ABSTRACT

STEVENSON, HAYLEY DIANA. First Year Growth Response to Mulching with On-Farm Wastes in an Oak-Pine-Soybean Agroforestry Trial. (Under the direction of Daniel J. Robison and Fred W. Cubbage).

Alley cropping may prove useful in the southeast U.S., providing multiple products and income streams, as well as affording sustainable land use alternatives to conventional farming and forest planting. Such systems in this region are of particular interest because they can help in soil conservation and nutrient retention and aid in sustaining and improving valued but degraded farmland. In the current study triple row single-species strips of loblolly pine (*Pinus taeda*), longleaf pine (*Pinus* palustris) and cherrybark oak (*Quercus pagoda*) were planted as 1-year-old seedlings separated by 12 or 24 m wide areas of soybean in spring 2007. Select individual tree seedlings of each species were treated with on-farm wastes, used as mulch in a circular area around each stem. These waste/mulches were hog bedding (corn stover + hog waste removed from swine houses), old hay (year-old rolled/slightly spoiled bermudagrass hay - *Cynodon dactylon*) and black plastic bedding film. After the first season of growth with the applied mulches, tree seedling growth rates were higher for cherrybark oak and longleaf pine seedlings mulched with old hay applied at 7.5 cm deep in 30 cm radius around each seedling. Other mulches had varying effects on soil conditions, but no significant impact on tree growth as compared to the untreated control seedlings. These first-year findings suggest that mulching with specific on-farm wastes may be a valuable management tool in temperate alley cropping systems. Longer term tree growth in this system and with regard to these initial mulching treatments will be studied.

First Year Growth Response to Mulching With On-Farm Wastes in an Oak-Pine-Soybean Agroforestry Trial

by
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BIOGRAPHY

Hayley Stevenson was born in Kobe, Japan and lived there until she moved with her family to Manila Philippines, where she graduated from high school at Faith Academy. She received her bachelor's degree from Gordon College in Wenham, MA, and spent the next several years working on organic farms and botanical gardens. Her experience and interest in working with the land, and desire to get involved internationally led her to pursue her degree in Forestry at North Carolina State and to this agroforestry project.

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INTRODUCTION

Historical misuse of land, coupled with an increasing population, has given rise to efforts focused on diversification of land use, fostering the need for research on land management systems with improved sustainability. Agricultural lands beset by soil degradation, wind and water erosion, decline in soil tilth, increased soil salinity and decreased fertility are all indicators that previous land use practices were not sustainable. Agroforestry is one system that can enhance sustainability, and diversify land use (Nair, 1991; Sanchez, 1995). Agroforestry has been practiced for centuries around the world, and new agroforestry systems and strategies are currently under research, with an emphasis on improving practices and preserving the quality of the environment (Jama, Elias, & Mogotsi, 2006; Nair, 2007; Sanchez, 2005). This thesis will examine an agroforestry system in North Carolina and the effects of various site treatments on early growth of trees.

Field-based research can efficiently lead to techniques and strategies most relevant to the landscapes where they may be deployed (Jose, Gillespie, & Pallardy, 2004; Rhoades, Nissen, & Kettler, 1998; Sanchez, 1987; Workman, Bannister, & Nair, 2003). The Southeast offers an opportunity to develop systems that reflect relevant regional practices. Research already conducted in the Southeast has focused mainly on silvopasture systems (Bendfeldt, Feldhake, & Burger, 2001), but there is need for agroforestry, and specifically, alley cropping research, which has much potential (Zinkhan & Mercer, 1996).

Traditional practices of growing annual agriculture crops differ widely from forestry practices common in North Carolina. Incorporating both of these into an agroforestry system poses management challenges. These challenges include figuring out how to optimize land use, adding fertilizers to crops that have differing requirements, using farm machinery, and managing weeds and the type and timing of herbicide applications. One of the challenges, and an opportunity, is the potential to enhance the micro-site conditions for early tree growth, by using/ testing on-farm wastes as mulch material around trees in this kind of system. These kinds of potential mulch materials are not available or used in traditional forest tree plantings, but in the context of farm-based agroforestry these materials are not only available, but are nearby, machinery to move and apply them is present, and this use may enhance tree growth and solve farm waste management problems. On-farm wastes with such potential use are, for example, spoiled hay/silage/grain, animal manure and bedding, and previously used black plastic.

While mulching studies have been done on cropping systems, as well as plantation style forestry, little has been done on mulching in agroforestry systems, where tree management interacts with agricultural conventions, and the adjacency of trees and on-farm wastes can be taken advantage of (Sanchez, 1987; Wakely, 1954; Walker & Mclaughlin, 1989).

Objectives

The objectives of the current study were to evaluate the impact of several on-farm waste materials as mulches on first year growth of cherrybark oak (*Quercus pagoda*), loblolly pine (*Pinus taeda*), and longleaf pine (*Pinus palustris*) seedlings in an agroforestry system, by considering the following variables:

- height growth,
- diameter growth,
- survival,
- soil moisture,
- soil temperature,
- weed suppression,
- nutrient concentration of soil,
- nutrient concentration in mulches, and
- nutrient concentration of leaf tissue.

The current study and its broader intent as a long-term research and demonstration site has been described in Stevenson et al. (2009, pending publication).

LITERATURE REVIEW

Agroforestry and Alley Cropping Defined

Agroforestry is an integrated land use that mixes tree and agricultural crops on the same parcel of land in various temporal and spatial patterns. This kind of system can promote/provide a diversified land use cover of cropped plant species, and the resulting diversity of associated plant, arthropod, and microbial agents, that are important factors in the ecological and production sustainability of agro-forest-ecosystems. Some of these agents may be helpful to the productivity of the cropped plants, such as beneficial soil microbial activity, while others can be detrimental, such as difficulty in managing weed species complexes. These systems require design that will foster increased productivity and income generation with environmental rehabilitation through the creation of biodiverse agro-forest-ecosystems (Izac & Sanchez, 2001). Agroforestry has been practiced around the world for centuries, and usually includes at least two of the following: agricultural crops, forestry, and livestock. In recent years, agroforestry research has focused on developing techniques and improving efficiency in systems, such as applying nutrient cycling abilities to improve degraded land without over-applying fertilizers, using trees to lower the water table in wet areas, and managing tree fallows to improve soil aeration (Erdmann, 2005; Sanchez, 1995; Young, 2004). One system of interest in the southeastern U.S. is alley cropping (Stamps & Linit, 1997).

Alley cropping is a system where trees and crops are managed on the same parcel of land at the same time. In temperate regions, alley cropping generally consists of tree rows running in narrow strips across agricultural fields planted in annual crops, such as corn (*Zea Mays*) or soybeans (*Glycine max*). Well-designed alley cropping will aim to benefit all of the crops on the farm, while improving aspects of the environment (Sanchez, 1995).

Agroforestry research in the Southeast should focus on improving water quality and wildlife habitat, recovering marginal lands, and diversifying the future sites of pine plantations, as pine plantations account for 10% of forested lands in the Southeast (Wood & Burley, 1991). Further, there is the recognized need to develop regionally-based agroforestry systems that employ relevant tree species, such as loblolly pine, longleaf pine and cherrybark oak (Bandolin & Fisher, 1991; Zinkhan, Holmes, & Mercer, 1997). Recent studies in the Southeast include research focused on N and P in pine tree alley cropping systems (Brauer et al., 2006; Michel, Nair, & Nair, 2007), and the relationship of light and plant growth in various alley cropping systems (Zamora et al., 2006).

Alley Cropping Design and Management

Successful alley cropping incorporates site knowledge with factors such as crop/ tree density and rotations, pest and weed management, soil fertility and conservation improvement, alley width, tillage, crop rotations, allelopathy, and water quantity and quality management. Various agriculture crops will interact differently within an alley cropping system, and one important aspect in the design of these systems is tree spacing and density, which depend to a large degree on land use objectives (Williams & Gordon, 1992). For example, a tree grown for timber might be spaced closer together to reduce branching and stimulate height growth, whereas an orchard tree should be spaced farther apart to allow for branching and fruit production (Izac & Sanchez, 2001; Raintree, 1990). One study reported that optimal spacing and choice of tree species reduced the need for synthetic fertilizers (Dommergues, 1987).

Well-designed alley cropping systems allocate for standard farm equipment to be used, reducing manual labor (Nair, 1991; Sanchez, 1995). Additionally, as agroforestry becomes more of a common practice, techniques and equipment use will improve, with better efficiency (Brandle & Marsh, 1995; Hoekstra, 1987; Whitefield, 2004).

One of the challenges of alley cropping is devising a system where multiple crops are managed in tandem. Ideally, alley cropping is designed to deal with trees and agriculture crops, without managing one at the expense of the other (Sanchez, 1995). However, some agroforestry studies have shown that where plants compete for water, alley cropping practices yield less than monoculture systems (Sanchez, 1995), and reduced soil fertility has been reported in other agroforestry studies (Schroth et al., 2001). It is also apparent that weed management and fertilizer regimes in intimately associated tree and herbaceous agricultural crops can pose significant difficulties in the care and effectiveness of system management (personal observation).

Attributes of Trees in Alley Cropping

In alley cropping systems, trees can provide a diverse and extensive range of ecological benefits. Land managed for both trees and agriculture have increased biodiversity and a more diverse community structure than trees or agriculture crops alone (Leakey, 1999). These systems thus support a wider range of host species, arthropods and members of the soil community, which can increase above ground productivity (Crutsinger et al., 2006), although also pose management challenges. Moreover, beneficial correlations have been found between trees planted in an area and pathogen-fighting qualities in the soil that could protect crops susceptible to disease (Stamps & Linit, 1997). Further, growing trees in agricultural fields helps stabilize and improve soil structure, which can also enhance crop root growth and nutrient accessibility of annual crops (Sanchez, 1987; Young, 1989). However, tree roots can also compete with root growth of annual crops, which poses another management issue in agroforestry systems (Schroth, 1995). Agroforestry crop mixtures are therefore able to efficiently access and recycle nutrients (Erdmann, 2005; Ledgard, 2001; Wood & Burley, 1991). Leguminous trees are often used in alley cropping because they can utilize atmospheric N and release it to the soil through leaf litter and root debris, thereby reducing the need for N fertilizer (Dommergues, 1987). Also, trees have the ability to pump water out of the soil (Jose, Allen, & Nair, 2007) which can enhance soil fertility (Bernstein, 1975; Prinsley, 1992). Trees provide ground cover for better protection of waterways (Long & Nair, 1999), create an improved microclimate for crops (Basavaraju & Gururaja Rao, 2000), and in some cases, minimize weed competition (Rizvi et al., 1999).

Trees in alley cropping systems can directly benefit productivity. For example, trees can block wind, protecting crops and soils from extreme weather, lessening evapo-transpiration and allowing plants to be more productive. In New Zealand and Australia, as well as in the American mid-west, where trees are often used as shelterbelts, studies have shown that tree wind breaks improved livestock and pasture production (Bird et al., 1992; Hawke & Wedderburn, 1994).

Alley cropping has contributed to economic diversity as well, and landowners growing trees may have an opportunity to earn carbon credits through carbon sequestration programs (Jose et al., 2007). Trees used in alley cropping can help promote both agricultural and economic diversity (Huxley, 1983; Williams, Gordon, Garrett, & Buck, 1997), especially if trees include non-timber products such as fruits, nuts, mulch and medicine (Whitefield, 2004; Wood & Burley, 1991), that can be realized prior to the attainment of the value associated with wood – that requires final harvest or earlier thinning.

There is however, the predetermined tradeoff of land use when alley cropping is deployed. The area planted to trees is not available for the agricultural crops, and vice versa, and as trees grow with each passing year, they inevitably capture site resources at greater distances from where they were planted, and thus deprive these resources to the agricultural crops between them. Optimal management of these systems then becomes an intricate series of tradeoffs and compensation mechanisms, over annual and longer-term time scales, which relate to accumulated ecosystem benefits, especially those linked to site fertility, production of the tree and agricultural crops, and the amount and timing of financial returns from the site.

The Practice of Mulching

Mulching can enhance plant growth while suppressing weeds, and has been practiced for centuries in gardening and food production and more recently in forestry plantations (Adams, 1997; Allen, 1987; Gupta, 1991; Haywood, 2000; Walker & Mclaughlin, 1989). A few studies have focused on mulching exclusively to test growth effects on tree seedlings, and some have shown mulching enhances tree growth (Adams, 1997; Gupta, 1991; Haywood, 2000; Walker & Mclaughlin, 1989), while others conclude that mulching has limited potential (Haywood & Tiarks, 1990) or that the increased growth effects diminished over time (Haywood, 1999). Marginal land has also been a focal point of some mulch studies (Green, Kruger, & Stanosz, 2003; Meyer, Wischmeier, & Foster, 1970).

Additional studies have focused on mulching to conserve soil moisture, reduce soil erosion, enhance soil fertility, and create an improved micro-climate for a mulched plant (Faucette et al., 2004; Laporte, Duchesne, & Wetzel, 2002; Wilson et al., 2004). Low fertility has also been a focal point of mulch studies (Green et al., 2003; Meyer et al., 1970). Although all three species in the study, (*Q. pagoda, P. taeda,* and *P. palustris*) are native to North Carolina, and grow well under hot conditions, they are accustomed to growing under moist conditions as well (Boyer & Miller, 1994; Lockhart, Ezell, Hodges, & Clatterbuck, 2006). Studies have shown that soil surface litter improves moisture retention (Boyer & Miller, 1994); especially in first year growth while trees are too small to have shading effects (Tolk, Howell, & Evett, 1999). One study done on Douglas Fir seedlings showed that temperature may have had a growth effect only when moisture was not limiting (Roberts, Harrington, & Terry, 2005). Adequate soil moisture conditions are required for root hair growth and nutrient uptake (Jose et al., 2007; Mackay & Barber, 1985; Schroth, 1998). Studies have shown that nutrient uptake and utilization by seedlings is possible only when sufficient moisture is in the soil (Jose, Merritt, & Ramsey, 2003; Kuperman, 1999). Mulches consisting of organic matter can augment soil organic matter, which can intensify soil microbial activity (Tisdale, unpublished; Toyota & Kuninaga, 2006) and increase available plant nutrients (Wilson et al., 2004).

Furthermore, mulching reduces weed pressure, and some studies indicate mulching to be just as, or more effective in certain circumstances, than chemical herbicides in controlling weeds. Others have shown that mulches can have a positive impact on plant growth (Haywood & Tiarks, 1990; Haywood, 1999; Miller et al., 1991; Ozores-Hampton, 1998; Ozores-Hampton, Obreza, Stoffella, & Fitzpatrick, 2002; Schonbeck, 1998). Studies have shown that weed control significantly increases survival rates and growth during early seedling stages (< 10 years) and weed competition can be a deterrent to growth for longleaf and loblolly pine, and cherrybark oak seedlings (Nelson, Zutter, & Gjerstad, 1985; Sweeney, Czapka, & Yerkes, 2002; Yeiser & Williams, 1996). Longleaf pine is particularly sensitive to weed competition in early development stages (Grelen, 1983; Ramsey, Jose, Brecke, & Merritt, 2003; Wakely, 1954).

One challenge of using mulches is the cost associated with buying and transporting materials. Agroforestry will only be practiced in southeast U.S. (or elsewhere) if the system is profitable to the landowner (Izac & Sanchez, 2001; Pannell, 1999; Workman et al., 2003; Workman, Monroe, & Long, 2005), and while mulching may benefit plant and soil stability, it is not always feasible on a large scale because of associated costs (Kormawa, Kamara, Jutzi, & Sanginga, 1999; Ramalan & Nwokeocha, 2000). However, certain agroforestry regimes provide a unique opportunity for incorporating mulching systems that might not otherwise be economically realistic (Ruhigwa, Gichuru, Spencer, & Swennen, 1994). Utilizing waste materials that are problematic on a farm is an alternative that may allow mulching to be more practicable. Mulching with farm wastes may have positive implications if successful, because there would be a system of disposing on-farm waste that could be beneficial as well as cost-effective, and allow the avoided cost of waste management to benefit the system.

On-farm organic wastes used as mulches have the potential to aid in soil fertility through improved water holding capacity without sacrificing soil aeration, the moderating effects of mulches on soil surface temperature, improved soil structure for root growth through organic matter dispersion into mineral soil, and availability of plant growth nutrients contained in the mulch that becomes available for the crop plants over time (and through avoided fertilizer needs reducing some cost and environmental concern associated with inorganic fertility treatments). There is also the potential for mulches to suppress weed growth and provide habitat for beneficial organisms, although pest organisms may also utilize mulch as habitat as well.

These kinds of benefits have been reported for mulches in the U.S. southeast (Young, 2004; Zinkhan et al., 1997). For example, corn stover-hog manure bedding mixtures have been used for erosion control with some effectiveness (Taylor, Hays, Bay, & Dixon, 1964), and farmyard manure can increase microbial activity in the soils (Toyota & Kuninaga, 2006), although effects can vary (Carrera et al., 2007). Manure amendments have been shown to saturate soils with P, possibly due to animal systems not being able to utilize P efficiently (Butler & Coale, 2005). An old feed hay study showed positive impacts of biomass growth in cherrybark oak seedlings, although the height growth of hay-treated oaks was not different from control oaks (Adams, 1997). Studies with black plastic mulching around tree seedlings indicate cherrybark oak, loblolly pine and longleaf pine can all respond positively (Adams, 1997; Walker & Mclaughlin, 1989). Other studies have shown that polyethylene plastic will retain soil moisture, suppress weed competition, and moderate temperatures (Balerdi, 1976; Green et al., 2003; Walker & Mclaughlin, 1989), all potential benefits to crop plants. These attributes of alley cropping with trees and associated mulching signify that such systems may have a role to play in modern farming in North Carolina.

Current Study

The current study, an alley cropping establishment trial, was designed for, and deployed at the North Carolina Department of Agriculture and Consumer Services (NCDA & CS), and North Carolina State University's, Cherry Research Farm in Goldsboro, North Carolina, in January 2007. It consists of cherrybark oak, loblolly pine, and longleaf pine in an alley cropping management scheme with annual crops that include corn, wheat *(Triticum aestivum),* and soybean in a three-year rotation. Being one of the first of its kind in the region, this study will provide a long-term research and development template for understanding and teaching about these systems and their potential application and optimization in the region typified by eastern North Carolina.

In the short-term, and the focus of this thesis, this study quantified the growth effects on tree seedlings of mulching with farm wastes in an agroforestry system that is regionally relevant and applicable. In this study, on-farm wastes were used as mulching materials, consisting of corn stover that had been used as hog bedding, and old feed hay that could no longer be used for livestock. Only materials that could reasonably be expected to enhance tree growth were chosen and applied to seedlings in this dual-cropping management system. We aimed to solve on-farm waste problems while pairing two cropping systems, agriculture and forestry, and executing management regimes that could support both systems. The strength of this study's on-farm approach allows for multiple levels of research interests to be conducted in realistic conditions on a demonstration farm in North Carolina. The demonstration aspect of the agroforestry system is intended for interested landowners as regionally relevant, on-site management techniques and strategies are tried and evaluated.

METHODS

Site Description

Wayne County

Wayne County is located in the eastern-central part of North Carolina in the upper Coastal plain physiographic region. Wayne County occupies 1,435 square km (554 square mi). In the eastern section of the county the elevation is 37 m (120 ft), rising to 44 m (145 ft) along the western border. The largest city in Wayne County is Goldsboro, which lies along the Neuse River. The current study was conducted in the portion of Wayne County near to Goldsboro and the Neuse River (35°20'N lat. and 077°58'W). Average temperature is 16.23 ºC (61.2 ºF), with average annual low and high temperatures falling between 0.5 and 33 ºC (33 – 92 ºF), and average yearly precipitation is 1,266 mm (50 in) (State Climate Office of North Carolina; Cherry Research Station, Goldsboro, North Carolina).

In 2007, when the current study was conducted, growing season rainfall (February to September) totaled 748 mm (40% decrease from the annual mean) and mean temperature during this period was 17.4 °C (0.4 °C above annual mean) (State Climate Office of North Carolina, Cherry Research Station; Goldsboro, North Carolina).

Cherry Research Farm

The research field site is located just north of Goldsboro, North Carolina. The research farm also hosts the Center for Environmental Farming Systems (CEFS), which was established in 1994 by a group of North Carolina State University and North Carolina Agricultural and Technical Institute professors and students interested in conducting agricultural research based around farming systems, in collaboration with private farmers. CEFS is one of the largest centers for the study of environmentally sustainable farming practices in the nation.

The research field site is a10 ha (25 acre) agriculture field that had been in corn and soybean production for several years prior to the current study, and in agriculture for many decades. The field is roughly 105 m (345 ft) wide and 667 m (2, 188 ft) long, running northwest to southeast (Figure 1). The southeast edge of the field borders the Neuse River and cypress grove swamps, and the northeastern edge borders a tree-lined ditch for drainage. The field varies in soil types and slope. Each part of the field represents a unique agro-ecosystem level of productivity. The southeastern end of the field, which is also at the bottom of a slight slope and a first flood plain, has high clay content. The northern-most edge of the field tends to flood in heavy rainstorms. The middle of the field is heavy with pebbles, like a river bottom, while other areas are sandy. The variation is most likely due to the flooding that happened across where the field is located. Prior to the 1940s the field would flood periodically from the upper part of the Neuse River, north of the field (beyond image in Figure 1), to the lower boundary of the field and into a southern section of the Neuse River. The silt and debris that was left after flooding allowed the field to develop various soil types over time. In the 1940s a dike was built on the northern part of the river to discourage flooding. Flooding currently occurs primarily from the river overcoming its banks to the southeast of the site.

Soil Types

According the USDA soil survey (http://soils.usda.gov/survey), the field site includes four soil types: Lakeville sand (49.7% of total field ha), Coxville loam (37.7% of total field ha), Chewacla loam (9.3% of total field ha), and Leaf loam (3.3% of total field ha).

Lakeland sand is a sandy soil composed of marine deposits and eolian sands and is not considered prime farmland according to the standards set by the Natural Resource Conservation Service (http://soils.usda.gov/survey). Lakeland soils are limited in productivity by drought because it is very deep sand and tends to be low in fertility and organic matter content. Lakeland sand is categorized by a generalized annual productivity of 1.4 metric tons/ha of soybean, and has a loblolly pine site index of 21 m (70 ft) and a longleaf pine site index of 18 m (60 ft), at a base age of 50 years (Barnhill et al., 1974).

Coxville loam is known to grow longleaf and loblolly pine well, and a variety of oaks, as well as corn and soybeans. It is a poorly drained soil on uplands and terraces, but in cultivated areas, where it is drained, it is considered “farmland of statewide importance” (http://soils.usda.gov/survey). Coxville loam has a generalized annual productivity of 3 metric tons/ha of soybeans, and a loblolly pine site index of 27 m (90 ft) and longleaf pine site index of 21 m (70 ft), at a base age of 50 years (Barnhill et al., 1974).

Chewacla is an alluvium soil suitable for growing soybean, corn, and forests, including loblolly pine. It is low in natural fertility and organic matter content, and these soils often are flooded. It is considered “prime farmland” when it is protected from flooding or not frequently flooded during the growing season (http://soils.usda.gov/survey). Chewacla loam has a generalized annual productivity of 2.7 metric tons/ha of soybeans, and a loblolly pine site index 30.5 m (100 ft), at a base age of 50 years (Barnhill et al., 1974).

Leaf loam originates from clayey marine deposits and has a high water holding capacity. It is considered “farmland of statewide importance” in North Carolina (http://soils.usda.gov/survey). Wetness is a limitation for leaf loam soils because of the high water table and high clay content. Leaf loam has a generalized annual productivity of 2.4 metric tons/ha of soybeans, and a loblolly pine site index of 27 m (90 ft) and longleaf pine site index of 21 m (70 ft), at a base age of 50 years (Barnhill et al., 1974).

Experimental Design

Tree Species

Three tree species were planted, loblolly pine, longleaf pine, and cherrybark oak. Loblolly pine was selected because it is a dominant timber species in the Southeast, which would be marketable and perhaps desirable for landowners considering agroforestry farms. Additionally, loblolly adapts easily to various soil types which suits the chosen field site very well. Longleaf pine was selected because it is a desirable timber species, and because of its suitability to sandy soils, which takes up much of the northwestern side of the field. Cherrybark oak was chosen because it is one of the faster growing oaks in this region, and is commonly used in the Southeast with high market value.

Field Plot Design

The field was blocked into five parts, from northwest to southeast, to account for the gradient of soil variation and slope (Figure 1). Each block was 105 m (345 ft) wide and 128 m (420 ft) long with five foot buffers established around the edges of the field. Each block was then divided into annual agricultural plots and tree plots. The annual crop sections were 12 m (40 ft) wide by 128 m long or 24 m (80 ft) wide by 128 m long. Each block contained two different widths of agricultural crop areas, 12 m width, and 24 m width. Each block also included five tree plots, 6 m (20 ft) wide and 128 m long (Figure 2).

The tree plots were laid out on the edges of the field and in-between the crop plots. The tree plots were further divided into thirds lengthwise, and each subplot then measured 6 m by 43 m (20 ft by 140 ft), and each subplot was planted to one of the three tree species (Figure 2). The research field was set up to manage both annual agriculture crops as well as long-term tree crops. The agriculture production was set up in a three-year soybean, corn, and wheat rotation with long term plans of turning over to pasture with possibility for grazing. Each tree subplot was then planted to loblolly, longleaf or cherrybark oak (Figure 2). Trees were planted in a triple row design within the plots at 1.5 m by 2 m (5 ft by 7 ft) spacing (Figure 3). There were 4.5 m (15 ft) unplanted areas running across the width of the field, between each block, and along field boundaries, for equipment access.

Site Preparation

The entire field site had been planted to corn in 2006 and harvested before the end of that year. It was not cultivated in any way after the 2006 corn harvest and before the start of the current study. In January 2007, an attempt was made to break up the hard pan that was present under the plow depth in the field by tractor ripping. However, the field was too wet and the operation was discontinued after 1/3 of the field had been ripped. The ripping was attempted again after the trees were planted in April, but it also proved to be futile so this operation was then permanently abandoned. The partial ripping is presumed to have minimal effects on the study since it uniformly crossed 1/3 of the field lengthwise, thereby equally crossing all 5 replications. Its impact was accounted for in the blocking layout, as were other soil variations across the site. Further, the trees were planted mid-way between the rip lines where they occurred, and thus during the first year or two of this study there would be little effect of rip lines on the small root systems of planted seedlings 0.76 m away from the nearest rip. A second approach to overcome the hard pan for each tree was to use a 21 cm (9 in) diameter auger drill to establish each planting hole. However, this operation was also abandoned due to the difficulty and time required to drill each hole and the uncertainty of actually penetrating the hard pan. Holes were only attempted in one corner of Block 1, were filled after the attempt was ended, and trees were planted away from the few holes actually made.

Trees were planted by block on January 12-15, 2007, by students, professors, and prison laborers. The average air temperature during those days was 9.4 ºC (49 ºF), average surface soil temperature was 9.9 ºC (49.8 ºF), winds averaged 7.7 km/h (4.8 mph) and there was an average relative humidity of 78% (State Climate Office of North Carolina, Cherry Research Station; Goldsboro, North Carolina).

All the tree seedlings came from the North Carolina Division of Forest Resources, Claridge State Forest Tree Nursery in Goldsboro. The loblolly pines were planted as 1-0 bare root seedlings grown from publicly available, genetically improved seed. The longleaf pines were planted as 1-0 containerized seedlings grown from seed that originated in Bladen County, North Carolina. The cherrybark oaks were planted as 1-0 bare root seedlings with seed that came from Pee Dee River basin in upper South Carolina. Cherrybark oak and loblolly pine seedlings were transported in brown paper bags and the containerized longleaf plugs were in cardboard boxes. They were kept under tarps out of the sun and left in bags until planting to avoid desiccation. All seedlings were sorted before planting and only the best were used. The seedlings were carried around the field in plastic planting bags with water in the bottom. The longleaf were planted using a plug planting tool in the sandy soil and dibble bars in the clayey soil. Loblolly were planted using dibble bars, and cherrybark oak with shovels.

On March 8, 2007, the pre-emergent herbicide, Oust (Du Pont Co.; Wilmington, Delaware, *sulfometuron methyl*) was sprayed over the tops of the tree seedlings in just the tree plots at 219 ml/ha (3oz/acre) using a 6.5 m (20 ft) boom off the back of a tractor so that the 3 rows of trees, each row 1.5 m apart, were completely covered with the herbicide, including a 1.75 m buffer on either side of the trees.

In August 2007 the entire tree area was weeded with hand hoes, with special attention to remove large sicklepod (*Senna obtusifolia)* that were shading seedlings, and morning glory, (*Ipomea spp.)* because it tended to twist around seedlings.

Between the triple row subplots of trees, in the agricultural areas, either 12 or 24 m wide, the field was disk harrowed on April 26, and again on May 2, 2007, but not closer than 1.5 m (5 ft) from the outer tree row in each subplot. On May 11, potash (p*otassium oxide*, K_2O) was broadcast applied to the entire field, including tree and agriculture areas, at 224 kg/ha (200 lbs/ac) with a Chandler spreader. The field areas between the trees were again disked on May 16, and on May 18 the same areas were conditioned with a Lorenz device

(Lorenz Mfg. Co.; Watertown, South Dakota). The Asgrow 5905 (Asgrow Seed Company; St. Louis, Missouri) variety of glyphosate-resistant soybeans were planted on May 21 on 76 cm (30 in) row spacing with a six-row JD planter (John Deere; Moline, Illinois) set on low range 35-25, at 7 seeds /30 cm (7 seeds/ft) or 49,398 seeds/ha (123,493 seeds/ac). The soybeans were sprayed on June 15, with glyphosate at 210 g/ha (40 oz/ac) with a hooded sprayer. On July 26, soybeans were sprayed with glyphosate at 210 g/ha (40 oz/ac) and Firstrate (Dow AgroSciences; Minneapolis, Minnesota, *cloransulam-methyl*) at 21.9 ml/ha (0.3 oz/ac) with a hooded sprayer. Soybeans were harvested in Fall 2007, with a Case International Harvester 2144 (Case – New Holland; Racine, Wisconsin) and yielded 670 kg/ha (10 bu/ac) for a total of 9,691 *l* (275 bu).

Tree Mulch Treatments

Six soil surface mulch treatments were applied around individual tree seedlings in early May 2007. Six tree seedlings of each species, in each row, in each of the five plots, within each block were selected (90 trees per block, 450 trees overall) (Figure 3). The healthiest looking trees were chosen and treatments were randomly assigned to each tree.

The treatments were: (1) Corn stover that had been used as hog *(Sus scrofa domestica)* bedding and was mixed with hog manure, labeled as “Corn High” (*C High*); (2) the same corn stover/ hog manure applied at a lower rate and labeled as “Corn Low” (*C Low*); (3) bermudagrass *(Cynodon dactylon)* feed hay from two seasons’ prior that was no longer usable as livestock feed and labeled as "Hay High" (*H High)*; (4) the same hay applied at a lower rate and labeled as "Hay Low" (*H Low*)*;* (5) black plastic mulch (*B Plastic*); and (6) no mulch as the *Control*. All mulches were applied uniformly in a 91 cm (3 ft) diameter circle around each study tree (Figure 3). Mulch was then pulled back a very short distance from the stem of the tree to avoid direct contact. When the corn and hay mulches were applied they were dispersed into a plastic ring set temporarily around each tree that was either 7.5 cm (3 in) or 2.5 cm (1 in) high on its side, for the High and Low rates of each treatment, respectively.

The *C High and C Low* mulch originated in hog houses on the Cherry Research Farm. This mulch was corn residue, including some corn husks, and air-dry hog manure and urine interspersed throughout the corn residue. It was not composted or weathered before application. The corn stover-hog manure was scooped out of the barn and taken directly the field where it was applied soon after. The amount of mulch applied to the *C High* treated trees was equivalent to two loosely filled 20 *l* (5 gal) buckets, or an average of 7.2 kg (15.8 lbs) of material applied to each treatment area. The *C Low* treatment was one loosely partially filled 20 *l* bucket or an average of 3.6 kg (7.9 lbs) of material applied to each treatment area. All corn mulches were applied on May 16, 17, and 25, 2007, when mean air temperature ranged from 17 to 22 °C, and mean soil temperature (10 cm depth) ranged from 21 to 22°C.

The *H High* and *H Low* mulch was in tightly wrapped round bale of hay that had been stored on its side. There was no pre-application treatment to the old hay. It was taken to the field and applied immediately. The *H High* mulch treatment was equivalent to 2 loosely filled 20 *l* buckets or an average of 2.7 kg (6 lbs) applied to each treatment area, and the *H Low* treatment was 1 partially filled 20 *l* bucket or an average of 1.4 kg (3 lbs) of material applied per treatment area. The Hay mulch was applied on May 22 and 24, 2007, when mean air temperature ranged from 20 to 21°C and mean soil temperature (10 cm depth) was 22°C.

The *B Plastic* mulch was cut from 4 mm thick plastic into 91 cm (3 ft) diameter circles and placed around each study tree by cutting a hole in its center. The plastic was held to the ground with 8 metal staples inserted on the edge of the plastic. This treatment was applied on May 23, 2007 when air temperature averaged 20°C and soil temperature (10 cm depth) was 22°C. *Control* trees without mulch treatments were identified and monumented.

Height, Diameter and Survival

The height of each mulched seedling was measured (± .5 cm). Cherrybark oak and loblolly pine height were determined by measuring from the soil surface to the tallest resting bud. For longleaf pine seedlings, height was measured from the soil surface to the top of the grass bunch. Diameter for cherrybark oak and loblolly pine were measured with a dial-caliper (± 0.1 cm) 2 cm above the root collar. Longleaf pine diameter was not recorded.

Height and diameter measurements were taken at the time mulch treatments were applied (May 22 - June 3, 2007), again on Aug 14, 2007, and finally on November 3, 2007. Height and diameter growth was calculated by subtracting initial heights from final measurements. The loblolly pine seedlings suffered Nantucket pine tip moth *(Rhyacionia frustana)* damage during the growing season, damaging the apical stems, and affecting height growth. Survival of study seedlings was recorded on November 3, 2007, at the end of the growing season, and confirmed in Spring 2007.

Soil Moisture and Temperature

Mineral soil moisture and temperature were recorded simultaneously under each mulch treatment for each species, in June and August. Mean soil moisture was measured in percent volumetric soil (%mV) using a theta probe moisture meter (Delta-T Devices Ltd. Cambridge, United Kingdom) with four 66 mm (2.5 in) metal soil probes at the end of plastic pipe casing holding the electronics of the theta probe, inserted into the ground their full length. Soil temperature was recorded using a soil thermometer, calibrated in hot water beforehand, at 10 cm depth. Both measurements were taken 20 cm (7.9 in) from the base of the seedling approximately halfway from the stem of the seedling to the edge of the mulch on the south facing side of the treatment to avoid possible shadow effects. The first measurements were taken on June 22, 25, and 29 and July 3, 2007, and the second sets of measurements were taken August 2 to 4, 2007. Rainfall data were collected from the Goldsboro weather station during the 2007 growing season.

Weed Analysis

In the 91 cm diameter mulch area around each study tree, on July 14, 2007, all weeds emerging within that area that had at least 2 cotyledons present, were clipped just below the soil surface, and the number of individual weed species were recorded. The clipped portions of each weed were put into a paper bag, by species, for each treatment plot. Weed species were identified by visual inspection, confirmed by Dr. Michael Burton, weed specialist and professor at North Carolina State University, Raleigh, North Carolina. There was very minimal soil disruption by this method and mulch was moved back into place after the individual weeds were excised. Weeds on the very outer thinning edge of each 91 cm diameter mulched area were not counted or clipped, nor were weeds found exactly at the 91 cm boundary in *Control* and plastic mulch plots. The paper bags containing cut weeds were then transferred to a greenhouse for two days until placed in a drier for ten days at 70 ºC (158 ºF). Bags of weeds were weighed, (± 0.1 mg) and the weight of the bag subtracted.

Soil Analysis

Soil samples were taken July 12-13, 2007, with a stainless steel soil tube sampler (6.35 cm diameter) pressed 20 cm into the ground, in two random locations at least 20 cm from the tree stem and 20 cm from the edge of the mulched area around each study tree. Before soil sampling, the mulch treatments were briefly moved aside, the soil surface swept of mulch residue, and a 0 to 20 cm depth core extracted. The two cores per treatment area were combined in a bucket common to the other cores from beneath the same tree species/mulch combinations in each block, for a total of 90 samples. From each pooled sample, after thorough mixing, a single 50 ml scoop was taken and used for soil analysis.

Soil samples were tested at the laboratory of North Carolina Department of Agriculture & Consumer Services (NCDA & CS) in Raleigh, North Carolina, for physical and chemical properties. Soil nutrients were analyzed using the Mehlich 3 soil test and soil acidity was tested using the Mehlich buffer-acidity test. Analyses included concentrations of P, K, (Indices) Ca, Mg (meq/100 cm^3), S, Mn, Zn, Cu (indices), and Na (meq/100 cm^3). Indices are based on volume and are rated as “very low” (0-10), “low” (11-25), “medium” (26-30), “high” (51-100), and “very high” (100+) (NCDA & CS). P values can be converted to an equivalent area (lbs P2O5/ac) based on 20 cm depth by multiplying index value by 2.29. K values can be converted to an equivalent area (lbs K2O/ac) based on 20 cm depth by multiplying index values by 1.2.

Humic matter (g/100 cm^3), weight volume ratio (g/cm^2), cation exchange capacity (meq/100 cm^3), % base saturation, exchangeable acidity (meq/100 cm^3), and soil pH were also determined using standard methodology.

Mulch Analysis

Mulch samples were collected May 31, 2007, by loosely filling a 7.5 cm (3 in) by 15 cm (6 in) plastic tube with mulch, collected in two random locations from each treatment area, at least 20 cm from the tree stem and 20 cm from the edge of the mulched area around each study tree (91 cm diameter areas). The mulch samples were pooled in a bucket for each species/mulch combination (not including *B Plastic* or *Control* plots) for each block, totaling 60 mulch samples. From each pooled sample, after thorough mixing, a single 50 ml scoop was taken and used for mulch analysis.

Mulch samples were analyzed by the North Carolina Department of Agriculture and Consumer Services (NCDA & CS) for concentrations (ppm) of 11 essential plant nutrients, including N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, and B. Na concentration (ppm) and pH were also determined.

Foliar Analysis

Leaf samples were collected on September 3, 2007, from each seedling in the study, and pooled by species/ mulch combination for each block, totaling 90 samples. Cherrybark oak were sampled by taking two of the healthiest-looking, most recently matured leaves near the upper part of the plant and removing their petioles. Loblolly and longleaf pine needles were sampled by taking three fascicles with recently matured needles from the top of the seedling or near the middle of the seedling, respectively. One seedling did not have mature needles present and it was not sampled. The tissue holding the fascicles was taken off of the needles before being placed into a paper bag. All foliar samples were analyzed by the

NCDA & CS for concentration of 11 essential nutrients; N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, and B. Na concentration was also determined.

Statistical Analysis

Statistical analyses were conducted using PROC MIXED (Littell et al., 2006) in SAS® v9.1, (SAS Institute Inc., Cary, NC) with significance level α=0.1. This level of significance was selected to accumulate the variation expected in field studies of this type. The model used to analyze a particular response (M_{ijk}), for each species, was $M_{ijk} = \mu + \alpha_i + b_j + r_{k(j)} + d_{ij} + e_{ijk}$ where; μ is the overall constant, α_i = fixed effect for i^{th}, treatment, i= 1, 2, …, 6; b_j = random effect for j^{th} block, j= 1,2, …, 5 blocks; $r_{k(j)}$ = random effect associated to k^{th} repetition (where repetition is the subplots within the blocks) within j^{th} block, k= 1, 2, …, 5; d_{ij} =random effect associated with the block*treatment interaction; and e_{ijk} = uncontrolled random effect associated with each observation.

When the PROC MIXED result was significant, Tukey's post-hoc multiple comparison tests (significance of adjusted p-value=0.1) were used to test pair-wise differences between treatments, and whenever appropriate, Tukey-Kramers' pair-wise comparison tests were used for uneven samples (p=0.1). Tukey-Kramers' was used in instances where seedlings had died and could no longer be used for collecting data. Except in a very few instances, *B Plastic* in block one, and *C low* in block five, there were no significant block or block by treatment interactions.

Where the treatment P-value was <0.15, a multiple comparisons analysis via Tukey's procedure with an alpha of 0.10 was used to separate treatment differences. A P-value of 0.15 was used for significance testing in the ANOVA as this level of probability is more relevant to the variation in this environment than a lower value; as per Quinn and Keough (2002) who discuss the need for rationale selection of significance levels. In all cases, in the current study, the calculated P-values are reported. The large variation in tree size within plots can be attributed to the young age of this mixed species stand, differences in stem origin, and micro-site variation. A smaller P-value was used during the multiple comparisons analysis to more conservatively evaluate treatment differences. All analyses were performed using SAS (1999). For all ANOVA applications, variance homogeneity was visually evaluated and, where necessary, transformations used to improve it as indicated for specific tests in tables and figures.

All data collected were used to determine statistical relationships between height growth, diameter growth, temperature, moisture, weed suppression, and nutrients in soil, mulches and foliage for all species. Pearsons' correlations were used to examine relationships in the data including for all species and treatment types. It was also used to determine relationships between the nutrients in the mulches, soils and foliage, by species and treatment, and to find relationships between height/diameter growth and soil moisture/temperature and nutrient data for each species by each mulch grouped mulch type. The grouped mulches were 1) corn stover-hog manure = *C High* and *C Low*; 2) old hay mulch = *H High* and *H Low*; and 3) black plastic/control – *B Plastic* and *Control*. Only mulch, soil and foliar nutrients that had significant differences in ANOVA, and/or were considered important for determining growth differences according to the literature review in this area, were included in the reported correlations coefficient output (Tables 3, 7, 10-18).

A few data records were omitted from the final analysis because they were orders of magnitude different than reasonable. The analyses were run with and without these omissions and results indicated no significant differences between the statistical results, regardless. Data are reported here without inclusion of outliers.

RESULTS

Height, Diameter, and Survival

Mulches had an impact on first year height growth of cherrybark oak seedlings, which had the highest growth in seedlings treated with *H High*. They had ca. 37% greater height growth than seedlings treated with *H Low*, and ca. 50% higher than seedlings under all other treatments (including *Control*) (Table 1, Figure 4). The first year height growth of longleaf pines followed a similar, but more moderate pattern, to the cherrybark oak, with seedlings treated with *H High* having the highest growth, ca. 20% higher than seedlings treated with *Control*, and 30% higher than seedlings treated with *C High* (Table 1 and Figure 4). All other treatment seedlings' growth estimates fell between *H High* and *Control* (Table 1). The first year height growth of loblolly pines did not differ significantly between treatments (Figure 4).

Although diameter estimates were not statistically different among mulch treatments for any species; height and diameter growth were strongly correlated (Table 10). Survival rates of cherrybark oak and loblolly pine ranged from 92-100% survival, with no obvious mulch-related trends. Survival of longleaf pines treated with *B Plastic*, *H High* and *Control* were 100%; those treated with *H Low* were 88%, with *C Low* were 76%, and those treated with *C High* had 56% survival rate (Table 1).

Soil Moisture and Temperature

<u>June Soil Moisture</u>

In June, the soil moisture levels under the six treatment mulches (including *Control*) was similar for each of the three species tested. Soil moisture was greatest under *C High*, lowest under *Control* and intermediate for the four other treatments, generally ranking, highest to lowest: *C Low, H High* (these two were very close for all three species, and in some cases places were reversed), *H Low* and *B Plastic*. Soil moisture varied between treatments from 9% to 18.8% (Table 2).

There were significant correlations between June soil moisture and height and diameter growth for cherrybark oak and loblolly pine seedlings under organic mulches. Cherrybark oak seedlings treated with corn stover-hog manure mulches (*C High, C Low*) had a significant (P=0.0003) and strong correlation (r=0.51) between June soil moisture and height growth and a significant (P=0.0034) and moderate correlation (r=0.42) between June soil moisture and diameter growth (Table 3). Cherrybark oak seedling treated with old hay mulch (*H High, H Low*) had a significant (P=0.027) and moderate correlation (r=0.32) between June soil moisture and height growth and a significant (P=0.0936) and moderate correlation (r=0.25) between June soil moisture and diameter growth (Table 3).

Loblolly pine seedlings treated with corn stover-hog manure mulches (*C High*, *C Low*) had a significant (P=<0.0001) and strong correlation (r=0.60) between June soil moisture and height growth, and a significant (P=0.0017) and moderate correlation (r=0.43) between June soil moisture and diameter growth (Table 3). Loblolly pine seedling treated with old hay mulch (*H High, H Low*) had a significant (P=0.0107) and moderate correlation (r=0.36) between June soil moisture and height growth (Table 3).

<u>August Soil Moisture</u>

August soil moisture determinations under the six mulches, were similar for each of the species tested, reflecting the same results as June measurements, with highest soil moisture levels under *C High*, lowest under *Control*, and the other treatments were intermediate (ranking in the same order as June: *C Low*, *H High*, *H Low*, *B Plastic*). Soil moisture varied between treatments from 16.7% to 25.8% (Table 2).

There were correlations between August soil moisture and height and diameter growth for cherrybark oak and loblolly pine seedlings under organic mulches. Cherrybark oak seedlings treated with corn stover-hog manure mulches (*C High, C Low*) had a significant (P=0.0067) and moderate correlation (r=0.39) between August soil moisture and height growth, and a significant (P=0.0226) and moderate correlation (r=0.33) between August soil moisture and diameter growth (Table 3).

Loblolly pine seedlings treated with corn stover-hog manure mulches (*C High, C Low*) had a significant (P=0.0005) and moderate correlation (r=0.48) between August soil moisture and height growth, and a significant (P=0.0286) and moderate correlation (r=0.31) between August soil moisture and diameter growth (Table 3). Loblolly pine seedlings treated with old hay mulch (*H High, H Low*) had a significant (P=0.0685) and moderate correlation (r=0.26) between June soil moisture and height growth (Table 3).

June Soil Temperature

June soil temperature estimates under the six mulches were similar for each of the species tested. Soils in *Control* plots had the highest temperatures (ca. 37°C), averaging 6°C hotter than the lowest soil temperature under *C High*, 31°C. Soil temperatures beneath the other mulches were similar to each other, ranging from 31°C to 35°C (Table 2).

When species were separately analyzed by grouped mulches, there were correlations between June soil temperature and height growth and diameter growth for cherrybark oak and loblolly pine seedlings under organic mulches. Cherrybark oak seedlings treated with corn stover-hog manure mulches (*C High*, *C Low*) had a significant (P=<0.0001) and strong negative correlation (r= -0.56) between June soil temperature and height growth, and a significant (P=0.0016) and moderate negative correlation (r=-0.45) between June soil temperature and diameter growth (Table 3). Cherrybark oak seedling treated with old hay mulch (*H High*, *H Low*) had a significant (P=0.0015) and moderate negative correlation (r=-0.47) between June soil temperature and height growth, and a significant (P=0.0107) and moderate negative correlation (r=-0.38) between June soil temperature and diameter growth (Table 3).

Loblolly pine seedlings treated with corn stover-hog manure mulches (*C High*, *C Low*) had a significant (P=<0.0001) and strong negative correlation (r= -0.59) between June soil temperature and height growth, and a significant (P=<0.0001) and strong negative correlation (r=-0.55) between June soil temperature and diameter growth (Table 3). Loblolly pine seedling treated with old hay mulch (*H High*, *H Low*) had a significant (P=0.0001) and strong negative correlation (r=-0.52) between June soil temperature and height growth, and a significant (P=0.004) and moderate negative correlation (r=-0.40) between June soil temperature and diameter growth (Table 3).

August Soil Temperature

In August, the difference in soil temperature estimates beneath mulches was less detectable than the June soil temperature estimates. Soils under *B Plastic* and *Control* were similar, averaging about 1°C higher than soil temperatures under each of the other treatments, all with similar temperatures of ca. 40°C, regardless of species (Table 2).

Soil moisture measurements were significantly correlated with soil temperature measurements for both June and August, regardless of species (Table 10). Soil moisture in June had a significant (p=<0.0001) but weak negative correlation (r=-0.27) with soil temperature in June. Soil moisture in August had a significant (p=<0.0005) but weak correlation (r=0.16) with soil temperature in August (Table 10).

There were significant correlations between August soil temperature and height growth and diameter growth for cherrybark oak and loblolly pine seedlings under organic mulches. Cherrybark oak seedlings treated with corn stover-hog manure mulches (*C High, C Low*) had a significant (P=0.0067) and moderate correlation (r=0.39) between August soil temperature and height growth, and a significant (P=0.0502) and a moderate correlation (r=0.29) between August soil temperature and diameter growth (Table 3). Cherrybark oak seedling treated with old hay mulch (*H High, H Low*) had a significant (P=0.0122) and moderate correlation (r=0.37) between August soil temperature and height growth (Table 3).

Loblolly pine seedlings treated with corn stover-hog manure mulches (*C High, C Low*) had a significant (P=<0.0001) and strong correlation (r=0.53) between August soil temperature and height growth, and a significant (P=0.0006) and moderately strong correlation (r=0.47) between August soil temperature and diameter growth (Table 3). Loblolly pine seedling treated with old hay mulch (*H High*, *H Low*) had a significant (P=0.008) and moderate correlation (r=0.37) between August soil temperature and height growth (Table 3).

Weed Analysis

Weed biomass estimates were significantly and consistently highest from the *Control* plots, and averaged 9.8 g/mulched area; ca. 93% higher than the average weed biomass obtained from areas under all other treatments, for all species (Table 4, Figure 6). Weed stem count reflected the same pattern as weed biomass for all species, with *Control* plots averaging 95% more weed stems all other treatments (Table 4). There was a significant (P=0.0007) but weak correlation (r=0.16) between weed stems and June soil temperature, and a significant (P=0.0216) but weak correlation (r=0.11) between weed stems and August soil temperature (Table 10).

Soil Analysis

<u>Soil Phosphorous</u>

Nutrient concentrations in the soil were affected by mulches, and produced similar results regardless of species, so that results described in this section of the text include averages across species. Soils in *Control* areas had the lowest P concentration. P concentrations in soils under *C High* and *C Low* were higher than P concentrations in soils under all other treatments, averaging ca. 43% higher than soils from *Control* (Table 5). K concentrations in the soils were highest in soils under *C High* and *C Low*, averaging ca. 50% higher than the soils from *Control*, which had the lowest K concentration (Table 5).

There was a significant (P= 0.0003) and a moderate negative correlation (r= -0.50) between height growth and soil P, and a significant (P= 0.0177) and moderate negative correlation (r= -0.34) between soil P and diameter growth of cherrybark oak seedlings treated with corn stover-hog manure mulch (*C High*, *C Low*) (Table 7). There was a significant (P= 0.0442) and moderate correlation (r=-0.29) between height growth and soil P, of cherrybark oak seedlings treated with old hay mulch (*H High*, *H Low*) (Table 7).

There was a significant (P= <0.0001) and strong negative correlation (r= -0.73) between height growth and soil P, and a significant (P= <0.0001) and strong negative correlation (r= -0.59) between soil P and diameter growth of loblolly pine seedlings treated with corn stover-hog manure mulch (*C High*, *C Low*) (Table 7). There was a significant (P= 0.0003) and moderate negative correlation (r=-0.50) between height growth and soil P, and a significant (P= 0.0137) and moderate correlation (r=0.35) between soil P and diameter growth of loblolly pine seedlings treated with old hay mulch (*H High, H Low*) (Table 7).

There was a significant (P= 0.0333) and moderate negative correlation (r=-0.31) between height growth and soil P, for loblolly pine seedlings treated with black plastic/control (*B Plastic*, *Control*) (Table 7).

Soil Calcium and Magnesium

Ca concentration in soils ranged from 2.1-2.9 (meq/100 cm^3) with the lowest levels in soils under *C High*, and the highest in soils under *H Low*, *B Plastic* and *Control*, all with similar levels, with the other 2 treatments being intermediate (Table 5). Mg concentration in soils ranged from 0.9-1.22 mirroring Ca trends, with soils under *C High* averaging the lowest (Table 5). There were strong correlations between Ca and Mg in soils for all three species treated with corn stover-hog manure (Tables 11, 12, & 13). S concentration in soils was highest under *C High*, followed by *C Low,* which were 100% and 59% higher, respectively, than S concentration in soils in *Control* plots. S levels in *H High and H Low* were similar to levels found in *Control* plots (Table 5).

There was a significant (P= 0.0029) and moderate correlation (r=0.42) between height growth and soil Ca, and a significant (P= 0.0558) and moderate correlation (r=0.28) between soil Ca and diameter growth of cherrybark oak seedlings treated with corn stover-hog manure mulch (*C High, C Low*) (Table 7).

There was a significant (P=<0.0001) and strong correlation (r=0.62) between height growth and soil Ca, and a significant (P=<0.0001) and strong correlation (r=0.53) between soil Ca and diameter growth of loblolly pine seedlings treated with corn stover-hog manure mulch (*C High, C Low*) (Table 7). There was a significant (P=0.0318) and moderate correlation (r=0.30) between height growth and soil Ca, for loblolly pine seedlings treated with old hay mulch (*H High, H Low*) (Table 7).

There was a significant (P= 0.0029) and moderate correlation (r=0.43) between height growth and soil Mg, and a significant (P= 0.0558) and moderate correlation (r=0.28) between soil Mg and diameter growth of cherrybark oak seedlings treated with corn stover-hog manure mulch (*C High, C Low*) (Table 7).

There was a significant (P=0.0005) and moderate correlation (r=0.49) between height growth and soil Mg, and a significant (P=0.0187) and moderate correlation (r=0.34) between soil Mg and diameter growth of loblolly pine seedlings treated with corn stover-hog manure mulch (*C High*, *C Low*) (Table 7). There was a significant (P=0.0275) and moderate correlation (r=0.32) between height growth and soil Mg, of loblolly pine seedlings treated with old hay mulch (*H High, H Low*) (Table 7).

Other Soil Nutrients

Cu and Mn concentrations in soils were highest, on average, under *C High* (Table 5). Na concentrations in soils under *C High* and *C Low* were ca. 50% and 40% higher, respectively, than Na concentrations in soils under *Control*. Na concentrations in soils of all other treatments varied (Table 5).

Mulch Analysis

Nutrient concentrations varied between the mulches, but were similar across species. N concentrations in *H High* and *H Low* were significantly higher (P=.0137) than levels in *C*

High and *C Low* mulch (Table 6). For most other nutrients, the *C High* and *C Low* mulch had higher concentrations of nutrients than *H High* and *H Low* (Table 6).

Nutrient content, applied in mulches to 91 cm treatment areas, significantly differed (P=<.0001) in the applied mulches. Each of the analyzed nutrients in the mulches followed similar patterns, ranking greatest to least, *C High*, *C Low*, *H High*, and *H Low*, with nutrients applied in *C High,* generally being double the amount applied in *C Low*, and *H High*, generally doubling the amount applied in *H Low*. N content in applied mulch ranged from an equivalent of 224-979 kg/ha, with *C High* having the highest levels, ca. 53% higher than the N content applied in *H High* (450 kg/ha) (Table 8). P content in applied mulch had a range the equivalent of 61-494 kg/ha, with *C High* having ca. 88% higher levels than *H High* (61 kg/ha). K content ranged from an equivalent of 195-1108 kg/ha, with *C High* having ca. 67% higher K levels than *H High* (361 kg/ha) (Table 8). Ca content ranged from an equivalent of 51-640 kg/ha, with *C High* having ca. 83% higher Ca levels than *H High*. Mg content ranged from an equivalent of 45-191 kg/ha, with *C High* having ca. 50% higher Mg levels than *H High*. S content ranged from an equivalent of 17-124 kg/ha, with *C High* ca. 72% higher S levels than *H High*. B content ranged from an equivalent of 0.1-1.2, with the highest levels in *C High*, ca. 500% higher than levels in *H High*. Other micronutrients followed similar trends. Na content applied in *C High* ranged from an equivalent of 1.7-166.7 kg/ha, and was ca. 98% higher than Na content in *H High* (Table 8).

Foliar Analysis

Foliar Nitrogen

Foliar N concentration in cherrybark oak seedlings ranged from 2.1-2.4%, with no statistical differences between treatments (Table 9). In loblolly and longleaf pine, foliar N concentrations differed statistically among mulch treatments, but with no obvious patterns, ranging 1.1-1.6% (Table 9).

There was a significant (P=0.0694) and moderate negative correlation (r=0.27) between height growth and foliar N in cherrybark oak seedlings treated with *C High* and *C Low* (Table 7).   There was a significant (P=<0.0001) and strong correlation (r=0.60) between height growth and foliar N, and a significant (P=<0.0001) and strong correlation (r=0.54) between foliar N and diameter growth of loblolly pine treated *C High* and *C Low* (Table 7). There was a significant (P= 0.0005) and moderate correlation (r=0.48) between height growth and foliar N, and a significant (P= 0.0021) and moderate correlation (r=0.43) between foliar N and diameter growth of in loblolly pine seedlings treated with *H High* and *H Low* (Table 7).

The foliage of cherrybark oak seedlings under *C High* and *C Low*, had strong and significant correlations between foliar N and P levels applied in mulch (P=0.0001), Ca levels applied in mulch (p=0.0002), Mg levels applied in mulch (P=0.0013), B levels applied in mulch (P=<.0001), P levels in the soil (P=<.0001), K levels in the soil (P=<.0001), foliar S (P=<.0001), and foliar B (P=<.0001) (Table 12). Cherrybark oak seedlings under *H High* and

H Low had a strong and significant correlation between foliar N and foliar S (p=<.0001) (Table 14). The cherrybark oak seedlings under *B Plastic* and *Control* had strong and significant correlations between foliar N and P levels in the soil (P=<.0001), K levels in the soil (P=<.0001), foliar Ca (P=<.0001), foliar B (P=<.0001), and foliar Na (P=<.0001) (Table 17).

The foliage of loblolly pine seedlings under *C High* and *C Low* had a strong and significant correlation between foliar N and P levels in the soil (P=<.0001), K levels in the soil (P=<.0001), and foliar Na levels ((P=<.0001) (Table 12). The loblolly pine under *H High* and *H Low* had a strong and significant correlation between foliar N and Mg levels in mulch (P=0.0003) (Table 15). The loblolly pine seedlings under *B Plastic* and *Control* had strong and significant correlations between foliar N and foliar Mg (P=<.0001), foliar Ca (P=<.0001), and foliar B (P=<.0001) (Table 18).

The foliage of longleaf pine seedlings under *C High* and *C Low* had a strong and significant correlation between foliar N and foliar P (P=<.0001), and foliar B (P=<.0001) (Table 12). The longleaf pine under *H High* and *H Low* had significant and strong correlations between foliar N and B levels applied in the mulch (P=<.0001) (Table 16). The longleaf pine under *B Plastic* and *Control* had a strong and significant correlation between foliar N and foliar B (P=<.0001) (Table 19).

Foliar Phosphorous

For each of the species, foliar P concentrations were consistently highest in seedlings treated with *C High* (ranging 0.06 to 0.12%), although differences were only significant for longleaf pines (P=0.0118) (Table 9).

The foliage of cherrybark oak seedlings under *C High* and *C Low*, had strong and significant correlations between foliar P and P levels in the soil (P=<.0001), K levels in the soil (P=<.0001), Ca levels in the soil (P=<.0001), Mg levels in the soil (P=<.0001), S levels in the soil (P=<.0001), and Na levels in the soil (P=<.0001) (Table 12). The cherrybark oak seedlings under *H High* and *H Low* had a strong and significant correlation between foliar P and Mg levels in the soil (p=<.0001) (Table 14). The cherrybark oak seedlings under *B Plastic* and *Control* had strong and significant correlations between foliar P and foliar K (P=<.0001), and foliar Mg (P=<.0001) (Table 17).

The foliage of loblolly pine seedlings under *C High* and *C Low* had strong and significant between foliar P and Ca levels in the soil (P=<.0001), Mg levels in the soil (P=<.0001), foliar Ca (P=<.0001), foliar Mg (P=<.0001), foliar S (P=<.0001), foliar B (P=<.0001), and foliar Na (P=<.0001) (Table 12). The loblolly pine seedlings under *H High* and *H Low* had a strong and significant correlation between foliar P and P levels in the soil (P=<.0001), and foliar S (P=<.0001) (Table 15). The loblolly pine seedlings under *B Plastic* and *Control* had strong and significant correlations between and foliar K (P=<.0001), foliar Ca (P=<.0001), foliar Mg (P=<.0001), foliar S (P=<.0001), and foliar B (P=<.0001) (Table 18).

The foliage of longleaf pine seedlings under *C High* and *C Low* had strong and significant between foliar P and S levels applied in the mulch (P=<.0001), B levels applied in the mulch (P=<.0001), Na levels in mulch (P=<.0001), foliar K (P=<.0001), foliar B (P=<.0001), and foliar Na levels (P=<.0001) (Table 13). The longleaf pine seedlings under *B Plastic* and *Control* had a strong and significant correlation between foliar P and foliar Mg (P=<.0001) (Table 19).

<u>Foliar Potassium</u>

Foliar K concentrations (ranging 0.5-1.2%) had consistently and significantly higher levels in seedlings treated with *C High*, regardless of species (Table 9). The foliage of cherrybark oak seedlings under *C High* and *C Low* had strong and significant correlations between foliar K levels and foliar Ca and foliar Mg (Table 12). The foliage of cherrybark oak seedlings under *H High* and *H Low* had strong and significant correlations between foliar K and Mg levels applied in the mulch (P=<.0001), foliar Ca (P=<.0001), foliar Mg (P=<.0001), and foliar S (P=<.0001) (Table 14). The foliage of cherrybark oak seedlings under *B Plastic* and *Control* had strong and significant correlations between foliar K levels and soil P levels in the soil (P=<.0001), Mg levels in the soil (P=<.0001), foliar P (P=<.0001), and foliar Ca (P=<.0001) (Table 17).

The foliage of loblolly pine under *C High* and *C Low* had strong and significant correlations between foliar K and foliar Ca (P=<.0001), foliar Mg (P=<.0001), foliar S

(P=<.0001), and foliar B (P=<.0001) (Table 12). The foliage of loblolly pine under *H High* and *H Low* had strong and significant correlations between foliar K and P levels in the soil (P=<.0001) (Table 15). The foliage of loblolly pine seedlings under *B Plastic* and *Control* had strong and significant correlations between foliar K levels and Ca levels in the soil (P=<.0001), Mg levels in the soil (P=<.0001), foliar P (P=<.0001), foliar Ca (P=<.0001) foliar Mg (P=<.0001), foliar S (P=<.0001), and foliar B (P=<.0001) (Table 18).

The foliage of longleaf pine under *C High* and *C Low* had significant and strong correlations between foliar K and foliar Ca (P=<.0001) (Table 13). The foliage of longleaf pine under *H High* and *H Low* had a strong and significant correlation between foliar K and P levels applied in the mulch (P=<.0001), Mg applied in the mulch (P=<.0001), S levels applied in the mulch (P=<.0001), B levels applied in the mulch (P=<.0001), foliar S levels (P=<.0001), and foliar Na levels (P=<.0001) (Table 16).

Foliar Calcium

The foliage of cherrybark oak foliar Ca concentrations were significantly (P=0.0121) lower in seedlings treated with *C High*, ca. 27% lower than Ca levels in cherrybark oak seedlings under *B Plastic* or *Control*. The foliage of cherrybark oak seedlings under *C High* and *C Low* had significant and strong correlations between foliar Ca and P levels in the soil, K levels in the soil (P=<.0001), Ca levels in the soil (P=<.0001), Mg levels in the soil (P=<.0001), foliar Mg (P=<.0001), foliar S (P=<.0001), and foliar Na (P=<.0001) (Table 12).

The foliage of cherrybark oak seedlings under *H High* and *H Low* had significant and strong correlations between foliar Ca and P levels in the soil (P=<.0001), K levels in the soil (P=0.0001), Ca levels in the soil (P=<.0001), Mg levels in the soil (P=<.0001), and Na levels in the soil (P=<.0001), and foliar Mg (P=<.0001) (Table 14). The foliage of cherrybark oak seedlings under *B Plastic* and *Control* had significant and strong correlations between foliar Ca and P levels in the soil (P=<.0001), K levels in the soil (P=<.0001), Mg levels in the soil (P=<.0001), S levels in the soil (P=<.0001), Na levels in the soil (P=<.0001), and foliar B (P=<.0001) (Table 17).

There were no statistical differences in Ca levels between treatments in the foliage of loblolly pine. The foliage of loblolly pine seedlings under *C High* and *C Low* had significant and strong correlations between foliar Ca and foliar Mg (P=<.0001), foliar S (P=<.0001), foliar B (P=<.0001), and foliar Na (P=<.0001) (Table 12). The foliage of loblolly pine seedlings under *H High* and *H Low* had significant and strong correlations between foliar Ca and K levels applied in mulch (P=<.0001), P levels in the soil (P=<.0001), Ca levels in the soil (P=<.0001), Mg levels in the soil (P=<.0001), and foliar Mg (P=<.0001) (Table 15). The foliage of loblolly pine seedlings under *B Plastic* and *Control* had significant and strong correlations between foliar Ca and foliar S (P=<.0001), and foliar B (P=<.0001) (Table 18).

There were no statistical differences in Ca levels between treatments in the foliage of longleaf pine; however, the foliage of longleaf pine seedlings under *C High* and *C Low* had significant and strong correlations between foliar Ca and P levels in the soil (P=<.0001), K levels in the soil (P=<.0001), Ca levels in the soil (P=<.0001), Mg levels in the soil

(P=<.0001), and foliar Mg (P=<.0001). The foliage of longleaf pine seedlings under *H High* and *H Low* had significant and strong correlations between foliar Ca and Ca levels applied in mulch (P=<.0001), Na levels applied in mulch (P=<.0001), foliar Mg (P=<.0001), and foliar Na (P=<.0001) (Table 16). The foliage of longleaf pine seedlings under *B Plastic* and *Control* had significant and strong correlations between foliar Ca and P levels in the soil (P=0.0002) and foliar Mg (P=<.0001) (Table 19).

Foliar Magnesium

In cherrybark oak, foliar Mg concentration (ranging from 0.12-0.18%) was significantly different (P=0.0648) between treatments. Although further analyses failed to determine which treatments differed, Mg levels in cherrybark oaks under *C High* and *C Low* were ca. 30% lower than levels from all other treatments, which all had similar Mg levels (Table 9).

The foliage of cherrybark oak seedlings under *C High* and *C Low* had significant and strong correlations between foliar Mg and P levels in the soil (P=<.0001), Ca levels in the soil (P=<.0001), and Mg levels in the soil (P=<.0001) (Table 12). The foliage of cherrybark oak seedlings under *H High* and *H Low* had significant and strong correlations between foliar Mg and P levels in the soil (P=<.0001), Ca levels in the soil (P=<.0001), and Mg levels in the soil (P=<.0001) (Table 14). The foliage of cherrybark oak seedlings under *B Plastic* and

Control had significant and strong correlations between foliar Mg and pH of the soil (P=<.0001), Mg levels in the soil (P=<.0001), and S levels in the soil (P=<.0001) (Table 17).

There were no statistical differences in foliar Mg in the loblolly pine, however; the foliage of loblolly pine seedlings under *C High* and *C Low* had significant and strong correlations between foliar Mg and foliar S (P=<.0001), foliar B (P=<.0001), and foliar Na (P=<.0001) (Table 12). The foliage of loblolly pine seedlings under *H High* and *H Low* had significant and strong correlations between foliar Mg and Na levels in the soil (P=<.0001), foliar B (P=<.0001), and foliar Na (P=<.0001) (Table 15). The foliage of loblolly pine seedlings under *B Plastic* and *Control* had significant and strong correlations between foliar Mg and foliar S (P=<.0001), and foliar B (P=<.0001) (Table 18).

There were no statistical differences in Ca levels between treatments in longleaf pine; however, the foliage of longleaf pine seedlings under *C High* and *C Low* had significant and strong correlations between foliar Mg and P levels in the soil (P=<.0001), Ca levels in the soil (P=<.0001), and Mg levels in the soil (P=<.0001). The foliage of longleaf pine seedlings under *H High* and *H Low* had significant and strong correlations between foliar Mg and Na levels in the soil (P=<.0001), foliar B (P=<.0001), and foliar Na (P=<.0001) (Table 16). The foliage of longleaf pine seedlings under *B Plastic* and *Control* had significant and strong correlations between foliar Mg and P levels in the soil (P=0.0002) and Ca levels in the soil (P=<.0001) (Table 19).

Foliar Sulfur

In cherrybark oaks, foliar S concentration ranged from 0.105-0.112% with no statistical differences among mulch treatments, while foliar S levels in loblolly and longleaf pines ranged from 0.08-0.09%, with significantly higher S concentration in longleaf pines under *C High* and *C Low* than all other treatments (Table 9).

The foliage of cherrybark oak seedlings under *C High* and *C Low* had significant and strong correlations between foliar S and soil P levels applied in mulch (P=<.0001), K levels applied in mulch (P=<.0001), Ca levels applied in mulch (P=<.0001), Mg levels applied in mulch (P=<.0001), S levels applied in mulch (P=<.0001), B levels applied in mulch (P=<.0001), and Na levels applied in mulch (P=0.0004). The foliage of cherrybark oak seedlings under *H High* and *H Low* had significant and strong correlations between foliar S and P Mg levels applied in mulch (P=<.0001) (Table 14). The foliage of cherrybark oak seedlings under *B Plastic* and *Control* had significant and strong correlations between foliar S and S in the soil (P=<.0001) (Table 17).

The foliage of loblolly pine seedlings under *C High* and *C Low* had significant and strong correlations between foliar S and S in the soil (P=<.0001), foliar B (P=<.0001), and foliar Na (P=<.0001) (Table 12). The foliage of loblolly pine seedlings under *B Plastic* and *Control* had significant and strong correlations between foliar S and foliar B (P=<.0001) (Table 18).

The foliage of longleaf pine seedlings under *C High* and *C Low* had significant and strong correlations between foliar S and K in soils (P=<.0001), S in soils (P=<.0001), and foliar B (P=<.0001). The foliage of longleaf pine seedlings under *H High* and *H Low* had significant and strong correlations between foliar S and N applied in mulch (P=0.0002), S applied in mulch (P=<.0001), and foliar Na (P=<.0001) (Table 16). The foliage of longleaf pine seedlings under *B Plastic* and *Control* had significant and strong correlations between foliar S and P in soils (P=0.0002), Ca in soils (P=<.0001), Mg in soils (P=<.0001), and S in soils (P=<.0001) (Table 19).

Other Foliar Nutrients

There were no significant differences in the cherrybark oak foliar Mn concentrations among mulch treatments, although Mn levels were higher in seedlings from *Control* than any other treatment, except for *C Low*. In loblolly and longleaf pines, foliar Mn concentration was highest for seedlings from *Control* plots for both species (Table 9). The foliage of all three species had foliar B concentrations that were significantly different between treatments and had consistently higher levels in seedlings treated with *C High* and *C Low* than all other treatments (Table 9).

DISCUSSION

The current study found that select farm wastes have promise as beneficial mulch on trees in an alley cropping system in North Carolina and further study is warranted.

Successful mulching operations require detailed knowledge of minerals and acidity levels in the mulch and their relation to growth attributes and ecological factors.

Although both organic mulches tested in the current study had similar effects on the soil environment (Table 5), we found that cherrybark oak and longleaf pine seedlings, mulched with *H High* had significantly higher first year growth than seedlings mulched with *C High* (Table 1). Cherrybark oak seedlings under *H High* mulch also had significantly higher first year growth than when treated with black plastic (Table 1).

Studies have reported various effects of farmyard waste application (Carrera et al., 2007). The causes of these differences may be important when considering using farm wastes as mulch. In our study we found increased mortality in longleaf pine when *C High* was applied. Results indicated that factors contributing to height growth are impacted by nutrients, and possibly by moisture or temperature, all of which are inextricably linked. Differences in nutrient levels applied via mulch (Table 6) were reflected in the foliar analyses (Table 9), reflect growth differences, and indicate that nutrient levels may have been a major factor in growth differences. These findings corroborate other studies showing that on some sites, nutrients are the most influential factor in tree growth and development (Albaugh, Allen, & Fox, 2008; Fox et al., 2007).

Nutrients and minerals affecting seedling height growth and survival

Sodium

Our findings indicate that corn stover-hog manure may have been a risky choice as mulch because it added salts to soils in close proximity with seedlings, and may have impeded their growth (Table 8). Results indicate that Na may have leached from mulch into the soils (Tables 5, 8). In a wet year, salinity may not be a problem, since excess nutrients in well-drained soils can leach out. However, in the dry year of 2007 (Figure 5), the build-up of salinity, which can inhibit growth, may have been exacerbated as soils received little rainfall (Bernstein, 1975; Butler & Coale, 2005).

While plants do need small amounts of Na for development (Bergmann & Shorrocks, 1992) it has been shown to be toxic to seedlings which have low salt tolerance, and may cause twig dieback on hardwoods or brown tips on conifers (Manion, 1981). Further, the affects of excess amounts of Na present in the soil have been shown to adversely affect leaf area and photosynthesis in cherrybark oak, longleaf pine and loblolly pine, which could help explain the height differences of *C High* treated cherrybark oak and longleaf pine seedlings (Bernstein, 1975; McLeod, McCarron, & Conner, 1999; Nieman & Clark, 1976).

Boron

Studies have shown there is a relationship between salinity and B in plants (Grattan et al., 1996), and that too much B can have a negative effect on plant growth and development.

The primary function of B in plant growth and development is not completely understood (Bergmann & Shorrocks, 1992; Silva et al., 2008). Differences between treatments of B present in the foliage, for all three species, may have contributed to varying growth effects, although it is unclear in exactly what capacity.

Phosphorous

Analyses showed that P, known to be less soluble with an increase in soil salts, which had been applied via mulches, may also have leached into soils (Tables 5, 6) (Bergmann & Shorrocks, 1992). Appropriate amounts of P are necessary for plant growth, and adding P can have dramatic effects on seedling root growth (Morris & Lowery, 1988), especially in soils with low P availability, like the typical coastal plain soils in North Carolina, (Chapin et al., 1986; Fox et al., 2007). Our site was previously in agriculture, however, and soils were not lacking in P, as indicated by soil tests run on the *Control* plots (Table 5). In fact, there may have been too much P, which is known to interfere with micronutrient uptake and has been shown to inhibit plant growth at high levels (Bergmann & Shorrocks, 1992). Furthermore, the applied P (kg/ha) in the *C High* (ca. 600 kg/ha) plots was about 10 times the usual P application rates for plantation establishment on sandy soils (ca. 60 kg/ha) (Jokela & Long, 2000).

The height growth of cherrybark oak seedlings treated with *C High* and *C Low* seemed to be affected by foliar P (Table 7). It seems reasonable to suggest that the high levels of Na, coupled with high P levels, may have been responsible for lagging height growth of seedlings treated with *C High.* In comparison with corn stover-hog manure, there were lower levels of Na, B, and P added in the hay mulch, which may have been a comparative growth advantage for seedlings treated with *H High*.

Nutrient Imbalances

<u>Calcium and Magnesium</u>

Low levels of foliar Ca (%) in the foliage of cherrybark oak seedlings treated with *C High* may have contributed to lesser height growth. Limited Ca uptake has been shown to lead to poor plant growth and development (Bergmann & Shorrocks, 1992; Mulder, 1956). Cherrybark oak seedlings treated with *C High* had a Ca (%) level of <0.5%, which is indicative of Ca deficiencies in plants (Munson, 1998).

Cherrybark oaks also suffered from lower levels of Mg, which were well under the critical value for foliar Mg (%), as recommended for oak seedlings (ca. 0.15%). Lack of Mg has also been shown to lead to poor plant growth, especially when complicated with K or Ca imbalances (Bergmann & Shorrocks, 1992). The critical level of foliar Mg for northern red oak (*Quercus rubra*) is <0.15% and some studies have shown that red oaks suffer adverse growth affects when foliar Mg (%) levels are lower (Hart & Sharpe, 1997; Plank, 1989). Both soil Ca and soil Mg in the current study were correlated with height growth of cherrybark oak and loblolly pine treated with *C High* and *C Low*. This may indicate that Ca and Mg were available in the soil but plants may not have been able to take it up, perhaps due to an imbalance of other nutrients (Table 7).

The lower levels of Ca and Mg in the cherrybark oak leaves may have been due to the high amounts of applied K (kg/ha) in mulches, as surplus K is often the cause of Ca and Mg deficiencies (Bergmann & Shorrocks, 1992). Generally, K is not lacking in soils of the Southeast and K (kg/ha) application is rarely recommended at all for these soils (Allen, 1987). To our study site, that already had sufficient K in the soils (labeled as "excess" amounts by the NCDA & CS laboratory results) (Table 5), the amount of K (kg/ha) applied to treatment plots via *C High* (ca. 1,000 kg/ha) (Table 8) was high by any standard. It would follow, then, that the high levels of K may have adversely affected the uptake of Ca and Mg in the cherrybark oak seedlings, and contributed to height growth differences.

Nitrogen and Magnesium

Magnesium is especially subject to imbalances caused by other nutrients (Mulder, 1956) and the high amounts N added (kg/ha) in the mulch may have caused an imbalanced foliar N:Mg ratio in cherrybark oak seedlings. Nutrient imbalance can contribute to poor growth and development. The recommended N:Mg ratio for broadleaved trees is <17.5 (Flückiger & Braun, 2003). Cherrybark oak seedlings that were treated with *C High* and *C Low* had >17.5 N:Mg ratio (Table 20).

Because our site had been farmed and fertilized in the past, N was not likely to be a limiting factor, as is usually the case for soils in the Southeast (Allen, 1987). The cherrybark oak seedlings treated with *C High* bore the consequence of too much K and N, but the loblolly pine and longleaf pine did not seem to show the same affects in foliar nutrients. Foliar N was negatively correlated to height growth in cherrybark oaks seedlings, but positively correlated in loblolly pine seedlings, and not correlated at all in longleaf pine seedlings (Table 7). This is possibly because of the different sensitivities to nutrients by different species. An excess of N may cause nutrient imbalance in oaks, yet not have the same affect on pines.

Weed Suppression

In this study, all mulches suppressed weeds (Figure 6), but the result of weed suppression on height growth was mixed. In the case of longleaf pine, seedlings treated with *B Plastic* had height growth more similar to *H High*, which might indicate that height growth of longleaf pine may have been partially affected by weed competition, which is in agreement with other studies that have shown that longleaf pine is particularly sensitive to weed competition in early development stages (Grelen, 1983; Ramsey et al., 2003; Wakely, 1954), and weeds can be a deterrent to pine and oak seedling growth (Nelson et al., 1985; Yeiser & Williams, 1996).

However, in the case of cherrybark oak seedlings height differences were not directly correlated to weed suppression. Some studies indicate that weed competition is a deterrent to growth of oak seedlings (Sweeney et al., 2002), while others have shown no results of early weed control (Dubois et al., 2000). However, many studies only report growth effects of weed control after the second growing season (Haywood, 1999; Knowe et al., 1985). Nevertheless, mulches acting as a weed suppressant may help to address some of the management concerns of having different weed management regimes for trees and crops.

Soil Moisture and Temperature

Soil moisture and soil temperature may have impacted height and diameter growth and survival of seedlings. Cherrybark oak and loblolly pine under the organic mulches conserved moisture and had significant height/temperature correlations (Table 3). This indicates that the four organic mulches, all which conserved moisture (Table 2), may have contributed to height growth. Secondly, the fact that longleaf pine did not have significant correlations between height growth and soil temperature under any mulches, may be an indicator that different tree species have different moisture and temperature requirements for early growth. Further, corn stover-hog manure mulches conserved more moisture than the hay mulch, which may indicate that corn stover-hog manure can be a mulching tool able to conserve soil moisture. Soil moisture beneath the *B Plastic* mulch was better conserved as compared to soils in *Control* plots, but was not as efficient as the organic mulches. The strong correlations between height/diameter growth and soil moisture in some species indicate that moisture can have an impact on seedling growth.

Soil temperatures beneath the black plastic were nearly as high as in *Control* plots, but there were no significant correlations between soil temperature and height growth in seedlings treated with *B Plastic* or *Control*. However, the correlations between height growth and soil temperature for seedlings treated with four organic mulches indicated that soil temperature can impact early growth of seedlings. June soil temperatures had a negative correlation with height and diameter growth (Table 3, 10), but soil temperatures in June were not nearly as high as they were in August. Reasons for the negative correlations are unknown.

Soil moisture and soil temperatures have been shown to impact nutrient uptake in plants, and plant growth and development (Laporte et al., 2002; Shoulders, 1974). Many studies have shown moisture to be the most limiting factor for plants (Bergmann & Shorrocks, 1992; Jose et al., 2003; Kuperman, 1999; Manion, 1981). It is not clear how much affect soil moisture and temperature had on the overall first year growth of seedlings in the current study. Moisture was correlated with height growth, but it was not the only factor, since the mulch that conserved the most moisture (*C High*) had lower height growth than the mulch that conserved moisture to a lesser extent (*H High*). Another possibility is that moisture may have been limiting to a point, but both mulches (*C High, H High*) may have alleviated the limitation. In this case, soil moisture conservation contributed to growth, but there were more confounding factors also contributing to growth differences.

Summary

The impact of applying hay mulch shows some promise for alley cropping systems because of the positive outcome on soil environment, weed control, and because hay did not add too many nutrients to the soil, as was the case with corn stover-hog manure. Many studies have shown positive effects of mulching that are attributed to these factors, but this study differed from previous studies in that, first, nutrient availability was not limiting on our site, like it is on many forestry sites. Secondly, manure has been shown to have varying affects when used as mulch and in this case seems to have “trumped” soil moisture, soil temperature and weed suppression (for cherrybark oak) in affecting plant growth. The corn stover-hog manure mulch used in the current study had not been composted prior to application.

Past research has shown that mulching has potential to suppress weeds, optimize soil conditions, add nutrients to the soil, and in some cases, aid in plant growth (Bernhardt & Swiecki, 1996; Grelen, 1983; Haywood, 2000; Miller et al., 1991; Ramsey et al., 2003; Wakely, 1954; Wilson et al., 2004). The results of this study support some of these findings, including suppressing weeds, optimizing soil conditions by retaining soil moisture under the mulches and keeping soils from getting as hot during mid-summer heat, and adding nutrients to the soil.

In this study, the mulches leached relatively quickly into the soil, so that 10 weeks after application, nutrients applied in the mulches showed up in the foliage. The timing of this may have implications that mulches may be able to be used in fertilizer-type applications. This also has some implications in that mulches can be subjected to pre-application handling. Mulches treated before being utilized on a field may have more utility. For instance, if corn stover-hog manure had been left outside to weather and fully composted, some of the nutrients in the mulch might have leached out, and/or been modified by microbial activity, possibly leaving the mulch without as much salts or P. Weathered mulch such as this, could be used without the fear of applying a too nutrient-rich mulch.

We also considered using different amounts of materials, which may have various implications for management strategies. If we added more old hay as mulch, it may have added more nutrients to the soil, which may result in a larger, positive growth effect. The higher application of hay was a more complete weed control, and thicker hay mulch could last longer, which may have longer-term impacts. It would also help to solve the problem of excess old hay on farms, because more old hay would be able to be used.

Another consideration would be to use less corn stover-hog manure, which could aid as a fertilizer since there were so many nutrients in the mulch. The corn stover-hog manure may have had too many nutrients, but we could consider a mixture of corn stover-hog manure and old hay mulch. A light spread of corn stover-hog manure and a thicker spread of hay mulch, would provide the benefits of conserving soil moisture, reducing soil temperature, suppressing weeds, and adding nutrients, but not too many.

Black plastic mulch had higher soil temperatures and lower moisture conservation than the four organic mulches. Additionally, black plastic mulch did not have the addition of nutrients. In the cherrybark oak, the *B Plastic* had lesser growth than the *H High,* which may have been partially attributed to moisture. Typically, black plastic mulch in agricultural use, includes irrigation lines beneath the plastic because the plastic does not allow for very much rain to pass through, except for the small hole for the stem. In a wet year, results of using black plastic mulch may have been different.

The different species responded in various degrees to the affects of moisture, temperature and nutrients, depending on species' needs and requirements. We should consider species' requirements when choosing mulch. Also, we could consider various pre-application handling of mulches, thereby possibly reducing the risk of over-applying nutrients.

Limitations

The results of the study indicate complex nutrient interactions and ratios, and while literature supported certain ideas about causes or symptoms, the conclusions are probably just the beginning of a much broader picture than could be fully discussed in this project. This project was limited by funds that covered only one summer's worth of data collection, and limited labor. Limitations may also include data collection during an unusually dry summer. With longer-term studies, nutrient complications and moisture effects could be factored out more fully. Nutrient comparisons became a focus of the study; however, this study was not set up to be a nutrient study, and no fertilizer comparison plots had been added, which would have been an interesting comparison. Additionally, the nutrient analyses were done in labs geared for farmer services, not in a laboratory aimed primarily at research. Furthermore, this was also the first study of its kind in the area, so comparison studies were not available. The study was also limited by damage to the loblolly pines by Nantucket Tip Moth, which could have lent a broader understanding to the story.

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Table 1. Mean estimates for May to November 2007 height growth (± SD, n= 5) of each species (see Figure 4), diameter growth (± SD, n= 5) 2 cm above ground level of cherrybark oak and longleaf pine, and November 2007 survival (± SD, n= 5) (%) for each species, by mulch treatment, during the first growing season following mulch treatment application in Goldsboro, NC. Treatment details are described in the text.

	----------Mulch Treatments----------							
***Species*/ Attribute**	**Black Plastic**	**Corn High**	**Corn Low**	**Control**	**Hay High**	**Hay Low**	**ANOVA**	
Cherrybark oak								
Ht (cm)	8.3 ± 9.1 b	8.0 ± 10.5 b	8.9 ± 11.6 ab	8.9 ± 6.7 ab	17.3 ± 14.5 a	10.9 ± 9.1 ab	$F_{5, 20}$=2.54	P=0.0621
Diameter (mm)	2.95 ± 2.63	2.44 ± 1.98	2.05 ± 2.23	2.8 ± 1.96	3.8 ± 2.75	3.63 ± 2.69	$F_{5, 20}$=1.28	P=0.3111
Survival (%)	100 ± 0	92 ± 27	100 ± 0	96 ± 20	92 ± 27	96 ± 20	$F_{5, 20}$=0.8235	P=0.5349
Loblolly pine								
Ht (cm)	6.1 ± 7.2	7.7 ± 9.1	8.8 ± 9.8	7.2 ± 8.1	7.2 ± 7.2	6.6 ± 7.0	$F_{5, 20}$= 0.39	P= 0.8519
Diameter (mm)	2.95 ± 3.38	2.44 ± 2.28	2.05 ± 3.43	2.8 ± 2.63	3.8 ± 2.58	3.63 ± 2.62	$F_{5, 20}$= 0.76	P=0.5921
Survival (%)	96 ± 20	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	$F_{5, 20}$= 2.0741	P=0.0722
Longleaf pine								
Ht (cm)	17.0 ± 4.9 ab	13.2 ± 6.8 b	15.4 ± 7.4 ab	14.5 ± 5.5 ab	18.6 ± 4.0 a	17.9 ± 6.3 ab	$F_{5, 20}$= 70.12	P=<0.0001
Survival (%)	100 ± 0 a	68 ± 48 b	88 ± 5.89 ab	100 ± 0 a	100 ± 0 a	88 ± 33 ab	$F_{5, 20}$= 9.1996	P=<0.0001

Note: All data were non-transformed. Means within a row, by species, followed by different letters were statistically different at P = 0.10 by Tukey's separation procedure following significant ANOVA of P≤ 0.1. Means within a row not followed by a different letter but with an ANOVA p-value of <0.1 indicate that although differences were apparent in ANOVA, Tukey's separation procedure was unable to detect which treatments differed.

Table 2. Mean mineral (at 6.6 cm depth) soil moisture (± SD, n= 5) (% volumetric moisture) under each mulch treatment, and mean mineral soil temperature (± SD, n= 5) (°C) at 10 cm depth, under each mulch treatment in June 2007, and August 2007, during the first growing season following mulch treatment application for each species, in Goldsboro, NC. Treatment details are described in the text.

	---Mulch Treatments---							
***Species*/ Attribute**	**Black Plastic**	**Corn High**	**Corn Low**	**Control**	**Hay High**	**Hay Low**	**ANOVA**	
Cherrybark oak								
Temp June (°C)	34.93 ± 2.84 b	31.08 ± 2.00 d	31.72 ± 2.12 cd	37.4 ± 3.12 a	31.23 ± 2.09 cd	32.12 ± 2.15 c	$F_{5, 20}$= 118.86	P=<0.0001
Temp August (°C)	40.82 ±7.4	39.91 ± 8.4	39.83 ± 8.0	40.49 ± 7.4	39.73 ± 8.4	39.92 ± 8.1	$F_{5, 20}$= 1.1	P=0.389
Moisture June (%Vm)	12.48 ± 5.62 c	18.83 ± 7.13 a	17.27 ± 7.49 ab	11.15 ± 6.42 c	17.41 ± 7.29 ab	16.09 ± 7.76 b	$F_{5, 20}$= 25.94	P=<0.0001
Moisture August (%Vm)	24.11 ± 4.9 b	28.01 ± 4.7 a	25.74 ± 5.6 ab	17.94 ± 3.3 c	24.21 ± 4.3 b	23.68 ± 4.7 b	$F_{5, 20}$= 19.44	P=<0.0001
Loblolly pine								
Temp June (°C)	34.94 ± 2.78 b	30.89 ± 2.21 c	31.65 ± 2.42 c	36.67 ± 3.39 a	31.03 ± 2.25 c	31.58 ± 2.44 c	$F_{5, 20}$= 96.5	P=<0.0001
Temp August (°C)	41.48 ± 7.55	40.28 ± 8.64	40.15 ± 8.13	41.4 ± 7.39	40.33 ± 8.59	40.49 ± 8.36	$F_{5, 20}$= 2.62	P=0.0558
Moisture June (%Vm)	12.1 ± 5.90 c	18.68 ± 8.00 a	15.96 ± 7.41 ab	9.55 ± 4.94 c	15.6 ± 7.44 b	14.11 ± 6.57 bc	$F_{5, 20}$= 23.13	P=<0.0001
Moisture August (%Vm)	21.31 ± 6.81 b	25.25 ± 7.68 a	23.17 ± 7.83 ab	16.35 ± 5.54 c	22.86 ± 8.21 ab	21.45 ± 7.35 b	$F_{5, 20}$= 17.95	P=<0.0001
Longleaf pine								
Temp June (°C)	35.41 ± 3.69 b	31.01 ± 2.20 c	31.67 ± 2.29 c	36.9 ± 3.53 a	31.04 ± 2.44 c	32.02 ± 2.76 c	$F_{5, 20}$= 70.12	P=<0.0001
Temp August (°C)	41.42 ± 7.12	40.20 ± 8.52	40.32 ± 8.00	41.38 ± 7.30	40.52 ± 8.32	40.48 ± 7.93	$F_{5, 20}$= 2.08	P=0.1105
Moisture June (%Vm)	12.04 ± 4.61 d	17.16 ± 4.77 a	15.47 ± 4.34 ab	9.01 ± 3.55 e	14.74 ± 4.49 bc	13.3 ± 4.91 cd	$F_{5,20}$= 35.85	P=<0.0001
Moisture August (%Vm)	21.44 ± 6.01 ab	24.23 ± 6.35 a	22.04 ± 5.41 ab	15.85 ± 4.28 c	23.38 ± 5.37 ab	21.36 ± 6.34 b	$F_{5, 20}$= 16.17	P=<0.0001

Note: All data were non-transformed. Means within a row, by species, followed by different letters were statistically different at P= 0.10 by Tukey's separation procedure following significant ANOVA of P≤ 0.1. Means within a row not followed by a different letter but with an ANOVA p-value of <0.1 indicate that although differences were apparent in ANOVA, Tukey's separation procedure was unable to detect which treatments differed.

Table 3. Pearson's correlation coefficients (r) among soil moisture (June, August, 2007)/ soil temperature (June /August 2007), and height/ diameter growth of first year cherrybark oak, loblolly pine and longleaf pine seedlings treated with corn stover-hog manure (*Corn High* and *Corn Low)* mulch treatment, old hay (*Hay High* and *Hay Low)*, and black plastic/control (*Black plastic* and *Control*) applied in May 2007 in Goldsboro, NC. Treatment details are described in text.

	Height Growth	**Diameter Growth**		**Height Growth**	**Diameter Growth**		**Height Growth**
Cherrybark oak			Loblolly Pine			Longleaf Pine	
Corn Stover-Manure			*Corn Stover-Manure*			*Corn Stover-Manure*	
June Soil Moisture	0.5067	0.42354	June Soil Moisture	0.59768	0.43255	June Soil Moisture	0.00613
	0.0003	0.0034		<.0001	0.0017		0.973
	46	46		50	50		33
August Soil Moisture	0.39034	0.33194	August Soil Moisture	0.47886	0.3128	August Soil Moisture	-0.00625
	0.0067	0.0226		0.0005	0.0286		0.9725
	47	47		49	49		33
June Soil Temperature	-0.55829	-0.44777	June Soil Temperature	-0.58837	-0.55195	June Soil Temperature	0.00709
	<.0001	0.0016		<.0001	<.0001		0.9688
	47	47		49	49		33
August Soil Temperature	0.39512	0.28735	August Soil Temperature	0.52839	0.46997	August Soil Temperature	0.02677
	0.006	0.0502		<.0001	0.0006		0.8844
	47	47		50	50		32
Old Hay			*Old Hay*			*Old Hay*	
June Soil Moisture	0.32216	0.24738	June Soil Moisture	0.35795	0.15302	June Soil Moisture	0.16759
	0.0272	0.0936		0.0107	0.2887		0.2602
	47	47		47	47		47
August Soil Moisture	0.23418	0.07703	August Soil Moisture	0.25977	0.00794	August Soil Moisture	0.0886
	0.1131	0.6068		0.0685	0.9564		0.5537
	47	47		47	47		47
June Soil Temperature	-0.46538	-0.38116	June Soil Temperature	-0.51833	-0.40047	June Soil Temperature	-0.22697
	0.0015	0.0107		0.0001	0.004		0.125
	44	44		47	47		47
August Soil Temperature	0.36647	0.16113	August Soil Temperature	0.36953	0.35755	August Soil Temperature	-0.05045
	0.0122	0.2847		0.0083	0.0108		0.7392
	46	46		46	46		46

Table 3. Continued

	Height Growth	Diameter Growth		Height Growth	Diameter Growth		Height Growth
Cherrybark oak			Loblolly Pine			Longleaf Pine	
Black Plastic/Control			*Black Plastic/Control*			*Black Plastic/Control*	
June Soil Moisture	-0.09442	-0.09308	June Soil Moisture	0.26528	0.06522	June Soil Moisture	-0.05311
	0.5278	0.5337		0.0748	0.6632		0.7141
	47	47		46	47		50
August Soil Moisture	-0.00397	-0.02327	August Soil Moisture	0.13885	-0.09101	August Soil Moisture	-0.15428
	0.9789	0.8766		0.352	0.5384		0.2847
	47	47		47	48		50
June Soil Temperature	0.03786	0.17593	June Soil Temperature	-0.26985	-0.39481	June Soil Temperature	-0.03631
	0.8027	0.2422		0.0697	0.006		0.8044
	46	46		46	47		49
August Soil Temperature	0.01288	-0.06063	August Soil Temperature	0.49279	0.34543	August Soil Temperature	0.03999
	0.9331	0.6924		0.0005	0.0174		0.7828
	45	45		46	47		50

Note: All data were correlated based on means and subjected to Pearson's correlation procedure. Correlation coefficient (slope) (r) is displayed as the top number in each row for each column and its significance level is displayed as the second number for each row and column. The third number in each set is n.

Table 4. Mean weed biomass (± SD, n= 5) (dry g/mulched area: 91 cm dia.), and mean count of weed stems (±SD, n=5) with two or more cotyledons in mulched area (91 cm dia.) for each species, in July 2007, during the first growing season after mulch treatments were applied, in Goldsboro, NC. Estimates <0.1 g were not reported. Treatment details are described in the text.

	--------Mulch Treatments--------							
***Species/* Attribute**	**Black Plastic**	**Corn High**	**Corn Low**	**Control**	**Hay High**	**Hay Low**	**ANOVA**	
Cherrybark oak								
Weed Biomass (dry g)	0 .0 ± 0.0 b	0.74 ± 3.72 b	2.79 ± 9.98 b	11.00 ± 15.17 a	0.0 ± 0.0 b	0.0 ± 0.0 b	$F_{5, 20}$=5.97	P=0.0016
Weed Stems/ 91 cm	0.0 ± 0.0 b	0.0 ± 0.2 b	1.2 ± 5.4 b	4.0 ± 5.2 a	0.0 ± 0.0 b	0.0 ± 0.0 b	$F_{5, 20}$=6.8	P=0.0007
Loblolly pine								
Weed Biomass (dry g)	0.004 ± 0.02 b	0.004 ± 0.02 b	0.26 ± 1.28 b	7.17 ± 13.99 a	0.41 ± 2.06 b	0.00 ± 0.02 b	$F_{5, 20}$=4.65	P=0.0056
Weed Stems/ 91 cm	0.0 ± 0.2 b	0.0 ± 0.2 b	0.0 ± 0.2 b	1.9 ± 2.9 a	0.1 ± 0.4 b	0.0 ± 0.2 b	$F=_{5, 20}$10.39	P=<0.0001
Longleaf pine								
Weed Biomass (dry g)	0.0 ± 0.0 b	0.36 ± 1.39 b	3.79 ± 13.81 b	11.09 ± 13.18 a	0.00 ± 0.02 b	0.95 ± 2.66 b	$F_{5, 20}$=7.83	P=0.0003
Weed Stems/ 91 cm	0.0 ± 0.0 b	0.1 ± 0.3 b	0.4 ± 1.5 b	3.5 ± 4.2 a	0.0 ± 0.2 b	0.3 ± 1.0 b	$F_{5, 20}$=11.45	P=<.0001

Note: All data were non-transformed. Means within a row, by species, followed by different letters were statistically different at P = 0.10 by Tukey's separation procedure following significant ANOVA of P≤ 0.1. Means within a row not followed by a different letter but with an ANOVA p-value of <0.1 indicate that although differences were apparent in ANOVA, Tukey's separation procedure was unable to detect which treatments differed.

Table 5. Mean mineral soil (0-20 cm depth) nutrient values (±SD, n=5) for P and K (index values, 0=low 100+= very high), Ca and Mg (meq/100 cm^3), S, Cu, Mn, Fe, and Zn (index values 0=low 100+= very high), Na (meq/100 cm^3), and soil pH under each mulch treatment, for each species. Soil samples collected July 2007, 6 weeks after treatments were applied in Goldsboro, NC. Treatment details are described in the text.

	----Mulch Treatments----							
***Species*/ Attribute**	**Black Plastic**	**Corn High**	**Corn Low**	**Control**	**Hay High**	**Hay Low**	**ANOVA**	
Cherrybark oak								
Soil - P (Index 0-100+)	133 ± 23 b	254 ± 33 a	237 ± 17 a	151 ± 12 b	161 ± 11 b	153 ± 20 b	$F_{5, 20}$=20.96	P=<0.0001
Soil - K (Index 0-100+)	107 ± 20 e	310 ± 21 a	268 ± 12 b	123 ± 22 de	169 ± 12 c	154 ± 12 cd	$F_{5, 20}$=80.36	P=<0.0001
Soil - Ca (meq/100 cm3)	2.6 ± 1.4	2.4 ± 1.2	2.7 ± 1.6	2.8 ± 1.1	2.5 ± 1.2	2.6 ± 1.2	$F_{5, 20}$=4.64	P=0.0057
Soil - Mg (meq/100 cm3)	1.22 ± 0.82	1.04 ± 0.75	1.20 ± 0.83	1.12 ± 0.79	1.19 ± 0.77	1.20 ± 0.78	$F_{5, 20}$=5.60	P=0.0022
Soil - S (Index 0-100+)	32 ± 6 c	67 ± 8 a	53 ± 5 b	34 ± 3 c	34 ± 5 c	35 ± 2 c	$F_{5, 20}$=28.33	P=<0.0001
Soil - Mn (Index 0-100+)	328 ± 35	379 ± 22	363 ± 19	353 ± 24	366 ± 16	325 ± 19	$F_{5, 20}$=3.05	P=0.0333
Soil - Zn (Index 0-100+)	119 ± 48	121 ± 8	123 ± 11	87 ± 15	105 ± 13	104 ± 21	$F_{5, 20}$=1.20	P=0.3461
Soil - Cu (Index 0-100+)	41 ± 10	57 ± 2	56 ± 5	47 ± 8	48 ± 2	50 ± 3	$F_{5, 20}$=4.01	P=0.0110
Soil - Na (meq/100 cm3)	0.12 ± 0.04 b	0.26 ± 0.03 a	0.22 ± 0.04 a	0.1 ± 0.02 b	0.1 ± 0.02 b	0.08 ± 0.03 c	$F_{5, 20}$=22.49	P=<0.0001
Soil - CEC (meq/100 cm^3)	5.7 ± 1.1 c	6.6 ± 1.1 a	6.56 ± 1.06 ab	6.0 ± 1.1 abc	5.8 ± 1.1 c	5.9 ± 1.1 bc	$F_{5, 20}$=5.04	P=0.0038
Soil - pH	5.4 ± 0.2	5.7 ± 0.1	5.9 ± 0.1	5.6 ± 0.1	6.0 ± 0.2	5.9 ± 0.1	$F_{5, 20}$=11.00	P=<0.0001
Loblolly pine								
Soil - P (Index 0-100+)	165 ± 29.9	197 ± 33	209 ± 45	163 ± 41.5	179 ± 35	150 ± 27	$F_{5, 20}$=1.38	P=0.2745
Soil - K (Index 0-100+)	157.2 ± 42.0	244.2 ± 53.1	220.4 ± 65.9	136.4 ± 75.1	156 ± 10.3	159.8 ± 14.0	$F_{5, 20}$=2.94	P=0.0380
Soil - Ca (meq/100 cm3)	2.6 ± 0.2	2.5 ± 0.3	2.7 ± 0.3	2.1 ± 0.4	2.2 ± 0.3	2.9 ± 0.4	$F_{5, 20}$=1.79	P=0.1607
Soil - Mg (meq/100 cm3)	1.16 ± 0.14	1.00 ± 0.12	1.19 ± 0.14	0.91 ± 0.20	0.95 ± 0.14	1.33 ± 0.13	$F_{5, 20}$=3.72	P=0.0153
Soil - S (Index 0-100+)	36.2 ± 8.7 b	58.2 ± 14.3 a	45.6 ± 9.6 b	32.6 ± 13.6 b	34.8 ± 2.8 b	34 ± 2.2 b	$F_{5, 20}$=4.04	P=0.0107
Soil - Mn (Index 0-100+)	352 ± 39.7	342.4 ± 26.0	333 ± 23.0	308.2 ± 53.5	317.2 ± 21.5	315.4 ± 42.7	$F_{5, 20}$=0.78	P=0.5787
Soil - Zn (Index 0-100+)	103.6 ± 14.5	98 ± 37.5	156.4 ± 65.8	86.2 ± 25.1	81.8 ± 31.9	128.6 ± 25.7	$F_{5, 20}$=2.04	P=0.1165
Soil - Cu (Index 0-100+)	42.6 ± 6.9	42.8 ± 10.8	46.8 ± 5.1	34.2 ± 12.9	41.2 ± 4.8	46 ± 5.6	$F_{5, 20}$=1.03	P=0.4287
Soil - Na (meq/100 cm3)	0.12 ± 0.06 ab	0.2 ± 0.04 a	0.14 ± 0.06 ab	0.1 ± 0.08 ab	0.08 ± 0.03 b	0.08 ± 0.03 b	$F_{5, 20}$=2.60	P=0.0573
Soil - CEC (meq/100 cm^3)	5.8 ± 0.8 abcd	5.98 ± 0.81 ab	6.1 ± 0.8 a	4.9 ± 0.8 d	5.1 ± 0.8 bcd	6.0 ± 0.8 ab	$F_{5, 20}$=4.66	P=0.0055
Soil - pH	5.62 ± 0.3	5.62 ± 0.4	6.1 ± 0.2	5.78 ± 0.1	5.76 ± 0.2	6.06 ± 0.08	$F_{5, 20}$=2.52	P=0.0635

Table 5. Continued

Species/ **Attribute**	Mulch Treatments **Black Plastic**	**Corn High**	**Corn Low**	**Control**	**Hay High**	**Hay Low**	**ANOVA**	
Longleaf pine								
Soil - P (Index 0-100+)	174 ± 26	193 ± 26	202 ± 48	138 ± 17	192 ± 48	166 ± 42	$F_{5, 20}$=1.42	P=0.2594
Soil - K (Index 0-100+)	152 ± 57	216 ± 50	180 ± 50	117 ± 14	201 ± 54	175 ± 61	$F_{5, 20}$=1.99	P=0.1248
Soil - Ca (meq/100 cm3)	2.4 ± 0.2	2.3 ± 0.1	2.2 ± 0.2	2.4 ± 0.1	2.2 ± 0.2	2.2 ± 0.3	$F_{5, 20}$=1.99	P=0.1240
Soil - Mg (meq/100 cm3)	1.01 ± 0.13	0.97 ± 0.09	0.93 ± 0.05	0.97 ± 0.06	0.93 ± 0.07	0.90 ± 0.12	$F_{5, 20}$=0.37	P=0.8653
Soil - S (Index 0-100+)	34 ± 4	49 ± 12	41 ± 10	30 ± 4	45 ± 14	40 ± 15	$F_{5, 20}$=1.63	P=0.1971
Soil - Mn (Index 0-100+)	320 ± 16	317 ± 20	306 ± 15	316 ± 9	316 ± 19	319 ± 18	$F_{5, 20}$=0.29	P=0.9152
Soil - Zn (Index 0-100+)	113.8 ± 8.2	97.6 ± 8.1	96.2 ± 18.6	94.8 ± 10.9	95.2 ± 8.3	110 ± 27	$F_{5, 20}$=1.05	P=0.4186
Soil - Cu (Index 0-100+)	41 ± 7	34 ± 11	44 ± 3	42 ± 4	45 ± 5	44 ± 5	$F_{5, 20}$=1.32	P=0.2945
Soil - Na (meq/100 cm3)	0.12 ± 0.04	0.18 ± 0.08	0.14 ± 0.05	0.1 ± 0.01	0.14 ± 0.05	0.14 ± 0.08	$F_{5, 20}$=0.92	P=0.4873
Soil - CEC (meq/100 cm^3)	5.4 ± 0.5	5.5 ± 0.5	5.3 ± 0.5	5.2 ± 0.5	5.4 ± 0.5	5.2 ± 0.5	$F_{5, 20}$=0.83	P=0.5423
Soil - pH	5.8 ± 0.3	5.9 ± 0.2	5.8 ± 0.2	5.7 ± 0.2	5.9 ± 0.1	5.7 ± 0.1	$F_{5, 20}$=1.14	P=0.3735

Note: All data were non-transformed. Means within a row, by species, followed by different letters were statistically different at P = 0.10 by Tukey's separation procedure following significant ANOVA of P≤ 0.1. Means within a row not followed by a different letter but with an ANOVA p-value of <0.1 indicate that although differences were apparent in ANOVA, Tukey's separation procedure was unable to detect which treatments differed.

Table 6. Mean nutrient content in organic mulch material (±SD, n=5) for N, P, K, Ca, Mg, S, B, Cu, Mn, Fe, Zn, Na (ppm), and pH of each mulch treatment applied, for each species in Goldsboro, NC. Mulch samples were collected May 2007. Treatment details are described in the text.

	--------------------------------Mulch Treatments------------------------					
***Species* /Attribute**	**Corn High**	**Corn Low**	**Hay High**	**Hay Low**	**ANOVA**	
Cherrybark oak						
Mulch - N (ppm)	21730 ± 2984 ab	18566 ± 2989 b	24805 ± 3964 a	25081 ± 2632 a	F3, 12 =5.42	P=0.0137
Mulch - P (ppm)	10991 ± 1622 a	10728 ± 2322 a	3613 ± 262 b	3276 ± 3276 b	F3, 12=45.78	P=<0.0001
Mulch - K (ppm)	22117 ± 4902	23324 ± 5563	18451 ± 3205	20285 ± 1293	F3, 12=1.76	P=0.2079
Mulch - Ca (ppm)	14713 ± 3606 a	14229 ± 5789 a	6170 ± 1509 b	5571 ± 747 b	F3, 12=16.19	P=0.0002
Mulch - Mg (ppm)	4370 ± 980	4365 ± 1347	5236 ± 357	4702 ± 369	F3, 12=1.06	P=0.4041
Mulch - S (ppm)	2565 ± 515 ab	2722 ± 441 a	1934 ± 312 b	1860 ± 353 b	F3, 12=4.68	P=0.0218
Mulch - Fe(ppm)	947 ± 308 a	941 ± 234 ab	178 ± 47 b	149 ± 249 b	F3, 12=20.90	P=<0.0001
Mulch - Mn (ppm)	174 ± 38	18 ± 44	163 ± 108	179 ± 123	F3, 12=0.05	P=0.9837
Mulch - Zn (ppm)	219 ± 67 a	213 ± 81 a	85 ± 57 b	45 ± 5 b	F3, 12=9.50	P=0.0017
Mulch - Cu (ppm)	52 ± 1.2 a	51 ± 1.3 a	13 ± 1.3 b	12 ± 1.3 b	F3, 12=27.63	P=<0.0001
Mulch - B (ppm)	23 ± 8 a	27 ± 7 a	10 ± 1 b	9 ± 0.4 b	F3, 12=14.74	P=0.0003
Mulch - Na (ppm)	3378 ± 761 a	3687 ± 900 a	177 ± 42 b	177 ± 46 b	F3, 12=46.86	P=<0.0001
Mulch - pH	7.3 ± 0.1 ab	7.2 ± 0.2 a	6.8 ± 0.4 b	6.9 ± 0.3 ab	F3, 12=3.46	P=0.0512
Loblolly pine						
Mulch - N (ppm)	19338 ± 7219 bc	18005 ± 3106 c	25885 ± 2893 a	24971 ± 2311 ab	F3,12=5.77	P=.01110
Mulch - P (ppm)	9503 ± 2626 a	7326 ± 1805 a	3303 ± 261 b	3579 ± 324 b	F3, 12=17.74	P= 0.0001
Mulch - K (ppm)	23146 ± 3881	21636 ± 3175	20852 ± 2833	22167 ± 3148	F3, 12=0.36	P=0.7838
Mulch - Ca (ppm)	11646 ± 3857a	10749 ± 3327 a	5857 ± 424 b	2850 ± 862 b	F3, 12=6.31	P=0.0082
Mulch - Mg (ppm)	3703 ± 1214 b	3377 ± 874 b	5202 ± 567 a	5300 ± 303 a	F3, 12=6.29	P=0.0082
Mulch - S (ppm)	2531 ± 499	2367 ± 343	1944 ± 240	1995 ± 265	F3, 12=2.75	P= 0.0890
Mulch - Fe (ppm)	709 ± 299 a	751 ± 248 a	138 ± 12 b	147 ± 21 b	F3, 12=12.03	P= 0.0006
Mulch - Mn (ppm)	145 ± 35 a	140 ± 30 a	139 ± 47 b	1356 ± 55 b	F3, 12=0.06	P=0.9808
Mulch - Zn (ppm)	183 ± 78 a	157 ± 49 a	50 ± 7 b	48 ± 4 b	F3, 12=10.04	P=0.0014
Mulch - Cu (ppm)	47 ± 15 a	40 ± 9 a	12 ± 0.8 b	12 ± 1.2 b	F3, 12=16.38	P=0.0002
Mulch - B (ppm)	26 ± 7 a	25 ± 4 a	10 ± 0.6 b	10 ± 0.4 b	F3, 12=21.63	P=<0.0001
Mulch - Na (ppm)	3455 ± 727 a	3145 ± 523 a	189 ± 31 b	199 ± 36 b	F3, 12=78.77	P=<0.0001
Mulch - pH	7.3 ± 0.1	7.4 ± 0.1	7.3 ± 0.5	7.2 ± 0.3	F3, 12=0.06	P= 0.9816

Table 6. Continued

Species /Attribute	Corn High	Corn Low	Hay High	Hay Low	ANOVA	
	--------------------------------Mulch Treatments------------------------					
Longleaf pine						
Mulch - N (ppm)	18779 ± 2472	18066 ± 2374	25382 ± 1119	24798 ± 2108	F3, 12=14.3	P=0.0003
Mulch - P (ppm)	9743 ± 1867 a	8123 ± 2530 a	3251 ± 220 b	3345 ± 150 b	F3, 12= 18.45	P=<0.0001
Mulch - K (ppm)	22482 ± 3728	21977 ± 3811	21349 ± 3964	22702 ± 3002	F3, 12=0.11	P=0.9507
Mulch - Ca (ppm)	12769 ± 3629 a	10770 ± 4448 a	5582 ± 466 b	5543 ± 696 b	F3, 12=6.69	P=0.0066
Mulch - Mg (ppm)	3591 ± 764 b	3517 ± 927 c	4805 ± 586 ab	4984 ± 343 a	F3, 12=5.3	P=0.0148
Mulch - S (ppm)	2463 ± 396 a	2302 ± 423 ab	1869 ± 81 b	1873 ± 249 b	F3, 12=3.78	P=0.0406
Mulch - Fe (ppm)	796 ± 253 a	661 ± 156 a	150 ± 46 b	134 ± 134 b	F3, 12=23.52	P=<0.0001
Mulch - Mn (ppm)	146.3 ± 28.4 a	141.2 ± 30.1 a	117.3 ± 48.2 b	120.0 ± 60.2 b	F3, 12=0.63	P=0.6120
Mulch - Zn (ppm)	176 ± 44 a	151 ± 66 a	46 ± 4 b	47 ± 4 b	F3, 12=12.34	P=0.0006
Mulch - Cu (ppm)	46 ± 11 a	38 ± 14 a	12 ± 2 b	12 ± 1 b	F3, 12=16.11	P=0.0002
Mulch - B (ppm)	25 ± 5 a	23 ± 4 a	9 ± 0.8 b	10 ± 0.7 b	F3, 12=28.05	P=<0.0001
Mulch - Na (ppm)	3296 ± 495 a	2844 ± 912 a	223 ± 41 b	203 ± 41 b	F3, 12=50.15	P=<0.0001
Mulch - pH	7.3 ± 0.1 ab	7.4 ± 0.1 a	7.2 ± 0.4 ab	6.9 ± 0.4 b	F3, 12=2.85	P=0.0819

Note: All data were non-transformed. Means within a row, by species, followed by different letters were statistically different at $P = 0.10$ by Tukey's separation procedure following significant ANOVA of $P \leq 0.1$. Means within a row not followed by a different letter but with an ANOVA p-value of <0.1 indicate that although differences were apparent in ANOVA, Tukey's separation procedure was unable to detect which treatments differed.

Table 7. Pearson's correlation coefficients (r) among nutrients of interest in soil (P, Ca, Mg), and foliar nutrients of interest (N, P) in first year cherrybark oak, loblolly pine and longleaf pine seedlings treated with corn stover-hog manure (*Corn High* and *Corn Low)* mulch treatment, old hay (*Hay High* and *Hay Low)*, and black plastic/control (*Black plastic* and *Control*) applied in May 2007 in Goldsboro, NC. Treatment details are described in text.

	Height Growth	Diameter Growth		Height Growth	Diameter Growth		Height Growth
Cherrybark oak			Loblolly Pine			Longleaf Pine	
Corn Stover-Manure			*Corn Stover-Manure*			*Corn Stover-Manure*	
Soil P	-0.50402	-0.34468	Soil P	-0.73278	-0.59433	Soil P	0.19282
	0.0003	0.0177		<.0001	<.0001		0.2823
	47	47		50	50		33
Soil Ca	0.42455	0.28094	Soil Ca	0.61705	0.53152	Soil Ca	-0.21783
	0.0029	0.0558		<.0001	<.0001		0.2233
	47	47		50	50		33
Soil Mg	0.48953	0.34172	Soil Mg	0.48953	0.53891	Soil Mg	-0.20155
	0.0005	0.0187		<.0001	<.0001		0.2607
	47	47		50	50		33
Foliar N	-0.26725	-0.18507	Foliar N	0.59546	0.54334	Foliar N	-0.0406
	0.0694	0.213		<.0001	<.0001		0.8225
	47	47		50	50		33
Foliar P	-0.37039	-0.24667	Foliar P	0.42913	0.38106	Foliar P	-0.02646
	0.0104	0.0946		0.0019	0.0063		0.8838
	47	47		50	50		33
Old Hay			*Old Hay*			*Old Hay*	
Soil P	-0.29482	-0.18251	Soil P	-0.49522	-0.34633	Soil P	-0.02921
	0.0442	0.2195		0.0003	0.0137		0.8455
	47	47		47	47		47
Soil Ca	0.20596	0.10743	Soil Ca	0.2696	0.2755	Soil Ca	-0.03086
	0.1649	0.4723		0.30401	0.10086		0.8369
	47	47		47	47		47
Soil Mg	0.32163	0.17298	Soil Mg	0.0318	0.4858	Soil Mg	-0.05622
	0.0275	0.2449		0.42493	0.24075		0.7074
	47	47		47	47		47
Foliar N	-0.03044	-0.20503	Foliar N	0.47699	0.42507	Foliar N	-0.19058
	0.839	0.1668		0.0005	0.0021		0.1994
	47	47		47	47		47
Foliar P	0.16044	0.0937	Foliar P	0.33514	0.20405	Foliar P	0.15002
	0.2813	0.531		0.0174	0.1552		0.3142
	47	47		47	47		47

Table 7. Continued

	Height Growth	Diameter Growth		Height Growth	Diameter Growth		Height Growth
Cherrybark oak			Loblolly Pine			Longleaf Pine	
Black Plastic/Control			*Black Plastic/Control*			*Black Plastic/Control*	
Soil P	0.02017	0.1676	Soil P	-0.31115	-0.21166	Soil P	0.22479
	0.893	0.2602		0.0333	0.1487		0.1165
	47	47		47	48		50
Soil Ca	0.02311	0.04861	Soil Ca	0.14648	0.14947	Soil Ca	-0.18555
	0.8775	0.7456		0.3259	0.3106		0.197
	47	47		47	48		50
Soil Mg	0.05448	-0.22195	Soil Mg	0.25991	0.31049	Soil Mg	-0.15573
	0.7161	0.1338		0.0777	0.0317		0.2802
	47	47		47	48		50
Foliar N	0.03393	0.12007	Foliar N	-0.03146	0.17014	Foliar N	0.13274
	0.8209	0.4214		0.8338	0.2476		0.3581
	47	47		47	48		50
Foliar P	0.15847	0.29749	Foliar P	0.19854	0.11354	Foliar P	0.27185
	0.2874	0.0423		0.1809	0.4423		0.0562
	47	47		47	48		50

Note: All data were correlated based on means and subjected to Pearson's correlation procedure. Correlation coefficient (slope) (r) is displayed as the top number in each row for each column and its significance level is displayed as the second number for each row and column. The third number in each set is n.

Table 8. Mean nutrient content, on a per hectare equivalent basis, in organic mulch material (±SD, n=5) for N, P, K, Ca, Mg, S, B, Cu, Mn, Fe, Zn, and Na (kg/ha) applied to treatment area, for each species in Goldsboro, NC. Samples were collected May 2007. Treatment details are described in the text.

	--------------------Mulch Treatments---------------------------					
Attribute *(All Species)*	**Corn High**	**Corn Low**	**Hay High**	**Hay Low**	**ANOVA**	
Mulch applied -N (kg/ha)	979 ± 44 a	456 ± 13 b	453 ± 11 b	224 ± 10 c	$F_{3, 12}$= 89.9	P=<0.0001
Mulch applied -P(kg/ha)	495 ± 21 a	229 ± 12 b	61 ± 5 c	31 ± 4 c	$F_{3, 12}$= 176.3	P=<0.0001
Mulch applied -K (kg/ha)	1108 ± 33 a	558 ± 14 b	361 ± 18 c	195 ± 16 d	$F_{3, 12}$= 193.5	P=<0.0001
Mulch applied -Ca (kg/ha)	640 ± 36 a	298 ± 22 b	105 ± 8 c	51 ± 8 c	$F_{3, 12}$=85.7	P=<0.0001
Mulch applied -Mg (kg/ha)	191 ± 9 a	94 ± 5 b	91 ± 4 b	45 ± 3 c	$F_{3, 12}$= 67.4	P=<0.0001
Mulch applied -S (kg/ha)	124 ± 4 a	62 ± 2 b	34 ± 2 c	17 ± 1 c	$F_{3, 12}$=192.5	P=<0.0001
Mulch applied -Fe (kg/ha)	40.1 ± 2.2 a	19.6 ± 1.0 b	2.8 ± 0.8 c	1.3 ± 0.6 c	$F_{3, 12}$= 104.2	P=<0.0001
Mulch applied -Mn (kg/ha)	7.6 ± 0.3 a	3.8 ± 0.2 b	2.5 ± 0.2 c	1.3 ± 0.2 d	$F_{3, 12}$= 104.73	P=<0.0001
Mulch applied -Zn (kg/ha)	9.5 ± 0.6 a	4.4 ± 0.3 b	1.1 ± 0.2 c	0.4 ± 0.2 c	$F_{3, 12}$=77.6	P=<0.0001
Mulch applied -Cu (kg/ha)	2.4 ± 0.1 a	1.1 ± 0.1 b	0.2 ± 0.03 c	0.1 ± 0.03 c	$F_{3, 12}$= 131.97	P=<0.0001
Mulch applied -B (kg/ha)	1.2 ± 0.06 a	0.6 ± 0.02 b	0.2 ± 0.02 c	0.1 ± 0.02 c	$F_{3, 12}$= 138.11	P=<0.0001
Mulch applied -Na (kg/ha)	166 ± 6 a	81 ± 4 b	3.5 ± 1.6 c	1.7 ± 1.7 c	$F_{3, 12}$= 250.9	P=<0.0001

Note: All data were non-transformed. Means within a row, by species, followed by different letters were statistically different at P = 0.10 by Tukey's separation procedure following significant ANOVA of P≤ 0.1. Means within a row not followed by a different letter but with an ANOVA p-value of <0.1 indicate that although differences were apparent in ANOVA, Tukey's separation procedure was unable to detect which treatments differed.

Table 9. Mean foliar nutrient concentration values (±SD, n=5) for N, P, K, Ca, Mg, S (%), B, Cu, Mn, Fe, Zn and Na (mg/kg), under each mulch treatment, for each species. Samples collected in August 2007, 10 weeks after treatments were applied, for each species. Treatment details are described in the text.

	---Mulch Treatments---							
***Species*/ Attribute**	**Black Plastic**	**Corn High**	**Corn Low**	**Control**	**Hay High**	**Hay Low**	**ANOVA**	
Cherrybark oak								
Foliar - N (%)	2.28 ± 0.19	2.35 ± 0.15	2.29 ± 0.14	2.37 ± 0.21	2.37 ± 0.09	2.17 ± 0.11	$F_{5, 20}$=0.82	P= 0.5467
Foliar - P (%)	0.08 ± 0.04	0.11 ± 0.01	0.10 ± 0.01	0.10 ± 0.01	0.11 ± 0.01	0.101 ± 0.01	$F_{5, 20}$=1.64	P=0.1962
Foliar - K (%)	0.51 ± 0.15 b	1.08 ± 022 a	0.69 ± 0.33 b	0.55 ± 0.08 b	0.66 ± 0.12 b	0.83 ± 0.05 ab	$F_{5, 20}$=4.49	P= 0.0066
Foliar - Ca (%)	0.66 ± 0.07 a	0.478 ± 0.05 b	0.58 ± 0.09 ab	0.66 ± 0.05 a	0.60 ± 0.08 ab	0.53 ± 0.05 ab	$F_{5, 20}$=3.93	P=0.0121
Foliar - Mg (%)	0.18 ± 0.04	0.12 ± 0.02	0.12 ± 0.05	0.17 ± 0.02	0.18 ± 0.02	0.17 ± 0.02	$F_{5, 20}$=2.50	P=0.0648
Foliar - S (%)	0.11 ± 0.002	0.11 ± 0.01	0.11 ± 0.01	0.10 ± 0.01	0.11 ± 0.01	0.10 ± 0.003	$F_{5, 20}$=1.19	P=0.3501
Foliar - Fe (mg/kg)	101 ± 7	93 ± 16	98 ± 9	96 ± 11	94 ± 13	87 ± 8	$F_{5, 20}$=0.65	P=0.6632
Foliar - Mn (mg/kg)	941 ± 300	778 ± 308	1032 ± 347	1007 ± 499	615 ± 255	538 ± 135	$F_{5, 20}$=1.46	P=0.2477
Foliar - Zn (mg/kg)	26 ± 3.3	28 ± 3.3	26 ± 3.4	28 ± 3.7	29 ± 2.6	29.9 ± 2.0	$F_{5, 20}$=.74	P=0.5995
Foliar - Cu (mg/kg)	7.7 ± 0.9	6.9 ± 0.9	7.1 ± 0.4	7.4 ± 0.3	8.1 ± 1.0	7.5 ± 1.1	$F_{5, 20}$=1.06	P= 0.4115
Foliar - B (mg/kg)	18.4 ± 0.02 b	25.9 ± 0.02 a	27.3 ± 0.03 a	17.8 ± 0.03 b	17.3 ± 0.01 b	16.6 ± 0.03 b	$F_{5, 20}$=16.39	P=<0.0001
Foliar - Na (mg/kg)	105 ± 10	126 ± 14	119 ± 14	105 ± 12	120 ± 10	127 ± 13	$F_{5, 20}$=2.26	P=0.0882
Loblolly pine								
Foliar - N (%)	1.72 ± 0.12 ab	1.64 ± 0.02 b	1.60 ± 0.04 b	1.69 ± 0.05 ab	1.68 ± 0.04 ab	1.77 ± 0.04 a	$F_{5, 20}$=3.72	P=0.0153
Foliar - P (%)	0.11 ± 0.04	0.12 ± 0.04	0.12 ± 0.02	0.12 ± 0.01	0.11 ± 0.01	0.11 ± 0.01	$F_{5, 20}$=0.47	P= 0.7927
Foliar - K (%)	0.74 ± 0.29 b	0.99 ± 0.38 a	1.02 ± 0.11 a	0.86 ± 0.12 b	0.76 ± 0.08 b	0.76 ± 0.08 b	$F_{5, 20}$=19.29	P=<0.0001
Foliar - Ca (%)	0.35 ± 0.14	0.31 ± 0.11	0.33 ± 0.05	0.34 ± 0.06	0.31 ± 0.03	0.35 ± 0.04	$F_{5, 20}$=1.29	P=0.3106
Foliar - Mg (%)	0.13 ± 0.06	0.10 ± 0.04	0.12 ± 0.02	0.13 ± 0.02	0.12 ± 0.01	0.12 ± 0.01	$F_{5, 20}$=2.02	P= 0.1236
Foliar - S (%)	0.08 ± 0.03 b	0.08 ± 0.03 ab	0.09 ± 0.01 a	0.08 ± 0.01 ab	0.09 ± 0.01 ab	0.09 ± 0.01 a	$F_{5, 20}$=3.28	P=0.0279
Foliar - Fe (mg/kg)	77 ± 11	76 ± 16	123 ± 9	82 ± 11	88 ± 13	83 ± 8	$F_{5, 20}$=1.48	P=0.2465
Foliar - Mn (mg/kg)	254 ± 112 ab	274 ± 145 ab	244 ± 143 ab	332 ± 155 a	250 ± 156 ab	236 ± 82 b	$F_{5, 20}$=2.81	P= 0.0476
Foliar - Zn (mg/kg)	45 ± 13	45 ± 9	46 ± 8	46 ± 7	48 ± 10	52 ± 7	$F_{5, 20}$=1.43	P=0.2616
Foliar - Cu (mg/kg)	9.8 ± 2.9	10.8 ± 4.1	10.0 ± 2.0	8.1 ± 0.9	7.8 ± 1.8	7.8 ± 0.9	$F_{5, 20}$=1.21	P=0.3451
Foliar - B (mg/kg)	13.4 ± 0.07 b	21.0 ± 0.08 a	19.6 ± 0.02 ab	16.5 ± 0.04 ab	16.9 ± 0.04 ab	16.0 ± 0.03 ab	$F_{5, 20}$=2.24	P=0.0950
Foliar - Na (mg/kg)	139 ± 7 bc	210 ± 49 a	243 ± 69 ab	137 ± 15 bc	137 ± 17 bc	121 ± 65 c	$F_{5, 20}$=5.78	P=0.0024

Table 9. Continued

Species/ Attribute	Black Plastic	Corn High	Corn Low	Control	Hay High	Hay Low	ANOVA	
	---Mulch Treatments---							
Longleaf pine								
Foliar - N (%)	1.22 ± 0.10 b	1.44 ± 0.14 a	1.34 ± 0.09 ab	1.28 ± 0.10 ab	1.19 ± 0.09 b	1.31 ± 0.03 ab	$F_{5, 20}$=3.04	P=0.0338
Foliar - P (%)	0.07 ± 0.01 ab	0.10 ± 0.01 a	0.09 ± 0.02 ab	0.08 ± 0.010 ab	0.06 ± 0.02 b	0.06 ± 0.01 ab	$F_{5, 20}$=3.95	P=0.0118
Foliar - K (%)	0.86 ± 0.12 b	1.26 ± 0.13 b	1.24 ± 0.14 a	0.94 ± 0.08 b	1.03 ± 0.05 ab	0.90 ± 0.09 b	$F_{5, 20}$=9.74	P=<0.0001
Foliar - Ca (%)	0.29 ± 0.04	0.24 ± 0.02	0.26 ± 0.04	0.31 ± 0.04	0.25 ± 0.03	0.25 ± 0.04	$F_{5, 20}$=2.03	P=0.1181
Foliar - Mg (%)	0.12 ± 0.01	0.10 ± 0.04	0.11 ± 0.01	0.12 ± 0.01	0.11 ± 0.01	0.11 ± 0.03	$F_{5, 20}$=0.91	P=0.4916
Foliar - S (%)	0.07 ± 0.004 b	0.09 ± 0.01 a	0.09 ± 0.002 a	0.07 ± 0.01 b	0.08 ± 0.01 b	0.07 ± 0.004 b	$F_{5, 20}$=14.43	P=<0.0001
Foliar - Fe (mg/kg)	69 ± 13	84 ± 10	92 ± 36	92 ± 13	64 ± 27	61 ± 22	$F_{5, 20}$=2.16	P=0.0999
Foliar - Mn (mg/kg)	117 ± 25 b	97 ± 25 b	128 ± 30 ab	197 ± 46 a	112 ± 58 ab	131 ± 22 ab	$F_{5, 20}$=3.13	P= 0.0302
Foliar - Zn (mg/kg)	34 ± 2	35 ± 2	35 ± 5	38 ± 4	38 ± 5	38 ± 5	$F_{5, 20}$=0.58	P=0.7142
Foliar - Cu (mg/kg)	6.2 ± 0.7	6.8 ± 1.0	6.2 ± 0.6	6.2 ± 1.0	6.7 ± 0.4	5.9 ± 0.7	$F_{5, 20}$=0.72	P=0.6165
Foliar - B (mg/kg)	15.9 ± 0.09 b	32.4 ± 0.06 a	28.1 ± 0.03 a	19.3 ± 0.01 b	24.4 ± 0.04 ab	20.1 ± 0.02 b	$F_{5, 20}$=6.13	P=0.0013
Foliar - Na (mg/kg)	158 ± 59 bc	564 ± 103 a	488 ± 332 ab	129 ± 12 c	126 ± 87 c	111 ± 93 c	$F_{5, 20}$=5.69	P=0.0020

Note: All data were non-transformed. Means within a row, by species, followed by different letters were statistically different at P = 0.10 by Tukey's separation procedure following significant ANOVA of P≤ 0.1. Means within a row not followed by a different letter but with an ANOVA p-value of <0.1 indicate that although differences were apparent in ANOVA, Tukey's separation procedure was unable to detect which treatments differed.

Table 10. Pearson's correlation coefficients (r) among first year tree, soil, and weed attributes for all planted species (cherrybark oak, loblolly pine, longleaf pine) and all mulch treatments (6 types) combined in Goldsboro, NC.

	Diameter Growth	Height Growth	Soil Moisture June	Soil Moisture August	Soil Temperature June	Soil Temperature August	Weed Biomass
Height Growth	0.57251	--	--	--	--	--	--
	<.0001	--	--	--	--	--	--
	287	--	--	--	--	--	--
Soil Moisture - June	0.16012	0.22802	--	--	--	--	--
	0.0066	<.0001	--	--	--	--	--
	287	416	--	--	--	--	--
Soil Moisture - August	0.02647	0.1538	0.84345	--	--	--	--
	0.6546	0.0016	<.0001	--	--	--	--
	288	417	447	--	--	--	--
Soil Temperature - June	-0.23727	-0.66749	-0.2098	-0.53485	--	--	--
	<.0001	<.0001	<.0001	<.0001	--	--	--
	283	441	411	442	--	--	--
Soil Temperature - August	0.26594	0.25179	0.36661	0.16473	-0.27211	--	--
	<.0001	<.0001	<.0001	0.0005	<.0001	--	--
	285	412	441	442	437	--	--
Weed Biomass	-0.02021	-0.0182	0.00055	-0.01579	0.10688	0.12589	--
	0.734	0.712	0.9908	0.7401	0.0253	0.0083	--
	285	414	443	444	438	438	--
Number of Weed Stems	-0.06243	-0.04588	-0.01147	-0.02865	0.16085	0.10946	0.6751
	0.2919	0.3517	0.8095	0.5467	0.0007	0.0216	<.0001
	287	414	444	445	439	440	441

Note: All data were correlated based on means and subjected to Pearson's correlation procedure. Correlation coefficient (slope) (r) is displayed as the top number in each row for each column and its significance level is displayed as the second number for each row and column. The third number in each set is n. Diameter growth has lower numbers of n because longleaf pine was not included in diameter measurements.

Table 11. Pearson's correlation coefficients (r) among selected nutrients in mulches (N, P, K, Ca, Mg, S, B), soil nutrients (P, K, Ca, Mg, S, Na) and pH, and foliar nutrients/minerals (N, P, K, Ca, Mg, S, B, Na) in first year cherrybark oak seedlings treated with corn stover-hog manure (*Corn High and Corn Low)* mulch treatment applied in May 2007 in Goldsboro, NC. Treatment details are described in text.

Attributes	**Mulch_N**	**Mulch_P**	**Mulch_K**	**Mulch_Ca**	**Mulch_Mg**	**Mulch_S**	**Mulch_B**	**Mulch_Na**	**Soil_pH**	**Soil_P**	**Soil_K**	**Soil_Ca**	**Soil_Mg**	**Soil_S**
Mulch_P	0.62196	--	--	--	--	--	--	--	--	--	--	--	--	--
	<.0001	--	--	--	--	--	--	--	--	--	--	--	--	--
	50	--	--	--	--	--	--	--	--	--	--	--	--	--
Mulch_K	-0.38669	-0.81838	--	--	--	--	--	--	--	--	--	--	--	--
	0.0055	<.0001	--	--	--	--	--	--	--	--	--	--	--	--
	50	50	--	--	--	--	--	--	--	--	--	--	--	--
Mulch_Ca	0.54733	0.98539	-0.87795	--	--	--	--	--	--	--	--	--	--	--
	<.0001	<.0001	<.0001	--	--	--	--	--	--	--	--	--	--	--
	50	50	50	--	--	--	--	--	--	--	--	--	--	--
Mulch_Mg	0.58369	0.98319	-0.84152	0.98789	--	--	--	--	--	--	--	--	--	--
	<.0001	<.0001	<.0001	<.0001	--	--	--	--	--	--	--	--	--	--
	50	50	50	50	--	--	--	--	--	--	--	--	--	--
Mulch_S	-0.14708	-0.57169	0.90809	-0.6461	-0.56899	--	--	--	--	--	--	--	--	--
	0.3081	<.0001	<.0001	<.0001	<.0001	--	--	--	--	--	--	--	--	--
	50	50	50	50	50	--	--	--	--	--	--	--	--	--
Mulch_B	-0.32191	-0.72252	0.91213	-0.77868	-0.70843	0.88865	--	--	--	--	--	--	--	--
	0.0226	<.0001	<.0001	<.0001	<.0001	<.0001	--	--	--	--	--	--	--	--
	50	50	50	50	50	50	--	--	--	--	--	--	--	--
Mulch_Na	-0.21248	-0.57534	0.91839	-0.66255	-0.59354	0.97869	0.85816	--	--	--	--	--	--	--
	0.1385	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	--	--	--	--	--	--	--
	50	50	50	50	50	50	50	--	--	--	--	--	--	--
Soil_pH	-0.27028	-0.0999	-0.07181	-0.02328	-0.02791	-0.05094	0.16507	-0.0923	--	--	--	--	--	--
	0.0576	0.49	0.6202	0.8725	0.8474	0.7254	0.252	0.5238	--	--	--	--	--	--
	50	50	50	50	50	50	50	50	--	--	--	--	--	--
Soil_P	-0.09205	0.35309	-0.44431	0.41123	0.33894	-0.37613	-0.52976	-0.32538	0.28023	--	--	--	--	--
	0.5249	0.0119	0.0012	0.003	0.016	0.0071	<.0001	0.0211	0.0487	--	--	--	--	--
	50	50	50	50	50	50	50	50	50	--	--	--	--	--
Soil_K	0.06519	0.05726	-0.10877	0.09732	0.00921	-0.12606	-0.35325	-0.09747	0.0217	0.61524	--	--	--	--
	0.6529	0.6928	0.4521	0.5014	0.9494	0.383	0.0119	0.5007	0.8811	<.0001	--	--	--	--
	50	50	50	50	50	50	50	50	50	50	--	--	--	--
Soil_Ca	0.13546	-0.14514	0.11517	-0.15087	-0.05845	0.14092	0.33098	0.03251	-0.08789	-0.84715	-0.78654	--	--	--
	0.3483	0.3146	0.4258	0.2956	0.6868	0.329	0.0189	0.8227	0.5439	<.0001	<.0001	--	--	--
	50	50	50	50	50	50	50	50	50	50	50	--	--	--

Table 11. Continued

Attributes	Mulch_N	Mulch_P	Mulch_K	Mulch_Ca	Mulch_Mg	Mulch_S	Mulch_B	Mulch_Na	Soil_pH	Soil_P	Soil_K	Soil_Ca	Soil_Mg	Soil_S
Soil_Mg	0.1584	-0.31655	0.37462	-0.34553	-0.25227	0.39758	0.5242	0.28196	-0.20834	-0.91187	-0.66148	0.94074	--	--
	0.2719	0.0251	0.0074	0.014	0.0772	0.0042	<.0001	0.0473	0.1465	<.0001	<.0001	<.0001	--	--
	50	50	50	50	50	50	50	50	50	50	50	50	--	--
Soil_S	0.42528	0.16239	-0.13032	0.10861	0.1248	-0.12534	-0.29992	-0.11983	-0.89873	-0.21262	0.06074	0.13387	0.22053	--
	0.0021	0.2599	0.367	0.4528	0.3878	0.3858	0.0343	0.4072	<.0001	0.1382	0.6752	0.354	0.1238	--
	50	50	50	50	50	50	50	50	50	50	50	50	50	--
Soil_Na	0.72445	0.67216	-0.56005	0.6217	0.61412	-0.47524	-0.48405	-0.51933	-0.4588	-0.08435	-0.10431	0.16343	0.11287	0.58873
	<.0001	<.0001	<.0001	<.0001	<.0001	0.0005	0.0004	0.0001	0.0008	0.5603	0.471	0.2568	0.4352	<.0001
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_N	0.30803	0.51228	-0.35565	0.50752	0.44131	-0.2512	-0.62389	-0.20022	-0.4041	0.5449	0.52848	-0.57925	-0.55553	0.27262
	0.0295	0.0001	0.0113	0.0002	0.0013	0.0785	<.0001	0.1633	0.0036	<.0001	<.0001	<.0001	<.0001	0.0554
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_P	-0.23645	-0.27521	0.08962	-0.2132	-0.27487	0.02501	0.03493	0.0423	0.70507	0.53366	0.59909	-0.57524	-0.54377	-0.63909
	0.0983	0.0531	0.536	0.1371	0.0534	0.8631	0.8097	0.7706	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_K	-0.26671	0.02653	-0.28747	0.11089	0.02943	-0.3784	-0.4801	-0.34085	-0.07473	0.66954	0.74662	-0.65523	-0.63979	0.23113
	0.0612	0.8549	0.0429	0.4433	0.8392	0.0067	0.0004	0.0154	0.606	<.0001	<.0001	<.0001	<.0001	0.1063
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_Ca	0.24964	0.28456	-0.07638	0.24314	0.30682	0.00671	0.0761	-0.03873	-0.27185	-0.72168	-0.70387	0.7653	0.67036	0.13445
	0.0804	0.0452	0.5981	0.0889	0.0302	0.9631	0.5994	0.7894	0.0562	<.0001	<.0001	<.0001	<.0001	0.3519
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_Mg	0.44598	0.23105	-0.10424	0.19817	0.22632	-0.07023	0.00585	-0.12112	-0.02446	-0.67338	-0.33656	0.60204	0.54226	-0.02658
	0.0012	0.1065	0.4713	0.1677	0.114	0.6279	0.9678	0.4021	0.8661	<.0001	0.0169	<.0001	<.0001	0.8546
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_S	0.36741	0.80622	-0.66776	0.80781	0.80318	-0.50837	-0.66605	-0.48553	-0.22525	0.09422	-0.13243	0.06342	-0.13477	0.12171
	0.0087	<.0001	<.0001	<.0001	<.0001	0.0002	<.0001	0.0004	0.1158	0.5151	0.3592	0.6617	0.3508	0.3998
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_B	-0.02353	0.61678	-0.43239	0.62109	0.55916	-0.32575	-0.5559	-0.23995	-0.15122	0.70532	0.32552	-0.66379	-0.74004	-0.02146
	0.8712	<.0001	0.0017	<.0001	<.0001	0.021	<.0001	0.0933	0.2945	<.0001	0.0211	<.0001	<.0001	0.8824
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_Na	-0.16391	-0.47585	0.23218	-0.38191	-0.38313	0.24901	0.22785	0.14484	0.4947	0.21572	0.3725	-0.07579	0.01884	-0.31892
	0.2554	0.0005	0.1047	0.0062	0.006	0.0812	0.1115	0.3156	0.0003	0.1324	0.0077	0.6009	0.8967	0.024
	50	50	50	50	50	50	50	50	50	50	50	50	50	50

Table 11. Continued

Attributes	Soil_Na	Foliar_N	Foliar_P	Foliar_K	Foliar_Ca	Foliar_Mg	Foliar_S	Foliar_B
Foliar_N	0.19876	--	--	--	--	--	--	--
	0.1664	--	--	--	--	--	--	--
	50	--	--	--	--	--	--	--
Foliar_P	-0.58591	0.05433	--	--	--	--	--	--
	<.0001	0.7079	--	--	--	--	--	--
	50	50	--	--	--	--	--	--
Foliar_K	-0.04277	0.32217	0.29668	--	--	--	--	--
	0.7681	0.0225	0.0364	--	--	--	--	--
	50	50	50	--	--	--	--	--
Foliar_Ca	0.35875	-0.17098	-0.73829	-0.6904	--	--	--	--
	0.0105	0.2351	<.0001	<.0001	--	--	--	--
	50	50	50	50	--	--	--	--
Foliar_Mg	0.28499	-0.13056	-0.27714	-0.65826	0.78028	--	--	--
	0.0449	0.3661	0.0514	<.0001	<.0001	--	--	--
	50	50	50	50	50	--	--	--
Foliar_S	0.39916	0.57214	-0.37741	-0.16051	0.55617	0.44988	--	--
	0.0041	<.0001	0.0069	0.2655	<.0001	0.001	--	--
	50	50	50	50	50	50	--	--
Foliar_B	0.15799	0.75474	-0.01791	0.37801	-0.13865	-0.33729	0.57159	--
	0.2732	<.0001	0.9018	0.0068	0.3369	0.0166	<.0001	--
	50	50	50	50	50	50	50	--
Foliar_Na	-0.53271	-0.14029	0.67629	0.2437	-0.5653	-0.29312	-0.5403	-0.39741
	<.0001	0.3312	<.0001	0.0881	<.0001	0.0388	<.0001	0.0043
	50	50	50	50	50	50	50	50

Note: All data were correlated based on means and subjected to Pearson's correlation procedure. Correlation coefficient (slope) (r) is displayed as the top number in each row for each column and its significance level is displayed as the second number for each row and column. The third number in each set is n.

Table 12. Pearson's correlation coefficients (r) among selected nutrients in mulches (N, P, K, Ca, Mg, S, B), soil nutrients (P, K, Ca, Mg, S, Na) soil pH, and foliar nutrients/minerals (N, P, K, Ca, Mg, S, B, Na) in first year loblolly pine seedlings treated with corn stover-hog manure (*Corn High and Corn Low)* mulch treatment applied in May 2007 in Goldsboro, NC. Treatment details are described in text.

Attributes	Mulch_N	Mulch_P	Mulch_K	Mulch_Ca	Mulch_Mg	Mulch_S	Mulch_B	Mulch_Na	Soil_pH	Soil_P	Soil_K	Soil_Ca	Soil_Mg	Soil_S
Mulch_P	0.78676	--	--	--	--	--	--	--	--	--	--	--	--	--
	<.0001	--	--	--	--	--	--	--	--	--	--	--	--	--
	50	--	--	--	--	--	--	--	--	--	--	--	--	--
Mulch_K	-0.26309	0.1577	--	--	--	--	--	--	--	--	--	--	--	--
	0.0649	0.274	--	--	--	--	--	--	--	--	--	--	--	--
	50	50	--	--	--	--	--	--	--	--	--	--	--	--
Mulch_Ca	0.75396	0.98128	0.06206	--	--	--	--	--	--	--	--	--	--	--
	<.0001	<.0001	0.6686	--	--	--	--	--	--	--	--	--	--	--
	50	50	50	--	--	--	--	--	--	--	--	--	--	--
Mulch_Mg	0.88129	0.96911	-0.04541	0.95359	--	--	--	--	--	--	--	--	--	--
	<.0001	<.0001	0.7542	<.0001	--	--	--	--	--	--	--	--	--	--
	50	50	50	50	--	--	--	--	--	--	--	--	--	--
Mulch_S	0.28916	0.68165	0.78168	0.59831	0.54364	--	--	--	--	--	--	--	--	--
	0.0417	<.0001	<.0001	<.0001	<.0001	--	--	--	--	--	--	--	--	--
	50	50	50	50	50	--	--	--	--	--	--	--	--	--
Mulch_B	-0.33984	0.10738	0.88626	0.0294	-0.04808	0.76193	--	--	--	--	--	--	--	--
	0.0158	0.4579	<.0001	0.8394	0.7402	<.0001	--	--	--	--	--	--	--	--
	50	50	50	50	50	50	--	--	--	--	--	--	--	--
Mulch_Na	0.24922	0.6252	0.80549	0.56179	0.46109	0.95803	0.69541	--	--	--	--	--	--	--
	0.0809	<.0001	<.0001	<.0001	0.0008	<.0001	<.0001	--	--	--	--	--	--	--
	50	50	50	50	50	50	50	--	--	--	--	--	--	--
Soil_pH	0.11217	0.2841	0.30736	0.28046	0.24533	0.4344	0.3006	0.40266	--	--	--	--	--	--
	0.438	0.0456	0.0299	0.0485	0.0859	0.0016	0.0339	0.0037	--	--	--	--	--	--
	50	50	50	50	50	50	50	50	--	--	--	--	--	--
Soil_P	0.01285	-0.25666	0.00039	-0.26157	-0.17914	-0.05234	0.01252	0.03872	0.24072	--	--	--	--	--
	0.9294	0.072	0.9979	0.0665	0.2132	0.7181	0.9312	0.7895	0.0922	--	--	--	--	--
	50	50	50	50	50	50	50	50	50	--	--	--	--	--
Soil_K	0.3551	0.56014	0.3955	0.52468	0.4969	0.74126	0.41575	0.76365	0.38336	0.19353	--	--	--	--
	0.0114	<.0001	0.0045	<.0001	0.0002	<.0001	0.0027	<.0001	0.006	0.1781	--	--	--	--
	50	50	50	50	50	50	50	50	50	50	--	--	--	--
Soil_Ca	0.04856	0.33015	-0.07523	0.37641	0.2883	0.03917	-0.06762	-0.06749	0.31506	-0.74887	-0.24462	--	--	--
	0.7377	0.0192	0.6036	0.0071	0.0423	0.7871	0.6408	0.6415	0.0258	<.0001	0.0869	--	--	--
	50	50	50	50	50	50	50	50	50	50	50	--	--	--

Table 12. Continued

Attributes	Mulch_N	Mulch_P	Mulch_K	Mulch_Ca	Mulch_Mg	Mulch_S	Mulch_B	Mulch_Na	Soil_pH	Soil_P	Soil_K	Soil_Ca	Soil_Mg	Soil_S
Soil_Mg	0.03996	0.31576	0.00852	0.33657	0.2648	0.10611	0.01305	-0.01816	0.38732	-0.74782	-0.19927	0.97984	--	--
	0.7829	0.0255	0.9532	0.0169	0.0631	0.4633	0.9283	0.9004	0.0055	<.0001	0.1653	<.0001	--	--
	50	50	50	50	50	50	50	50	50	50	50	50	--	--
Soil_S	0.02924	0.36961	0.32616	0.35027	0.27695	0.50419	0.34207	0.50616	0.06658	-0.33309	0.68317	0.14476	0.12921	--
	0.8403	0.0082	0.0208	0.0126	0.0515	0.0002	0.015	0.0002	0.646	0.0181	<.0001	0.3159	0.3711	--
	50	50	50	50	50	50	50	50	50	50	50	50	50	--
Soil_Na	0.14342	0.47976	0.33548	0.42366	0.40279	0.59345	0.39816	0.51501	0.11392	-0.34063	0.74814	0.09341	0.14783	0.82225
	0.3204	0.0004	0.0172	0.0022	0.0037	<.0001	0.0042	0.0001	0.4308	0.0155	<.0001	0.5188	0.3056	<.0001
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_N	-0.43355	-0.23496	0.12024	-0.22235	-0.3564	-0.251	-0.05794	-0.2092	-0.48455	-0.67761	-0.56586	0.37204	0.35424	-0.07873
	0.0017	0.1005	0.4055	0.1207	0.0111	0.0787	0.6894	0.1448	0.0004	<.0001	<.0001	0.0078	0.0116	0.5868
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_P	0.15404	0.40916	-0.00393	0.45137	0.37162	0.13645	0.04271	0.02472	0.20769	-0.42683	-0.25011	0.61342	0.6209	-0.35265
	0.2855	0.0032	0.9784	0.001	0.0079	0.3447	0.7684	0.8647	0.1478	0.002	0.0798	<.0001	<.0001	0.012
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_K	0.2698	0.27421	-0.12101	0.29841	0.30671	-0.02949	-0.13728	-0.1073	0.26036	0.00527	-0.39274	0.33963	0.34063	-0.69763
	0.0581	0.054	0.4025	0.0353	0.0303	0.8389	0.3418	0.4583	0.0678	0.971	0.0048	0.0158	0.0155	<.0001
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_Ca	0.33885	0.40783	-0.0332	0.38279	0.44343	0.20235	0.07687	0.01873	0.33602	-0.17171	-0.10645	0.38293	0.45618	-0.43638
	0.0161	0.0033	0.8189	0.0061	0.0013	0.1588	0.5957	0.8973	0.017	0.2331	0.4619	0.0061	0.0009	0.0015
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_Mg	0.44181	0.46102	-0.08644	0.43399	0.52126	0.24034	0.06001	0.04795	0.39591	-0.10181	0.01886	0.33074	0.41021	-0.37616
	0.0013	0.0008	0.5506	0.0016	0.0001	0.0927	0.6789	0.7409	0.0044	0.4817	0.8966	0.019	0.0031	0.0071
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_S	0.12273	0.25726	0.07783	0.26028	0.23251	0.12284	0.081	0.02093	0.32828	-0.15756	-0.25786	0.39038	0.45148	-0.56336
	0.3958	0.0713	0.5911	0.0679	0.1042	0.3954	0.576	0.8853	0.0199	0.2745	0.0706	0.0051	0.001	<.0001
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_B	0.32737	0.32984	-0.06274	0.32424	0.38473	0.11173	0.04931	-0.0187	0.04461	0.06549	-0.26655	0.10803	0.10778	-0.61892
	0.0203	0.0193	0.6651	0.0216	0.0058	0.4398	0.7338	0.8975	0.7584	0.6514	0.0613	0.4552	0.4562	<.0001
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_Na	0.38955	0.07209	-0.06294	-0.04727	0.22784	0.16104	0.11301	-0.00742	0.33402	0.43449	0.17114	-0.28194	-0.17636	-0.23373
	0.0082	0.6379	0.6813	0.7578	0.1322	0.2906	0.4598	0.9614	0.0249	0.0029	0.261	0.0606	0.2465	0.1223
	50	50	50	50	50	50	50	50	50	50	50	50	50	50

Table 12. Continued

Attributes	Soil_Na	Foliar_N	Foliar_P	Foliar_K	Foliar_Ca	Foliar_Mg	Foliar_S	Foliar_B
Foliar_N	-0.0943	--	--	--	--	--	--	--
	0.5148	--	--	--	--	--	--	--
	50	--	--	--	--	--	--	--
Foliar_P	-0.04676	0.32274	--	--	--	--	--	--
	0.7471	0.0223	--	--	--	--	--	--
	50	50	--	--	--	--	--	--
Foliar_K	-0.41374	0.09052	0.84738	--	--	--	--	--
	0.0028	0.5318	<.0001	--	--	--	--	--
	50	50	50	--	--	--	--	--
Foliar_Ca	0.02098	-0.03625	0.85268	0.83712	--	--	--	--
	0.885	0.8027	<.0001	<.0001	--	--	--	--
	50	50	50	50	--	--	--	--
Foliar_Mg	0.07593	-0.21288	0.76546	0.7629	0.97892	--	--	--
	0.6002	0.1377	<.0001	<.0001	<.0001	--	--	--
	50	50	50	50	50	--	--	--
Foliar_S	-0.15948	0.20173	0.91622	0.91273	0.9173	0.83608	--	--
	0.2686	0.1601	<.0001	<.0001	<.0001	<.0001	--	--
	50	50	50	50	50	50	--	--
Foliar_B	-0.28929	-0.04045	0.75403	0.88744	0.83012	0.78338	0.79915	--
	0.0416	0.7803	<.0001	<.0001	<.0001	<.0001	<.0001	--
	50	50	50	50	50	50	50	--
Foliar_Na	-0.02324	-0.72954	-0.59513	0.25209	0.82848	0.82781	0.23416	0.48406
	0.8796	<.0001	<.0001	0.0948	<.0001	<.0001	0.1216	0.0008
	50	50	50	50	50	50	50	50

Note: All data were correlated based on means and subjected to Pearson's correlation procedure. Correlation coefficient (slope) (r) is displayed as the top number in each row for each column and its significance level is displayed as the second number for each row and column. The third number in each set is n.

Table 13. Pearson's correlation coefficients (r) among selected nutrients in mulches (N, P, K, Ca, Mg, S, B), soil nutrients (P, K, Ca, Mg, S, Na) soil pH, and foliar nutrients/minerals (N, P, K, Ca, Mg, S, B, Na) in first year longleaf pine seedlings treated with corn stover-hog manure (*Corn High and Corn Low)* mulch treatment applied in May 2007 in Goldsboro, NC. Treatment details are described in text.

Attributes	**Mulch_N**	**Mulch_P**	**Mulch_K**	**Mulch_Ca**	**Mulch_Mg**	**Mulch_S**	**Mulch_B**	**Mulch_Na**	**Soil_pH**	**Soil_P**	**Soil_K**	**Soil_Ca**	**Soil_Mg**	**Soil_S**
Mulch_P	0.58303	--	--	--	--	--	--	--	--	--	--	--	--	--
	<.0001	--	--	--	--	--	--	--	--	--	--	--	--	--
	50	--	--	--	--	--	--	--	--	--	--	--	--	--
Mulch_K	0.30546	-0.14193	--	--	--	--	--	--	--	--	--	--	--	--
	0.031	0.3255	--	--	--	--	--	--	--	--	--	--	--	--
	50	50	--	--	--	--	--	--	--	--	--	--	--	--
Mulch_Ca	0.53981	0.97994	-0.1912	--	--	--	--	--	--	--	--	--	--	--
	<.0001	<.0001	0.1835	--	--	--	--	--	--	--	--	--	--	--
	50	50	50	--	--	--	--	--	--	--	--	--	--	--
Mulch_Mg	0.62716	0.82282	-0.36296	0.87515	--	--	--	--	--	--	--	--	--	--
	<.0001	<.0001	0.0096	<.0001	--	--	--	--	--	--	--	--	--	--
	50	50	50	50	--	--	--	--	--	--	--	--	--	--
Mulch_S	0.68506	0.28611	0.82363	0.20579	0.10734	--	--	--	--	--	--	--	--	--
	<.0001	0.044	<.0001	0.1516	0.4581	--	--	--	--	--	--	--	--	--
	50	50	50	50	50	--	--	--	--	--	--	--	--	--
Mulch_B	0.32371	-0.00485	0.69954	-0.14684	-0.24358	0.80201	--	--	--	--	--	--	--	--
	0.0218	0.9733	<.0001	0.3089	0.0883	<.0001	--	--	--	--	--	--	--	--
	50	50	50	50	50	50	--	--	--	--	--	--	--	--
Mulch_Na	0.58593	0.51009	0.71246	0.4058	0.14789	0.89431	0.77436	--	--	--	--	--	--	--
	<.0001	0.0002	<.0001	0.0035	0.3054	<.0001	<.0001	--	--	--	--	--	--	--
	50	50	50	50	50	50	50	--	--	--	--	--	--	--
Soil_pH	0.41753	0.50411	-0.13301	0.41136	0.35292	0.18926	0.21278	0.29669	--	--	--	--	--	--
	0.0026	0.0002	0.3571	0.003	0.0119	0.188	0.1379	0.0364	--	--	--	--	--	--
	50	50	50	50	50	50	50	50	--	--	--	--	--	--
Soil_P	-0.28427	0.03285	-0.46206	0.16176	0.22596	-0.46799	-0.75277	-0.55581	-0.42536	--	--	--	--	--
	0.0454	0.8208	0.0007	0.2617	0.1146	0.0006	<.0001	<.0001	0.0021	--	--	--	--	--
	50	50	50	50	50	50	50	50	50	--	--	--	--	--
Soil_K	-0.01525	-0.00891	-0.45008	-0.01756	0.14773	-0.29446	-0.27275	-0.3928	0.43625	0.21902	--	--	--	--
	0.9163	0.951	0.001	0.9036	0.3059	0.0379	0.0553	0.0048	0.0015	0.1265	--	--	--	--
	50	50	50	50	50	50	50	50	50	50	--	--	--	--
Soil_Ca	0.24612	-0.03216	0.20557	-0.13994	-0.08045	0.33541	0.64417	0.35894	0.6033	-0.88351	0.10009	--	--	--
	0.0849	0.8245	0.1521	0.3324	0.5787	0.0173	<.0001	0.0105	<.0001	<.0001	0.4892	--	--	--
	50	50	50	50	50	50	50	50	50	50	50	--	--	--

Table 13. Continued

Attributes	Mulch_N	Mulch_P	Mulch_K	Mulch_Ca	Mulch_Mg	Mulch_S	Mulch_B	Mulch_Na	Soil_pH	Soil_P	Soil_K	Soil_Ca	Soil_Mg	Soil_S
Soil_Mg	0.32863	0.12886	0.21616	0.00903	-0.0011	0.3709	0.65125	0.47039	0.62465	-0.92385	-0.14741	0.93059	--	--
	0.0198	0.3725	0.1316	0.9504	0.994	0.008	<.0001	0.0006	<.0001	<.0001	0.307	<.0001	--	--
	50	50	50	50	50	50	50	50	50	50	50	50	--	--
Soil_S	-0.02109	-0.09782	-0.38235	-0.11254	0.08719	-0.21744	-0.18306	-0.37481	0.27798	0.27137	0.96568	0.04172	-0.232	--
	0.8844	0.4992	0.0061	0.4365	0.5471	0.1293	0.2032	0.0073	0.0506	0.0566	<.0001	0.7736	0.105	--
	50	50	50	50	50	50	50	50	50	50	50	50	50	--
Soil_Na	0.11665	-0.08274	-0.31738	-0.09834	0.19413	-0.08904	-0.02671	-0.28279	0.21938	0.12295	0.8691	0.17614	-0.09285	0.93333
	0.4198	0.5678	0.0247	0.4969	0.1767	0.5386	0.8539	0.0466	0.1258	0.395	<.0001	0.2211	0.5213	<.0001
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_N	0.22653	0.41759	-0.48221	0.32033	0.25139	-0.26288	-0.17872	-0.02569	0.43145	-0.11536	0.15506	0.04552	0.21865	0.06665
	0.1137	0.0026	0.0004	0.0233	0.0782	0.0651	0.2143	0.8594	0.0018	0.425	0.2823	0.7536	0.1271	0.6456
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_P	-0.07356	0.20506	-0.78074	0.19818	0.32633	-0.52655	-0.50378	-0.49385	0.02591	0.56439	0.3689	-0.44953	-0.3836	0.39944
	0.6117	0.1531	<.0001	0.1677	0.0207	<.0001	0.0002	0.0003	0.8582	<.0001	0.0084	0.0011	0.006	0.0041
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_K	-0.66759	-0.1093	-0.85595	-0.07894	-0.07173	-0.89519	-0.66881	-0.74761	0.02926	0.50968	0.44299	-0.31303	-0.35374	0.38276
	<.0001	0.4499	<.0001	0.5858	0.6206	<.0001	<.0001	<.0001	0.8402	0.0002	0.0013	0.0269	0.0117	0.0061
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_Ca	0.09724	-0.01673	-0.22084	-0.09333	0.09312	0.02707	0.39393	0.03924	0.55333	-0.60472	0.24113	0.87489	0.78506	0.2048
	0.5017	0.9082	0.1233	0.5191	0.5201	0.852	0.0046	0.7867	<.0001	<.0001	0.0916	<.0001	<.0001	0.1537
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_Mg	0.38769	0.06174	-0.0528	0.00684	0.24114	0.18156	0.38515	0.13344	0.47102	-0.65917	-0.08497	0.75466	0.82811	-0.14364
	0.0054	0.6702	0.7157	0.9624	0.0916	0.207	0.0057	0.3556	0.0006	<.0001	0.5574	<.0001	<.0001	0.3197
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_S	0.00253	-0.34493	-0.04423	-0.42669	-0.39	-0.13741	-0.02623	-0.20476	0.19319	-0.13663	0.57423	0.18143	0.01029	0.58129
	0.9861	0.0142	0.7604	0.002	0.0051	0.3413	0.8565	0.1537	0.1789	0.3441	<.0001	0.2073	0.9435	<.0001
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_B	-0.0273	0.20716	-0.36343	0.14393	-0.03182	-0.39409	-0.37273	-0.15206	0.16051	0.08499	0.12989	-0.2577	-0.1145	0.04132
	0.8507	0.1489	0.0095	0.3187	0.8264	0.0046	0.0077	0.2918	0.2655	0.5573	0.3686	0.0708	0.4285	0.7757
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_Na	-0.06916	0.15047	-0.57593	0.09987	0.2866	-0.21976	0.04791	-0.18549	0.02074	0.14068	0.3122	0.05956	0.00699	0.42395
	0.6332	0.2969	<.0001	0.4902	0.0436	0.1252	0.7411	0.1972	0.8863	0.3298	0.0273	0.6812	0.9616	0.0022
	50	50	50	50	50	50	50	50	50	50	50	50	50	50

Table 13. Continued

Attributes	Soil_Na	Foliar_N	Foliar_P	Foliar_K	Foliar_Ca	Foliar_Mg	Foliar_S	Foliar_B
Foliar_N	-0.00964	--	--	--	--	--	--	--
	0.947	--	--	--	--	--	--	--
	50	--	--	--	--	--	--	--
Foliar_P	0.32507	0.61584	--	--	--	--	--	--
	0.0213	<.0001	--	--	--	--	--	--
	50	50	--	--	--	--	--	--
Foliar_K	0.18578	0.36626	0.67518	--	--	--	--	--
	0.1965	0.0089	<.0001	--	--	--	--	--
	50	50	50	--	--	--	--	--
Foliar_Ca	0.34443	0.1223	-0.08198	0.02936	--	--	--	--
	0.0143	0.3975	0.5714	0.8396	--	--	--	--
	50	50	50	50	--	--	--	--
Foliar_Mg	0.08126	0.16473	-0.11396	-0.27185	0.79166	--	--	--
	0.5748	0.2529	0.4307	0.0562	<.0001	--	--	--
	50	50	50	50	50	--	--	--
Foliar_S	0.43673	0.37144	0.13533	0.18774	0.08721	-0.16125	--	--
	0.0015	0.0079	0.3487	0.1917	0.547	0.2633	--	--
	50	50	50	50	50	50	--	--
Foliar_B	-0.14137	0.86749	0.51818	0.44379	-0.27582	-0.25687	0.50098	--
	0.3275	<.0001	0.0001	0.0012	0.0525	0.0717	0.0002	--
	50	50	50	50	50	50	50	--
Foliar_Na	0.54726	0.29572	0.65573	0.39346	0.42729	0.19098	-0.02821	0.00289
	<.0001	0.0371	<.0001	0.0047	0.002	0.184	0.8458	0.9841
	50	50	50	50	50	50	50	50

Note: All data were correlated based on means and subjected to Pearson's correlation procedure. Correlation coefficient (slope) (r) is displayed as the top number in each row for each column and its significance level is displayed as the second number for each row and column. The third number in each set is n.

Table 14. Pearson's correlation coefficients (r) among selected nutrients in mulches (N, P, K, Ca, Mg, S, B), soil nutrients (P, K, Ca, Mg, S, Na) soil pH, and foliar nutrients/minerals (N, P, K, Ca, Mg, S, B, Na) in first year cherrybark oak seedlings treated with hay mulch (*Hay High and Hay Low)* treatment applied in May 2007 in Goldsboro, NC. Treatment details are described in text.

Attributes	**Mulch_N**	**Mulch_P**	**Mulch_K**	**Mulch_Ca**	**Mulch_Mg**	**Mulch_S**	**Mulch_B**	**Mulch_Na**	**Soil_pH**	**Soil_P**	**Soil_K**	**Soil_Ca**	**Soil_Mg**	**Soil_S**
Mulch_P	-0.55706	--	--	--	--	--	--	--	--	--	--	--	--	--
	<.0001	--	--	--	--	--	--	--	--	--	--	--	--	--
	50	--	--	--	--	--	--	--	--	--	--	--	--	--
Mulch_K	-0.42387	-0.13035	--	--	--	--	--	--	--	--	--	--	--	--
	0.0022	0.3669	--	--	--	--	--	--	--	--	--	--	--	--
	50	50	--	--	--	--	--	--	--	--	--	--	--	--
Mulch_Ca	0.47412	0.09446	-0.37262	--	--	--	--	--	--	--	--	--	--	--
	0.0005	0.5141	0.0077	--	--	--	--	--	--	--	--	--	--	--
	50	50	50	--	--	--	--	--	--	--	--	--	--	--
Mulch_Mg	-0.21601	0.6469	-0.06896	0.19838	--	--	--	--	--	--	--	--	--	--
	0.1319	<.0001	0.6342	0.1673	--	--	--	--	--	--	--	--	--	--
	50	50	50	50	--	--	--	--	--	--	--	--	--	--
Mulch_S	0.42186	-0.03808	0.07646	0.86173	0.11032	--	--	--	--	--	--	--	--	--
	0.0023	0.7929	0.5977	<.0001	0.4457	--	--	--	--	--	--	--	--	--
	50	50	50	50	50	--	--	--	--	--	--	--	--	--
Mulch_B	-0.58245	0.45817	0.21385	-0.11029	0.54952	-0.15059	--	--	--	--	--	--	--	--
	<.0001	0.0008	0.1359	0.4458	<.0001	0.2965	--	--	--	--	--	--	--	--
	50	50	50	50	50	50	--	--	--	--	--	--	--	--
Mulch_Na	-0.40299	0.06483	0.16441	-0.70749	0.35967	-0.65809	0.25514	--	--	--	--	--	--	--
	0.0037	0.6547	0.2539	<.0001	0.0103	<.0001	0.0737	--	--	--	--	--	--	--
	50	50	50	50	50	50	50	--	--	--	--	--	--	--
Soil_PH	0.18444	-0.23472	-0.33488	0.04278	-0.0282	-0.22751	0.28333	-0.17207	--	--	--	--	--	--
	0.1998	0.1008	0.0174	0.768	0.8459	0.1121	0.0462	0.2321	--	--	--	--	--	--
	50	50	50	50	50	50	50	50	--	--	--	--	--	--
Soil_P	0.04728	-0.2744	0.05681	0.449	-0.02081	0.41548	0.45185	-0.36539	0.52746	--	--	--	--	--
	0.7444	0.0538	0.6951	0.0011	0.886	0.0027	0.001	0.0091	<.0001	--	--	--	--	--
	50	50	50	50	50	50	50	50	50	--	--	--	--	--
Soil_K	-0.23482	0.31829	-0.12752	0.43679	0.10555	0.29482	0.40544	-0.48321	0.30162	0.58681	--	--	--	--
	0.1007	0.0243	0.3775	0.0015	0.4657	0.0377	0.0035	0.0004	0.0333	<.0001	--	--	--	--
	50	50	50	50	50	50	50	50	50	50	--	--	--	--
Soil_Ca	0.30703	-0.26425	-0.22326	-0.56102	-0.2748	-0.57117	-0.39944	0.41544	-0.14173	-0.67516	-0.5907	--	--	--
	0.0301	0.0637	0.1191	<.0001	0.0534	<.0001	0.0041	0.0027	0.3262	<.0001	<.0001	--	--	--
	50	50	50	50	50	50	50	50	50	50	50	--	--	--

Table 14. Continued

Attributes	Mulch_N	Mulch_P	Mulch_K	Mulch_Ca	Mulch_Mg	Mulch_S	Mulch_B	Mulch_Na	Soil_pH	Soil_P	Soil_K	Soil_Ca	Soil_Mg	Soil_S
Soil_Mg	-0.11324	0.22314	-0.15317	-0.63453	-0.01714	-0.69415	-0.21175	0.49241	-0.284	-0.88172	-0.45613	0.83935	--	--
	0.4336	0.1193	0.2883	<.0001	0.906	<.0001	0.1399	0.0003	0.0456	<.0001	0.0009	<.0001	--	--
	50	50	50	50	50	50	50	50	50	50	50	50	--	--
Soil_S	-0.12419	0.22169	0.18464	-0.14879	0.10422	0.01607	-0.19754	0.3294	-0.89814	-0.59925	-0.29551	0.39928	0.52293	--
	0.3902	0.1218	0.1993	0.3024	0.4714	0.9118	0.1691	0.0195	<.0001	<.0001	0.0372	0.0041	<.0001	--
	50	50	50	50	50	50	50	50	50	50	50	50	50	--
Soil_Na	0.29671	0.38004	0.01102	0.1995	0.31793	0.26517	-0.0778	-0.30426	-0.13401	-0.41583	-0.06372	0.1635	0.29304	0.17032
	0.0364	0.0065	0.9395	0.1648	0.0244	0.0627	0.5913	0.0317	0.3535	0.0027	0.6602	0.2566	0.0389	0.237
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_N	0.22564	0.24985	-0.40228	0.39514	0.49458	0.28582	0.40211	-0.11041	0.39328	0.412	0.38063	-0.22878	-0.33854	-0.39569
	0.1151	0.0801	0.0038	0.0045	0.0003	0.0442	0.0038	0.4453	0.0047	0.0029	0.0064	0.11	0.0162	0.0045
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_P	-0.52579	0.27756	0.07388	-0.5517	-0.17057	-0.6585	0.32593	0.18495	0.03529	-0.25217	0.20928	0.33143	0.57638	0.21583
	<.0001	0.051	0.6101	<.0001	0.2363	<.0001	0.0209	0.1985	0.8078	0.0773	0.1447	0.0187	<.0001	0.1322
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_K	-0.20976	-0.39513	0.43381	0.03728	-0.65437	0.21543	-0.04184	-0.36711	-0.05296	0.48191	0.14131	-0.43164	-0.54261	-0.19681
	0.1437	0.0045	0.0016	0.7971	<.0001	0.133	0.7729	0.0087	0.7149	0.0004	0.3276	0.0017	<.0001	0.1707
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_Ca	0.24793	0.21444	-0.21635	-0.20812	0.45997	-0.25214	-0.27818	0.43875	-0.16367	-0.74527	-0.51765	0.56058	0.65714	0.31736
	0.0826	0.1348	0.1313	0.147	0.0008	0.0773	0.0505	0.0014	0.2561	<.0001	0.0001	<.0001	<.0001	0.0247
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_Mg	0.3011	0.08408	-0.65317	-0.28797	-0.12257	-0.53605	-0.28404	0.14435	0.16925	-0.58275	-0.35483	0.76926	0.72729	0.0259
	0.0336	0.5616	<.0001	0.0426	0.3965	<.0001	0.0456	0.3173	0.24	<.0001	0.0115	<.0001	<.0001	0.8583
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_S	0.04637	0.19347	0.14145	-0.00401	0.79859	0.05484	0.48828	0.39176	0.22183	0.10184	-0.03025	-0.07306	-0.05786	-0.10909
	0.7492	0.1782	0.3272	0.978	<.0001	0.7052	0.0003	0.0049	0.1216	0.4816	0.8348	0.6141	0.6898	0.4508
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_B	0.4703	0.03509	-0.49167	0.74671	0.07279	0.47958	0.09008	-0.73422	0.59053	0.52185	0.39926	-0.42695	-0.52819	-0.62639
	0.0006	0.8088	0.0003	<.0001	0.6154	0.0004	0.5338	<.0001	<.0001	0.0001	0.0041	0.002	<.0001	<.0001
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_Na	-0.6074	0.07442	0.39416	-0.63935	-0.13138	-0.44335	0.46292	0.43175	-0.04777	0.06885	-0.11138	0.03413	0.06324	-0.06146
	<.0001	0.6075	0.0046	<.0001	0.3631	0.0013	0.0007	0.0017	0.7418	0.6347	0.4413	0.814	0.6626	0.6716
	50	50	50	50	50	50	50	50	50	50	50	50	50	50

Table 14. Continued

Attributes	Soil_Na	Foliar_N	Foliar_P	Foliar_K	Foliar_Ca	Foliar_Mg	Foliar_S	Foliar_B
Foliar_N	0.18953	--	--	--	--	--	--	--
	0.1874	--	--	--	--	--	--	--
	50	--	--	--	--	--	--	--
Foliar_P	-0.00191	-0.37427	--	--	--	--	--	--
	0.9895	0.0074	--	--	--	--	--	--
	50	50	--	--	--	--	--	--
Foliar_K	-0.5394	-0.39548	-0.02331	--	--	--	--	--
	<.0001	0.0045	0.8723	--	--	--	--	--
	50	50	50	--	--	--	--	--
Foliar_Ca	0.55034	0.04941	-0.09301	-0.87371	--	--	--	--
	<.0001	0.7333	0.5206	<.0001	--	--	--	--
	50	50	50	50	--	--	--	--
Foliar_Mg	0.27745	0.11318	0.27303	-0.544	0.53157	--	--	--
	0.0511	0.4339	0.0551	<.0001	<.0001	--	--	--
	50	50	50	50	50	--	--	--
Foliar_S	0.36421	0.55445	-0.24749	-0.63332	0.49108	-0.11234	--	--
	0.0093	<.0001	0.0831	<.0001	0.0003	0.4373	--	--
	50	50	50	50	50	50	--	--
Foliar_B	0.25556	0.48797	-0.2952	0.01158	-0.23736	0.04881	0.03447	--
	0.0733	0.0003	0.0374	0.9364	0.097	0.7364	0.8122	--
	50	50	50	50	50	50	50	--
Foliar_Na	-0.3792	0.05954	0.26346	0.34496	-0.3364	-0.02641	-0.0502	-0.44589
	0.0066	0.6813	0.0645	0.0142	0.0169	0.8556	0.7292	0.0012
	50	50	50	50	50	50	50	50

Note: All data were correlated based on means and subjected to Pearson's correlation procedure. Correlation coefficient (slope) (r) is displayed as the top number in each row for each column and its significance level is displayed as the second number for each row and column. The third number in each set is n.

Table 15. Pearson's correlation coefficients (r) among selected nutrients in mulches (N, P, K, Ca, Mg, S, B), soil nutrients (P, K, Ca, Mg, S, Na) soil pH, and foliar nutrients/minerals (N, P, K, Ca, Mg, S, B, Na) in first year loblolly pine seedlings treated with hay mulch (*Hay High and Hay Low)* applied in May 2007 in Goldsboro, NC. Treatment details are described in text.

Attributes	Mulch_N	Mulch_P	Mulch_K	Mulch_Ca	Mulch_Mg	Mulch_S	Mulch_B	Mulch_Na	Soil_pH	Soil_P	Soil_K	Soil_Ca	Soil_Mg	Soil_S
Mulch_P	-0.73622	--	--	--	--	--	--	--	--	--	--	--	--	--
	<.0001	--	--	--	--	--	--	--	--	--	--	--	--	--
	50	--	--	--	--	--	--	--	--	--	--	--	--	--
Mulch_K	0.73601	-0.20329	--	--	--	--	--	--	--	--	--	--	--	--
	<.0001	0.1568	--	--	--	--	--	--	--	--	--	--	--	--
	50	50	--	--	--	--	--	--	--	--	--	--	--	--
Mulch_Ca	0.8252	-0.69854	0.60597	--	--	--	--	--	--	--	--	--	--	--
	<.0001	<.0001	<.0001	--	--	--	--	--	--	--	--	--	--	--
	50	50	50	--	--	--	--	--	--	--	--	--	--	--
Mulch_Mg	-0.71619	0.56627	-0.36316	-0.3348	--	--	--	--	--	--	--	--	--	--
	<.0001	<.0001	0.0095	0.0175	--	--	--	--	--	--	--	--	--	--
	50	50	50	50	--	--	--	--	--	--	--	--	--	--
Mulch_S	0.79627	-0.40036	0.86713	0.84126	-0.29437	--	--	--	--	--	--	--	--	--
	<.0001	0.004	<.0001	<.0001	0.038	--	--	--	--	--	--	--	--	--
	50	50	50	50	50	--	--	--	--	--	--	--	--	--
Mulch_B	-0.26145	0.29432	-0.09251	0.03031	0.65224	0.07124	--	--	--	--	--	--	--	--
	0.0667	0.038	0.5229	0.8345	<.0001	0.623	--	--	--	--	--	--	--	--
	50	50	50	50	50	50	--	--	--	--	--	--	--	--
Mulch_Na	-0.65882	0.52785	-0.40953	-0.35774	0.87721	-0.31047	0.84655	--	--	--	--	--	--	--
	<.0001	<.0001	0.0031	0.0108	<.0001	0.0282	<.0001	--	--	--	--	--	--	--
	50	50	50	50	50	50	50	--	--	--	--	--	--	--
Soil_pH	-0.38887	0.19409	-0.28235	-0.2201	0.1036	-0.42893	-0.1117	0.0005	--	--	--	--	--	--
	0.0053	0.1768	0.047	0.1246	0.474	0.0019	0.44	0.9972	--	--	--	--	--	--
	50	50	50	50	50	50	50	50	--	--	--	--	--	--
Soil_P	-0.04383	0.05694	-0.16851	-0.02292	-0.17582	-0.01486	0.10465	-0.03349	-0.27741	--	--	--	--	--
	0.7625	0.6945	0.2421	0.8745	0.222	0.9184	0.4695	0.8174	0.0511	--	--	--	--	--
	50	50	50	50	50	50	50	50	50	--	--	--	--	--
Soil_K	-0.48317	0.2222	-0.22739	-0.1759	0.7804	-0.2358	0.56269	0.6479	0.38601	-0.45826	--	--	--	--
	0.0004	0.1209	0.1123	0.2217	<.0001	0.0992	<.0001	<.0001	0.0056	0.0008	--	--	--	--
	50	50	50	50	50	50	50	50	50	50	--	--	--	--
Soil_Ca	0.40324	-0.32525	0.35849	0.37802	-0.27594	0.22533	-0.277	-0.34961	0.47615	-0.7829	0.1213	--	--	--
	0.0037	0.0212	0.0106	0.0068	0.0524	0.1156	0.0515	0.0128	0.0005	<.0001	0.4014	--	--	--
	50	50	50	50	50	50	50	50	50	50	50	--	--	--

Table 15. Continued

Attributes	Mulch_N	Mulch_P	Mulch_K	Mulch_Ca	Mulch_Mg	Mulch_S	Mulch_B	Mulch_Na	Soil_pH	Soil_P	Soil_K	Soil_Ca	Soil_Mg	Soil_S
Soil_Mg	-0.03019	-0.03868	0.03149	0.05829	0.12473	-0.03727	0.02828	0.13577	0.5345	-0.84847	0.39685	0.82697	--	--
	0.8351	0.7897	0.8281	0.6876	0.3881	0.7972	0.8454	0.3472	<.0001	<.0001	0.0043	<.0001	--	--
	50	50	50	50	50	50	50	50	50	50	50	50	--	--
Soil_S	0.63518	-0.48955	0.29403	0.5364	-0.43394	0.54203	-0.01054	-0.18489	-0.57637	-0.01619	-0.5418	0.15498	0.11561	--
	<.0001	0.0003	0.0382	<.0001	0.0016	<.0001	0.9421	0.1987	<.0001	0.9112	<.0001	0.2825	0.424	--
	50	50	50	50	50	50	50	50	50	50	50	50	50	--
Soil_Na	0.42103	-0.31756	0.38364	0.09602	-0.64895	0.11494	-0.89328	-0.79536	0.13297	-0.3837	-0.44831	0.5586	0.24361	0.09492
	0.0023	0.0246	0.006	0.5071	<.0001	0.4267	<.0001	<.0001	0.3573	0.0059	0.0011	<.0001	0.0882	0.512
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_N	-0.46643	0.50019	-0.25655	-0.19818	0.67556	-0.19618	0.46986	0.63699	0.2831	-0.54647	0.53884	0.27966	0.62812	-0.03728
	0.0006	0.0002	0.0721	0.1677	<.0001	0.1721	0.0006	<.0001	0.0464	<.0001	<.0001	0.0492	<.0001	0.7971
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_P	-0.31165	0.18273	-0.32295	-0.45062	0.13685	-0.41857	-0.00214	0.0843	0.36496	-0.52991	0.44653	0.29026	0.44286	-0.27621
	0.0276	0.204	0.0222	0.001	0.3433	0.0025	0.9882	0.5605	0.0092	<.0001	0.0012	0.0409	0.0013	0.0522
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_K	0.24704	-0.20128	0.058	0.30841	-0.25526	0.26129	0.22506	-0.18686	-0.01097	0.6108	-0.1032	-0.29596	-0.48338	-0.04009
	0.0837	0.161	0.6891	0.0293	0.0736	0.0668	0.1161	0.1938	0.9397	<.0001	0.4757	0.0369	0.0004	0.7822
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_Ca	0.29494	-0.06118	0.61543	0.23543	-0.12761	0.41697	0.01147	-0.0425	0.21366	-0.52747	0.12242	0.60707	0.63791	0.18147
	0.0376	0.673	<.0001	0.0998	0.3772	0.0026	0.937	0.7695	0.1363	<.0001	0.397	<.0001	<.0001	0.2072
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_Mg	0.29171	-0.37657	0.37723	0.05909	-0.32115	0.10991	-0.29762	-0.33823	0.23898	-0.4481	0.20741	0.47248	0.34721	-0.16381
	0.0398	0.007	0.0069	0.6836	0.023	0.4473	0.0358	0.0163	0.0946	0.0011	0.1484	0.0005	0.0135	0.2557
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_S	-0.04731	0.35722	0.27027	-0.23707	-0.1258	0.02013	0.00553	-0.14788	0.43035	-0.20229	0.18846	0.27016	0.21924	-0.37177
	0.7442	0.0109	0.0577	0.0974	0.384	0.8896	0.9696	0.3054	0.0018	0.1589	0.19	0.0578	0.1261	0.0079
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_B	0.3807	-0.44983	0.33293	0.2558	-0.21083	0.26682	0.27617	-0.02336	-0.05781	-0.02136	0.26172	0.10215	0.01662	0.0063
	0.0064	0.001	0.0182	0.073	0.1416	0.0611	0.0522	0.8721	0.69	0.883	0.0664	0.4802	0.9088	0.9654
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_Na	0.45229	-0.1718	0.67922	0.13438	-0.35795	0.35694	-0.51438	-0.58027	-0.17585	-0.30727	-0.11993	0.27771	-0.08424	-0.15193
	0.001	0.2329	<.0001	0.3521	0.0107	0.0109	0.0001	<.0001	0.2219	0.03	0.4068	0.0509	0.5608	0.2922
	50	50	50	50	50	50	50	50	50	50	50	50	50	50

Table 15. Continued

Attributes	Soil_Na	Foliar_N	Foliar_P	Foliar_K	Foliar_Ca	Foliar_Mg	Foliar_S	Foliar_B
Foliar_N	-0.37222	--	--	--	--	--	--	--
	0.0078	--	--	--	--	--	--	--
	50	--	--	--	--	--	--	--
Foliar_P	-0.01018	0.42772	--	--	--	--	--	--
	0.9441	0.0019	--	--	--	--	--	--
	50	50	--	--	--	--	--	--
Foliar_K	-0.41075	-0.35853	0.00625	--	--	--	--	--
	0.003	0.0106	0.9657	--	--	--	--	--
	50	50	50	--	--	--	--	--
Foliar_Ca	0.38931	0.09652	-0.04867	-0.36436	--	--	--	--
	0.0052	0.5049	0.7371	0.0093	--	--	--	--
	50	50	50	50	--	--	--	--
Foliar_Mg	0.55065	-0.37137	0.22256	-0.16457	0.64814	--	--	--
	<.0001	0.0079	0.1203	0.2534	<.0001	--	--	--
	50	50	50	50	50	--	--	--
Foliar_S	0.09627	0.10353	0.61087	0.32438	0.31083	0.35691	--	--
	0.506	0.4743	<.0001	0.0215	0.028	0.0109	--	--
	50	50	50	50	50	50	--	--
Foliar_B	-0.06159	-0.42472	0.05348	0.32177	0.40255	0.71125	0.25201	--
	0.6709	0.0021	0.7122	0.0227	0.0038	<.0001	0.0775	--
	50	50	50	50	50	50	50	--
Foliar_Na	0.68804	-0.44884	-0.00031	-0.18042	0.34703	0.63873	0.28974	0.28214
	<.0001	0.0011	0.9983	0.2099	0.0135	<.0001	0.0413	0.0471
	50	50	50	50	50	50	50	50

Note: All data were correlated based on means and subjected to Pearson's correlation procedure. Correlation coefficient (slope) (r) is displayed as the top number in each row for each column and its significance level is displayed as the second number for each row and column. The third number in each set is n.

Table 16. Pearson's correlation coefficients (r) among selected nutrients in mulches (N, P, K, Ca, Mg, S, B), soil nutrients (P, K, Ca, Mg, S, Na) soil pH, and foliar nutrients/minerals (N, P, K, Ca, Mg, S, B, Na) in first year longleaf pine seedlings treated with hay mulch (*Hay High and Hay Low)* treatment applied in May 2007 in Goldsboro, NC. Treatment details are described in text.

Attributes	**Mulch_N**	**Mulch_P**	**Mulch_K**	**Mulch_Ca**	**Mulch_Mg**	**Mulch_S**	**Mulch_B**	**Mulch_Na**	**Soil_pH**	**Soil_P**	**Soil_K**	**Soil_Ca**	**Soil_Mg**	**Soil_S**
Mulch_P	0.15403	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.2855	--	--	--	--	--	--	--	--	--	--	--	--	--
	50	--	--	--	--	--	--	--	--	--	--	--	--	--
Mulch_K	0.59979	0.7513	--	--	--	--	--	--	--	--	--	--	--	--
	<.0001	<.0001	--	--	--	--	--	--	--	--	--	--	--	--
	50	50	--	--	--	--	--	--	--	--	--	--	--	--
Mulch_Ca	0.72741	-0.04064	0.54871	--	--	--	--	--	--	--	--	--	--	--
	<.0001	0.7793	<.0001	--	--	--	--	--	--	--	--	--	--	--
	50	50	50	--	--	--	--	--	--	--	--	--	--	--
Mulch_Mg	-0.12202	0.64739	0.23651	-0.34755	--	--	--	--	--	--	--	--	--	--
	0.3986	<.0001	0.0982	0.0134	--	--	--	--	--	--	--	--	--	--
	50	50	50	50	--	--	--	--	--	--	--	--	--	--
Mulch_S	0.78824	0.00399	0.55896	0.87881	-0.05904	--	--	--	--	--	--	--	--	--
	<.0001	0.978	<.0001	<.0001	0.6838	--	--	--	--	--	--	--	--	--
	50	50	50	50	50	--	--	--	--	--	--	--	--	--
Mulch_B	0.17501	0.59785	0.50571	-0.21466	0.30907	-0.09216	--	--	--	--	--	--	--	--
	0.2241	<.0001	0.0002	0.1344	0.029	0.5244	--	--	--	--	--	--	--	--
	50	50	50	50	50	50	--	--	--	--	--	--	--	--
Mulch_Na	-0.12003	0.52092	0.00977	-0.61343	0.76427	-0.35308	0.26606	--	--	--	--	--	--	--
	0.4064	0.0001	0.9463	<.0001	<.0001	0.0119	0.0618	--	--	--	--	--	--	--
	50	50	50	50	50	50	50	--	--	--	--	--	--	--
Soil_pH	0.27905	0.37826	0.37975	0.01883	0.17856	-0.03014	0.44495	0.29496	--	--	--	--	--	--
	0.0497	0.0068	0.0065	0.8968	0.2147	0.8354	0.0012	0.0376	--	--	--	--	--	--
	50	50	50	50	50	50	50	50	--	--	--	--	--	--
Soil_P	0.5654	0.21163	0.29775	0.03368	0.01156	0.26715	0.29406	0.37003	-0.03794	--	--	--	--	--
	<.0001	0.1401	0.0357	0.8164	0.9365	0.0607	0.0382	0.0082	0.7936	--	--	--	--	--
	50	50	50	50	50	50	50	50	50	--	--	--	--	--
Soil_K	0.46608	0.62334	0.51471	-0.11094	0.50512	0.14134	0.51811	0.73481	0.45421	0.73403	--	--	--	--
	0.0006	<.0001	0.0001	0.4431	0.0002	0.3275	0.0001	<.0001	0.0009	<.0001	--	--	--	--
	50	50	50	50	50	50	50	50	50	50	--	--	--	--
Soil_Ca	-0.43032	-0.2467	-0.18665	0.07735	-0.20626	-0.17193	-0.10367	-0.54216	0.16093	-0.92303	-0.74738	--	--	--
	0.0018	0.0841	0.1943	0.5934	0.1507	0.2325	0.4737	<.0001	0.2642	<.0001	<.0001	--	--	--
	50	50	50	50	50	50	50	50	50	50	50	--	--	--

Table 16. Continued

Attributes	Mulch_N	Mulch_P	Mulch_K	Mulch_Ca	Mulch_Mg	Mulch_S	Mulch_B	Mulch_Na	Soil_pH	Soil_P	Soil_K	Soil_Ca	Soil_Mg	Soil_S
Soil_Mg	-0.40177	-0.06514	-0.11257	0.02843	0.00778	-0.21692	-0.0771	-0.32923	0.32909	-0.94587	-0.58344	0.94909	--	--
	0.0038	0.6531	0.4364	0.8446	0.9572	0.1302	0.5946	0.0196	0.0196	<.0001	<.0001	<.0001	--	--
	50	50	50	50	50	50	50	50	50	50	50	50	--	--
Soil_S	0.34921	0.49967	0.33305	-0.25008	0.41442	0.02108	0.46195	0.75064	0.26387	0.82893	0.95512	-0.84663	-0.73385	--
	0.0129	0.0002	0.0181	0.0798	0.0028	0.8845	0.0007	<.0001	0.0641	<.0001	<.0001	<.0001	<.0001	--
	50	50	50	50	50	50	50	50	50	50	50	50	50	--
Soil_Na	0.20463	0.6248	0.38936	-0.33474	0.57198	-0.03086	0.61231	0.78284	0.30151	0.69067	0.92045	-0.68859	-0.57915	0.94931
	0.154	<.0001	0.0052	0.0175	<.0001	0.8316	<.0001	<.0001	0.0333	<.0001	<.0001	<.0001	<.0001	<.0001
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_N	0.15035	0.4532	0.60881	0.11808	0.11209	0.14019	0.80603	-0.16238	0.2747	0.00757	0.22775	0.16882	0.14179	0.13212
	0.2973	0.0009	<.0001	0.4141	0.4383	0.3315	<.0001	0.2599	0.0535	0.9584	0.1117	0.2412	0.326	0.3604
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_P	-0.47369	-0.54599	-0.48766	-0.22653	-0.13645	-0.05924	-0.1086	-0.27758	-0.488	-0.22647	-0.44306	0.28282	0.07051	-0.28615
	0.0005	<.0001	0.0003	0.1137	0.3447	0.6828	0.4528	0.051	0.0003	0.1138	0.0013	0.0466	0.6266	0.044
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_K	0.02077	-0.74835	-0.36909	0.27111	-0.71976	0.10079	-0.65485	-0.50557	-0.04714	-0.15526	-0.41527	0.18895	0.08416	-0.39993
	0.8862	<.0001	0.0083	0.0569	<.0001	0.4862	<.0001	0.0002	0.7451	0.2816	0.0027	0.1888	0.5612	0.004
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_Ca	0.46076	-0.14745	0.42555	0.60813	-0.43505	0.48998	0.18087	-0.62892	0.37629	-0.13751	-0.12713	0.36119	0.28919	-0.30574
	0.0008	0.3069	0.0021	<.0001	0.0016	0.0003	0.2088	<.0001	0.0071	0.341	0.379	0.01	0.0417	0.0308
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_Mg	0.47581	-0.06755	0.46066	0.71972	-0.34014	0.57352	-0.01907	-0.63301	0.24922	-0.20815	-0.24917	0.37645	0.32757	-0.45824
	0.0005	0.6412	0.0008	<.0001	0.0157	<.0001	0.8954	<.0001	0.0809	0.1469	0.081	0.007	0.0202	0.0008
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_S	0.50537	-0.41572	0.05768	0.34882	-0.29588	0.52276	-0.09803	-0.17087	0.02701	0.42515	0.27647	-0.35958	-0.42674	0.27939
	0.0002	0.0027	0.6907	0.013	0.037	<.0001	0.4982	0.2354	0.8523	0.0021	0.0519	0.0103	0.002	0.0494
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_B	0.34685	0.26674	0.18058	-0.1102	0.42092	0.06705	0.09745	0.67378	0.55718	0.38932	0.78383	-0.51766	-0.28801	0.69338
	0.0136	0.0611	0.2095	0.4462	0.0023	0.6436	0.5008	<.0001	<.0001	0.0052	<.0001	0.0001	0.0425	<.0001
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Foliar_Na	0.34115	-0.11172	0.27795	0.30675	-0.39242	0.20281	0.13287	-0.20783	0.68362	0.03707	0.20624	0.14908	0.15227	0.08827
	0.0153	0.4399	0.0507	0.0303	0.0048	0.1578	0.3576	0.1475	<.0001	0.7983	0.1507	0.3015	0.2911	0.5422
	50	50	50	50	50	50	50	50	50	50	50	50	50	50

Table 16. Continued

Attributes	Soil_Na	Foliar_N	Foliar_P	Foliar_K	Foliar_Ca	Foliar_Mg	Foliar_S	Foliar_B
Foliar_N	0.29669	--	--	--	--	--	--	--
	0.0364	--	--	--	--	--	--	--
	50	--	--	--	--	--	--	--
Foliar_P	-0.15573	0.08751	--	--	--	--	--	--
	0.2802	0.5456	--	--	--	--	--	--
	50	50	--	--	--	--	--	--
Foliar_K	-0.58824	-0.4245	0.10129	--	--	--	--	--
	<.0001	0.0021	0.484	--	--	--	--	--
	50	50	50	--	--	--	--	--
Foliar_Ca	-0.33133	0.4897	-0.09351	0.43572	--	--	--	--
	0.0188	0.0003	0.5183	0.0016	--	--	--	--
	50	50	50	50	--	--	--	--
Foliar_Mg	-0.49027	0.23942	-0.2712	0.38821	0.88183	--	--	--
	0.0003	0.094	0.0568	0.0053	<.0001	--	--	--
	50	50	50	50	50	--	--	--
Foliar_S	0.12513	0.08934	0.19449	0.51169	0.4734	0.21142	--	--
	0.3866	0.5372	0.1759	0.0001	0.0005	0.1405	--	--
	50	50	50	50	50	50	--	--
Foliar_B	0.58523	-0.08583	-0.44918	0.01001	-0.03472	-0.17198	0.44104	--
	<.0001	0.5534	0.0011	0.945	0.8108	0.2324	0.0013	--
	50	50	50	50	50	50	50	--
Foliar_Na	0.02257	0.28316	-0.15553	0.53728	0.7215	0.45422	0.56953	0.40418
	0.8764	0.0463	0.2808	<.0001	<.0001	0.0009	<.0001	0.0036
	50	50	50	50	50	50	50	50

Note: All data were correlated based on means and subjected to Pearson's correlation procedure. Correlation coefficient (slope) (r) is displayed as the top number in each row for each column and its significance level is displayed as the second number for each row and column. The third number in each set is n.

Table 17. Pearson's correlation coefficients (r) among selected soil nutrients (P, K, Ca, Mg, S, Na), and foliar nutrients/minerals (N, P, K, Ca, Mg, S, B, Na) in first year cherrybark oak seedlings treated with black plastic mulch and control (grouped together) treatment applied in May 2007 in Goldsboro, NC. Treatment details are described in text.

Attributes	**Soil_pH**	**Soil_P**	**Soil_K**	**Soil_Ca**	**Soil_Mg**	**Soil_S**	**Soil_Na**	**Foliar_N**	**Foliar_P**	**Foliar_K**	**Foliar_Ca**	**Foliar_Mg**	**Foliar_S**	**Foliar_B**
Soil_P	-0.0647	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.6553	--	--	--	--	--	--	--	--	--	--	--	--	--
	50	--	--	--	--	--	--	--	--	--	--	--	--	--
Soil_K	0.09569	-0.21013	--	--	--	--	--	--	--	--	--	--	--	--
	0.5086	0.143	--	--	--	--	--	--	--	--	--	--	--	--
	50	50	--	--	--	--	--	--	--	--	--	--	--	--
Soil_Ca	-0.11064	-0.19433	-0.10378	--	--	--	--	--	--	--	--	--	--	--
	0.4443	0.1763	0.4733	--	--	--	--	--	--	--	--	--	--	--
	50	50	50	--	--	--	--	--	--	--	--	--	--	--
Soil_Mg	0.13371	-0.89219	0.27203	-0.10511	--	--	--	--	--	--	--	--	--	--
	0.3546	<.0001	0.056	0.4676	--	--	--	--	--	--	--	--	--	--
	50	50	50	50	--	--	--	--	--	--	--	--	--	--
Soil_S	-0.68987	-0.44852	0.31099	0.29285	0.43792	--	--	--	--	--	--	--	--	--
	<.0001	0.0011	0.0279	0.039	0.0015	--	--	--	--	--	--	--	--	--
	50	50	50	50	50	--	--	--	--	--	--	--	--	--
Soil_Na	-0.422	-0.53399	0.04767	0.04545	0.46257	0.68555	--	--	--	--	--	--	--	--
	0.0023	<.0001	0.7424	0.754	0.0007	<.0001	--	--	--	--	--	--	--	--
	50	50	50	50	50	50	--	--	--	--	--	--	--	--
Foliar_N	0.08677	0.58714	-0.53211	-0.09841	-0.44667	-0.27908	-0.19347	--	--	--	--	--	--	--
	0.5491	<.0001	<.0001	0.4966	0.0011	0.0497	0.1782	--	--	--	--	--	--	--
	50	50	50	50	50	50	50	--	--	--	--	--	--	--
Foliar_P	0.11273	0.06854	-0.24872	0.54092	-0.16259	0.04113	-0.03221	0.56688	--	--	--	--	--	--
	0.4357	0.6363	0.0816	<.0001	0.2593	0.7767	0.8243	<.0001	--	--	--	--	--	--
	50	50	50	50	50	50	50	50	--	--	--	--	--	--
Foliar_K	0.06341	0.64751	-0.0222	0.1486	-0.58492	-0.21072	-0.32193	0.48801	0.60805	--	--	--	--	--
	0.6617	<.0001	0.8784	0.303	<.0001	0.1419	0.0226	0.0003	<.0001	--	--	--	--	--
	50	50	50	50	50	50	50	50	50	--	--	--	--	--

Table 17. Continued

Attributes	Soil_pH	Soil_P	Soil_K	Soil_Ca	Soil_Mg	Soil_S	Soil_Na	Foliar_N	Foliar_P	Foliar_K	Foliar_Ca	Foliar_Mg	Foliar_S	Foliar_B
Foliar_Ca	-0.04151	-0.68722	0.68786	0.04227	0.6508	0.5866	0.58202	-0.65006	-0.37704	-0.58443	--	--	--	--
	0.7747	<.0001	<.0001	0.7707	<.0001	<.0001	<.0001	<.0001	0.007	<.0001	--	--	--	--
	50	50	50	50	50	50	50	50	50	50	--	--	--	--
Foliar_Mg	0.61171	0.1307	0.36895	-0.63209	0.03763	-0.57552	-0.33563	-0.20253	-0.63505	-0.22533	0.18724	--	--	--
	<.0001	0.3656	0.0084	<.0001	0.7953	<.0001	0.0172	0.1584	<.0001	0.1156	0.1929	--	--	--
	50	50	50	50	50	50	50	50	50	50	50	--	--	--
Foliar_S	0.3056	0.10802	-0.38012	-0.48154	-0.1143	-0.52093	0.06376	0.35664	0.15856	0.13648	-0.37786	0.15701	--	--
	0.0309	0.4552	0.0065	0.0004	0.4293	0.0001	0.66	0.011	0.2714	0.3446	0.0068	0.2762	--	--
	50	50	50	50	50	50	50	50	50	50	50	50	--	--
Foliar_B	0.09477	0.82491	-0.35748	-0.29333	-0.81202	-0.61348	-0.45012	0.65041	0.01525	0.28952	-0.60082	0.25993	0.38716	--
	0.5127	<.0001	0.0108	0.0387	<.0001	<.0001	0.001	<.0001	0.9163	0.0414	<.0001	0.0683	0.0055	--
	50	50	50	50	50	50	50	50	50	50	50	50	50	--
Foliar_Na	-0.18932	-0.29495	0.59317	-0.03749	0.09629	0.24109	0.3442	-0.5254	-0.09911	-0.02448	0.45456	0.04301	0.07456	-0.26643
	0.1879	0.0376	<.0001	0.796	0.5059	0.0917	0.0144	<.0001	0.4935	0.866	0.0009	0.7668	0.6069	0.0615
	50	50	50	50	50	50	50	50	50	50	50	50	50	50

Note: All data were correlated based on means and subjected to Pearson's correlation procedure. Correlation coefficient (slope) (r) is displayed as the top number in each row for each column and its significance level is displayed as the second number for each row and column. The third number in each set is n.

Table 18. Pearson's correlation coefficients (r) among selected soil nutrients (P, K, Ca, Mg, S, Na), and foliar nutrients/minerals (N, P, K, Ca, Mg, S, B, Na) in first year loblolly pine seedlings treated with black plastic mulch and control (grouped together) treatment applied in May 2007 in Goldsboro, NC. Treatment details are described in text.

Attributes	**Soil_pH**	**Soil_P**	**Soil_K**	**Soil_Ca**	**Soil_Mg**	**Soil_S**	**Soil_Na**	**Foliar_N**	**Foliar_P**	**Foliar_K**	**Foliar_Ca**	**Foliar_Mg**	**Foliar_S**	**Foliar_B**
Soil_P	-0.08556	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.5547	--	--	--	--	--	--	--	--	--	--	--	--	--
	50	--	--	--	--	--	--	--	--	--	--	--	--	--
Soil_K	0.41602	0.63059	--	--	--	--	--	--	--	--	--	--	--	--
	0.0027	<.0001	--	--	--	--	--	--	--	--	--	--	--	--
	50	50	--	--	--	--	--	--	--	--	--	--	--	--
Soil_Ca	0.06231	-0.82593	-0.57158	--	--	--	--	--	--	--	--	--	--	--
	0.6673	<.0001	<.0001	--	--	--	--	--	--	--	--	--	--	--
	50	50	50	--	--	--	--	--	--	--	--	--	--	--
Soil_Mg	0.36757	-0.82037	-0.32187	0.90446	--	--	--	--	--	--	--	--	--	--
	0.0086	<.0001	0.0226	<.0001	--	--	--	--	--	--	--	--	--	--
	50	50	50	50	--	--	--	--	--	--	--	--	--	--
Soil_S	0.41189	0.64318	0.99046	-0.59155	-0.34969	--	--	--	--	--	--	--	--	--
	0.003	<.0001	<.0001	<.0001	0.0128	--	--	--	--	--	--	--	--	--
	50	50	50	50	50	--	--	--	--	--	--	--	--	--
Soil_Na	0.36701	0.66925	0.94413	-0.45368	-0.26955	0.94452	--	--	--	--	--	--	--	--
	0.0087	<.0001	<.0001	0.0009	0.0584	<.0001	--	--	--	--	--	--	--	--
	50	50	50	50	50	50	--	--	--	--	--	--	--	--
Foliar_N	0.61743	-0.01462	0.49454	0.14077	0.25022	0.51211	0.54168	--	--	--	--	--	--	--
	<.0001	0.9198	0.0003	0.3295	0.0797	0.0001	<.0001	--	--	--	--	--	--	--
	50	50	50	50	50	50	50	--	--	--	--	--	--	--
Foliar_P	0.09418	0.21906	0.1832	-0.43078	-0.25281	0.21912	0.17901	-0.34632	--	--	--	--	--	--
	0.5153	0.1264	0.2029	0.0018	0.0765	0.1263	0.2136	0.0138	--	--	--	--	--	--
	50	50	50	50	50	50	50	50	--	--	--	--	--	--
Foliar_K	-0.05188	0.43016	0.10711	-0.58612	-0.51486	0.14323	0.11943	-0.47615	0.90826	--	--	--	--	--
	0.7205	0.0018	0.4591	<.0001	0.0001	0.321	0.4088	0.0005	<.0001	--	--	--	--	--
	50	50	50	50	50	50	50	50	50	--	--	--	--	--

Table 18. Continued

Attributes	Soil_pH	Soil_P	Soil_K	Soil_Ca	Soil_Mg	Soil_S	Soil_Na	Foliar_N	Foliar_P	Foliar_K	Foliar_Ca	Foliar_Mg	Foliar_S	Foliar_B
Foliar_Ca	-0.17045	0.21608	-0.00731	-0.3337	-0.25397	0.01599	0.02642	-0.61053	0.91212	0.91551	--	--	--	--
	0.2366	0.1318	0.9598	0.0179	0.0751	0.9122	0.8555	<.0001	<.0001	<.0001	--	--	--	--
	50	50	50	50	50	50	50	50	50	50	--	--	--	--
Foliar_Mg	-0.38587	0.05977	-0.25632	-0.22725	-0.22614	-0.24969	-0.23874	-0.78375	0.81165	0.81142	0.92934	--	--	--
	0.0056	0.6801	0.0724	0.1125	0.1143	0.0803	0.095	<.0001	<.0001	<.0001	<.0001	--	--	--
	50	50	50	50	50	50	50	50	50	50	50	--	--	--
Foliar_S	-0.03299	0.02964	-0.00733	-0.27776	-0.14503	0.02323	-0.01212	-0.45384	0.96897	0.8663	0.9321	0.88798	--	--
	0.8201	0.8381	0.9597	0.0508	0.3149	0.8728	0.9334	0.0009	<.0001	<.0001	<.0001	<.0001	--	--
	50	50	50	50	50	50	50	50	50	50	50	50	--	--
Foliar_B	-0.01241	0.04612	-0.21123	-0.26842	-0.2395	-0.18054	-0.22441	-0.55095	0.80338	0.88953	0.86198	0.80466	0.84437	--
	0.9319	0.7505	0.1409	0.0595	0.0939	0.2096	0.1172	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	--
	50	50	50	50	50	50	50	50	50	50	50	50	50	--
Foliar_Na	0.15271	0.11481	-0.13956	0.32735	0.1708	-0.10407	0.14057	0.15803	0.25734	0.43718	0.64246	0.0706	0.23956	0.41964
	0.3166	0.4527	0.3605	0.0282	0.2619	0.4963	0.357	0.2998	0.0879	0.0027	<.0001	0.6449	0.113	0.0041
	50	50	50	50	50	50	50	50	50	50	50	50	50	50

Note: All data were correlated based on means and subjected to Pearson’s correlation procedure. Correlation coefficient (slope) (r) is displayed as the top number in each row for each column and its significance level is displayed as the second number for each row and column. The third number in each set is n.

Table 19. Pearson's correlation coefficients (r) among selected soil nutrients (P, K, Ca, Mg, S, Na), and foliar nutrients/minerals (N, P, K, Ca, Mg, S, B, Na) in first year longleaf pine seedlings treated with black plastic mulch and control (grouped together) treatment applied in May 2007 in Goldsboro, NC. Treatment details are described in text.

Attributes	**Soil_pH**	**Soil_P**	**Soil_K**	**Soil_Ca**	**Soil_Mg**	**Soil_S**	**Soil_Na**	**Foliar_N**	**Foliar_P**	**Foliar_K**	**Foliar_Ca**	**Foliar_Mg**	**Foliar_S**	**Foliar_B**
Soil_P	-0.21769	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.1288	--	--	--	--	--	--	--	--	--	--	--	--	--
	50	--	--	--	--	--	--	--	--	--	--	--	--	--
Soil_K	0.54318	0.13458	--	--	--	--	--	--	--	--	--	--	--	--
	<.0001	0.3515	--	--	--	--	--	--	--	--	--	--	--	--
	50	50	--	--	--	--	--	--	--	--	--	--	--	--
Soil_Ca	0.38587	-0.82266	-0.34938	--	--	--	--	--	--	--	--	--	--	--
	0.0056	<.0001	0.0129	--	--	--	--	--	--	--	--	--	--	--
	50	50	50	--	--	--	--	--	--	--	--	--	--	--
Soil_Mg	0.48744	-0.88757	-0.12361	0.93297	--	--	--	--	--	--	--	--	--	--
	0.0003	<.0001	0.3924	<.0001	--	--	--	--	--	--	--	--	--	--
	50	50	50	50	--	--	--	--	--	--	--	--	--	--
Soil_S	0.01576	0.58738	0.61309	-0.65207	-0.62267	--	--	--	--	--	--	--	--	--
	0.9135	<.0001	<.0001	<.0001	<.0001	--	--	--	--	--	--	--	--	--
	50	50	50	50	50	--	--	--	--	--	--	--	--	--
Soil_Na	0.59977	0.30326	0.93702	-0.34731	-0.2029	0.59957	--	--	--	--	--	--	--	--
	<.0001	0.0323	<.0001	0.0135	0.1576	<.0001	--	--	--	--	--	--	--	--
	50	50	50	50	50	50	--	--	--	--	--	--	--	--
Foliar_N	-0.69982	0.33306	-0.21682	-0.4115	-0.49104	0.11685	-0.14237	--	--	--	--	--	--	--
	<.0001	0.0181	0.1304	0.003	0.0003	0.419	0.324	--	--	--	--	--	--	--
	50	50	50	50	50	50	50	--	--	--	--	--	--	--
Foliar_P	-0.72851	0.50622	-0.33044	-0.59595	-0.69958	0.18616	-0.33727	0.46458	--	--	--	--	--	--
	<.0001	0.0002	0.0191	<.0001	<.0001	0.1955	0.0166	0.0007	--	--	--	--	--	--
	50	50	50	50	50	50	50	50	--	--	--	--	--	--
Foliar_K	-0.17701	0.12549	0.32702	-0.47157	-0.39772	0.10206	0.29458	0.45285	0.1286	--	--	--	--	--
	0.2188	0.3852	0.0204	0.0005	0.0042	0.4807	0.0378	0.001	0.3735	--	--	--	--	--
	50	50	50	50	50	50	50	50	50	--	--	--	--	--

Table 19. Continued

Attributes	Soil_pH	Soil_P	Soil_K	Soil_Ca	Soil_Mg	Soil_S	Soil_Na	Foliar_N	Foliar_P	Foliar_K	Foliar_Ca	Foliar_Mg	Foliar_S	Foliar_B
Foliar_Ca	-0.13744	-0.50017	-0.13004	0.32938	0.34471	-0.45402	-0.18639	-0.03025	-0.4238	0.24373	--	--	--	--
	0.3412	0.0002	0.3681	0.0195	0.0142	0.0009	0.195	0.8348	0.0022	0.0881	--	--	--	--
	50	50	50	50	50	50	50	50	50	50	--	--	--	--
Foliar_Mg	0.34006	-0.78505	0.07189	0.65544	0.77134	-0.5905	-0.02219	-0.39284	-0.67761	0.02515	0.76919	--	--	--
	0.0157	<.0001	0.6198	<.0001	<.0001	<.0001	0.8784	0.0048	<.0001	0.8624	<.0001	--	--	--
	50	50	50	50	50	50	50	50	50	50	50	--	--	--
Foliar_S	-0.24571	-0.15864	-0.07408	0.01469	0.05664	-0.2777	-0.10725	0.3491	0.43145	0.16608	-0.17343	0.08383	--	--
	0.0854	0.2712	0.6092	0.9194	0.696	0.0509	0.4585	0.013	0.0018	0.249	0.2284	0.5627	--	--
	50	50	50	50	50	50	50	50	50	50	50	50	--	--
Foliar_B	-0.12659	-0.03121	-0.20727	0.24618	0.08938	-0.22587	0.0158	0.59028	-0.20703	0.14951	0.32008	0.17271	0.18385	--
	0.381	0.8296	0.1487	0.0848	0.5371	0.1148	0.9133	<.0001	0.1491	0.3	0.0234	0.2304	0.2012	--
	50	50	50	50	50	50	50	50	50	50	50	50	50	--
Foliar_Na	-0.06589	-0.26405	-0.07849	0.33266	0.27523	0.26658	-0.15858	0.05929	-0.20062	-0.37995	-0.0405	0.04624	-0.0596	0.15189
	0.6494	0.0639	0.588	0.0183	0.053	0.0613	0.2714	0.6825	0.1624	0.0065	0.7801	0.7499	0.681	0.2924
	50	50	50	50	50	50	50	50	50	50	50	50	50	50

Note: All data were correlated based on means and subjected to Pearson's correlation procedure. Correlation coefficient (slope) (r) is displayed as the top number in each row for each column and its significance level is displayed as the second number for each row and column. The third number in each set is n.

Table 20. Ratio of foliar N to Mg concentration generally recommended for broad leaved trees (Flückiger and Braun, 2003), and N to Mg ratio estimates from the foliar nutrient analysis for the cherrybark oak seedlings under mulch treatments in August 2007, 10 weeks after mulch treatment had been applied, in Goldsboro, NC. Treatment details are described in text.

Species /Mulch Treatment	N:Mg Ratio
Recommendations for broadleaved trees:	<17.5
Cherrybark Oak	
Black Plastic	19.0
Corn High	19.1
Corn Low	13.4
Control	12.8
Hay High	12.9
Hay Low	13.6

Note: All data were non-transformed and based on foliar nutrient values under each mulch treatment for cherrybark oak species.

Figure 1. Map and dimensions of study site at Cherry Research Farm in Goldsboro, North Carolina. Colored areas designate five blocks at the site. Patterns on the field within the blocks do not indicate plantings related to the current study, but do suggest soil variation.

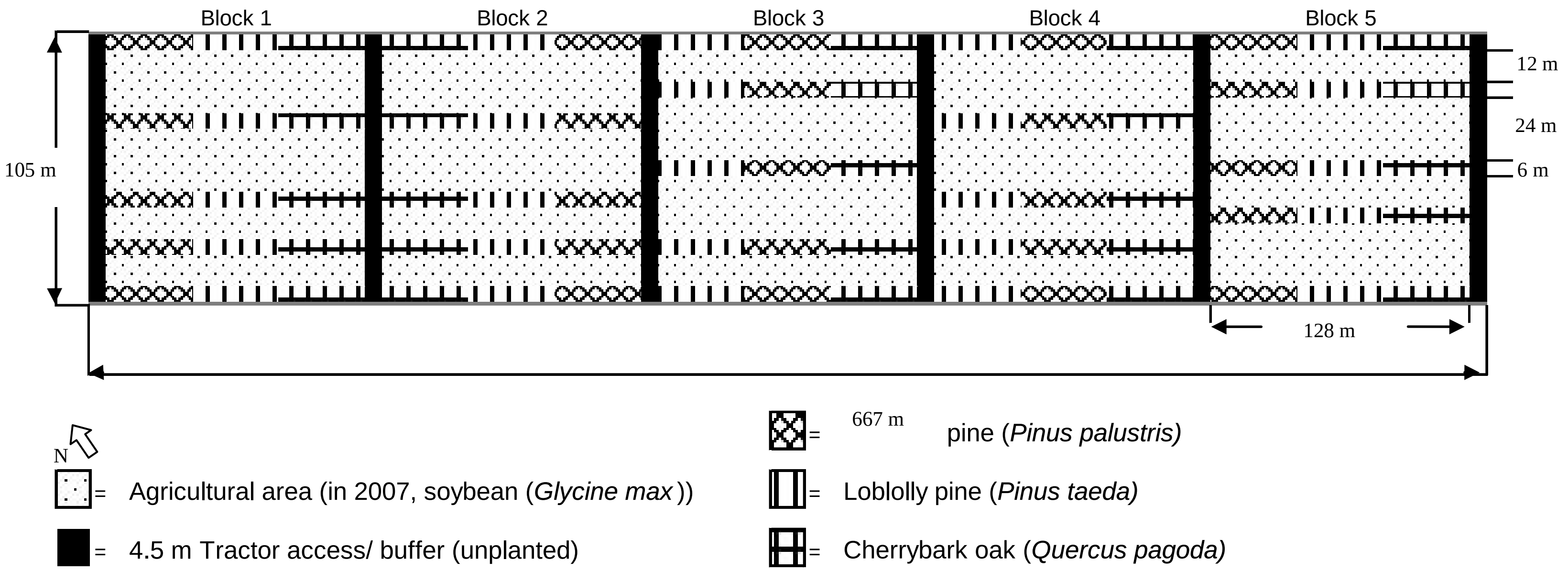

Figure 2. Layout and dimensions of agroforestry field, including tree species, planted in narrow strips, and agricultural areas in plots of two different widths. Five foot buffers run 667 m lengthwise down all five blocks on both sides.

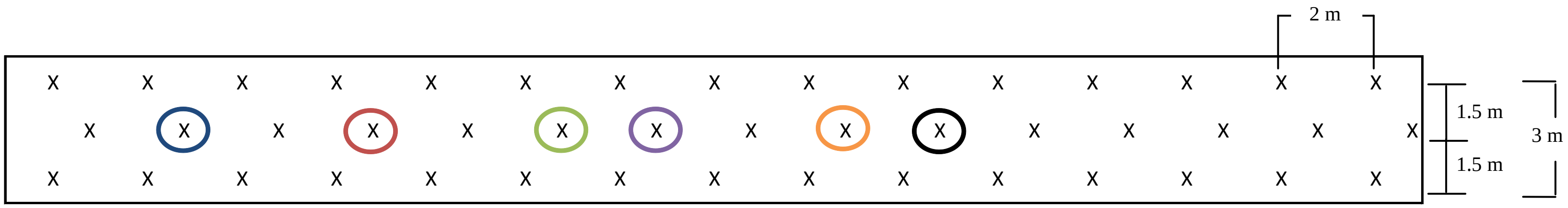

Figure 3. A close-up example of one mulch treatment replication in block 3, of a tree plot planted in loblolly pine. X's indicate tree seedlings in the 6 m x 43 m subplot, planted at 1.5 m x 2 m off-set spacing, and circles indicate 91 cm diameter mulched areas around trees. Each different color is matched with a mulch treatment (blue= *Corn High*, red= *Hay High*, green= *Control*, purple= *Hay Low*, orange= *Black Plastic*, and black= *Corn Low*). This illustrates a typical design used for each species, and each replication in each block, where the six different treatment mulches were randomly assigned to six randomly chosen healthy tree seedlings.

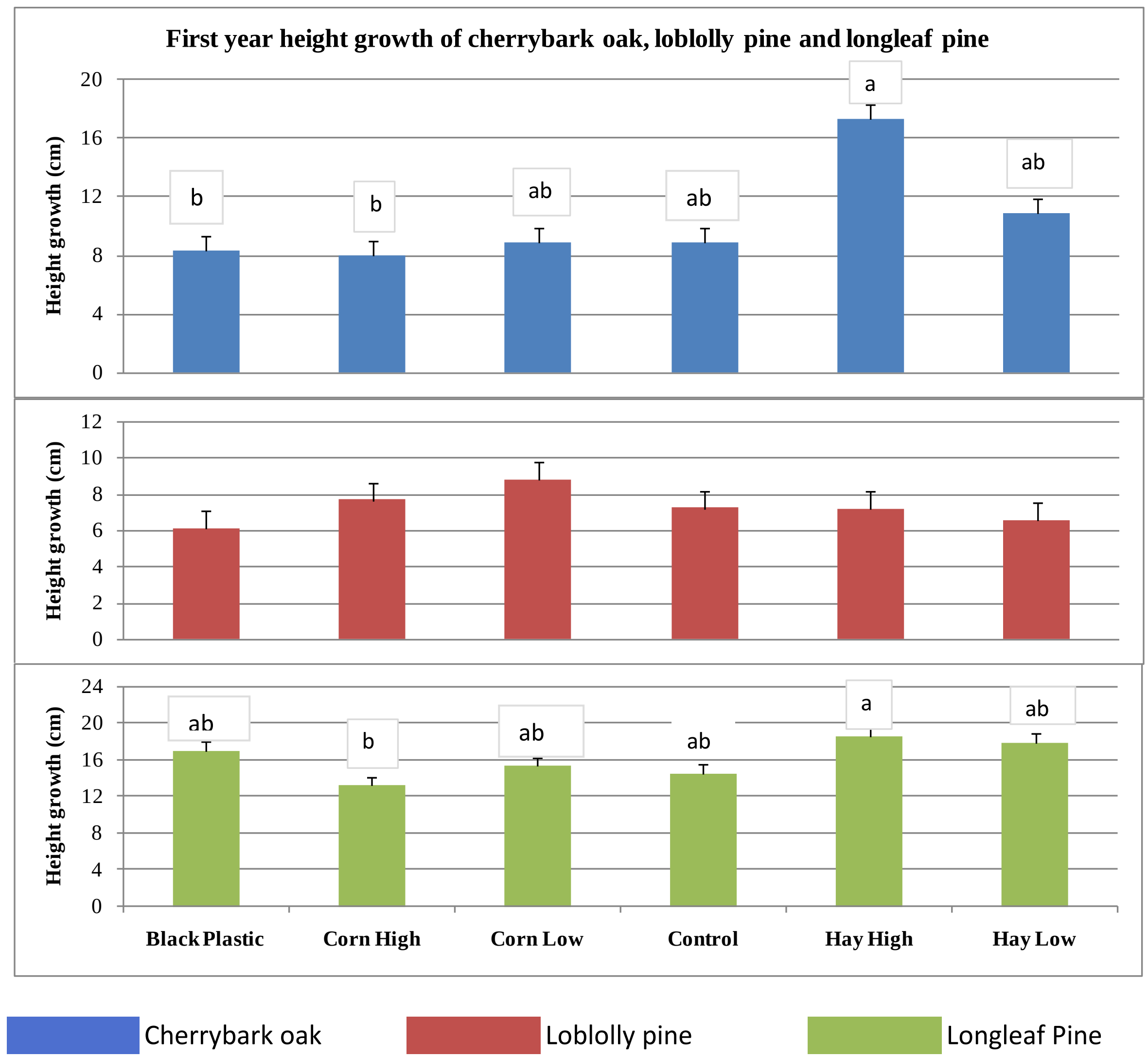

Figure 4. First year estimates of height growth of cherrybark oak, loblolly pine, and longleaf pine seedlings with different mulch treatments (see Table 1). All means were subjected to ANOVA. For each species, different letters indicate significant differences between treatments dervied by Tukey's pairwise comparision tests at significance level, α=0.1, when the ANOVA was significant at 0.1.

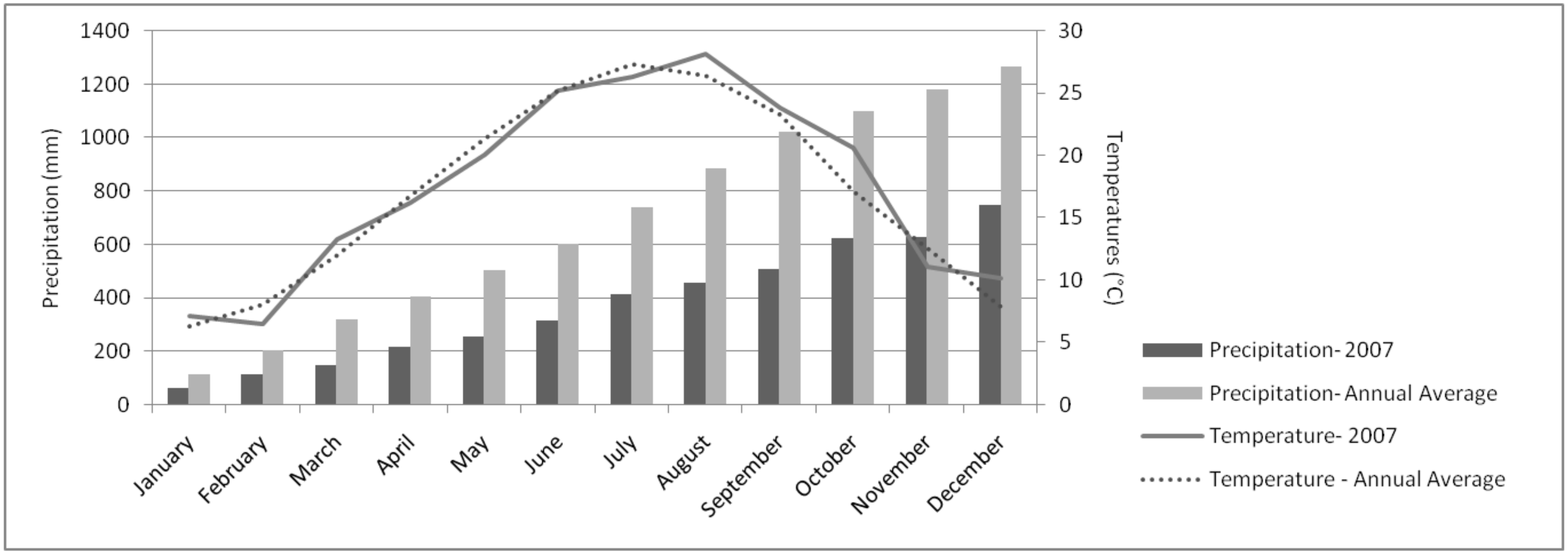

Figure 5. Average monthly precipitation and 2007 actual precipitation (mm), and average monthly temperature (°C) and 2007 actual monthly temperature in Goldsboro, NC.

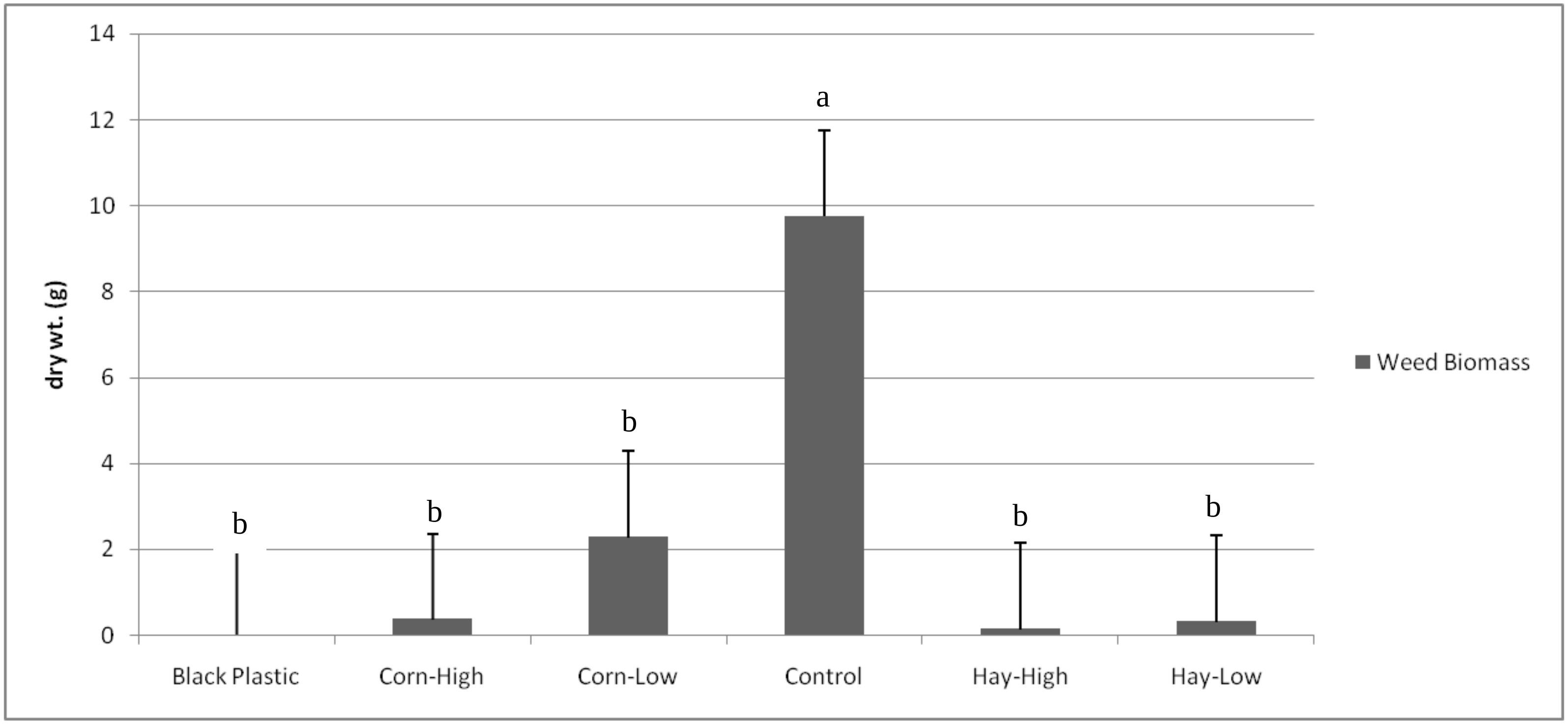

Figure 6. First year estimates of weed biomass collected from each 91 cm mulched treatment area, and each planted seedling, inclusive of all three tree species.