Poster Abstracts: Northwest Bioenergy Research Symposium, November 13, 2012

101. Education at the Speed of Research: Communicating the Science of Biofuels

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NARA Energy Literacy Matrix: energyliteracyprinciples.org

Overcoming key obstacles that prevent wood-based jet fuel and petrochemical substitutes from being economically viable is the focus of the Northwest Advanced Renewables Alliance (NARA). The NARA Education Initiative, GreenSTEM, includes an imaginative suite of programs that seamlessly link an array of educational and training programs with our university and commercial partners in order to meet the region's most compelling energy development needs. The overarching goal of GreenSTEM is to increase the capacity of the region for a transition to biofuels. GreenSTEM K-12 is a program whereby energy and biofuel curricula are developed and field-tested at the award winning McCall Outdoor Science School, annually reaching 2,500 K-12 students and 150 teachers. K-12 education and teacher education will work to educate/train our future bio-energy workforce and provide a conduit to transfer science/technology of biofuels and co-products. This approach is an exciting and tangible way to address a very important concept that can engage learners in many modalities. This work introduces, deepens, and reinforces elements of chemistry, earth physics, biology and developing skills around the nature of science. It is pertinent and timely that science curriculum address the basic components of this concept in secondary education, in-service teacher training and pre-service teacher coursework in order to prepare science- literate students for the changing environments and economies of the twenty-first century. This is a foundation for conversations pertaining to bio-fuels, food security, and energy security- ultimately supporting biofuel workforce and economies while addressing sustainability and environmental outcomes in this growing industry.

102. Selection Process of Potential NARA Pilot Supply Chain Coalitions in the Pacific Northwest

Vikram Yadama, Karl Englund and Rui Zhu, Washington State University
Scott Leavengood, Oregon State University
Eini Lowell, USDA Forest Service PNW Research Station
Randy Brooks, University of Idaho
Peter Kolb and Martin Twer, Montana State University
Todd Morgan and Erik Berg, University of Montana
Craig Rawlings, Forest Business Network
Michael Kern, The Ruckelshaus Center
Mike Gaffney, Division of Governmental Studies and Services, Washington State University
Paul Smith, The Penn State University

For the development of a framework of biofuels and co-products manufacturing from forest residues, it will facilitate to build comprehensive supply chain coalitions at regional level involving a set of communities. Engaging regional stakeholders as partners in the project is critical in identifying local assets and developing meaningful and viable supply chain coalitions. Focus of this poster is to present the methodology of identifying manageable number of regional pilot supply chain coalitions in the Pacific Northwest for studying the viability of a biofuel-based infrastructure.

103. Bioenergy Education at Oregon State University: The Bioenergy Minor

Katherine G. Field, Celeste Frazier-Barthel, Shawn Freitas, Kimi Grzyb and Jay Well
Oregon State University

As part of the USDA-NIFA funded Advanced Hardwoods Biofuels project, Oregon State University has established a new interdisciplinary research-based Bioenergy Minor, which began in Fall 2012. The minor will provide graduates with needed skills to drive innovation, commercialization, and operation of next generation biofuels technologies. These skills include discovery science, feedstock development and production, logistics, pilot-scale and commercial-scale industrial conversion, business and marketing, education, economics and social sciences. The minor is open to undergraduate students from any department. Incentives for faculty and student participation include scholarships and funds for research and internships. Minor classes introduce central bioenergy concepts, regional bioenergy industries and issues, and research skills. A required mentored research project, public seminar and thesis provide critical thinking and professional skills. In the Bioenergy Education Pipeline under development by this project, the Bioenergy Minor fills a niche between precollege and associate-level programs and the Professional Science Masters program. Additional ties with regional Bioenergy will be created by recruiting research mentors from regional Research, Industry and Extension personnel, to the mutual benefit of all participants.

104. Preparing the Pacific Northwest for Hardwood Biofuels: Extension's Role

Shiba Kar, Patricia Townsend, Jim Funck and Kevin Zobrist, Washington State University Extension

Advanced Hardwood Biofuels Northwest is a USDA-funded consortium of universities and industry partners working to develop a Pacific Northwest (PNW) biofuel industry that provides 100% renewable and infrastructure-compatible transportation fuels derived from sustainably grown hardwoods. This initiative will strengthen the PNW region's capacity to meet renewable fuels standard, revitalize the region's rural communities, support large and small growers, and create new jobs and economic opportunities. Extension plays an important and foundational role in preparing the PNW for growing hybrid poplar as feedstock for biofuels. WSU Extension is developing a biofuels outreach and education program to bring research-based information to key community stakeholders, including citizens, land managers, and policy makers. Expected outcomes include a critical mass of competent and engaged feedstock producers, and strengthened regional extension capacity to support a sustainable hardwood biofuels industry.

105. Tailoring Outreach and Education to Region-specific Oilseed Production Zones in Washington State

Karen Sowers, Dennis Roe and Bill Pan, Washington State University

The Washington State Biofuels Cropping Systems Research and Extension (WBCS) Project was initiated in 2007 to evaluate alternative crops that may have the potential to meet some of the increasing demand for biofuel production, and transfer research results to oilseed producers via the outreach component of the project. Canola, camelina, mustard, safflower, flax, sunflower, switchgrass and giant reedgrass were included in studies across four major agroclimatic zones: 1) High rainfall (annual cropping), 2) Low (wheat-fallow) to intermediate (winter wheat-spring cereal-summer fallow) rainfall, 3) Irrigated (central Washington), and 4) western Washington. After five years of research trials, research and Extension efforts are now focused on optimizing production management practices for winter and spring canola, camelina, and safflower in zones 1-3. We have found the most effective means of outreach and education are 1) field events, 2) case studies, 3) winter workshops, 4) website, and 5) Extension publications. We will continue to provide relevant, timely and easily accessible information based on research from specific cropping zones and cropping systems.

106. Partnerships to Create A Sustainable Biofuel System

Frank L. Young, USDA-Agricultural Research Service

In 2006, the Colville Confederated Tribes of north-central Washington requested assistance from the USDA-Agricultural Research Service stationed at Pullman to explore the potential of growing crops for biodiesel. At the time the CCT was consuming 15,000 gallons of petroleum diesel per day in their 140 logging trucks in their forestlands. The CCT has 100,000 acres of arable farmland on which part could grow biofuels crops. Thus, with processors they could create a closed biofuels system for "Farm to Fuel Tank". By 2007, the first canola grown was promising, with yields of 1000 pounds to 1300 pounds per acre. The USDA-ARS began experiments in cooperation with famers on CCT land to answer questions about when, how, and where to plant. With a shorter growing season than central and southern Washington, growers at the CCT have found winter canola after fallow is more feasible than spring canola, with snow lasting longer in the spring. The region has a Mediterranean climate which receives 60% to 70% of its precipitation in the winter, and the summers are dry. Several entities formed a partnership for the project they named the Canola Project.

- Colville Confederated Tribes
- USDA-Agricultural Research Service
- Paschal Sherman Indian School
- Local farmers
- WSU Ferry County Extension
- WSU Biofuels Project
- Washington State Department of Agriculture

The potential capacity of CCT land is 20,000 acres per year from 100,000 acres of arable land. The yield of canola oil is 33%. The potential yield of canola is found to be 1500 lbs per acre. The potential oil yield on CCT land is 500 pounds per acre. The potential is 70 gallons per acre, and thus, 70 gallons of biodiesel per acre. The potential production of oil for biodiesel on CCT land is 1,400,000 gallons per year if 20,000 acres of canola were grown on CCT land.

107. Life Cycle Assessment of Poplar Feedstock to Drop-in Fuels

Erik Budsberg[1], Rick Gustafson[1], Rich Shuren[2], Jose Zerpa[2], Brian Stanton[2] and Jordan Crawford[1]
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[2]GreenWood Resources

A preliminary Life Cycle Assessment (LCA) of jet fuel produced using an acetogenic biochemical conversion process with poplar as a feedstock has been completed. A poplar plantation in Boardman, OR has been used as a model to provide estimates of the life cycle impacts for feedstock production. All growth, harvesting, and transportation operations, including irrigation, are within the system boundaries. A first pass life cycle model of the conversion process - with all of its required chemical inputs, as well as impacts associated with delivery and combustion of the jet fuel - has also been developed. Initial LCA results focus on global warming potential and fossil fuel use. Future work will concentrate on refining these data to produce more accurate and reliable results from which to draw conclusions. Water usage and other environmental impacts, such as acidification and eutrophication, are to be fully investigated as well. Unique unit processes modeled during the LCA work will be uploaded to the USDA LCA Commons. The completed LCAs will be used to address policy and regulatory issues, especially as they may relate to carbon emissions and water usage, and to identify areas for improved environmental performance.

108. Advanced Hardwood Biofuels Northwest: An Overview

Jim Funck, Shiba Kar, Patricia Townsend and Kevin Zobrist, Washington State University Extension

Advanced Hardwood Biofuels Northwest is a project to develop biofuels from woody feedstock to support more sustainable air and ground transportation, create jobs, and support rural economies in the Pacific Northwest region. The project is funded by a $40 million AFRI CAP (coordinated agricultural project) grant from the USDA. The project is led by the University of Washington and includes a broad consortium of universities and industry partners who are working together to develop a system to convert sustainably grown hybrid poplar into liquid biofuels, including gasoline, diesel, and jet fuel, that are fully compatible with existing infrastructure. These fuels will be direct replacements for existing fossil fuels and will be certified to run in existing car, truck, aircraft, and other types of engines. The target is to produce enough biofuel to meet 75% of the region’s target for the 2022 renewable fuel standard (RSF2).

109. A Meta-analysis on Forest Bioenergy Carbon Greenhouse Gas Accounting

Dr. J. Gunn, Dr. T. Buchholz and Dr. D. Saah, Spatial Informatics Group - Natural Assets Lab

Many recent comprehensive biogenic GHG emissions studies of forest biomass energy systems relative to fossil fuel energy system have been published in the peer reviewed and gray literature challenging the assumption of the immediate carbon neutrality of biomass energy. We conducted a quantitative meta-analysis of these studies to document common assumptions and conclusions related to the atmospheric benefits of switching from fossil fuels to forest-based woody biomass energy. We summarized the temporal component of lifecycle GHG emissions and sequestration for bioenergy systems. The analytical matrix included elements such as: Baseline Definition, Energy Type Considered (fossil and biomass), Life Cycle Boundary Definition, Carbon Pools Considered, Regional Differences, Forest Management Practices, and Land Use Change.

110. Clearwater Basin Bioenergy Survey

Randall Brooks and Jillian Marotz-Moroney, University of Idaho

It is important to carefully assess regional norms and values that could have an impact on community responses to the development of woody biomass as an energy source. A person’s perception of a particular regional landscape is an important indicator of their values, attitudes, and behaviors toward that region. In order to gather information about the regional norms, values, and attitudes of the people in the Clearwater Basin, a survey was conducted aimed at gauging the knowledge and perceptions of the region towards the gathering, processing, and utilization of biomass. The survey was sent to 43 city and regional leaders. The community leaders were asked to fill out the surveys using their knowledge and perspective about their own communities. Questions focused on ascertaining the amount of knowledge community members possess regarding woody biomass, the benefits to be gained from the harvesting, processing, and utilization of woody biomass, the disadvantages or potential obstacles which could impede a biomass project, and the demographics of the people being surveyed. Answer formats included both write-in and multiple choice. A brief summary of what was found through the survey is contained in the report. Many of the positive aspects of biomass energy plants are realized in the potential for economic development within a region where the facilities are located. There needs to be more research regarding the cultural norms, ethical values, community acceptance, and environmental concerns in the Clearwater region in order to ascertain the viability of biomass as an economic development option.

111. Techno-economic Analysis of Hydrocarbon Biofuels from Poplar Biomass

Jordan Crawford, Dr. Rick Gustafson and Dr. Renata Bura, University of Washington

Biofuel derived from lignocellulosic biomass is a promising source of renewable transportation fuel. In order to enter this new technology space, process planning should occur to investigate if performance will meet expectations. The conversion of poplar biomass to an ethanol intermediate and a hydrocarbon fuel end-product is modeled using rigorous chemical processing software. A spreadsheet is also developed to model economic tendencies of the biorefinery including both capital and operating expenditures. Techno-economic work being done is collaborative with life cycle assessment work at the University of Washington and system optimization work at UC Davis. Preliminary results are given.

112. Economic Returns to Canola Rotations in Eastern Washington

Vicki A. McCracken and Jenny Ringwood, School of Economic Sciences, Washington State University, Pullman

Inclusion of canola into cropping systems may offer agronomic benefits to farms that translate into improved overall farm profitability over time. Favorable current prices for canola and potential demand in regional food, feed, and fuel markets may also make canola a profitable alternative crop in Washington. We compare economic returns of cropping systems that incorporate canola with the returns to traditional cropping systems appropriate to each region. Returns are based on typical yields and costs of production for each cropping region, with sensitivity analyses performed for yields and output prices.

113. Isolation and Characterization of NARA Lignins

Dr. Carter Fox and Dr. Dave Fish, Weyerhaeuser

In 2011, the Northwest Advanced Renewables Alliance (NARA), led by Washington State University, was awarded a five-year grant by the USDA National Institute of Food and Agriculture to develop an economical pathway for the production of aviation fuel from woody biomass. As an industry member of NARA, one of Weyerhaeuser’s roles in the project is to produce new value-added materials from the lignin co-products that will be produced along with the biofuel. This has been identified as a critical step in making the biofuel production process economically viable. This poster will present the methods identified by the research team at Weyerhaeuser for the isolation of lignins produced by the various biomass pretreatment processes currently under investigation within NARA. Also included will be a brief description of methods used to characterize the chemistry of these lignins, along with some of the data generated from those methods.

114. Targeted Discovery of Biomass-Degrading Enzymes from Rumen Fungi and Bacteria Using Large-scale Metatranscriptomics and Metaproteomics

Hailan Piao[1] and Matthias Hess[1,2,3]
[1] School of Molecular Biosciences, Washington State University, Tri-Cities
[2] Pacific Northwest National Laboratory
[3] USDOE Joint Genome Institute

The cow's rumen is one of the most efficient biomass-degrading ecosystems on Earth and it contains a microbial community that contains billions of microorganisms that have a highly evolved molecular machinery that facilitates the conversion of complex plant cell wall polysaccharides into monomeric sugars and other intermediates. Although there has been a significant interest of the scientific community in these microorganisms only a small fraction of the rumen microbes can currently be cultivated in the laboratory, limiting our ability to study their molecular mechanisms. Nucleotide and peptide sequencing is a powerful tool to overcome this cultivation bottleneck, and we recently discovered >27,000 potential biomass-degrading genes and several draft genomes from prokaryotes using shotgun sequencing of environmental DNA. We expanded the repertoire of -omics techniques (metatranscriptomics and metaproteomics) to identify specifically those genes and proteins that are actively expressed and produced during the degradation process of biofuel crops in the cow rumen. To test biomass-degrading activity and to evaluate industrial potential, we will clone selected candidates into fungal and bacterial expression systems, subject the recombinant proteins to detailed enzymatic activity tests and determine their physicchemical characteristics. We expect that our large-scale discovery effort will provide valuable insights into the molecular machinery that is required for the efficient conversion of biomass into biofuel precursors and other small molecules, which will help to advance the scientific community that is interested in the basic and applied aspects of biological biomass conversion.

115. Optimization of Continuous Acetate Fermentation for Maximal Performance

Elliott C. Schmitt, Biofuels and Bioproducts Lab, University of Washington

This research investigates the continuous fermentation of glucose to acetate using the acetogen, *M. thermoacetica*. A kinetic model is developed based on data obtained from literature, and used to compare several bioreactor configurations to examine maximal productivity and substrate conversion. A metaheuristic evolutionary algorithm called Particle Swarm Optimization is employed to achieve global optimization of process parameters.

116. Detection, Seed Transmission, and Chemical Control of Downy Mildew Disease of Camelina in Washington State

E. M. Babiker, S. H. Hulbert and T. C. Paulitz, Washington State University, Pullman

Camelina plants with downy mildew symptoms found in three different locations in

Washington State. Based on PCR and sequencing of the ribosomal genomic region, the causal pathogen was identified as *Hyaloperonospora camelinae*. Diagnostic PCR primers designed for this region consistently amplified 699 bp bands from the infected plants, but not from the asymptomatic plants. A comparison of the sequences with those in GenBank revealed 100% sequence similarity to *H. camelinae*. Growth and development of the *H. camelinae* was observed in different tissues using light and scanning electron microscopy (SEM). Light microscopic observation revealed the presence of oospores in the infected leaves and SEM revealed the presence of conidia and conidiophores on the seed surface. To determine whether *H. camelinae* is a seed-transmitted pathogen, seeds collected from infected plants were planted in growing mix and maintained in a growth chamber. Disease symptoms were observed in 96% of the seedlings compared to 3% of the seedlings grown from seed from asymptomatic plants, which indicates that *H. camelinae* is a seed-transmitted pathogen. Seeds treated with mefenoxam, a fungicide specific for Oomycetes, significantly reduced the incidence of the disease.

117. Safflower Oilseed Production under Deficit Irrigation and Variable N Fertilization

Hal Collins[1], An Hang[2], Bill Pan[2] and Rebecca Cochran[1]
[1] USDA-ARS Prosser
[2] Washington State University Prosser

The production of oilseed crops represents a unique opportunity for PNW producers to provide a biodiesel feedstock for an emerging renewable energy industry. The inclusion of oilseeds in rotation offers producers an alternative strategy to improve farm economies and gain additional benefits that improve soil and water conservation, reduce pest cycles, and diversify cropping systems. Safflower (*Carthamus tinctorius*) is considered a low input and drought tolerant crop, but responds well with irrigation and fertilizers. The objectives of this study were to determine: 1) Varietal responses of safflower to deficit irrigation and N fertilization under center pivot irrigation, 2) oil production and quality under deficit irrigation and N fertilization. Three safflower varieties S334, S345 and CW99OL were planted in April 2009-2011 under center pivot irrigation. The experimental design has been a strip-split plot with four replications. Standard irrigation and deficit irrigation were 725 mm and 555 mm, respectively. Safflower oilseed yields averaged 3100 kg ha^{-1} among years in for all treatments under center pivot irrigation. Safflower oilseed yields were significantly higher (+224 kg yield ha^{-1}) under the 112 than 162 kg N ha^{-1} fertilizer rate in 2008. Indicating low N rates (<112 kg ha^{-1}) are viable. Safflower oilseed yields were not significantly different between the 90 and 70% ET treatments. Indicating a potential 12 - 17 cm water savings using a deficit irrigation strategy. Deficit irrigation (70% of ET) had a positive effect on WUE with an average increase of 10 kg seed yield ha-1 cm-1 of water applied. Oil contents of the seed were 1.5 – 2.2% higher under deficit irrigation than under full irrigation following the higher yields and greater water use efficiencies.

118. Switchgrass Understory in Poplar Production

Steve Fransen, Hal Collins, Jeff Smith, Brian Stanton, Jose Zerpa, Emi Kimura and Alex Crump
Washington State University, USDA-ARS and GreenWood Resources

We are investigating intercropping switchgrass (*Panicum virgatum*) for carbon sequestration and bioenergy feedstock potential grown undesrstory with hybrid poplar (*Populus spp*.) at

GreenWood Resources, Boardman, OR. This is the second year of a five year USDA grant funded study. Interesting results are emerging suggesting in the early years of a new poplar planting for dimension lumber. Switchgrass and poplars in the first two years have shown synergistic responses to total feedstock yields per land area as based on land equivalent ratios (LER). In 2012 LER ranged from 1.71 to 2.04.

119. Double-cropping Irrigated Biennial Canola with Green Pea for Biodiesel Feedstock, Crop Diversification and Animal Feed

Kefyalew Desta[1], Harold Collins[2], William Pan[3], Steve Fransen[1], Steven Norberg[4] and Don Llewellyn[5]
[1] Department of Crop & Soil Sciences, Washington State University, Prosser
[2] Vegetable & Forage Crops Research Unit, USDA -ARS, Prosser
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[4&5] Washington State University Extension, Pasco and Kennewick

Currently, sole canola (*Brassica napus* L.) production for biodiesel is not profitable in the south Columbia Basin. Double-cropping of fresh (green) pea (*Pisum sativum* L.) with biennial canola could create new opportunities when growing canola to maximize land productivity while protecting the environment. The purpose of this project was to develop a sustainable double-crop system based on green pea-biennial canola for irrigated agricultural systems in the south Columbia Basin that protects the soil, reduces nitrogen fertilizer costs and leaching, and improves the overall health of the soil while increasing total land productivity. A study was initiated in the spring of 2012 at Paterson, WA. The experiment included green pea-biennial canola cropping sequences with the canola phase arranged in a split plot design. Treatments in the canola phase were simulated canola grazing or no grazing in the main plot, and a 3 x 3 factorial combination of three N fertilizer rates (0, 100, 200 lbs/a) and three S fertilizer rates (0, 30, and 60 lbs/a) in the subplots. Both main and subplots were arranged in a randomized complete block design with four replications. Biennial canola was planted in late August 2012 following the green pea harvest in June 2012. Average green pea (shelled) yield was 6.5 ton/A. Canola for simulated grazing system was cut on October 13, 2012. The project outcomes will provide a new innovative alternative to farming in the region while protecting the land resource base. In the long term, the adoption of the cropping system will improve the biodiesel feedstock supply, bring additional income for growers, and protect the soil and water in the region

120. Soil Profile Nitrogen Under Different Biofuel Feedstock Grasses and Irrigation Regimes

Kefyalew Girma Desta[1], Steven Fransen[1], Romulus O. Okwany[1], Troy Peters[2], William Pan[3], Harold P. Collins[4] and Joan Davenport[1]
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[4] Vegetable & Forage Crops Research Unit, USDA-ARS, Prosser

Managing soil profile NO_3-N through crop selection and irrigation is a fundamental requirement for sustainable cellulosic biofuel feedstock crop production. A four-year study was initiated in 2008 to assess the effect of biofuel feedstock grasses on soil profile NO_3-N. The experimental design was a split plot with four blocks. The main plots were irrigation

levels (60%, 80%, and 100% ET). The subplots constituted three cultivars of switchgrass, *Panicum virgatum* (Kanlow, Shawnee, and Blackwell); Sugar T sorghum (*Sorghum bicolor*); and Pete gamagrass (*Tripsacum dactyloides*). Seven sampling depths (0-105 cm, at 15 cm interval) were also superimposed over each subplot. Soil and root samples were collected from 0-105 cm depth at 15-cm intervals following the fourth harvest in October 2011. The soil and root mixture was dried in a forced air oven at 60^oC for 7-days and separated mechanically using a 1-mm sieve. The soil samples were used to determine soil NO_3-N levels. The root samples were washed mechanically, sieved using a 0.125-mm sieve, dried in a forced air oven at 60^oC for 7-days, and weighed. Soil profile NO_3-N was 1.7 mg/kg in switchgrass, 5.6 mg/kg in gamagrass, and 13.1 mg/kg in sorghum averaged over depths. Sorghum exhibited increased soil profile NO_3-N levels at 0-60 cm depth and decreased as depth increases. Nitrate accumulated in the soil profile of switchgrass was significantly lower than the other species across all depths. Sorghum exhibited higher soil-NO_3 at different depths than switchgrass or Pete gamagrass. The switchgrass cultivars had the lowest soil profile NO_3-N across all soil depths. Similarly, the correlation between root biomass and soil profile NO_3-N for switchgrass ($r=0.63$, $p<0.001$ for Kanlow; $r=0.58$, $p<0.001$ for Blackwell; and $r=0.46$, $p<0.05$ for Shawnee) was significant, unlike sorghum ($r= -0.05$, $p>0.1$). This suggests that the switchgrass cultivars were superior in scavenging nitrogen when compared with either gamagrass or sorghum.

121. Assessing Crop Rotational Nitrogen Use Efficiency Using an N Balance Approach

Tai McClellan[1], William Pan[1], Ashley Hammac[1] and Frank Young[2]
[1] *Washington State University*
[2] *USDA-ARS*

In annual cropping systems, nitrogen use efficiency (NUE) is typically estimated on a single crop basis. However, this approach ignores the dynamic nature of nitrogen cycling within multi-year crop rotations featuring a diverse set of crops. Our objective is to develop a component analysis of NUE of an entire crop rotation. As the first step, we will construct N budgets and calculate N balances, which are useful to demonstrate fertilizer carry-over and N recycling as important aspects of NUE. This approach will also provide insight into the propensity of cropping systems to retain and recycle N within a rotation. The rotational NUE analysis will factor in crop yields, grain and residue N, fertilizer N, N mineralization estimates, and changes in soil residual inorganic N. The analysis will be applied to two-and three-year rotation studies in the low, intermediate, and high rainfall zones of Eastern WA. There is evidence that fertilizer carry over contributes to overall rotational NUE. By tracking changes in soil N supply between crops, the rotational NUE will help us evaluate and adopt alternative cropping systems with the propensity to retain and recycle N within a rotation.

122. Yield Potential, Nitrogen Use Efficiency, and Unit Nitrogen Requirement of Spring Canola in Eastern Washington

Ashley Hammac, Tai McClellan, Bill Pan and Rich Koenig, Washington State University

On-going nitrogen (N) fertility trials are being conducted in Eastern Washington to determine the yield potential of canola as well as its N requirement at two site locations within the high and intermediate rainfall zones. The unit N requirement for crop production is the quantity of N necessary to achieve optimal yields, often expressed as kg N per bushel (or kg of yield).

It can be easily calculated as the inverse of its N use efficiency (yield/N supply) at economically optimal yields. Canola is characterized by a high N uptake efficiency (plant N uptake/N supply), but a relatively lower N utilization efficiency (yield/plant N uptake). At high levels of residual soil N, canola has consistently shown little to no yield response to increasing N supply. Although seed N has also shown little response to N supply, N may be consumed luxuriously and accumulated in the stems, leaves, and pods of canola. From 2008 to 2012, the economic optimal N fertilizer rates ranged from 0 to 80 lb N per acre at both site locations. Importantly, unlike wheat, a higher yield potential was not correlated with a higher N requirement, thereby raising the question of whether a yield-based N requirement calculation is appropriate for canola production. Rather, nitrogen use efficiency was enhanced by an increase in water availability. As a result, we have been unable to determine a single unit N requirement, which has differed between sites and years.

123. Oilseed Root Characteristics: Implications for Water and Nutrient Management

W. Pan, A. Hammac, T. McClellan, I. Madsen, L. Graves, K. Sowers and L. Young
Washington State University, Pullman

Canola and camelina have distinctly different root systems compared to the cereal crops grown in the PNW. Some of these differences should be considered when designing soil and fertilizer management schemes for maximizing water and nutrient use efficiencies. Root morphology and activity analysis was accomplished with in-soil digital scanning, root excavation and monolith construction, and pre-plant vs. post-harvest soil water and nitrate analysis of extraction depths. A primary difference in the root morphology can be seen immediately following germination. The oilseeds initiate one main tap root radical with highly geotropic directional growth, and horizontally oriented lateral branches. In contrast, wheat and barley exhibit a multiple seminal axes root system with each axis exhibiting different directional growth angles. The single tap root exhibits greater potential seedling susceptibility to ammonium toxicity from banded fertilizer. Depth of rooting, water and N extraction appears to be similar to that of cereal crops, to depths of at least 120 cm for winter and spring canola. Tap root thickening occurs in winter canola from 2.5 cm wide at base, tapering to 1 mm diameter at 30 cm depth, potentially creating vertical macropores for postharvest water infiltration and soil water storage. Oilseed root hairs are longer, but less dense than wheat, flax or lentil, suggesting oilseeds may have greater ability to extract soil immobile nutrients such as ammonium, phosphate and potassium.

124. A Comparison of Oilseed and Grass Crop Residue Si and Fiber Composition and Impacts on Soil Quality

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Agronomic crop residues have the potential to be used as feedstocks for manufacturing and industrial production, but structural components (e.g. lignin and silicon (Si)) may inhibit crop decomposition, and affect thermochemical industrial processing. Similarly, Si may also affect soil quality by causing surface crusting, which can reduce water infiltration, enhance runoff and erosion, and interfere with seed germination. The objective of this research was to characterize specific structural components from several species of oilseed and grass crops with the goal of understanding their potential resistance to degradation and impacts on soil crusting. Above-ground residues from five field grown crops (*Arundo donax*, wheat (*Triticum aestivum* L.), camelina (*Camelina sativa* (L.) Crantz), canola (*Brassica napus* L.), and flax (*Linum usitatissimum* L.)) were analyzed for neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), total carbon (C), nitrogen (N) and Si. Two soil incubations were initiated utilizing wheat and canola residue and applications of varying amounts of silica solution (SiO_2). Soil samples were analyzed for surface resistance, crust thickness, and water soluble Si. Fiber and Si varied among crop types and an inverse relationship between ADL and Si was found. Grass crops (wheat and *A. donax*) had high Si (1.3 $g \cdot 100g^{-1}$) and low ADL (9.4%), whereas oilseed crops (camelina, canola and flax) had high ADL (14.1%) and low Si (0.1 $g \cdot 100g^{-1}$). High amounts of Si in crop residues and solution had a positive effect on soil crust thickness and surface resistance, suggesting that crops high in Si have the ability to contribute to soil crusting.

125. Effect of Sulfuric Acid Addition on the Lignin-derived Oligomers Obtained from the Pyrolysis of Douglas-fir Wood

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[3] Fuels and Energy Technology Institute, Curtin University, Perth

Lignin pyrolytic products from the bio-oils are important fractions which could be converted into transportation fuels. The effect of sulfuric acid (H2SO4) concentration, as an additive to enhance the production of anhydrosugars via pyrolysis of Douglas-fir, on the yield and composition of the lignin derived oligomers were investigated. Pyrolysis tests at 500 oC were conducted in auger and fluidized bed reactors. For both reactors the yield of lignin derived oligomers decreased as H2SO4 was added. Several analytical techniques (UV-Fluorescence, TGA, ESI-MS, FTIR, Solid state 13C-NMR and Pyrolysis-GC/MS) were used to characterize the lignin derived oligomers collected. Four peaks were observed in the UV-fluorescence spectra. The addition of H2SO4 reduces the yield of all the fractions. DTG curves also show the presence of several peaks. The addition of H2SO4 decreased the yield of all the peaks but its effect was more pronounced on peaks at 320 and 400 oC. Electrospray ionization-mass spectrometry studies did not show any major change on the molecular weight of the lignin oligomers ionized products obtained as a function of H2SO4 concentration. Solid state NMR results indicate that the methoxyl groups decreased and the carbonyl increased gradually as sulfuric acid concentration increases. The Py-GC/MS confirmed the phenolic compounds with methoxyl substitutions were substantially reduced as the acid concentration increased. The experimental results obtained suggest the presence of H2SO4 enhances the polycondensation of methoxyl substituted aromatic rings.

126. Optimization of Hot Water Pretreatment for Enzymatic Hydrolysis of Poplar

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Hot water pretreatment of poplar was investigated as pretreatment for enzymatic hydrolysis to produce sugars. Pretreatment conditions were varied in the range of 160-210 °C, 3-40 min and 10-50% solid loading according to a 2^3 full central composites design. The pretreatment was achieved in a high temperature-pressure reactor without the addition of catalysts in order to minimize chemicals used in the process. Subsequent enzymatic hydrolysis was conducted using an industrial enzyme cocktail (cellulase and xylanase) specifically designed for cellulosic ethanol production at 50 °C for 72 h. The released sugars and pretreatment by-product (acetic acid, furfural and hydroxylmethylfurfural) were quantified by HPLC. The total anhydrous sugar yield to the original dry wood (%) after enzymatic hydrolysis was applied as response variable and evaluated by response surface methodology. The optimal condition for producing sugars was a pretreatment at 200 °C, 19 min and 21% solid loading with predicted yield 73% after enzymatic hydrolysis.

127. Making Isoprene from Lignocellulosic Biomass Using *Bacillus subtilis*

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The objective of our research is to substantially increase the productivity and yield of isoprene in genetically modified *Bacillus subtilis*, the gram-positive equivalent of *Escherichia coli*. The ultimate goal of the proposed research is to reduce the dependence on fossil fuels and emission of greenhouse gases. Sugars released after pretreatment and hydrolysis of biomass, including glucose, xylose, etc., could feed *Bacillus* and produce isoprene through microbial fermentation. Isoprene, 2-methyl-1, 3-butadiene, is a pure and volatile hydrocarbon. It can be utilized as a transportation fuel and a platform chemical to produce high-value biobased drop-in fuels and chemicals, such as rubber, elastomers, and isoprenoid medicines. *B. subtilis* produces the highest concentration of isoprene compared to other bacteria species tested, such as *E. coli*, and it uses the 1-deoxy-D-xylulose-5-phosphate (DXP) pathway to produce isoprene. Several knowledge gaps hinder the progress of rational strain design to overproduce isoprene in *B. subtilis*. 1) The regulation mechanism of the DXP pathway is not fully understood; 2) the physiological function of isoprene in bacteria is unclear. To unravel the regulation mechanism of the DXP pathway and the physiological function of isoprene, three high throughput technologies (transcriptomics, proteomics, and metabolomics) have been utilized. Our data shows that 1) selective overexpression of the DXP pathway genes is a viable strategy to overproduce isoprene; 2) Isoprene production is directly related to the NADH pool; 3) It is highly likely that isoprene functions as an overflow metabolite

128. Scenario-based LCA Analysis for Minimizing Environmental Burdens Associated with Collection of Woody Feedstock for Bio-jet Fuel

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Combustion of fossil fuel as the major source for aviation energy continues to be a significant contributor of carbon emissions into the atmosphere. The search for economically and environmentally viable sources of biofuels is an evolving process. The Northwest Advanced

Renewables Alliance (NARA) research project is exploring the potential for converting woody biomass into bio-jet fuel within the Pacific Northwest region. In order to document the environmental benefits of substituting biofuel for fossil fuel, a detailed Life Cycle Assessment (LCA) is being conducted to evaluate the environmental impacts of using woody biomass as a feedstock for conversion into bio-jet fuel. This paper presents the results of a series of LCA analysis comparing various harvesting and transportation scenarios associated with forest residuals collection in the Pacific Northwest region as a feedstock for bio-jet fuel. Emissions generated and total energy use was calculated for various harvesting and feedstock transportation scenarios to evaluate the optimal solutions and minimize environmental burdens, measured in terms of global warming and acidification potentials. In these scenario-based comparisons, emissions associated with traditional tree skidding is compared with the alternate harvesting scenarios of cable-yarding and helicopter-yarding. For the transportation scenarios, hauling forest residuals directly to a biomass processing facility is compared with two alternate transportation scenarios: 1) hauling forest residuals to a central landing for chipping and 2) transporting chips to a biomass processing facility.

129. Complete Wheat Straw Bioconversion Process

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Wheat straw is an abundant agricultural residue that remains underutilized despite its potential to provide a wide range of bioproducts. While much work has been focused solely on its conversion into transportation fuel, this study investigated a two-step fractionation process that cleanly separated raw wheat straw into hemicellulose, lignin, and cellulose product streams. First, pretreatment via low-temperature, environmentally friendly autohydrolysis extracted 85% of native hemicellulose content, recovered as pentose sugars or degradation products in the liquid fraction. Second, catalyst-aided delignification solubilized much of the remaining lignin, producing raw material for value added products. The resultant cellulosic pulp was shown to be immediately amenable to enzymatic hydrolysis for glucose-based fuel production. This pulp could also be processed further into nanocrystalline cellulose for potential medical applications.