E3B The Elements of Bioremediation, Biomanufacturing & Bioenergy Metals in Biology

Durham University · University of Kent · Manchester 1824 The University of Manchester · UKRI Biotechnology and Biological Sciences Research Council

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Crops for Energy

University of York

Assessing nickel uptake and pyrolysis potential of willow biomass produced from nickel-contaminated soils

"We knew that Terra Nova was a resilient and adaptable variety that can tolerate lots of extremes. This project shows that this variety has the potential to be a real all-rounder when it comes to greening-up contaminated sites" Crops for Energy

PROJECT AIMS: Phytoremediation offers a solution to remove nickel and other metals from contaminated land. This project tested the ability of three types of willow to grow on and remove nickel from soil that mimics that at the Clydach nickel refinery in Wales. Willows were grown in pots at the University of York. The plants were characterised for nickel uptake and tolerance, and the biomass tested for catalytic activity and platform chemical production. The specific aims were to:

- Assess the growth of willow hybrids on Ni-contaminated soils
- Use microwave-assisted pyrolysis techniques to establish threshold requirements for cost-effective use of Ni-containing biomass
- Obtain biological samples for (later) Ni gene expression studies
- Produce a report extrapolating the potential for Ni-contaminated site remediation

OUTCOMES & NEXT STEPS:

- This research has supported the publication of two papers: Johar P et al (2022) Biologically bound nickel as a sustainable catalyst for the selective hydrogenation of cinnamaldehyde Applied Catalysis B: Environmental doi.org/10.1016/j.apcatb.2022.121105 | Johar P et al (2021) Phytocat – a bio-derived Ni catalyst for rapid de-polymerization of polystyrene using a synergistic approach. Green Chem doi.org/10.1039/D0GC03808C
- Proof of concept funding from the E3B Network was secured "*Tailoring nickel uptake capacity of willow for phytoremediation, biomass pyrolysis and metal recovery*" with new collaborators Green Lizard Technologies (GLT) and Kew Technologies, and new partner Barbara Zeeb from the Royal Military College, Ontario, Canada
- A Knowledge Transfer Partnership proposal is being prepared with GLT to use Terra Nova to remediate metal and cyanide wastes
- An outreach presentation was delivered to year 10 and 12 students at All Saints School, York

RESULTS: Project advisors Joe Dean and Bill Perkins, soil geologists at Aberystwyth University, helped establish a metal dosing regimen to best-mimic the metal-contaminated soil environment at the Clydach nickel refinery. Crops for Energy recommended and provided hybrid willows likely to grow well on this soil: Terra Nova, Endeavour and Endurance.

Established willows were dosed to concentrations of Ni, Cu, Co and As representing median levels found at Clydach; 160, 110, 18 and 61 mg/kg soil respectively.

Post-dosing, the three types of willow visually appeared healthy. Terra Nova produced significantly higher aerial fresh weights, and higher stem and leaf biomass than the other lines. ICP-OES (inductively coupled plasma optical emission spectroscopy) confirmed the presence of Ni, Cu and Co in the leaf and stem tissues of the dosed willows, with 50, 20 and 40% partitioning respectively into the stems (As was not detected in aerial tissues).

The *in-planta* metal concentrations were lower than expected, yet microwave-assisted pyrolysis analysis showed the dosed Terra Nova biomass formed more char while hydrolysis gave a greater number of carbonyl-containing compounds and less free sugars. The results indicate that all three lines would withstand well the Clydach site conditions, with Terra Nova the most suitable for site remediation.

Change in technology readiness level: 3 to 4

Willows supplied by Crops4Energy, growing at the University of York