REPURPOSING ZINC FROM MINING TIRE WASTE TO A FERTILIZER RESOURCE

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ABSTRACT

Waste tires are a major environmental concern around the globe. Pyrolysis under high vacuum can be used to recover petrochemicals, steel, and recovered Carbon Black (CB) char that may have value as a zinc fertilizer and soil amendment. Our preliminary work with a by-product of mining tires, CB4000, showed significant increases in the Zn supplying power of soils using short term burials of PRS® probes. This confirmed that the Zn contained in CB4000 was in a bioavailable form. Further studies growing corn in pots showed a significant increase in Zn uptake from the CB4000 amended soils. This work shows repurposing the Zn from used tires to fertilizer can be highly successful.

INTRODUCTION

Waste tires have been a major environmental concern in Canada since the 1990 Hagersville, ON tire fire that burned for more than 2 weeks at the dumpsite with over 10 million scrap tires. Although many changes in the environmental footprint of vehicles have happened since this time, the global demand for tires has not slowed down. In fact, within the last 5 years, tire sales have increased by 4.1% per year with 2019 seeing over 3B tires sold.

Although giant mining tires make up a small fraction of this number, they do make up a significant mass as they can weigh over 6 tons each. These tires are commonly concentrated in their use and disposal around mining sites like the oil sands of Fort McMurray, AB. This close proximity to world-class expertise in optimizing oil recovery has provided a special opportunity in tire recycling in Alberta, Canada. Thermal Vacuum Recovery (TVR) of oils and gas from the waste tires is not new (Williams, 2013). However, using local expertise the Titan Tire Reclamation Corp. has perfected a proprietary system that results in a very efficient and complete separation with the remaining char or Carbon Black (CB) containing between 6-8% Zn. Although total elemental analysis shows significant quantities of essential plant nutrients, this does not mean that these elements will be bioavailable to the plant in the year of application.

Zinc (Zn) is the fifth most important human nutrient deficiency according to the World Health Organization. Within the broad acre field crops of North America, Zn deficiency in corn, barley, and wheat are common on soils with high pH, low organic matter, and high carbonate. This limit in Zn supply is often exacerbated by increased plant demand under high yielding hybrids and new semi-dwarf genetics.

Our goal was to assess the char derived from this proprietary TVR process (called CB4000) to supply bioavailable Zn and other minor plant nutrients.

MATERIALS AND METHODS

The propriety process of TVR results in almost complete removal of the volatile rubber compounds, leaving behind only the steel belting and CB4000 in the batch reactor. Table 1 provides an analysis of the major elements contained in the CB4000. The concentration of deleterious heavy metals/contaminants was very low with Pb averaging 30 ppm and Cd averaging 1.40 ppm.

Table 1. CB4000 Total elemental analysis (selected major components).

Element	% of total
Carbon	78.92
Zinc	7.76
Silicon	4.22
Sulfur	4.20
Iron	0.68
Calcium	0.49
Nitrogen	0.16
Phosphorus	0.13
Cobalt	0.08

CB4000 impact on bioavailable soil nutrients was performed using Plant Root Simulator (PRS®) probes according to the WERA standardized saturated paste method (Bremer, 2013). We added CB4000 at a rate of 1.3% by weight to three different soil types (Table 2). These were thoroughly mixed and 10:1 and 20:1 "dilution" of this stock soil was made with fresh soils of each type. This resulted in CB4000 in the concentration ranges of 1.3%, 0.13% and 0.065% that corresponded to Zn application rates of 1000 lb/ac, 100 lb/ac and 50 lb/ac, respectively.

Table 2. Properties of the soils amended with CB4000 in the preliminary PRS® bioavailability study and Stage 2 Corn pot experiment.

Soil Label	Description	Location	Soil Series	Texture	SOM (%)	pH	EC
PRS001	Low slope	Enchant, AB	Cranford	Loam	3.3	6.65	0.24
PRS002	Hilltop	Enchant, AB	Helmsdale	Loam	1.3	8.41	0.18
PRS003	Level, compost-amended	Bow Island, AB	Chin	Loam	1.7	7.38	0.32
Soil A (corn pot study)	Upper slope/level	Leroy, SK	Oxbow	Loam	3.0	7.80	0.50

A further stage 2 corn pot experiment was set up to test the phytoavailability of Zn from the CB4000 product added at typical fertilizer rates (0.5ppm and 2.0ppm) to a PRS® Zn deficient soil (0.3 ug/10cm2/day). The generalized pot culture protocol listed below:

- 1.8 kg of soil per pot with 3 replicates Control and CB4000 treatments.
- CB4000 Zn product coated on granular fertilizer (0.34 g urea, 0.39 g MAP, and 0.48 g potassium sulfate) and mixed into the middle third of each treated pot.
- Sweet corn (Honey and Cream Bicolour, Heritage Garden Products, Brandon, MB) was planted at 4 seeds/pot on 20/06/2019, thinned to one plant/pot after three weeks
- Randomized pot placement
- Watered to weight (field capacity) as required (once every one or two days)
- Duration: 7 weeks (50 to 70 cm in height)
- Measurements: water use during final two weeks of growth, plant height, shoot and root dry weights, shoot nutrient concentration, and uptake
- Plant tissue was dried and ground, with a subsample sent for acid digest and ICP analysis.

RESULTS AND DISCUSSION

The preliminary study revealed significantly increased PRS® bioavailability of Zn on all soil types when CB4000 was applied at the highest rate (Figure 1). Upon combined analysis of all soils, the 0.065% and 0.13% rates of CB4000 showed a significant but less clear trend toward increasing PRS® Zn. The Hilltop soil (Helmsdale) was significantly lower in Zn supply than the other two soil types due to the high pH and free carbonates fixing Zn. These 'white Hilltop" soils, with thin A horizons and admixed high lime Cca horizons, are common in the glacial till of the Northern Great Plains. Effectively improving the Zn supply rate to a sufficient level (0.5 ug/10cm2/3day, Greer et al. 2002) will require substantially more CB4000.

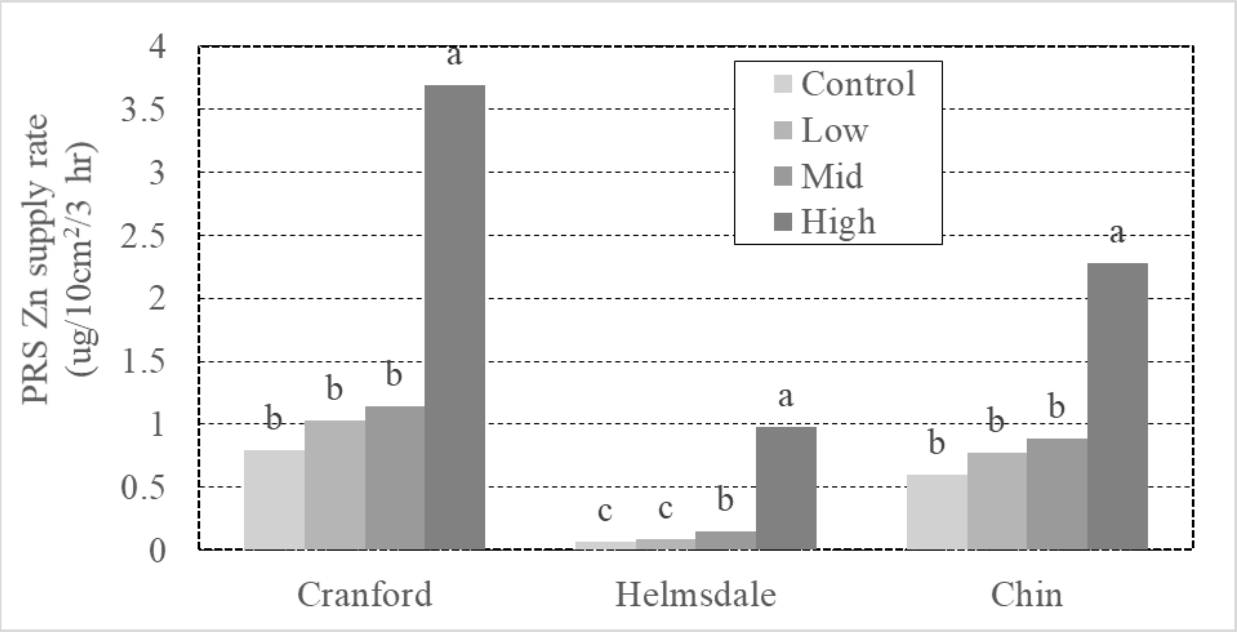

Figure 1. Mean PRS® Bioavailable Zn supply rates from standard soils (Cranford, Helmsdale, and Chin) having CB 4000 amended at 0 (control), 0.065% (Low), 0.13% (Mid) and 1.3% (High) rates (letters indicate LSD P=0.05).

STAGE 2 CORN POT STUDY:

A stage 2 corn pot study was set up following the PRS® bioavailability screening confirming that the CB4000 Zn was in an ionic/exchangeable form. It is important to note the ease and simplicity of the 3 hour saturated paste PRS® probe measurement as an initial step in testing repurposed nutrient products. By confirming that the repurposed products are in a form that the plant can take up, we eliminated one of the biggest questions before entering the costly and often confounding step, the pot study.

CB4000 exists as a fine black powder that readily coated the blended NPKS fertilizer prills, making distribution and amendment to the pots relatively simple. Given the distribution and proximity to other nutrients, we assumed the root access would be very similar to other co-precipitated or impregnated Zn fertilizer products. Therefore, more typical field rates of 0.5 ppm and 2 ppm of actual Zn (6.4 and 25.7 lbs/ac CB4000, respectively) were applied to the corn pots.

Following seven weeks of plant growth, the corn plant height and dry weight showed a significant response to the CB4000. Shoot dry matter was ground and analyzed in a total plant nutrient digest to allow shoot Zn yield (Zn uptake) to be calculated. The trend in shoot Zn concentration and shoot Zn yield agree with the conclusion of a Zn response. However, the variance in the tissue analysis was rather high (relative standard deviation=25%) and reduced the statistical robustness of our conclusion.

Table 3 Average corn height, shoot dry weight, and Zn content as affected by CB4000 application. (letters indicate LSD P=0.05; *significantly different from control at P<0.13).

Treatment	Plant height (cm)	Shoot dry wt. (g/pot)	Shoot Zn conc. (ppm)	Shoot Zn yield (µg/pot)
Control (no Zn)	59.0b	6.3ab	7.2a	55
CB4000 (0.5 ppm)	61.0ab	6.0b	9.5a	74*
CB4000 (2 ppm)	63.5a	7.1a	10.2a	96*

CONCLUSIONS

This study found that the proprietary TVR method of reclaiming giant mining tires results in a fine Carbon Black powder (CB4000) that has nutrients, specifically Zn, that can be repurposed to fertilizer. A circular economy of nutrients has always been part of the agricultural system as manures, composts, and other biological products. However, with 3B tires sold per year containing more than 2.2M tons of Zn, repurposing this nutrient to agricultural soil is a much-preferred scenario compared to effectively stranding it within rubber crumb/aggregate products, reformed rubber ramps, curbs, and mats (Shercom Industries Inc. 2020). Further new evidence has reported raw tire rubber will experience leaching/chemical transformations that deleteriously impact the environment (Tian et al., 2020). Given the efficiency of oil and gas extraction with the proprietary TVR process, the remaining CB4000 appears to have very few volatile organic components left in the product. As such land application as a beneficial plant nutrient appears to be a very promising win-win.

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