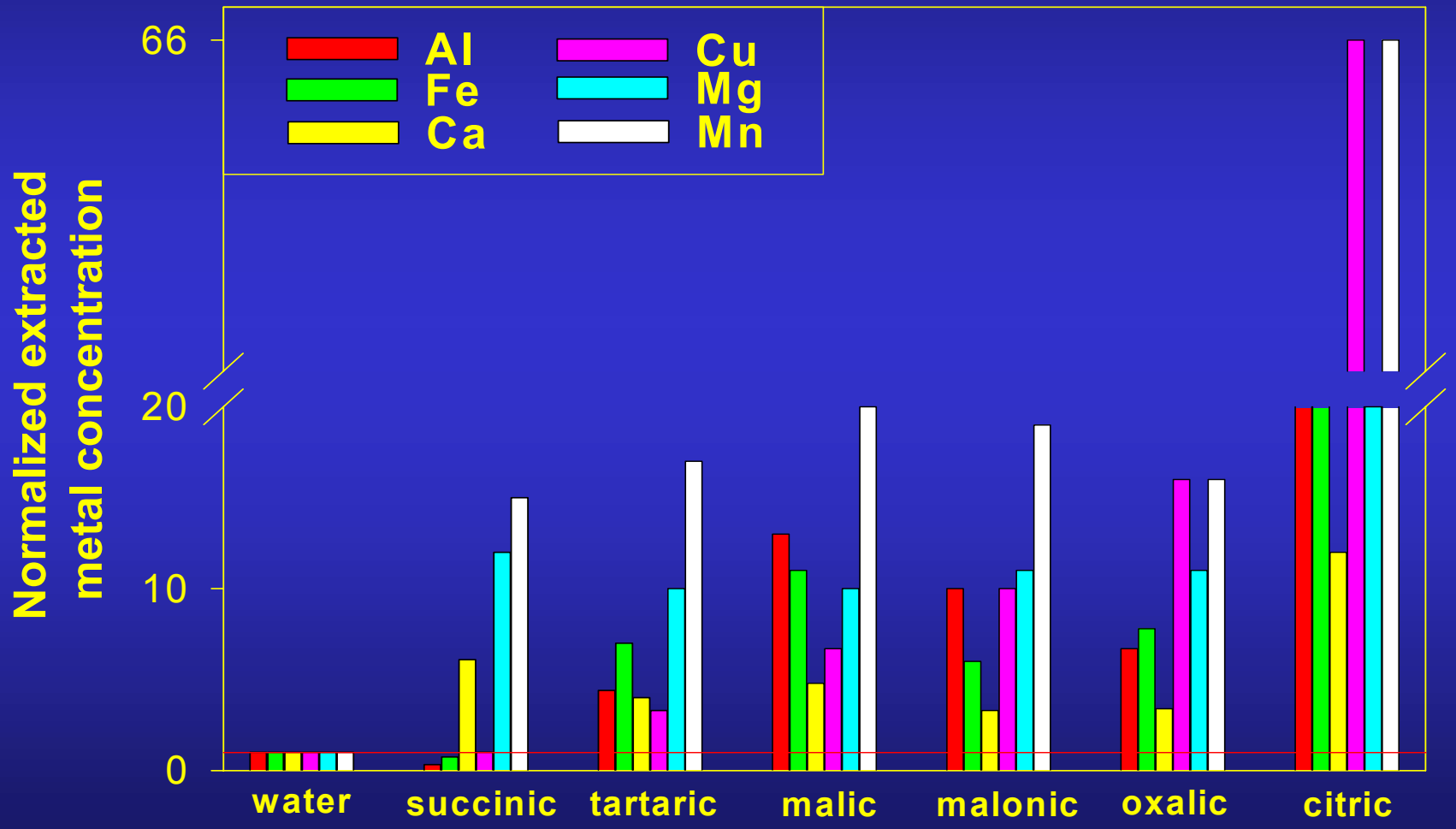
Issues raised by POP uptake data

- **Traditional mechanisms do not explain the data**
- **Not degraded outside the plant**
- **Weathered residues should not be mobilized by flowing water**
- **We propose a new mechanism- root exudate-facilitated phytoextraction**

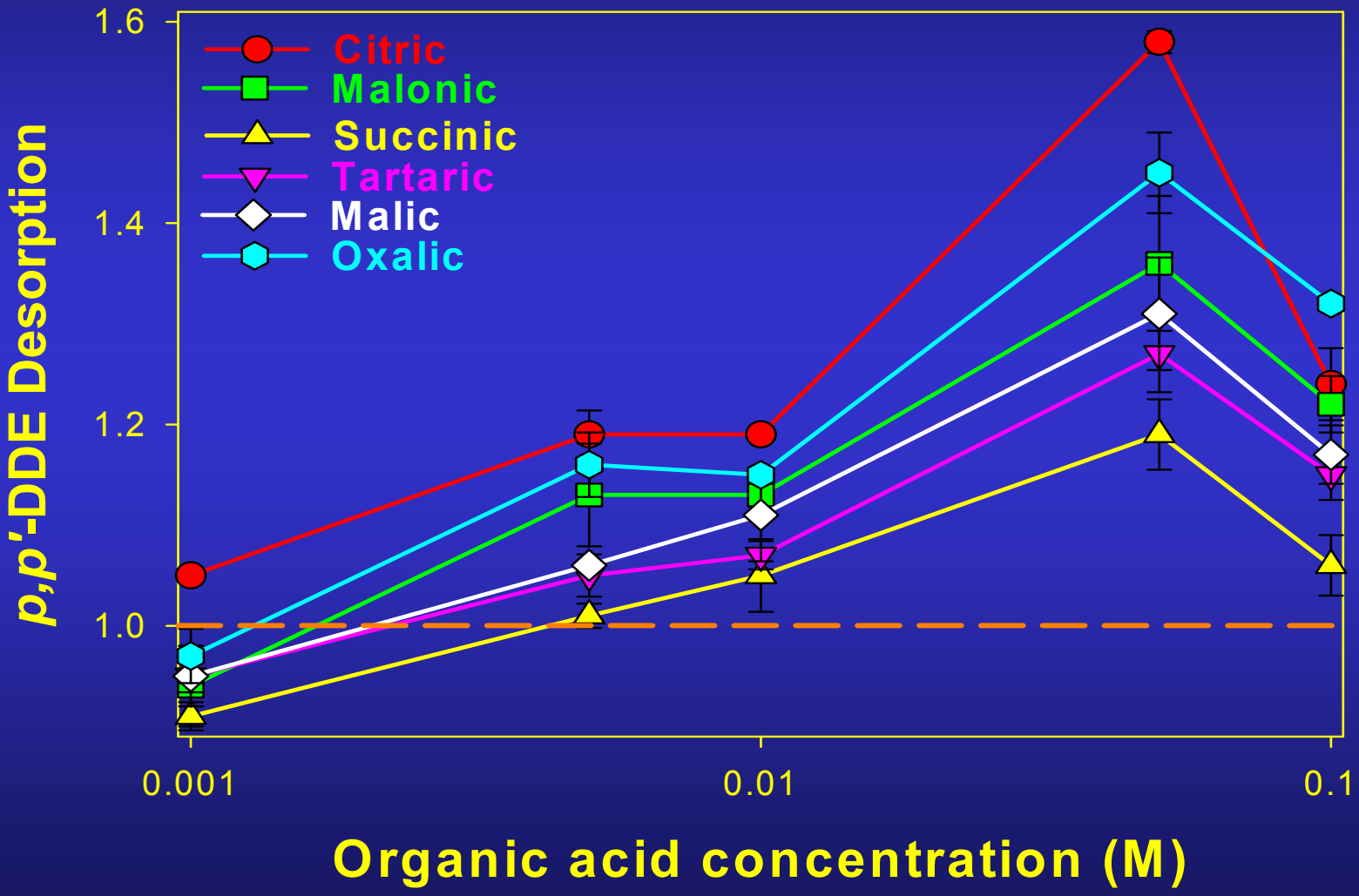
CAES- root exudates released to scavenge nutrients inadvertently increase the bioavailability of weathered POPs

U. Conn.- root exudates attract a bacterial community that in acquiring nutrients, does the same

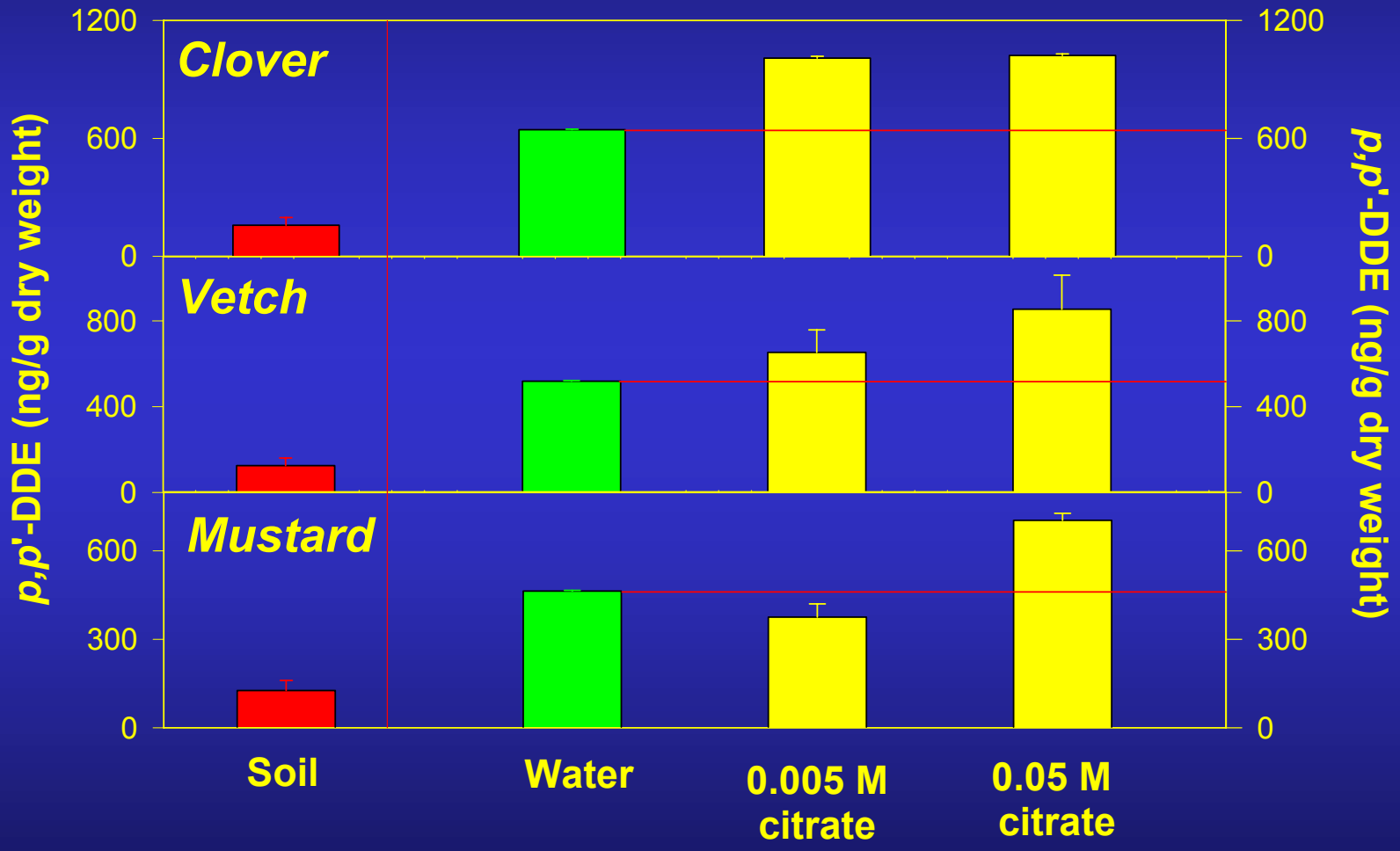
Effect of synthetic root exudates (50 mM) on the extraction of inorganic elements from *p,p'*-DDE-contaminated soil



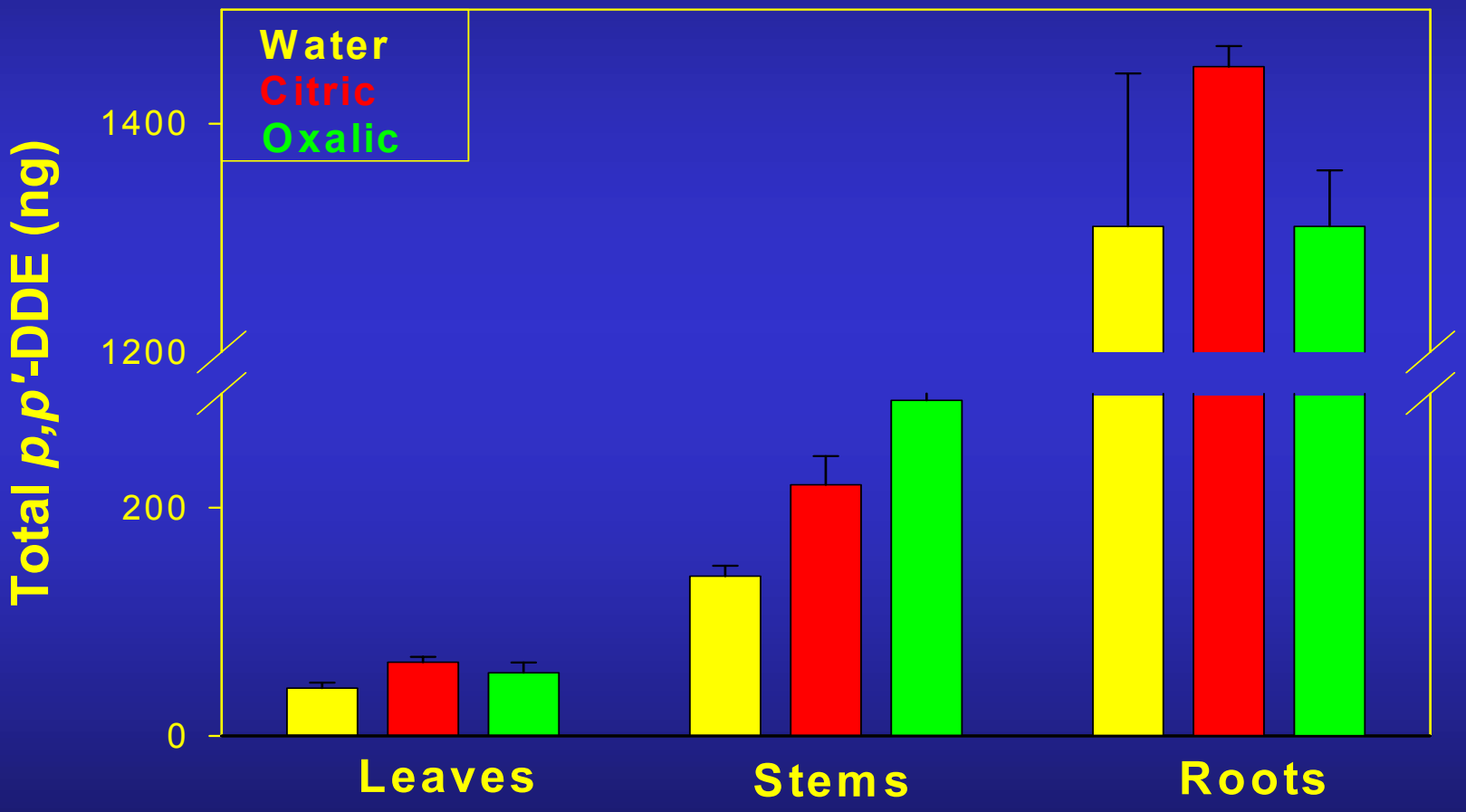
Influence of organic acids known to root exudates on the abiotic desorption of *p,p'*-DDE

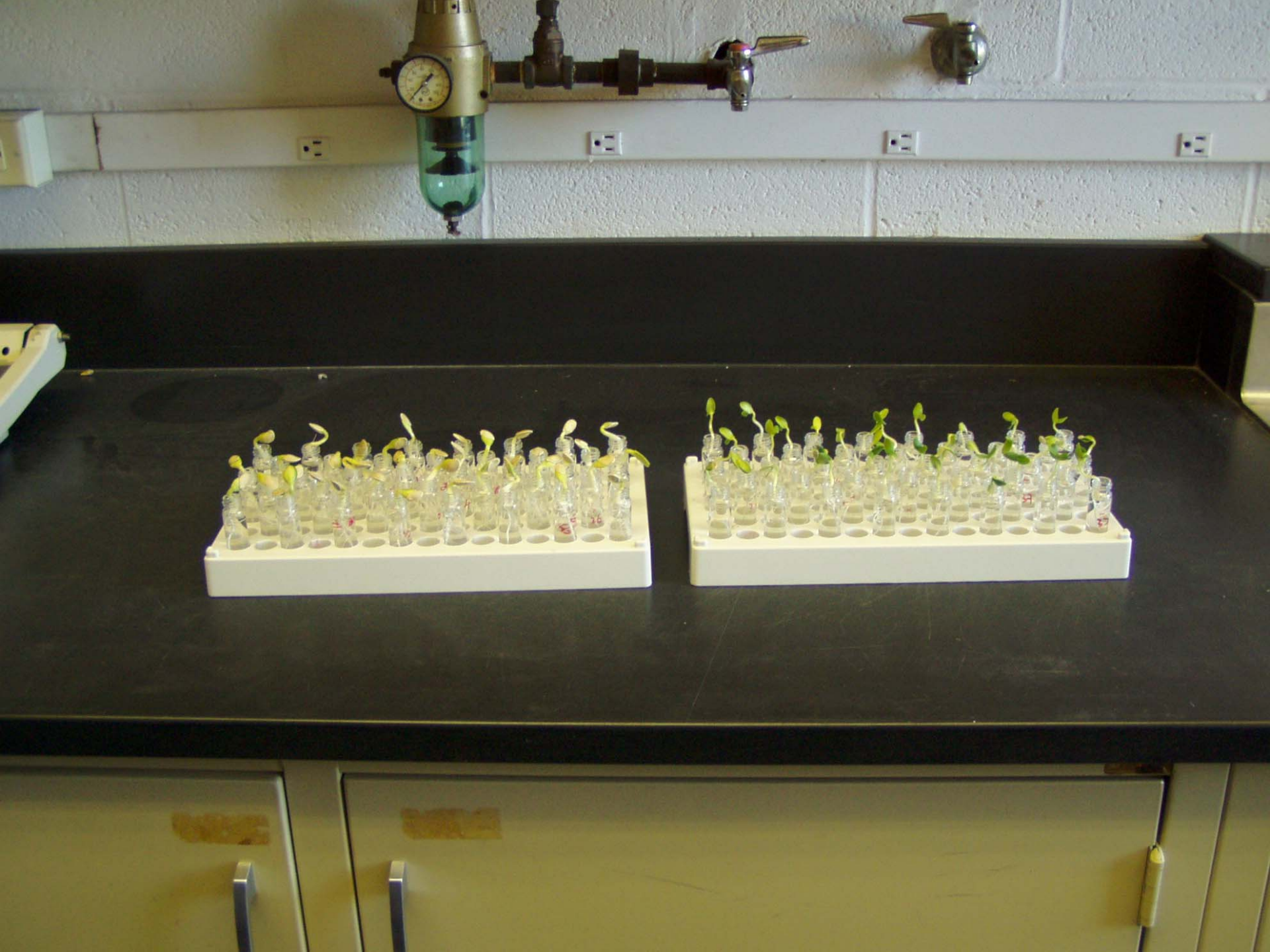


Effect of citrate amendments on the root concentration of *p,p'*-DDE of clover, vetch, and mustard



Influence of organic acid amendments on the uptake and translocation of weathered *p,p'*-DDE by zucchini

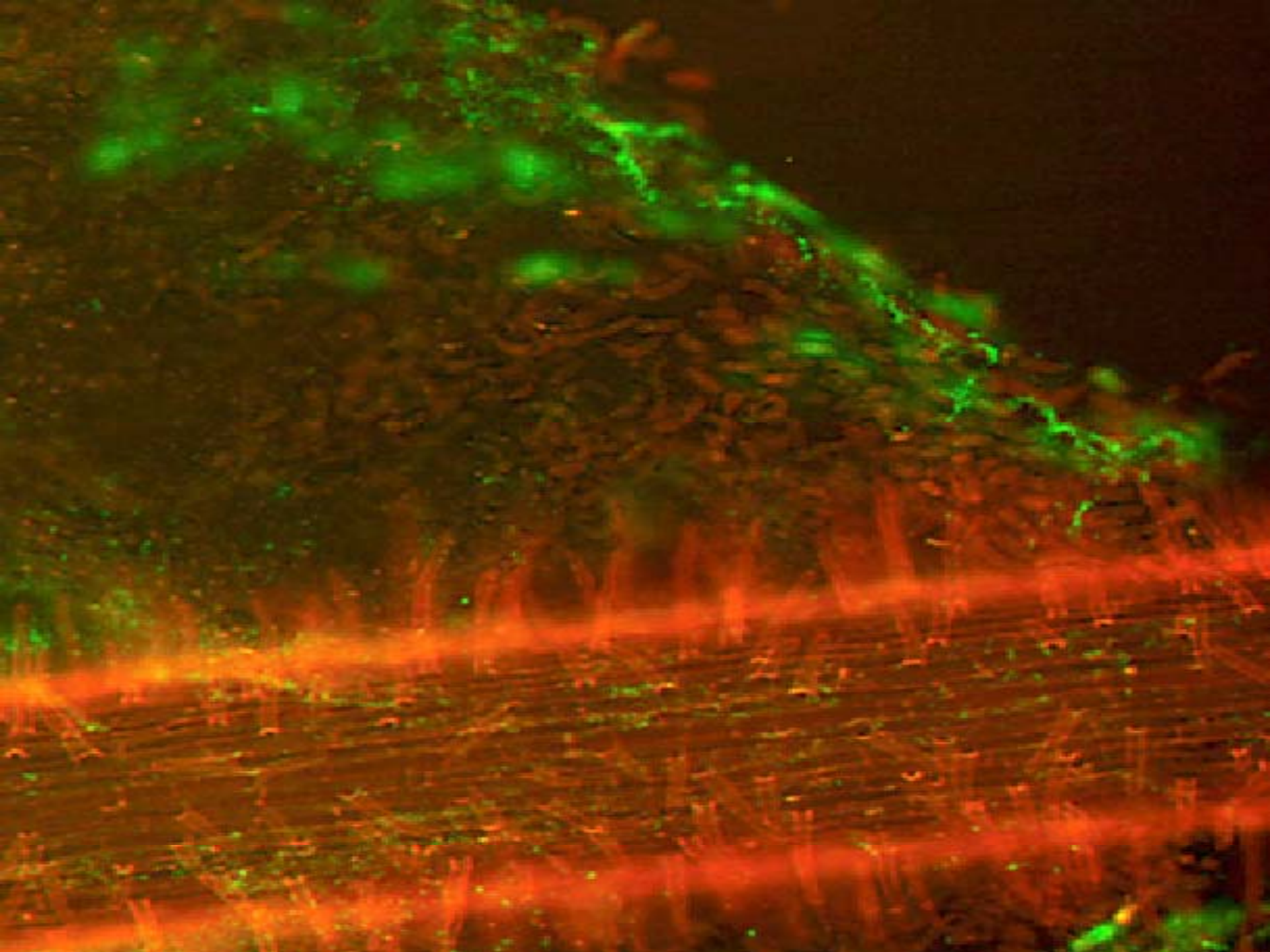




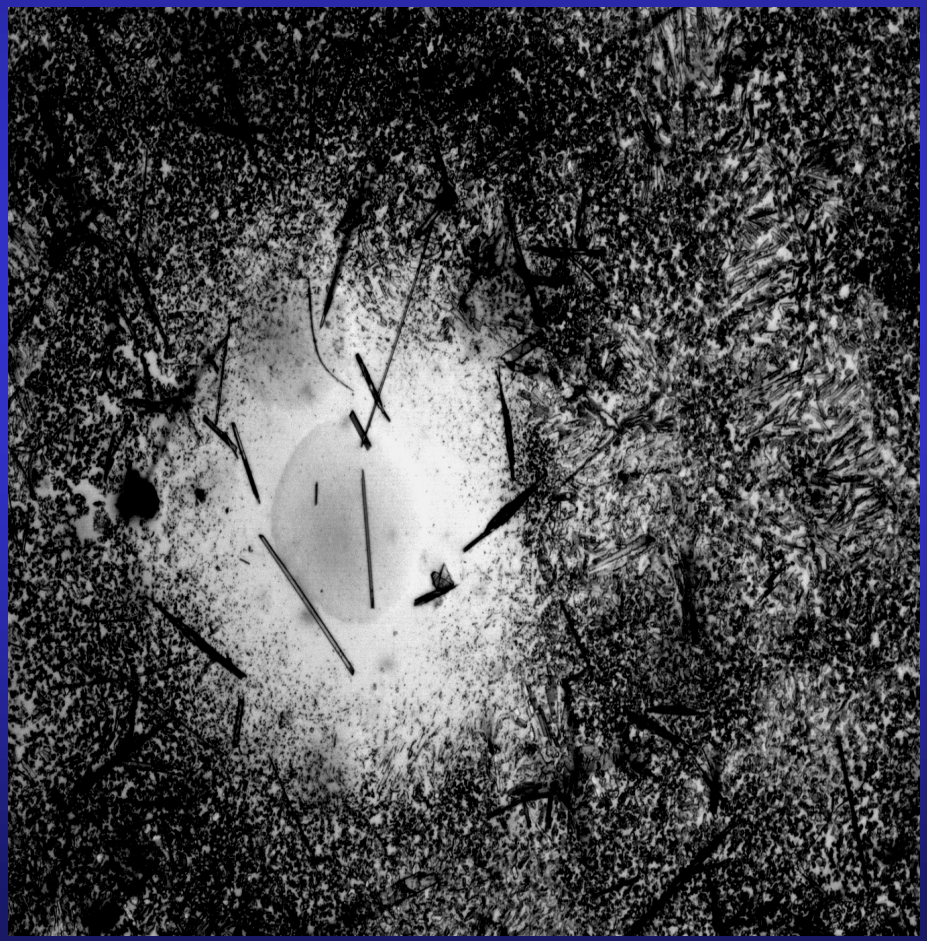

Ratio of Citric Acid Exudation (-P/+P plants)
Cucumber- 2.15
Zucchini- 58.9

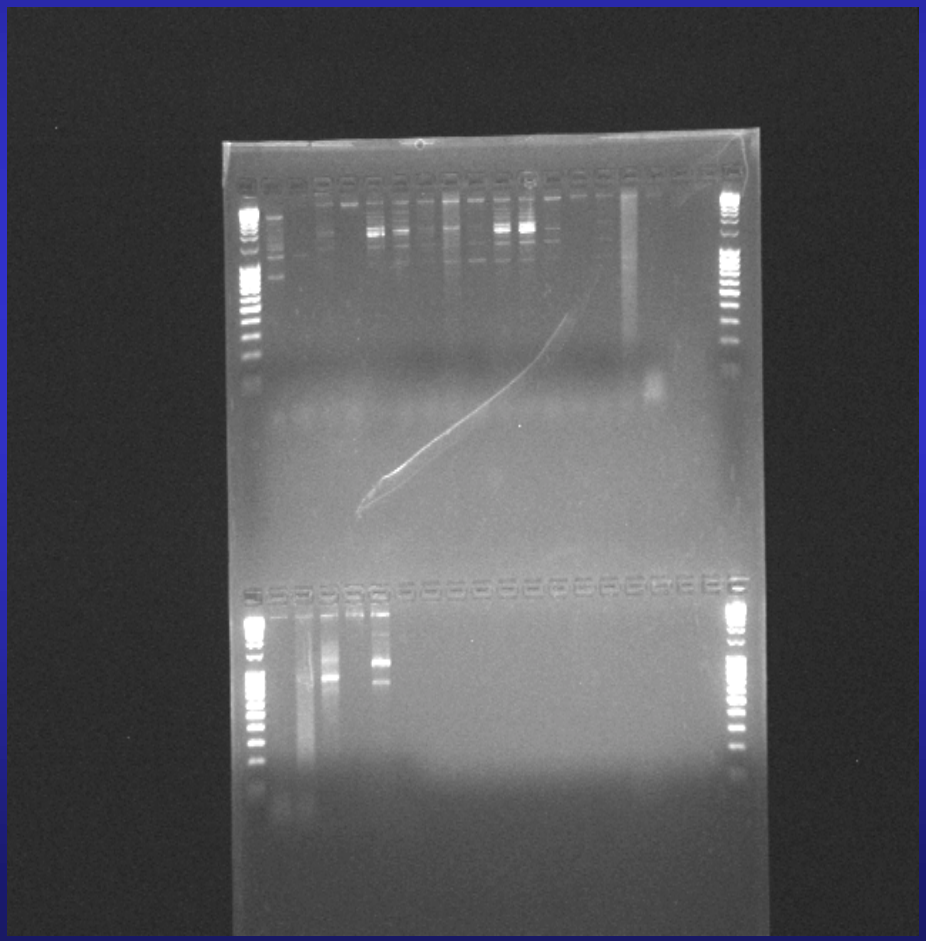

EP - P
EP +P 3


STRAP WARNING: WEAR SAFETY GLASSES DURIN
DISCARD IF CUT CRACKED OR ABRADED



PAH-degrading bacteria have been isolated from the rhizosphere of uptaker and non-uptaker plants growing in an MGP soil. Isolates are being characterized by BOX-PCR





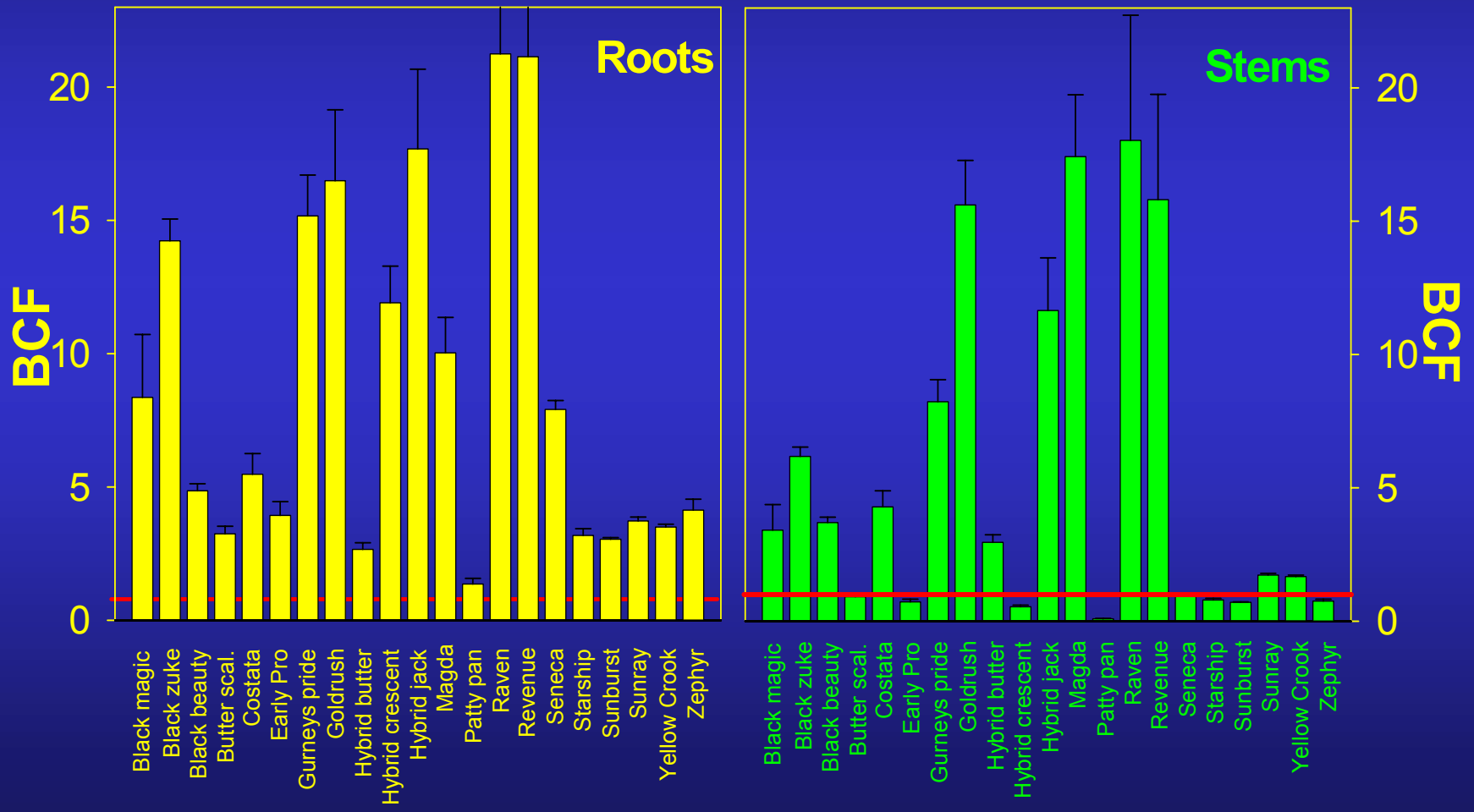
How did we get to *Cucurbita pepo*?

- CAES does pesticide residue analysis for CT-DPH
- Through ’90s, periodic “hits” for old OC pesticides were always on cucurbits
- 1996- An organic farm produces squash with OC pesticide residues
- Eventually became a research program- how are sequestered POPs being accessed
- Certain *C. pepo* seem to do 2 things

    a. It appears to be the best plant at mobilizing weathered POPs into roots

    b. It seems to be the only able to translocate significant quantities to the shoots

Differential uptake of weathered *p,p'*-DDE by 21 cultivar varieties of *Cucurbita pepo* (Summer squash)



Subspecies-level differences in uptake of *p,p'*-DDE and inorganic constituents from soil

Index	*ssp ovifera*	*ssp pepo*
Avg. root BCF	4.42 A	13.4 B
Avg. stem BCF	1.08 A	10.2 B
Avg. leaf BCF	0.437 A	1.72 B
Avg. % phytoextracted	0.125 A	0.551 B
Avg. plant biomass (g)	800 A	746 B
Cd (mg in root)	6.00 A	8.10 B
Cu (mg in root)	118 A	144 B
Zn (mg in root)	439 A	536 B
K (mg in root)	269,000 A	349,000 B
P (mg in root)	24,600 A	39,300 B

Abiotic desorption of weathered *p,p'*-DDE in presence of isolated root exudates

Treatment	Trial #1 DDE desorption	Trial #2 DDE desorption
Nutrient solution	1.00 A	1.00 A
Raven (uptaker)	1.07 A	0.970 A
Goldrush (uptaker)	1.09 B	1.01 A
Hybrid crescent (non-uptaker)	1.09 B	1.01 A
Early Pro. (non-uptaker)	1.09 B	0.943 B

Comparison of common heavy metal hyperaccumulators and *Cucurbita pepo*

Vegetation		Stem BCF	% Phytoextracted
Thlaspi caerulescens	Zn	1.1	0.1-0.6
	Cd	1.7	0.3-1.3
Brassica juncea	Pb	<0.5	<0.1
	Cs	0.6	<0.1
Amaranthus retroflexus	Cs	2.2-3.2	3.0
Pteris vittata	As	17-73	0.15-25.9
Cucurbita pepo	DDE	5.8-12	0.4-1.5
	Chlordane	1.5-6.7	0.2-1.0

Conclusions

- Highly weathered POPs may be available for plant uptake
- The mechanisms of plant uptake need to be elucidated but likely involves the exudation of low molecular weight organic acids (by either plants or bacteria)
- Other work- DNA profiling of uptaker and non-uptaker microbes, Biosensors (GFP bacteria)
- Mechanism of transport within the *C. pepo* is completely unknown
- The amount removed from soil is significant
- Practical application? Not likely for zucchini but can this system be located in or translated to other plant species?

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