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Soil pH and Liming Issues Affecting Bahiagrass Pasture[1]

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Soil Acidity

Soil acidity refers to the concentration of active hydrogen ions (H^+) in the soil. It is measured by an index called pH. A lower pH is associated with more active hydrogen ions and a more acidic soil. The normal range of soil pH relative to its acidity or alkalinity is shown in Figure 1.

A pH of 7 (as is the case for distilled water) is neutral because its acidity is equal to its alkalinity ($H^+ = H^-$) and, for soil, a pH of 7 is too high for most forages grown in Florida. A pH of 5 to 6 is slightly acidic and satisfactory for the growth of most Florida forages. A pH of 4 is too acidic and will result in poor root growth or function of most Florida forages. There are a few native Florida soils with pH greater than 7 and these are usually underlain by marl and, in some places, hard limestone. In general, most native Florida flatwoods soils are acidic, with pH of <4.5.

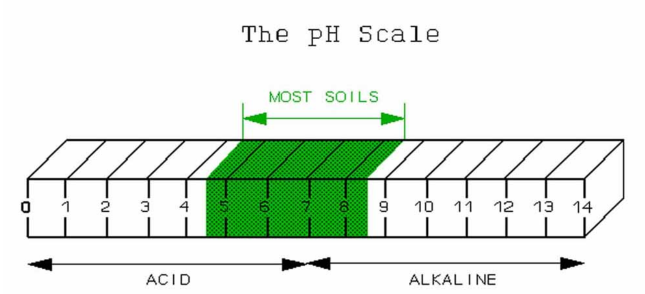

Figure 1. The normal range of soil pH on an acidity-alkalinity scale.

Effect of Nitrogen Fertilizer on Soil Acidity

Soil acidity tends to increase with repeated use of nitrogen (N) fertilizer because the commonly used N fertilizers contain ammonium, or ammonium and sulfate radicals. Soil micro-organisms cause biological oxidation of ammonium to nitrate in a process called nitrification. This is a two-step process that generates hydrogen ions:

1) $NH_4^- + 3O_2 = 2NO_2^- + 2H_2O + 4H^+$ (caused by nitrosomonas bacteria)

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2) $NO_2^- + O_2 = 2NO_3^-$ (caused by nitrobacter)

With ammonium sulfate fertilizer, additional acidity may result from hydrolysis as follows:

3) $(NH_4)_2SO_4 + 2H_2O = H_2SO_4 + 2NH_4OH$

4) $H_2SO_4 = 2H^+ + SO_4^{-2}$

Increase in soil acidity following repeated application of N fertilizers is naturally countered to some extent by soil buffering capacity (clay minerals and organic matter). The sandy flatwoods soils in south Florida tend to have low clay and organic matter content and generally low buffering capacities (<2.0%) . Hence, the increase in soil acidity must eventually be countered by liming with calcium or calcium/magnesium compounds, which have the ability to neutralize hydrogen ions and increase soil pH. For example, it requires 60 pounds (lb) of lime to neutralize the acidity from 100 lb of ammonium nitrate and 110 lb of lime to neutralize the acidity from 100 lb of ammonium sulfate. However, lime requirements for pasture should always be determined by an approved soil lab based on soil test results.

Effect of Soil pH on Nutrient Availability

In acid soils with pH less than 5, the availability of boron (B), molybdenum (Mo), and sulfur (S) is reduced, and nutrient uptake and forage production is lowered by more than a third, regardless of N fertilization. There is also the potential for active aluminum (Al^{3+}) toxicity to grass roots at soil pH of about 4.0. Additionally, increasing soil acidity to pH less than 5 can predispose grass to yellowing and damage by soil-borne insects. Increasing soil alkalinity to pH greater than 7 (such as from repeated use of lime-stabilized sludge) can also be harmful. High soil pH will reduce the availability of iron, manganese, zinc, copper and cobalt, and create forage production problems similar to increased acidity.

Bahiagrass Decline in Relationship to Mole Crickets and Changing Soil pH

Bahiagrass decline is a major problem in Florida. It usually begins with yellowing of the pasture in small or big patches. Later, affected pasture areas turn brown and die which is normally associated with the burrowing and tunneling activity of mole crickets. On damaged areas with high mole cricket infestation, the 6 to 10 inches of soil surface layer is honeycombed with numerous mole cricket galleries and the ground feels spongy underfoot. A severely damaged pasture has virtually no root system and the plants are easily pulled from the soil by cattle or foot traffic in a pasture. Research and surveys conducted throughout south-central Florida have shown a link between grazing intensity, declining soil pH and severity of mole cricket-induced bahiagrass decline. Bahiagrass roots under low soil pH cannot absorb B, Mo, S, K and P sufficiently, and feeding on roots by mole crickets aggravates the situation, whereas healthy roots under optimum soil pH can withstand some mole cricket damage.

Field Study

At the Range Cattle Research and Education Center, Ona, we have evaluated the long-term combined effect of liming and N fertilization on the performance of two bahiagrass pastures (A and B). We applied three types of fertilizer and a control (no fertilizer) annually to portions of bahiagrass pasture that were either limed to maintain a pH of 5.0, or not limed and had a pH decline to about 4.3. The four fertilizer treatments that were applied every spring from 1998 and will continue to 2007 are: 1) 60 lb/acre of N from ammonium sulfate (N); 2) 60-25-60 lb/acre of $N\text{-}P_2O_5\text{-}K_2O$ from ammonium sulfate, triple super phosphate, and muriate of potash (NPK); 3) 60-25-60 lb/acre of $N\text{-}P_2O_5\text{-}K_2O$ plus 20 lb/acre of a micro-nutrients mix (Frit Industries, Inc.) which contained B, Cu, Mo, Fe, Mn and Zn (NPKM); 4) no fertilizer control (Cont). Approximately a ton of dolomite was applied every three years to maintain the pH of 5 on limed areas. Bahiagrass performance was measured annually by determining dry matter yield, crude protein content, forage digestibility, and condition (color) of bahiagrass sod in the spring.

Dry Matter Yield

Pasture A in Hardee county was low-lying and may have had a slightly better soil buffering capacity, because soil pH decline was slow and dry matter yield was not significantly affected by liming to a pH of 5 through 5 years of the study (Figure 2). The no-lime plots on pasture A declined to a pH of about 4.5 during that period. However, liming plus N (either from N, NPK or NPKM) improved bahiagrass yield by 30 % over plots in pasture B that received N fertilizer with no lime (Figure 2). Soil pH of N-fertilized plots without lime declined to 4.3 in three years on pasture B, an elevated and well-drained site. On average, the yield increase from N-fertilizer over the no fertilizer control for both pastures was about 25%. We did not observe any major yield response of bahiagrass forage yield to P and K fertilization under grazing on both Hardee Co. pastures for 8 years, although tissue P levels declined by 33% and K levels by 36% without their application during the same period. We also did not observe any improvement in yield by applying micronutrients.

Nutritive Value

Lime application had little effect on seasonal crude protein content or digestibility (IVOMD) of grazed bahiagrass forage. However, in addition to yield increase, seasonal crude protein content increased by about 2% units (12% versus 10%) with the application of any fertilizer containing N. This protein enhancement attribute of applied N was greater immediately after N application in spring and diminished with time through the season. Forage IVOMD for the no-fertilizer control was always among the lowest (47%) although improvement with N application varied from site and season.

Effect of Lime and Fertilizer on Spring Sod Ground Cover

We observed that damage to bahiagrass sod was made worse by acid soil (pH<4.5). At the beginning of grazing in the spring of 1998, all the newly established bahiagrass plots had excellent stands with nearly 100% green ground cover. Two years later (2000), the color of bahiagrass ground cover on pasture B began to vary based on liming management, where all limed plots were completely

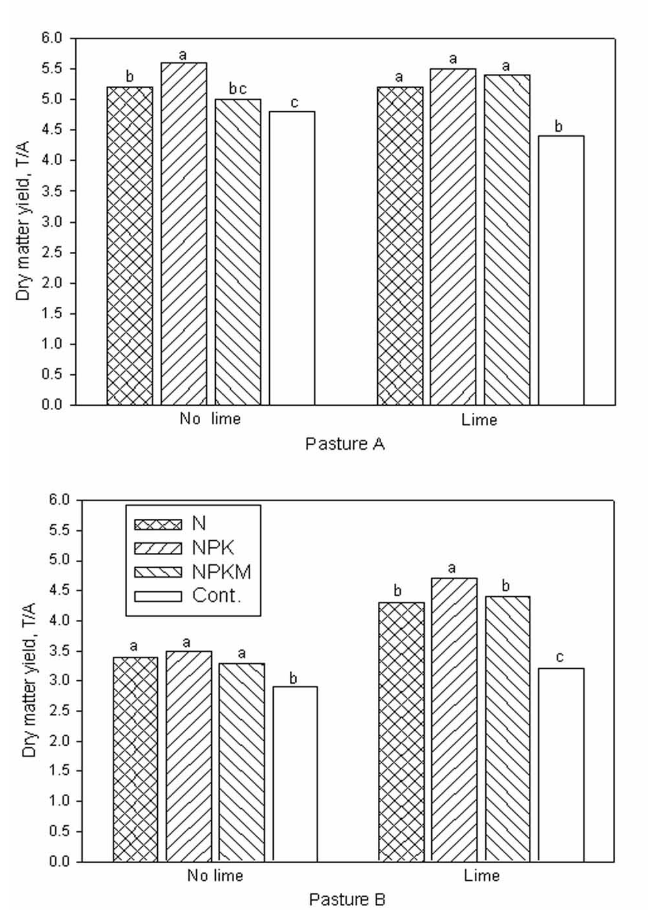

Figure 2. Bahiagrass dry matter yield under grazing as influenced by fertilizer and lime treatments on Hardee Co. pastures A and B in south-central Florida. Note the 30% increase in forage yield from N application to pasture B when field is limed.

green in spring but the color of no-lime plots depended on fertilizer treatment. This interaction between lime and fertilizer treatment intensified with time. In 2002, five years into the experiment, minimum spring color change or damage to bahiagrass sod (1-4% ground cover consisting of yellow, brown, or weedy cover) was noticed for plots limed to pH 5 whether or not they received fertilizer, or for no-limed plots that were not fertilized (Figures 3 and 4) . Sod damage was most severe (20-69% of ground cover) when bahiagrass pasture was not limed but received yearly application of any N-containing fertilizer even at the rate of 50 lb N/acre. The combination of acidic soil conditions (pH less than 4.5) and repeated N fertilization reduced bahiagrass stolon/root biomass by 30%, weakened the root system, caused severe yellowing in early spring growth, and made it easier for mole cricket damage to occur and weeds to invade. Similar damage to sod was observed later on pasture A beginning in 2002 (Figure 4), probably as a result of differences in soil buffering capacity to pH changes.

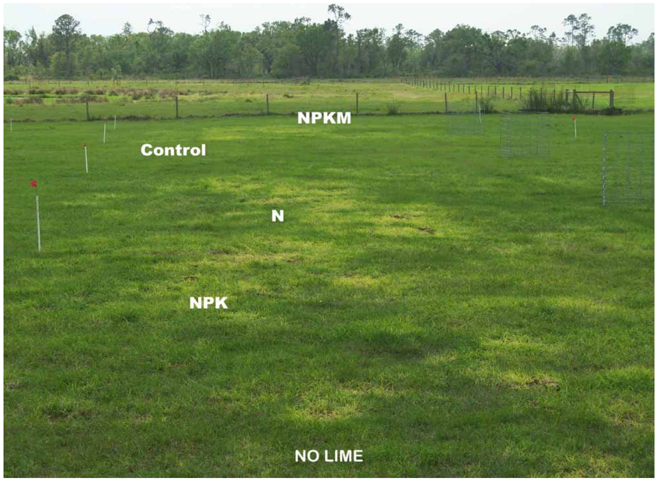

Figure 3.a

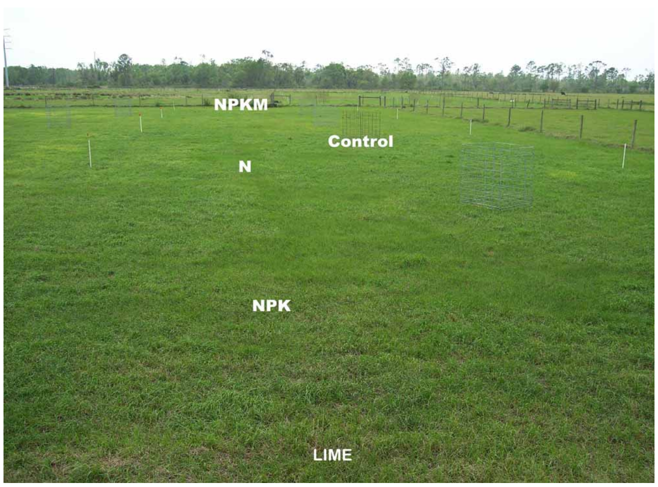

Figure 3.b

Figure 3. Spring color of bahiagrass sod on Hardee Pasture B in 2002 as affected by the interaction of lime and N fertilizer treatment. Note that the control, which received no N, is green even without lime application (a), but with lime application sod is green under all fertilizer treatments (b).

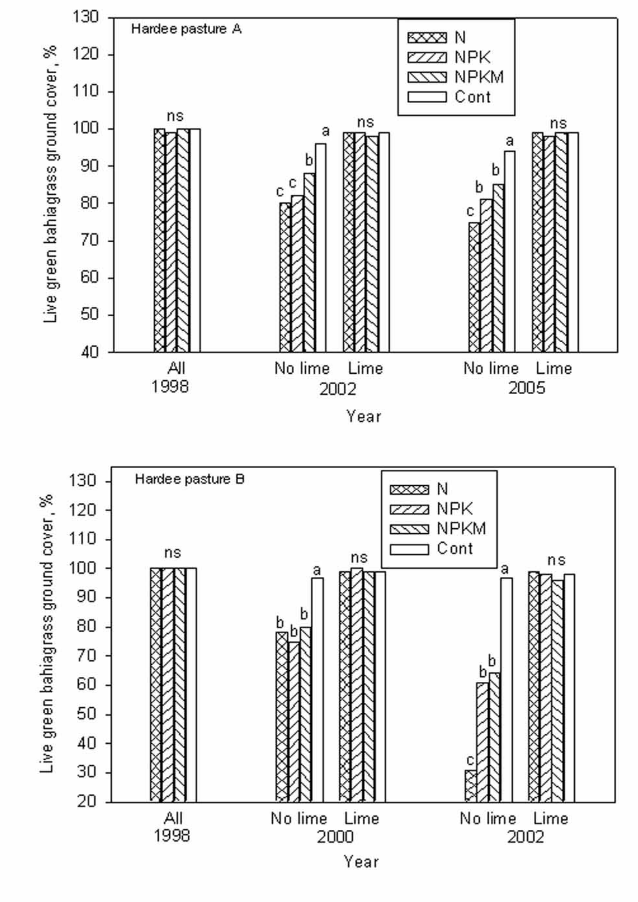

Figure 4. The interaction between fertilizer, lime and year on percentage spring live green bahiagrass ground cover (damage consisted of yellow, brown, weedy cover). Note that deterioration of cover on pasture A lagged 2-3 years behind pasture B.

Effect of Sludge on Bahiagrass Sod

Some livestock producers apply lime-stabilized sludge to pastures to reduce the cost of fertilizer and lime. In the processing of sludge, lime is added for the control of pathogens, insect vectors, and odor; but this makes limed-sludge an excellent source of lime, slow-release plant nutrients (especially N and P), and organic matter. At the time of application, the pH of limed-sludge could range between 7 and 11, N content between 3% and 5% of dry sludge, and P content between 2% and 4% of dry sludge. Four consecutive years of repeated application of limed-sludge at the Range Cattle REC, Ona, showed that when used at recommended agronomic rate (200 lb N/acre), bahiagrass forage production responded well to sludge organic fertilizer and there was no damage to the sod. In those studies, we applied limed sludge up to 160 lb of N yearly and improved annual forage dry matter yield from <1.0 ton/acre where no sludge was applied to 2.5 ton/acre when sludge was applied (Figure 5). There was no excessive build-up of plant nutrients or trace metals in the soil from repeated sludge application and soil pH increased from 5.0 to 5.3 in four years. However, several bahiagrass pastures in Polk, Pasco and Hardee counties where excessive amounts of limed-sludge were applied repeatedly attained a soil pH of about 7. Bahiagrass roots cannot function properly to absorb sufficient iron, manganese, and other micronutrients when the soil pH approaches 7, so those pastures lost substantial portions of grass sod to weeds in a manner similar to the symptoms of bahiagrass decline. It was easy to identify the strips in those pastures where limed-sludge was heavily applied.

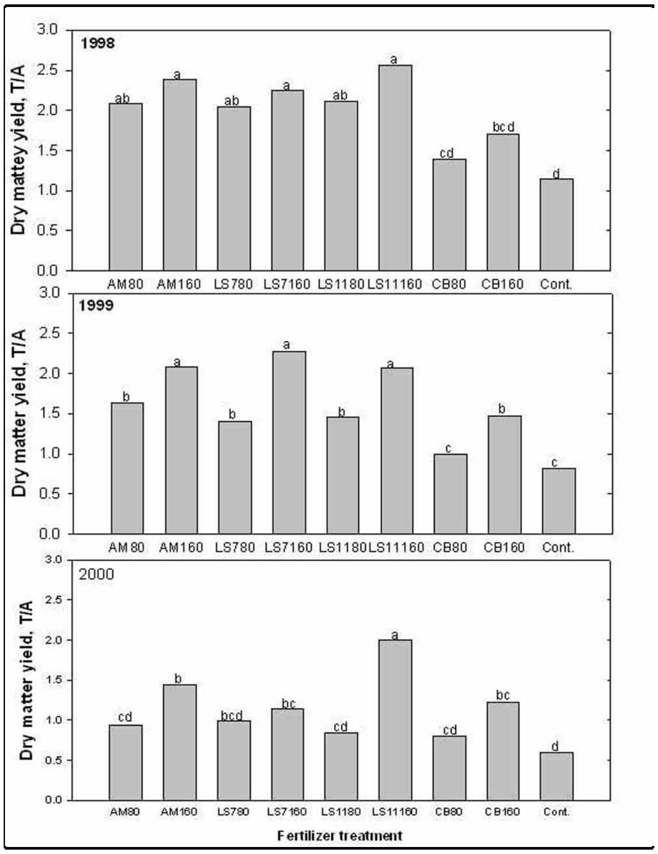

Figure 5. The effect of fertilizer treatment by year by harvest date on seasonal bahiagrass forage dry matter yield at the Range Cattle REC, Ona. Ammonium nitrate (AM); liquid (slurry) sludge at pH 7 (LS7); liquid sludge at pH 11 (LS11); cake biosolid (CB); and non-fertilized control (Cont.) at annual N rates of 80 and 160 lb/A.

Summary and Recommendations

Under grazing conditions in south-central Florida flatwoods:

1. Apply 50 lb of N/acre to bahiagrass in early spring to boost yield and forage crude protein content.

2. Bahiagrass forage yield often does not respond to P and K application under grazing but tissue concentrations will decline over several years.

3. Repeated N fertilization with ammonium nitrate or ammonium sulfate will cause a substantial decline in soil pH. Look for signs of early spring yellowing.

4. When using N fertilizer, test for soil pH every 3 years and apply calcitic or dolomitic lime to adjust soil pH to about 5.0. When applying lime/dolomite, be realistic and economical in choosing amount to apply. For example, if the lab result asks you to apply 800 lb/A to raise your soil pH to 5.0, it would be better to go ahead and apply 1 ton/acre, provided pH does not increase above 6.0., in order to save on future re-application costs.

5. When using limed-sludge, apply material uniformly at the recommended agronomic rate and also test for soil pH increases every 3 years.

6. Because of their contrasting effects on soil pH, alternate the use of limed-sludge with inorganic N fertilizer such as ammonium sulfate in order to stay within the optimum pH range of 5.0 to 6.0 and avoid accumulation of excess P.