SELECTION OF POPLARS AND WILLOWS FOR PHYTOREMEDIATION OF NITRATE

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Zalesny, R.S. Jr., Bauer, E.O. 2019. Genotypic variability and stability of poplars and willows grown on nitrate–contaminated soils. International Journal of Phytoremediation. 21(10) 969-979. https:doi.org/10.1080/15226514.2019.1583721.

Rationale

Groundwater nitrate (NO_3^-) contamination is exacerbated in the Midwestern United States due to agricultural operations and physical characteristics of the land (e.g., tile drainage). When unmitigated, excessive NO_3^- can lead to serious environmental degradation. It is critical, therefore, to establish sustainable, economically feasible methods for remediating existing NO_3^- contamination. Phytoremediation, the use of plants to clean up contaminated soils and water, is a long-term, aesthetically pleasing option for sustainable pollutant mitigation, including NO_3^-.

While agricultural crops and trees both have demonstrated success at phytoremediation of soil and water pollutants, the biological characteristics of trees lend them particularly well to effective phytoremediation (e.g., perennial growth, extensive rooting, and biomass production). One particular group of trees commonly implemented in phytoremediation systems includes members of the *Populus* genus and their hybrids (i.e., poplars). Poplars have been used to remediate a broad range of contaminants, from explosives, to heavy metals, to agricultural byproducts such as NO_3^- [1]. Another compatible group for phytoremediation is the *Salix* genus and its hybrids (i.e., willows). Contaminants that have been targeted by willow-based phytoremediation systems are also varied, and include wastewater sludge, cadmium, and dairy-farm effluent, to name a few [2].

Poplars and willows are ideal for phytoremediation; both are able to produce large amounts of biomass when grown on marginal lands, and have elevated hydraulic control potential. These traits can vary extensively among clones, however, and careful clonal selection based on field conditions and site objectives is necessary for effective remediation. The current study examines the effectiveness of poplar and willow clones grown for remediation of NO_3^-.

> *"Given the broad range in height and diameter among genotypes and the ability to select better clones within this variation, our findings suggest that … selection … was favorable … based on the geographic location and soil conditions of the site."*
>
> *- Zalesny et al. (2019)*

Objectives

- Evaluate the variation in parameters related to phytoremediation success (i.e., survival, height, and diameter) of poplars and willows grown on NO_3^--contaminated soils, and
- Assess the long-term stability of survival and diameter in selected poplar clones.

Key Points

- Poplar and willow clones exhibit broad variation in growth and survival when grown on nitrate-contaminated soils
- System success can be maximized by selecting genotypes for site conditions

Methods

Researchers used the following materials and methods for this field study:

Plantings

- 42 poplar clones (15 rooted, 27 unrooted) and 10 willow clones (all unrooted) were planted
- Trees planted in four replications of soils with varying levels of NO_3^-
- Grown for one year
- 27 clones selected and grown for 11 years to test for stability in performance

Data collected

- Year 1: height, diameter, survival, total aboveground biomass*
- Year 11: diameter, survival, total aboveground biomass*

Statistical Analyses

- Analysis of variance (ANOVA), analysis of means (ANOM), correlation coefficients, Fisher's protected least significant difference (LSD)

*Total aboveground biomass estimated for both years from diameter data using biomass equations [3]

Findings

Genotypic Variability (Year 1): Survival, Height and Diameter

The experiment-wide survival rate after one year of growth was 72%. Willow survival was greater than that of poplar by 4%, and rooted poplar greater than that of unrooted poplar by 7%.

Poplar and willow differed significantly for both height ($p < 0.0001$) and diameter ($p < 0.0001$), likely due to morphological differences. Rooted and unrooted planting stock also differed significantly for height ($p < 0.0001$) and diameter ($p < 0.0001$).

High levels of soil heterogeneity led to significant differences in height ($p < 0.0001$) and diameter ($p < 0.0001$) across the four replications.

There was broad variability among genotypes for height ($p = 0.0002$), which ranged from 49.1 ± 7.5 to 186.0 ± 12.0 cm, and diameter ($p = 0.0003$), which ranged from 5.26 ± 0.31 to 18.64 ± 1.88 mm across all genera and planting stock.

Conclusions

The large overall variation in survival and growth among poplar and willow genotypes in this study indicates the need for proper genotype selection prior to tree establishment for phytoremediation of NO_3^- contamination. Further, planting stock type must also be taken into consideration to increase a system's effectiveness, as evidenced by the marked differences in survival across stock types in this study. Stock type trends in the four response groups for genotypic stability in diameter are further illustrative of this point.

Implications for the Future

- Research may expand upon this study with:
  - More in-depth testing of the differences between poplar and willow, among their genotypes, and among stock types
  - Further investigations of genotypic stability to identify favorable genotypes (e.g., those that exhibit stability in performance over time, those whose performance increases over time)

Findings

Genotypic Stability (Year 11): Survival and Diameter

The overall survival rate after 11 years of growth was 42%. Trees that were planted as rooted cuttings had over twice the survival than those that were unrooted, and there were no significant differences in survival rate among replications.

Four response groups resulted from comparing the difference between observed diameter and mean diameter at year 1 and year 11. The most optimal group for phytoremediation of NO_3^- contained clones that exhibited high survival rates and above-average diameter at both year 1 and year 11. All of the clones in this group were planted as rooted cuttings.

Change in rank of diameter was used as a measure of genotypic stability over time. Between year 1 and year 11, 12 clones had positive rank changes, 12 had negative rank changes, and three had the same rank at both times.

Hybrid poplars grown for phytoremediation of nitrate-contaminated soils in the Midwest, USA.

Photo by Ron Zalesny

Sources

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