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14th Biennial Short Rotation Woody Crops International Conference

The Future is Green: Integrating Short Rotation Woody Crops (SRWCs), Agroforestry, and Ecosystem Services for Sustainable, Productive Landscapes

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Abstract

The 14th biennial Short Rotation Woody Crops International Conference was held from May 13-16, 2024, at the University of Missouri in Columbia, Missouri, USA. Hosted by the University of Missouri Center for Agroforestry, the conference brought together researchers, practitioners, policymakers and students interested in the science and practice of growing and using fast-growing trees for agroforestry, bioenergy, forest products, and environmental applications. The theme of the conference was “The Future is Green: Integrating Short Rotation Woody Crops (SRWCs), Agroforestry, and Ecosystem Services for Sustainable, Productive Landscapes” with a goal of enhancing information exchange and fostering collaboration for integrating SWRC into agroforestry systems. The conference consisted of 31 oral presentations and 17 poster presentations in addition to 2 plenary presentations and a welcome plenary by Dr. Benjamin Knapp about the University of Missouri Center for Agroforestry. This conference proceedings details abstracts from all presentations given during the conference.

Preface

The Short Rotation Woody Crops International Conference is a biennial meeting of the Short Rotation Woody Crops Operations Working Group with the aim of promoting information exchange and collaborative efforts for short rotation woody crop (SRWC) operations and research. The 14th biennial Short Rotation Woody Crops International was hosted by the University of Missouri Center for Agroforestry from May 13-16, 2024 in Columbia, MO. A joint meeting of the Short Rotation Woody Crops International Conference and the Poplar and Willow Council of Canada (PWCC), the 2024 conference brought together members of leading SRWC and agroforestry organizations, including the University of Missouri Center for Agroforestry, the International Commission on Poplars and Other Fast-Growing Trees Sustaining People and the Environment (IPC) Working Party on Environmental and Ecosystem Services (WP-ENV), the International Union of Forest Research Organizations (IUFRO) Working Party 1.03.00 (Short Rotation Forestry), the IUFRO Working Party 1.06.01 (Phytotechnologies for Degraded Sites in Rural and Urban Communities), and the IUFRO Working Party 2.08.04 (Physiology and Genetics of Poplars and Willows). With a theme of "The Future is Green: Integrating Short Rotation Woody Crops (SRWCs), Agroforestry, and Ecosystem Services for Sustainable, Productive Landscapes", the objective of the 2024 conference was to highlight current SRWC and agroforestry research with the goal of enhancing information exchange and fostering collaboration for integrating SWRC into agroforestry systems. Additionally, unique to this conference, there were multiple student-focused initiatives throughout, including: 1) the first ever Woody Crops Scholars Program, 2) a student career panel discussion, and 3) a student presentation competition. These initiatives enhanced student participation and engagement at the conference. The conference consisted of 2 plenary presentations, 31 oral presentations and 17 poster presentations from a variety of topic areas including agroforestry, biomass production, economics, ecosystem services, genetics, physiology, and phytotechnologies. In addition, Dr. Benjamin Knapp from the University of Missouri presented a welcome plenary about the University of Missouri Center for Agroforestry. The following proceedings details all presentations that were given to the over 60 people who attended the conference.

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14th Biennial Short Rotation Woody Crops International Conference

The Future is Green:
Integrating Short Rotation Woody Crops (SRWCs), Agroforestry, and Ecosystem Services for Sustainable, Productive Landscapes

A Joint Meeting of the:

Short Rotation Woody Crops Operations Working Group

Poplar and Willow Council of Canada

IUFRO Working Party 1.03.00 (Short Rotation Forestry)

IUFRO Working Party 1.06.01 (Phytotechnologies)

IUFRO Working Party 2.08.04 (Physiology and Genetics of Poplars and Willows)

IPC Environmental and Ecosystem Services Working Party

Plenary Speakers

Revitalizing Wetlands: The Role of Willow in the Nature-Driven Recovery of Agro-Ecosystems

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The Prairie Pothole Region (PPR) in the glaciated Great Plains of North America is home to millions of small freshwater mineral soil wetlands within agricultural landscapes. These wetlands play a crucial role in regulating soil hydrological and biogeochemical cycles, offering essential ecosystem services such as water and nutrient storage, flood mitigation, groundwater recharge, carbon sequestration, and providing habitats for wildlife, thus enhancing biodiversity. In Canada, recognizing wetlands as a nature-based climate solution for climate mitigation, there is a potential to achieve an annual reduction of 3.5 Mt CO_2e through the restoration and protection of wetlands in agricultural lands. Our research focused on rewilding wetlands with native willow vegetation, aimed to address salinity issues around wetlands and explore the carbon sequestration potential of marginal lands to enhance their ecological health and overall resilience. Our investigation examined crucial factors including groundwater table depth, salinity levels, soil organic carbon, soil nutrient dynamics, and enzyme activities. My presentation seeks to bridge the gap between agriculture and environmental conservation by advocating for bioenergy crops, particularly through the cultivation of willow, as a sustainable management practice and nature-based solution.

Keywords: agroecosystems, bioenergy, nature-based solution, wetlands, willow

The Summary of a Long-Term Shrub Willow Agricultural Buffer Designed for Bioenergy Production and Ecosystem Service Provision: Lessons Learned and Future Objectives

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Agricultural landscapes are expected to provide a wide range of products including food, fiber, energy and other bioproducts. As demand for these products continues to increase, there is also increased pressure to improve the long-term sustainability of agricultural systems and minimize their environmental impacts. Designing multifunctional agricultural landscapes with integrated perennial crops has gained increased attraction to address these various concerns by improving land-use efficiency and supporting long-term economic and environmental sustainability. Producing perennial bioenergy crops such as short rotation woody crops (i.e., willow and poplar) or herbaceous crops (i.e., switchgrass, energy cane, Miscanthus) on marginal (economically poor or susceptible to environmental degradation) agricultural lands is one such design to provide both a harvestable crop and ecosystem service benefits. This presentation will summarize a long-term research study in central Illinois evaluating the strategic placement of a short-rotation shrub willow buffer in a row crop field to address nutrient loss while enhancing the production of biomass. In addition to water quality benefits, this integrated design also provided additional ecosystem service benefits. This study has laid the groundwork for evaluating other designs for producing perennial bioenergy crops to address various environmental and production goals across the USA. Furthermore, the success of this study and others has led to the development of an online geospatial tool called SUPERBEEST to aid in the decision-making by producers, watershed managers, and commercial organizations in the adoption of perennial bioenergy crops in the USA. Midwest. Our research team at Argonne National Laboratory has partnered with the American Farmland Trust to provide community outreach (workshops, listening sessions, and educational materials) and technical assistance to producers interested in adopting perennial bioenergy crops (site visits and tailored management plans). Their outreach work over this past year has highlighted the continued interest by producers in adopting perennial crops for their production systems.

Keywords: marginal land, multifunctional agricultural landscape, outreach, perennial bioenergy crops, short-rotation coppice

Oral Presentations

Technical Session:
Populus in the Southeast for Integrated Ecosystem Services
(PoSIES)

Impacts of Endophyte Inoculation and Planting Diversity on Leaf Physiological and Biochemical Properties in Eastern Cottonwood and its Hybrids

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Maximizing productivity is important for short rotation woody crop plantations and various strategies can increase productivity including choosing superior genotypes, applying treatments like endophytic bacteria, and/or implementing various planting schemes that increase taxonomic or functional diversity. While productivity is important, other physiological traits including water use efficiency and nitrogen uptake also need to be considered to select genotypes and planting treatments for specific site conditions and maximize other environmental benefits like nitrogen mitigation. Therefore, the objectives of this study were to compare three genomic groups (two genotypes each) of *Populus* including D×D (*Populus deltoides* Bartr. ex Marsh. × *P. deltoides*) genotypes, D×T (*P. deltoides* × *P. trichocarpa* Torr. & Gray) genotypes, and D×M (*P. deltoides* × *P. maximowiczii* A. Henry) genotypes and determine if inoculation with endophytic nitrogen-fixing bacteria or increasing functional and/or taxonomic diversity had a significant impact on physiological and biochemical leaf traits. Two sites located in the southeastern USA (northeastern Mississippi) were selected and trees were planted in 30-tree plots as: genotypic monocultures, genomic groups containing two genotypes with different functional traits (functional diversity), one genotype from each genomic group (taxonomic diversity), and all six genotypes together (functional and taxonomic diversity), with half receiving the endophytic inoculation. We found that effects of endophyte inoculation tended to be site specific, however endophyte-inoculated trees at both sites were more water use efficient and had lower leaf nitrogen concentrations than non-inoculated trees particularly for D×D genotypes with D×M genotypes exhibiting the least endophyte treatment effects. Planting diversity mainly impacted leaf nitrogen characteristics with functional diversity mixtures exhibiting higher leaf N concentrations than monocultures. D×D and D×T genotypes also tended to exhibit the largest diversity impacts with D×M genotypes largely unaffected. In total, these results highlight the potential of planting diversity and endophyte inoculation to improve nitrogen uptake and water use efficiency respectively in short rotation poplar plantations in the Southeastern USA.

Keywords: leaf traits, physiology, plantation, *Populus*

Biomass Yield of *Populus* in Experimental Monoclonal and Polyclonal Plantings

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There is mounting empirical evidence of a general positive relationship between biodiversity and productivity. However, there remain numerous counter examples where species richness is unrelated or negatively correlated with productivity in plant communities. A possible explanation for these exceptions is that functional diversity, rather than taxonomical diversity drives biodiversity/productivity relationships. Thus, targeted increases in functional diversity through intimate mixtures of varieties or genetic lines may lead to increased productivity and yield in monospecific cropping systems. The goals of this study were to test the relative impact of taxonomical diversity and functional diversity on the productivity of trees using short rotation *Populus* L. spp. and their hybrids as a model system. We established monocultures and mixed clonal plantings of six *Populus* clones from three different taxa (*Populus deltoides* Bartr. ex Marsh., hybrids of *P. deltoides* × *P. maximowiczii* A. Henry, and hybrids of *P. deltoides* × *P. trichocarpa* Torr. & Gray). The mixed clone plantings were designed to be either more functionally diverse, with two clones of the same taxa but contrasting nitrogen use characteristics, or more taxonomically diverse with three clones, each of a different taxon, but with more similar nitrogen use characteristics. There was also a treatment that included all six clones. Here we report aboveground biomass of mixed clone plantings compared to the weighted average of their constituent monocultures. We found that, on average, functionally diverse two-clone mixtures overyielded by producing more aboveground biomass than either of their constituent monocultures, while the more taxonomically diverse three-clone mixtures underyielded, producing less aboveground biomass than the average of their constituent monocultures. The mixture with all six clones was not significantly different from the average of all monocultures. Our results do suggest that, with careful implementation, increasing biodiversity in managed ecosystems, like *Populus* biomass plantations, may be a viable strategy for increasing production.

Keywords: biodiversity productivity relationship, complementarity, intraspecific biodiversity, mixed plantation, overyielding

Transcriptomic Data and Enrichment Pathway Analysis Reveals Oxidative Stress and Growth Responses in Polyclonal Plantings of Two *Populus deltoides* Genotypes

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Polyclonal plantings of *Populus deltoides* Bartr. ex Marsh. may be more stress tolerant, display increased site resource use and productivity through phenotypic plasticity contributing to niche differentiation. In the present study two *P. deltoides* clones were established in monoculture and polyculture plots. RNAseq was used to explore differences in gene expression and enriched biological pathways between genotypes and planting schemes. Transcriptomic analysis of leaves revealed upregulation of oxidative stress genes in polyclonal plantings and upregulation of an exocyst subunit exo70 family protein H7 isoform that play important roles in plant stress, stress tolerance and growth in polyclonal plantings. Secondary metabolic pathways were upregulated in monoclonal plantings. Supporting phenotypic results revealed a decrease in estimated aboveground biomass and leaf area index in multiple monoclonal plots, suggesting increased susceptibility to stress. Results suggested a potential increased tolerance in polyclonal plantings to water and heat stress contributing to greater productivity and resource use relative to monocultures.

Keywords: differential gene expression, eastern cottonwood, niche differentiation, nitrogen-use efficiency

Populus Genotype Diversity Improves Nutrient Uptake from Agricultural Runoff

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Populus L. species and their hybrids represent ideal short rotation woody crops (SRWCs) with high biomass productivity. As a consequence of high growth rates, these trees may require higher nutrient inputs. However, careful location of SRWC plantations to capture agricultural nutrient runoff may improve water quality. Furthermore, the diversity of genotypes in a SRWC production system may impact nutrient uptake. To explore these relationships, we established two field trials evaluating nitrogen and phosphorus uptake from shallow groundwater as a function of taxonomic and functional diversity using three *Populus* taxa [*Populus deltoides* Bartr. ex Marsh. × *P. deltoides* (D×D), P. *deltoides* × *P. trichocarpa* Torr. & Gray (D×T), and *P. deltoides* ×*P. maximowiczii* A. Henry (D×M)] each with genotypes exhibiting high and low nitrogen use efficiency (NUE). Following two growing seasons, we observed higher uptake of nitrate and ammonium by high NUE genotypes compared to low NUE genotypes in single-genotype plots. We also observed an increase in nitrate uptake due to taxonomic diversity in multi-genotype plots of high NUE. Results from the third growing season are still pending. Our findings provide preliminary evidence that functional and taxonomic diversity could be leveraged in SRWC cultural practices and improve environmental services, specifically water quality.

Keywords: environmental services, nutrient uptake, poplar

Evaluating Functional and Taxonomic Controls on Soil Carbon Sequestration in Short Rotation Woody Crop Bioenergy Plantations

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Short rotation woody crops such as *Populus* L. species and their hybrids are important components of the bioenergy plantation landscape. These trees grow quickly both above- and below-ground and have the potential to provide a range of ecosystem services including soil carbon storage and sequestration. In efforts to maximize these ecosystem services, we hypothesize that mixed clonal plantations will enhance diversity and soil carbon sequestration. We established monocultures and mixed clonal plantings of six *Populus* clones across three taxa (*Populus deltoides* Bartr. Ex Marsh., hybrids of *P. deltoides* × *P. maximowiczii* A. Henry, and hybrids of *P. deltoides* × *P. trichocarpa* Torr. & Gray) and two contrasting nitrogen use efficiencies (NUE) at two research sites containing three replicated blocks in central Mississippi. At the end of each growing season, soil samples were collected in research plots and in adjacent agricultural fields to determine business-as-usual rates of soil carbon sequestration.

After two growing seasons, agricultural soils showed no significant change in soil carbon (1.64 ± 0.09 Kg C/m^2). Only two monoclonal plots had significant increases in soil carbon, wherein the low NUE *P. deltoides* × *P. trichocarpa* clone increased 17.4 ± 7.6% ($p = 0.023$) and the high NUE *P. deltoides* clone increased 14.7 ± 7.6% ($p = 0.055$). Interestingly, much of this increase was observed in deeper soils (10-30 cm) compared to surface soils (0-10 cm) ($p < 0.001$). Results from the third growing season are pending. We demonstrate small, but significant, increases to soil carbon within the first two growing seasons of short rotation woody crop bioenergy plantations. Soil disturbances from plantation establishment and continued site maintenance of "free to grow" conditions may limit soil carbon sequestration in early production years. As root systems expand and aboveground inputs from annual litterfall continue, we expect to see larger gains in soil carbon.

Keywords: bioenergy, poplar, soil carbon

Evaluation of Monoclonal and Mixed Plantings of *Populus* Clones in the Southeastern USA

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Rapid juvenile growth and growth performance render poplar clones important components of bioenergy plantations. Poplar has the potential to provide a variety of ecosystem services, including carbon storage and sequestration in the soil and water quality mitigation. To optimize these ecosystem services, we propose that mixed clonal plantings will provide higher levels of taxonomic and functional diversity and help in soil carbon mitigation. We established monocultures and mixed clonal plantings of six *Populus* clones across three taxa (*Populus deltoides* Bartr. Ex Marsh. × *P. deltoides* (D×D), *P. deltoides* × *P. maximowiczii* A. Henry (D×M), and *P. deltoides* × *P. trichocarpa* Torr. & Gray (D×T)) in the spring of 2021 in Mississippi, USA. These clones were planted in three blocks per site with 24 plots per block to test the impacts of taxonomic and functional diversity on productivity with endophytic and non-endophytic soil treatments. Growth and survival rates were recorded at the end of each growing season, along with monthly measurements of soil respiration. Overall, the largest growth at the end of the second growing season was recorded for D×M (6.1 m), while D×D (5.2 m) had the highest survival rate above 90%. Mixed clone plantings had nearly 1.3-times more productivity than monocultures. Soil respiration was 2-times higher during wet growing season months (June-August) than in dry growing season months (September-November). Agriculture fields showed higher soil respiration flux (4.3 gC m^{-2} d^{-1}) than monoclonal plantings (2.5 gC m^{-2} d^{-1}). Endophyte-treated plots showed slightly higher production (1.2×) and soil respiration (3.2 gC m^{-2} d^{-1}) than non-endophyte-treated plots. In conclusion, we found a positive relationship between intraspecific functional diversity and productivity and soil respiration. Application of nitrogen-fixing bacteria helps improve soil health and respiration. Intimate mixtures of genetically diverse individuals have the potential to improve the productivity of populus production.

Keywords: planting diversity, poplar, productivity, short rotation, soil physiology, soil respiration

Integrated Analysis of *Populus deltoides* as a Biomass Feedstock

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In the United States (USA), woody biomass is becoming increasingly important for renewable bioenergy production. The most widely used genera are *Eucalyptus* L'Hér, *Populus* L., and *Salix* L. *Populus* trees make an excellent feedstock for renewable biofuel, bioenergy, and bioproducts. They endure biochemical conversion to fuels without complexity, making them a promising, purpose-grown, woody perennial energy source with environmental benefits, such as air filtration, erosion prevention, carbon sequestration, increased agricultural biodiversity, and soil remediation, including mining site restoration. *Populus* species produce a huge amount of biomass in a short rotation, and are able to resprout rapidly from stumps after harvest. Therefore, growing *Populus* for biomass on marginal lands has the potential to promote rural economies and can relieve strain on natural forests by providing a valuable resource.

The study will be based on secondary and primary data sources of poplar species to assess the overall sustainability of using *Populus deltoides* Bartr. ex Marsh. as biomass feedstock. Therefore, to better understand the potential financial and environmental benefits of growing *Populus* for biomass, we will conduct a techno-economic analysis (TEA) and will use a discounted cash flow model over a 20-year rotation with a 2-year establishment cycle followed by 2-year coppice cycles. Data were collected from field trials grown from 2020 to 2024 at Pontotoc Ridge-Flatwoods Branch Experiment Station near Pontotoc, Mississippi, USA, the Bearden Dairy Research Center near Starkville, Mississippi, USA on the Upper Coastal Plain physiographic subsection, and two sites in the Lower Mississippi Alluvial Valley. These data will be used to estimate site preparation costs, planting expenditures, and yields. This data will also be used to conduct a limited Life Cycle Assessment (LCA), which will be developed to evaluate the environmental performance in terms of greenhouse gas (GHG) emission based on energy used in the application of fertilizers, herbicides, and farming machinery.

Keywords: biomass, feedstock, poplar

Technical Session: Agroforestry, Biomass Production, Economics

Field Trials of Poplars in Pastoral Land using Alternative Planting Materials

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Poplar poles planted for soil conservation in pastoral hill country are expensive to produce and plant. Planting material that is quicker and cheaper to produce and easier to plant has the potential to increase planting rates and soil protection and may cope better with drought in the establishment years than poles. A field trial was undertaken between July 2021 and June 2023 in three regions in North Island, New Zealand. Two of the regions are drought susceptible. We tested the hypotheses that alternative materials to poles (wands, rooted cuttings) are (1) equally likely to survive and grow when planted and protected on pastoral hill slopes in the presence of grazing animals, and (2) will have higher survival in drought vulnerable sites such as northern faces and in drought prone regions. Thirty reps of each material type were planted on a north-facing slope and a south-facing slope in a grazed paddock on a single farm in each of the three regions. Poles (P) were planted 10-12 m apart, with a wand (W) and a rooted cutting (R) planted between adjacent poles at 3-4 m spacing. At each site, 10 of each of the P, W, and R were planted on a lower slope, 10 on a mid-slope, and 10 on an upper slope. Summer rainfall was atypically high in the drought susceptible regions during the two seasons over which the trial occurred.

Pole survival to December 2022 was significantly higher than W ($p = 0.026$) or R ($p = 0.025$) survival. There was no significant difference between W and R survival ($p = 0.77$). Survival was not significantly different between the three locations. Across all sites, height growth of P significantly exceeded that of R ($p < 0.01$) and W ($p < 0.01$), and height growth of W significantly exceeded that of R ($p = 0.04$).

Wands and particularly R proved susceptible to cattle browsing, which reduced height growth. Poles were faster growing, easier to protect and showed little damage from the cattle. However, survival and growth of W and R was sufficiently encouraging that they could replace P in stock-free or sheep-only situations.

Keywords: livestock, pastoral, planting materials, poplar

Exploring *Asimina triloba* Through Metabolomics: Pathways to Enhanced Crop Utilization

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Asimina triloba (L.) Dunal, commonly known as pawpaw, is a native North American tree belonging to the *Annonaceae* family. Pawpaw is significant in Native American culture, serving as a food and a traditional remedy for various health conditions, including inflammation, gastrointestinal problems, skin ailments, and respiratory issues. This study aimed to investigate unexplored bioactive secondary metabolites from *A. triloba* that may be associated with the plant's traditional use. The study investigated the bioactivity of putatively identified compounds from the ripe fruit of *A. triloba* using a metabolomics and high-throughput screening analysis approach. The methanolic extracts of the ripe fruit of *A. triloba* were subjected to UHPLC-HRMS analysis. Twenty-six compounds were putatively identified with XCMS online and METLIN databases. Furthermore, the study explored these putative compounds' anticancer, antioxidant, and antibacterial properties. Of the twenty-six compounds, fourteen exhibited a significant total antioxidant capacity surpassing that of Trolox, a widely recognized antioxidant. Moreover, two compounds showed activation of the Nrf2/ARE pathway comparable to the positive control tert-butylhydroquinone. Two compounds displayed anticancer activity against leukemia (HL-60), melanoma (SKMEL5), breast cancer (MCF-7), ovarian cancer (SKOV3), and prostate cancer (PC3) cell lines. Lastly, twelve compounds exhibited significant antibacterial activity against *Pseudomonas aeruginosa*, *Staphylococcus aureu*s, *Mycobacterium smegmatis*, and *Escherichia coli* at varying concentrations. From these findings, four lead compounds were identified. These results validate the traditional usage of *A. triloba* as a valuable resource for treating several maladies. Furthermore, the results highlight the critical need for further research to unlock the full potential of *A. triloba* and its compounds through cutting-edge metabolomics and high-throughput screening approaches. This scientific exploration will bridge traditional knowledge with innovative research, deepening the understanding of *A. triloba*'s healing properties and explore novel treatments for various ailments.

Keywords: *Asimina triloba*, metabolomics, pawpaw, UPLC-HRMS, XCMS Online

Fast Growing Woody Crops for Carbon Sequestration in Florida, USA

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Fast growing *Eucalyptus* L'Hér and bamboo are carbon sequestration options in Florida. *Eucalyptus* grown as short rotation woody crops (SRWCs) with soil amendments including biochar (BC) may sequester over 10 Mg of C/ha/year. In windbreaks, *Eucalyptus grandis* W. Hill ex Maid. cultivars may sequester up to 34 Mg of C/ha in three years, with additional sequestration by amending soil with BC. *E. grandis* and *E. grandis* × *E. urophylla* S.T. Blake cultivars grown and coppiced as SRWCs with BC and slow-release fertilizer may sequester up to 20, 1.5, and 2.5 tons C/ha/year of stemwood, crown, and roots, respectively. Short rotation woody crop management with BC is more profitable than operational culture if BC application costs are ≤450/Mg. High quality biochar from Green Carbon Solutions' (GCS') biochar production facility at Indiantown, FL, will be produced primarily from eucalypts. Eucalypt SRWCs harvested every 3-4 years are ideal for GCS' process, and Asper bamboo (*Dendrocalamus asper* [Schult. & Schult. F.] Backer ex K. Heyne) in 3-5-year rotations producing over 5,000 1-5" diameter culms per acre and sequestering up to 24 Mg C/ha in 4 years is also ideally sized for GCS' process. Field drying for one month can reduce Asper culm moisture content by ~50%. Using BC produced from eucalypts and bamboo SRWCs as a soil amendment could be both a long-term sequestration strategy and an opportunity to increase crop productivity.

Keywords: bamboo, carbon sequestration, *Eucalyptus*, Florida, USA

Evaluating the Economic Feasibility of Hybrid Poplar for Veneer Wood in Western North Carolina

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Hybrid poplar (*Populus* L. spp.) is grown globally for bioenergy, high-quality wood products such as veneer and saw logs, as well as environmental services including erosion control and pollution mitigation. Over the last decade, North Carolina State University, in partnership with ArborGen and GreenWood Resources, Inc. has identified select poplar clones that perform well in the mountains of western North Carolina (WNC) and yield high-value veneer-quality logs in 8-15-year rotations. Poplar logs from low-elevation montane sites have been successfully milled as veneer products by Columbia Forest Products in Old Fort, NC in WNC. To facilitate decisions for commercial deployment, both productivity and profitability models were developed to assess economic viability for WNC mills, forest consultants, and landowners. An existing productivity and economic assessment model (SRWC-PEAM) for hybrid poplar and other short-rotation forest species in North Carolina was adapted to WNC-specific conditions and coupled to a WNC veneer-quality poplar enterprise budget to produce a feasibility and profitability tool using a publicly accessible Excel sheet. An added feature is an opportunity cost comparison between veneer-quality poplar cultivation and current agricultural production yields and profits from pasture, hay, and pumpkin crops. The opportunity cost comparison includes estimation of carbon credits for hybrid poplar growth on former non-forested agricultural sites. There is landowner interest in alternative forest-markets in WNC, particularly lands once in cultivation for profitable Fraser fir Christmas trees but now unusable due to the soil pathogen *Phytophthora*.

Keywords: feasibility, modeling, poplar, veneer

Financial Analysis of Short Rotation Tree Crops: A Comparative Analysis with Competitive Land-Use in Northwestern Ethiopia

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Northwestern Ethiopia possesses abundant resources of short rotation tree crops (SRTCs), actively cultivated and managed by rural communities as integral components of their livelihood strategies. However, the rising demand for conventional crop production has significantly reduced the availability of these resources over time. This study examines the financial performance of SRTCs with the prevalent land-use system in Banja district. The investigation relies on both primary and secondary data, obtained from 140 households across two kebeles, and includes field inventory and market surveys on selected land-use systems. The land-uses considered are Conventional Cereal-Based Mono-Cropping (CCBMC), highland bamboo plantations, *Acacia decurrens* (Wendl. f.) Willd. plantations, and *Eucalyptus* L'Hér plantations. The study employed Cost-Benefit Analysis to evaluate financial profitability and econometric analysis to estimate the contribution of SRTCs to overall income. Financial analysis results reveal positive Net Present Value (NPV), Benefit-Cost Ratio (BCR), and Annual Equivalent Value (AEV) for all land-use systems, with *Eucalyptus* plantations emerging as the most profitable, followed by bamboo plantations and *Acacia decurrens*. Despite farmers' dissatisfaction with CCBMC due to lower returns and weather sensitivity, smallholder farmers still rely on it. Econometric analysis indicates that variables such as household landholding size, livestock size, education level, and access to extension services positively influence household decisions on short rotation tree crop plantation, while distance from the market has a negative impact. The study concludes that SRTC production is economically feasible compared to CCBMC and is a lucrative enterprise in the study area. To address farmers' dissatisfaction and encourage the transition to more profitable and sustainable tree crop cultivation, collaborative efforts are essential. Key areas include promoting extension services, providing access to credit, establishing robust marketing systems, and addressing barriers like transportation infrastructure, which can enhance the economic viability of SRTC, fostering prosperity among smallholder farmers and contributing to regional economic development.

Keywords: *Acacia decurrens*, *Eucalyptus* plantation, financial profitability, highland bamboo, short rotation tree crop

Whole Tree Transportation System for Timber Processing Depots

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The growing demand for alternative energy has led those interested in producing sustainable energy from renewable biomass such as timber to devise new concepts to satisfy those demands. The concept of timber processing depots, where whole stem trees will be delivered for future processing into wood products and high-quality energy fuel, has led to the re-evaluation of current timber transportation methods and whether they can feasibly transport unprocessed trees in an efficient, legal, and safe manner. Modifications for standard double bunk log trailers were developed to accommodate tree length of unprocessed southern yellow pine. The first design was a swinging gate design, and the second was an extendable bolster design. These modification designs ensured that tree crowns were contained within the trailer to prevent contact with and damage to other vehicles while in transport. Consideration of criteria including modification weight, load force analysis, ease of attachment and detachment, and overall feasibility determined which of the two trailer modification designs was chosen for trial load testing. The selected design was fabricated and attached to a standard two bunk log trailer which was loaded to its maximum volume capacity with chip-n-saw- and pulpwood-sized *Pinus taeda* L. Axle weights were recorded three times for each load of timber: unprocessed, trimmed, and delimbed and processed to a merchantable top. Net load weights and anecdotal observations were used to determine that transporting whole tree chip-n-saw- and pulpwood-sized loblolly pine on the modified trailer was unfeasible.

Keywords: timber processing, transportation, tree length, whole-tree

Optimized Site Selection for Short Rotation Woody Crop Systems in the Lower Mississippi Alluvial Valley

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The advent of the carbon market along with demands for bioenergy outside North America has created expanding opportunities for Short Rotation Woody Crop (SRWC) systems. In the Lower Mississippi Alluvial Valley (LMAV), opportunities for landowners manifest as afforestation projects for *Populus deltoides* Bartr. ex Marsh. and *Salix nigra* Marshall on marginal agricultural sites. Both pioneer species thrive on alluvial sites and have strong genetic improvement. This makes both species strong candidates for SRWC plantations in the region. Building on previous work, this project seeks to develop a spatial process-based, 3PG (Physiological Processes Predicting Growth) model for both species and conduct simulations across the LMAV based on a variety of silvicultural and site inputs. Biomass yield from this model will be used to develop an economic analysis to determine the viability of the site for afforestation in the context of previous agricultural yield. This talk will showcase preliminary results and implications along with discussion of future work.

Keywords: 3PG (physiological principles predicting growth) model, black willow, Lower Mississippi Alluvial Valley (LMAV), poplar, site selection

Technical Session: Phytotechnologies

Pump and 'Treet': USGS and EPA Pilot-Scale Results, 2018 to 2023

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Phytoremediation of contaminated shallow groundwater using trees is firmly established as a successful remediation technology for certain contaminants. Since the mid-1990s, several Superfund and private sites have used trees to achieve environmental clean-up goals to restore groundwater to beneficial use. What has been less established, however, is using trees to remediate deeper groundwater contamination. Since 2018, the United States Geological Survey (USGS) has provided technical support at multiple Superfund sites characterized by shallow and deep groundwater contamination across the United States where the USGS and Environmental Protection Agency (EPA) established pilot-scale plantings. At each site, contaminated groundwater from deep aquifers is pumped using solar power to irrigate trees to decontaminate the groundwater.

Keywords: contamination, deep groundwater, phytoremediation

Exploring the Potential Use of Short Rotation Woody Crops in Urban Phytoremediation Initiatives: A Detroit Pilot Study

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In this talk, we will review a Detroit-based application of short rotation woody crops (SRWCs) in a city-wide phytoremediation pilot project. The project was initially led by a local NGO and is now advanced through an ongoing NGO-university-government partnership. Eight phytoremediation sites were established between 2011-2015, with adjacent land use among the sites including residential, commercial, and historic industrial developments. There is current interest in redeveloping four of the sites. A mix of hybrid and native willow and poplar genotypes were planted at these four sites between 2014 and 2015, with 216-1405 trees planted per site. Preliminary soil sampling indicated that arsenic, lead, and Benzo(a)pyrene were present at each site. Tree height and caliper data were collected at the time of planting and 1-2 years post-planting, along with tree survival. Preliminary results indicate that caliper size and height differed between genotypes and between and within sites. Additionally, survival varied notably among the genotypes planted, with mortality rates highest for *Salix alba* L. and lowest for 'SX61' and 'SX64' (*Salix miyabeana* Seemen). Variability in survival and growth rates may be attributed to heterogeneous distribution of contaminants, physical site characteristics or suitability of one genotype over another within these sites. We will review upcoming plans for *in situ* sampling of tree growth measurements, survival, and health condition, and to collect soil and plant tissue to determine levels of contaminants present approximately 10 years post-planting. Findings from this study are intended to strengthen our understanding of growth and survival of different genotypes, improve future urban SRWC-based phytoremediation initiatives, and help identify potential uses of SRWC phytoremediation sites once trees have reached the end of their life cycle. Lessons learned from our multi-institutional collaboration will also provide insights on how to leverage the respective strengths of project partners to ensure the success of urban SRWC phytoremediation projects.

Keywords: phytoremediation, poplars, urban, willows

Uptake and Fate of Chlorinated Solvents Among Three Hybrid Poplar Clones Grown for Phytoremediation: Preliminary Results

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Chlorinated volatile organic compounds (VOCs) such as tetrachloroethylene (PCE) and trichloroethylene (TCE) are widespread environmental pollutants due to spills and improper disposal of industrial solvents. Phytoremediation is a cost-effective and sustainable option for remediation of sites contaminated with PCE and TCE. Hybrid poplars (*Populus* L. spp.) in particular, are commonly implemented in phytoremediation systems due to their rapid growth, extensive rooting, and elevated water use. In 2018, a phytoremediation buffer system comprised of hybrid poplar trees was established at a site contaminated with chlorinated VOCs in eastern Wisconsin, USA. The site, located less than 4 miles from Lake Michigan, experienced unregulated dumping of industrial liquid waste in the 1960s and 1970s. Site monitoring activities since the 1990s have indicated elevated levels of PCE, as well as its byproducts from bacterial degradation, TCE, isomers of dichloroethane (DCE), and vinyl chloride (VC), within groundwater samples. Our overarching objectives for establishing the phytoremediation buffer at the site were to: 1) reduce onsite contamination through uptake and degradation of contaminants, and 2) mitigate offsite transport of contaminants via surface- and groundwater interception. To investigate the uptake and fate of chlorinated contaminants at the site, we sampled the leaves and branches of three poplar clones in the phyto buffer: 'DN34' (*Populus deltoides* Bartr. ex Marsh. × *P. nigra* L.), 'NM2' (*P. nigra* × *P. maximowiczii* A. Henry), and '9732-11' (*P. deltoides* × *P. nigra*). Leaf and branch samples were collected from 18 trees (6 trees per clone). Following sample extraction, targeted analyses will be performed to identify and quantify chlorinated parent compounds and their metabolites. Volatile compounds will be analyzed using solid phase micro extraction paired with gas chromatography-mass spectrometry (SPME GC-MS). Non-volatile compounds will be analyzed using ultra-performance liquid chromatography paired with tandem mass spectrometry (UPLC-MS/MS). Sample processing and analytical method development are currently underway. Preliminary results from these analyses will be presented.

Keywords: chlorinated compounds, industrial solvents, phytotechnologies, remediation, VOCs

Sulfur Mass Balance of Poplars Selected using Phyto-Recurrent Selection for *in situ* Sulfate Treatment

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Poplars (*Populus* L. spp. and their hybrids) have been recognized throughout the world for their ability to provide a variety of ecosystem services. Due to their fast growth, extensive root systems and elevated hydraulic control potential, poplars have been used for a multitude of environmental applications, including agroforestry, land restoration, and pollution mitigation. Although poplars can be used to remediate several types of inorganic and organic contaminants through the process of phytoremediation, there is limited knowledge about the use of poplars to remediate elevated levels of sulfur that pose a threat to human health and the environment. Understanding the uptake of sulfur species by poplar can contribute to our understanding of poplars as a viable solution to sulfur pollution. Therefore, in this greenhouse study we investigated the fate and transport of sulfur in poplar phytoremediation systems within the soil-poplar-water continuum. To do so, five poplar clones were grown for eight weeks under three sulfate irrigation treatments: 0 mg/L, 400 mg/L and 1,000 mg/L. In addition to collecting growth and physiology data, sulfur concentrations within the irrigation water, poplar plant tissues (roots, stems, leaves, cutting), soil, and leachate were collected in order to calculate the sulfur mass balance of each system, and therefore determine its effectiveness to reduce sulfur concentrations. Results from this study as well as its implications for a broader study on the use of phytoremediation and biological treatment methods for mitigating sulfur pollution will be discussed.

Keywords: greenhouse, growth, physiology, phytoremediation, *Populus*

Evaluating the C Sequestration Co-Benefits of Short Rotation Woody Crop Cultivation in Combination with Enhanced Weathering

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Cultivation of short rotation woody crops such as willow (*Salix* L. spp.) offers C sequestration and offsets in the form of bioenergy production, as well as accumulation of soil organic C. Recently, enhanced weathering of terrestrial rock material is being explored as a promising method for the removal of anthropogenic CO_2 emissions from the atmosphere. Enhanced weathering has been combined with the production of certain other crops, however combining willow cultivation with enhanced weathering has not been explored previously. Here we show that an ameliorated silicate-rich mining waste can be effectively weathered in the soil environment when used as a soil amendment in conjunction with cultivation of fast-growing willows (*Salix matsudana* Koidz. × *S. alba* L. 'Austree') in a pot study environment. Results showed that the willows were able to tolerate high concentrations of ameliorated mining waste and sequester inorganic carbon through the production of bicarbonate in soil solution. Ten weeks after planting, alkalinity measurements of soil solution from pots with willows and the addition of 25% by mass mine waste product indicated an inorganic C sequestration per liter of leached soil solution that was 4.5 times higher than in unamended soils with willows. The addition of ameliorated mine tailings also increased the pH of the soil solution by up to two units (pH of 6 in control vs. pH of 8 with the addition of 25% amendment). Weathering of the ameliorated mining waste product may also provide essential base cations to the soil environment. We did not observe an increase in biomass production associated with the presence of this mineral amendment, likely due to nutrient limitations on growth, not adverse effects of the mineral amendment itself. We additionally evaluated the potential of these trees to phytoremediate nickel present in the amendment, but Ni concentrations in willow biomass were too low.

Keywords: bioenergy, carbon sequestration, enhanced weathering, willow

New Advances in Enhanced Phytoremediation and Keys to Success on Challenging Sites

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In 2014, Intrinsyx Environmental collaborated with NASA to introduce endophytic bacteria with hybrid poplar trees to address trichloroethylene (TCE) groundwater contamination at the Middlefield-Ellis-Whisman (MEW) Superfund site. During the last eight years, the company has installed over 35 endophyte-assisted phytoremediation systems (EAPS) on Superfund sites, state-mandated clean-ups, and Fortune 500 redevelopment sites across the USA. Endophyte-enhanced tolerance and appropriate tree selection of unique varieties are newly discovered keys to successful phytoremediation on polluted sites with phytotoxic concentrations of both organic and inorganic constituents.

This presentation covers design, methodologies, and data from phytoremediation projects currently deployed and lessons learned from utilizing EAPS technology. These synergistic bioremediation tools and innovative techniques have been deployed to address eco-restoration and several classes of pollutants, including chlorinated volatile organic carbons (VOCs), petroleum hydrocarbons, and 1,4-Dioxane and mixed wastes. Data will be shared from several active remediation installations where grass, tree, and plant species have been inoculated with endophytes. Data and lessons learned will be highlighted from contaminated sites where EAPS is currently installed.

Success with phytoremediation comes from careful site assessment and selecting appropriate tree and microbe varieties. Data and lessons learned will be highlighted from eco-restoration and contaminated sites where EAPS is currently installed treating both the soil and groundwater. Lessons learned along the way include additional confirmation that endophytes contribute to phytoremediation success and improved plant establishment, soil restoration, *in planta* degradation, and enhanced source-zone depletion rates. Data suggests that the selection and application of appropriate endophytes are the key factors in plant establishment on sites with phytotoxic concentrations of petroleum hydrocarbons or chlorinated solvents. Additionally, selecting site-appropriate tree varieties and providing them with consistent care is vital for establishment and long-term success on contaminated sites. EAPS now represents a standalone treatment for mitigating soil restoration and *in situ* degradation of soil and groundwater contaminants.

Keywords: contamination degradation, endophytes, phytoremediation

Eight Case Histories Where the *Salicaceae* Successfully Manages Pollutants

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Phytoremediation's primary objective is reducing the public health risk and improving cleanup cost efficacy for Contaminants-of-Concern (COC). Rational sustainability will be reviewed based on measured data and critical evaluation of eight keystone projects. Phytoremediation began in 1986 based on short rotation woody crop research using *Salicaceae* spp. (*Populus* L./*Salix* L.; poplar/willow (P/W)) species. The first 1988 phytoremediation buffer specifically planted unrooted 'DN34' (*Populus deltoides* Bartr. ex Marsh. × *P. nigra* L.) poplar whips in 1.5-m deep trenches using 1.8-m trees. The roots grew from pre-formed root initials along the full buried stem depth. As an engineering practice, this research demonstrated that a reliable rhizosphere depth develops a reliable soil volume with predictable properties.

Fundamentally, the root surface area poses the ultimate limit to growth and efficacy assuming agronomic care follows forestry practices. Roots that grow and expand into surrounding soil create a surface area covered with microbes. Simplistically, photosynthesis in leaves creates sugars and proteins that flow down the phloem to the rhizosphere to exude through roots, hence feeding the microbes.

Water is pulled to the root surfaces, up the xylem and transpired through leaf stomata. The P/W leaf canopy increases Potential Evapotranspiration (PET) due to the 'clothesline' effect. Poplar PET is significantly higher than reference crops (alfalfa, grasses, corn). Transpired water pulls unwanted soluble pollutants through to the microbe-rich root-soil surface where carbon and the microbe population is the greatest.

Ecolotree project plantings have used unrooted stems ranging 30 cm to 3 m long. Planting equipment has involved shovels, augers, excavators, and vibratory rippers. The rhizosphere has been amended with composted biosolids, mineral fertilizer, gypsum, and composted manure. In >30% of the projects, trees are irrigated with contaminated water pumped from landfills, wastewater treatment systems, industrial brownfields, and military bases.

These projects document where the P/W phytoremediation has worked and where it has failed.

Keywords: economics, evapotranspiration, microbes, phytoremediation, rhizosphere

Technical Session:
Genetics and Physiology

Growth and Biomass of Poplar Seedlings Grown from Geographically Different Seeds in Mongolia

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This study assesses the distribution and characteristics of native poplar species in Mongolia. About 8.2% (12.4 million ha) of the total territory of Mongolia is covered with forests, which is mostly boreal forests dominated by coniferous species. Poplars and aspen occupy less than 1% of forests. Currently there are 5 native species of *Populus* recorded in Mongolia, including aspen (*Populus tremula* L.) and desert poplar (*P. euphratica* Olivier), which grow in lower mountains and desert, respectively. The other species mostly grow along the riparian zone: *P. laurifolia* Ledeb., *P. suaveolens* Fisch. ex Poit. & A.Vilm., and *P. Pilosa* Rehder. There have not been many studies on the native poplars in Mongolia. In this study, we determined the natural distribution of two main species and collected their seeds to test seedlings for the growth difference, to define the superior characteristics to use for restoration of degraded riparian forest, which has high adaptation potential.

We collected *P. suaveolens* seeds from Onon, Selenge, and Terelj Rivers, and *P. laurifolia* seeds from Khovd, Tamir, Tes, and Bulgan Rivers and Zuunsaikhan Mountain. Seeds were planted in the nursery in open soil and pots. Seedlings were studied for their growth parameters, and specific leaf areas. Growth and biomass of these seedlings differed ($p < 0.001$), and superior growth was observed for the seedlings collected from Selenge River Basin. Further, seedlings were transferred to the field at two years old. Growth parameters and biomass were studied for the destructively sampled 40 seedlings.

Results from this study showed that the tree diameter distribution curve is different from normal forest according to A.V. Turin's scale. This indicates natural growth balance is lost. We conclude that riparian forests are overexploited for recreation, firewood, and livestock grazing, and therefore need to be restored with the seedlings grown from native species to continue providing ecosystem services and energy for local communities.

Keywords: distribution, *P. laurifolia*, *P. suaveolens*, specific leaf area

Elevated CO_2 Sensitizes *Populus* Response to Rising Temperatures: Provenance, Nitrogen, and Leaf Traits

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In the context of rising CO_2 levels and temperatures due to changing climates, understanding the physiological responses of *Populus* L. species, which are integral to carbon sequestration and forestry, is crucial. This study gathered 30 unique genotypes of *Populus* with varied provenances in their parentage and planted them in the same field conditions to explore how they respond to elevated CO_2 and rising temperatures, focusing on key physiological parameters including maximum assimilation rate (A_{sat}), optimal temperature (T_{opt}), photosynthetic rate at the optimal temperature (A_{opt}), maximum Rubisco-limited carboxylation rate (V_{cmax}), maximum rate of electron transport (J_{max}), and water use efficiency. We find that elevated CO_2 significantly amplifies the temperature responses of these parameters. Elevated CO_2 markedly sensitizes *Populus* species' response to rising temperatures, increasing A_{sat}, adjusted T_{opt}, and enhanced A_{opt}, indicating a more robust photosynthetic capacity under elevated temperatures. V_{cmax} and J_{max} responses to higher temperatures were also higher, suggesting increased enzymatic activity and transport efficiency. Notably, intrinsic water use efficiency (iWUE) and instantaneous water use efficiency (WUE) exhibit divergent responses to temperature fluctuations, with iWUE consistently increasing, reflecting an adaptation to conserve water in higher CO_2 environments. Furthermore, our study reveals significant correlations between *Populus* provenance and key photosynthetic parameters, such as A_{opt} and T_{opt}, and male provenance has more profound effects than female provenance. These correlations suggest that genetic and ecological backgrounds, manifesting in variations in leaf nitrogen content and leaf mass per area (LMA), significantly influence these species' thermal and photosynthetic adaptation. The provenance-related differences likely arise from adaptive and acclimatization evolution, tailoring each genotype's physiological responses to its native environmental conditions. Overall, the study highlights the complex interplay between CO_2, temperature, and genetic diversity in shaping the physiological traits of *Populus*, with significant implications for their management and conservation in a changing climate.

Keywords: leaf functional traits, photosynthetic capacity, temperature response curves, thermal acclimation

Dehydration Tolerance of Black Cottonwood (*Populus trichocarpa*) for Sustainable Biomass Production

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The use of woody crops for sustainable, large-scale bioenergy production will require the use of marginal agricultural lands that experience recurrent droughts. Given their high productivity and wide distribution, poplar (*Populus* L.) species and their interspecific hybrids are potential woody bioenergy crops for the Pacific Northwest of the USA. Poplar species and genotypes within a given species have a wide variation in their drought tolerance capacity. A large genome-wide association study population of black cottonwood (*Populus trichocarpa* Torr. & Gray) was established at Boardman, Oregon under two irrigation levels to determine variation in dehydration tolerance across the population under field conditions. Differential irrigation treatments were established based on weekly potential evapotranspiration (PET) demand for Boardman, Oregon with the calculated irrigation treatments delivering 100% and 59% of PET in 2017. These treatments were maintained through 2020. Soil water potential, plant growth, leaf osmotic potential, and leaf metabolite profiles analyzed by gas chromatography-mass spectrometry (GCMS) were determined over three growing seasons. Dehydration tolerance was assessed by leaf osmotic potential, the capacity to lower osmotic potential via osmotic adjustment, and by the total organic solutes measured by GCMS analyses. Overall, there was a wide variation in dehydration tolerance across the genotypes tested, but surprisingly, few genotypes displayed osmotic adjustment to drought at this site. Results will be presented on the metabolite profiles across genotypes, between treatments, their year-to-year variation, and the relationship between these variables and their overall growth and drought tolerance.

Keywords: dehydration tolerance, metabolite, osmotic potential, poplar, *Populus trichocarpa*

Bark Morphological and Chemical Features are Differentially Correlated with Disease Resistance and Yield in Hybrid Poplar Taxa

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In the southeastern United States, the establishment of short-rotation intensively cultured plantations of hybrid poplar has been hindered by its susceptibility to stem cankers. We evaluated the tradeoffs between biomass yield and disease tolerance in hybrid poplar genotypes belonging to *Populus deltoides* Bartr. ex Marsh. × *P. maximowiczii* A. Henry (DM), *P. deltoides* × *P. nigra* L. (DN), *P. trichocarpa* Torr. & Gray × *P. maximowiczii* (TM), and *P. deltoides* × P. deltoides (DD) taxa. We hypothesized that canker resistant genotypes will have thicker bark, but bark thickness and biomass yield will be negatively correlated. After two growing seasons, the DD genotypes developed thicker bark compared to the genotypes of other taxa and bark thickness was not correlated with biomass yield in the DD genotypes ($R^2 = 0.002$). However, in the TM, DM and DN genotypes, bark thickness was negatively correlated with biomass yield ($R^2 = 0.33$-0.77). Disease incidence studies revealed that the DM genotypes were most susceptible to canker whereas no disease was detected in DD genotypes. Furthermore, bark analysis conducted by Fourier transform infrared spectroscopy coupled with multivariate analysis showed DD genotypes to be chemically separate from the three hybrid genotypes and that bark chemistry was correlated with canker disease incidence. Taken together, these results reveal that it is possible to generate hybrid poplar genotypes with thicker bark, disease resistance and higher biomass yields. This insight should guide further efforts to develop genetically improved hybrid poplar genotypes, both in terms of biomass yield and disease tolerance, for cultivation in the southeastern United States.

Keywords: bark, disease, genotypes, hybrid poplar, taxa, yield

Suitability of Veneer Poplar on *Phytophthora*-Infested Sites in Western North Carolina

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North Carolina is the lead producer of the premier Christmas tree in the USA, the Fraser fir (*Abies fraseri* [Pursh] Poir.). However, Fraser fir production is threatened by the continued spread of Phytophthora root rot (PRR). Phytophthora root root is the most significant biotic threat to fir (*Abies* Mill. spp.) Christmas tree production in North America and is caused primarily by the pathogen *Phytophthora cinnamomi*. Phytophthora root root kills 100% of the Fraser fir trees that become infected as they lack any inherent genetic resistance to this disease. Due to continued losses from PRR, an economically profitable alternative is needed that can replace Fraser fir on these diseased sites. Christmas tree growers have the skills necessary for short rotation woody crop production, which provides new opportunities for alternative species. One potential replacement is poplar (*Populus* L. spp.) that can be processed for veneer wood. However, resistance of available veneer poplar germplasm needs to be assessed before it can be planted on PRR infested sites. We screened 17 elite clonal hybrids of *Populus deltoides* Bartr. ex Marsh. and *P. trichocarpa* Torr. & Gray veneer poplar genotypes for PRR resistance. Dormant cuttings were collected and rooted in spring 2023. Inoculation of the containerized poplar clones was carried out using *P. cinnamomi*-colonized rice grains from an aggressive isolate isolated from PRR symptomatic Fraser fir. Growth rate and several physiological traits were collected weekly for 12 weeks following *Phytophthora* challenge. Overall, *P. trichocarpa* × *P. deltoides* hybrids were impacted the least by PRR inoculation with an average height of 39.1 cm for un-inoculated controls compared to 32.0 cm for *Phytophthora*-treated trees. Conversely, a *P. deltoides* × *P. deltoides* cross had an average height of 28.5 cm in the un-inoculated group compared to 16.4 cm in the inoculated group. As climates continue to change, the threat from *Phytophthora* will continue to increase. Therefore, hybrid *P. trichocarpa* × *P. deltoides* represent a potential alternative for PRR-impacted Christmas tree farmers.

Keywords: pathology, *Phytophthora*, plantation, poplar, veneer

Technical Session:
Large Initiatives

Research and Development of Fast-Growing Trees in the United States from 2020 to 2023: A Report from the International Commission on Poplars and Other Fast-Growing Trees Sustaining People and the Environment (IPC) of the Food and Agriculture Organization of the United Nations (UN FAO)

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The International Commission on Poplars and Other Fast-Growing Trees Sustaining People and the Environment (IPC) is a treaty-based statutory body placed within the framework of the Food and Agriculture Organization of the United Nations (UN FAO). The IPC mission is to reduce poverty and improve ecosystem services worldwide by fostering the sustainable management of fast-growing trees (FGTs) to realize many of the United Nations Sustainable Development Goals (SDGs) and other international frameworks. The IPC strategy is to contribute to the SDGs along with the UN Global Forest Goals and the UN Decades of Family Farming and Ecosystem Restoration by maximizing the potential of sustainable management of FGTs to improve livelihoods and facilitate production of ecosystem goods and services. In this role, the IPC serves as a knowledge and capacity development network as well as a science-policy-practice platform, converting science-based approaches into practice. The IPC has 38 member nations on five continents who present national reports at a formal session every four years. At the conference, highlights from the upcoming United States national report will be presented, with a focus on achievements in research and development of FGTs in the United States from 2020 to 2023. While focusing on ecosystem services that FGTs provide, information will be presented according to the five IPC working parties that existed during that time period: 1) Taxonomy, Nomenclature, and Registration, 2) Domestication, Breeding, and Selection of Genetic Resources, 3) Plant Health and Resilience to Threats, 4) Production Systems for the Bioeconomy, and 5) Environmental and Ecosystem Services. In addition to key research outcomes, highlights will include peer-reviewed publications, notable partnerships and collaborations with other countries, and new innovations in science and technology.

Keywords: breeding and selection, environmental and ecosystem services, plant health, production systems, taxonomy

Review of Poplar and Willow Activities in Canada

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In April 2024, the four-year Canadian country report on poplars and willows was submitted to the International Poplar Commission (IPC) of the UN's Food and Agriculture Organization (FAO) (https://www.fao.org/ipc/overview/en/). It was prepared for the Poplar and Willow Council of Canada (PWCC) under contract to Natural Resources Canada (NRCan), the Government of Canada's ministry responsible for forestry, which then submitted it to the IPC. The report's main chapters are: 1) Policy and legal framework; 2) Technical information; 3) General information; 4) Summary statistics. The presentation discusses research in Canada, which is conducted by universities, NRCan's Canadian Forest Service and, in some cases, by provinces. Research projects address: genetics and tree improvement; physiology; insects; diseases; management practices; and utilization. Also included is discussion about funding and other programs by the federal government, provincial governments and other institutions. Forestry and agricultural policies and regulations that affect poplar and willow use are generally under provincial jurisdiction and are discussed in the presentation. Environmental applications are reviewed, including the use of willows and poplars for phytoremediation, riparian protection, greenhouse gas mitigation and other uses. Industrial use of poplar and willow as a fiber source or renewable fuel will also be addressed. Interested persons will be provided with links or electronic versions of the report and past reports.

Keywords: poplar, research, utilization, willow

Woody Biomass for the Bioeconomy, a Billion-Ton 2023 Report Update on SRWCs

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In the pursuit of net-zero targets, the United States Department of Energy released the fourth in a series of national biomass resource assessments. Building on the studies conducted in 2005, 2011, and 2016, the Billion Ton 2023 (BT23), provides an advancement in the understanding of biomass resources in terms of quantity, spatial distribution, and economic accessibility. The goals of this report are to update to latest available input data (e.g., costs, yields, and economic inputs), and ensure equitable access to the latest biomass resource data and that results are findable, accessible, interoperable, and reusable (FAIR) through a data new portal. The assessment unveils nuanced regional variations in biomass availability, ranging from the immediate potential of forest wastes to the maturation of the market for woody energy crops cultivated on agricultural land.

This presentation provides an assessment of renewable carbon resources potentially available from the forested and agricultural land bases in the CONUS for production of fast-growing trees. The analysis of biomass resources extends to forested landscapes, with small-diameter tree potential assessed using the Forestry Sustainability and Economic Analysis Model (ForSEAM). Short rotation woody crops on agricultural land are modeled using the Policy Analysis System Model (POLYSYS), a partial-equilibrium linear programming model with a focus on the agricultural producer response. Throughout these analyses, sustainability constraints are incorporated including the net regeneration of forested stands, limitations on harvesting on steep slopes and other good practices that would need to be applied based on local conditions. By providing detailed insights into woody biomass suitability for energy production, this research lays the groundwork for near-term woody biomass resource potential and a mature-market potential contributing to a developing bioeconomy. This comprehensive analysis underscores the pivotal role of woody biomass resources in steering the U.S. toward net-zero targets.

Keywords: billion-ton, bioenergy, economic analysis, SAF

Overview of DOE BETO Purpose-Grown Energy Crops

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The Department of Energy Bioenergy Technologies Office (DOE BETO) has a long history of supporting research that uses forest-based biomass as a renewable energy feedstock. Over the years, the Renewable Carbon Resources (RCR) program has invested in a wide range of projects, from high tonnage systems to harvesting shrub willow to preprocessing equipment. Applications selected for competitive funding often include team members from DOE National Laboratories.

BETO also directly funds work at several of the DOE National Laboratories. At the Biomass National User Facility located at the Idaho National Laboratory, work includes determining the critical material attributes for feedstocks. Researchers at the Argonne National Laboratory have developed a life cycle analysis (LCA) model, the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model, that can be instrumental in evaluating energy and environmental effects of feedstocks and their conversion-related pathways. Researchers from the Idaho National Lab and the Oak Ridge National Lab are collaborating on a project that uses woody biomass for 3D printing media. Another on-going project is the analysis of the sustainable biomass supply, which includes short-rotation woody crops as a purpose-grown energy crop.

A third mechanism for working with DOE is through the Small Business Innovation Research (SBIR) program. BETO often supplies topic areas for the SBIR Funding Opportunity Announcements. One recent selection is focused on developing an affordable mobile biochar unit.

There are several ways to participate in BETO's research program. Each subprogram, including RCR, hosts workshops and publishes requests for information where stakeholders can voice their thoughts on specific topics of interest. Results of these activities are typically recorded in formal reports that are made available at: www.energy.gov/eere/bioenergy/beto-meetings-and-workshops). Funding opportunities are announced at: https://www.energy.gov/eere/bioenergy/bioenergy-technologies-office-funding-opportunities. To join the BETO mailing list, enter an email in the 'Subscribe for Updates' section of the BETO website (https://www.energy.gov/eere/bioenergy/bioenergy-technologies-office).

Keywords: bioenergy

From Controlled Crossings to Commercial Sales: A Brief History of the Poplar Breeding Program at University of Minnesota Duluth NRRI and Future Perspectives

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The University of Minnesota Duluth's Natural Resources Research Institute (NRRI) has been conducting hybrid poplar research for almost three decades. This program has selected and bred pedigreed families and selected promising clones since 1996, supported by industry and various state and federal grants. Projects have included working closely with Verso Corporation's former large-scale plantation program in central Minnesota and a $1 million USDA grant for researching hybrid poplar plantation establishment in the Midwest USA. Since the start of the breeding activities, a total of 2419 intra- and interspecific and intra- and intersection control-pollinated crosses were performed from 1996-2016. During the given period, obtained plant materials were tested at 43 sites with a total area of approximately 41 ha.

In 2020 the NRRI hybrid poplar team began the commercialization of clone '99059016', a geo-robust clone that performed well in trials across the upper Midwest. It has the registered trademarked name "InnovaTree™." Five commercial tree nurseries began evaluations of this clone in 2021, concurrent with a USA provisional plant patent application submission. Commercial sales began in 2023 at Hauser's Nursery in Bayfield, WI, under a license agreement with the University of Minnesota. The future development of NRRI's poplar program will be aligned with contemporary trends in poplar research and current national and international policies on sustainable development, while following NRRI's vision for R&D. Such a principle will create a program focused on the development of new poplar cultivars that provide additional ecosystem services, in addition to the production of biomass for various uses and purposes.

Keywords: biomass production, ecosystem services, Midwest U.S., poplars, selection

Poster Presentations

Strategies to Reduce Cadmium Phyto-Availability and Uptake in Avocado (*Persea americana* var. Drymifolia, i.e., Hass)

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The avocado market plays a significant role in the United States economy and market. Despite the challenges faced by domestic producers, the U.S. avocado market continues to expand its consumption, driven by factors such as increasing awareness of the nutritional benefits of avocados and marketing campaigns promoting the fruit. However, high toxic levels of cadmium in avocados have raised concerns about consumer food safety and this has impacted export markets. The recall of U.S. avocados in 2019 due to high cadmium levels highlighted the need for devising cadmium mitigation strategies in avocados to ensure consumer food safety and maintain the reputation of avocado-exporting countries. In this study, we explored 1) the application of amendments and 2) iron foliar treatment to reduce the uptake of cadmium by avocado plants and fruit grown in cadmium contaminated soil (10 mg/L aged 2 months) under greenhouse conditions. Amendments tested were biochar, lime, and iron foliar application at two levels and their combinations resulting in 27 treatments, including the control treatment. According to our results, rice biochar at two levels of 2.5% and 5% (w/w), immediate release lime at two levels of 0.1% and 1% (w/w), and foliar application of iron at two levels of 5 mg/L and 50 mg/L could relatively reduce the uptake of the cadmium by leaves and decrease the bioavailable cadmium levels in soil after 3 months. The effects of the biochar were the most significant. A kinetics study revealed that the rice biochar, compared to the control, has the capacity to remove up to 60% of the cadmium from the solution within 48 hours. According to scanning electron microscopy images, the rice biochar sample had sheet-like layers with different morphology present in each layer. In conclusion, uptake of cadmium by the avocado plant can be mitigated using these strategies to ensure food safety.

Keywords: avocado, biochar, food safety, heavy metal removal

Identification and Characterization of American Elderberry Bioactive Compounds Using High-Throughput Screening Assays in Combination with Untargeted Global Metabolomics Approach

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American elderberry (*Sambucus canadensis* L.) is a rapidly emerging new perennial crop for Missouri. Missouri has been one of the leading producers for commercial-scale production of elderberries in the United States. American elderberry has become popular in the U.S. as a remedy for treating cold and flu symptoms. It has been reported to contain high levels of bioactive compounds with health benefit functions such as anti-microbial, anti-viral, and anti-inflammatory, and has been popular as a dietary supplement. High-throughput screening assays in combination with untargeted metabolomics analysis were conducted to identify and characterize the bioactive compounds in elderberry juice of 21 American elderberry cultivars. Early metabolomics analysis has identified more than 173 bioactive compounds in the cultivars (unpublished data). An array of high-throughput screening bioassays (total antioxidant capacity, activation of antioxidant response element, anti-HIV activity, and antibacterial activity) was conducted to analyze 32 compounds identified from American elderberry. Our preliminary result shows that 14 out of 32 elderberry compounds had antioxidant capacity greater than 5-fold above the control (Trolox). Quercetin 3-galactoside (hyperoside) was found to have the highest total antioxidant capacity (TAC) among other elderberry compounds. Quercetin, luteolin, kaempferol and isorhamnetin 3-0-glucoside also induced an antioxidant response element (ARE) activation in the HepG2 cell line. Seven out of 32 compounds were found to show significant inhibition of NL4-3 and BAL viruses. Nine elderberry compounds were found to have antibacterial activity. Further analysis will be conducted to elucidate the bioactive mechanism of action of elderberry compounds.

Keywords: American elderberry, high-throughput screening, LCMS, metabolomics

Impact of Long-Term Cover Cropped Organic Farming Practices on the Development of Disease Suppressive Soils

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This research focuses on assessing the impact of long-term organic farming practices under cover cropped systems on soil health, and the alteration of rhizosphere chemical composition that is associated with disease resistance. The hypothesis puts forward that the interactions between plant exudates and beneficial microorganisms within these systems create conditions unsuitable for pathogenic organisms, leading to disease-suppressive soils. The study outlines a comprehensive approach involving a metabolomics-based investigation to elucidate the complete soil chemical profiles. It aims to assess the disease suppression capabilities across a chronosequence of organic farming practices under cover cropped systems and further seeks to understand the biological functions of identified molecules in suppressing disease development. The approach involves the extraction of rhizosphere chemicals followed by analysis with ultra-high-pressure liquid chromatography coupled with high-resolution mass spectrometry (UPLC-HRMS). The ion chromatograms will be processed via the XCMS metabolic platform, operated by the Center for Metabolomics at the Scripps Research Institute. Peak detection, grouping, spectra extraction, and retention alignment will be facilitated by XCMS. Subsequently, the spectra will be annotated, and the compounds will be identified and categorized through integration with METLIN, the world's largest metabolite database. Multivariate analysis and principal component analysis (PCA) using XCMS will enable the comparison of chemical profiles among treatments. Each identified compound will be assigned and correlated with its biological pathway through XCMS biological pathway/network analysis. Preliminary findings revealed over 1550 different soil compounds identified through the metabolomics approach. Ongoing efforts are focused on linking these compounds to various biological functions within plants, microbes, and pathogenic organisms.

Keywords: metabolomics, pathogenic organisms, rhizosphere, soil health

Tree/Shrub Leaf-Silage: Production using a Chain-Flail Leaf-Separator Machine Prototype, Labor Efficiency, Cattle, Sheep and Goat Free-Choice Intake Rates, Effect on Milk Qualities and Yield, and Analyses of Nutrition and Toxins

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Tree and shrub leaf-silage was regeneratively harvested from field edges using a prototype Chain-Flail Leaf-Separator, (Project FNE22-013 funded by Northeast SARE). We generally pollarded trees with a 2.7 m pole chainsaw, and coppiced shrubs with a brush-saw. Cutting, limbing and stacking took ¾ to 2 person-hrs per 113.6 L barrel of intact leaves; machine leaf-separation took 10 to 15 minutes per barrel, varying with species leaf attachment. Scooping armfuls of leaves into lever-top barrels, set within the 227.1 L receiving bin, took 5 to 10 minutes, including stick removal. Contents averaged 23.6 kg per sealed barrel of intact leaves with some twigs; twig content varied by species fragility and choice of feed and flail speed settings. Yields averaged about 1.8 kg leaf-silage per LFT field edge, with mean site-average of 3.7 m per 113.6 L barrel. The leaf-separator successfully took up to 6.1 m × 8.9 cm butt D trunks, and stiff, leafy branches; 3 of 23 species proved partially or wholly impractical.

Ruminants at four farms ate substantial recorded amounts of this leaf-silage as free-choice winter supplement; milk yields (goat and cow) were maintained or enhanced. Nutritional results on leaf-silages are in process (FNE24-083 additionally funded by Northeast SARE); so far, tests confirm much higher NFC, RFV, and mineral content than in grass hay, and lower protein content with probable exception of two species. Tests of hydrogen cyanide in cherry species including young and wilted leaves, and of gallotannin in maple species and sumac, are underway, comparing fresh to ensiled.

Two collaborators have samples from SARE FNE22-013: Wayne Zeller (US Dairy Forage Research Center) is examining tannin content to determine digestive and health benefits for ruminants, and Yulica Santos Ortega (Maine Health Institute for Research) has identified lipids, and will identify proteins, in goats' milk with and without leaf-silage.

Keywords: agroforestry, leaf separation, ruminants, tanniferous forages, tree canopy harvest

Impacts of Biodiversity of Short-Rotation Woody Crops on Water Quality

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Mitigating agricultural nutrient runoff and improving water quality is a key challenge in meeting food and energy demands. To address this challenge, short-rotation woody bioenergy crops, specifically *Populus deltoides* Bartr. ex Marsh. (eastern cottonwood) and its hybrids can be planted at the interface of riparian areas and agricultural production fields to alleviate fertilizer runoff into adjacent bodies of water. This research employed an experimental design to evaluate the effects of *P. deltoides* diversity on tree productivity and nutrient uptake and how it mitigates agricultural runoff. We deployed ion exchange resins 0.5 meters below the soil surface at four different sites in Mississippi that contained either monoculture plantings of a single *P. deltoides* genotype or a mixture of two genotypes for the entire growing season. After year one, tree plots reduced soil nitrate concentrations by 34% and soil ammonia by 42% relative to concentrations in agricultural soils across all study sites. Multi-genotype plots reduced soil ammonia concentrations more than single-genotype plots, while the opposite trend was observed for soil nitrate. Year two results are pending. The results of this study display the efficiency of the short-rotation woody crops in reducing water quality degradation that may have positive downstream impacts. This study can be used as an example of mitigation techniques for fertilizer runoff in agricultural fields to limit such degradation of water quality and prevent monetary /economic loss for agricultural producers.

Keywords: *Populus* biodiversity, SRWC, water quality

A Future Where *Salicaceae* Normally Cleans Up a Stressed Global Ecosystem

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All Ecolotree projects use poplar and willow (P/W) from the *Salicaceae* family. Two constant design objectives are 1) to improve public health and 2) to reduce cleanup cost with increased efficiency. The following nine traits support rational sustainability for future adoption on a global scale:

Trait 1 – P/W grow on 75% of the earth's surface
Trait 2 – P/W create an 'engineered' root zone reactor by placing roots to a desired depth, thus growing a defined treatment reactor volume with predictability
Trait 3 – P/W are pioneering trees that establish well and grow tall in disturbed soils normally found on polluted sites
Trait 4 – P/W leaf area extends high into the wind causing the 'clothesline' transpiration effect which moves more water out of the rhizosphere
Trait 5 – P/W regrow by coppicing and/or pollarding from a cut stem cambium, permitting routine harvests while maintaining perennial root functions
Trait 6 – P/W root surface exudes sugar and proteins grown by photosynthesis culturing healthy and abundant microbes
Trait 7 – P/W harvest is raw input for commercial products, and since biomass is not normally directly consumed, there is a decreased health risk if there is pollutant uptake
Trait 8 – P/W agronomy uses well-established farming techniques with room for innovation in products, equipment, monitoring, irrigation and automation
Trait 9 – P/W species have a long academic and forestry research history with established associations to share technology

In 1988, poplar tree buffers were first tested to denitrify farm field runoff; it worked effectively. Ecosystem stress is now identified with ocean acidification, microplastics, species extinction, war munitions (RDX) and drinking water contaminated by 'forever chemicals' (PFOS).

P/W is a tool that can be immediately applied to mimic natural processes to help clean this mess.

Keywords: future, innovation, phytoremediation, poplar, rational sustainability, *Salicaceae*, willow

Degradation of SARS-CoV-2 in Wastewater: Bioassay Guided Tests and Suppression Kinetics

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In recent years, wastewater-based epidemiology (WBE) has been used as a predictive tool to report and observe population-wide infectious diseases. Many regional industries and manufacturing facilities, specifically, the food processing industry, release different classes of molecules to wastewater treatment facilities that significantly contribute to the suppression of SARS-CoV-2 signals in wastewater by breaking down the lipid-bilayer of the membranes. Macon is a city located in the north of Missouri; it has one of the facilities that exhibited low recovery in viral material per diagnosed case, as well as a large frozen food manufacture called ConAgra. The ConAgra company produces a variety of food products for both retail and food service customers.

In order to track the source of suppression, wastewater samples were collected from five different manholes, and the degradation rate of SARS-CoV-2 in each wastewater was tested after 24h reaction. Post-DWTP and post-ConAgra showed the highest degradation rates of 66.5% and 55.7%, respectively. Untargeted metabolomic analysis was employed and developed to identify the chemicals suppressing the SARS-CoV-2 signals in the municipal sewage network. Moreover, XCMS Online, a web-based platform, was used to process the LC/HRMS data. A comprehensive untargeted metabolomic workflow, including statistics, chromatogram, spectrum details, and putative METLIN assignments for each feature, is well-suited for identifying candidate compounds that can suppress the SARS-CoV-2 genetic signal in complex wastewater matrices. Suppression activities were further confirmed by incubation studies on Puro virus, and the suppression kinetics for each bioactive compound were determined. In this study, we investigated the impact of Hydratropaldehyde(2-Phenylpropionaldehyde), 1-Dodecyl-2-pyrrolidinone, Cyclohexylamine, and Octadecanamide (Streamside) on the stability of SARS-CoV-2 in wastewater. According to the results of these experiments, bioactive molecules in wastewater can significantly reduce the stability of SARS-CoV-2 genetic marker signals by up to 98% within 12 h.

Keywords: degradation, SARS-CoV-2 suppression, surfactants, wastewater surveillance

Molecular Archiving of Stoneville and Other Eastern Cottonwood Clones

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Eastern cottonwood (*Populus deltoides* Bartr. ex Marsh.) is a model species that exhibits numerous beneficial characteristics including carbon fixation and storage, phytoremediation, water and nutrient use efficiencies, biofuel quality, and urban site tolerance. The USDA Forest Service, Southern Research Station (SRS) has had a significant increase in national and international demand for *P. deltoides* clones in the last decade, primarily driven by carbon sequestration applications for climate mitigation. Unfortunately, the material origin, molecular identity, and genetic structures of many clones are unclear. The objective of this project is to produce and archive molecular identities of the *P. deltoides* clones maintained by the SRS in Stoneville, Mississippi and determine their genetic diversity. We will collect leaves from 400 clones in two populations (Clone Bank, and Breeding Orchard) in Stoneville. DNA extraction will be carried out at the Galeano Lab, Department of Forestry, Mississippi State University. Genotyping will be performed using targeted sequencing, followed by cleaning and selecting the most informative single nucleotide polymorphisms (SNPs). Finally, we will submit sequencing results to an open-access genetic data repository. We expect to: (1) identify mislabeled clones in the two source populations and material from other origins, (2) recognize the relatedness and genetic diversity of the sampled clones, and (3) provide public access to the genetic identity of each clone for germplasm conservation purposes. As management implications, we will provide critical first steps to ecological genetics for restoration with *P. deltoides* under USDA and private non-governmental organization (NGO) programs.

Keywords: genetic diversity, genotyping, haplotype, population genetics, *Populus deltoides*

Integrating Fast-Growing Trees and Biochar to Remediate and Stabilize Mining Waste for the Keweenaw Bay Indian Community (KBIC)

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During the 20th century, ore mining activities in the north central United States generated billions of pounds of ore processing waste, known as stamp sands. Stamp sands are small pieces of rock resembling coarse sand that result from mechanical crushing of ore-bearing rock to obtain the minerals within. These stamp sands are prone to erosion, and often contain elevated levels of heavy metals, posing risks to human health and the environment. In the Upper Peninsula of Michigan, where copper ore deposits are plentiful, much of these stamp sands were deposited along the shores of or directly into Lake Superior. One such area is Sand Point, a 18.2-hectare site located within the Keweenaw Bay Indian Community (KBIC) L'Anse Indian Reservation that contains over 344,050 cubic meters of stamp sands. Sand Point and its surrounding area provide a variety of beneficial uses to the KBIC, including those related to subsistence, cultural activities, and recreation. The KBIC has led extensive restoration activities at the site, involving soil capping of stamp sands, placement of mounds and boulders to provide protection from the wind, and annual plantings of trees, shrubs, and herbaceous native plants. Despite these efforts, the stamp sands continue to impair many of the beneficial uses of Sand Point. Therefore, researchers at the USDA Forest Service, Michigan Technological University, and the University of Missouri have partnered with the KBIC to design and deploy an adaptive silvicultural system that combines specialized, fast-growing trees (hybrid poplars and willows) with biochar soil amendments to enhance stamp sands phytoremediation and phytostabilization. Planning efforts are currently underway to develop the planting design and maintenance regime of the phytostabilization system. Outplanting will occur during the 2024 growing season. More information on proposed activities at Sand Point, as well as updates on project progress will be presented at the conference.

Keywords: mining waste, phytoremediation, phytostabilization, poplars and willows, stamp sands

Innovations in Phytotechnologies from a Regional Network of Phytoremediation Buffer Systems in the Great Lakes Basin, USA

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Phytoremediation systems, in which trees are used to mitigate soil and water pollution, are sustainable, cost-effective solutions to environmental contamination. From 2017-2019, researchers from the USDA Forest Service and their partners established a regional network of 16 phytoremediation buffer systems at landfills and similarly contaminated sites in the Great Lakes Basin. The network of plantings, consisting of nearly 25,000 hybrid poplars (*Populus* L. spp.) and willows (*Salix* L. spp.) was originally established with an overarching goal of reducing runoff and subsurface flow at the sites. Multiple phytotechnologies research efforts are currently ongoing that utilize the infrastructure of this network. We will present on one of these ongoing projects that involves developing and testing a novel method of pollutant prioritization. Effectively identifying and prioritizing pollutants that exist at contaminated sites is critical for designing successful phytoremediation systems. A global non-targeted approach for identifying priority pollutants based on their toxicity is needed but does not exist. Therefore, we developed a standardized method for pollutant identification and prioritization which combines a global metabolomics approach with toxicity profiling using freely available toxicity data. First, non-targeted global chemical profiling of high-resolution mass spectral data is performed using XCMS Online to identify candidate compounds in the METLIN library. Then, putatively identified compounds are prioritized according to freely available toxicity data from multiple toxicity databases. We conducted a pilot test of this prioritization approach using landfill leachate and contaminated groundwater collected at two phyto-buffer sites, both closed municipal solid waste landfills with unknown contaminant profiles. Preliminary results from this testing will be presented, including putatively identified and prioritized compounds. Our standardized pollutant prioritization approach is flexible and can be broadly applied within phytotechnologies projects. This approach can also be used in combination with targeted chemical analysis for robust pollutant monitoring.

Keywords: metabolomics approach, METLIN, pollutant prioritization, toxicity profiling, XCMS

Integrated Bioremediation-Phytoremediation with Biochar to Mitigate Environmental and Human Health Impacts

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Human activities, including mining, fossil fuel burning, and municipal wastewater production, have contributed to increased mercury and sulfur pollution in lakes and streams around the world. If left untreated, this pollution can pose serious risks to human health and the environment. In particular, elevated sulfate levels can lead to increased production of methylmercury, a neurotoxin, due to sulfate-stimulating microbial activity that methylates mercury. Sustainable, cost-effective solutions are needed to remediate elevated levels of sulfate in order to mitigate the effects on human health and the environment. Therefore, researchers from the USDA Forest Service, Northern Research Station (USDA FS NRS) and the University of Minnesota – Duluth, Natural Resources Research Institute (UMD NRRI) have partnered to develop a novel integrated treatment system for sulfate remediation that combines biological sulfate reduction with sulfate phytoremediation. To synthesize current knowledge of sulfur remediation, we are conducting a systematic literature review on biological treatment methods for sulfur in the environment that focuses on engineered solutions, as well as phytoremediation, to remove excess sulfur from polluted water and soils. Such a synthesis on sulfur remediation does not exist but will provide necessary context for the establishment of field-scale sulfate phytoremediation systems. In addition, we are conducting greenhouse and laboratory experiments aimed at investigating the potential for *Populus* L. phytoremediation systems and engineered, biological solutions to reduce excess sulfate levels in polluted water. These studies aim to 1) evaluate the sulfate uptake and threshold concentration for hybrid *Populus*, 2) determine the fate and transport of sulfur species in *Populus* phytoremediation systems, and 3) analyze sulfur speciation and characterize *Populus* microbial communities involved in sulfur transformation. Results of these experiments will be synthesized in order to develop and implement a novel sulfate treatment system at a potential field location at a former mine pit lake in Aurora, Minnesota.

Keywords: phyto-recurrent selection, *Populus*, sulfate, sulfur

Using Phyto-Recurrent Selection to Identify Sulfate Thresholds Impacting Early Growth of Poplars Used for Phytoremediation

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Short rotation woody crops (SRWCs) have demonstrated the ability to remediate a wide range of organic and inorganic contaminants in a variety of environments. One genus of SRWCs, *Populus* L., has been used for several phytotechnology applications, yet the study of *Populus* for the remediation of sulfur species in soil and water is limited despite the environmental and human health impacts of elevated sulfur levels. To better understand the remediation capacity of *Populus*, we conducted three greenhouse selection cycles using phyto-recurrent selection. Our objectives were to 1) identify hybrid poplar clones with superior growth and establishment under varying sulfate conditions, 2) determine the threshold sulfate concentration at which growth and physiology are impacted for hybrid poplars, and 3) investigate the fate and transport of sulfur within the soil-poplar-water continuum. In Cycle 1, poplar establishment data (i.e., height, diameter, number of leaves, number of roots, root dry mass, stem dry mass, leaf dry mass) was collected for 20 poplar clones that were grown for 21 days under 2 sulfate irrigation treatments (0 mg/L and 400 mg/L). In Cycle 2, 10 poplar clones were grown for 28 days under 6 sulfate irrigation treatments (0 mg/L, 200 mg/L, 400 mg/L, 600 mg/L, 800 mg/L, 1000 mg/L). Growth, physiology and health data were collected. In cycle 3, the top five performing clones were grown for 56 days under 3 sulfate irrigation treatments (0 mg/L, 400 mg/L, 1000 mg/L. In addition to collecting growth, physiology and health data, samples of synthesized irrigation water, leachate, soils, and plant tissues were collected to investigate the sulfur mass balance in the system. Results of this study will be presented at the conference as well as its implications for phytoremediation as a method for mitigating sulfur pollution.

Keywords: phytotechnologies, *Populus*, sulfur

Measuring Newly Developed Stomatal and Guard Cell Metrics for Plant Physiology and Growth Using StoManager1

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Automated guard cell detection and measurement are vital for understanding plant physiological performance and ecological functioning in global water and carbon cycles. Most current methods for measuring guard cells and stomata are laborious, time-consuming, prone to bias, and limited in scale. We developed StoManager1, a high-throughput tool utilizing geometrical and mathematical algorithms and convolutional neural networks to automatically detect, count, and measure over 30 guard cell and stomatal metrics, including guard cell and stomatal area, length, width, stomatal aperture area/guard cell area, and orientation, stomatal evenness, divergence, and aggregation index. Combined with leaf functional traits, some of these StoManager1-measured guard cell and stomatal metrics explained 90% and 82% of tree biomass and intrinsic water use efficiency (iWUE) variances respectively in hardwoods, making them significant factors in leaf physiology and tree growth. StoManager1 demonstrates exceptional precision and recall (mAP@0.5 over 0.96), effectively capturing diverse stomatal properties across over 100 species. StoManager1 facilitates the automation of measuring leaf guard cells, enabling broader exploration of stomatal control in plant growth and adaptation to environmental stress. This has implications for global gross primary productivity (GPP) modeling and estimation, as integrating stomatal metrics can enhance predictions of plant growth and resource usage worldwide. Easily accessible open-source code and standalone Windows executable applications are available on a GitHub repository (https://github.com/JiaxinWang123/StoManager1) and Zenodo (https://doi.org/10.5281/zenodo.7686022).

Keywords: computer vision, convolutional neural networks, leaf functional traits, phenotyping, shoelace formula

Identification of Health-Promoting Phytoncides in Urban Forest Bathing by Thermal Desorption Gas Chromatography-Mass Spectrometry

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It is estimated that 2.5 to 5 million people regularly practice forest bathing. Studies completed in Japan have noted that participants had significantly lower blood pressure, reduced anxiety, and improved cardiovascular health after a forest bathing trip, while the same activity level in the city showed no benefit. Previous studies proposed this health benefit to be from exposure to phytoncides, a class of volatile organic compounds (VOCs), such as limonene, beta-pinene, and alpha-pinene. Currently, there are no thorough analyses that quantify what VOCs a person is exposed to on a forest bathing walk. This project proposes a novel approach to this research topic by using thermal desorption (TD) gas chromatography-mass spectrometry (GC-MS) to quantify the human exposure to health-promoting VOCs. The goals of this project are (1) to compare the VOC exposure between an urban forest and unforested-urban area, (2) to discover the role of the health-promoting VOCs and their concentration levels based on previous literature, and (3) to develop a new protocol for the TD/GC-MS for future research or experiment replication. The TD/GC-MS was chosen over other methods due to its precision and portability. The first diurnal triplicate sampling was completed in the fall of 2023. Moving forward, more samples will be seasonally collected. This research seeks to impact the way urban forestry policies are written and raise awareness for the health benefits of urban green space integration. Additionally, the data gathered here will be the first of its kind to introduce the scientific link between forest exposure and the observed health benefits.

Keywords: forest bathing, gas chromatography, phytoncides, urban green space, volatile organic compounds

Using Phyto-Recurrent Selection to Choose Poplars and Willows for Phytoremediation and Phytostabilization of Stamp Sands Mining Waste in Michigan, USA

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Industrial copper ore mining activities during the 20th century substantially impacted waters and soils of the Keweenaw Peninsula in the Upper Peninsula of Michigan, USA. The mining activities involved processing and dumping billions of pounds of ore processing waste, known as stamp sands, into Lake Superior and its coastal wetlands. Copper and other metals in the stamp sands prompted the need for sustainable pollution solutions protecting human health and the environment. To address community restoration needs, we used two phyto-recurrent selection cycles to identify specialized poplar and willow clones with enhanced potential to: 1) immobilize copper and other contaminants in the soil (i.e., phytostabilization), and 2) reduce toxicity and clean the stamp sands (i.e., phytoremediation). Three soil treatments were tested in each cycle: 1) 100% stamp sands collected from Gay, Michigan, USA, 2) 50% stamp sands + 50% nursery soil (v:v), and 3) greenhouse potting soil (experimental control). In Cycle 1, 45 poplar and 21 willow clones were tested for differences in survival, height, diameter, and biomass of roots, stems, and leaves after 21 days of growth. In general, control and pure stamp sand trees were largest and smallest, respectively. Willows had greater growth and biomass overall, yet diameter and biomass of poplars grown in the 50:50 treatment was similar to the control. In contrast, willow control trees were consistently larger than their 50:50 and pure stamp sands counterparts, indicating a greater stamp sand tolerance of poplars despite their smaller size. In Cycle 2, the best 15 poplar and 7 willow clones from Cycle 1 were tested for these parameters and physiological and health traits after 35 days of growth. We will present results from both selection cycles, highlighting the potential of using clones chosen from phyto-recurrent selection to remediate and stabilize lands impacted by stamp sands.

Keywords: clone selection, copper ore, heavy metals, phytotechnologies, selection indices

International Opportunities for Engagement and Collaboration Associated with the International Union of Forest Research Organizations (IUFRO) and the International Commission on Poplars and Other Fast-Growing Trees Sustaining People and the Environment (IPC) of the Food and Agriculture Organization of the United Nations (UN FAO)

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While the Short Rotation Woody Crops Operations Working Group has traditionally focused on the science and practice of poplars, willows, eucalypts, and other species grown for a variety of applications in the United States, international opportunities exist for engagement and collaboration. Our objective is to raise awareness of such opportunities related to the International Union of Forest Research Organizations (IUFRO) and the International Commission on Poplars and Other Fast-Growing Trees Sustaining People and the Environment (IPC) of the Food and Agriculture Organization of the United Nations (UN FAO).

IUFRO's mission is to advance research excellence and knowledge sharing, and foster development of science-based solutions to forest-related challenges for the benefit of forests and people worldwide. IUFRO is organized into nine divisions and dozens of working parties within divisions that address specific research topics. Conference participants are invited to attend meetings of three working parties: 1) 1.03.00 Short Rotation Forestry, 2) 1.06.01 Phytotechnologies for Degraded Sites in Rural and Urban Communities, and 3) 2.08.04 Physiology and Genetics of Poplars and Willows.

The IPC's mission is to reduce poverty and improve ecosystem services worldwide by fostering the sustainable management of fast-growing trees (FGTs). The IPC serves as a knowledge and capacity development network as well as a science-policy-practice platform, converting science-based approaches into practice. The IPC is organized into five working parties: 1) Genetic Resources (WP-GEN), 2) Production Systems for the Bioeconomy (WP-PRO), 3) Policy and Livelihoods (WP-POL), 4) Environmental and Ecosystem Services (WP-ENV), and 5) Communication and Outreach (WP-COM). Conference participants are invited to attend a general meeting of the IPC to learn more about these working parties.

Keywords: IPC WP-COM, IPC WP-ENV, IPC WP-GEN, IPC WP-POL, IPC WP-PRO, IUFRO 1.03.00, IUFRO 1.06.01, IUFRO 2.08.04