A Comparison of the Attributes of Pine Straw from Southern Pine Species[1]

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Abstract

Longleaf pine (*Pinus palustris* Mill.), and slash pine (*Pinus elliottii* Engelm.) are two southern pine species that are popular for producing pine straw for landscaping. The objective of this research was to determine the response of soil properties and weed growth to the application of pine straw. Longleaf pine, slash pine, and two non-mulched controls (with and without chemical weed control) were tested. Volumetric soil water content, soil nutrients, soil temperature, weed biomass, and seedling growth were measured. Compared to non-mulched controls, both longleaf and slash pine plots had a greater soil moisture during extended periods without rainfall in the full sun environment. When soil temperatures increased, mulched plots had lower soil temperature relative to non-mulched plots. Soil pH and soil nutrients were generally similar between pine straw types with few significant differences in measured variables. Both pine straw treatments reduced weed growth and longleaf pine maintained a greater straw depth over the study period compared to slash pine, but no differences were observed for decomposition. These results indicate that longleaf pine straw and slash pine straw perform equally as well in terms of increasing soil moisture, moderating soil temperature, and reducing weed growth compared to not using mulch.

Index words: *Pinus elliottii*, *Pinus palustris*, organic mulch, soil properties, landscaping.

Species used in this study: Shumard oak, *Quercus shumardii* Buckl., Eastern redbud, *Cercis canadensis* L.

Significance to the Horticulture Industry

Pine straw is a commonly used organic mulch in landscaping applications. Organic mulches can provide benefits such as improved soil moisture, moderating soil temperatures, and suppressing weed growth. Longleaf pine straw and slash pine straw are the two most commonly used species of southern pine found in pine straw markets in the Southeast region of the United States and longleaf pine straw is often sold at a premium price compared to slash pine straw. To better understand the attributes of these pine straw types, this research compared the response of soil properties, weed biomass, and tree growth to the application of longleaf pine straw and slash pine straw. We found that both longleaf and slash pine straw maintained greater soil moisture, moderated soil temperatures, reduced weed growth compared to non-mulched control treatments, and decomposed at similar rates. This provides evidence that both types of pine straw provide similar benefits in landscape settings when used as mulch and differences between the two are likely aesthetic in nature but further research is warranted on this regard. Between longleaf and slash pine straw, we recommend choosing the one that is most aesthetically pleasing as both will provide similar attributes.

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Introduction

The southeastern United States consists of approximately 83 million hectares (205 million acres) of forestland, in which 15.8 million hectares (39 million acres) is planted to pine (Wear and Greis 2012). This region is often referred to as the "wood basket" of the United States (Schultz 1997), as it produces approximately 60% of all timber in the country (Fox et al. 2007, Smith et al. 2009). After harvesting these trees for timber, non-timber forest products (NTFPs) from these forests create opportunities for many alternative markets.

NTFPs are comprised of plants, fungi, and other flora materials such as seeds and bark (Chamberlain and Predny 2003) and can be classified into five categories, which are the following: culinary, decorative, dietary and medicinal, nursery stock and landscaping, and fine arts and crafts (Barlow et al. 2015). Many parts of plants and fungi, such as roots, tubers, branches, sap, pine needles, and small diameter wood, are harvested for monetary gain or personal enjoyment (Chamberlain et al. 2018). An emerging NTFP category is sales to nurseries and landscapers. In the Southeast, a common enterprise within this category is pine straw.

Pine straw is commonly used as an organic mulch. Organic mulches, such as pine straw, are commonly used in landscaping applications for households and businesses. Organic mulches can offer an array of benefits, such as improved soil moisture, maintenance of soil temperatures, and weed suppression (Taylor and Foster 2004, Maggard et al. 2012). When exposed to the elements, bare soil loses water by evaporation and the presence of weeds can increase water loss through evapotranspiration but when mulched, the soil has a higher water content due to increased percolation and retention, and suppressed weed growth (Chalker-Scott 2007). In regard to the maintenance of soil temperature, compared to a mulched soil, non-mulched soils have been reported to be as much as 10 C (50

F) warmer (Greenly and Rakow 1995). Mulch can suppress weeds, and the size of the mulch particles can play an important role in determining the effectiveness of weed suppression as coarser mulch is found to be more effective than finer mulch (Billeaud and Zajicek 1989, Greenly and Rakow 1995, Maggard et al. 2012). Mulch can also affect nutrient availability by way of decomposing or leaching. As pine straw decomposes, nutrients such as potassium (K), nitrogen (N), and phosphorus (P) are released into the soil (Blevins et al. 1996).

Traditionally in the Southeast, there are three common pine species used for producing pine straw for mulch: longleaf pine (*Pinus palustris* Mill.), slash pine (*Pinus elliottii* Engelm.), and loblolly pine (*Pinus taeda* L.). Longleaf pine needles occur in three per fascicle and are approximately 20 to 46 cm (7.87 to 18.11 in) long, which is the longest of the three species. Slash pine needles occur in two to three needles per fascicle and are approximately 15 to 28 cm (5.90 to 11.02 in) long. Loblolly pine, considered to be the most commercially important forest species in the South, is the most widely planted of the three. Its needles occur in three or four needles per fascicle and are approximately 12 to 23 cm (4.72 to 9.05 in) long, which is the shortest of the three species.

The use of pine straw as a mulch is a growing market in the Southeast. Across much of the southern United States, the value of pine straw as a forest product has increased greatly since the early 2000's as income received by landowners has increased by as much as 80% from the product, even though timber revenues decreased over much of the same time period (Dickens et al. 2018). Pine straw markets have been especially dominant in both the number of businesses and revenue produced in Florida, Georgia, and North Carolina in years past, as these states have been superior in the industry (Mills and Robertson 1991). In Georgia, revenues from pine straw paid to landowners grew from approximately $15.5 million in 1999 to approximately $60 to $80 million between 2010 and 2017 (Dickens et al. 2018). In North Carolina, longleaf pine straw revenues were estimated to exceed $34.8 million annually in 2016 (Megalos et al. 2019).

Longleaf pine straw seems to be the preferred pine straw species for sellers and is typically sold at a premium (Dyer et al. 2015). Largely anecdotal, reasons for this are said to be due to longer needles, better color retention, and slower rate of decomposition of longleaf pine straw compared to other commonly used species. However, there is a lack of scientific information that can support or reject these statements and to the best of our knowledge there are no scientific studies that directly compare the attributes of pine straw from southern pine species as a mulch in a landscape setting.

The objective of this research was to determine the response of soil properties, weed biomass, and tree growth to the application of pine straw of three commonly used species of southern pine. However, to our finding, loblolly pine straw was not found to be available for purchase after researching and contacting numerous market places in the region. Therefore, the study focused on longleaf and slash pine straw. To accomplish this, longleaf pine straw, slash pine straw, and two non-mulched controls (with and without chemical weed control) were tested by measuring volumetric soil water content, soil temperature, soil nutrients, soil pH, decomposition, weed biomass, tree growth, and pine straw depth change over time.

Materials and Methods

Study site. The research site was located at Mary Olive Demonstration Forest (MOTDF) (N 32° 34′ 42.9″, W 85° 25′ 24.4″) located in Auburn, Alabama, approximately five miles from Auburn University. Soil consisted of a very deep, well drained, moderately permeable fine sandy loam in the Pacolet series (USDA 2019). The 20-year mean precipitation for Auburn, AL for the months of March through August was 74.1 cm (29.17 in). The 20-year mean maximum and minimum air temperature for Auburn, AL for the months of March through August were 27.8 C and 15.9 C (82.0 to 60.6 F), respectively.

Treatments. The study period occurred over the 2019 growing season (March to September). In March 2019, three locations, which included non-tilled full sun (full-sun), non-tilled shade (shade), and tilled full sun (tilled in early March 2019 a few days before tree planting) areas, were located within 100 m of each other. Within each of the three locations, a randomized complete block consisting of three treatment replicates were established (12 plots per location). For the tilled trial, plots were tilled to a depth of 7.6 cm (3.0 in) and a width of 66.0 cm (26.0 in) using a walk-behind rotary tiller (Honda model FC600, Alpharetta, GA) in March, prior to tree planting and mulch application. Three passes of the tiller, equaling 198 cm (78 in), were applied. Existing vegetation at all sites were cut at ground level before mulch application using a push lawnmower and string trimmer. Within each replication, four circular 1.5 m (4.9 ft) diameter plots (1.77 m^2) were established and randomly assigned one of the following treatments: longleaf pine (LL) (Southeast Straw Company, Inc., Opelika, AL, USA), slash pine (SL) (Southeast Straw Company, Inc., Opelika, AL, USA), a non-mulched control where weeds were killed with herbicide (CWH), or a non-mulched plot without weed control (CNH) (36 total plots).

On 14 March 2019, within each 1.50 m (59.1 in) diameter plot, two trees were planted, one 1.2 to 1.5 m (3.9 to 4.9 ft) tall, bareroot Shumard oak (*Quercus shumardii* Buckl.) and one 1.2 to 1.5 m (3.9 to 4.9 ft) tall, bareroot eastern redbud (*Cercis canadensis* L.) (TyTy Plant Nursery, LLC, TyTy, GA, USA). These trees were selected because both species are native and commonly used within landscape and mulched settings across the Southeast. On 18-19 April 2019, an estimated 6.0 liters (1.6 gal) of mulch was applied to their respective treatments to a depth of approximately 7.6 cm (3.0 in).

After planting, the plots were undisturbed. Plots were watered every three to four days for the first several weeks and then only as needed during extended periods without precipitation. Glyphosate (Roundup ® Ready to Use Weed and Grass Killer ®(2% glyphosate, Monsanto Company, St. Louis, MO) was applied to control competing vegetation within the non-mulched herbicide plots. We followed the directions on the label. Glyphosate was applied following cutting of vegetation at ground level in the herbicide-treated plots and following tilling in the tilled, full-sun plots, prior to tree planting. Directed sprays of glyphosate were used following each measurement date for weed biomass and weed biomass in the herbicide-treated plots, but weed growth was negligible for each of those measurement dates. The goal of including herbicide-treated plots was to determine the effect of weeds versus bare soil on soil moisture, comparing herbicide-treated plots to CNH plots and mulched plots.

Measurements and experimental design. Measurements were conducted from April 2019 to September 2019. Soil measurements included volumetric soil water content, soil nutrients, soil pH, and soil temperature. Soil water content and soil temperature were measured every seven to ten days throughout the study duration at a depth between 0.0 and 12.0 cm (4.7 in) (Hydrosense II, Campbell Scientific, Inc., Logan, UT). Soil temperature was measured at a depth of 10.0 to 12.0 cm (3.9 to 4.7 in) and coincided with volumetric soil water measurements (Vee Gee Scientific, LLC, Vernon Hills, IL Model 83210-12 digital thermometer). Soil was collected from 0.0 to 7.6 cm (3.0 in) using a 1.90 cm (0.75 in) diameter probe on 17 April 2019 before the application of mulch and on 6 September 2019 at the end of the study. Four samples per plot were combined into one composite sample. All soil pH and nutrient samples were analyzed by the University of Georgia's Agriculture & Environmental Services Lab (AESL). Soil nutrients were analyzed using Acros and Thermo iCAP 7000 inductive coupled plasma optical emission spectrometers (ICP-OES) (Thermo Fisher Scientific, Waltham, MA, USA), and the nutrients analyzed included the following: calcium (Ca), magnesium (Mg), manganese (Mn), phosphorus (P), potassium (K), and zinc (Zn). Soil pH was analyzed using a Labfit AS-3000 (Labfit, Bayswater, Western Australia) with Thermo Fisher double junction electrodes (Thermo Fisher Scientific, Waltham, MA, USA). Soil nitrate-nitrogen was measured on a cadmium reduction continuous flow analyzer (OI Analytical FS3100, OI Analytical, College Station, TX). Weed suppression was measured by cutting plant biomass at the mulch surface, collecting in paper bags, and oven drying at a temperature of 65 C (149 F). Harvesting dates occurred on 26-28 June, 8-12 July, and 14-17 August. Pine straw depth change measurements were conducted monthly during dry times to prevent compaction from precipitation events. Depth changed was measured with a ruler at the same four locations within each plot and averaged to determine change in depth from measurement date to measurement date.

The experimental design was a generalized randomized complete block design (n=3) with sub-block (n=3) and treatment (n=9). For volumetric soil water content, soil temperature, depth change, and color change, a repeated measure analysis was conducted for 15 sampling dates (Proc Mixed, SAS Inc., Cary, NC, USA) with block as a random factor and treatments as fixed factors. When there was a significant block by treatment interaction, each block was analyzed separately by treatment (n=3).

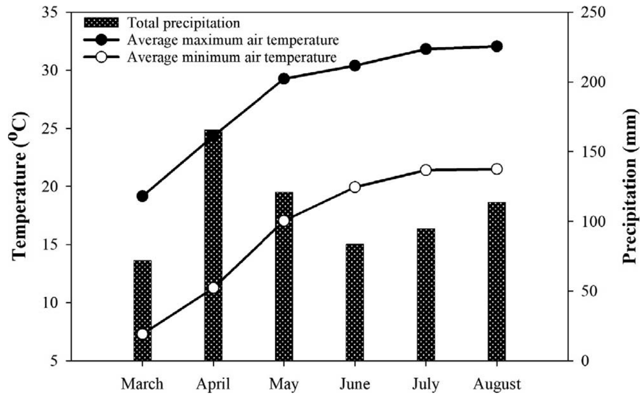

Fig. 1. Monthly precipitation and average maximum and minimum air temperature in 2019 for Auburn, Alabama, USA, during the study period.

Results and Discussion

Climate. Total precipitation during the study period was 66.1 cm (26.0 in). During the study, the greatest precipitation occurred in April (16.6 cm) (6.5 in) and least occurred in March (7.2 cm) (2.8 in) (Fig. 1). Average daily maximum and minimum air temperatures during the study period were 27.8 C and 16.4 C (82.0 and 61.5 F), respectively (Fig. 1). August had the highest average daily maximum and minimum air temperatures (32.1 C, 21.5 C) (89.8 F, 70.7 F) and March had the lowest average daily maximum and minimum air temperatures (19.2 C, 7.3 C) (66.6 F, 45.1 F).

Soil moisture. For volumetric soil water content (VWC), there was a block by treatment interaction (block*-treatment$<$0.0001). Therefore, each block was analyzed separately. For the full sun environment, there was a date by treatment interaction (P=0.01) (Fig. 2A). For significant dates, as soil conditions became drier from the end of June through the end of August, all pine straw-treated plots had a higher VWC compared to the CNH and CWH plots. There were no significant differences among pine straw treatments during significant dates within that period of time. For the tilled environment, there was a treatment effect (treatment=0.04). The CWH plots had significantly higher VWC than the CNH plots (P=0.01) and LL treated plots (P=0.005) (Fig. 2B). This is likely a result of exposed bare soil in the CWH plots allowing greater water absorption into the soil, less runoff, and less water use from weeds than in the CNH plots. There was no significant difference among pine straw-treated plots. For the shaded environment, there was a treatment effect (treatment=0.002). Plots receiving pine straw had a significantly lower VWC (LL=0.03; SL=0.0004) compared to the CWH plots (Fig. 2C). Precipitation on plots in the shaded environment was likely impacted by the tree canopy above the plots, reducing precipitation throughfall to the soil, which was likely further reduced by the plots treated with pine straw compared to the non-mulched plots. It has been well observed that the use of organic mulch maintains greater soil moisture during drier periods (Watson 1988, Greenly and Rakow 1995, Zhang et al. 2008, Maggard et al. 2012). In a landscape setting, the effects of pine straw mulch on soil moisture is limited but

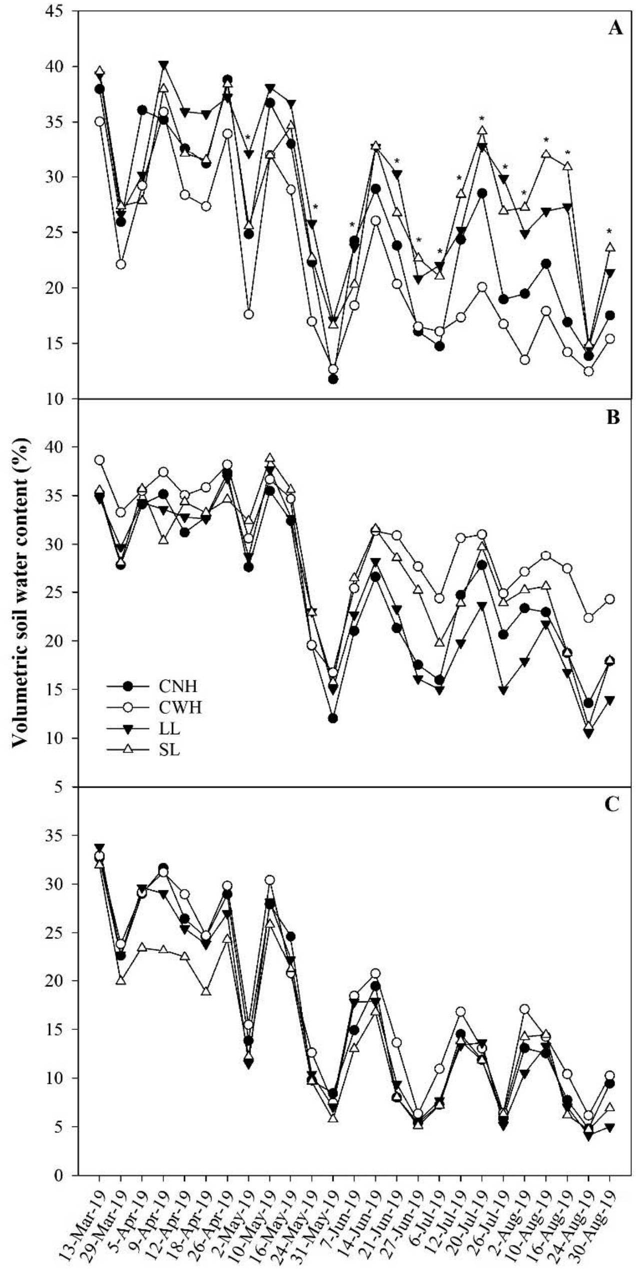

Fig. 2. Mean volumetric soil water content (%) for (A) Full sun environment, (B) tilled environment, and (C) shaded environment measured between 0-12 cm. CNH = control no herbicide, CWH = control with herbicide, LL = longleaf pine straw, and SL = slash pine straw. An asterisk (*) above the data represents dates when the mulch treatment effect was significant (P<0.05, n=3).

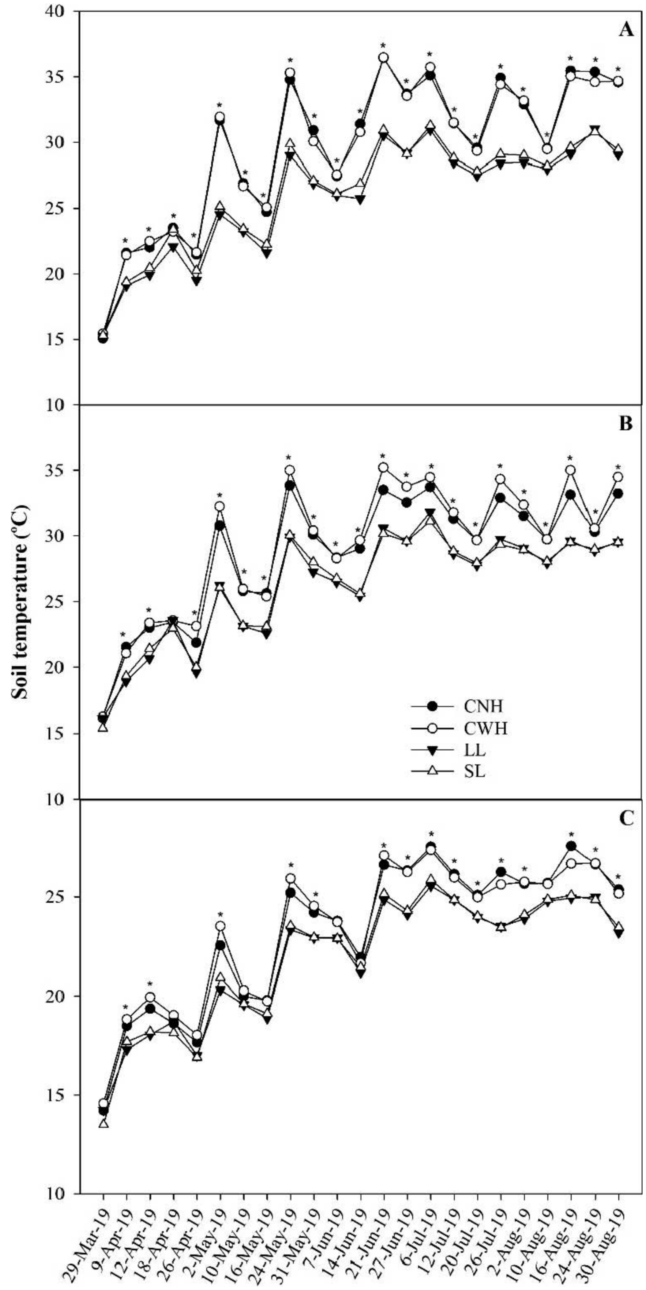

Fig. 3. Mean soil temperature (C) for (A) Full sun environment, (B) tilled environment, and (C) shaded environment measured between 0-12 cm. CNH = control no herbicide, CWH = control with herbicide, LL = longleaf pine straw, and SL = slash pine straw. An asterisk (*) above the data represents dates when the mulch treatment effect was significant (P<0.05, n=3).

the results support our finding that the application of pine straw mulch maintains greater soil moisture compared to no mulch application during extended periods without precipitation (Stinson et al. 1990). The average monthly precipitation over our study period was 11 cm (4.3 in), which is 11% below the 20-year average for the same time period. More prominent in the literature is the effect of pine straw litter on water availability in forest stands, where it is documented that the presence of pine straw in the litter layer had significant, positive impacts on water availability (Ginter et al. 1979, McLeod et al. 1979).

Soil temperature. Like VWC, there was a block by treatment interaction for soil temperature (block*-treatment<0.0001). Therefore, each block was analyzed separately. For the full sun environment, there was a date by treatment interaction (date*treatment<0.0001) (Fig. 3A). When soil temperatures increased, plots treated with pine straw moderated and had lower soil temperature compared to CNH and CWH plots. There were no significant differences between pine straw treatment types. For the tilled environment, there was a date by treatment interaction (date*treatment<0.0001) (Fig. 3B). Like the treatments in the full sun environment, as soil temperatures increased throughout the growing season, plots treated with pine straw moderated and had lower soil temperature compared to CNH and CWH plots. There were no significant differences between pine straw treatment types. For the shaded environment, there was a date by treatment interaction (date*treatment=0.001) (Fig. 3C). Except for several dates with lower soil temperatures and all treatments were equal, plots treated with pine straw moderated and had lower soil temperature compared to CNH and CWH plots. As in our study, shading and insulation by mulch moderated soil temperature in previous studies (Stinson et al. 1990, Cook et al. 2006, Maggard et al. 2012). In regards to mulch effects on soil temperature, mulch color could have an effect during warmer months as it has been found that under organic mulches, lighter colored mulches resulted in lower soil temperatures compared to mulches of darker colors (Cook et al. 2006). The similar color of the pine straw types in our study may be a reason for the lack of difference in soil temperature results.

Soil pH. Initial soil pH across all plots had a mean of 5.08 ± standard error (SE) 0.04 and there was a significant initial difference among environment types (env<0.0001) (data not shown). The pH in the shaded environment with a mean of 5.46 ± SE 0.06 was significantly higher than the tilled environment with a mean of 4.97 ± SE 0.04, which was significantly higher than the full sun environment with a mean of 4.79 ± SE 0.02. During the study, soil pH increased in all plots and treatments did not significantly alter pH (treatment=0.59). Mulch can have an effect on soil pH. However, its effects are inconsistent as it has been found that different mulch types can raise, lower, or not alter soil pH. Previous studies have found that organic mulches can lower soil pH (Billeaud and Zajicek 1989, Himelick and Watson 1990). However, other studies have found that organic mulches maintained higher soil pH levels than mineral mulches and control treatments (Iles and Dosmann 1999) or had no effect on soil pH (Broschat 1997). Pine straw has been noted to lower pH (Stinson et al. 1990, Makus et al. 1994, Duryea et al. 1999). In our study, soil pH increased across all treatments and the plots treated with pine straw did not significantly alter pH. The increase in pH across all treatments could be related to the soils being low in pH (acidic) or seasonal variation in pH at the study site. Significant increases in pH were observed in the CWH plots within the tilled environment. This may be a response of increased mineralization due to tillage combined with herbicide, increasing soil nitrate levels in the tilled environment. Once tilling was complete, CWH plots were installed and sprayed with herbicide, eliminating any remaining weeds. However, further research is needed to determine the exact cause.

Soil nutrients. Mulches can affect soil fertility by way of decomposition followed by the leaching of nutrients from the mulch. Initial soil nitrate concentrations across all plots had a mean of 1.13 ± SE 0.07 $mg{\cdot}kg^{-1}$ and there was a significant initial difference among environment types (env=0.0005). The shaded environment with a mean of 1.33 ± SE 0.10 $mg{\cdot}kg^{-1}$ was significantly higher than the tilled environment (1.10 ± SE 0.06 $mg{\cdot}kg^{-1}$) and full sun environment (0.96 ± SE 0.05 $mg{\cdot}kg^{-1}$). An environment by treatment interaction occurred during the study for soil nitrate (env*treatment<0.0001). Therefore, each environment was analyzed separately. Mean soil nitrate across all plots decreased in the full sun environment and treatments did not significantly alter soil nitrate in the full sun environment (treatment=0.89) (Fig. 4A). For the tilled environment, mean soil nitrate across all plots increased and increased significantly greater in the CWH plots (P<0.0001). Further, soil nitrate was significantly higher in the SL plots than in the LL plots (P=0.02) or the CNH plots (p = 0.01) (Fig. 4B). Mean soil nitrate across all plots decreased in the shaded environments and treatments did not significantly alter soil nitrate in the shaded environment (treatment=0.06) (Fig. 4C). In times of heavy rainfall, the shaded environment in our study would become saturated and was slower to dry out compared to the full-sun and tilled environment types. This could cause denitrification, which could lower the soil nitrate levels.

Initial phosphorus (P) concentrations across all plots had a mean of 19.32 ± SE 2.77 $mg{\cdot}kg^{-1}$ and there was a significant initial difference among environment types (env<0.0001) (data not shown). The shaded environment with a mean of 34.66 ± SE 4.65 $mg{\cdot}kg^{-1}$ was significantly higher than the tilled environment (15.85 ± SE 2.59 $mg{\cdot}kg^{-1}$) and full sun environment (0.7.43 ± SE 1.08 $mg{\cdot}kg^{-1}$). During the study, P concentrations decreased in all plots and treatments did not significantly alter P concentration (treatment=0.90).

Initial potassium (K) concentrations across all plots had a mean of 49.97 ± SE 3.41 $mg{\cdot}kg^{-1}$ and there was a significant initial difference among environment types (env=0.0004) (data not shown). The shaded environment with a mean of 57.51 ± SE 3.97 $mg{\cdot}kg^{-1}$ and the full sun environment with a mean of 53.08 ± SE 4.33 $mg{\cdot}kg^{-1}$ was significantly higher than the tilled environment with a mean of 39.31 ± SE 1.93 $mg{\cdot}kg^{-1}$. During the study, K concentrations increased in all plots and treatments did not significantly alter K concentration (treatment=0.70)

Above-ground weed biomass. Mulches, in general, have been known to suppress weed growth. It has been found that the use of mulch, rather than the type of mulch, reduces weed growth (Broschat 1997, Abouziena 2008, Maggard et al. 2012). Due to an environment by treatment interaction in our study, each environment was analyzed separately (env*treatment<0.0001). For the full sun environment, the presence of pine straw significantly reduced weed growth (treatment=0.0007) and there was no significant difference between the two mulch types. Further, the CWH plots had significantly less weed growth than the LL (P=0.006) and SL (P=0.03) plots (Fig. 5A). Similarly, adding pine straw significantly reduced weed growth compared to the CNH plots (treatment<0.0001) and there was no significant difference between the two mulch types in the tilled environment. Further, the CWH plots had significantly less weed growth than the SL plots

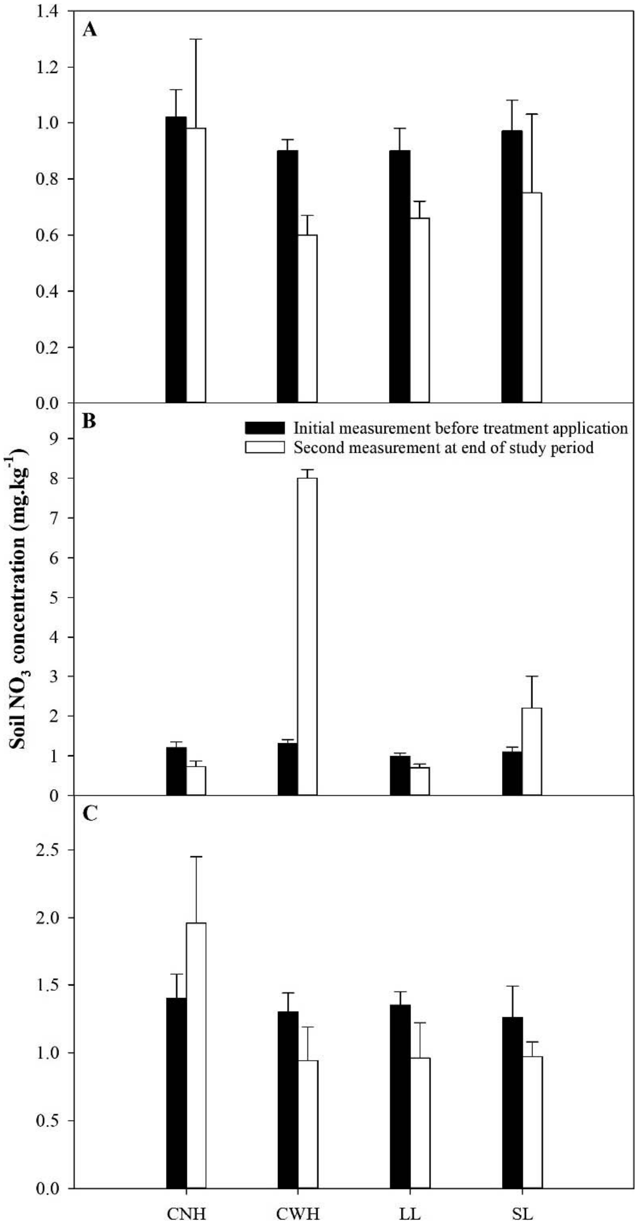

Fig. 4. Mean soil nitrate concentration (mg.kg^{-1}) ($\pm$ SE) in (A) Full sun environment, (B) tilled environment, and (C) shaded environment between the 0 and 7.6 cm soil depth. Soil measurements were taken before treatment application at the beginning of the study period (black bar) and at the end of the study period (white bar). CNH = control no herbicide, CWH = control with herbicide, LL =longleaf pine straw, SL = slash pine straw (n=3). Soil nitrate was collected and sent for analysis prior to treatment establishment in March and again at the end of the study the first week of September.

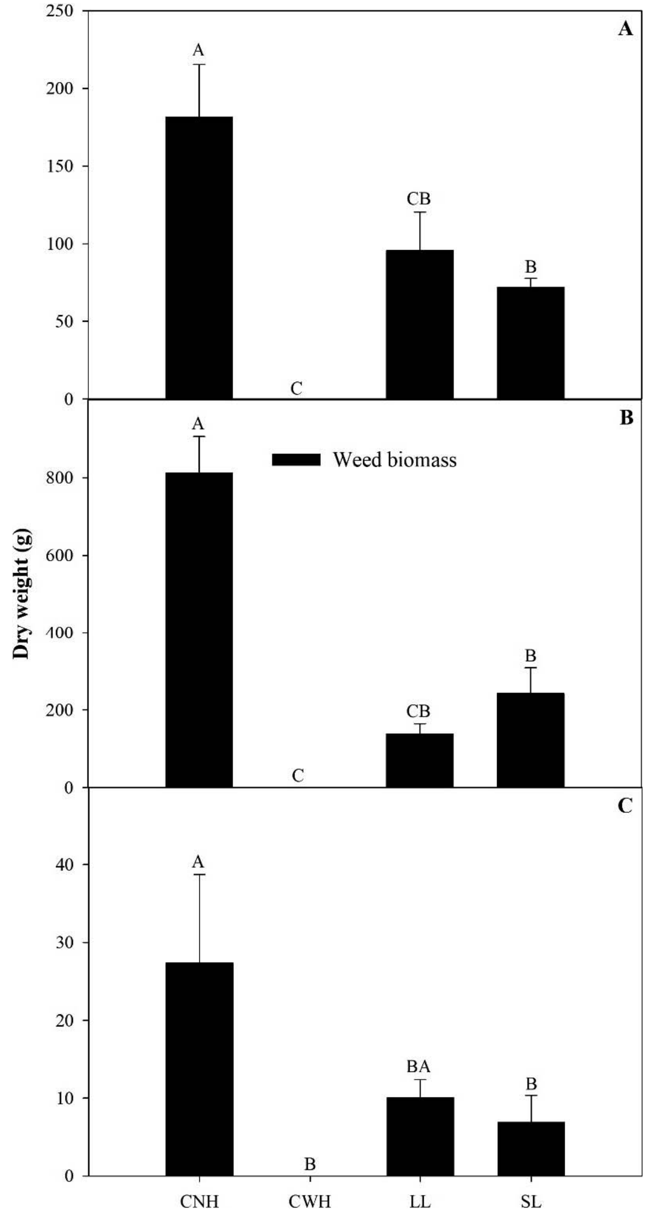

Fig. 5. Mean above-ground weed biomass (g) ($\pm$ SE) by treatment for the (A) Full sun environment, (B) tilled environment, and (C) shaded environment. Means with the same letter are not significantly different (P=0.05, n=3). CNH = control no herbicide, CWH = control with herbicide, LL =longleaf pine straw, SL = slash pine straw (n = 3). Biomass was cut and collected on 26-28 June, 8-12 July, and 14-17 August.

(P=0.01) (Fig. 5B). For the shaded environment, the presence of pine straw significantly reduced weed growth compared to CNH plots (treatment=0.007) and there was no significant difference between the two mulch types (Fig. 5C). CWH plots had negligible weed biomass throughout the duration of the study. This could be related to the size of the plots and area being controlled. Herbicide treatment was confined to 1.5 m diameter plots. As with our results, the use of pine straw as a mulch has been found to suppress weeds (Stinson et al. 1990, Makus et al. 1994). Weeds that did penetrate the mulch layer appeared to be coarser in size, creating a path of sunlight for additional weed growth. This has also been noted in a previous study using organic wood-based mulch (Maggard et al. 2012). For better weed suppression, the application of herbicide prior to the mulch application would help (Greenly and Rakow 1995, Maggard et al. 2012).

Tree height and diameter growth. The use of mulch has been found to improve tree growth (Greenly and Rakow, 1995, Ferrini et al. 2008, Maggard et al. 2012). However, in our study, the use of pine straw as mulch did not affect height growth or stem diameter growth of eastern redbud (treatment=0.72, 0.70) or Shumard oak trees (treatment=0.69, 0.47) compared to non-mulched plots (data not shown). Initial eastern redbud average height across all treatments was 1.3 m (4.3 ft). Height increase was greatest in the shaded environment for eastern redbud trees (env=0.0004). Total eastern redbud height increase by environment type was 0.21 ± SE 0.04 m for the shaded environment, 0.08 ± SE 0.02 m for the tilled environment, and 0.008 ± SE 0.04 m for the full sun environment. No environment by treatment interaction occurred for eastern redbud height growth (P=0.33). Total eastern redbud height increase by treatment was 0.15 ± SE 0.07 m for SL, 0.09 ± SE 0.03 m for LL, 0.09 ± SE 0.03 for CWH, and 0.09 ± SE 0.03 for CNH. Initial eastern redbud average stem diameter across all treatments was 0.9 cm (0.4 in). Total eastern redbud diameter increase by treatment was 0.6 ± SE 0.1 cm for SL, 0.8 ± 0.07 cm for LL, 0.8 ± SE 0.2 cm for CWH, and 0.6 ± SE 0.1 cm for CNH. There was no environment effect for eastern redbud stem diameter increase (env=0.39).

Initial Shumard oak average height across all treatments was 1.4 m (4.6 ft). Total Shumard oak height increase by treatment was 0.02 ± SE 0.03 m for SL, 0.02 ± SE 0.004 m for LL, 0.03 ± SE 0.07 m for CWH, and 0.02 ± SE 0.04 m for CNH (data not shown). Initial Shumard oak average stem diameter across all treatments was 1.2 cm (0.5 in) Total Shumard oak diameter increase by treatment was 1.0 ± SE 0.1 cm for SL, 0.9 ± SE 0.1 cm for LL, 0.8 ± SE 0.1 cm for CWH, and 1.0 ± SE 0.1 cm for CNH. Stem diameter increase for Shumard oaks was greater in the full sun environment compared to the tilled environment (env=0.02). Total Shumard oak stem diameter increase by environment type was 1.1 ± SE 0.09 cm for the full sun environment, 0.8 ± SE 0.08 cm for the tilled environment, and 0.9 ± SE 0.06 cm for the shaded environment. No environment by treatment interaction occurred for Shumard oaks stem diameter increase (P=0.10). We used bareroot trees to eliminate any potting soil effects. Therefore, establishment of trees in our study was prolonged and likely caused a delay in mulch effects, if any were to be observed. An additional growing season would likely be needed to encompass the full effects of pine straw on tree growth.

Decomposition. In terms of mulch decomposition between the two pine species, there was no significant difference. Across all pine straw treatments, average percent loss in dry weight was 0.17 ± SE 0.02 g for SL and 0.15 ± SE 0.02 g for LL (data not shown). Across all pine straw treatments, decomposition was greatest in the shaded environment than the full sun and tilled environments (env=0.04). Average percent loss in dry weight for the shaded, tilled, and full sun environments were 0.24 ± SE 0.04 g, 0.17 ± SE 0.01 g, and 0.16 ± SE 0.02 g, respectively. There have been several studies that have monitored decomposition among southern pine species needle fall (Gholz et al. 1985, Sanchez 2001, Binkley 2002). Gholz et al. (1985) found that over the course of two years, the average decay rate for slash pine was about 15% mass loss per year. However, to the best of our knowledge, pine straw decomposition rates have not been studied in a landscape setting as a mulch. A potential influence for our results could be related to the age of the pine straw and the condition in-which it was stored prior to purchase. The time from harvests to use was not possible to determine.

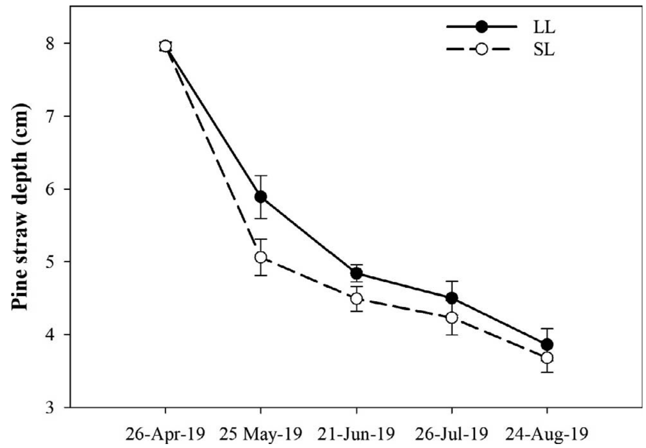

Fig. 6. Mean pine straw depth (cm) (± SE) over time measured from the top of pine straw to soil. LL = longleaf pine straw and SL = slash pine straw (n=9).

Pine straw depth. The depth change over time among pine straw types used as mulch has not been well documented, although it is known that pine straw can settle over time, reducing its original application depth (Taylor and Foster 2004b). In our study, LL maintained a greater depth than SL (treatment=0.0006) (Fig. 6). Across all pine straw treatments, depth was significantly lower in the tilled environment type compared to the full sun and shaded environment types (environment<0.0001). The greater maintenance of original application depth for LL plots could be attributed to the differences in the length of the pine needles between the two species, causing differences in how the needles interlock and rest on the ground. However, to our knowledge this has not been scientifically proven. Further research is needed to better understand the differences in depth over time.

This study indicates that both longleaf and slash pine straw maintained greater soil moisture, moderated soil temperatures, reduced weed growth compared to not using mulch, and decomposed at similar rates. This provides evidence that both types of pine straw provide similar benefits in landscape settings when used as mulch. Further, information about these attributes can help provide better context to pine straw markets and the financial and economic aspects of the benefits associated with these southern pine species. To fully understand the pricing differences between longleaf and slash pine straw and the potentially higher demand for longleaf pine straw, further research on aesthetic quality would be beneficial. Specifically, research focusing on color differences and change overtime along with appearance surveys would be beneficial for better understanding consumer preference and demand.

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