**ACCOMPLISHMENTS REPORT**
**Southeast Regional Biomass Research Center**
**May, 2014 – October, 2015**
**Submitted by: Bill Anderson, Coordinator**

**Summary:**

The coordinators of the USDA Biomass Research Centers are developing a series of review papers based on the accomplishments of the centers over the past 5 plus years. These will be in a special issue of BioEnergy Research in 2016. The primary authors of each are Jeff Steiner (The Origin of the USDA Regional Biomass Centers); William Anderson (Dedicated Herbaceous Biomass Feedstock Genetics and Development – interpretive summary below); Rob Mitchell (Dedicated Energy Crops and Crop Residues for Bioenergy Feedstocks in the Central and Eastern US); Dan Long (Ongoing Development of Dryland Oilseed Production Systems in Northwestern Region of the United States); Bill Orts (Biorefinery Strategies: Conversion of Crops and Residues to Bioenergy and Bioproducts); Jeff Novak (Effectiveness of Biochar as an Amendment to Revitalize Soil Health, Stimulate Microbioal Activity, and Improve Environmental Abatement); and Kyoung Ro (Biochar Energetics Properties) as well as four others from the Forest Service. The following accomplishments are from six locations that are actively participating in biomass/bioenergy related work.

**Locations Reporting**

Auburn, AL
Houma, LA
Florence, SC
Temple TX
Tifton, GA

## I. Feedstock Development:

Review paper of USDA ARS breeding and genetics activities for herbaceous grasses in BioEnergy Research: The United States government placed emphasis on the development of biofuels and bio-based products a decade ago. The United States Department of Agriculture (USDA) implemented the creation of Regional Biomass Research Centers that included existing research labs of the Agricultural Research Service (ARS) and the Forest Service (FS) in 2010. These centers have compiled a record of the research progress in the areas of improving biomass production for conversion to ethanol and bio-based products over the past five years. This paper reviews the advances made in genetics and breeding of herbaceous biomass species in the United States. Many genes have been discovered that will enhance the use of grass biomass for the biofuel industry. Breeding has begun to exploit these genes for the development of improved cultivars for many species.

**Citation**: Anderson WF, Sarath G, Edme S, Casler MD, Mitchell, RB, Tobias CM, Hale AL, Sattler SE, Knoll JE (2016) Dedicated Herbaceous Biomass Feedstock Genetics and Development. BioEnergy Research (submitted).

Fall armyworm resistance in sweet sorghum. Sweet sorghum [*Sorghum bicolor* (L.) Moench] is a potential renewable energy feedstock for many areas of the Southeast. The fall armyworm

*Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) is an economically-important pest of sorghum. However, resistance to fall armyworm in sweet sorghum has not been extensively studied. Scientists with USDA/ARS Tifton, GA. evaluated a collection of primarily sweet sorghum accessions in the field for natural fall armyworm infestation. Fall armyworm damage ratings ranged from 1.88 ± 0.35 to 4.75 ± 0.37 suggesting that a range of response to fall armyworm feeding exists in this collection. Based on the results of field data from 2 planting dates, accessions with the highest and lowest fall armyworm damage ratings were selected for greenhouse evaluations. At 7 d after infestation, the sorghum accessions, excluding BTx623 and PI 147573, had significantly higher fall armyworm damage than resistant control MP708. Furthermore, at 7d after the infestation, genotype PI 147573 was the most resistant; whereas, genotypes 13, 22, 'GT-IR8', and 'GT-IR6' were the most susceptible to fall armyworm feeding. For the damage ratings at 14 d after the infestation, sorghum entry 13 had significantly higher fall armyworm damage than GT-IR7 and PI 17548. At 14 d after infestation, all 9 sorghum accessions were as resistant as the MP708 resistant control and had significantly less damage than the susceptible control AB24E. These data suggest that the sorghum lines at 14 d have induced resistance in the growing whorl. In conclusion, this study identifies sweet sorghum accessions that are resistant to fall armyworm damage that can be used by sorghum producers.

**Citation:** Harris-Shultz, K.R., Ni, X., Anderson, W.F. and Knoll, J.E. 2015. Evaluation of whorl damage by fall armyworm (Lepidoptera:Noctuidae) on field-and greenhouse-grown sweet sorghum plants. Journal of Entomological Science 50(1)14-27.

Effectivness of estimates of ethanol from fermentation of sweet sorghum juice. Sweet sorghum is an excellent source of soluble sugars that can be fermented into alcohol for use an alternative fuel. It is important to develop pure-line or hybrids lines for producers. There are many reports in the literature that estimate ethanol yields from sugar yields of different sweet sorghum genotypes. However, the accuracy of the estimates from different equations is not known. Scientists at the USDA/ARS Crop Genetics and Breeding Research Unit in Tifton, GA collaborated with scientists in Thailand to compare five different reported estimates of ethanol production with actual laboratory values using four sorghum varieties (KKU40, Theis, BJ248 and SPV1411) and one sugarcane (*Saccharum* hyb.) variety (KK3) at Khon Kaen Thailand. A second objective was to determine relationships of juice traits with ethanol conversion. Ethanol yield estimates calculated from published methods were generally higher than laboratory values. However, estimates based on (Smith et al., 1987) and multiplying theoretical yields by 80% was not significantly difference from laboratory results. Though ethanol yield was heavily correlated with sugar yields, juice traits influenced the rate of fermentation of sugars over time. Nitrogen content in the juice had a positive effect on ethanol concentration after 12 hours of fermentation while multiple juice traits were significantly associated with ethanol concentrations after 48 hours of fermentation.

**Citation:** Bunphan, D., P. Jaisil, J. Sanitchon, J.E. Knoll, and W.F. Anderson. 2015. Estimation methods and parameter assessment for ethanol yields from total soluble solids of sweet sorghum and sugarcane. Ind. Crops and Prod. 63:349-356.

Hybid sweet sorghum evaluation for juice and multiple bioenergy components. Sweet sorghum (*Sorghum bicolor* (L.) Moench) is a sugar-based biofuel crop that is well-suited to tropical environments. Most sweet sorghum cultivars are open-pollinated, but hybrids could offer yield

and seed production advantages. Plant Geneticists with USDA/ARS in Tifton, GA collaborated with scientists in Thailand to evaluate fifteen hybrids of sweet sorghum. The hybrids, parents, and three inbred checks were evaluated for sugar yield and related traits under two environments in Thailand in 2013; Field Crop Research Station at Khon Kaen University, Khon Kaen (KKU) and National Corn and Sorghum Research Center, Nakhon Rachsima (NCSRC). Sugar yield was positively correlated with juice Brix, plant height, stalk diameter, biomass yield, stripped stalk yield, and juice yield. Grain yield was negatively correlated with Brix and sugar yield. Positive heterosis for juice Brix was not observed, though five hybrids had negative mid-parent heterosis for this trait. Positive heterosis for biomass yield, juice yield, grain yield, and sugar yield was observed in some hybrids. General combining ability (GCA) was observed for most traits, but specific combining ability (SCA) effects were of greater importance. This information along with similar studies on hybrids developed at Tifton, GA help elucidate traits that have the greatest potential for improvement in sweet sorghum as a bioenergy crop in the United States.

**Citation:** Bunphan, D., P. Jaisil, J. Sanitchon, J.E. Knoll, and W.F. Anderson. 2015. Heterosis and combining ability of $F_1$ hybrid sweet sorghum in Thailand. Crop Sci. 55:178-187.

A new inexpensive method for evaluating fall armyworm resistance for sorghum**.** Effective screening of sorghum for resistance to fall armyworm feeding in the field, greenhouse, or via laboratory bioassays require many replications and as entries increase a large amount of time is required which can reduce the number of entries that can be screened. Scientists at ARS Tifton, GA adapted a procedure from a previous study that uses agar plates containing benzimidizole, a chemical that prevents leaf dying. Leaves of the sorghum are placed on agar plates in the laboratory and preserves the leaves long enough for fall armyworms to feed on the leaves to determine preference. This method is used to accurately identified resistant and susceptible sorghum lines. Furthermore, this method requires no labor by the experimenter until 7 days after the experimental setup and preserved the sorghum leaf tissue with minimal fungal and bacterial contamination. This method is an easy and effective method for assessing fall armyworm feeding and will be used to identify resistant sorghum plants in breeding programs.

**Citation:** Harris-Shultz, K., X. Ni, H. Wang, J.E. Knoll, and W.F. Anderson. 2015. Use of benzimidazole agar plates to assess fall armyworm (Lepidoptera: Noctuidae) feeding on excised maize and sorghum leaves. Florida Entomologist 98:401-404.

## II. Feedstock Production:

Effects of removing corn stover for biomass use in Southeast US. Corn grain production is important given its many uses for human food, animal feed and other industrial products, but the abundance and potentially large biomass yield also makes corn an attractive bioenergy feedstock. ARS researchers at the National Soil Dynamics Laboratory in Auburn, AL in cooperation with scientists from Auburn University conducted experiments to evaluate the effect of in-season weather conditions, rye as a winter cover crop, and corn residue harvest on grain yield and biomass distribution across a loamy sand and silt loam soil types. Grain yield ranged from 5,328-9,251 kg $ha^{-1}$ for the loamy sand and 5,404-7,733 kg $ha^{-1}$ for the silt loam. Total stover dry weight ranged from 3,486-5,482 kg $ha^{-1}$ and 3,732-6,706 kg $ha^{-1}$ for the same soils. Vertical fractionation of corn stover enables stover harvest to serve as a biofuel feedstock, while leaving a portion of the plant residue in the field for erosion control and soil organic matter

maintenance. These results indicate that harvesting the above-ear corn plant fraction could be an attractive option for partial biomass harvesting in southeastern US.

**Citation:** Mourtzinis, S., F. Arriaga, K.S. Balkcom, and A. J. Price. 2015. Vertical Distribution of Corn Biomass as Influenced by Cover Crop and Stover Harvest. Agron J. 107:232-240.

Optimizing bioenergy feedstock production without reducing soil health. Sustainable biofuel crop production requires that a portion of the biomass yield be removed for processing, while a fraction is returned to soil. However, the balance between biomass removal and the amount returned to soil is unknown. USDA-ARS scientists at the Florence, South Carolina location participated in a long-term field evaluation to determine the quantity of biomass removed without reducing soil health. After 5 years, scientists discovered that removal of about one-half of the biomass caused shifts in soil microbial communities, along with a minor depletion of plant nutrients. These results corroborate that biomass can be removed from soils for sustainable biofuel production provided that a biomass fraction be returned.

Citations: Cantrell, K.B., Novak, J.M., Frederick, J.R., Karlen, D.L., Watts, D.W. 2014. Influence of corn residue harvest management on grain, stover, and energy yields. BioEnergy Research. 7(2):590-597.

Johnson, J.M., Novak, J.M., Varvel, G.E., Stott, D.E., Osborne, S.L., Karlen, D.L., Lamb, J.A., Baker, J.M., Adler, P.R. 2014. Crop residue mass needed to maintain soil organic carbon levels: Can it be determined? BioEnergy Research. 7(2): 481-90. 2014.

Karlen, D.L., Birrell, S.J., Johnson, J.M., Osborne, S.L., Schumacher, T.E., Varvel, G.E., Ferguson, R.B., Novak, J.M., Frederick, J.R., Baker, J.M., Lamb, J.A., Adler, P.R., Roth, G.W., Nafziger, E.D. 2014. Multi-location corn stover harvest effects on crop yields and nutrient removal. BioEnergy Research. 7:528-539.

Lehman, R.M., Ducey, T.F., Jin, V.L., Acosta Martinez, V., Ahlschwede, C.M., Jeske, E.S., Drijber, R.A., Cantrell, K.B., Frederick, J.R., Borkowski, D.M., Osborne, S.L., Novak, J.M., Johnson, J.M., Varvel, G.E. 2014. Soil microbial community response to corn stover harvesting under rain-fed, no-till conditions at multiple U.S. locations. BioEnergy Research. 7:540-550.

Effects of harvest time on quantity and quality of napiergrass and energycane. Napiergrass (*Cenchrus purpureus* Schumach) and energycane (*Saccharum* hyb.) are high-yielding perennial grasses that are well-suited for biomass production in the southeast USA. The purpose of this study was to determine the effects of delayed winter harvest on biomass yield and quality of these two grasses. ARS scientists collaborating with University of Georgia found that napiergrass yields tended to decline sharply as harvests were delayed from December to January, most likely due to leaf drop. However, energycane (*Saccharum* spp.) yields were relatively stable from December to January, and then declined in later harvests. Delayed harvest of napiergrass from December to January returned an average of 144 kg $ha^{-1}$ N to the soil, while energycane only returned an average of 54 kg $ha^{-1}$ N by delaying harvest to February. Ethanol production from SSF of napiergrass was relatively unaffected by harvest date, but energycane tended to produce less ethanol in later harvests. These studies can be used to determine best

production practices for high biomass species napiergrass and energycane used for renewable energy and provide information on the effect of these practices on soil nutrient amendments.

**Citation:** Knoll, J.E., Johnson, J.M., Huang, P., Lee, R.D., and Anderson, W.F. 2015. Effects of delayed winter harvest on biomass yield and quality of napiergrass and energycane. Biomass and Bioenergy 80:330-337.

Potential of using bermudagrass as a biomass feedstock. Bermudagrass (*Cynodon* spp.) is a common perennial summer forage crop in the Southeastern USA that could also be used for cellulosic ethanol. This study was conducted at Midville, GA to assess biomass yields, nutrient utilization, and cellulosic ethanol production from bermudagrass. The crop was grown with or without irrigation, and harvested either once, twice, or three times over two years (2010 and 2011). Irrigation did not affect dry matter (DM) yields in 2010, but in 2011 the two- and three-cut systems under irrigation out-yielded the other treatments. The concentrations of N, P, and K in harvested biomass were generally unaffected by irrigation, but they did change with age of the crop and harvest timing. Total N removal was greatest in the three-cut system under irrigation, particularly in 2011. Biomass neutral and acid detergent fiber concentrations (NDF and ADF) and in-vitro dry matter digestibility (IVDMD) were also affected by harvest timing, but these data did not show correlations with ethanol yield. Ethanol production was measured by subjecting biomass to dilute-acid pretreatment and simultaneous saccharification and fermentation (SSF) at bench-scale in the laboratory. Some variation in ethanol production was observed between treatments. Under dryland production a single fall harvest appears to be the most economical system for producing cellulosic ethanol from bermudagrass. Under irrigation two cuts should be possible, one in summer and one in the fall. A three-cut system could yield slightly more biomass under irrigation, but much more N would be removed in the biomass.

**Citation:** Knoll, J.E., J.M. Johnson, R.D. Lee, and W.F. Anderson. 2014. Harvest management of Tifton 85 bermudagrass for cellulosic ethanol production. Bioenerg. Res. 7:1112-1119 DOI: 10.1007/s12155-014-9449-1.

Potential for production of perennial biofuel feedstocks on the Coastal Plain of Georgia, USA
With global increases in the production of cellulosic biomass for fuel, or “biofuel”, concerns over potential negative effects of using land for biofuel production have promoted attention to concepts of agricultural landscape design that sustainably balance tradeoffs between food, fuel, fiber and conservation. The Energy Independence Security Act (EISA) of 2007 mandates an increase in advanced biofuels to 21 billion gallons in 2022. The southeastern region of the USA has been identified as a contributor to meeting half of this goal. We used a geographic information system (GIS) to identify areas for biofuel production from perennial grasses, i.e. "biofeedstocks". We estimated the total production of three perennial biofeedstocks planted as conservation buffers (field borders associated with riparian buffers, and grassed waterways) on the Coastal Plain of Georgia, USA. Land cover, hydrology, elevation and soils data were used to identify locations within agricultural landscapes that are most susceptible to runoff, erosion, and nutrient loss. The protection of water quality and biodiversity are critical environmental concerns in agricultural landscapes, where Nitrogen (N) from agricultural runoff can cause degradation in water bodies. In addition to the amount of biofuel produced by these plantings, we calculated the amount of N that they would remove from the environment. When production strategies were taken into consideration, we estimated total biomass yield of perennial grasses for the Georgia

Coastal Plain at 2.2-9.4 teragrams per year. Using published rates of N removal and ethanol conversion, we calculated the amount of potential N removal by these systems as 8100-51000 megagrams per year, and biofuel production as 706-2993 megalitres per year (187 to 791 million gal US).

**Citation:** Coffin, A., Strickland, T., Anderson, W., Lowrance, R., and Smith, C. 2016. Potential for production of perennial biofuel feedstocks on the Coastal Plain of Georgia, USA. BioEnergy Research (in review)

Energycane grown solely as a bioenergy feedstock displays high growth potential. Production of high yielding biomass is a prerequisite and foundation of a successful bioenergy industry. Scientists at ARS Sugarcane Research Unit led a National Institute of Food and Agriculture (NIFA), Agriculture and Food Research Initiative (AFRI) cap grant field team that planted high fiber sugarcane, also known as energycane, in a northern location in Louisiana. With minimal agrichemical input, the crop yielded 24 tons per acre, or 9 tons per acre of dry feedstock. The experiment was duplicated with similar yields in 2015. An economist from the Louisiana State University AgCenter estimates total production costs for energycane at $103 per dry ton spread over 5 harvests. A harvest test with ten energycane varieties and 2 commercial sugarcane varieties to determine the range of biomass production and quality that is achievable. Averaged across varieties, energycane tons peaked in November at 65 tons per acre, or 24 dry tons per acre. Sucrose accumulation progressed until November and tapered off, while fiber stayed constant after this time point. The difference between simulated yields and actual yields (in Winnsboro, LA) was substantial (9 dry tons vs. 24 dry tons). The reason for this difference is probably the cooler growing temperatures in Winnsboro, when compared to Houma, and simulated yields includes a high proportion of stalk leaves and growing points, when are usually discarded when using a combine to harvest fields (as in Winnsboro).

Sugar and fiber content of energycane over extended harvest times. Our research objectives coalesced based on industry demands of an available feedstock all year for bioenergy production. Our industrial bioenergy collaborators, need data showing cane yield characteristics (fiber and brix) during the harvest interval expected for Louisiana energycane (August to March). Since multiple harvests are possible within the same cane field, season variability in brix and fiber could be very important when converting feedstock to biofuels. For this test, the commercially released energycane Ho 02-113 was harvested from August to March and analyzed for brix and fiber at two locations near Houma. Brix increased rapidly from October to December and decreased until March. Similarly, fiber increased each month from August to November, peaked in December, but stayed mostly unchanged until March. This information would be critical to a processor who bases biofuel estimates on crop characteristics available, as well as when choosing cane varieties for particular characterstics. Examples of important variable for bioenergy conversion of cane include brix, fiber, lignin, and ash.

Using ALMANAC and SWAT models to estimate short rotation woody crops for bioenergy use. Short rotation woody crops (SRWCs) such as hybrid poplar have great potential as biofuel feedstocks. Plant dry weight yields and yield stability at sites are important considerations when

SRWCs are widely planted. The computer simulation model Agricultural Land Management Alternative with Numerical Assessment Criteria (ALMANAC) offers promise as a useful tool to evaluate tree growth over large ranges of conditions. The model was modified and it realistically simulated leaf area indices (LAI), aboveground biomass production and root biomass of hybrid poplar and eastern cottonwood. Thus, this model was shown to be useful in modeling expected biomass feedstocks for these threes. Poplar growth and its impacts on runoff, sediment and nitrate losses were simulated by the Soil and Water Assessment Tool (SWAT). SWAT tree growth algorithms and parameters for hybrid poplar in Midwestern US and cottonwood in Southern US were improved based on hybrid poplar and cottonwood site data. Tree growth representation led to code changes including a new leaf area parameter, new leaf area index algorithm, and leaf biomass algorithm, while fraction of tree biomass accumulated each year converted to residue during dormancy was removed. The modified SWAT realistically simulated hybrid poplar leaf area index and aboveground woody biomass. The model reasonably simulated cottonwood aboveground biomass, seasonal runoff, sediment, nitrate-N, and total nitrate. Thus, the modified SWAT model can be used for modeling Poplar biofeedstock production and hydrologic and water quality response to its growth.

**Citations**: Guo, T., B.A. Engel, G. Shao, J.G Arnold, R. Srinivasan, and JR. Kiniry. 2015. Functional approach to simulating short rotation woody crops in process based models. Bioenergy Research (in review).

Guo, T., B.A. Engel, G. Shao, J.G Arnold, R. Srinivasan, and JR. Kiniry. 2016. Development and improvement of the simulation of woody bioenergy crops in the Soil and Water Assessment Tool (SWAT). Bioenergy Research (in review).

Duel-sue of three tall perennial grasses in the Southeast. Many small commercial livestock farms find it difficult to remain profitable and must remain adaptable to changes in market conditions. Livestock forages that contain enough combustible energy to also satisfy emerging bioenergy markets could provide these farmers with dual-use options to help them minimize risk and maximize production efficiency. Researchers at USDA-ARS in Temple, TX and collaborating universities compared nutritive value and energy content of three perennial grass species (giant miscanthus, giant reed, and miscane). Results suggest that miscane and giant reed could serve as livestock forages though foarage trials are needed before they are recommended for use. These grass species may be useful for dual-use as bioenergy feedstocks and livestock forages.

**Citation**: Burner, D.M., D.H. Pote, J.R. Kiniry, D.P. Belesky, J.H. Houx III, P. Carver, F.B. Fritschi. 2016. Dual-Use Potential of Giant Miscanthus, Giant Reed, and Miscane for Feed and Fuel. Crop Science (in review)

Evaluation of high biomass sorghums lines at biomass feedstocks in Hawaii. Since the 1970s the state of Hawaii (HI) has been aggressively seeking alternative and renewable energy resources to reduce its overdependence on imported oil. Of the available alternatives, fuels produced from biological raw materials are viewed favorably due to the tropical year-round growing season for the production of fast-growing biofuel feedstocks. Although biomass sorghum [Sorghum bicolor (L.) Moench] has been identified as a high yielding bioenergy feedstock crop on the continental

USA, there is lack of conclusive data on its performance in HI. The objective of this study was to (i) determine the adaptability and productivity of two biomass sorghum varieties, and (ii) identify the associated crop parameter attributes and environmental factors for high biomass yields. Two parallel trials were conducted on Maui, HI and in Temple, TX. At Temple, the sorghum varieties responded as expected, growing to heights in excess of 3 m and producing average biomass yields of 37.4 Mg ha-1. The biomass sorghum varieties also had large leaf surface areas that captured more solar radiation which resulted in a faster plant growth rate. In Maui, and in sharp contrast to the results obtained at Temple both biomass sorghum varieties behaved like grain sorghums, flowering in approximately 90 days after planting. The varieties did not grow as tall as the ones in Texas and yields were drastically reduced. The study underscored the importance of not only choosing the right bioenergy crop species, but also the suitability of target environments, planting season and management practices.

**Citation:** Meki, M.N., R.M. Ogoshi, J.R. Kiniry, S.E. Crow, A.H. Youkhana, and K. Littlejohn. 2016. BioEnergy Research (in review)

Comparison of mustard seed germplasm for production of oils for Jet Fuel production. The commercial airline industry and the U.S. Department of Defense are pushing to develop renewable fuels for aircraft use to replace petroleum-based fuels in an effort to reduce greenhouse gas emissions and create a reliable, domestically-produced source of alternative fuel. For aircraft fuel, few alternative options are practical and therefore a "drop-in" replacement similar to petroleum is needed. Hydrotreated Renewable Jet fuel (HRJ) made from plant oils by a patented process is one such option that has been proven to work. Large-scale production of HRJ, however, has not yet occurred because the cost of the fuel is slightly higher than petroleum, mainly due to the cost of producing the oil crop. There are several species of plants belonging to the mustard family (Brassicaceae) that can serve as feedstock for HRJ that may be cheaper to produce than food-grade commodity oil crops like soybean and sunflower thus, leading to a lower fuel cost. The most feasible area within the U.S. to expand production of oilseed feedstock for HRJ extends from the southern to the northern Great Plains and the Pacific Northwest where wheat-based cropping systems dominate. It is not known, however, what particular mustard species will work best to meet the needs for HRJ feedstock, and it’s probable that the most suitable specie(s) for a given region may vary. A study was conducted at Morris, MN, and is being replicated at seven other locations across the Plains region and Pacific Northwest to evaluate the agronomic production of a common set of mustard species varieties (a total of 18 varieties, representing 6 different species) to determine which is most suitable for HRJ feedstock for a given region. In MN, a commercial line of canola (Invigor L130) produced the greatest seed and oil yield. However, two varieties of Ethiopian mustard, which may be cheaper to produce than canola, also produced very high seed and oil yields in MN. As expected, other location in the study saw that other species/varieties performed better in their environments, indicating that the best choice of specie/variety of mustard oil crop will differ for a given environment and cropping system. These results will benefit the biofuel industry, oilseed breeders/geneticists, and agricultural scientists developing biofuel feedstocks.

**Citation**:

Gesch, R.W., T. Isbell, E.A. Oblath, B.L. Allen, D.W. Archer, J. Brown, J.L. Hatfield, J.D. Jabro, J.R. Kiniry, D.S. Long, and M.F. Vigil. 2015. Comparison of several Brassica species in the north central US for potential jet fuel feedstock. Industrial Crops and Products http://dx.doi.org/10.1016/j.indcrop.2015.05.084

Use of near-infrared spectroscopy to evaluate rapeseed germplasm. Rapeseed, along with other oilseeds from the mustard family, is a potential feedstock for biofuel production but minor seed components can cause poor oil quality and increased refining costs. A rapid screening method using near-infrared spectroscopy was developed for six oilseed species from the mustard family. Intact seeds can be quickly analyzed for characteristics of interest including moisture, oil, fatty acid profile, nitrogen, glucosinolate, and chlorophyll content. Traditional analysis methods for many of these characteristics can be time-consuming and require large amounts of seeds to be destroyed. This rapid screening method allows samples to be non-destructively scanned in less than two minutes each. This is particularly useful for situations when only a small amount of seed is available, such as screening large numbers of samples from genetic trials to choose the best varieties for future research.

Oblath, E.A., T. Isbell, M.A. Berhow, B.L. Allen, D.W. Archer, J. Brown, R.W. Gesch, J.L. Hatfield, J.D. Jabro, and J.R. Kiniry. 2016. Development of near-infrared spectroscopy calibrations to measure quality characteristics in intact Brassica germplasm. Industrial Crops and Products (in review).

## III. Conversion and Co-product Utilization

### Biochar Research

### Florence, SC

Review paper of USDA ARS activities on biochar in BioEnergy Research. Over the past 10-20 years, USDA-ARS scientists have been evaluating biochars potential to improve degraded soil quality characteristics with anticipation of increasing soil C sequestration, improving plant growth conditions, obtaining higher crop yields, and attenuating microbial movement in soil. Our understanding of the positive and negative impacts of biochar performance on soil conditions and crop yields has been obtained through individual or collaborative multi-location experiments at the laboratory, greenhouse, and field scales. From these studies, ARS scientists have reported that the success of biochars as soil amendments for improving crop yields has been mixed. Some studies report that crop yields were improved after adding biochar to soil, while others report no change in crop yields. These mixed results prompted ARS scientists to theorize that biochars may be more effectively used if they are produced with chemical and physical characteristics that target specific soil health deficiencies. Biochars have demonstrated an emerging capability for remediation of mine impacted soils. Reclamation of mine spoils or mine-impacted soils is a complicated task, often involving intricate methods and multiple state and federal agencies. For example, USDA-ARS scientists have collaborated with EPA scientists to determine if biochars can be engineered to restore mine-impacted soils, to promote the ability of native plant cover to re-colonize mine-impacted soils, increase soil C stocks, stimulate microbial activity, and sequester heavy metals in-situ. From these experiments, it is anticipated that biochar management practices will be developed to reclaim vast areas of mine impacted soils and spoils as well as improve soil health characteristics in agricultural lands.

**Citation:** Novak, J.M., S. Uchimiya, I. Lima, C. Bolster, K. Spokas, J. Ipploito, R. Lentz, and G. Sigua. 2016. Effectiveness of biochar as an amendment to revitalize soil health, stimulate microbioal activity, and improve environmental abatement. BioEnergy Research (in review)

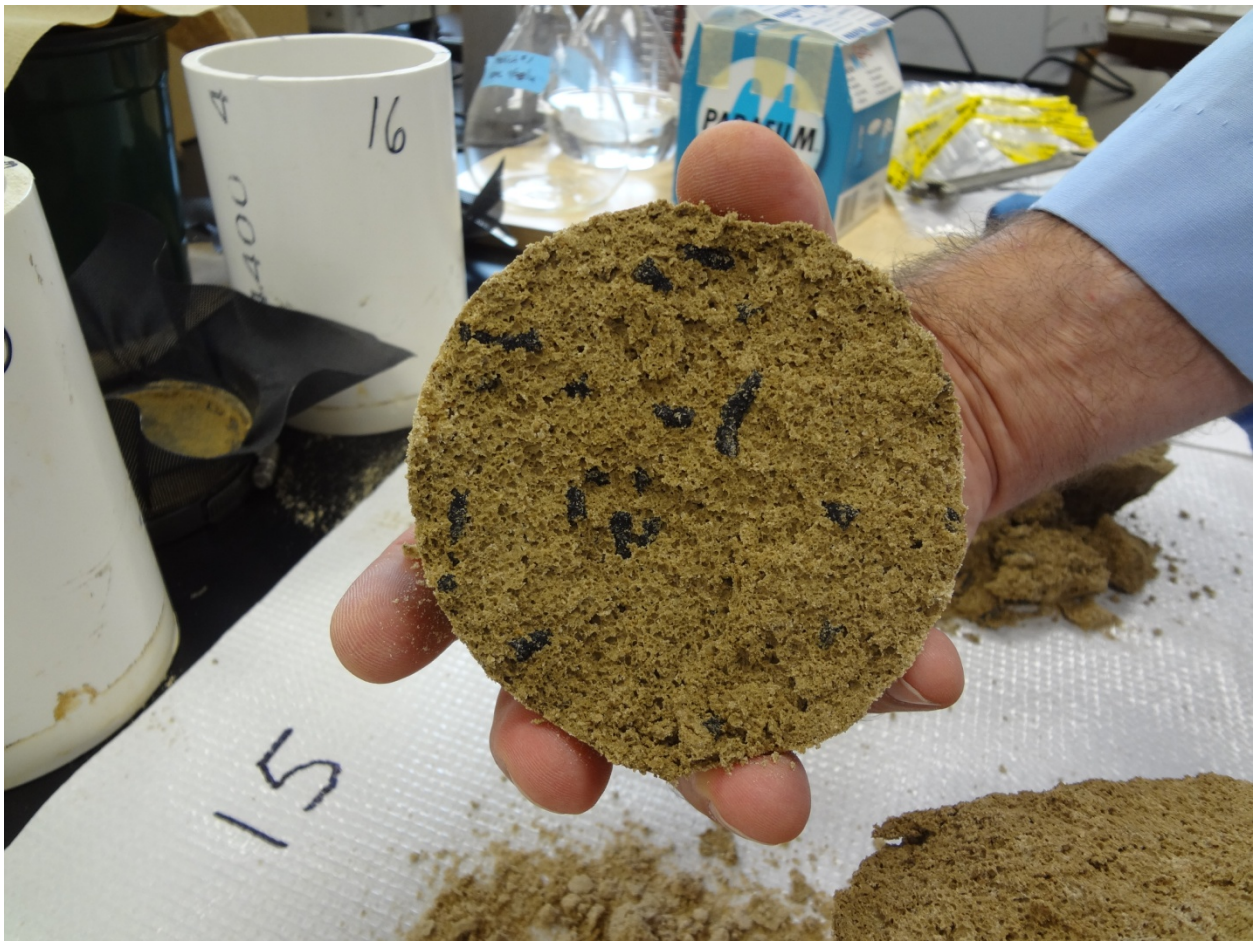
Rebuilding soil organic carbon levels in southeastern Coastal Plain soils. Agricultural production in the Coastal Plain region of the US is hampered by highly weathered sandy soils that have inherently low soil organic carbon contents and a meager ability to retain water and nutrients. To increase crop productivity in these soils, strategies using crop management or adding amendments are needed that can successfully rebuild carbon, while also increasing nutrient and water retention. Conservation tillage under typical row crop production was found to be a slow promoter of carbon accumulation and carbon storage under switchgrass can be transitory. A more rapid and longer lasting improvement in soil quality was found using biochar, which mixed into soil at 1 to 2% by weight vastly improved the soil organic carbon content and increased nutrient and water retention. These results were related to slower mineralization by biochars linked to more aromatic structures in their chemical makeup and/or to larger particles sizes. Our results confirmed that the degree of soil quality improvement using biochars were dependent on feedstock selection, pyrolysis conditions and biochar chemical and physical characteristics.

**Citations:** Busscher, W.J., Novak, J.M., Ahmedna, M., Niandou, M. 2011. Physical effects of organic matter amendment of a southeastern USA coastal loamy sand. Soil Science. 176(12):661-667.

Novak, J.M., Busscher, W.J., Watts, D.W., Amonette, J., Ippolito, J.A., Lima, I.M., Gaskin, J., Das, K.C., Steiner, C., Ahmedna, M., Rehrah, D., Schomberg, H.H. 2012. Biochars impact on soil moisture storage in an Ultisol and two Aridisols. Soil Science. 177(5):310-320.

Spokas, K.A., Cantrell, K.B., Novak, J.M., Archer, D.W., Ippolito, J.A., Collins, H.P., Boateng, A.A., Lima, I.M., Lamb, M.C., Mcaloon, A.J., Lentz, R.D., Nichols, K.A. 2012. Biochar: A synthesis of its agronomic impact beyond carbon sequestration. Journal of Environmental Quality. 41(4):973-989.

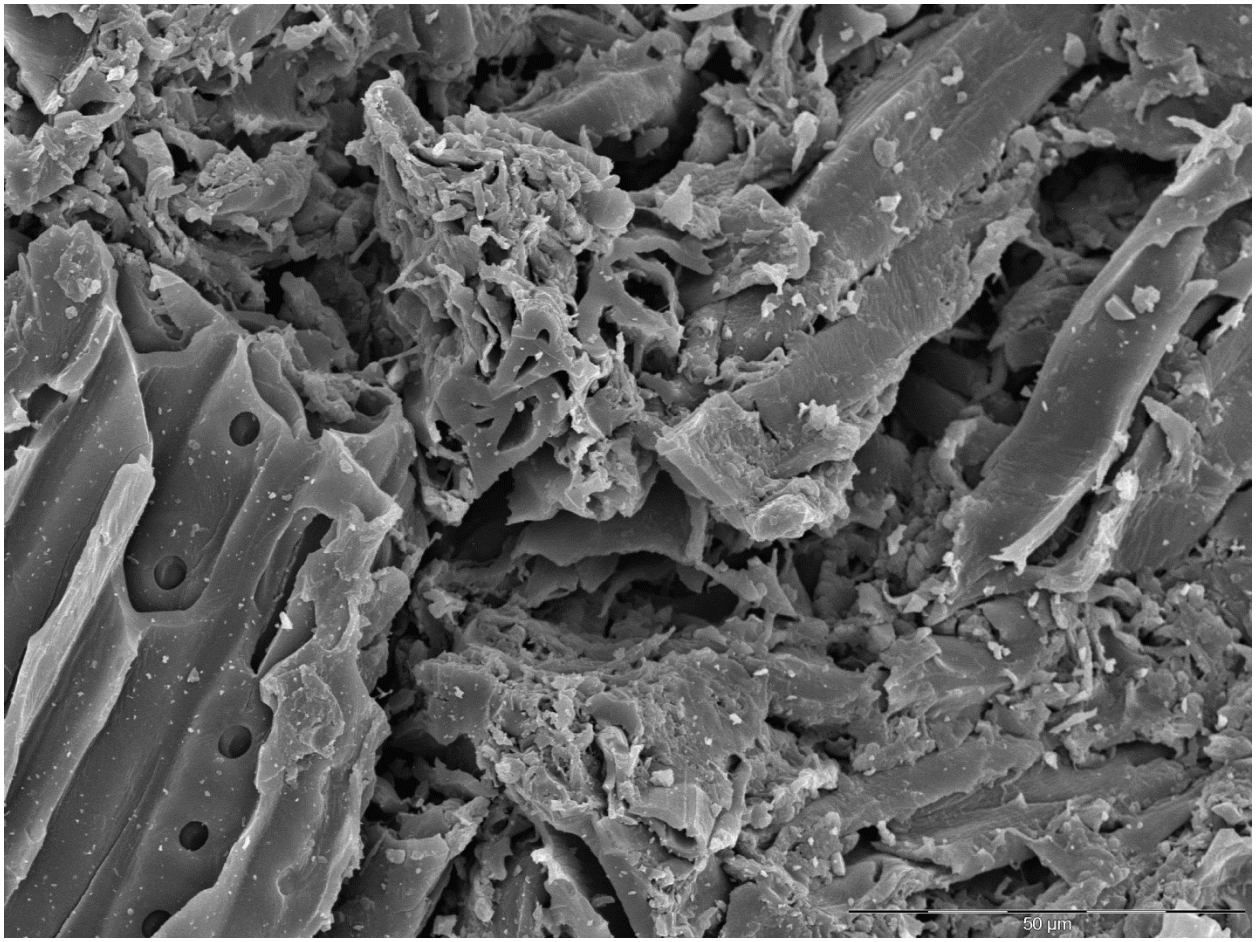
Sigua, G.C., Novak, J.M., Watts, D.W., Cantrell, K.B., Shumaker, P.D., Szogi, A.A., Johnson, M.G. 2014. Carbon mineralization in two ultisols amended with different sources and particle sizes of pyrolyzed biochar. Chemosphere. 103:313-321.




Responses of biochars to microbial communities and nutrient processing**.** Biochar is a solid material that is a byproduct from the biofuel processing industry. Because it contains both organic carbon compounds and inorganic elements it is viewed as an excellent soil amendment. The inorganic portion from biochar serves as a good source of plant nutrients while the organic portion can improve soil organic carbon levels, and retention of nutrients. However, biochars interaction with soil microbial communities and nutrient turnover processes in sandy soils is unknown. Scientists with the USDA-ARS evaluated the impact of several different biochars on the ability of soil microbial communities to produce enzymes involved with nitrogen cycling. During nitrogen cycling in soils, the enzymes convert unavailable nitrogen forms to plant available nitrogen forms. Results from this research show that biochars have no negative impact on nitrogen enzyme production and do not interfere with microbial nitrogen conversion processes that provide available nitrogen for crops. Agricultural operators as well as other stakeholders can benefit from applying biochars to sandy soils since it did not interfere with nitrogen conversion into plant available forms.

**Citations:** Ducey, T.F., Ippolito, J.A., Cantrell, K.B., Novak, J.M., Lentz, R.D. 2013. Addition of activated switchgrass biochar to an aridic subsoil increases microbial nitrogen cycling gene abundances. Applied Soil Ecology. 6:65-72.

Ducey, T**.,** Novak, J.M., Johnson, M.G. 2015. Effects of biochar blends on microbial community composition in two coastal plain soils. Agriculture. doi:10.3390/agriculture50x000x.




Using biochar to improve water and nutrient retention in sandy soils of the SE USA coastal plain region: Sandy, coastal soils contain low organic carbon contents, and have meager abilities to retain water and nutrients that affects long-term productivity of these soils. Additionally, a hard setting subsoil-layer limits deep root penetration into deeper horizons that causes higher incidence of plant water stress. Scientists with the USDA-ARS examined strategies to improve these soil limitations by using biochar as a soil amendment. Biochar applications were found to improve plant available soil nutrients concentrations. Additionally, biochars produced from different feedstocks and processing conditions were found to improve water infiltration through the hard-setting soil layer and increase water retention. Agricultural producers, biochar users and other stakeholders can use biochars to improve the sandy soils fertility, physical issues of hard setting subsoil layers, and water holding capacities. We showed that biochar was a suitable soil amendment to improvement these soil characteristics potentially resulting in higher crop productivity.

**Citations:** Novak, J.M., Watts, D.W. 2013. Augmenting soil water storage using uncharred switchgrass and pyrolyzed biochars. Soil Use and Management. 29(1):98-104.

Novak, J.M., Spokas, K.A., Cantrell, K.B., Ro, K.S., Watts, D.W., Glaz, B.S., Hunt, P.G., Busscher, W.J. 2014. Effects of biochars and hyrdochars produced from lignocellulosic andanimal manure on fertility of a Mollisol and Entisol. Soil Use and Management. 30:175-181.

Novak, J.M., Sigua, G.C., Watts, D.W., Cantrell, K., Shumaker, P.D., Szogi, A.A., Johnson, M., Spokas, K.A. 2015. Biochars impact on water infiltration and water quality through a compacted subsoil layer. Chemosphere. doi: 10.1016/j.chemosphere.2015.06.038.

Sigua, G.C., Novak, J.M., Watts, D.W., Johnson, M.G., Spokas, K.A. 2015. Efficacies of designer biochars in improving biomass and nutrient uptake of winter wheat grown in a hard setting subsoil layer. Chemosphere. doi: 10.1016/j.chemosphere.2015.06.015.

Sigua, G.C., Novak, J.M., Watts, D.W. 2015. Ameliorating soil chemical properties of a hard setting subsoil layer in coastal plain USA with different designer biochars. Chemosphere. doi: 10.106/j.chemospher.2015.06.16.

Swine manure hydrochar as soil amendment**.** Hydrochar is a carbonaceous solid made from heating wet biomass slurry under pressure (wet pyrolysis). This study evaluated the potential of hydrochar made from swine manure as a soil amendment. Soil fertility and water quality characteristics of swine hydrochar amended soils were compared with other swine based soil amendments such as raw swine manure, swine compost, and thermal swine char made from dry

pyrolysis. All swine manure-based amendments significantly increased soil carbon, cation exchange capacity and available nutrient contents of the soil. However, thermal swine char and swine compost amended soils leached high concentrations of phosphorus, which may cause water pollution problems for receiving water bodies. On the other hands, swine hydrochar did not leach nutrients such as nitrogen, phosphorus, and potassium. Although it is still not clear how these nutrients were retained in the soil amended with hydrochar, it suggests a great potential for hydrochar as an alternative manure management option as the hydrochar can be soil applied while minimizing potential environmental issues from the leaching of high nutrient concentrations to water bodies.

**Citation**: Ro, K.S., Novak, J.M., Johnson, M.G., Szogi, A.A., Libra, J.A., Spokas, K.A., and Bae, S. 2015. Leachate water quality of soils amended with different swine manure-based amendments. http://dx.doi.org/10.1016/j.chemosphere.2015.05.023. Chemosphere

Co-pyrolysis of manure with plastic mulch waste. Many researchers report that manure-based biochar, the solid char product obtained from heating animal manures without air (i.e., pyrolysis), has considerable potential both in improving soil quality and reducing water pollution. However, one of major obstacles of obtaining manure-based biochar is its high energy requirement for pyrolyzing wet animal manures. ARS researchers at Florence, SC, showed when mixtures of swine solids and plastic mulch film wastes were pyrolyzed, the process produced combustible gas with heating values much higher than that of natural gas. If more than 10% plastic mulch wastes were mixed with swine solids, it generated energy enough for both biochar and power production. Furthermore, commonly used fumigants were not detected from the process. The results of this study suggested the potential of using pyrolysis technology to manage two prominent agricultural waste streams (plastic mulch film wastes and swine solids) while producing value-added biochar and power that could be used for local farm operations

**Citation:** Ro, K.S., Hunt, P.G., Jackson, M.A., Compton, D.L., Yates, S.R., Cantrell, K., and Chang, S.C. 2014. Co-pyrolysis of swine manure with agricultural plastic waste: laboratory-scale study. Waste Management 34:1520-1528.