Efficacy of Designer Biochars with or without Lime Application for Remediating Heavy Metals in Mine Spoil Soils

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Take Home Message(s)

Miscanthus biochar + Lime Treatments:

- Increased/improved pH of acid mine spoils;
- Improved the uptake of critical plant nutrients (e.g. P, K, Ca) while reducing potential heavy metal uptake of plants; and
- Reduced concentrations of heavy metals (e.g., Al, Cr, Zn, Ni, Mn, Pb, Cu and Cd) in the soils.

Formosa Mine Superfund Site
Riddle, Oregon

The acid rock drainage flowing from the mine and mine materials have severely degraded 13 miles of Middle Creek and the South Fork of Middle Creek, affecting macroinvertebrates, resident fish, coastal steelhead trout, and Oregon coastal Coho salmon.

map courtesy Google and Wikipedia - 2008

- The 76-acre Formosa Mine Superfund Site was originally mined for copper and zinc from approximately 1910 to 1937.
- The mine was reopened in 1989 by Formosa Exploration, Inc. and its parent company Formosa Resources Corporation.

SUPERFUND Fact Sheet

Formosa Mine Superfund Site

Douglas County, Oregon

U.S. Environmental Protection Agency, Region 10 — August 2008

This fact sheet provides information about the Formosa Mine Superfund Site, located on Silver Butte, one of the headwaters of the South Fork of Middle Creek. This site is located approximately 10 miles south of Riddle, Oregon in Douglas County.

The site was added to the Environmental Protection Agency (EPA) National Priorities List on September 19, 2007, because heavy metals and acid mine drainage at the site pose a risk to people and the environment.

Biochar Potential: Mine Spoil Remediation and Phytostabilization

- Biochar's ability to sequester metals has caught the attention of the reclamation sector.
- We proposed that biochar is a suitable amendment to remediate heavy metals in mine spoils.

Biochar Potential: Working Hypotheses

- Improve chemical conditions for enhance plant growth;
- Better plant growth in mine spoils will improve phytostabilization; and
- Increase containment of metal-laden while reducing potential metal uptake of plants.

Miscanthus senensis: Chinese Silver Grass

It is a warm-season grass. It flowers in October in Oregon. In North and South Carolina, it flowers from September through November.

In Southeast, Chinese silvergrass flowers from August to November and produces seed from September to January.

Objectives

- We conducted laboratory and greenhouse experiments to determine the ability of miscanthus biochars with or without lime in improving soil pH, nutreint contents and sequestations of heavy metals; and

- We examined the capacity of designer biochars with or without lime to limit heavy metals uptake by blue rye grass grown in mine spoils.

Formosa mine site (Riddle,OR)

2016 Greenhouse study:

- Used Miscanthus biochar (18.5% ash, pH = 10)
- Added 0.8% lime (CaO)
- Added 200 kg N/ha (~0.2205 g/pot)
- Planted Wild Blue Rye (Native species for OR)
- Had lime vs. no lime trt.
- Had biochar vs. no biochar trt.

Soils (Formosa Mine): 2,150 g/pot
Amount of water: 15% by weight

Experimental Design and Treatments

Experimental Design: Randomized Complete Design; Greenhouse; 4 Reps

Experimental Treatments:

- T1 – Control
- T2 – + Lime
- T3 – + Lime + N
- T4 – 1.0% Biochar + N + 0 Lime
- T5 – 2.5% Biochar + N + 0 Lime
- T6 – 5.0% Biochar + N + 0 Lime
- T7 – 1.0% Biochar + N + Lime
- T8 – 2.5% Biochar + N + Lime
- T9 – 5.0% Biochar + N + Lime

Miscanthus Biochar

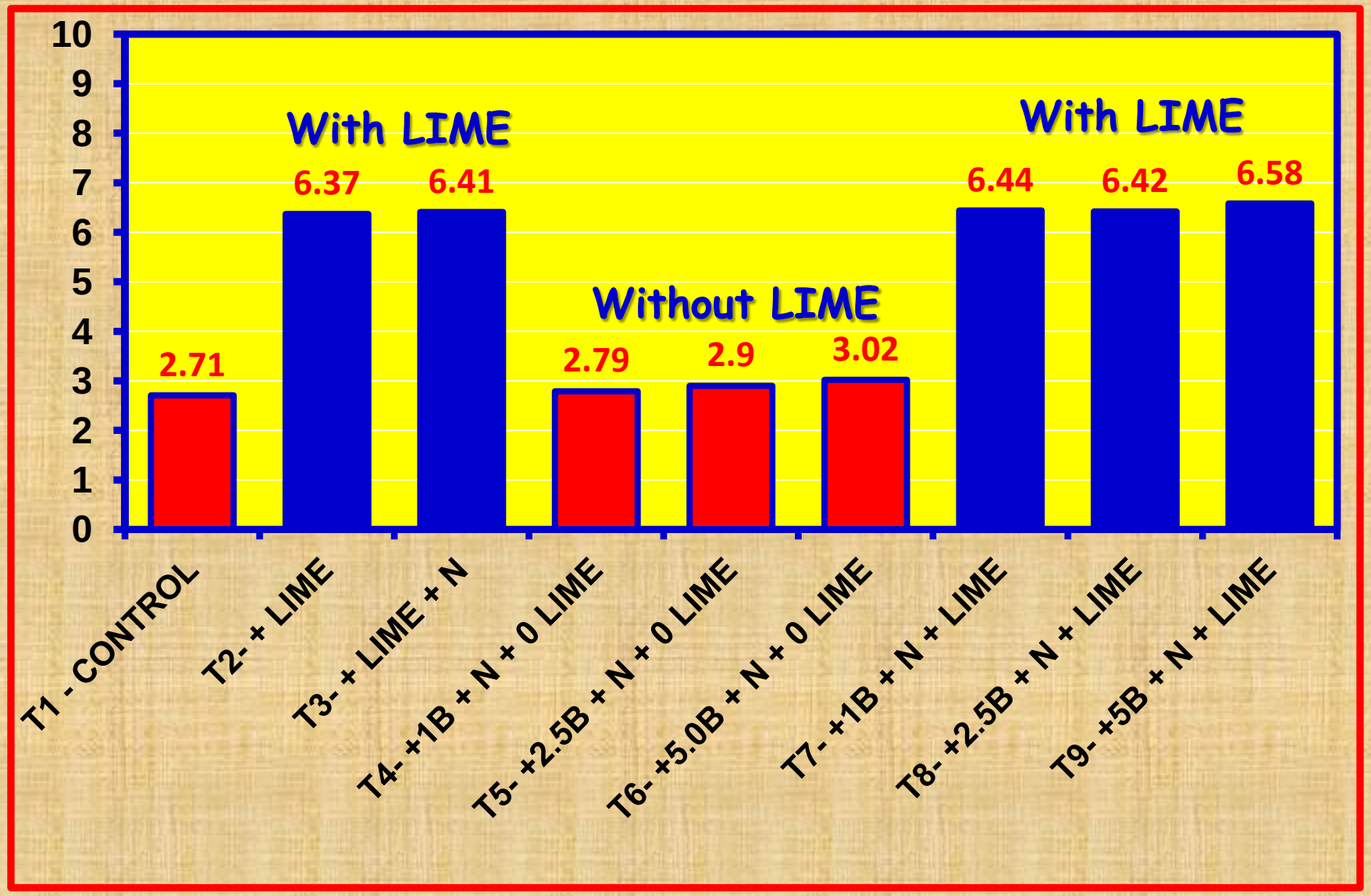
Soil Sampling and Soil Analyses

- Soil Samples were air-dried and sieved.

- Extracted with double acid (0.025 N H_2SO_4 + 0.05 N HCl). Analyzed for extractable nutrients using an ICP.

- Soil Samples were also analyzed for total Carbon and total N using LECO; pH and EC (1:2 soil:water) using pH meter.

Biochar + Lime Effects on soil pH



Biochar + Lime Effects on K, Ca, Mg & S

Expt'l Treatments	K	Ca	Mg	Fe
	----------(mg/kg)----------			
T1 - Control	16.1e*	82d	93cd	506a
T2 - + Lime (L)	29.4e	2189bc	121a	308c
T3 - + Lime + N	29.3e	2174c	112ab	296c
T4 - 1.0%B + N + 0 L	28.2e	128d	105bc	494a
T5 - 2.5%B + N + 0 L	84.2d	113d	89d	449b
T6 - 5.0%B + N + 0 L	202.5b	151d	96cd	430b
T7 - 1.0%B + N + L	94.4d	2299bc	111ab	243d
T8 - 2.5%B + N + L	131.8c	2500ab	116ab	283c
T9 - 5.0%B + N + L	236.9a	2555a	112ab	256d
LSD ($p<0.05$)	17.3	226	15	26.7

Biochar + Lime Effects on Al, Cr, Zn & Ni

Expt'l Treatments	Al	Cr	Zn	Ni
	----------(mg/kg)----------			
T1 - Control	435ab	0.542a	45.4abc	0.694bc
T2 - + Lime (L)	297d	0.510d	39.9bcd	0.658bc
T3 - + Lime + N	274de	0.51cd	36.4cde	0.636c
T4 – 1.0%B + N + 0 L	464a	0.536a	54.1a	0.725b
T5 – 2.5%B + N + 0 L	396bc	0.524b	46.8ab	0.690bc
T6 – 5.0%B + N + 0 L	374c	0.523b	46.9ab	0.841a
T7 – 1.0%B + N + L	264de	0.514cd	27.2e	0.622c
T8 – 2.5%B + N + L	295d	0.519bc	38.6bcd	0.654bc
T9 – 5.0%B + N + L	226.4e	0.507d	35.6de	0.645c
LSD ($p<0.05$)	49.5	0.007	9.8	0.08

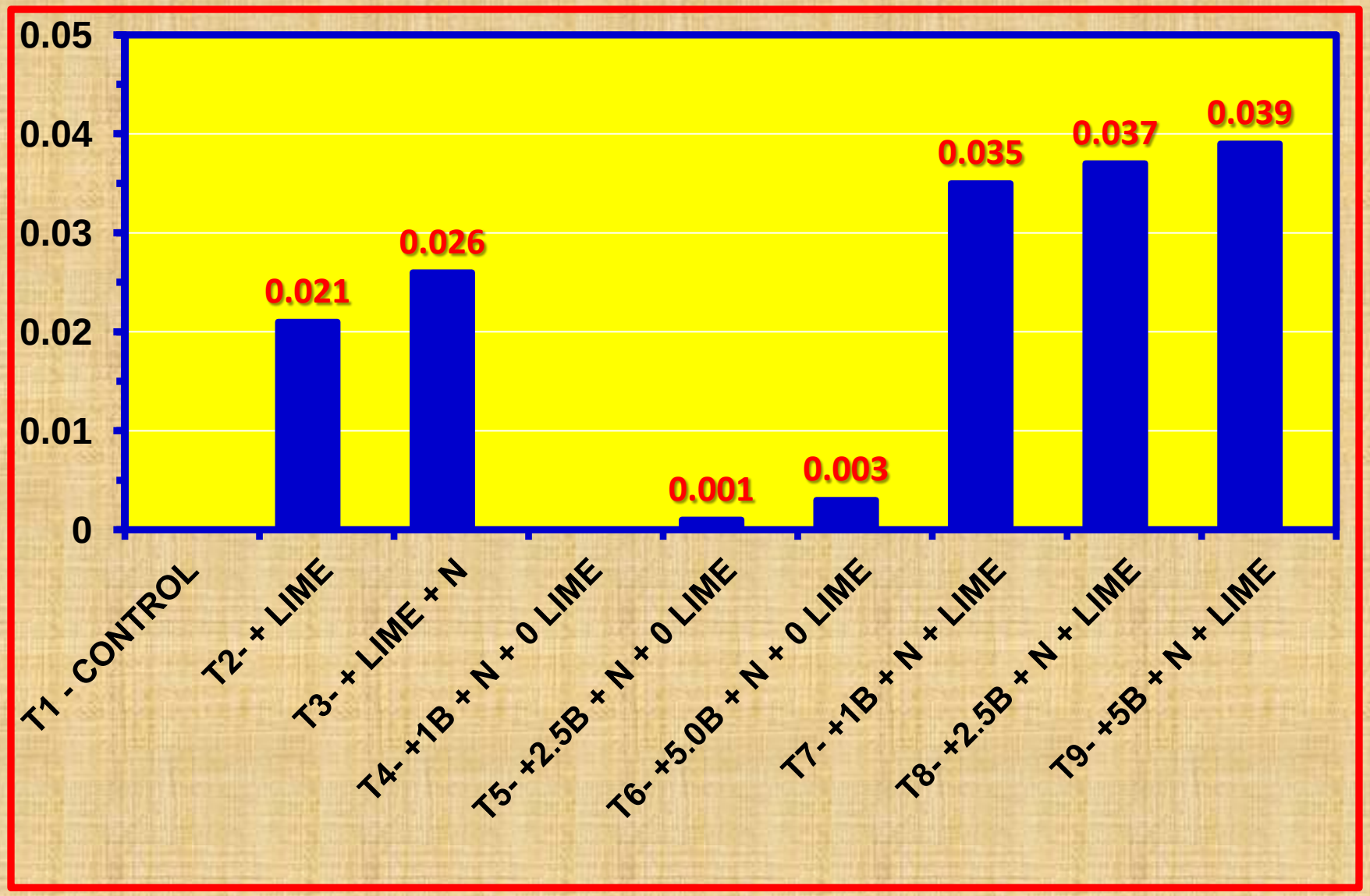
Mehlich 3 extractable Cu concentrations measured in Formosa spoil after treatment with lime and Miscanthus biochar (2-way ANOVA, $p < 0.05$)

Biochar (%)	+ Lime	0 lime
0	18.4 a,z	30.3 b,a
1.0	13.2 a,a	36.6 b,a
2.5	17.6 a,a	30.0 b,a
5.0	13.5 a,a	28.7 b,a
average	15.7a	30.8 b

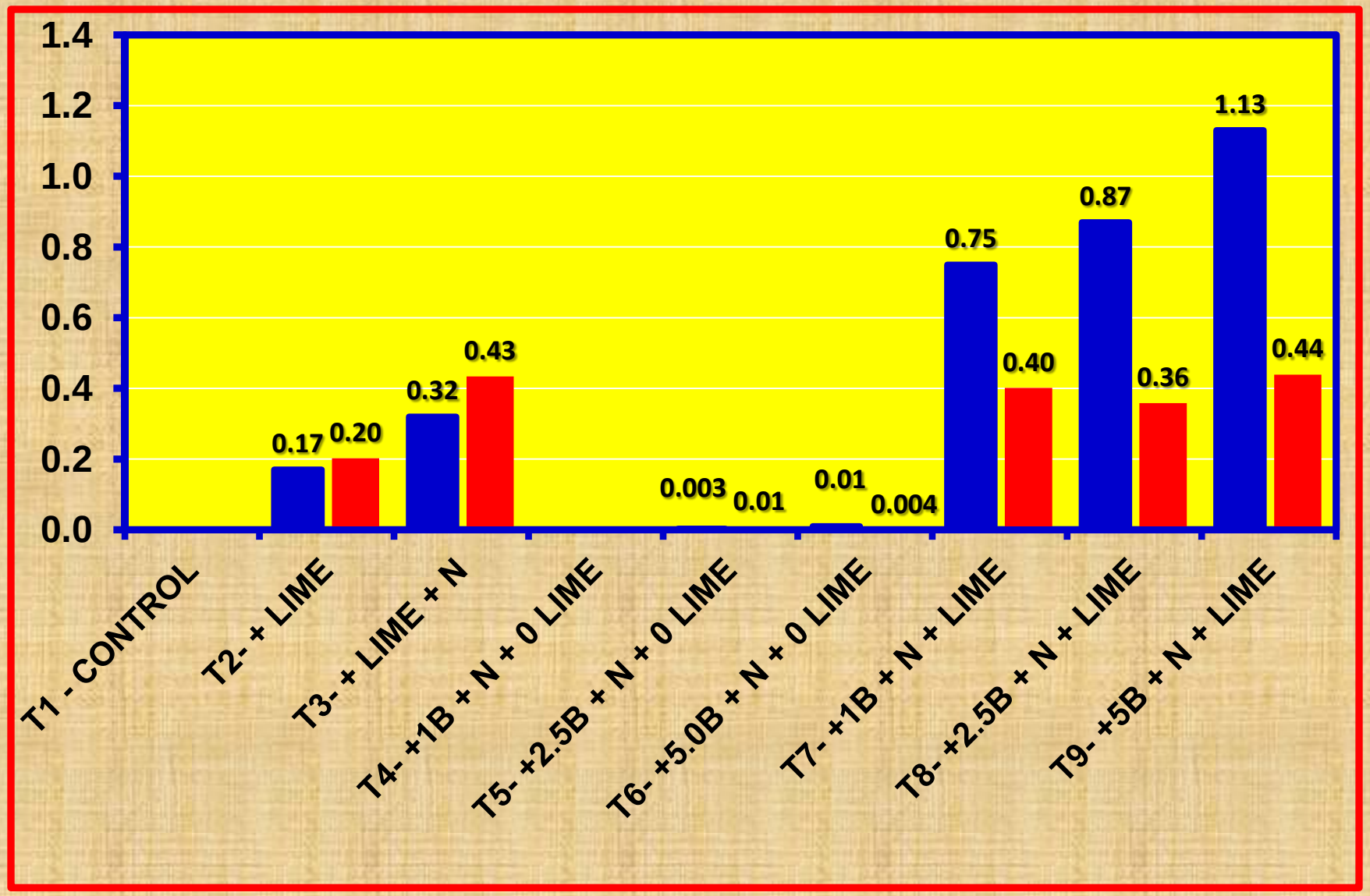
First letter shows significance differences between columns (lime vs. 0 lime)
Second letter shows significant differences within a column (%biochar vs. lime, and 0 lime).

Mehlich 3 extractable Cu is more impacted by lime than by the amount of Miscanthus biochar.

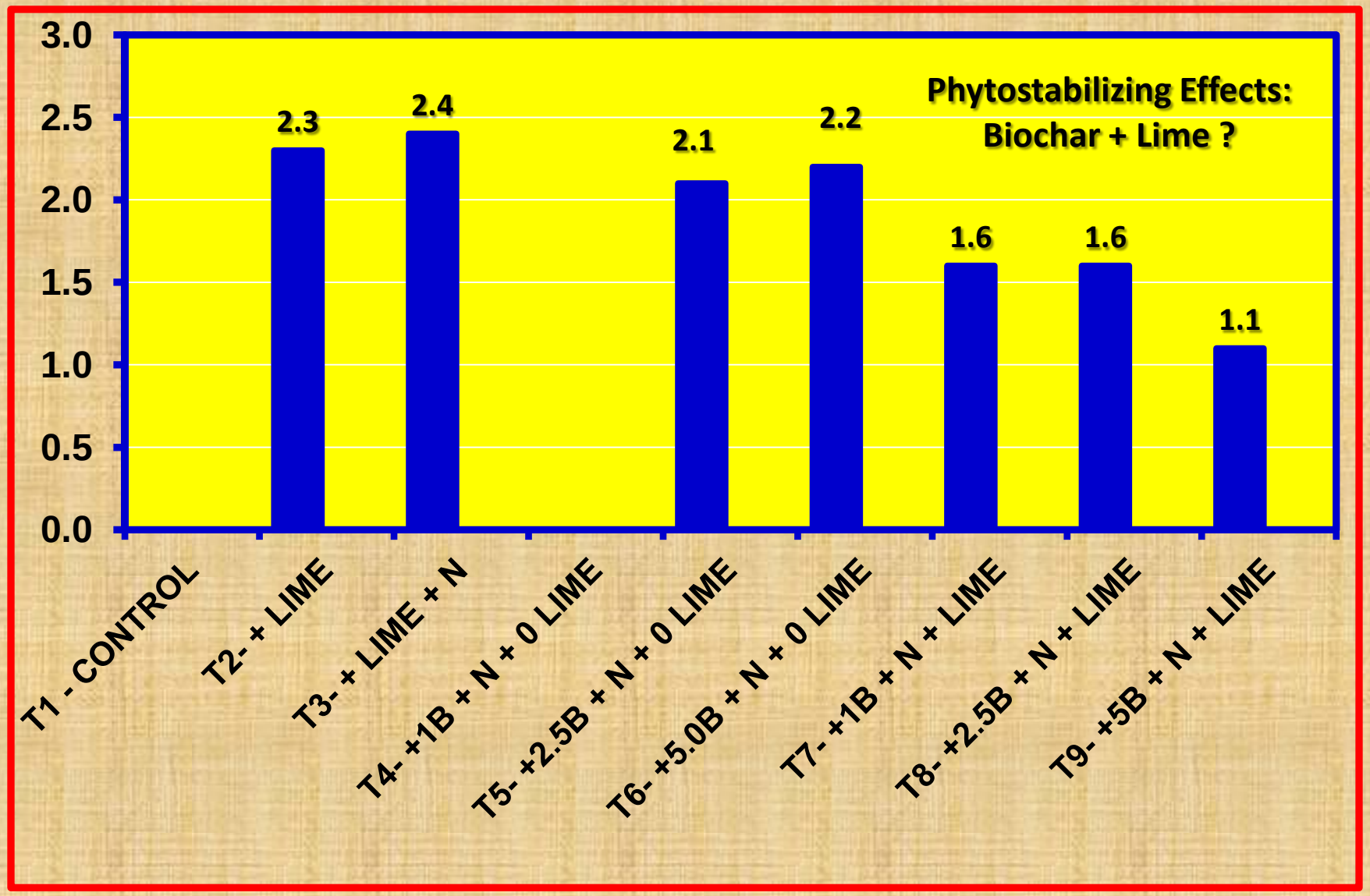
Biochar + Lime Effects on P in Plant Tissue (g/kg)



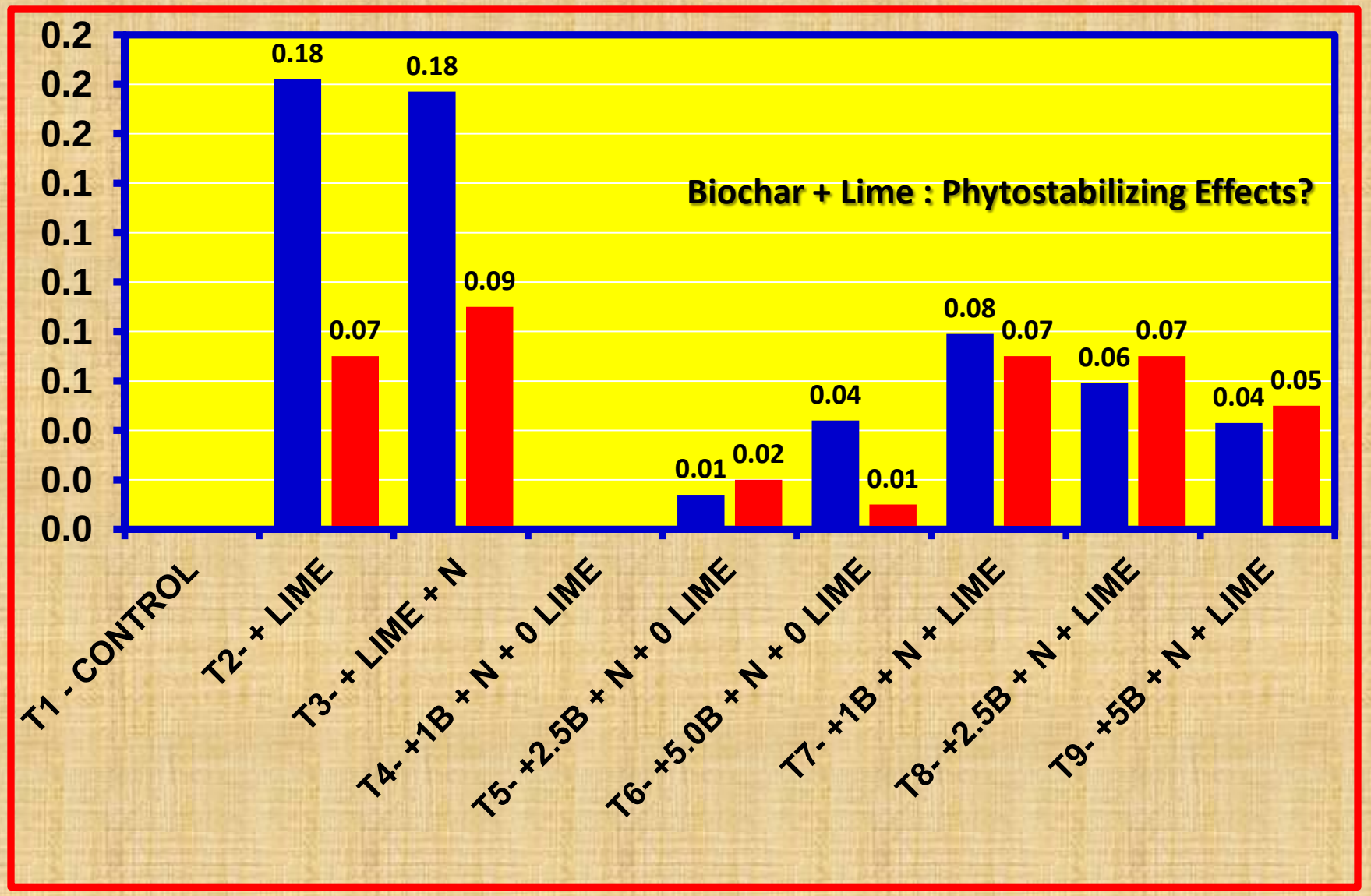
Biochar + Lime Effects on K (blue) and Ca (red) in Plant Tissue (mg/kg)



Biochar + Lime Effects on Cu in Plant Tissue (mg/kg)



Biochar + Lime Effects on Pb (blue) and Cd (red) in Plant Tissue (mg/kg)



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Take Much for your Attention

QUESTIONS AND ANSWERS

USDA ARS

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY