LONG-TERM PHYTOREMEDIATION USING POPLAR: ECOSYSTEM SERVICES

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Rationale

Environmental degradation is increasing around the world, largely due to human activities (e.g., industry, agriculture, disposal of waste) [1]. A sustainable and aesthetically-pleasing solution to this problem is phytoremediation, the use of plants to clean up contaminated soils and water [2, 3]. Species of the *Populus* genus and their hybrids, known hereafter as poplars, are well-suited for use in phytoremediation systems due to their genetics and physiology [4]. Hybridization is common in poplars, and breeding efforts to select for desirable traits have led to the creation of *generalist* clones, which perform well across a variety of sites and contaminants, and s*pecialist* clones, which are adapted to specific conditions. Researchers employ phyto-recurrent selection to choose superior clones for their sites [5]. This involves evaluating clonal response to soil and/or site conditions through multiple testing cycles. Selecting clones in this manner helps to enhance the ecosystem services provided by phytoremediation systems, specifically biomass production and carbon sequestration. Collecting long-term data on phytoremediation systems is crucial in advancing the use of poplars in such systems, but can be vary challenging. Thus, a need exists for long-term data of poplars grown in these systems.

"… phytoremediation success can be increased with the identification and deployment of genotypes tailored to grow well and tolerate a broad diversity of contaminants (generalists)..."

- Zalesny et al. (2019)

Objective

- Address the need for long-term results from phytoremediation systems by providing a summary of results from
    - Case studies of long-term plantings in the Midwest and Southeast United States

Key Points

- Long-term data collection and monitoring is important to the advancement of phytoremediation systems
- Implementing a successful phyto-mediation system involves testing of planting procedures and careful clone selection

Methods

Researchers used the following methods for this review paper:

Plantings

- 15 poplar plantings were sampled, including
    - 55 total clones
    - Trees 5-15 years old
    - Organic and inorganic contaminants

Measurements and Calculations

- Stem diameter and stand density were measured at each site
    - From these, annual biomass production and carbon sequestration were calculated

Statistical Analyses

- Analysis of variance (ANOVA), least significant difference (LSD)

Mapping

- Annual carbon sequestration was mapped for 7 sites
    - Carbon hotspots were located

Hybrid cottonwood at a field site with TCE and PCE contamination.

Photo by Ron Zalesny

Case Studies*

Brief descriptions of the long-term plantings evaluated in this study.

Case Study A: Rhinelander, WI

A1:** Clones 'NM6' and 'DN34' were established to remediate leachate containing nitrates. 'NM6' had significantly greater DBH and annual biomass production and carbon sequestration than 'DN34.'

A2: Another planting in the same system as A1, but solely 'NM6'.

A3: Phyto-recurrent selection was used to select the most favorable clone for remediating high-salinity leachate, 'NM2', which was then grown for a long-term trial.

A4: Clones 'NM6' and 'DN182' were used to remediate paper mill fiber cake effluent. Similar to the A1 planting, 'NM6' produced significantly larger values for all three parameters.

Case Study B: Lemont, IL

B1: Clone 'NE308' was grown for long-term remediation of volatile organic compounds (VOCs) and tritium.

* Three parameters were evaluated for each of the case studies: diameter at breast height (DBH), annual biomass production, and annual carbon sequestration.

** Some case study locations (i.e., A, C, and E) had multiple plantings from multiple studies. Individual plantings are denoted by number.

Case Study C: LaSalle, IL

C1: 19 clones were tested for remediation of VOCs when grown on top of a contaminated plume.

C2: Another planting in the same system as C1, but eight clones were grown in groundwater treatment units that controlled subsurface water flow and impacted rooting.

Case Study D: Midwest

D1: 27 clones were grown at an agricultural production facility in soils contaminated with salts, metals, and nitrates. Three of the clones were planted as both rooted and unrooted cuttings. Unrooted cuttings produced greater values for all three parameters.

Case Study E: Elizabeth City, NC

E1, E2, E3: At all "E" plantings, four hybrid poplar clones were planted for remediation of petroleum hydrocarbons and VOCs. Three planting procedures were implemented, with differences in size of planting holes, type of backfill for filling holes, and plant material (longer whips versus unrooted cuttings). Clonal instability was observed across the three sites.

Case Study F: Aberdeen, NC

F1: Clones 'NE308' and 'NE41' were grown for phytoremediation of DDT and lindane at an industrial brownfield. 'NE308' produced significantly greater values for all three of the parameters tested.

Case Study G: Union Springs, AL

G1: Six clones were tested for phytoremediation of organic contaminants at an industrial brownfield. For the three variables of interest, differences were negligible across clones.

Case Study H: Panama City, FL

H1: 15 poplar clones were grown for phytoremediation of arsenic at an industrial brownfield. Differences in clonal performance were observed for all three parameters.

Case Study I: Northeast NC

I1: One hybrid poplar clone was grown to remediate nitrates in a hog lagoon.

Conclusions

The environmental cleanup technique phytoremediation is used successfully around the world to restore degraded lands. The current study reported extensive variability in aboveground biomass production and carbon sequestration of poplars grown in long-term phytoremediation sites, which highlights the need for:

- Long-term data collection and monitoring at phytoremediation sites,
- Testing of multiple silvicultural prescriptions– specific "recipes" for growing trees (e.g., open-grown vs grown in groundwater treatment units, unrooted vs rooted planting stock), and
- Genotype selection to match site objectives.

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Sources

1. United Nations Environment Programme (UNEP). 2012. Global environment outlook GEO5: Environment for the future we want. Nairobi, Kenya: United Nations Environment Program.
2. Arthur, E.L., Rice, P.J., Rice, P.J., Anderson, T.A., Baladi, S.M., Henderson, K.L.D., and Coats, J.R. 2005. Phytoremediation: An overview. Crit. Rev. Plant Sci. 24:109-122.
3. Burges, A., Alkorta, I., Epelde, L., and Garbisu, C. 2018. From phytoremediation of soil contaminants to phytomanagement of ecosystem services in metal contaminated sites. Int. J. Phytorem. 20:384-397.
4. Dickman, D.I., and Keathley, D.E. 1996. Promises and prospects of phytoremediation. Plant Physiol. 110:715-719.
5. Zalesny, J.A., Zalesny, R.S. Jr., Wiese, A.H., and Hall, R.B. 2007. Choosing tree genotypes for phytoremediation of landfill leachate using phyto-recurrent selection. Int. J. Phytorem. 9:513-530.