FY 2012 DRAFT Annual Report
National Program 214—Agricultural & Industrial Byproducts

Introduction

According to the National Agricultural Statistics Service, over one billion tons of agricultural (e.g., manure), municipal (e.g. biosolids), and industrial (e.g. coal combustion products) wastes with potential uses in agriculture are generated annually in the United States. Many of these materials are spread, sprayed or otherwise applied to agricultural land because of the benefits they provide. These benefits include: providing a nutrient source for crops; improving soil chemical, physical and biological properties; improving soil water storage and use; reducing movement of contaminants to water and air; and reducing production costs and energy use. However, improperly managed manure and other byproducts can pose a threat to soil, water and air quality, and to human and animal health.

The goal of the Agricultural and Industrial Byproducts National Program is to develop and evaluate management practices and systems, control technologies, and decision tools to allow producers and their advisors to (1) use manure and other byproducts effectively and safely while protecting the environment and human and animal health and (2) provide policy-makers and regulators with information and tools to establish appropriate conservation and environmental credit trading programs, and make environmental protection decisions. To achieve this goal, this National Program is focused on four major areas of research: atmospheric emissions, nutrient management, pathogens and pharmaceutically active compounds, and municipal and industrial byproducts. Sustainable agriculture depends on effective management of manure and byproducts. Selected accomplishments from these four components are described in the following section.

NUTRIENT MANAGEMENT

The utilization of nutrients in manure in an environmentally sustainable manner is one of the critical management issues facing livestock producers. Movement of nutrients in excess amounts from manure and other byproducts to soil, water and air can cause significant environmental problems. Nitrogen and phosphorus from manure and other sources have been associated with algal blooms, accelerated eutrophication of lakes and streams, and development of hypoxic zones in the Gulf of Mexico. ARS scientists are conducting research to develop management practices, control technologies, and decision tools for effective agricultural use of nutrients from manure and other byproducts, while protecting environmental quality and public health.

Selected Accomplishments

Injecting liquid manure improves ammonia retention but increases other nitrogen losses. Incorporation of liquid manure into the soil is often recommended to reduce ammonia losses, odor, and nutrient runoff in surface water. However, incorporation with tillage is not compatible with high-residue conservation practices, such as no-till, and is not possible with pasture or perennial forages. Manure injection technologies allow incorporation with limited disruption of the soil surface or plant residue cover. ARS scientists at Beltsville, Maryland conducted a critical review and analysis of the literature and found many publications that show injection of liquid manures can reduce ammonia N emissions by 40-90%, compared to surface application. However, injection can create anaerobic soil conditions leading to losses of other gaseous forms of nitrogen (N). Up to half of the N that is conserved by reducing ammonia emissions can later be lost as N_2 (a chemically inert gas that makes up 78% of earth's atmosphere) or as nitrous oxide (a potent greenhouse gas). Improved crop utilization of the N conserved by reducing ammonia emissions is the most common observation following injection, but this benefit can be minimal. These results provide scientists, nutrient managers, and policy makers with improved estimates of the effects of manure injection on the fate and transport of manure N that can be used to improve economic return and minimize adverse affects of manure N.

Managing manure to reduce runoff phosphorus (P) losses. Manure application to cropland can contribute to runoff losses of P, which can lead to excessive algae growth in lakes and streams. ARS researchers in Marshfield, Wisconsin, conducted a series of rainfall simulation experiments to assess how the amount of dissolved P in runoff would be affected by: 1) P supplementation of dairy heifer diets; 2) manure application method and rate; and 3) the amount of available P already in the soil. Phosphorus supplementation in the diet resulted in more P in manure, which led to 2 to 3 times more dissolved P in runoff. Incorporation of manure into the soil reduced runoff P concentrations by 85 to 90% compared to surface application. These results show that large reductions in P runoff losses can be achieved by avoiding unnecessary dietary P supplementation, by incorporation of manure, by limiting application rate when applying to cropland, and by avoiding soils with excessive P. By adopting these practices, farmers can greatly reduce the amount of P leaving their farms, which subsequently will reduce algae growth and eutrophication in surface waters.

Subsurface banding of broiler litter is a better method for corn fertilization. The fertilizer value of broiler litter has been recognized by farmers and applied to row crops under both tillage and no-till systems. However, application of poultry litter to the row crops under no-till soil management concentrates litter-derived nutrients at the soil surface, enhances volatilization of nitrogen, and greatly increases nutrient losses in runoff water. Losses of applied nutrients can cost farmers substantial income and degrade air and water quality. ARS scientists in Mississippi State, Mississippi, studied the impacts of broiler litter placement on corn yield and N utilization under the no-till system and found that subsurface banding of broiler litter substantially increased corn N use efficiency by 56% and grain yield by 16% when compared to surface broadcast litter. This indicates that subsurface banding of broiler litter could be an effective management practice for no-till corn and other row crop production and would become a method of choice for applying solid manures, if the technology can be developed and commercialized as a practical option for the producers.

Minimizing impacts of manure application on water quality using narrow grass hedges. Narrow grass hedges placed at selected intervals along a hill slope reduce runoff nutrient loads. Specific information about how manure application and runoff rates affect runoff nutrient transport following land application of swine manure was unknown. ARS scientists at Lincoln, NE determined that runoff loads of ammonium nitrogen increased 40% as swine manure application rate increased by 300%. As runoff rate increased, runoff loads of dissolved phosphorus and total phosphorus increased proportionately. Over-application of manure to meet multi-year requirements increases the risk for nutrient runoff.

Winter cover crop increases effectiveness of fall-applied broiler litter as cotton fertilizer. Applying broiler litter and other manures in the fall to fertilize spring-planted crops carries great risk of losing the nutrient benefits. ARS scientists at Mississippi State, MS, in cooperation with researchers at other ARS locations, and Mississippi State University found that planting a wheat cover crop as a conservation practice soon after applying poultry litter in the fall in shallow subsurface bands increases the effectiveness of the litter as cotton fertilizer for spring-planted crops. The same research also showed the cover crop was much more beneficial for cotton that received no fertilizers in the fall or spring suggesting that the winter-planted wheat conserved nutrients from loss during the fall or winter months before planting cotton in the spring. These results are expected to contribute to the sustainability and environmental acceptability of poultry litter use as a fertilizer for cotton and other row crops in the southern and southeastern United States.

PATHOGENS AND PHARMACEUTICALLY ACTIVE COMPOUNDS

Pathogens and pharmaceutically active compounds in manure, biosolids, and other byproducts can be transmitted to animals and humans through food supplies, water and possibly air. Livestock and poultry can also be re-infected not only via water and air, but from other vectors such as birds, rodents and insects. The most significant of the manure-borne zoonotic pathogens are the protozoan parasites *Cryptosporidium parvum* and *Giardia duodenalis*, and the bacterial pathogens Salmonella, Campylobacter, *Escherichia coli*, and *Listeria monocytogenes*. Pharmaceutically active compounds such as hormones and antibiotics may also be present in animal waste and disseminated in the environment. The potential for serious health effects both on and off the farm, the lack of knowledge about pathogen survival in manure during collection, storage, treatment and application, and uncertainty about fate and transport of pathogens in soil, water and air from the animal production site or manure application area, clearly point to the need for research on these issues.

Selected Accomplishments

Bacterial communities in beef cattle with diets containing corn and wet distillers grains. There is concern that use of wet distiller's grains, a byproduct of the ethanol industry; in cattle feed may create a gastrointestinal environment that allows the growth of bacterial pathogens such as *Escherichia coli* O157:H7 that can impact human health. Since all *E. coli* must compete for resources with other fecal community members, ARS researchers in Lincoln, Nebraska looked to see what other kinds of bacteria are present with *E. coli* in the cattle gut. Results indicate that *E. coli* experiences fundamentally different microbial communities in animals fed distillers grain compared to animals fed corn. Competition within different communities may reduce O157:H7 in the gut and thus, management of animal diet could be a legitimate practice to reduce the potential for O157:H7 food contamination.

Antibiotic resistance genes were identified in swine feces and manure. Bacteria commonly present in swine feces and stored manure may provide reservoirs of antibiotic resistance genes which may possibly be transferred to bacteria affecting human health. However, relatively little is known about such genes in these ecosystems. Scientists in Peoria, Illinois demonstrated that a variety of antibiotic resistance genes are present in both swine feces and stored swine manure. These results will guide the development of methods to quantitatively measure each of these genes in these ecosystems and assess the impact of varying management practices on reducing the concentration of such genes. Such reductions will aid swine producers, environmental protection agencies, health officials, and local residents that live near swine facilities.

Improved assay for measurement of pathogens in water and manure. When using DNA-based technologies for quantifying pathogen levels in manure or the environment, there are naturally-occurring compounds that can inhibit the detection assay, causing it to fail or underestimate pathogen quantity. ARS researchers in Marshfield, Wisconsin, developed a method for accurately measuring the level of assay inhibition and mitigating the biasing effects of inhibitors. The method works in a variety of sample types such as groundwater, manure, or runoff from agricultural fields. Quantifying pathogens accurately in the environment is important for correctly identifying those management practices best suited for minimizing pathogen transport and maximizing pathogen removal. Such practices would benefit producers by preventing herd-to-herd disease transmission through environmental routes, and the public would benefit by preventing transmission of the types of pathogens found in dairy manure that are capable of infecting people.

Pathogen survival in organic waste is related to organic matter content. The presence of foodborne pathogens in soils used for food crop production can be influenced by many factors, including the level and type of organic matter (OM) in the organic fertilizer. Traditionally, quantitative risk analyses have relied on "one size fits all" pathogen inactivation rates when predicting pathogen survival. ARS scientists at Mississippi State, Mississippi, have demonstrated the influence of the high OM content in the organic fertilizer on pathogen survival in a series of studies. Experiments using culture and molecular analyses demonstrated that high OM matrices, such as biosolids and cattle manure, protected Salmonella and *E. coli* O157 better than low OM liquid matrices. Pathogen inactivation rates were substantially affected by OM levels, and demonstrated that traditional inactivation rates for biosolids and cattle manure need to be revised. In addition, the exclusive use of molecular data can yield more conservative results than culture only; future risk analyses need to take this into account. This research is the first of its kind to produce and compare cultural and molecular data in risk analyses. These results provide further light on foodborne outbreaks potentially linked to manure.

Culturable bacteria concentrations are not affected by sprinkler irrigation. ARS researchers in Kimberly, Idaho, conducted spray irrigation events of dairy wastewater to assess the impact on culturable bacteria concentrations. This research is important since many dairies; particularly those in the arid west, land apply their manure wastewaters using pressurized irrigation devices. During spray irrigation events, pathogens associated with the wastewater can become aerosolized and transported downwind, possibly causing infection in exposed individuals. In this study, the pre- and post-sprinkler bacteria concentrations were determined to be statistically similar in most cases, indicating that culturable viability was not affected when wastewater flowed through the sprinklers. The data suggests that the number of viable bacterial pathogens available for aerosolization will also not be affected by sprinkler type and pressure setting. The results from this study will be particularly useful to regulatory agencies performing microbial risk assessments.

Use of biochar to increase *Escherichia coli* retention in soils. The incorporation of biochar into soils has been proposed as a means to sequester carbon from the atmosphere. Recent studies have shown added environmental benefits to biochar amendments to soil such as increased soil retention of nutrients, heavy metals, and pesticides, yet no studies have looked at the role biochar plays on microbial transport in soils. ARS scientists in Bowling Green, Kentucky, have conducted studies to evaluate whether biochar amendments can reduce the transport of *E. coli* through soils. Results from this research show that the addition of biochar to soil can indeed affect the retention and transport of *E. col*i – a commonly used indicator of fecal contamination in groundwater. Results indicate that the amount of *E. coli* retention in biochar-amended soils depends on biochar application rate, temperature that the biochar was produced, and surface characteristics of the bacteria. If biochar is to be widely used as a soil amendment, it is important that its impact on microbial transport through the soil be understood, especially for fields where animal manure is applied. This research is the first to investigate this important environmental topic and results from this research provide important information on the factors controlling bacterial transport through biochar-amended soils. Results suggest that biochar has the potential of being used as a management practice for protecting shallow groundwater supplies from contamination by pathogenic microorganisms.

ATMOSPHERIC EMISSIONS

Air emissions from animal production operations and land application of manure and other byproducts include particulate matter, ammonia, volatile organic compounds (that cause odor or serve as precursors for ozone formation), hydrogen sulfide, greenhouse gases and pathogens. Research is being conducted to: (1) develop new methods and improve existing methods to measure particulate matter and gaseous emissions; (2) develop and determine the effectiveness and environmental benefits of management practices and control technologies to reduce emissions; and (3) develop and test decision tools to predict emissions and their dispersion across a range of animal production systems, management practices, and environmental conditions. Tools and practices for measurement, control and prediction of emissions from animal production operations will help provide the scientific background for management, policy and regulatory decisions.

Selected Accomplishments

Ammonia loss from poultry litter is amplified by higher air flow rates. ARS scientists at Mississippi State, Mississippi, quantified ammonia generation from litter while increasing air flow rates per volume of litter. Ammonia release to the atmosphere is an environmental concern with potential negative effects for air quality (particulate formation), terrestrial life (decreased ecosystem diversity), and water resources (eutrophication). For emerging mitigation technologies where ammonia is captured, the results indicate a need to combine forced ventilation with other parameters (like temperature) that maximize ammonia generation from litter. Growers can reduce ammonia on the farm by covering litter stockpiles to reduce wind flow over them or, within broiler houses, couple intense ventilation between flocks with an ammonia scrubber.

Recommendations for litter moisture and ammonia control in broiler houses are conveyed to growers. ARS scientists at Mississippi State, Mississippi, discovered the critical litter moisture content where ammonia generation is maximized. Simple techniques were communicated, via factsheet, showing growers how to measure litter moisture and barn ammonia concentration to improve litter management. In addition, broiler house management solutions to optimize water inputs to litter were provided. Growers and integrators can use this information to produce healthier birds, reduce environmental concerns due to ammonia release, and to improve profits.

Standardization of emission measurements. The various methods used to measure gas emissions result in different values even when measuring the same source. ARS scientists at Clay Center, Nebraska standardized a method for measuring gas emission rates from soil and feedlot surfaces using water evaporation within instrument chambers. A correction factor was obtained that was used to adjust emission values across a variety of instruments which allows for improved comparisons.

Trace gas emissions at an open-freestall dairy. The implementation of air quality regulations in livestock-producing states increases the need for accurate on-farm determination of emission rates for trace gases. In this study, ARS researchers in Kimberly, Idaho, determined emission rates for greenhouse gases (methane and nitrous oxide) and ammonia from the animal housing and manure management sectors at an open-freestall commercial dairy. This study is the third completed study aimed at determining emissions from dairy production facilities representative of western dairy production. The results from this research program have been submitted to the U.S. Environmental Protection Agency (EPA) for use to determine emission factors from dairy production facilities. An indirect result of this work has been that a scientist from our facility has been invited to serve on the EPA Scientific Advisory Board to review EPA's methodologies for estimating air emission from animal feeding operations and selected by the USDA Climate Change Program Office to assist in the development of technical guidelines and scientific methods for the estimation of entity-scale greenhouse gas emissions. These activities will help our stakeholders obtain the maximum benefit from this research and assist both producers and regulators in determining realistic on farm emissions of ammonia and greenhouse gasses.

Models predict nitrogen excretion by beef cattle. Reliable estimates of nitrogen excretion in the urine and feces of beef cattle are important to determine how much nitrogen is lost from feedyards as ammonia gas. Researchers in Bushland, Texas, analyzed 50 different beef cattle diets to determine the relationships between nitrogen intake, the amount of protein in the diet, and nitrogen excretion in the urine and feces of beef cattle. Then, statistical models were developed that predict excretion of urinary and fecal nitrogen by beef cattle. These simple and robust statistical models were very accurate and provide a simple tool to predict nitrogen excretion for a wide range of dietary and animal characteristics. They could be incorporated into more complicated process-based models, which track ammonia production based on numerous animal management and environmental factors, to improve their accuracy for predicting feedyard ammonia loss.

Methane and ammonia loss from dairy lagoons. Dairies are a growing industry in the Southern High Plains and are sources of environmentally important gases such as methane and ammonia. However, the amounts of ammonia and methane emitted from typical High Plains dairies have not been determined. Scientists at Bushland, Texas, teamed with researchers at Texas A&M AgriLife Research, West Texas A&M University, and New Mexico State University to study emissions from the lagoons that collect dairy wastewater at a 3,500-cow dairy. Ammonia loss from the lagoons was low (from 14 to 30 grams per cow daily, or less than 5% of the nitrogen fed) compared with losses typically measured from the pen area. However, the open, uncovered lagoons were a significant source of methane, ranging from 208 to 359 grams of methane per cow daily. Understanding the quantity and sources of atmospheric emissions can help dairy managers more effectively adopt and apply measures to reduce emissions.

Atmospheric emissions of greenhouse gases (GHG) from different nitrogen fertilizers. Increasing demand for food and agricultural products directly relate to increased GHG emissions, particularly the three primary gases associated with agriculture [Nitrous Oxide (N_2O), Methane (CH_4), and Carbon Dioxide (CO_2)]. Commercial nitrogen fertilizers and organic N sources such as animal manure stimulate N emissions mainly through biochemical processes. ARS scientists in Bowling Green, Kentucky, have investigated the effects of N_2O, CH_4, and CO_2 emissions from application of several inorganic N fertilizers, commercially available enhanced-efficiency N fertilizer, and poultry litter under no-till corn production. No significant differences were observed in N_2O emissions among the enhanced-efficiency N fertilizers and other N fertilizer sources. The CH_4 and CO_2 emissions were impacted by the environmental factors more than the N source. Results demonstrated that N fertilizer source and climate conditions need consideration when selecting N fertilizer that reduces greenhouse gas emissions.

Reducing odor emissions from swine lagoons. Malodorous emissions from swine lagoons are a problem for swine producers and their neighbors. ARS scientists at Clay Center, Nebraska demonstrated that a product derived from soybean, soybean peroxidase, was effective at reducing odorous chemical emissions from swine manure by 68 to 81 percent. The research has resulted in awarding of additional grant funds from the National Pork Board for further development in commercial swine production facilities.

BYPRODUCTS

Each year millions of tons of agricultural, municipal and industrial byproducts are generated in the United States. These materials are frequently considered to be wastes and are often disposed in landfills. However, many of these materials have characteristics that make them potentially useful to improve soil properties for enhanced crop production, to prevent movement of contaminants to critical bodies of water, and to lower energy inputs in agricultural systems. Research is being conducted to determine benefits and risks of the materials, to develop and evaluate the effectiveness and economic benefits of byproduct-based management practices and control technologies, to document the environmental benefits of using these materials, and to develop guidelines for specific uses.

Selected Accomplishments

Beneficial use of zinc (Zn) from ground rubber tires. Waste tires are a significant environmental problem, but beneficial uses have been found for this waste. Tires can be used to produce energy or ground rubber to mix with soil to reduce physical compaction in high traffic areas. Because tire rubber contains about 1.5% Zn because highly purified Zn (very low in cadmium and lead) is used in the vulcanization of rubber, ARS scientists at Beltsville, Maryland tested use of ground rubber as a Zn fertilizer and as a potting medium component. Additional field testing was undertaken by a cooperator in Iran, where Zn deficient soils were amended with varying rates of ground rubber or Zn sulfate to increase crop yield and reduce grain cadmium (Cd); significant reduction in grain Cd was observed. In another test in Arizona, different rates of Zn were applied as Zn sulfate or ground rubber to field plots of durum wheat cultivars to learn if high Zn fertilizer applications could reduce grain Cd levels; in this case, where Zn was not deficient, little or no reduction in grain Cd was observed. This finding may provide the rubber industry additional uses for old rubber tires.

Beneficial use of flue gas desulfurization (FGD)-gypsum in agriculture. The electrical generating industry produces FGD-gypsum during the process of removing sulfur dioxide (SO_2) from exhaust gases, resulting in large quantities of this product. ARS researchers in Beltsville, Maryland and other locations have been conducting research to evaluate the beneficial use of FGD-gypsum in agriculture. Ultimately, the adoption of FGD-gypsum use will depend on "Beneficial Use Designation" at the State level. ARS is cooperating with the EPA in conducting a full risk evaluation of this use to provide information needed by States to make regulatory decisions about FGD-gypsum use as fertilizer and soil conditioner. Field tests have been conducted to assess the ability of FGD-gypsum to reduce the runoff of phosphate from soils, including soils amended with poultry litter on the surface of hay fields. To date, research has shown that application of FGD-gypsum can significantly reduce runoff phosphorus and arsenic. Other research has not found adverse effects of soils amended with FGD-gypsum compared to unamended soils. These findings will inform EPA as they formulate new rules for the use and disposal of coal combustion byproducts.

Flue gas desulfurization (FGD) gypsum and poultry manure application. Poultry manure-derived nutrients placed in the soil surface from manure application are vulnerable to loss through emission and runoff and reduces the fertilizer value of this by-product. A mechanism to help protect nutrients from loss and enhance their potential uses is needed for sustained productivity. ARS scientists at Mississippi State, Mississippi, evaluated the impact of combining FGD gypsum, a low cost coal combustion by-product, with poultry manure applied to no-till corn and cotton, and results indicated that co-application of broiler litter with FGD gypsum improved soil carbon (C) storage, protected nutrient from loss, enhanced crop nutrient utilization potential, and improved yield, particularly in soils low in organic matter. FGD gypsum can be an agriculturally important resource and its co-application with poultry manure could be recommended as a best management practice if the growers become aware of its beneficial and potential uses.

Corn processing and distiller's grain effects on production of odors from feedlot manure. The composition of diets fed to finishing cattle can have significant effects on odors emitted from feedlots. The effects of feeding steam-flaked corn and wet distiller's grains, a byproduct of the grain-based bioethanol industry, on odor production from beef cattle fed high-concentrate finishing diets is not known. ARS scientists in, Bushland, Texas, collected feces and urine from steers fed varying diets, and ARS scientists at the Meat Animal Research Center, Clay Center, Nebraska, incubated the feces and urine in chambers in order to measure the production of volatile fatty acids, methane, total gas, and other volatile organic compounds that contribute to feedlot odor. Cattle fed diets containing dry rolled corn excreted more starch than cattle fed steam-flaked corn based diets. Production of odors, volatile fatty acids, and other gases increased as the starch content of the feces increased. Production of sulfur-containing odorous compounds was greater from feces of cattle fed diets containing distiller's grains. These results indicate that odors from feedyards may be decreased by steam flaking corn and by limiting the quantity of distiller's grain in the diet.

Biochars produced from plant residues and poultry litter as effective bioenergy sources. Plant and manure feedstocks can be made into energy dense char products by undergoing thermochemical conversion via pyrolysis. Effective conversion of plant and manure feedstocks into char is dependent on ash content and their composition of elements such as chlorine, potassium, silica, sodium, and sulfur, which in excessive amounts can dramatically reduce char conversion efficiency and foul pyrolysis equipment. Scientists at ARS-Florence, South Carolina characterized the elemental composition in several plant (bagasse, peanut hulls, pecan shells, pine chips, switchgrass) and manure (poultry litter) feedstocks and their biochar counterparts to determine how individual elements may influence pyrolysis conversion efficiency. Plant-based chars had better thermal energy contents and lower ash contents than poultry litter implying efficient thermal conversion. Instead, poultry litter char had medium heating values and substantial amounts of chlorine and sulfur, which could promote equipment corrosion during thermal energy processing. This study indicates that energy conversion of poultry litter and the integrity of thermal processing equipment can be greatly improved by blending it with plant residue feedstocks.

Use of hydrothermal carbonization products as sorbent of environmental contaminants. Hydrothermal carbonization is an aqueous thermal process that converts organic wastes into a product called hydrochar. ARS scientists in Florence, South Carolina, working with university collaborators, discovered that the hydrochar made from chicken litter and swine manure showed excellent sorption capacity of environmental contaminants such as endocrine disrupting chemicals, herbicides, and polyaromatic hydrocarbons. This high sorption capacity toward these compounds was attributed to the hydrochar’s diverse surface chemistry. In addition, it was found that hydrochar surface chemistry can be easily modified with activating compounds to produce more stable hydrochar products. For example, hydrochar activated with citric acid resulted in a more stable hydrochar in soil environments. Formulations and application methods for field uses of hydrochar are in development.

Method to reduce arsenic in rice. Arsenic accumulates in the grain of rice since it is grown under flooded conditions. Since arsenic is a known carcinogen, methods to lower arsenic in rice are needed. During the past year, researchers at Fayetteville, Arkansas, hypothesized that arsenic solubility could be lowered in flooded rice soils by adding aluminum, iron, or manganese amendments, which would lower arsenic uptake by rice. Laboratory studies showed that amendments, such as alum, lowered soluble arsenic by up to 70%. Small plot studies are currently underway in Stuttgart, Arkansas, to determine the effects of this treatment are on rice yields and arsenic uptake.

Trash tree, Eastern red cedar, found to be effective potting media substrate replacement for pine bark for greenhouse production. Peat and perlite have served as industry standards in greenhouse substrates for over 50 years. Expanded perlite has long been used as an amendment in container mediums because of its ability to add air space to container substrates without adding to bulk density or affecting substrate pH and electrical conductivity (EC). However, due to increased restrictions on the harvesting of peat, as well as fluctuations in fuel prices necessary for shipping, the future availability of peat is a largely unknown factor in greenhouse production. Additionally, growers consider perlite to be a general nuisance due to the lung and eye irritation problems. These studies evaluated three possible substrate alternatives for use in greenhouse products, fresh sweetgum, hickory, and eastern redcedar. Three greenhouse annual crops (petunia, impatiens, and vinca) were planted in varying ratios of these three wood species mixed with peat. Plants grown with sweetgum and hickory as amendments did not perform as well as a traditional peat: perlite mix with respect to flower number and growth indices. However, plants grown in red cedar tended to be equivalent to those grown in a traditional mix. Data showed that greenhouse producers could amend their standard greenhouse substrate with up to 50% eastern red cedar with little to no differences in plant growth and overall aesthetic quality.