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# Influence of Spike-tooth Aeration on Permanent Pastures in Mississippi

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# INTRODUCTION

The occurrence of tillage pans below the Ap (surface) horizon in intensively cultivated sandy soils in the Southeast has been recognized as detrimental to crop production (*1, 2, 8, 13*). The tillage pan is commonly referred to as a "traffic pan" because it is associated with repeated disking and equipment traffic. Researchers have determined that high bulk density "traffic pans" in many Typic Paleudult soils form in compaction-prone horizons typically containing less than 10 percent clay and 2 percent organic matter (*3*).

Recent concern has focused on whether intensive grazing compacts pastures and retards water infiltration and root growth. One study found that water infiltration was inversely proportional to grazing intensity in a Pratt loamy fine sand (Psammentic Haplustalfs) in Oklahoma which had 22.8 inches annual precipitation (*12*). This study showed that grazing animals compacted the soil and increased bulk density with resultant lower porosity. They found a sod-protecting cover of about 6 tons per acre of standing vegetation and litter occurred in non-grazed sites and 2-3 tons on grazed sites.

Various implements have been used with mixed results to aerate pastures with suspected grazing compaction. Aeration treatments have been reported to reduce compaction (*7*) and increase forage production (*5*). Another study found little or no response to spike-toothed aeration on a grazed bermudagrass [*Cynodon dactylon* (L.) Pers.] pasture of Pocasset silty clay loam (Fluventic Haplustolls) receiving 30 inches of precipitation each year (*18*). Their research (*18*) indicated there is little or no benefit from pasture aeration and even showed a reduction in forage production from several commonly used pasture aeration implements.

Permanent grass cover is widely used to reduce accelerated soil erosion and ameliorate soils impacted by intensive cultivation. Researchers reported Pensacola bahiagrass (*Paspalum notatum* L.) penetrated compacted layers in a Cahaba loamy sand (Typic Hapludult) (*9*). They further reported that the root channels remained open and the soil could be penetrated by cotton roots for as long as 4 years. Another study (*17*) found cultivars could be selected on root-penetrating ability to deal with compacted soil layers.

The objectives of this study were to determine: (1) forage yield response to a spike-tooth pasture aerator; and (2) impacts of aeration on two soils of extensive occurrence in Mississippi.

# MATERIALS AND METHODS

## Study Areas

The study sites were located at the Brown Loam Branch Experiment Station at Raymond in Hinds County, and the White Sands Unit of the South Mississippi Branch Experiment Station at Poplarville in Pearl River County (Figure 1.).

The Brown Loam Branch is in the Southern Mississippi Valley Silty Uplands Major Land Resource Area (MLRA 134), where soils formed in thick deposits of the Peorian Loess. These are deep, silty soils that have a thermic temperature regime (59-72 °F) and mixed mineralogy.

The average annual precipitation is about 52.3 inches with 48 percent (25 inches) occurring during the April through September growing season. The average summer temperature is 80 °F, and the average winter temperature is 48 °F.

The White Sands Unit is in the Lower Southern Coastal Plan Major Land Resource Area (MLRA 133A), where soils formed in thick coastal plain sandy sediments. These soils are highly leached and have a thermic temperature regime (59 to 72 °F) and siliceous mineralogy. The average annual precipitation is about 53.2 inches with 48 percent (26 inches) occurring April through September. The average summer temperature is 80 °F, and the average winter temperature is 48 °F.

## Field Characterization and Sampling: Bahiagrass Pastures

Detailed soil characterization was conducted in the center of the study area in freshly excavated backhoe pits. The pits were 15 feet long, 4 feet wide, and 7 feet deep. Landscape elements were determined at each site. Soil morphological parameters were determined using standard methods (*19*) and included horizonation and depth, Munsell color, texture, structure, consistence, mottling, presence of concretions, topography, thickness of horizon boundaries, and size and distribution of roots.

Undisturbed core samples were taken in major horizons for determination of bulk density, saturated hydraulic conductivity, and moisture retention. Duplicate core samples were taken for each horizon within a one-meter (40-inch) distance of a contiguous pedon by cutting back the face of the pit and exposing each horizon from the surface to the bottom of the pit.

Each subplot within the bahiagrass pasture aeration study was sampled at depth intervals of 0-2 and 2-5 inches at three random locations. Undisturbed cores were taken of the surface (0-4 inches) at three random locations in each subplot for bulk density and hydraulic conductivity determinations. Soil penetration resistance measurements were made across each subplot with a Delphi recording penetrometer to 24 inches depth.

## Soil Analyses: Bahiagrass Pasture Aeration Studies

Soil samples were air-dried in the laboratory, crushed with a wood cylinder, and sieved through a No. 10 mesh sieve to remove coarse fragments larger than 2 millimeters (*19*). Particle-size distribution was determined by the hydrometer method and sieving (*6*). Soil organic matter was determined by acid dichromate digestion (*10*). Extractable acidity was determined by the $BaCl_2$ triethanolamine method (*11*). Cations were extracted with M $NH_4OAc$ (pH 7.0) and determined by atomic absorption spectrophotometry. Exchangeable $Al^{3+}$ was extracted with M KCl and determined by titration (*20*). Soil pH was measured in a 1:1 soil/water suspension.

## Bahiagrass Pasture and Aeration Treatments

At the Brown Loam Branch, the pasture selected for initial aeration treatments in 1992 was a dense Pensacola bahiagrass (*Paspalum notatum* L.) sod with 100 percent ground cover. The pasture had been grazed for 25 years with one cow per 1.5 acres. The grass was mowed to 3 inches height before treatment. The aeration treatments were implemented at a gravimetric soil moisture level of 19.9 percent, which was considerably less than field capacity (29.5 percent). The pasture had a thick thatch layer above the mineral soil.

At the White Sands Unit, the pasture selected for initial aeration treatments in 1992 was a dense Pensacola bahiagrass (*Paspalum notatum* L.) sod with 100 percent ground cover. The pasture had been grazed 10 years with one cow per 2 acres. The grass was mowed to 3 inches height before treatment. The soil moisture was near field capacity (13.6 percent) when the aeration treatments were performed. A very thick thatch layer covered the mineral soil.

Five pasture aeration treatments were compared for forage yield at the White Sands Unit and Brown Loam Branch during the 1993 growing season. The treatments were: (1) Aer Way$^{TM}$ pasture aerator [see description below]; (2) shank renovator; (3) disk; (4) deep chisel to 10 inches; and (5) control/no treatment. Treatments were installed on bahiagrass pastures at both locations in the fall prior to measurement. Forage yield was determined during the 1993 growing season. Forage yield data were also collected at the White Sands Unit during the 1994 growing season. Penetrometer readings (Lang$^{TM}$ Penetrometer) were collected at the Brown Loam Branch during 1993 (10 subsample measurements per plot).

## Bermudagrass Hayfields and Aeration Treatments

Bermudagrass studies were conducted in 1994-95 at the Brown Loam Branch Experiment Station in Raymond on a Coastal bermudagrass hay field; Coastal Plain Branch Experiment Station in Newton on a Tifton 78 bermudagrass hay field; and South Mississippi Branch Experiment Station White Sands Unit in Poplarville on an Alicia bermudagrass hay field. Hay fields at the Brown Loam Branch and White Sands Unit were used as holding areas for wintering cattle and then used for hay production during the summer. The field at the Coastal Plain Branch was used only for hay production. All fields were soil tested, and fertilizer and lime were applied according to soil test recommendations for hay production.

Timing of pasture aeration was compared during the 1994 and 1995 growing season. Plots at each location were maintained to allow detection of aeration effects in consecutive years. The four timing treatments were as follows: (1) spring aeration, April; (2) summer aeration, July; (3) combined spring and summer aeration, April and July; and (4) control/no aeration. In 1995, an additional set of timing treatments were implemented in an area separate but adjacent to the original experiments. The 1995 study compared six treatments at each location. They were: (1) spring aeration only; (2) spring aeration and after every forage harvest; (3) combined spring and fall aeration; (4) spring and after the second forage harvest; (5) two times in the spring [aerator operated slightly offset to first run which produced more spike impressions per unit area]; and (6) control/no treatment. Plots at all locations were harvested three times during 1994 and three times during 1995. All studies were arranged in a randomized complete block design with four replications.

For all studies, forage samples were clipped with a Sensation$^{TM}$ plot mower equipped with a grass bag attachment. Samples were dried at 160 °F for 72 hours and then weighed for determination of dry matter yield (pounds per acre). Data were analyzed using analysis of variance and means separated using the Fisher's Protected Least Significant Difference Test with a significance level of 5 percent.

An additional study conducted at Raymond in 1994 involved operating the Aer Way$^{TM}$ aerator in a bermudagrass variety yield trial. Half of each variety plot (6 by 10 feet) was aerated at green-up (late February in 1994), after the first harvest in May, and after the third harvest in August. The plots were harvested four times during the 1994 growing season. Standard small plot forage techniques were used for dry matter yield determinations. The experiment was set up as a split-plot arrangement of treatments in a randomized complete block design with four replications. Variety served as the main plot factor and aeration as the subplot factor. Data were analyzed using analysis of variance and treatment means separated using Fisher's Protected Least Significant Test with a significance level of 5 percent.

# RESULTS AND DISCUSSION

## Soils: Brown Loam Branch

Bahiagrass pasture aeration plots were located in a uniform Loring silt (fine-silty, mixed, thermic Typic Fragiudalfs) with slopes of 2 percent. The deep, moderately well-drained soil has a brown epipedon (surface horizon) with silt texture and very friable consistency (Table 1). The subsoil has a well-developed silt loam argillic horizon (Bt) with a fragipan (Btx) extending from 26-60 inches. Many fine and medium roots permeate the argillic horizon, and few fine roots extend into the fragipan horizon in polygonal seams between prismatic structural aggregates. The lower horizons contain many soft round dark reddish brown concretions.

The surface horizon has 84.9 percent silt with 3.6 percent sand and 11.4 percent clay (Table 2). Maximum clay contents occur in the argillic horizon and range from 18-24.5 percent. Soil reaction ranges from strongly acid to slightly acid (Table 3). Organic matter content ranges from 2.39 percent in the surface horizon to less than 0.1 percent below depths of 33 inches (Table 3). The organic matter content generally coincides with the root distribution. Calcium is the dominant exchangeable cation with cation exchange capacities ranging from 10.3-17.4 percent. Base saturation increased with depth to levels exceeding 80 percent at 42 inches.

Saturated hydraulic conductivity was highest in the surface horizon and decreased in the subsoil to less than 0.01 inches per hour in the fragipan (Table 4). Bulk density ranged from 1.35 g/cc in the surface horizon to 1.51 g/cc in the fragipan. Soil water field capacity (1/3 bar) ranged from 29.5 percent in the surface horizons to 22.1 percent in the eluvial E horizon. The soil bulk density levels and morphology in the surface horizon (Ap) do not indicate compaction. The dense fibrous root system permeating the surface horizon produced large macrovoids and contributed to enhanced organic matter contents. Large fibrous roots had thick crowns ranging to 0.5 inch diameter in the surface 4 inches.

**Plots.** The low bulk density levels do not indicate compaction from grazing. Bulk density and saturated hydraulic conductivity were not different (P=0.05) between the aeration treatment and control. Soil particle size distribution in the control and aerated plots was uniform and not statistically different (P=0.05) in the 0-2 and 2-5 inch layers (Table 5). Soil bulk density levels were less than 1.2 g/cc due to the extensive root system and associated macrovoids. Soil chemical characteristics of the surface layers were not different (P=0.05) between treatments (Table 6). Organic matter contents were maximum in the 0-2 inch layer and exhibited a marked decrease in the 2-5 inch layer.

## Soils: White Sands Unit

Bahiagrass pasture aeration plots were located in a uniform Malbis fine sandy loam (fine-loamy, siliceous, thermic Plinthic Paleudults) with slopes of 2-5 percent. The deep, well-drained soil has a dark brown epipedon (surface horizon) with fine sandy loam texture and friable consistency (Table 7). The surface horizon contains many fine and medium roots and root crowns. The subsoil has a well-developed argillic horizon (Bt) with firm restrictive plinthic horizons (Btv) occurring below 22 inches. Many fine and medium roots permeate the upper argillic horizon (Bt1) and common to few fine roots extend into the upper plinthic horizon (Btv1).

The surface horizon has 65.9 percent sand with 27.8 percent silt and 6.3 percent clay (Table 8 ). Clay content increases with depth with a maximum of 36.9 percent at 35-52 inches. Soil reaction ranges from very strongly acid to strongly acid (Table 9). Organic matter content ranges from a maximum of 2.12 percent in the surface horizon to less than 0.1 percent below 35 inches. The highly leached sandy soil has a low content of exchangeable cations with acidity ($H^+$) dominating the exchange complex. Cation exchange capacities range from 4.19-9.70 $cmol_c$ per kilogram. Base saturation decreased below depths of 35 inches.

Saturated hydraulic conductivity was highest in the surface horizon (Ap) and decreased with depth with very low conductivity in the restrictive plinthic horizon (Table 10). Bulk density ranged from 1.46 g/cc in the surface horizon to 1.61 g/cc in the plinthic horizon (Btv2). The soil had low moisture retention capacity. Soil water field capacity (1/3 bar) ranged from 13.6 percent in the surface horizon to 24.1 percent at 52 inches depth.

**Plots.** Soil bulk density levels do not indicate compaction from grazing. The bulk density and saturated hydraulic conductivity were not statistically different (P=0.05) between aerated and control plots. The surface horizon had sandy loam textures. Soil particle size distribution was uniform and not statistically different (P=0.05) in the 0-2 and 2-5 inch layers (Table 11). Exchangeable cations and base saturation levels in the surface horizon were low (Table 12) and typical of highlyweathered Ultisols. Chemical characteristics were not different (P=0.05) between treatments. Maximum organic matter contents occurred in the surface 2 inches and corresponded to root content.

## Soil Impacts of Aeration Treatment: Bahiagrass Pasture

The pasture aeration implement used at all three locations was an Aer Way spike-tooth pasture aerator (12 feet wide). Spikes (8 inches long) were arranged on two separate 6-foot-wide rotating drums, with each 6-foot drum section movable to obtain 0, 2.5, 5, 7.5, and 10 degrees of angle from directly horizontal. The more angle placed in the drum sections, the more soil disturbance achieved. Additional weight (1,000 pounds) was placed in a tray above the rotating drums to improve spike penetration under drier soil conditions. The aeration treatment made 1.1 diamond-shaped slits in the soil per square foot. The shape and surface dimensions (Figure 2) of the slits were similar at both sites. Plaster of Paris casts of the slits indicate uniform shape. The surface area impacted by the treatment was less than 2 percent of the total surface area. The average slit depth was 2 inches in the silt-textured surface horizon at the Brown Loam site and 2.75 inches deep in the sandy loam at White Sands.

Excavation and examination of the angular slit faces and bottom revealed smearing of the Loring silt which annealed pores and could reduce water infiltration and movement. Bulk density in the slit bottom area immediately after treatment was higher (1.37 g/cc) than in adjacent undisturbed soil (1.09 g/cc) at the same depth. Soil penetration resistance measurements also indicated compaction at the slit bottom at both sites. Penetration resistance was 976 pounds per square inch in the slit bottom at the Brown Loam site compared to 718 pounds per square inch in the adjacent undisturbed soil at the same depth. Penetration resistance was 980 pounds per square inch in the slit bottom compared to 480 pounds per square inch in the adjacent undisturbed soil at White Sands. Soil conditions limiting root growth may occur when penetration resistance exceeds 290-435 pounds per square inch, depending on the soil and root type (*1, 4, 15*). Previous research on a loessial soil reported resistance that limited root growth was 522 pounds per square inch in the tilled Ap (surface) horizon and 667-739 pounds per square inch in the untilled Ap horizon and the subsoil of both treatments (*16*). Root elongation is usually inversely correlated with mechanical impedance (*14*).

Temporal measurements the summer after aeration treatment showed no statistical differences in soil penetration resistance, and they showed similar soil moisture content between aerated and control plots. Soil penetration resistance was lowest in the surface horizons (Ap) at both sites (Figures 3 and 4) and increased at the top of the argillic horizons (Bt) which had higher clay contents.Soil moisture contents in the aerated and control plots were very similar at the Brown Loam site on June 24, 1993, (Figure 5) in the surface horizon and upper subsoil. The White Sands site had slightly higher moisture content at 6 inches depth in the control plots (Figure 6) on June 25, 1993.

## Forage Yields: Bahiagrass Pasture Aeration Study

Forage yield of bahiagrass pastures at the White Sands Unit and Brown Loam Branch as affected by the different pasture aeration implements are presented in Tables 13 and 14. At the White Sands Unit in 1993, the shank renovator resulted in significantly less (P=0.05) forage production on the first harvest and also for total yield as compared to the control. Disking also resulted in less total dry matter accumulation (not significant at P=0.05) than the check. The deep chisel resulted in about a 5 percent increase (not significant at P=0.05) in dry matter yield over the control. For each of the three harvest dates, the Aer Way$^{TM}$ aerator resulted in the greatest dry matter yield. Although not statistically significant, the Aer Way$^{TM}$ produced a 13.2 percent increase in total dry matter yield (Table 13), as compared to the control. At the Brown Loam Branch in 1993, there were no significant differences in forage yield among the pasture aeration implements (Table 14). However, the shank renovator and disk resulted in less forage accumulation as compared to the control. Penetrometer measurements made in mid-summer indicated the shank renovator, disk, and deep chisel each significantly reduced soil penetration resistance as compared to the control (Table 14). However, by November of the same year, only the deep chisel treatment had maintained lower soil penetration resistance. In 1994, five harvests were made at the White Sands Unit from the bahiagrass test area. No significant differences (P=0.05) in forage yield were detected among the aeration implements at any of the harvests(Table 15).

## Forage Yields: Bermudagrass Hay Fields

Data for the influence of timing of pasture aeration on forage yield of bermudagrass at three locations are presented in Tables 16-25. Data were analyzed as a combined analysis of a series of randomized complete block designs where years and locations were not randomized. The overall analysis of variance indicated a significant (P=0.05) year by location interaction for dry matter yield. Therefore, data for each location is presented by year. In 1994, the Coastal bermudagrass hay field at the Brown Loam Branch produced the greatest dry matter yield with over 12,000 pounds per acre (Table 16). At the Coastal Plain Branch, Tifton 78 yields averaged 8,479 pounds per acre (Table 17). Alicia bermudagrass at the White Sands Unit produced 8,976 pounds per acre during the test period (Table 18). In 1995, forage yield at the Brown Loam Branch averaged 7,613 pounds per acre (Table 19). The dry matter yield of Tifton 78 at the Coastal Plain Branch averaged 9,831 pounds per acre (Table 20). Forage yield at the White Sands Unit was similar to that at the Brown Loam Branch, averaging 7,898 pounds per acre (Table 21). Over the 2-year study, there were no statistically significant differences in forage yield among the aerator timing treatments at any harvest at any location in any year. Soil penetration resistance measurements made at two times during the growing season indicated no significant influence of spike-tooth aeration on soil penetration resistance in the Coastal bermudagrass hay field at the Brown Loam Branch (Table 22).

Forage production results from the additional studies of aeration timing were similar to the initial experiments. The experiments were harvested on the same dates at each location (Tables 23-25). At the Brown Loam Branch, total dry matter yield averaged 7,944 pounds per acre, with the greatest dry matter yield occurring in the control (8,546 pounds per acre). There were no significant differences (P=0.05) in forage yield at any harvest or for total yield. At the Coastal Plain Branch, significantly less forage (P=0.05) was produced when the aerator was operated twice in the spring (Table 24), as compared to the control. However, by the end of the growing season, no significant differences (P=0.05) were found in total forage yield. Total dry matter yield at the White Sands Unit averaged 7,286 pounds per acre (Table 25). No significant differences occurred among aeration treatments at any harvest or for total yield.

In the study using bermudagrass variety trial plots at the Brown Loam Branch, aeration in late February just before green-up resulted in a significant decrease (P=0.05) in forage production from the first harvest averaged across all varieties (Table 26). All varieties produced less dry matter yield in the aerated plots at the first harvest. However, there were no significant differences in total dry matter yield of varieties between aerated and non-aerated treatments (Table 27).

# SUMMARY

Temporal evaluations of aeration treatments of grazed bahiagrass pastures in extensively occurring Loring and Malbis soils showed no statistical differences (P=0.05) in particle size distribution or chemical characteristics in the surface 4 inches. Soil penetration resistance and moisture contents in the upper 24 inches were not different after aeration treatment. The aeration treatment impacted less than 2 percent of the total surface area. Treatment slits had smeared walls and compacted bottoms which could retard water movement and root growth.

Spike-tooth aeration of bahiagrass pasture and bermudagrass hay fields resulted in no increase in dry matter forage production at three locations in central and southern Mississippi, regardless of the time of treatment. Two instances of detrimental effects on forage production were observed when timing of aeration was employed in the spring.

The conclusion to be drawn from this study is that aeration of bermudagrass and bahiagrass pastures does not improve forage dry matter production. Aerating to improve forage yield is not recommended on the soil types used in this study.

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