23rd Annual Mine Design, Operations & Closure Conference

Interactive Effects of Plants, Bacteria, and Amendments on Soil Arsenic Levels

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Why We Care About Arsenic

http://chemistswithoutborders.blogspot.com/2010/07/new-study-shows-77-million-bangladeshis.html

Should We Really Care?

ICP-MS Hair Analysis
Average ppm concentration

Element	Butte	Bozeman	Normal levels (Goulle et al 2004)
Aluminum	7.313	5.206	<5.30
Arsenic	0.122	0.080	<0.08
Cadmium	0.073	0.051	<0.17
Copper*	40.95	21.441	<61.3
Lead	1.582	1.353	<4.57
Selenium	1.909	0.891	<1.37
Mercury	0.191	0.214	<1.66

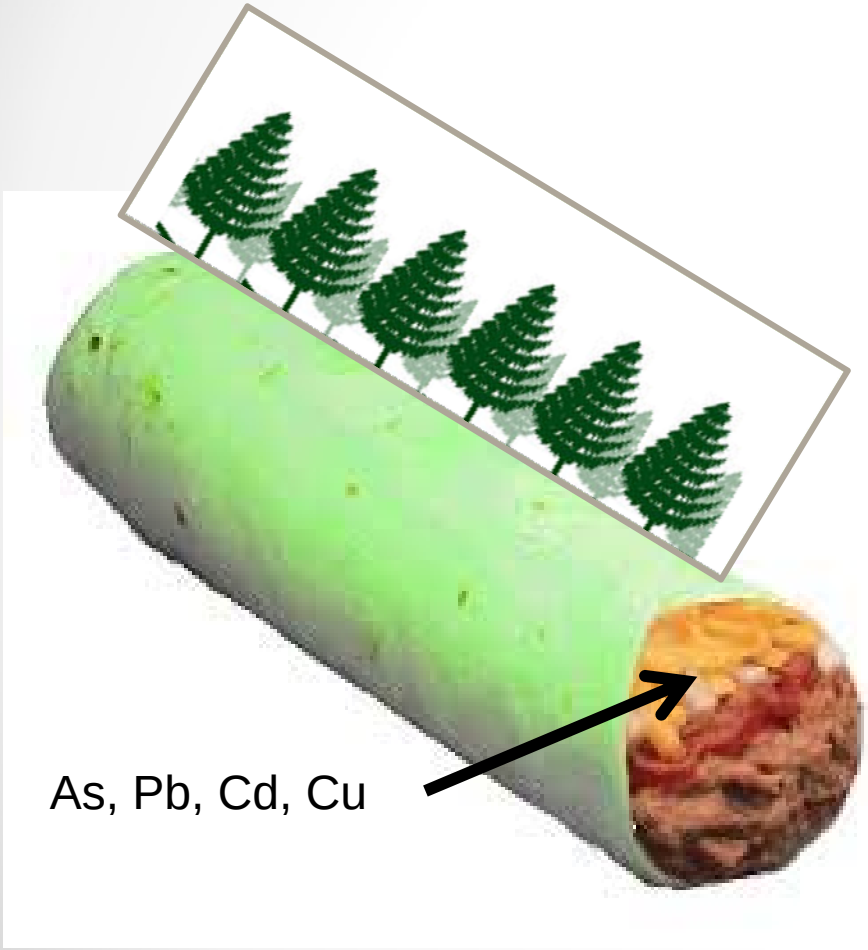
ICP-MS Blood Analysis
Average ppb Concentration

Arsenic	17	16	< 16.8
Cadmium	32	ND	<2.04
Copper*	919	802	<890
Lead*	22	13	<62.8
Manganese*	96	84	<12.8
Selenium*	227	205	<154

Calhoun *et, al*. 2015 non publish data

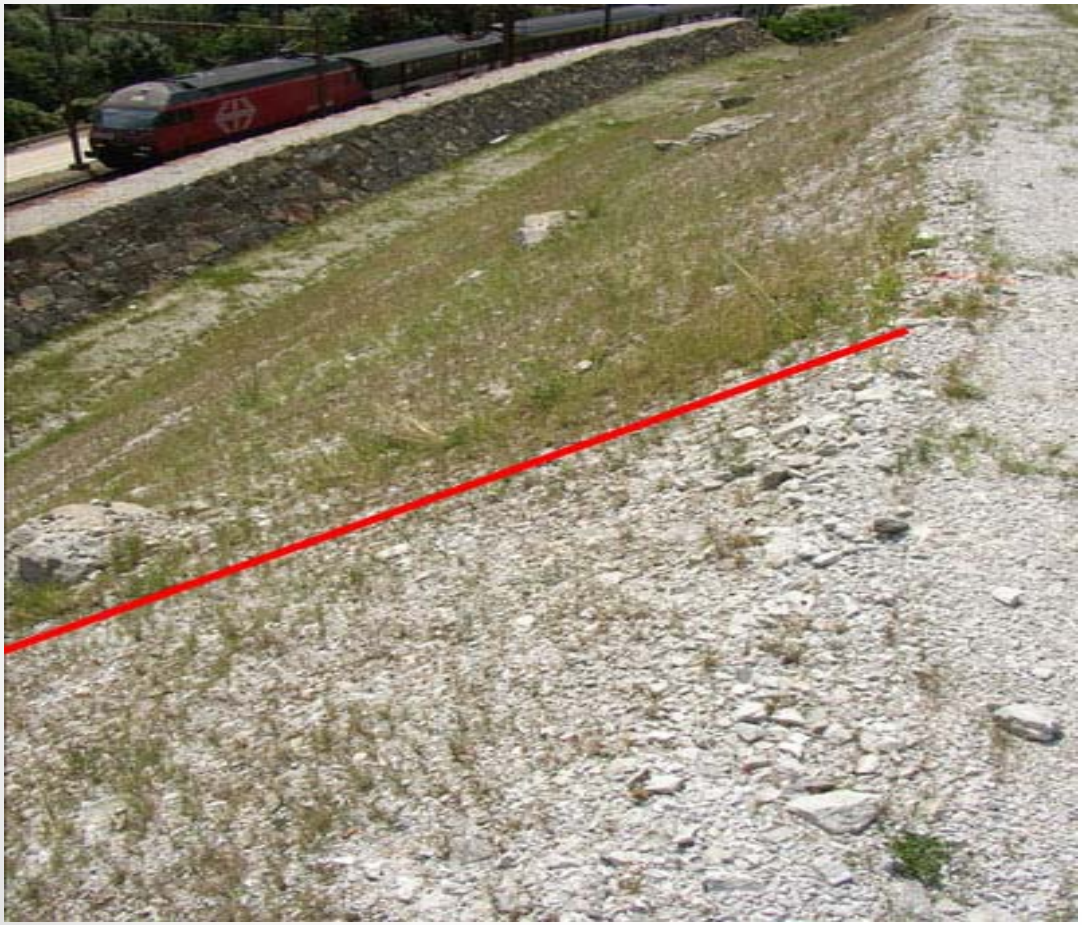
How do we reestablish vegetation in mining sites?

Alternative 1: Encapsulating the Toxic Soil



$640,000 per acre?
(Berti and Cunningham , 2000)

Alternative 2: Direct Revegetation



$24,000 per acre?

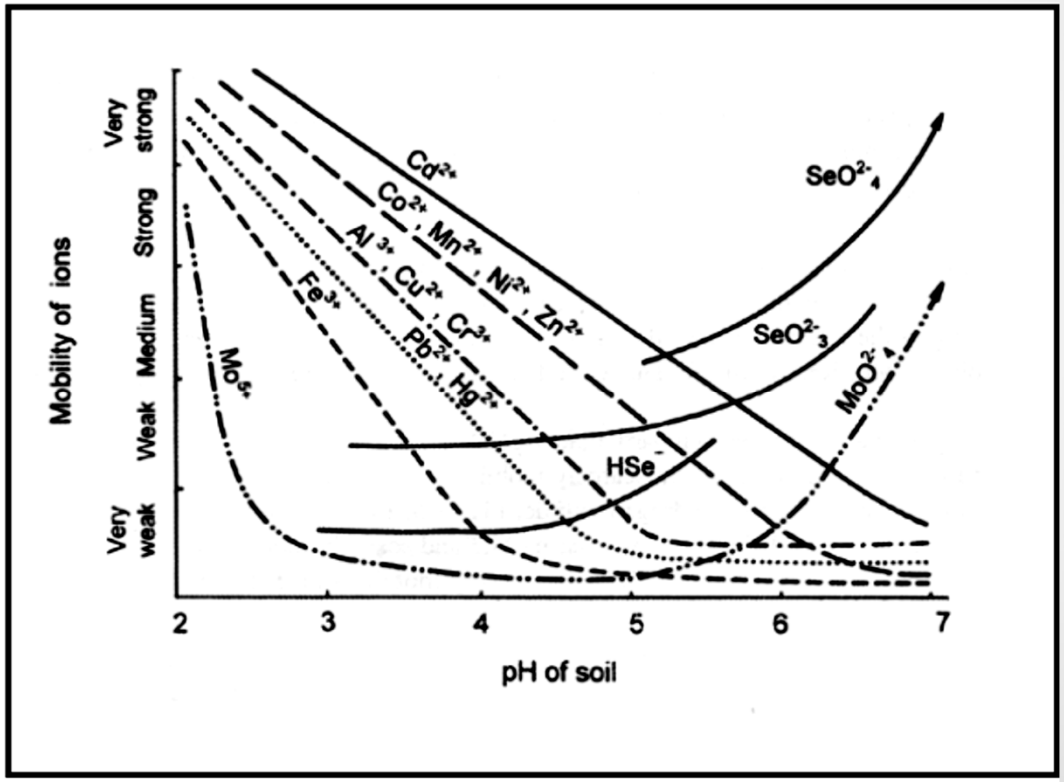
Berti and Cunningham , 2000)

Why is it Difficult to Establish Vegetation in mine areas?

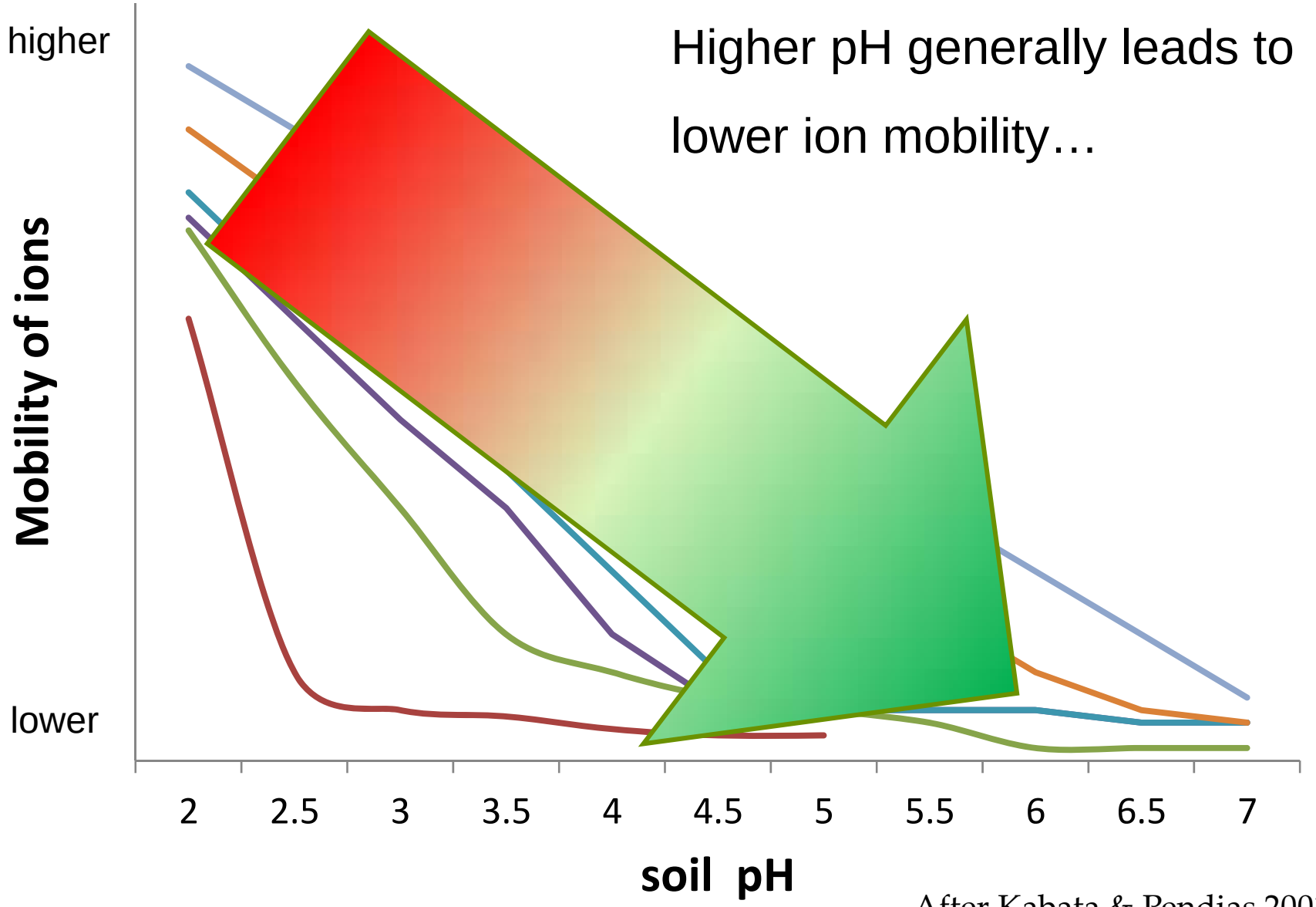
- High soil acidity
- Low nutrient availability
- Toxic heavy metals and metalloids

Establishing Vegetation Using Lime and Organic Matter

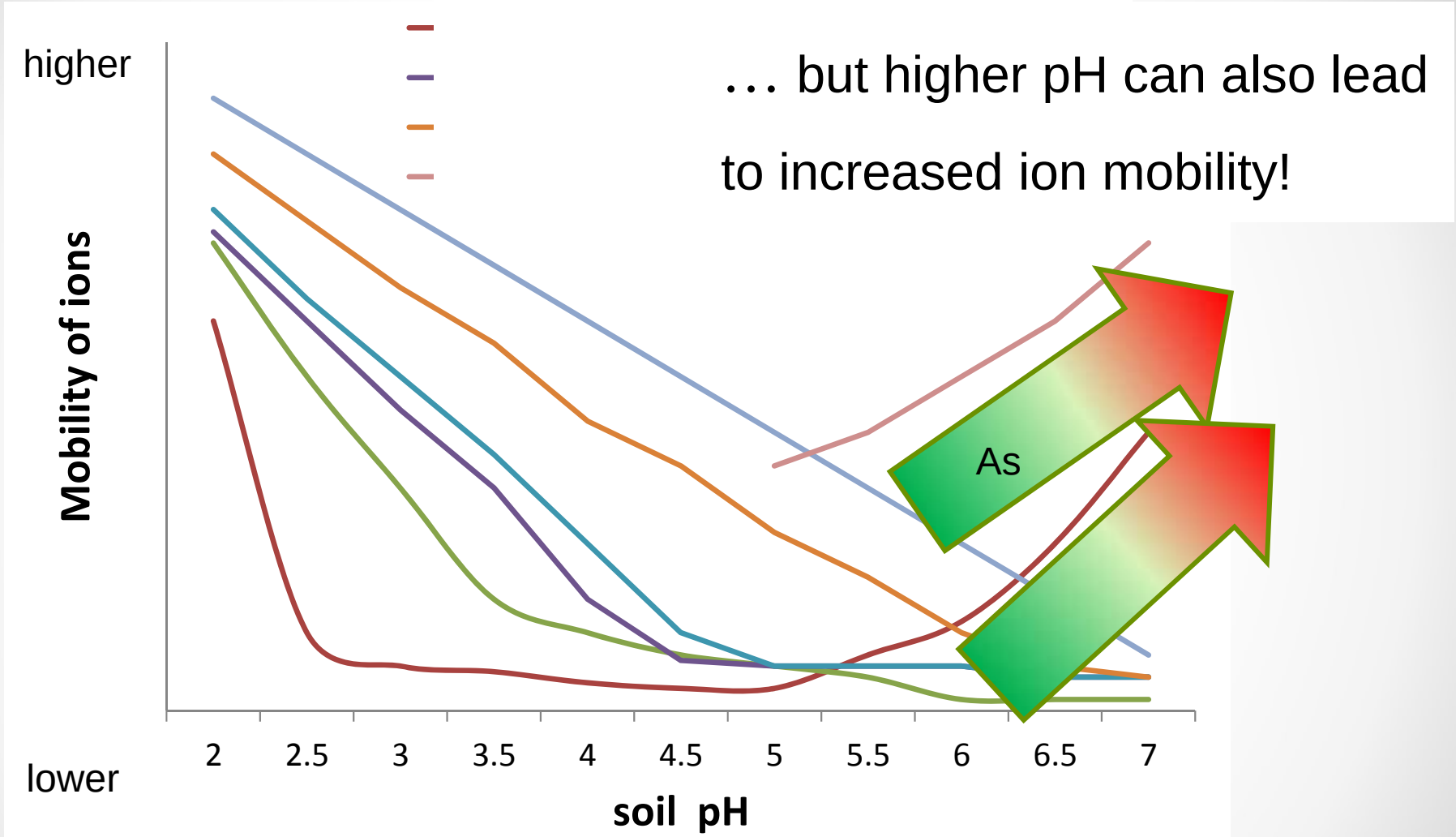
- Increases soil pH
- Immobilizes metals
- Provide nutrients
- Enhance structure



Kabata & Pendias, 2001



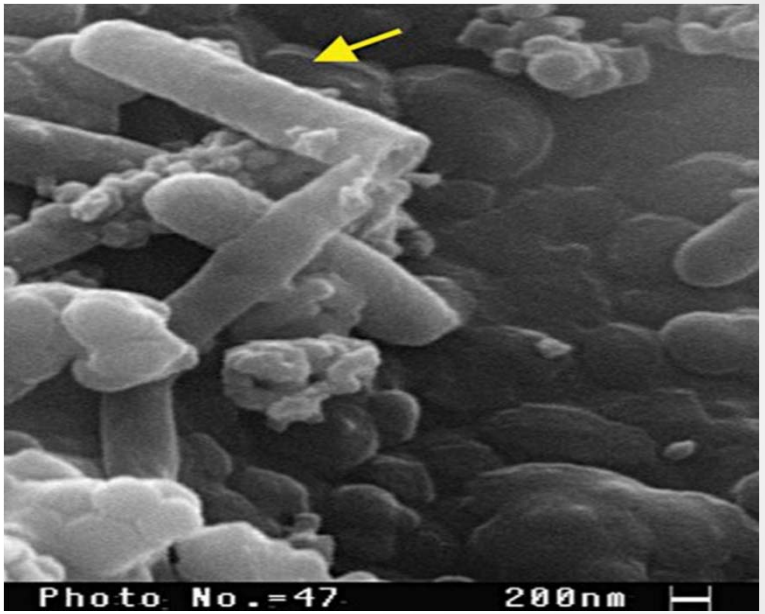
After Kabata & Pendias 2001



After Kabata & Pendias 2001

Another Way to Deal With Arsenic

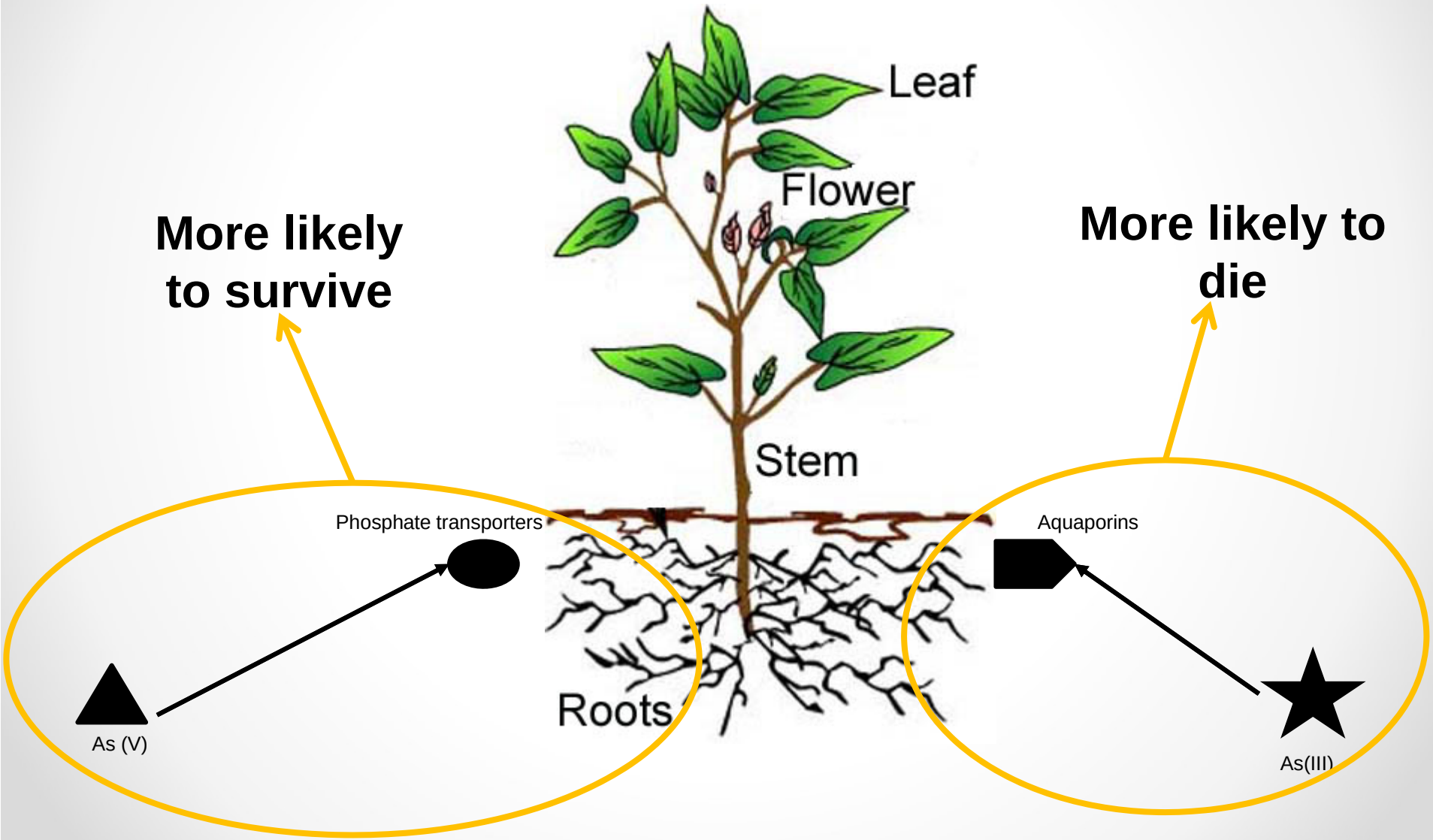
The arsenite oxidizing strain *Agrobacterium tumefaciens* is able to oxidize arsenite (III) to arsenate (V).



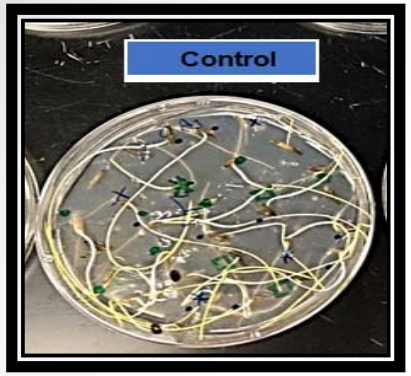
http://perspectives.geoscienceworld.org/content/1/4-5/628/F17.large.jpg

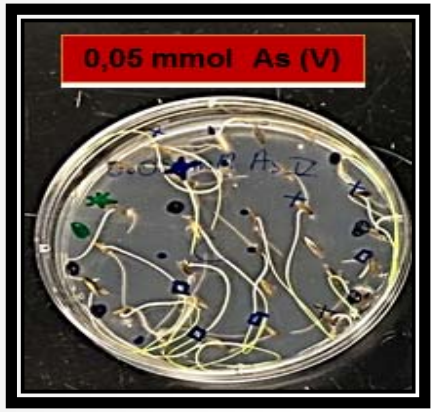
Patent pending

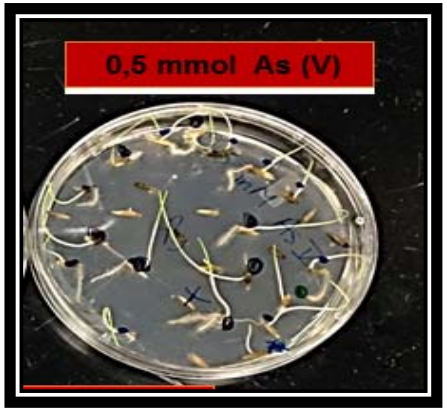
Why Arsenic Species Matter

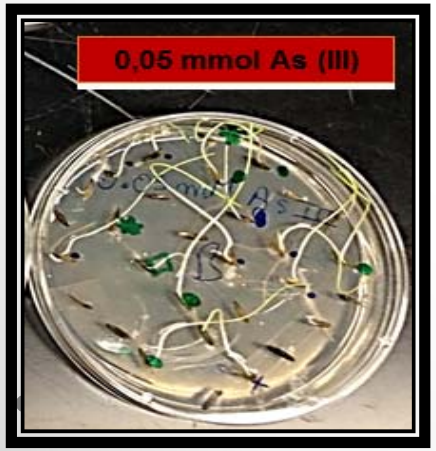


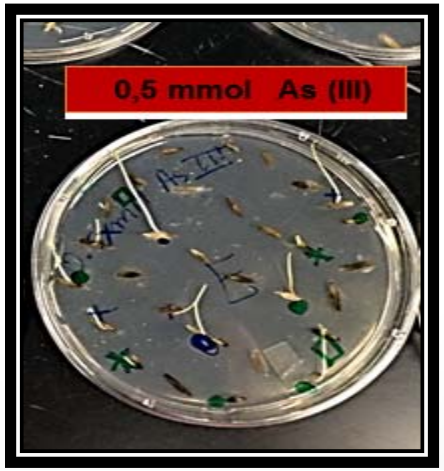
Germination of basin wildrye under different arsenic species

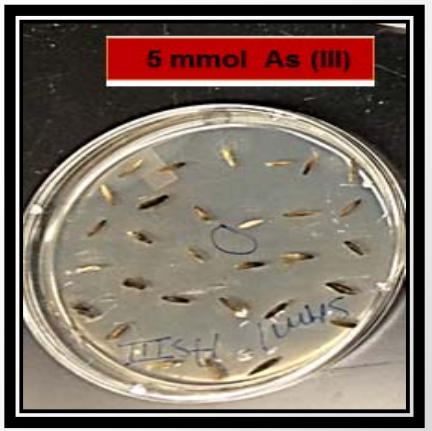




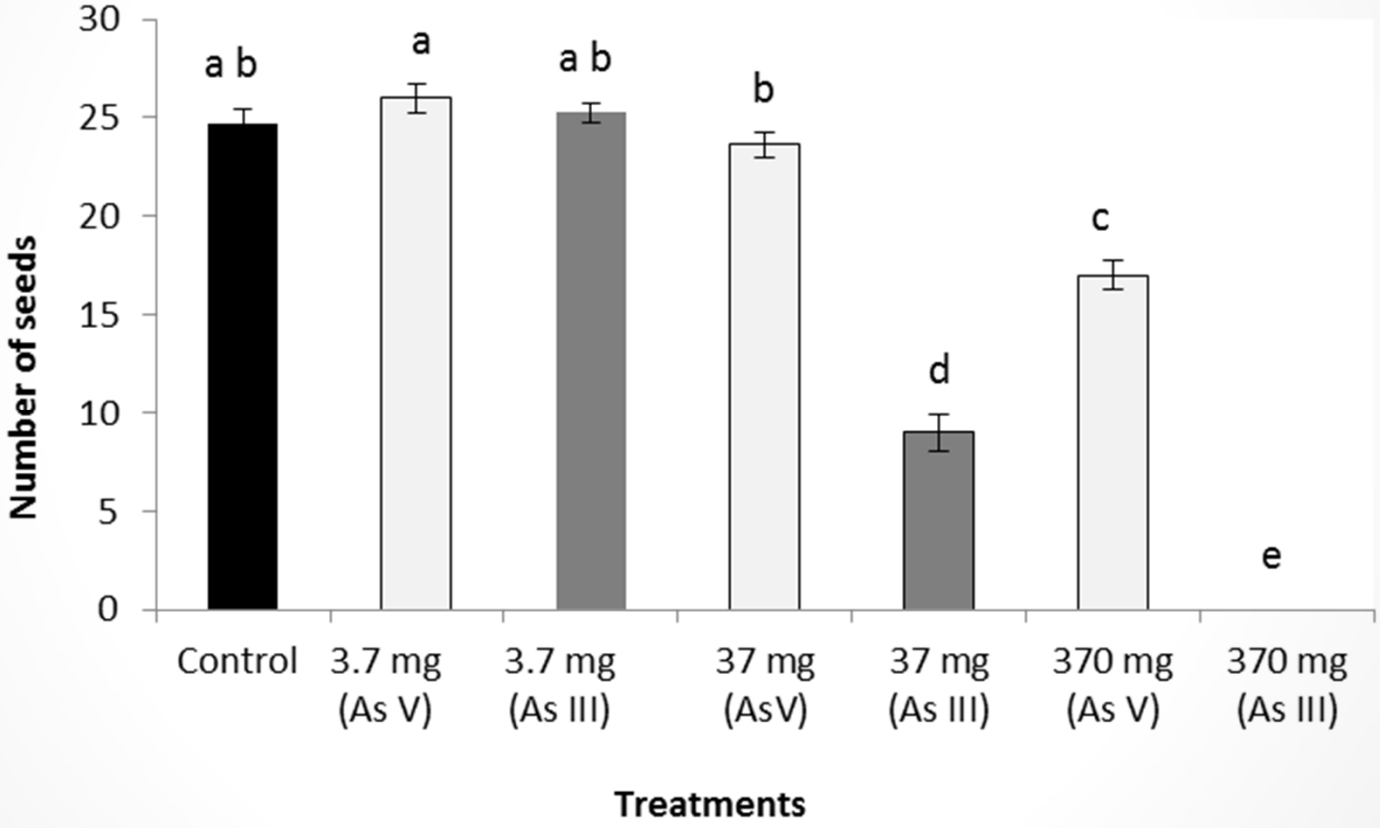








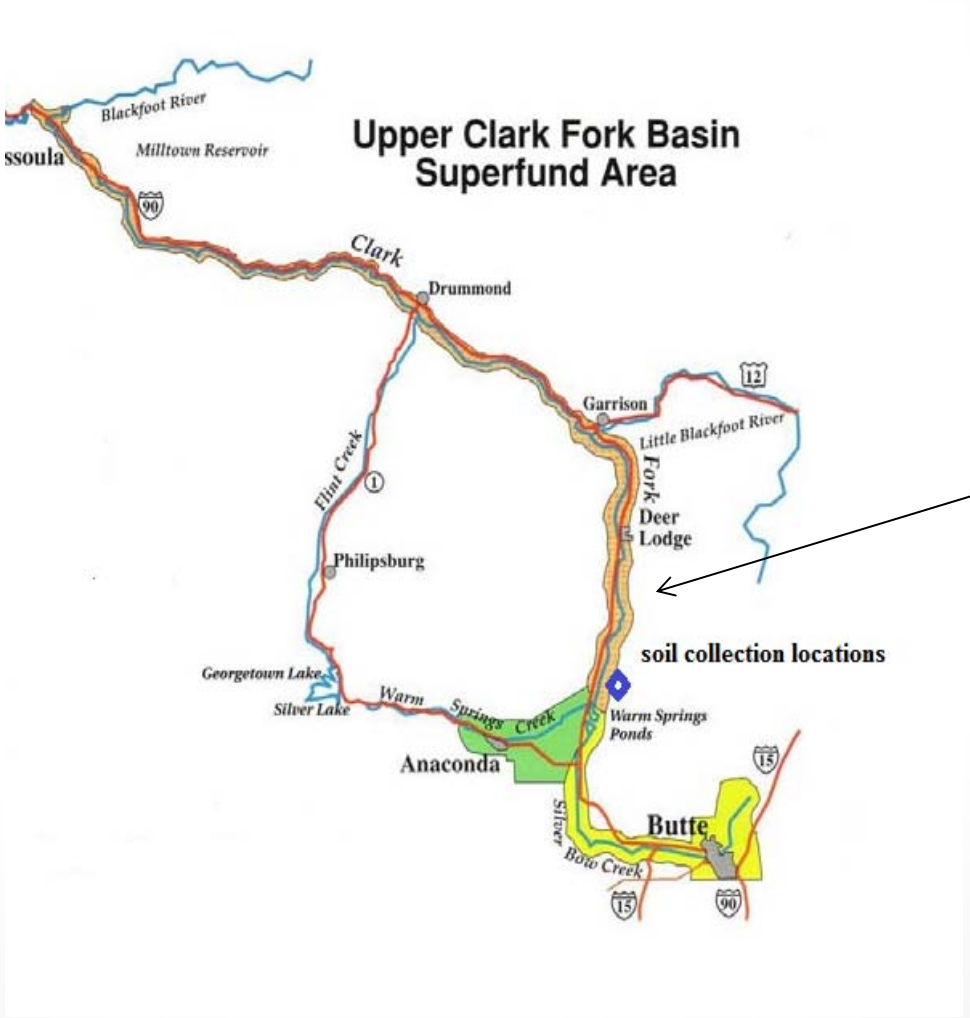
Germination of basin wildrye under different arsenic species



Average germination (means ± 1 SE) of basin wildrye under different arsenic species (As V or As III) at four concentrations (0, 3.7, 37, and 370 mg 0.2 L^{-1}). Means with same letters are not significantly different ($p < 0.05$).

We Evaluate the Use of Bacteria in Combination with Amendments Used In Reclamation

Methods: Study Location



Lompert Ranch

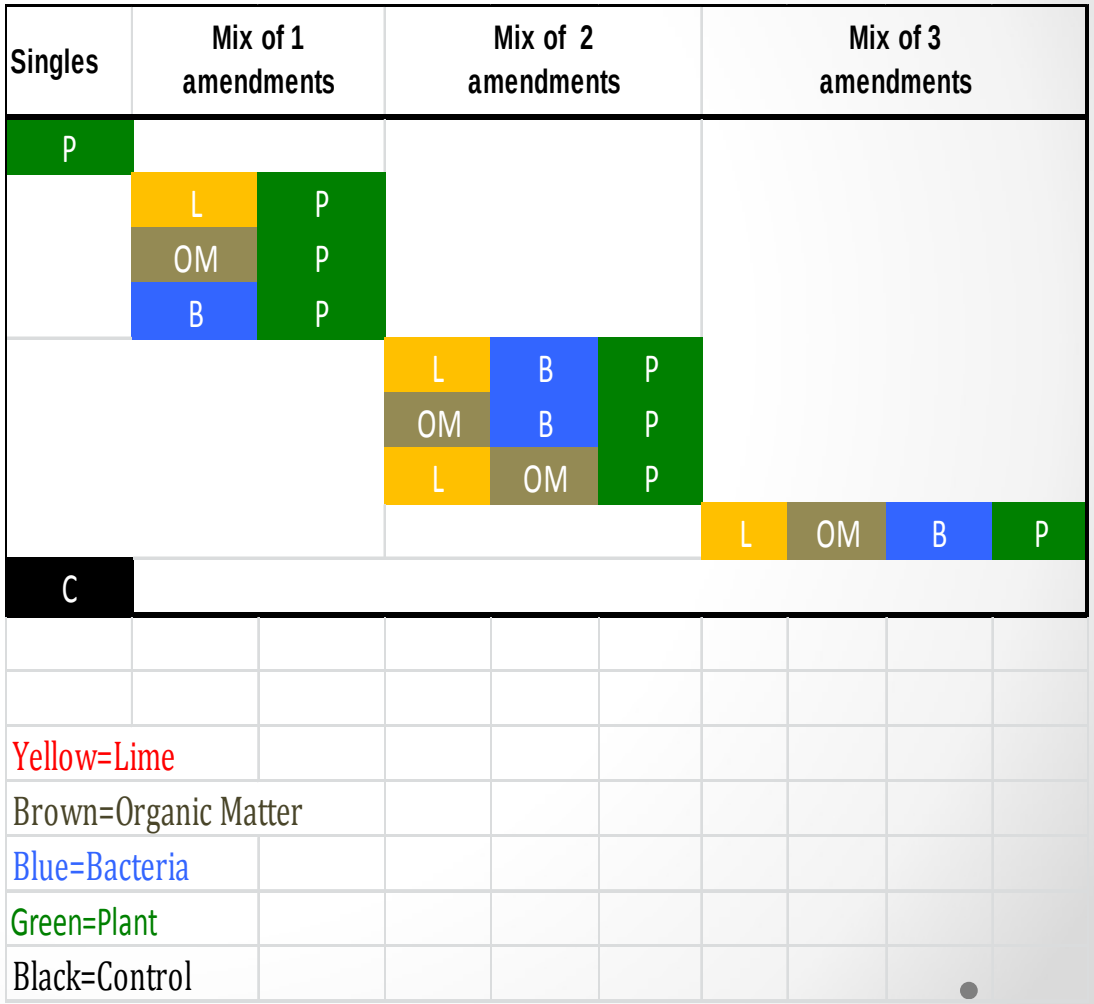
Sois Metal Content

Parameter	Uncontaminated Soils Around Anaconda	Average Tailing Soils (avg±1SE, n=3)
As mg/kg	31	2367±728
Cu mg/kg	45	5673±1894
Pb mg/kg	29	1115±174
Zn mg/kg	110	1913±281
pH	8.5	3.86
	(Neuman *et al*., 2005)	This study

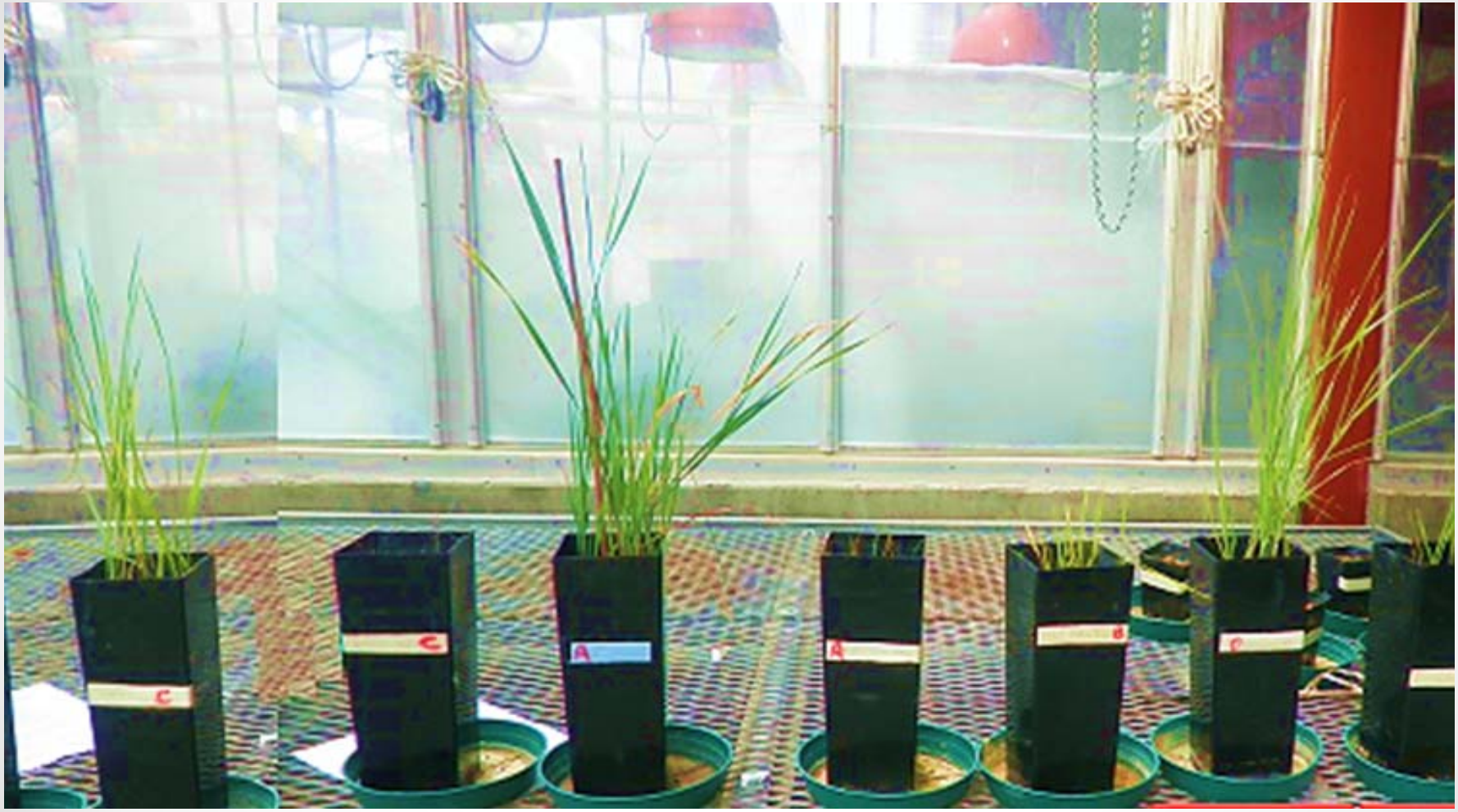
Green House Study 1

TREATMENTS

- Lime
- Organic Matter
- *Agrobacterium tumefaciens*
- *Leymus cinereus*



Plant Biomass



OM+Bacteria

Lime

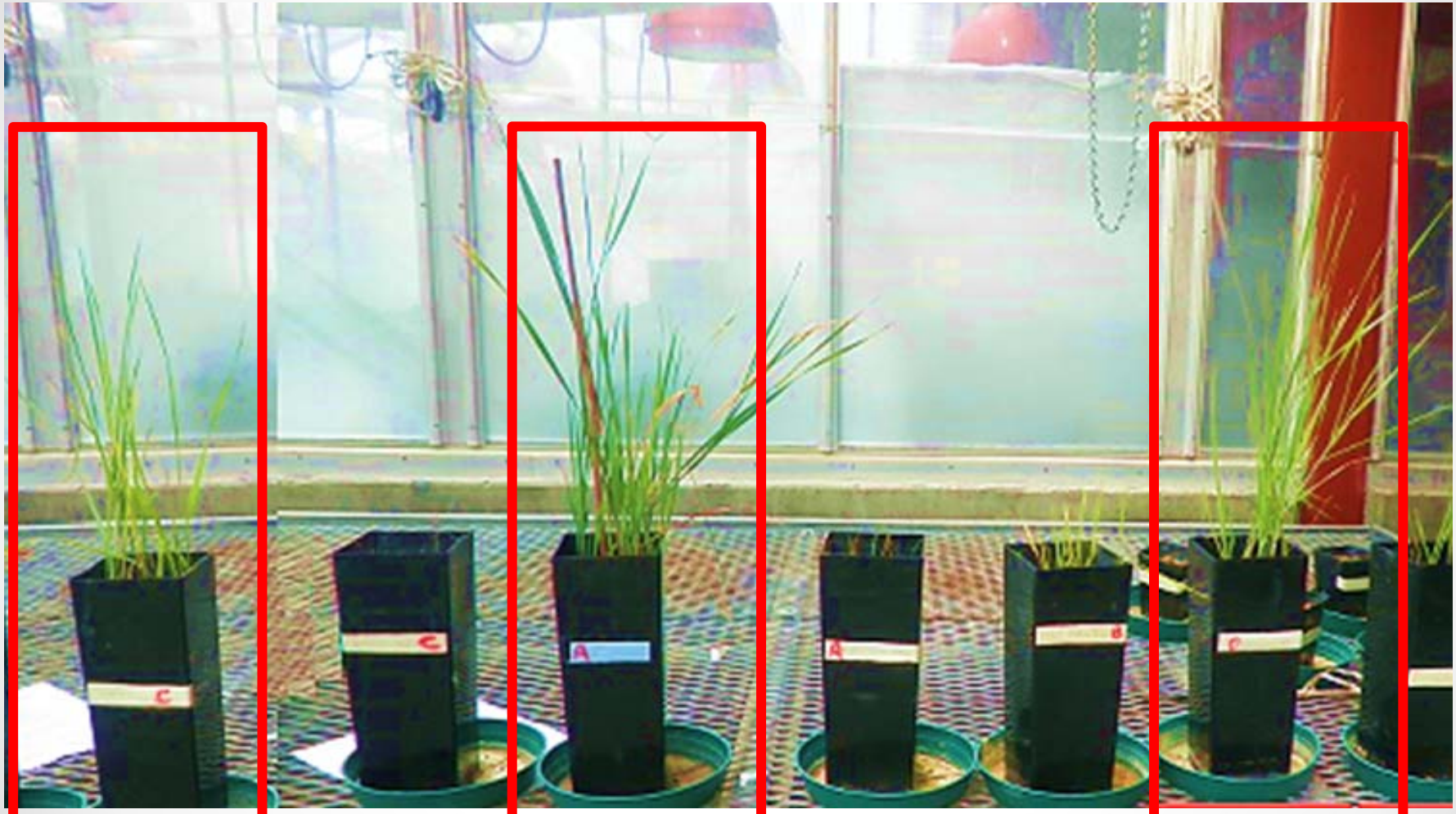
Control

Lime+ Bacteria

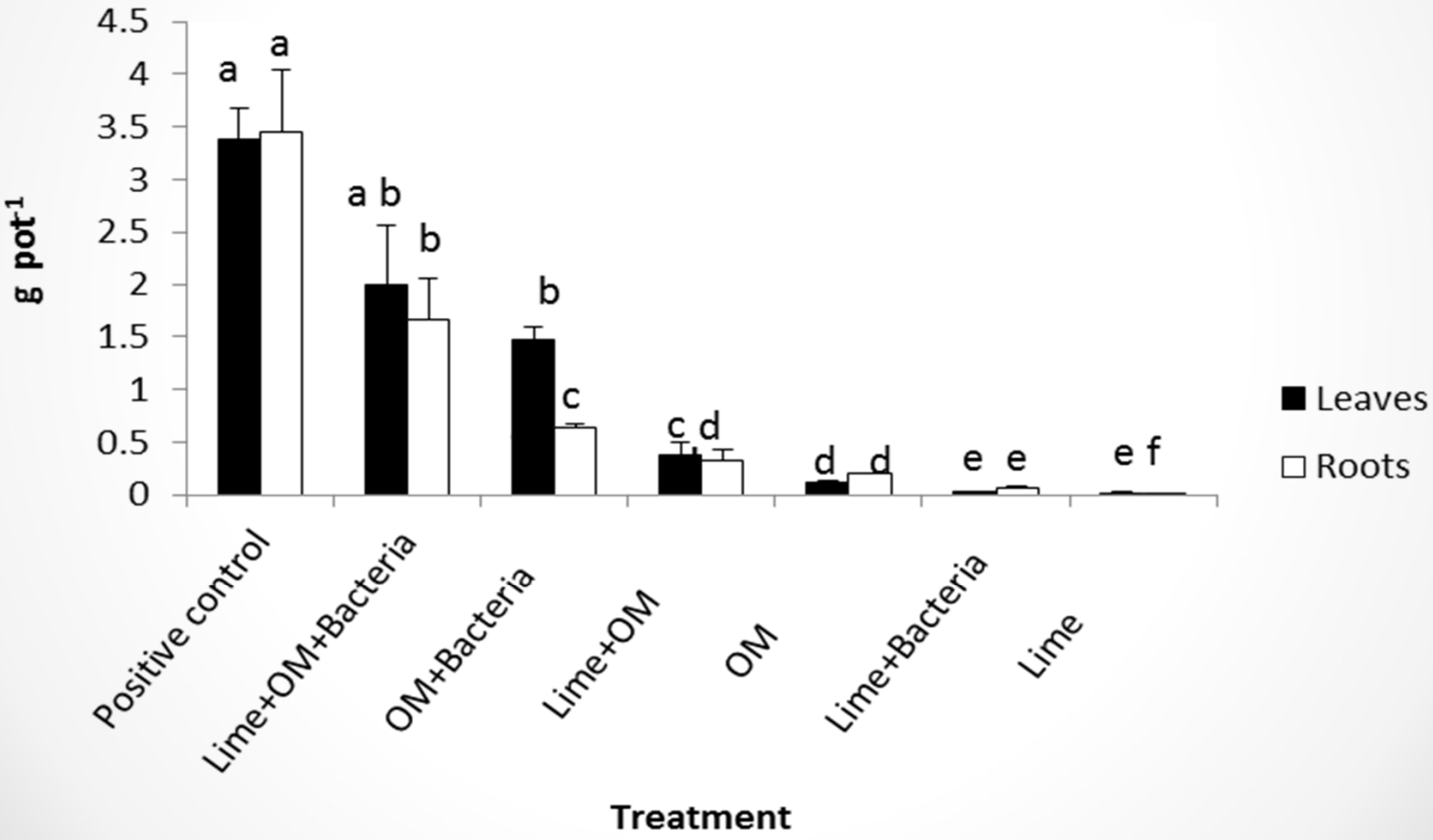
OM

Lime+ OM Bacteria

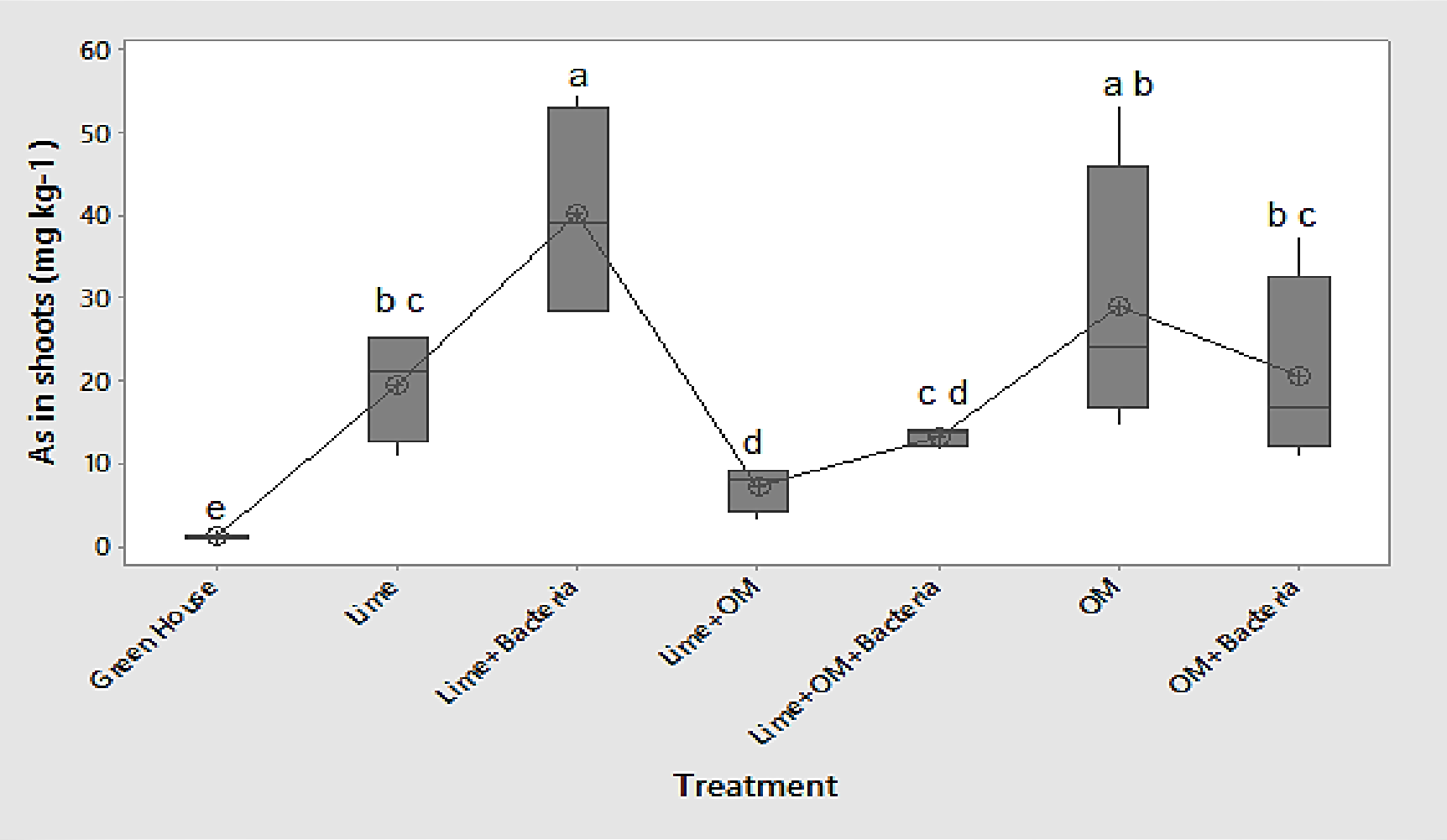
Plant Biomass



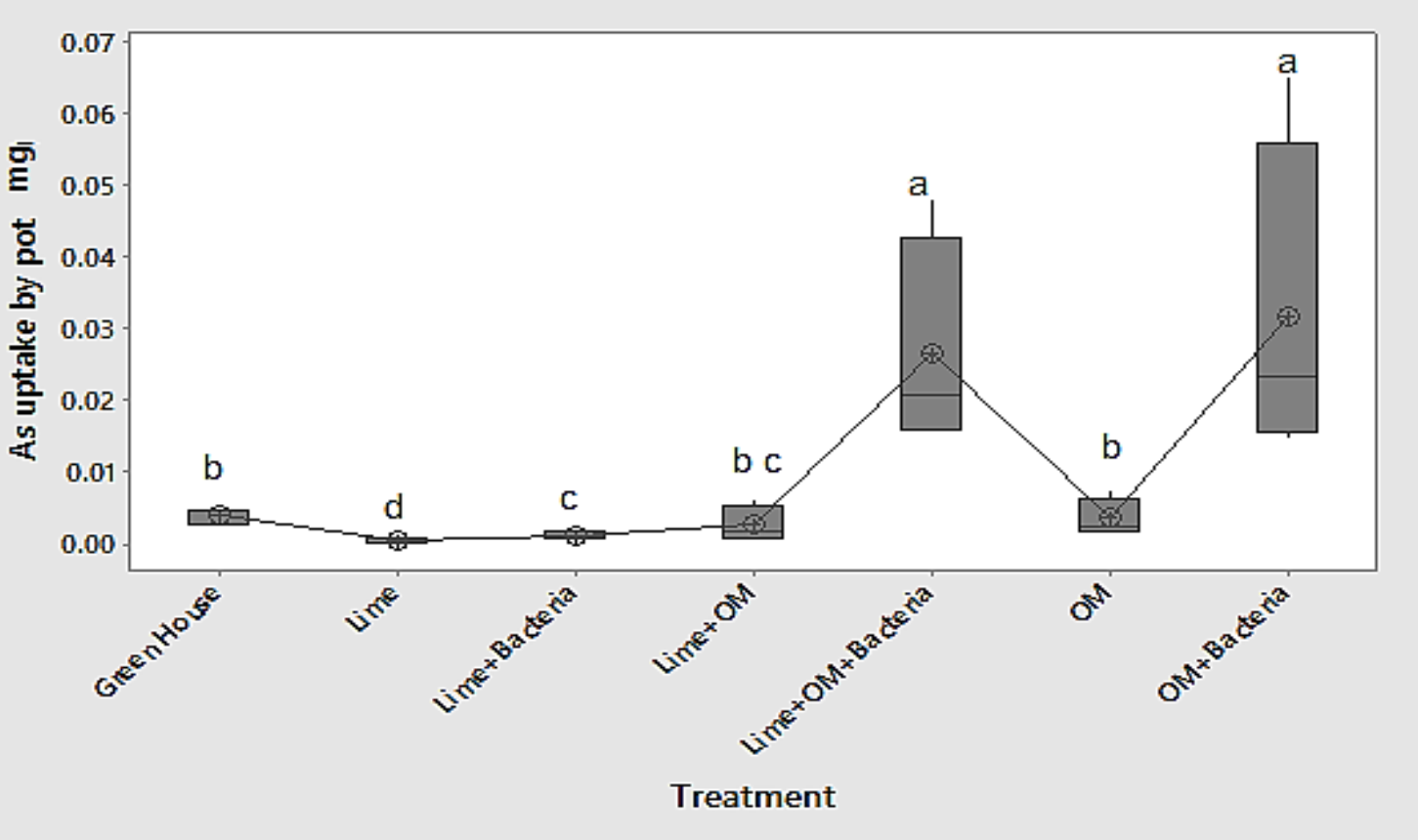
Plant Biomass



Arsenic Accumulation in Shoots



Plant Arsenic Uptake



Arsenic uptake by basin wildrye shoots (As concentration x biomass) after 12 weeks of growing. Circles in the middle of each boxplot indicate mean value per treatment. Means with the same letter are statistically not different (P >0,05)

Green House Study 2

- Organic Matter **1.5%** **5%**

TREATMENTS

Lime+OM

- Lime+OM+ Oxidizing bacteria
- OM+ Oxidizing bacteria

- Lime+OM+ Reducing bacteria
- OM+ Reducing bacteria

AsIII→ AsV

(wildtype)

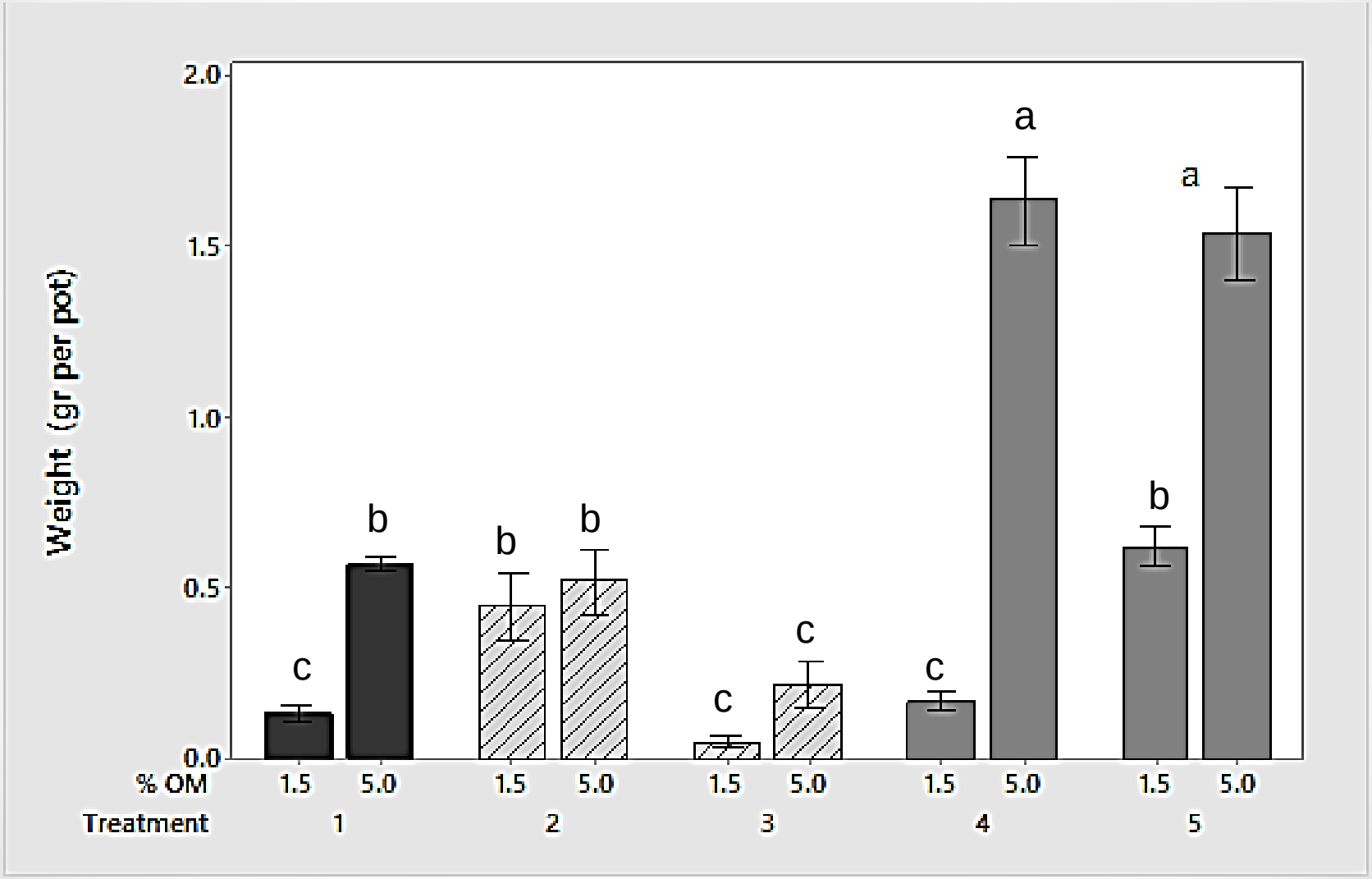
AsV→ AsIII

(mutant)

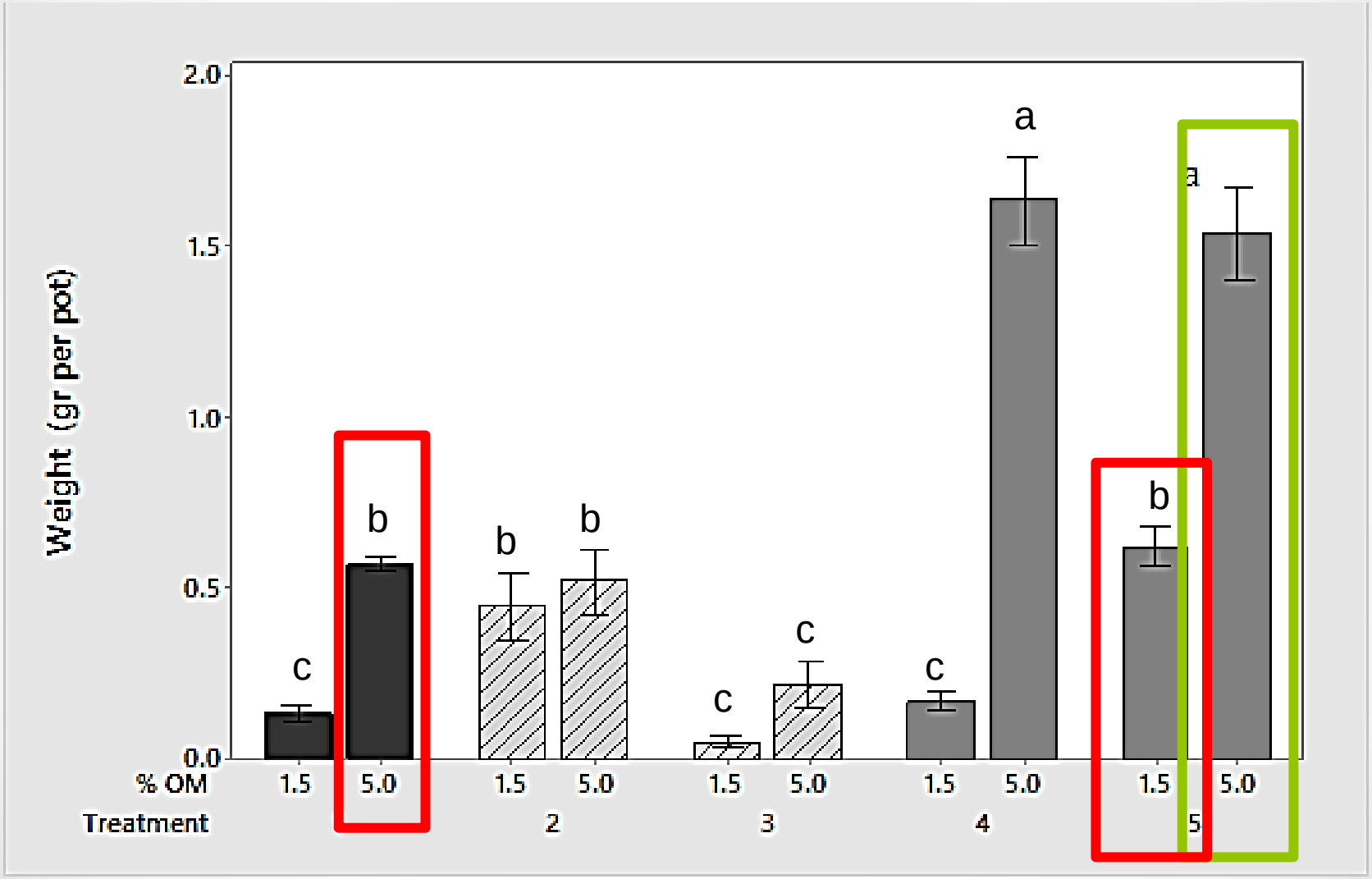
Patent pending

Plant Foliar Biomass

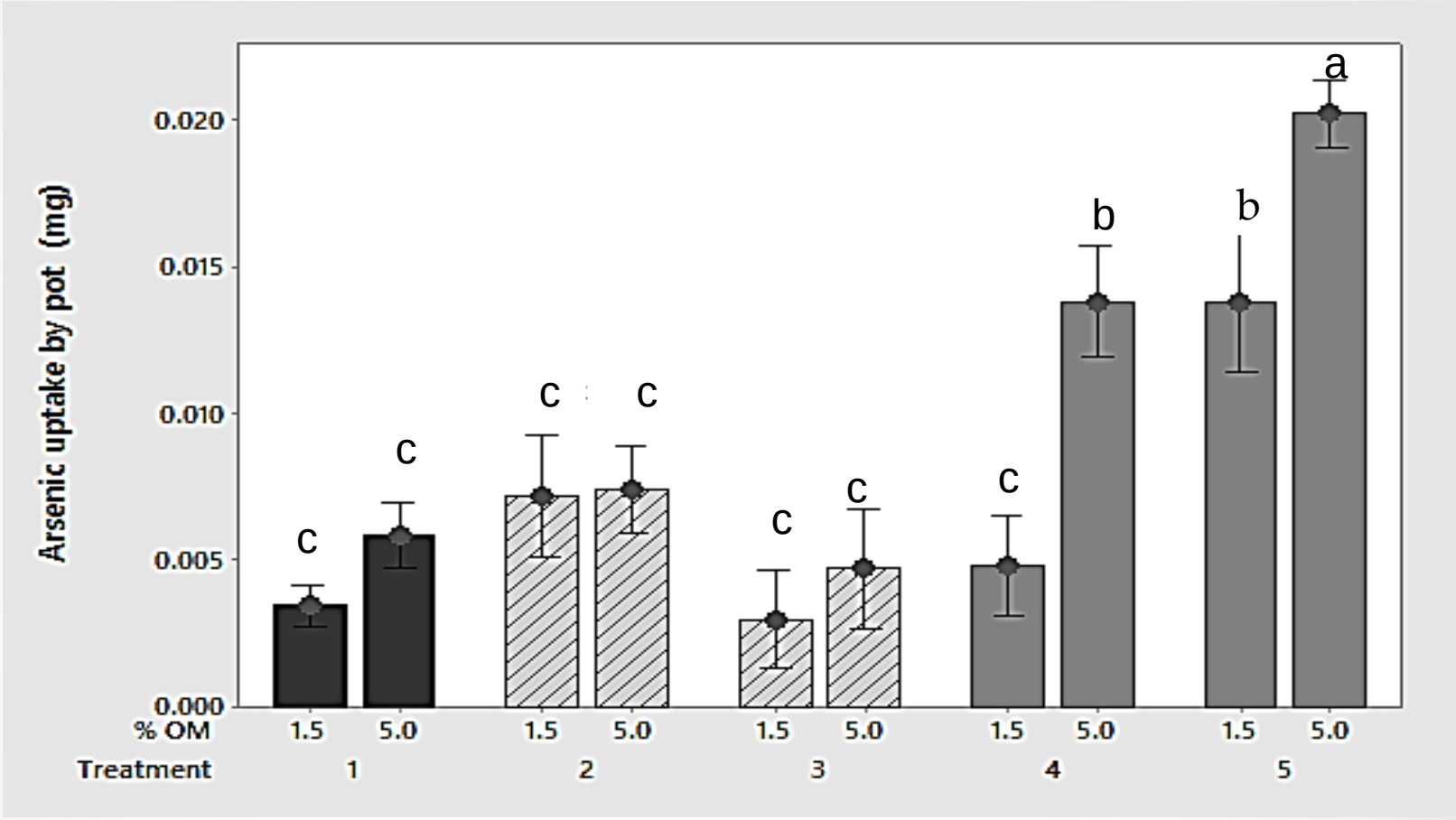
Plant Foliar Biomass



Plant Foliar Biomass



Plant Arsenic Uptake



Lime +OM

Lime+OM+ Red bacteria

OM+ Red bacteria

Lime+OM+ Ox bacteria

OM+Ox bacteria

Acknowledgments

Tony Hartshorn

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Yanacocha

Questions

Good

Cheap **Fast**