MICHIGAN OHIO UNIVERSITY TRANSPORTATION CENTER

Alternate energy and system mobility to stimulate economic development.

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From Phyto-Remediation to Phyto-Mining: Maximizing Value in Producing Bio-diesel From Pennycress

FINAL REPORT

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EXECUTIVE SUMMARY

A series of pennycress seeds were germinated hydroponically in solutions spiked with varying amounts of lead (II) nitrate. Uptake of the lead into the roots and stalks of the plants was examined via Energy Dispersive X-Ray Fluorescence (EDXRF). Results and findings show promise for larger scale use of this phyto-remediation technique and the use of EDXRF to quantify it.

Additionally, a plant sample provided by The Power Alternative (TPA) was examined by EDXRF for the presence of lead in the stalk material.

1. Introduction

In our original proposal, we asked, "Wouldn't it be amazing if one type of plant could be used to produce bio-diesel fuel, clean the soil in which it grows, serve as the source of a valuable commodity based on a metal, and do it all without competing for space with food crops? It certainly would be – and pennycress just might be that plant."

We have found since asking this that pennycress grows well in the metro Detroit area and that the uptake of lead in the plants' roots and stems can be measured by EDXRF.

Faculty in the Biology Department at the University of Detroit Mercy (UDM), the Chemistry & Biochemistry Department of UDM, the Civil & Environmental Engineering Department of UDM, and the company, The Power Alternative (TPA), recognize that the production of biofuel from novel, non-food plants is an important goal for the nation in the near future. In Michigan, decades of industrial activities and manufacturing plants have left a number of properties environmentally degraded, contaminated with petroleum constituents, heavy metals, organic and inorganic chemicals, and containing dilapidated buildings and wreckage. Brownfields in urban areas create unique environmental challenges that can become a big issue. They can contribute to urban sprawl, limit economic development and growth, decrease employment opportunities, reduce tax revenues, and potentially cause harm to the environment and human health. It is also recognized that cities such as Detroit often have heavy metal pollutants in the soils of the area, mostly from previous occupancy of the sites by heavy industry, which need to be remediated before the areas are again safe for human use and habitation. A possible solution to both situations is the growth of specific crops that will produce a biofuel, while at the same time remediating the soil. Such plants, called hyper-accumulators or phytoremediators, hold significant promise as an inexpensive, biologically based way to clean the soil in an urban or post-urban environment. While some studies of different species have been done towards this end, (*1-4*) one such crop – pennycress – appears to be an untapped source as both a feedstock of biodiesel and a remediator of lead or other heavy metals from soil. In addition, pennycress is not a food crop, and thus production of biodiesel from it does not compete with food for humanity.

Importantly, this proposal examines not just the growth of pennycress as a feedstock for bio-diesel and as a soil remediator, but examines the possibility of producing a second product, one or more heavy metal salts, ultimately from the remediation of the soil in which the pennycress is grown, and through the processing of the parts of the plant not used for bio-diesel production. Too often, accumulated heavy metals in plant matter are simply not utilized in any productive manner after phytoremediation. Thus, heavy metals have been captured and removed from soils, but ultimately are just returned to them in a different place and at a different concentration when the accumulator plant matter is dumped in some landfill or compost pile. As far as using plant material, precedents do exist for producing organic materials other than just bio-diesel or bio-ethanol from such.(*5*) As well, a relatively slim body of literature has been published addressing the phytomining of heavy metals for the manufacture of some product.(*6-14*) None however appear to have examined pennycress as the bio-accumulator in an urban scenario, or as a source of what is called "phyto-ore," a starting point for some commercially marketable heavy metal-containing material.

2. Objective

The team desired to measure the uptake of lead into pennycress, to determine if such uptake can be quantified, and to further determine if the lead can then be extracted from the plant matter in pennycress roots and stems, in order to produce a secondary product, most likely lead nitrate. The primary product resulting from the growth of pennycress remains bio-diesel.

3. Scope

This project has the potential to be scaled up in urban areas, or other areas with soil that has been contaminated with lead. This may apply to other plants as well, such as various mustards, but the focus of the current study was pennycress.

4. Methodology

The broad steps for the project included:

1. Growing pennycress plants in a controlled environment, in which the growth solutions have been spiked with varying concentrations of lead (II) nitrate.
2. Separating roots and stems from each of the samples, then drying the plant matter.
3. Examining the samples via energy dispersive X-ray fluorescence spectrometry (EDXRF) to determine the amount of lead taken up in each.

In addition, we took a single sample of plant material grown by TPA, Inc. at their site on Linwood Avenue, and examined it via EDXRF. It was found to have lead in the stems (the roots are not normally harvested, and thus were not provided).

5. Discussion of Results

The uptake of lead in pennycress roots and stems (in ppm) is shown in Figure 1, and the molarities – the concentrations – of lead nitrate solutions from which these samples were grown is listed in Table 1.

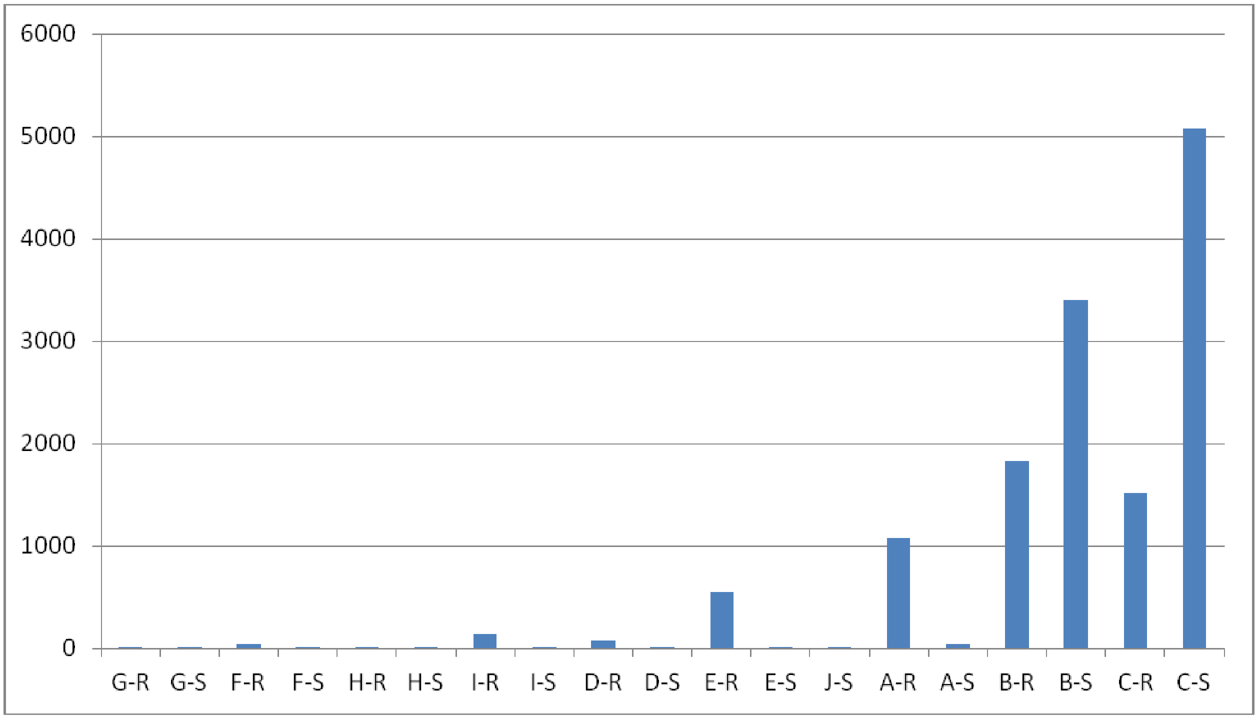

Figure 1. Uptake of Lead in Roots and Stems of Pennycress, Grown In Spiked Solutions

Table 1. Lead (II) Nitrate Concentrations in Plant Growth Solutions

Alphabetic sequence	mmol	Molar sequence	mmol
A	1.0	G	0.00
B	5.0	F	0.001
C	10.0	H	0.005
D	0.05	I	0.01
E	0.10	D	0.05
F	0.001	E	0.10
G	0.00	J	0.50
H	0.005	A	1.0
I	0.01	B	5.0
J	0.5	C	10.0

At first pass, the correlation overall is somewhat difficult to see in a single graph, therefore the data was separated into root samples, and stem samples. Root samples are shown in Figure 2. It is apparent that the correlation is not exact, but it is also apparent that as the molarity of the lead solution is ramped up from zero to 10 milli molar the uptake increases significantly.

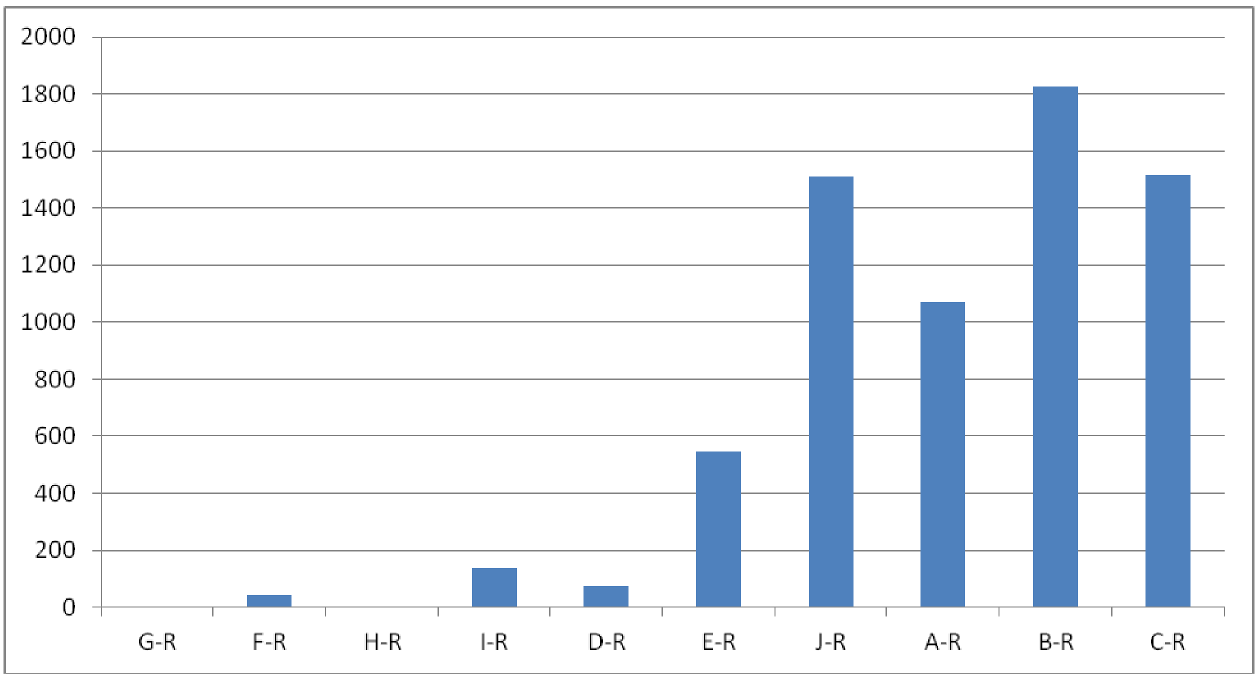

Figure 2. Uptake of Lead in Roots of Pennycress, Grown In Spiked Solutions

In any larger scale project that utilizes this technique, the roots will most likely be left in place, which means that uptake in the stems becomes the primary means by which pollutant lead will be extracted from soil. The lead uptake in stem samples is shown in Figure 3.

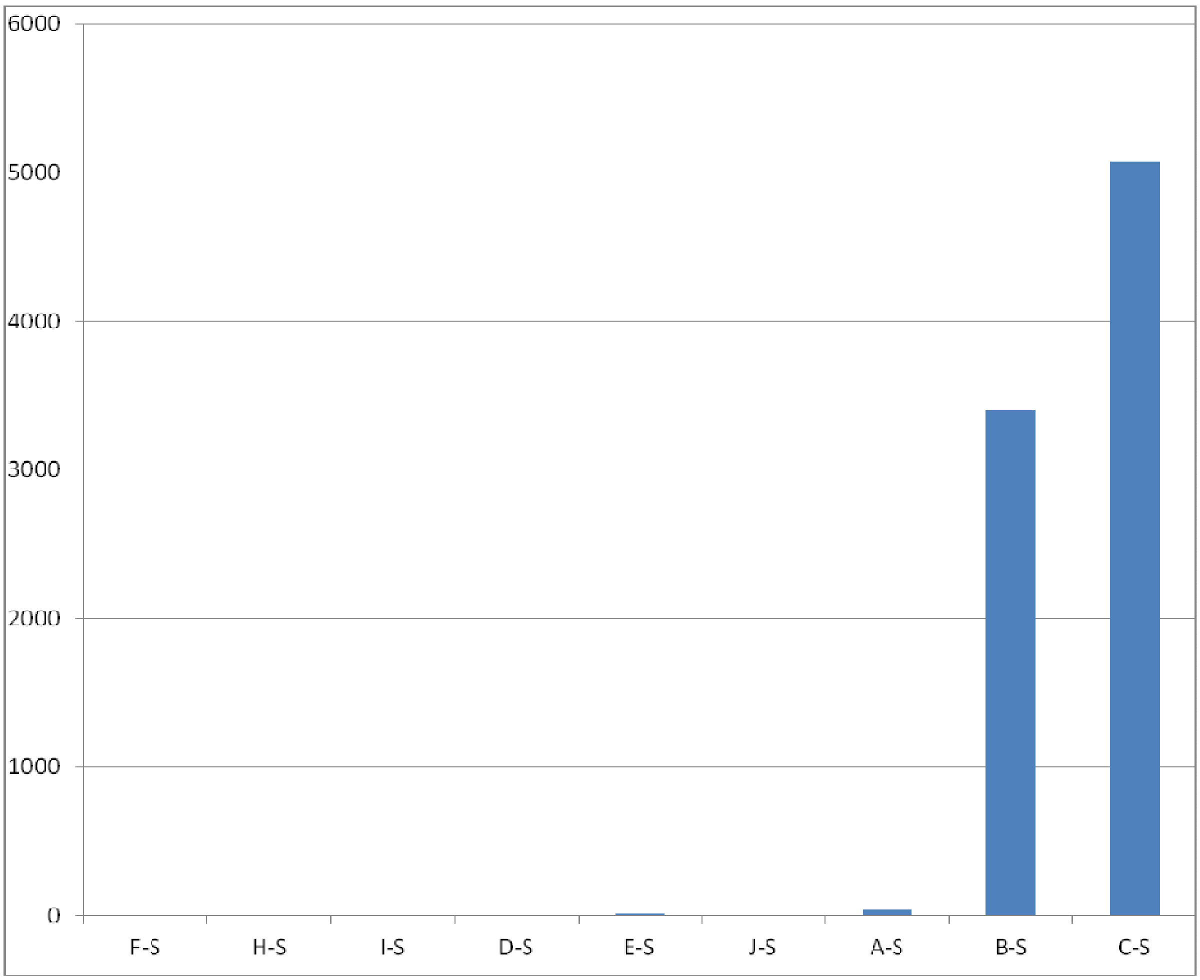

Figure 3. Uptake of Lead in Stems of Pennycress, Grown In Spiked Solutions

Plotting the various uptakes from the stem samples is difficult to do effectively in a single graph, thus Figure 4 illustrates the uptakes in stem samples where the molarities were smallest.

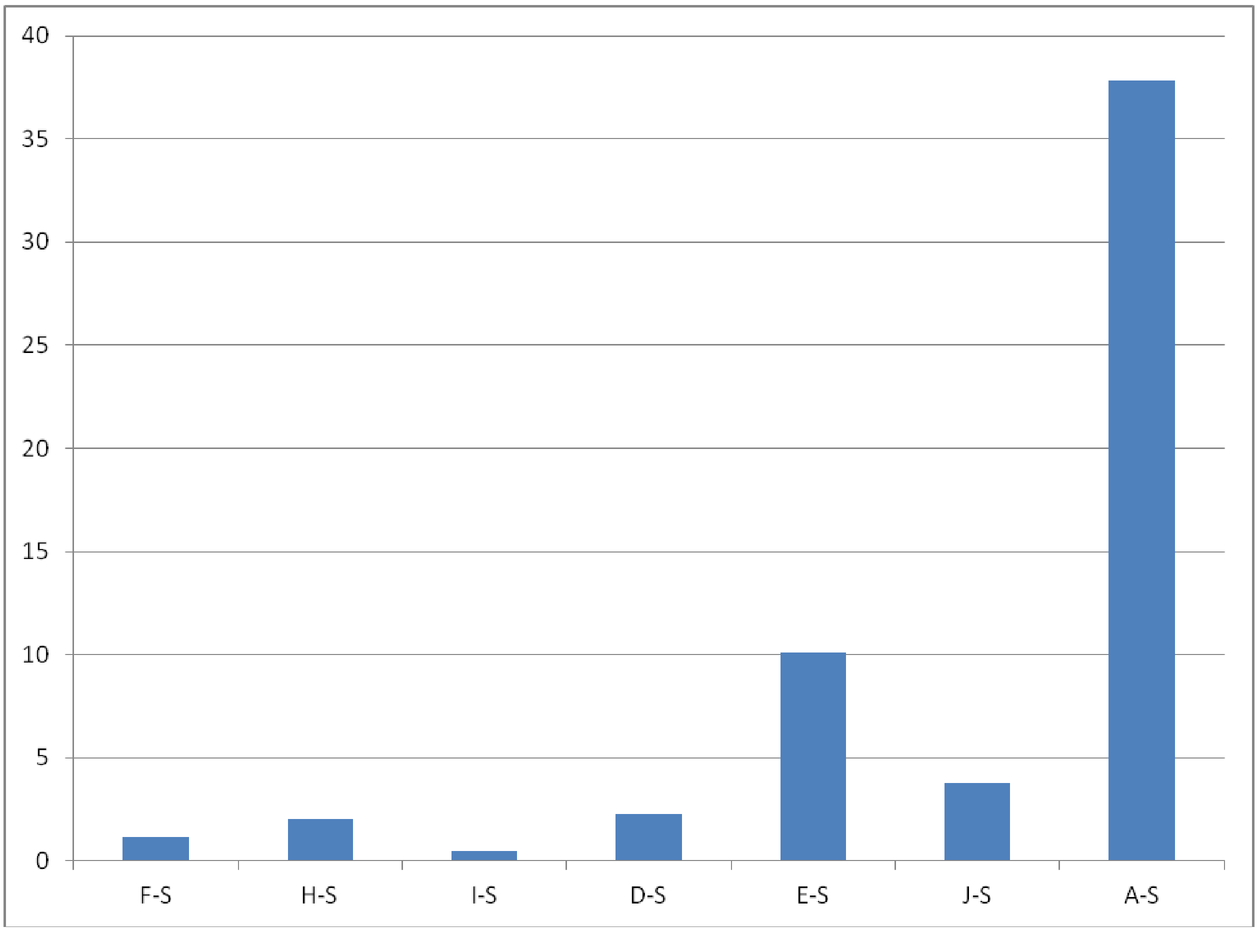

Figure 4. Uptake of Lead in Stems of Pennycress, Grown In Spiked Solutions, Lower Molarity Samples

Once again, the correlation is not linear, but there is a rough correlation as the concentration of lead increases. This is quite promising, as it indicates that a significant amount of lead can be extracted from soil into pennycress in a single growth cycle. Had Figures 3 and 4 shown a flat line, it would be a strong indicator that pennycress could only play a limited role in lead uptake, or that it would take several growth cycles to clean contaminated areas.

6. Conclusions

It appears that the use of pennycress can be scaled up to real world applications, meaning that pennycress could be planted in brownfield areas, grown, harvested for the seeds and their bio-diesel, and the lead extracted from the stems.

The greater the concentration of lead in a growth medium (water, or wet soil), the greater the uptake of lead appears to be. One can assume there is an upper limit of lead contamination, a point at which the pennycress simply will not grow because the soil is too contaminated, but our study has not found it.

EDXRF is an effective way to measure the uptake of lead in dry pennycress root and soil samples.

7. Recommendations for Further Research

The next logical step to this research is the just-mentioned growing of pennycress in brown-fields in and around the metro Detroit area, then examining and trying to quantify the amount of lead taken up in stems from the harvested plants. If possible, such plant matter should then be dried, powdered, and washed with nitric acid to determine if lead (II) nitrate can be extracted from the plant matter.

8. Acronyms

EDXRF	Energy Dispersive X-Ray Fluorescence
PPM	Parts Per Million
TPA	The Power Alternative
UDM	University of Detroit Mercy

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