Phytoremediation-Humification Strategies for RDX in Surface Soil

Mike Reynolds[1], Dave Ringelberg[1]
Lee Newman[2], Steve Larson[3]

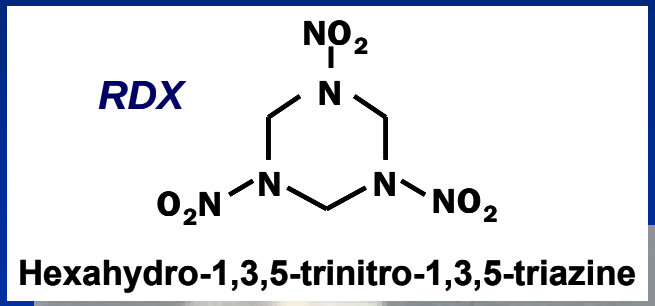
Army EQ Research Program
SERDP

[1]Engineer Research and Development Center (ERDC), Cold Regions Research and Engineering Laboratory (CRREL) [1]Soil Microbiology Laboratory
[2]University of South Carolina
[3]ERDC - Environmental Laboratory

Third International Phytotechnologies Conference
April 20-22, 2005 Atlanta

Problem

- RDX from low-order detonations
- Deposition onto surface soils
- Heterogeneous and widely dispersed
- Potential for range restrictions/closures



Hexahydro-1,3,5-trinitro-1,3,5-triazine

Relatively high solubility
Weak soil binding

- Potential human health effects
- Seizures
- Possible carcinogen effects

Remediation strategies?

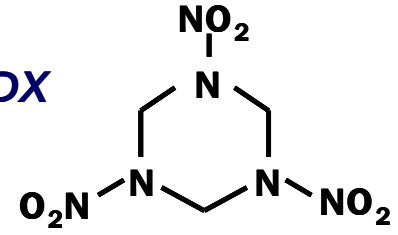
- Cost effective, easily implemented, applicable to surface soils

RDX Degradation Background

RDX Biodegradation

- Favored in saturated soils rather than surface soils
- Plant uptake of RDX is significant, but degradation in plants is limited
- RDX conjugated in plant tissue can be re-deposited onto soils as plants die
- Surface soils are not constant with regard to temperature, soil water potential, and carbon
- Can we identify, predict, or enhance processes that reduce the potential for RDX movement?

RDX



Hexahydro-1,3,5-trinitro-1,3,5-triazine

Relationship to Other Phytoremediation

Previous research – rhizosphere enhanced remediation for petroleum

Similarities

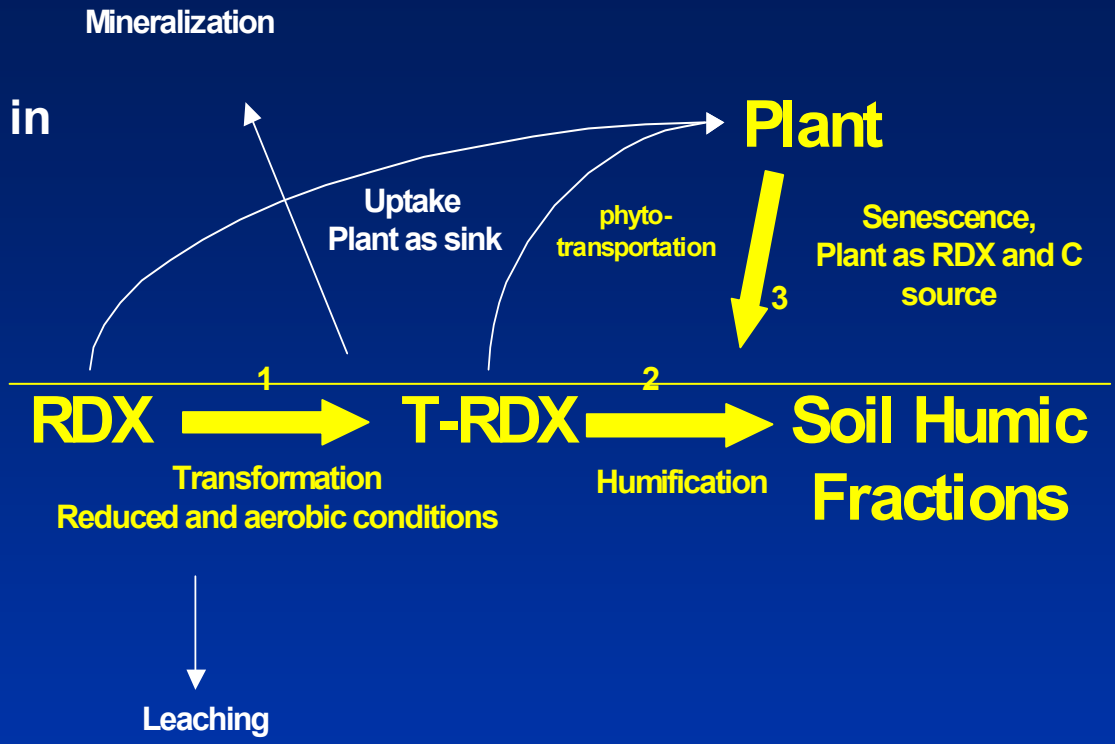
Surface soil	Limited site access
Root Accessible	Few alternatives

Different mechanisms

Objective/Description

Objective

Sequester RDX-derived C in soil humic fractions



Hypotheses

- Soil RDX concentrations can be decreased by microbially driven transformations and plant uptake
- Humification can serve as an RDX sink
- Bioavailable carbon drives the microbiology
- Mineralization-Immobilization Turnover (MIT) drives humification
- Plant-conjugated RDX gives a humification advantage
- There is characteristic microbiology associated with humification

Approach- Theory & Hypothesis

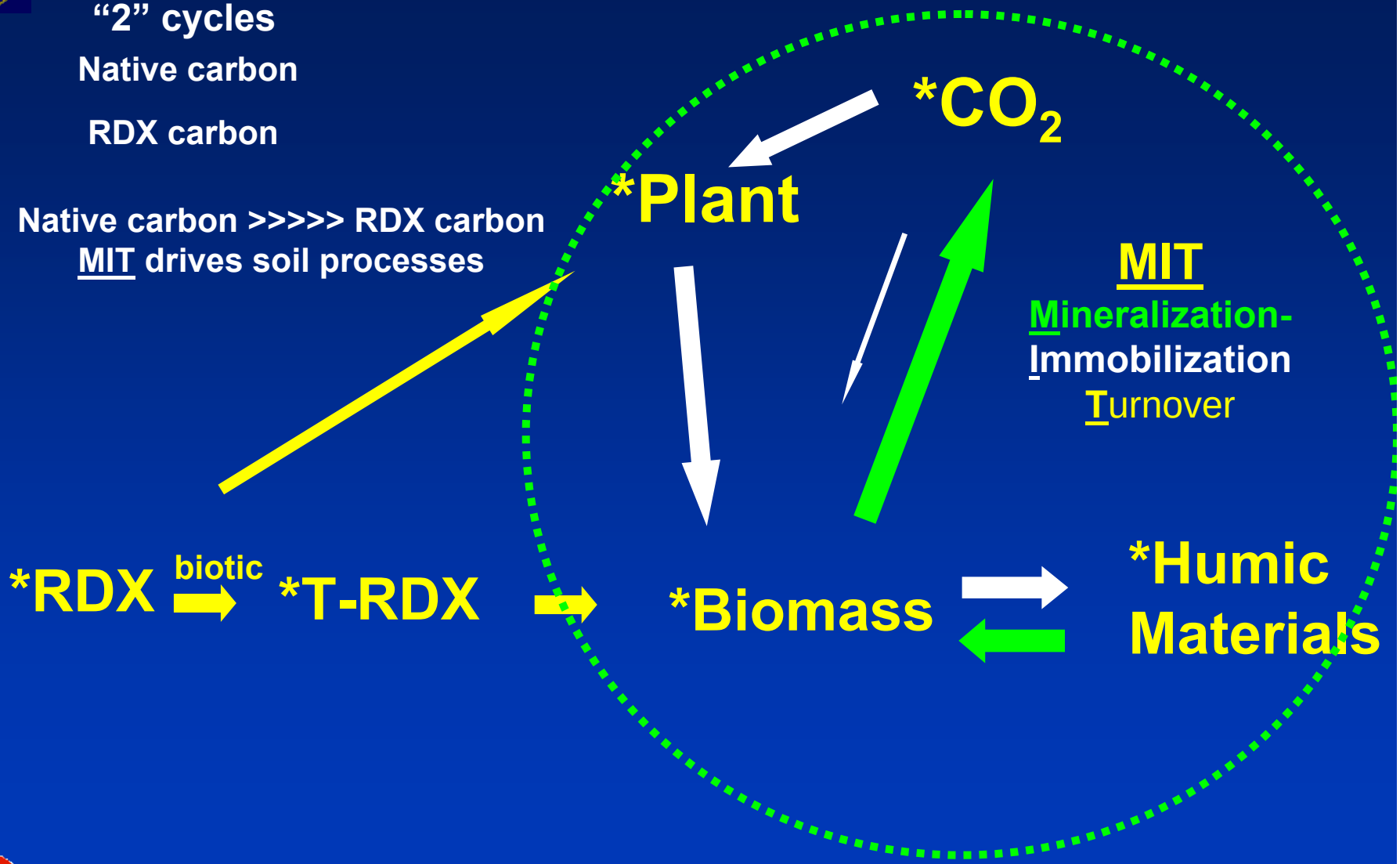
"2" cycles

Native carbon

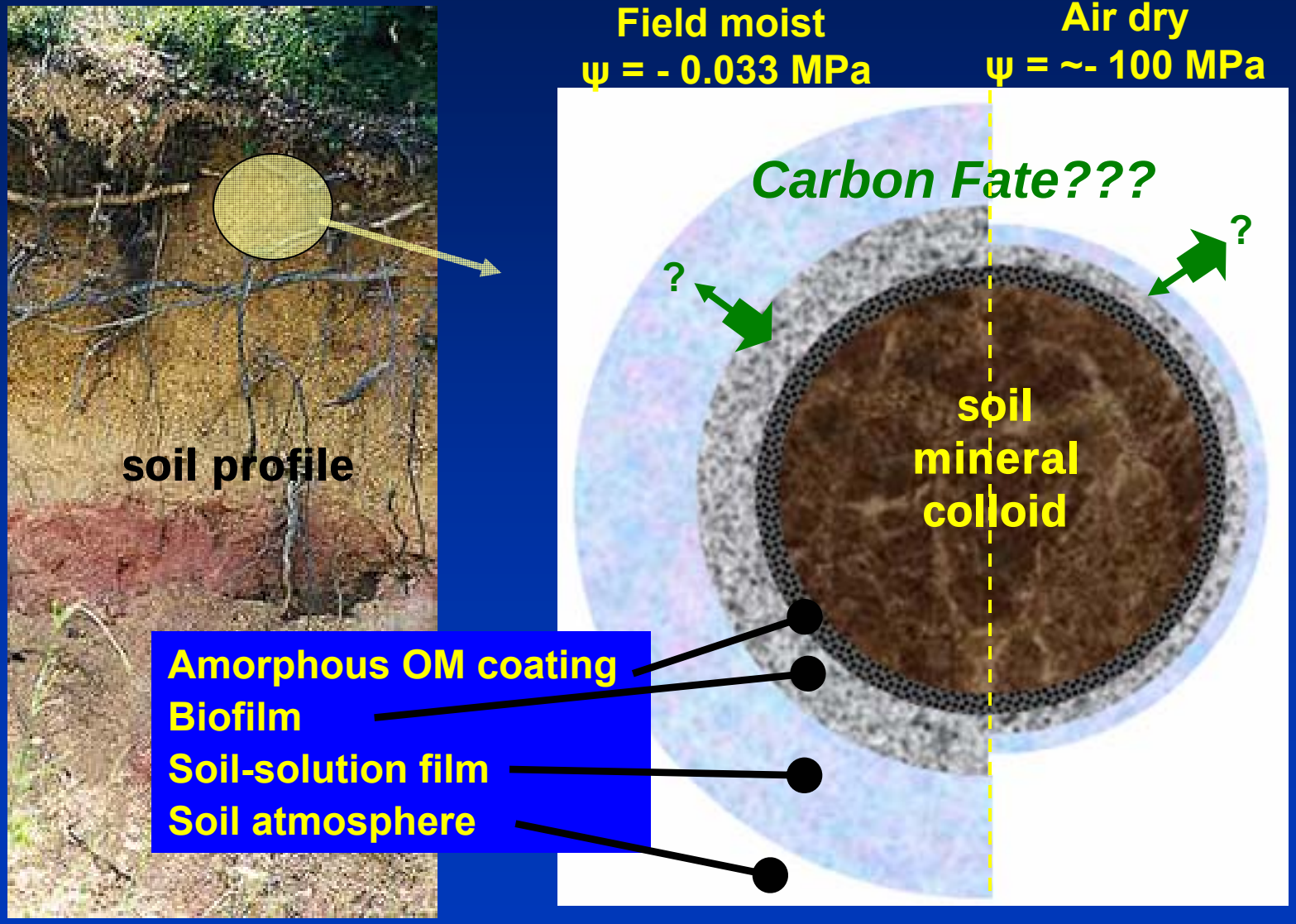
RDX carbon

Native carbon >>>>> RDX carbon

MIT drives soil processes



Soil Water → Biofilm → A-OM → Particle



Approach

RDX humification in surface soils

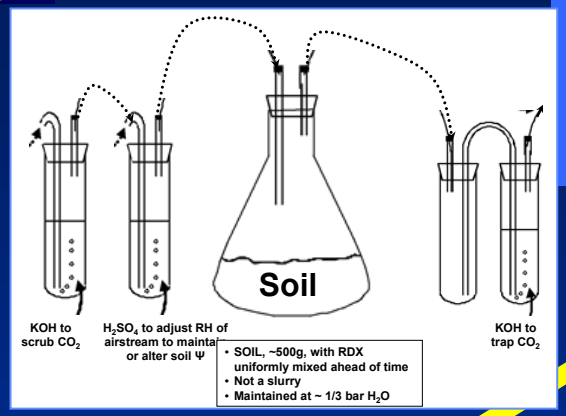
- Humification studies using both ^{14}C and non-labeled RDX
- Add ^{14}C-RDX directly to soil
- Use 2 soils with different OM levels
- Defined soil moisture and temperature conditions

Plant-associated RDX (underway)

- Grow plants and load with ^{14}C-RDX
- Add plant tissue with RDX-derived ^{14}C to soils
- Use same soil moisture and temperature

RDX photo-degradation using variegated plants (underway)

Approach- Methods



~ 1500g
RT
~1/3 bar

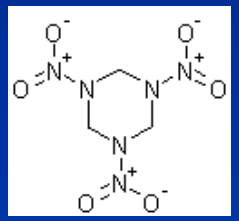
KOH trap
$BaCO_4$
LSC

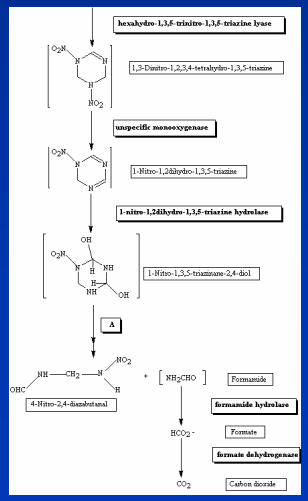
CO_2

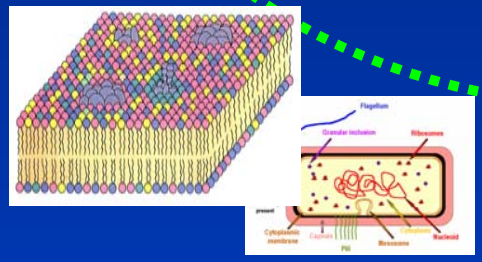
MIT
Mineralization-
Immobilization
Turnover

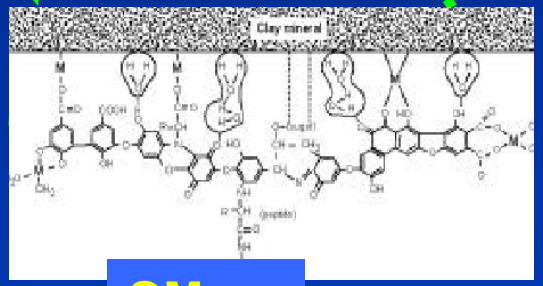
*Plant

*RDX → biotic → *T-RDX → *Biomass ⇄ *Humic Materials









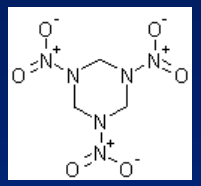
RDX_{ACN}
HPLC
LSC

$Lipid_{BD}$ & GCMS
LSC
T-RFLP

OM_{MIBK}
LSC

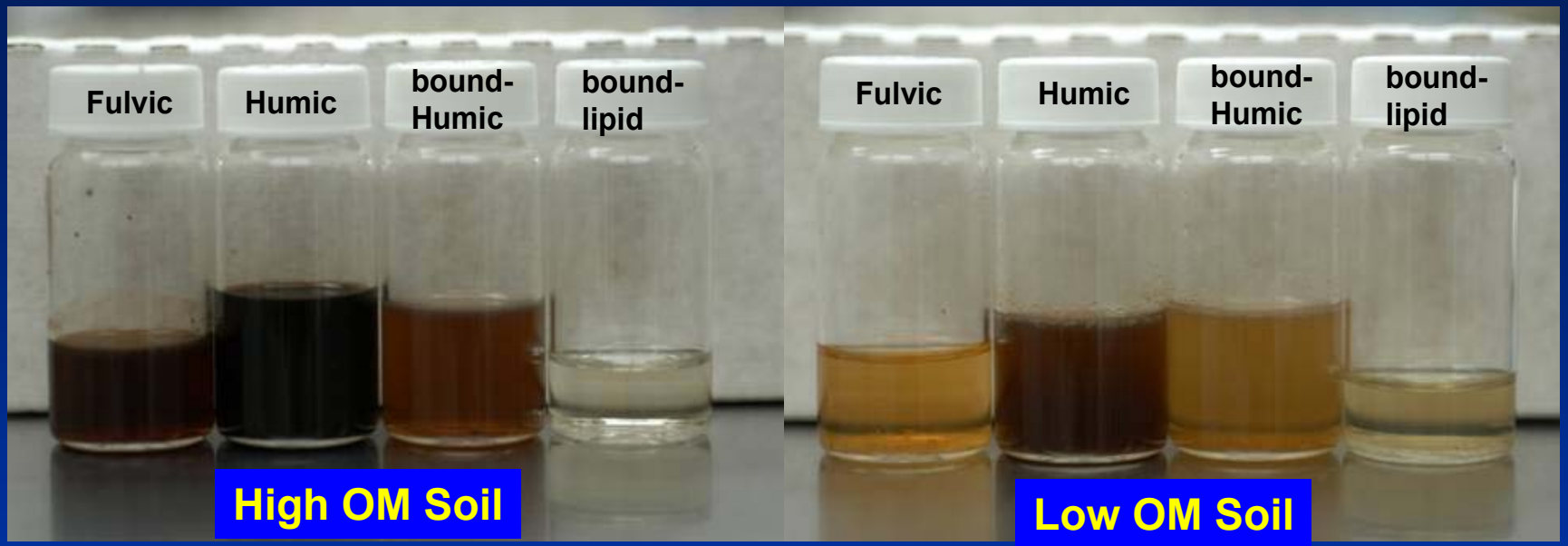
4 reps
2 soils (hi and lo OM)
Controls (no RDX)
Dark
Mini-core sampling

Results – Partial Summary



- RDX loss slow but consistent
- T-RDX transient
- *C in microbial biomass low and consistent
- RDX-specific microbial community changes …??
- Mass balance decreases with time…??
  - Cumulative error…??
  - Missing a pool…??

Results – RDX directly to Soil



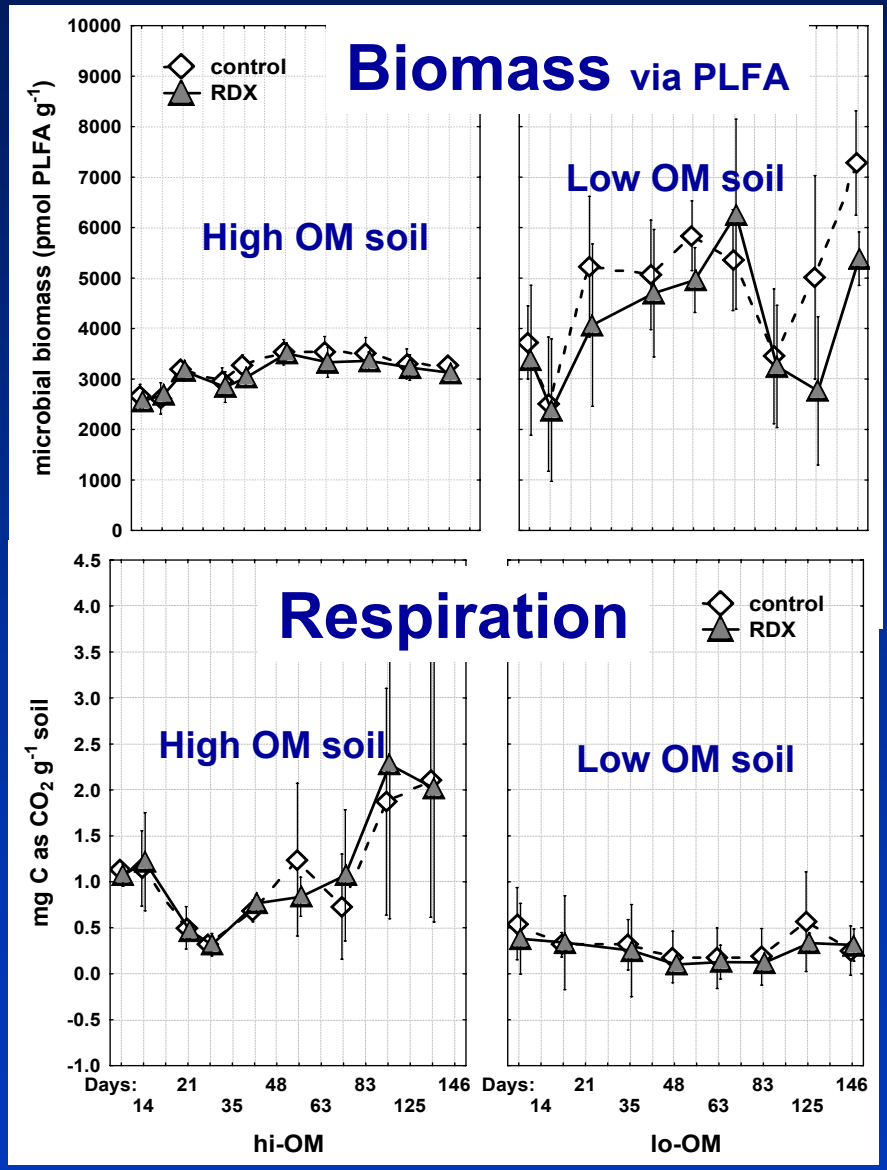
(OM fractionation – MIBK method)

Results – RDX directly to Soil

Soil biomass, normalized to soil dry weight showed:

- No sig. RDX effect on biomass
- More consistency in high OM soil (biomass responds to soil C rather than RDX-C)

- Yet respiration was greater in the high OM soil, and increased with time.
- Biomass and respiration sometimes viewed as "equivalent" but they diverge for both soils…
- These data suggest:
  - greater "activity" or "through-put" or MIT for the high OM soil,
  - greater cellular storage for the low OM soil



Results – RDX to Soil

Fate of 14C derived from RDX ?

Is there a difference between soils?

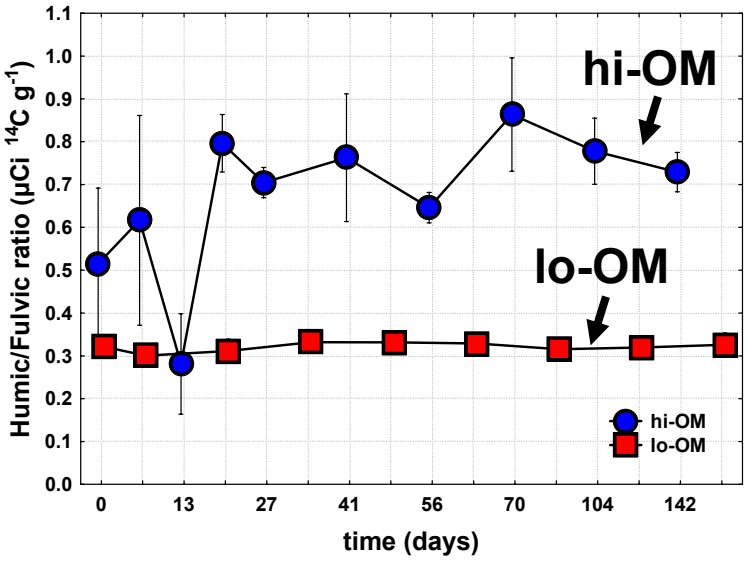
- **In high OM soil, a significantly greater amount of RDX derived C moves into the bound humic fraction --"humification"**

And

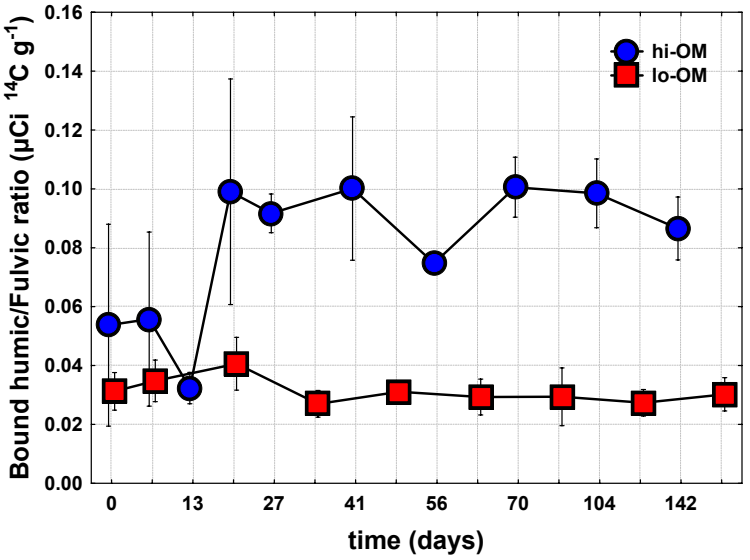
- **This appears related to MIT**

14C location

Humic



Bound Humic

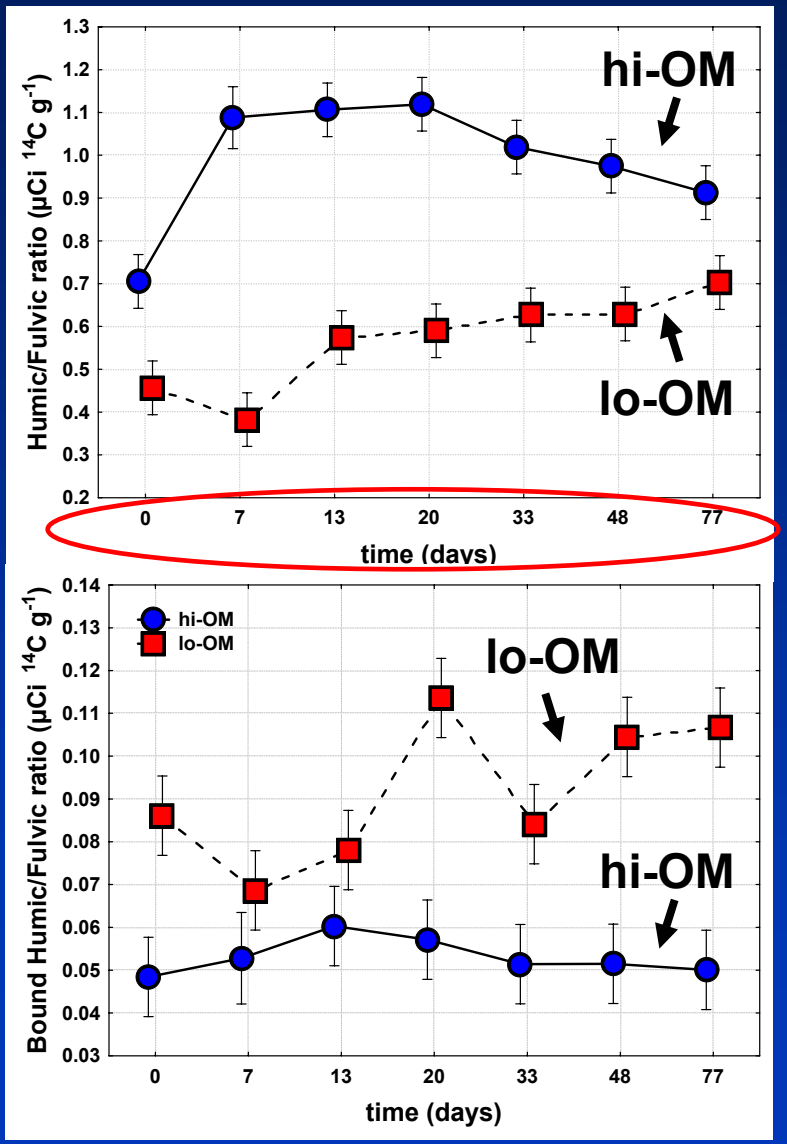


Results – Plant Tissue RDX to soil

Fate of 14C derived from Plant RDX ?

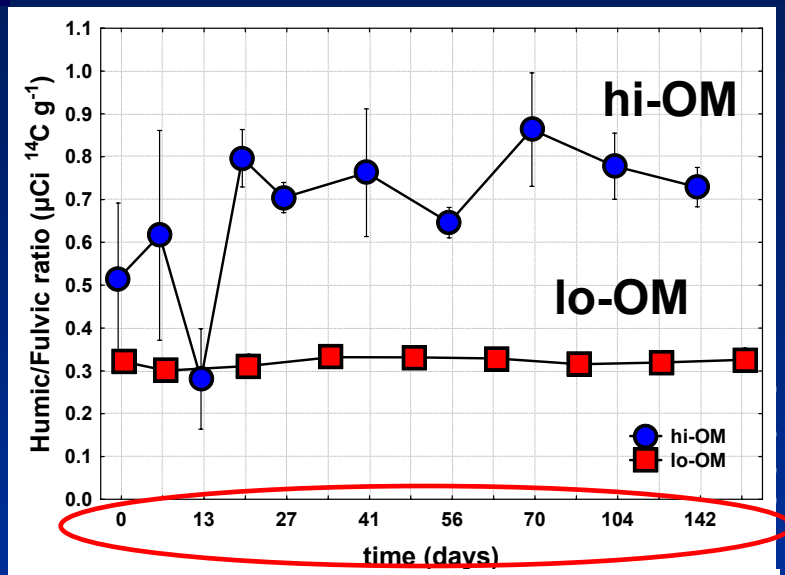
Is there a difference between soils?

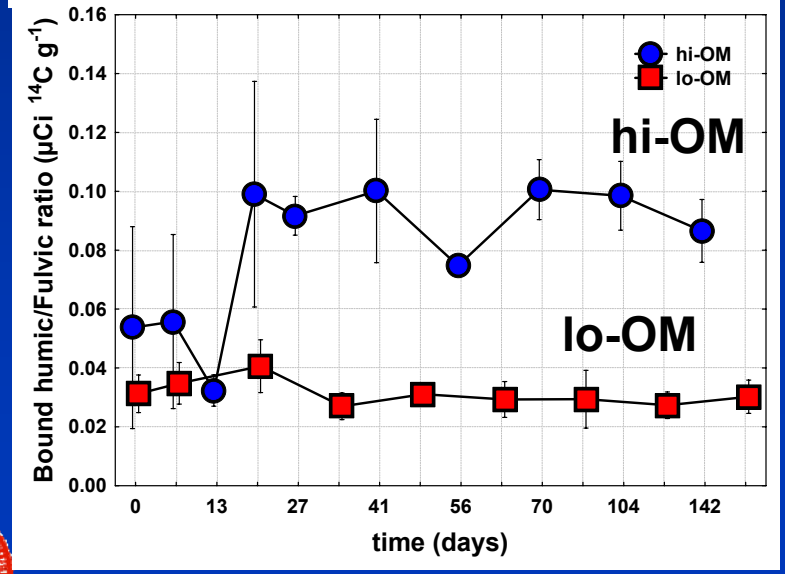
- **Yes, but a different pattern than seen for RDX added directly to soil is emerging**



Plant Tissue RDX to soil

RDX to soil



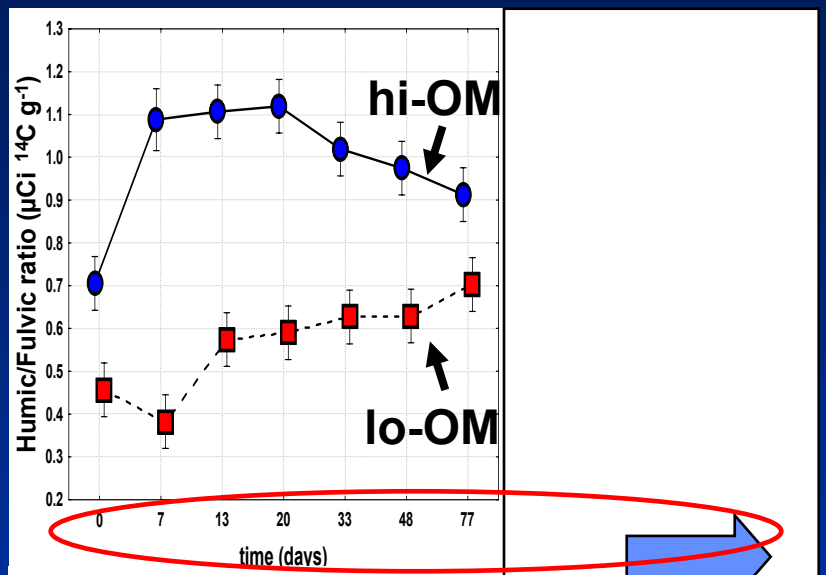


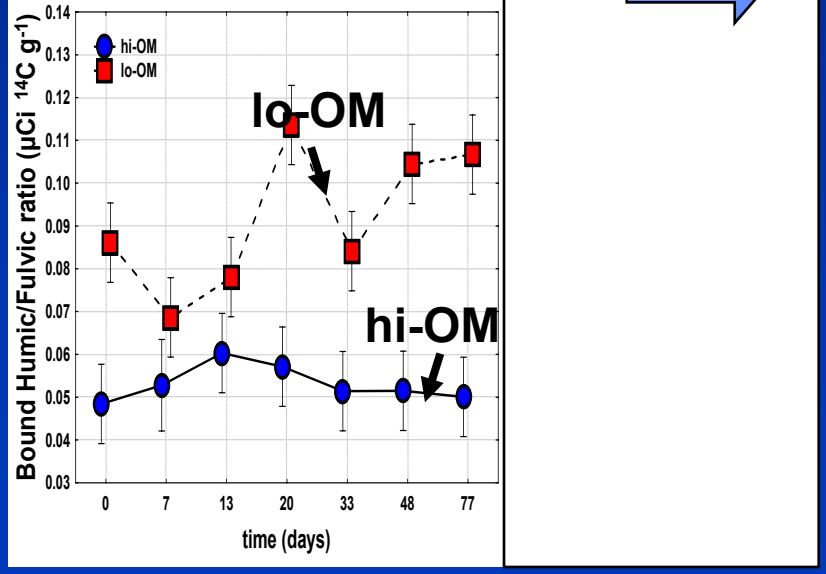
14C location

Humic

Bound Humic

Plant Tissue RDX to soil



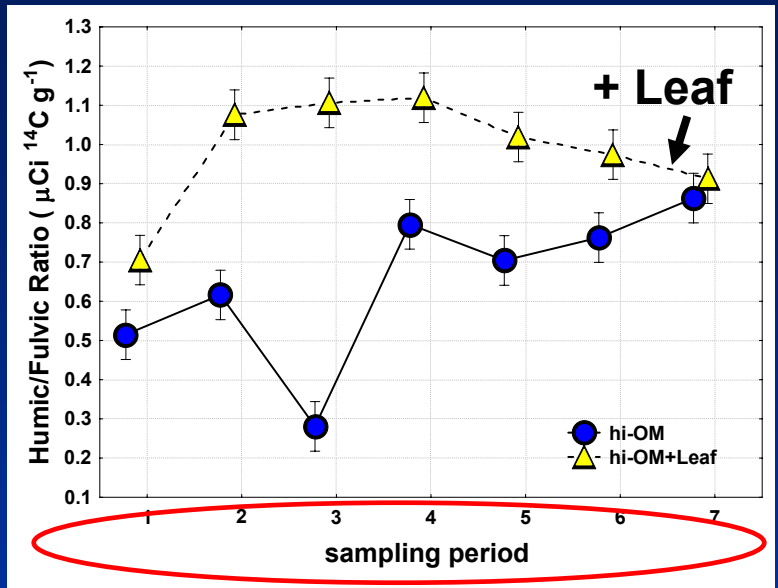


Results

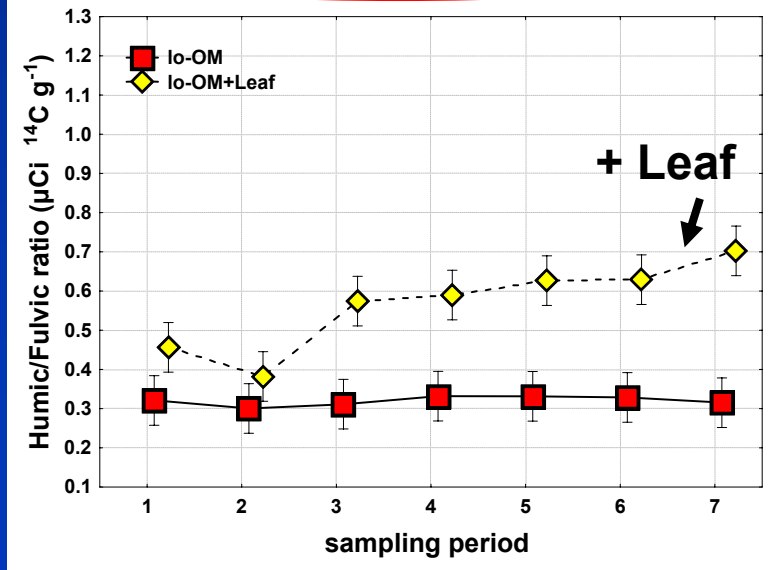
- Using Humic/Fulvic Ratio
- Direct soil RDX vs Plant Tissue RDX
- High OM soil – convergence
- Low OM soil - divergence

14C location

High OM soil

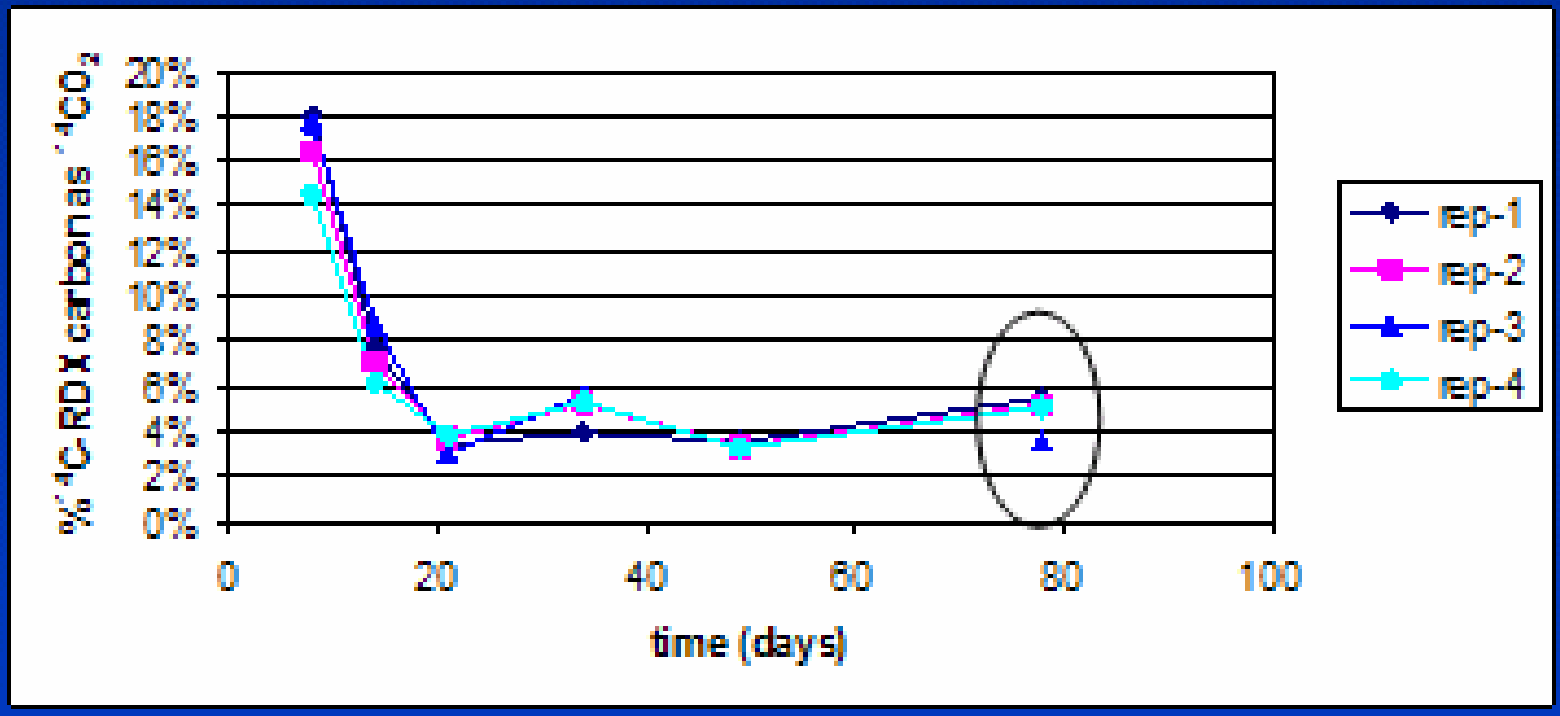


Low OM soil



Evolving Soil Communities

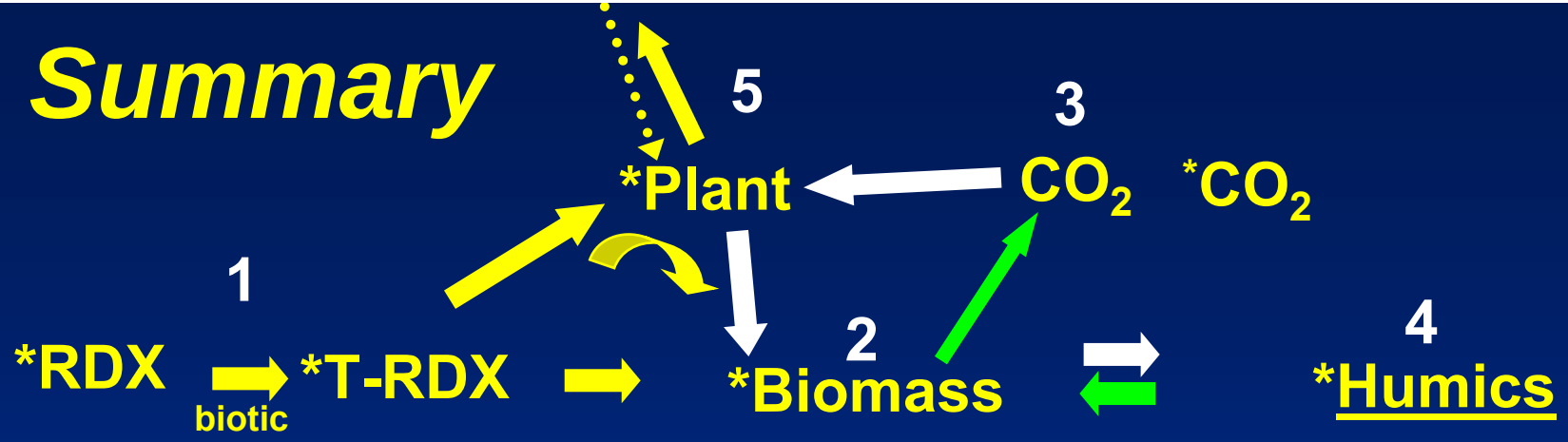
Sudden variability in 14C evolution



Results – Odd 14 C Rep for Plant Tissue RDX to soil

Phanerochaete ?

Summary



1. Biotic transformation of RDX in surface soils is slow but does occur.
2. *C in biomass low but constant – suggesting steady state role in flow of RDX into other pools.
3. *CO_2↑ low but constant. General CO_2↑ may be important as an indicator of MIT
4. RDX (soil) - Greater amount of *C associated with bound-humic fraction in the high OM, high respiration soil relative to the lower OM soil.

   RDX (plant) – changes in *C in humic fractions for both soils, more so for low OM soil.
5. Photo-degradation in plant tissue, variegated plants (underway)

Data suggest possible plant-based, agronomic site management practices that encourage binding of RDX residues to soil