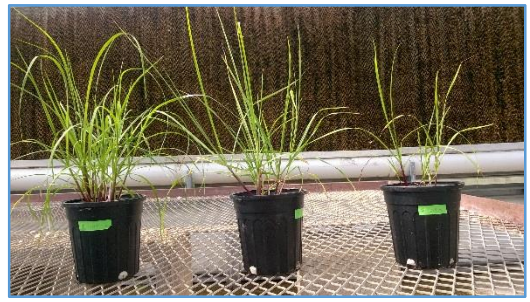

Options for phosphorus fertilization and retention in bahiagrass pastures
FDACS Contract No. 24122, 2017 Final Report

UF | UNIVERSITY of FLORIDA

Options for Phosphorus Fertilization and Retention in Bahiagrass Pastures

Florida Department of Agriculture and Consumer Services
Office of Agricultural Water Policy

FDACS Contract No. 24122, 2017 Final Report

Investigators: Dr. Cheryl Mackowiak (Lead PI), Dr. Vimila Nair (Co-PI), Dr. Jose Dubeux (Co-PI), and Dr. Ann Blount (Co-PI)

UF-IFAS North Florida Research and Education Center, Quincy, FL 32351

For further information, please contact:

Cheryl Mackowiak, Associate Professor, NFREC, Quincy (850) 544-7126; echo13@ufl.edu

September 07, 2017

BACKGROUND

Pursuant to the Florida Watershed Restoration Act (FWRA), section 403.067(7)(c)3, F.S., the Florida Department of Agriculture and Consumer Services (FDACS), Office of Agricultural Water Policy (OAWP), develops, adopts, and assists with the implementation of agricultural Best Management Practices (BMPs) to protect and conserve water resources. This project addressed Florida's cow/calf BMPs and more specifically, the following Florida Cattlemen's Association (FCA) 2016 research priorities: 1) biosolids and alternative fertilizer sources, 6) fertilization impacts on the environment, and 9) land application of biosolids environmental impact, as it relates to fertilizer P.

Many soil types are characterized by greater plant-available P located near the soil surface, and decreasing P concentrations with depth. In contrast, the Spodosols will often have greater subsoil P found in association with the spodic horizon (Chakraborty et al., 2011). This is why a surface (0 to 6 inches) soil sample may test as deficient for soil P, while the plant tissue report may prove adequate, as is often the case with bahiagrass. However, many ranchers are concerned that they may not have adequate soil P to support optimal bahiagrass growth. Additionally, the vast majority of bahiagrass root mass (as with most other plant species) where much of plant P is taken up, is located in the surface (0 to 6 inches) soil. The concern is whether bahiagrass pastures can capture soil P fertility at lower depths than what we typically measure for fertilizer recommendations.

The soil P test is designed for testing the surface soil (typically 0 to 6 inch depth). It provides no assessment of the P storage capacity or P reserve in surface or subsoils to support a plant's P requirement over time. Neither does it estimate soil vulnerability to P leaching losses. The soil phosphorus storage capacity (SPSC) methodology (Nair and Harris, 2014) was adapted for Florida's acid mineral soils, based on earlier findings on the relationship between P and [Fe+Al] (Nair et al., 2004). Using the same soil extraction method (Mehlich-3) that is used in soil test reporting, soil P, aluminum (Al), and iron (Fe) measurements are included to calculate the P storage capacity of our surface and subsoils. It works well, in part, because the soil Al and Fe minerals in Florida soils control soluble P release. Those soils with a positive SPSC rating will tolerate additional P inputs, while those with a negative rating are beyond the P storage capacity of the soil and therefore are prone to P leaching or movement into the environment.

Another development is that the UF-IFAS soil analytic laboratory recently changed from using the Mehlich-1 to Mehlich-3 soil extraction method for their soil reporting, resulting in greater amounts of P measured in most soils. Care was taken to assure scientifically sound adjustments to the soil P interpretation but further validation of the new extractant is required for bahiagrass. The tissue P testing requirement for bahiagrass provides some insurance against the possibility that soil P interpretations are over- or underestimated for different soil types.

Grasslands are one of the most environmentally friendly agricultural systems in the state and bahiagrass may have a relatively lower P fertilizer demand than other perennial grass hay options. This translates potentially to improved conservation of P reserves and reduced P fertilizer costs. Additionally, the capture and recovery of P from waste water treatment plants to be converted to Class AA biosolids, a slow-release fertilizer, is another means of P conservation at the state level. Demonstration and verification of a P efficient system, using scientifically sound metrics, as exemplified by experimental testing and demonstrations on Florida ranchlands, is needed. The data and on-farm evaluations helps provide area ranchers evidence that with a minimal amount of soil P management and tracking, their pastures will be productive while becoming more nutrient efficient and thereby, economically more effective.

Our overall goal was to improve bahiagrass nutrition and production through sustainable soil P fertility management by addressing the four Rs of nutrient stewardship: Right source, Right rate, Right time, and Right place. More specifically, we continued with research efforts initiated and funded by the FCA in 2016 (Objectives 1 and 2) and built upon those results (Objectives 3 and 4).

OBJECTIVES

1. Complete the tissue and data analyses from the 2016 column study testing different P sources on bahiagrass P uptake, P fertility, and soil phosphorus storage capacity of Spodosols and Ultisols.
2. Complete the tissue and soil analyses from the 2016 omission plot study located at Silver Spurs Ranch that provided an assessment of which macronutrients were limiting forage production and continue with a second, final year of testing in 2017.
3. Test N by P fertilizer rates, soil type, and bahiagrass cultivar interactions on yield, P uptake, soil P fertility, and soil P storage capacity.
4. Compare mineral P and biosolids single application vs split applications on bahiagrass response, soil P fertility, and soil P storage capacity at Silver Spurs Ranch.

OBJECTIVE 1 (planted vs unplanted soil columns of bahiagrass)

Materials and Methods (Obj 1): This experiment tested six P fertilizer sources using two soil types (Spodosol and Ultisol) in unplanted vs. planted columns. The Ultisol testing was an add-on to the original proposal in 2015 and resulted in data on P behavior in Central and North Florida soils with greater inherent P fertility and P fixing ability. The two soil types were 1) an Ultisol, Orangeburg series, Fine-loamy, kaolinitic, thermic Typic Kandiudults and 2) a Spodosol, Myakka series, Sandy, siliceous, hyperthermic Aeric Alaquods. Orangeburg was from NFREC, Quincy, FL and Myakka was from the Silver Spurs Ranch, Keenansville, FL. The Orangeburg soil was taken from the A and upper B horizons (approximately 0 to 12 inch depth), while the Myakka soil was collected in two parts, the surface A horizon (0 to 6 inches) and the subsoil (Bh horizon at approximately 12 inch depth). The soils from each location filled 42 (4-inch diameter x 12-inch deep) PVC columns. The soils were air-dried and passed through a 2 cm screen, then used to fill the plastic sleeve of 4-inch diameter x 12 inch deep PVC columns. Approximately 2 inches of inert gravel were placed at the bottom of each slit sleeve to aid with drainage. The Bh horizon soil occupied the lower 6 inches, while the A horizon soil occupied the upper 6 inches of each column for the Spodosol. In the case of the Ultisol, the entire 0-12 inch depth was uniformly mixed.

Seven different P treatments were tested (applied at 40 lbs P_2O_5 ac^{-1} rate) with and without plants (and 3 replicates; n=84). The fertilizer treatments were as follows: 1) control (no P), 2) triple super phosphate (TSP), 3) class AA biosolids from Tallahassee (BAA1), 4) class AA biosolids from Jacksonville (BAA2), 5) class B biosolids from Tallahassee (BioB or BB), 6) biochar created from class B Tallahassee biosolids (Biochar or Char), and 7) struvite (a recovered mineral from wastewater treatment, Ostera, Vancouver, CA). The act of pyrolyzing (burning under moderate heat (~400 ^oC) and low oxygen conditions) results in a charcoal-like product that can be used as a soil amendment and slow-release fertilizer. Struvite ($NH_4MgPO_4{\cdot}6H_2O$), is a mineral that can be synthesized from the wastewater of human (via waste water treatment plants) or animal (waste lagoons) origin. It has attributes similar to other mineral (i.e., TSP, MAP, DAP, etc) fertilizers. All treatments received similar applications of nutrients other than P, regardless of P source or soil type, to assure that other nutrients were not limiting. The P fertilizer treatments were mixed in the upper 2 inches of soil prior to planting.

Half of the columns were planted with bahiagrass (*Paspalum notatum* (Flugge) cv Pensacola transplants that were initiated in shallow, plastic flats 4 to 6 weeks prior to transplanting. The remaining columns were not planted to better understand the interaction of plants with soil P. Soil moisture was manually monitored, using a portable soil moisture measuring device. Watering of the unplanted columns was managed to simulate rain events, to better estimate production season effects. Watering of the planted columns was managed to maintain soil moisture between 40 to 80% of field capacity (averaging two to three 200 ml DI water applications per week during maximum growth). All columns contained a drain valve for collecting leachate, if overwatered. Only previous to the first clipping was there leachate to collect. Greenhouse temperature averaged 24 C day/ 20 C night and RH averaged 70% day/75% night.

Beginning 13 April 2016, planted columns were clipped to a 2-inch stubble height. The tissue was weighed, dried (60 C for 7 days) and dry mass determined. The tissue was ground to pass through a 2-mm screen, digested in concentrated HNO3 and 30%H2O2 (Jones, 1989), and analyzed for plant essential nutrients, including P via ICP-OES. Two more clippings occurred (5 May, 15 June) and a final harvest (tops and roots) on 18 July.

At the final harvest, planted columns had the plants separated into shoots and roots, dried, weighed, ground, and analyzed, as described above. Roots were rinsed with deionized water to removed surface soil, prior to drying. The soil from the columns was segmented into 4, 3-inch depth sections. Roots were separated from each section and weighed separately. The air-dried soils were analyzed for Mehlich-3 extractable nutrients (including P, Fe, and Al) and water soluble P. Leachates were analyzed for N and P content.

Data were analyzed using PROC MIXED in SAS (SAS for Windows V 9.4, SAS Institute, 2009, Cary, NC, USA). Fixed effects included fertilizer treatment and soil depth. Blocks were considered as random effect. The LSMEANS were compared using the PDIFF procedure adjusted for Tukey’s test. Differences were declared significant at $P \leq 0.05$.

Results (Obj 1): The amount of fertilizer P available for plant uptake during a growing season can be qualitatively estimated by addressing the fertilizer P composition, such as fertilizer total P and Mehlich-3 (M3) available P. Product total P varied, as expected, by product type, on a dry mass basis (Fig. 1-1). Mehlich-3 extraction method uses, among other things, dilute acid and chelate to solubilize P forms that are not readily available by water extraction alone. It is interesting to note that the proportion of struvite mineral P was not as soluble as TSP P, which was the most soluble, in fact, nearly all of the TSP was extracted via M3 (Fig. 1-1). The proportion of Class B biosolids extracted by M3 was greater than it was from Class AA2 biosolids, whereas the biochar derived from class B biosolids had a much lower proportion of M3 extractable P. Based upon these data, the relative amount of P available to plants receiving these different P sources would be TSP>> Class B biosolids>struvite, Class A Biosolids1 or 2>>biochar derived from biosolids. When the products were applied to the column soils, it was at equivalent total P rates, not M-3 extractable P rates, which is similar to how a farmer would estimate application rates.

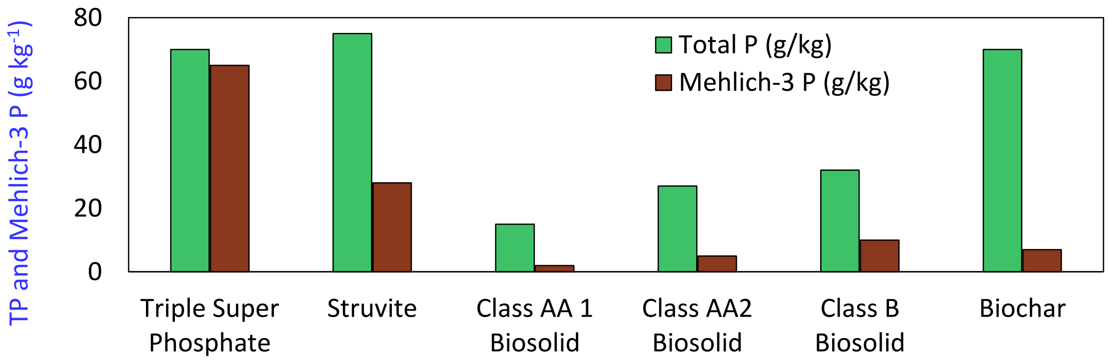

Fig. 1-1. Fertilizer product composition based upon Total P and Mehlich-3 extractable P.

Prior to the first bahiagrass clipping, water would occasionally leach from the bottom of the columns. This excess water was collected weekly and analyzed for orthophosphate (PO_4^-P) (Fig. 1-2). The amount of leachate that was collected from the bottom of the columns was about 30% greater from columns containing Ultisol soil than Spodosol soil. Even so, more leachate P was often collected from columns containing Spodosol soil (Fig. 1-2). Additionally, the unplanted columns tended to leach more P than planted columns, regardless of soil type. Among treatments, the TS Class AA biosolids and the Biochar biosolids had P leaching loss amounts similarly low losses to the untreated Control (Fig. 1-1).The total amount of P found in the leachate accounted for a small fraction (<1%) of P that was applied to the columns as fertilizer. In the case of the Control treatment, it represents the inherent soil P susceptible to leaching, prior to any P applications. After a few weeks of experience and guidance from a portable soil moisture probe, water was metered to avoid water leaching from the columns.

There were interactions between soil type and treatment for the total seasonal above-ground biomass yields with the Ultisol soil supporting generally greater growth. Therefore, the treatments were compared within each soil type. The struvite treatment resulted in the greatest total bahiagrass yields, followed by the TSP and all of the biosolids treatments. The control (no P additions) had the lowest amount of biomass, while the biochar treatment had yields similar to the Control and TSP treatments (Fig. 1-3). The TSP treatment resulted in the greatest growth in the Ultisol soil, but the Class B biosolids also had similarly high production (Fig. 1-4). As with the Spodosol soil, the control (no P applied) performed relatively poorly.

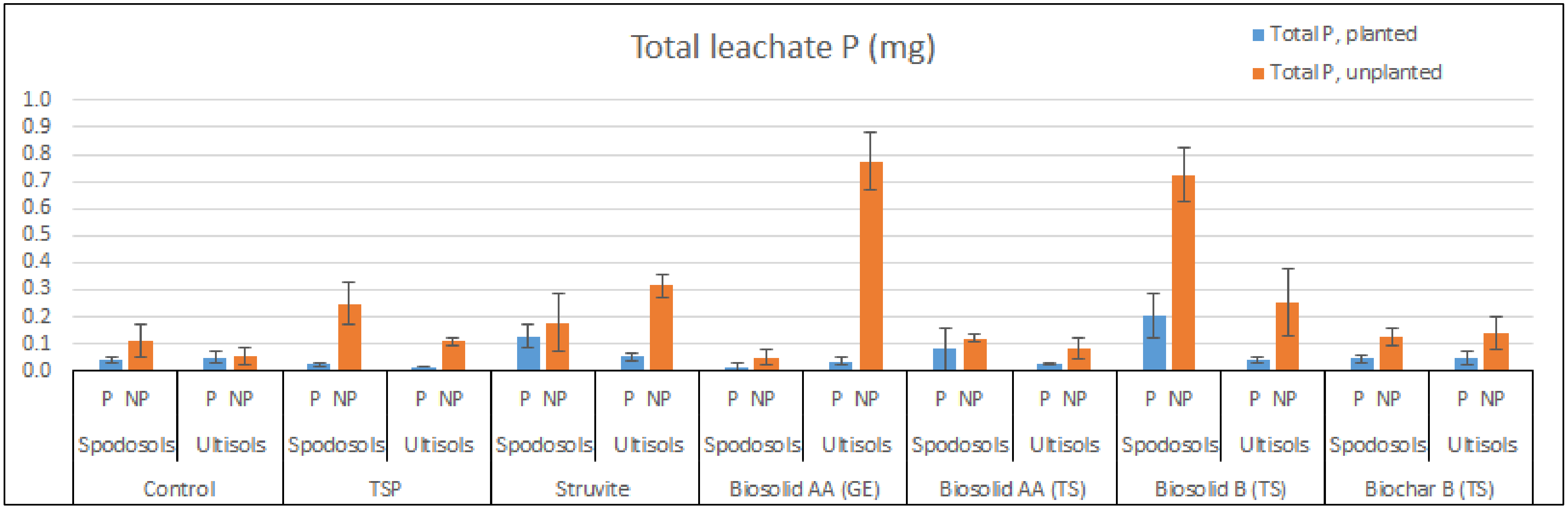

Fig. 1-2. The total amount of P in leachate recovered from the columns (both, planted and unplanted). Trends show a fairly similar risk of P losses from the columns containing Spodosol soil or Ultisol soil. However, there appeared to be a greater risk of P loss in unplanted versus planted columns. More P was collected from some unplanted biosolids treatments than from other treatments, but among planted columns, the leachate P amounts were fairly similar. Each colored bar represents the mean of three replicate columns and the vertical bars represent the standard error of each mean. Biosolid AA (GE)=Class AA biosolids 1 and Biosolid B (TS)=Class AA biosolids 2.

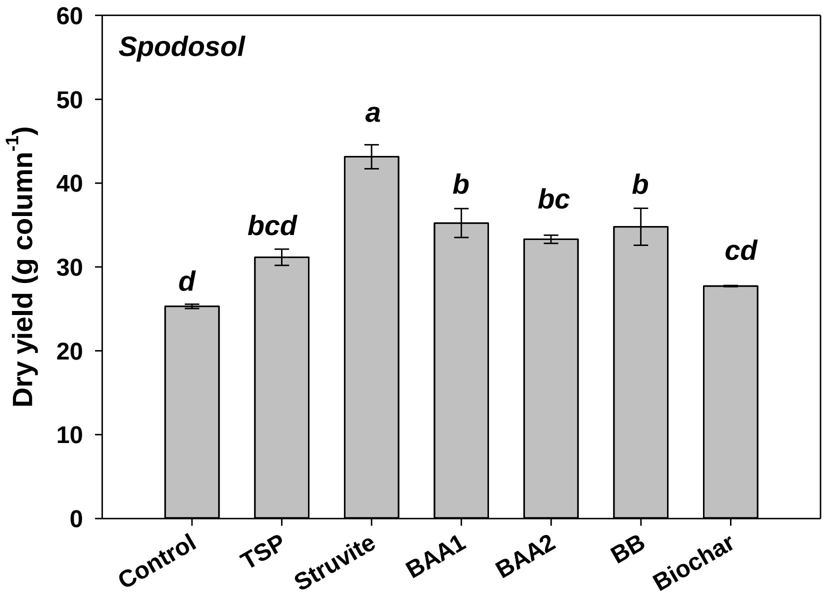

Fig. 1-3. Phosphorus fertilizer treatment effects on total seasonal yields of bahiagrass grown in a Spodosol soil. Each colored bar represents the mean of 3 replicates and the vertical bars represent the standard error of each mean. Bars sharing the same letter, are not significantly different at alpha=0.05.

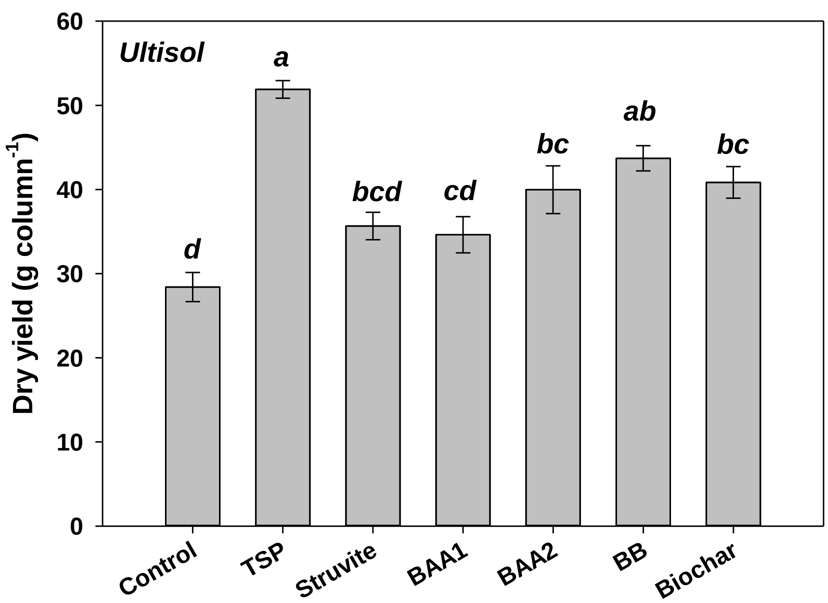

Fig. 1-4. Phosphorus fertilizer treatment effects on total seasonal yields of bahiagrass grown in an Ultisol soil. Each colored bar represents the mean of 3 replicates and the vertical bars represent the standard error of each mean. Bars sharing the same letter, are not significantly different at alpha=0.05.

Based upon biomass accumulation and tissue P content, P uptake by the above-ground forage was calculated and compared. There were no soil interactions so data from both soil types were combined (n=6) and compared by P treatment. The amount of P removed from the soil was similar among all of the columns receiving P fertilizer, regardless of the source. Additionally, the Class B biosolids treatment took up more P in biomass than the Control (no P additions) treatment (Fig. 1-5).

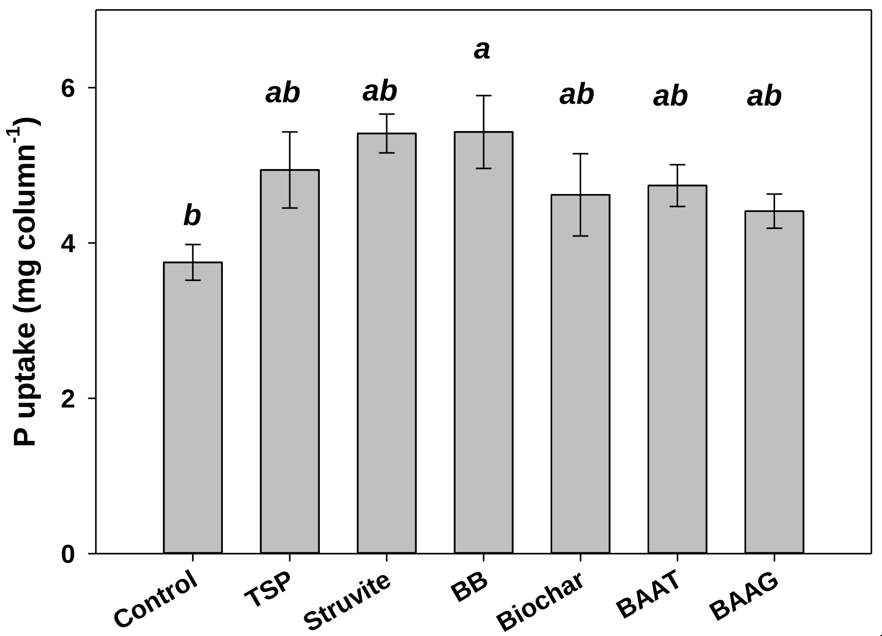

Fig. 1-4. Phosphorus uptake into above-ground biomass of bahiagrass grown under different P fertilizer treatments. Each colored bar represents the mean of 6 replicates and the vertical bars represent the standard error of each mean. Bars sharing the same letter, are not significantly different at alpha=0.05.

What P is not taken up by the plants may be susceptible to leaching or erosion losses to the environment. At the conclusion of the study the soils were analyzed for water soluble P (WSP), since it is the form most susceptible to movement into the environment. Soils from the unplanted columns will be discussed. Similar data will be generated from the planted columns in the coming weeks. The soils were separated by depth increments to compare relative differences in potential P migration through the column.

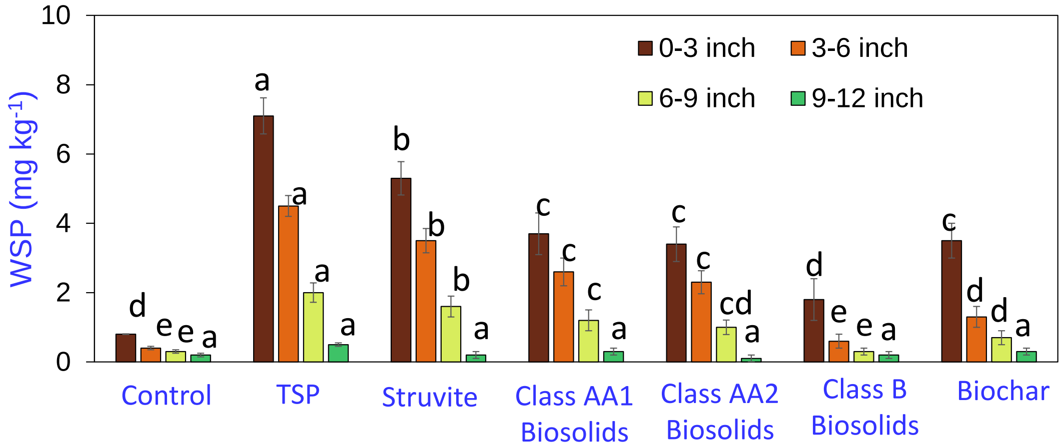

Fig. 1-5. Phosphorus fertilizer treatment and depth effects on water soluble P in a Spodosol soil, under different P fertilizer treatments. Each colored bar represents the mean of 3 replicates and the vertical bars represent the standard error of each mean. Bars sharing the same letter at a given depth, are not significantly different at alpha=0.05.

The concentration of WSP declined with soil depth in the Spodosol soil from unplanted columns, regardless of P fertilizer source (Fig. 1-5). In the upper 6 inches, the TSP and struvite treatments had the greatest WSP concentrations, while Class B biosolids and Control (no P applied) had the lowest. At 9-12 inch depth, all treatments had similarly low WSP (Fig. 1-5). A similar response pattern was observed with the Utlisol soil (Fig. 1-6).

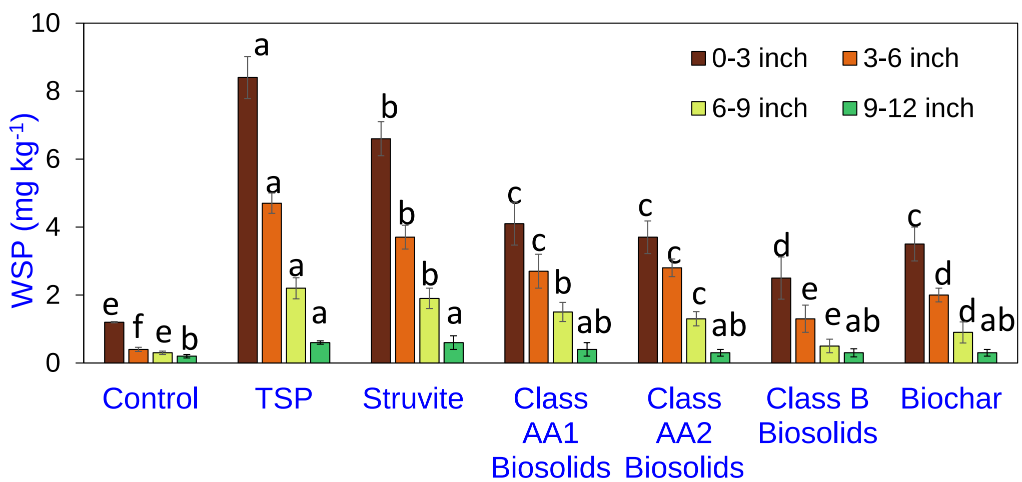

Fig. 1-5. Phosphorus fertilizer treatment and depth effects on water soluble P in a Spodosol soil, under different P fertilizer treatments. Each colored bar represents the mean of 3 replicates and the vertical bars represent the standard error of each mean. Bars sharing the same letter at a given depth, are not significantly different at alpha=0.05.

Another approach to assessing the potential for soil P losses to the environment is to address the soil P storage capacity (SPSC) of the soil profile. The SPSC requires measurements of soil P, Fe, and Al. In this study, Mehlich-3 extractions were used. Additionally, soils from unplanted versus planted were compared, in order to determine if plants would impact SPSC.

Unplanted columns using Spodosol A horizon soil (depths from 0 to 6 inches) had negative SPSC values, even for the Control soil that did not receive P inputs (Fig. 1-6). There were some response differences among P treatments, where TSP resulted in a much more negative SPSC value at the 0-3 inch depth than other treatments. However, any negative value, regardless of degree, implies P losses to the environment, since the soils contain more P than it can hold against the forces of rainfall or irrigation events.

The planted Spodosols greatly increased their SPSC values. Positive SPSC values imply that the soil can receive additional P with reduced risk of P loss. In the case of the 0-6 depth, it calculates to only a few pounds per acre. The SPSC for Spodosols at the 6 to 12 inch soil depth was made up of the Bh (or Spodic) horizon. This soil type contains ample Al and some Fe. These constituents in acid soils help bind labile P, which protects against P leaching losses.

The Ultisol soils responded similarly to the Spodosols, in terms of TSP and struvite applications, where highly negative SPSC values were created in the upper 3 inches (Fig. 1-6). This also continued into the 3-6 inch depth, as well. It is interesting to note that in planted Ultisol columns that there were some instances where the planted columns under in the Control and Biosolids B treatments had more negative values than their unplanted counterparts (Fig. 1-6). This needs to be addressed further to determine if there is a natural cause of if it is an artifact of something else. Soil phosphorus storage capacities close to zero (either positive or negative) suggests that there is little or no additional P storage available and therefore additional P inputs have a high risk of moving off-site.

Discussion (Obj. 1): Regardless of soil type, the tested bahiagrass productivity often increased with additional P fertilizer inputs. It did not matter much what fertilizer source was used. Plants grown in the Ultisol soil took up somewhat greater amounts of P (5.3 ± 0.2 mg P versus 4.2 ± 0.2 mg P), compared to the Spodosol soil. Regardless of these minor differences, the P amounts represented approximately 8 to 10% of the entire fertilizer P applied to the soil, regardless of P source. If the control plants removed 3.8 mg P and subtract that value from each of the fertilizer treatments (assuming they also were taking up soil derived P), then the amount of P contributed by the fertilizers becomes much less, regardless of P treatment. There appears to be a loss of efficiency where the plants benefit from the fertilizer P but they leave much of it in the soil, where it becomes susceptible to movement off-site. The goal is to provide ample soil P to plants for uptake while minimizing these P losses.

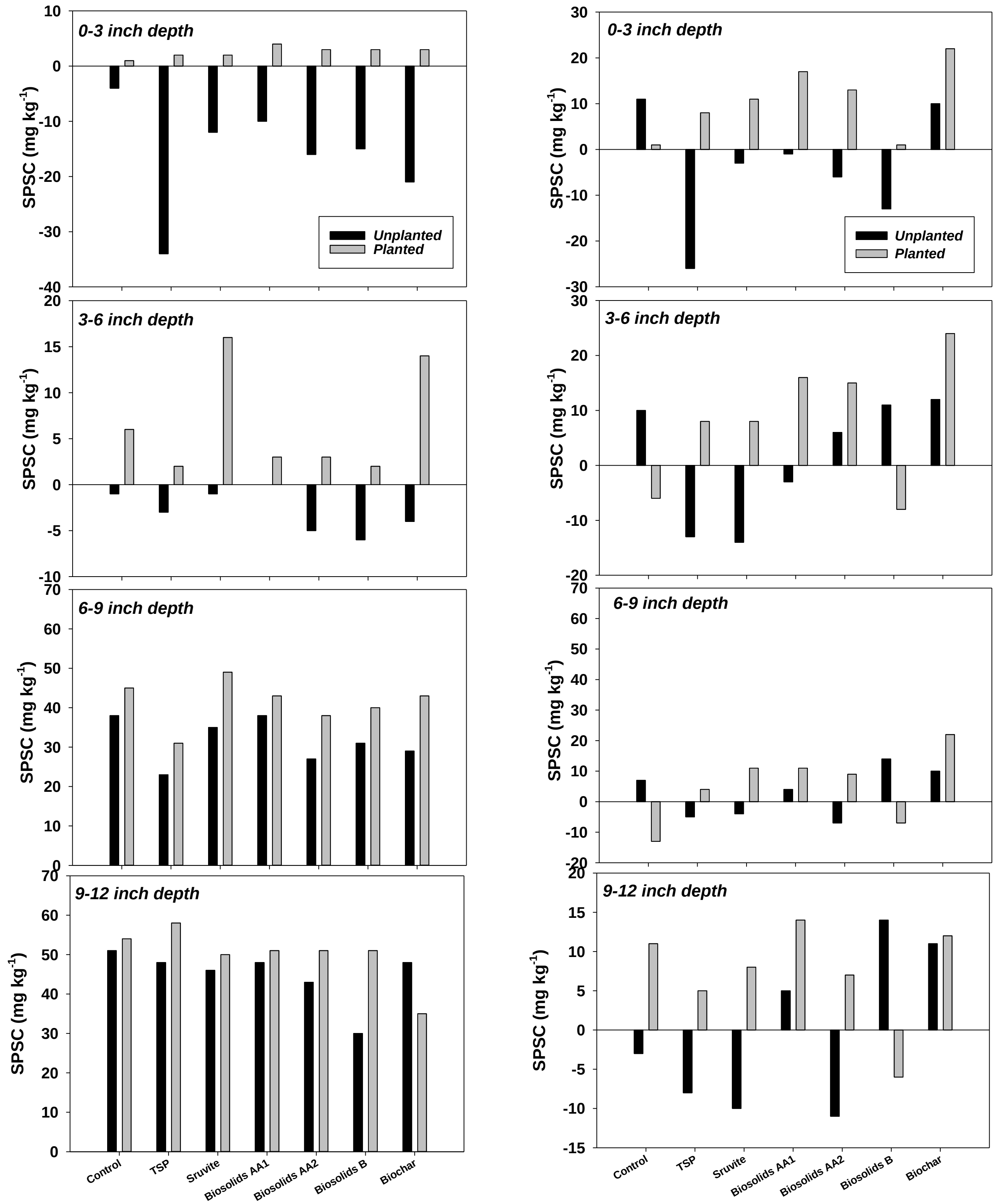

Fig. 1-6. Phosphorus fertilizer treatment and depth effects on soil P storage capacity (SPSC) in a Spodosol soil (left panels) and an Ultisol soil (right panels), under different P fertilizer treatments. Each colored bar represents the mean of 3 replicates. Negative SPSC values represent soils that are prone to P losses.

Water soluble P was greatest in the upper 6 inches of soil. Unfortunately, in the case of the Spodosol, these soils can hold only the smallest amounts of P without it being prone to loss from rainfall or irrigation. The spodic Bh and underlying Bt horizons often have the capacity to hold a large P reserve which is available to bahiagrass, if they have the roots there to capture it. When the seasonal high water table expands into the soil horizons above the spodic layer, that soil P is extremely susceptible to moving with the water, often resulting in surface and subsurface lateral losses off-site. The good news is that plant uptake can remove large amounts of soil P into biomass. Some of that P gets converted into organic P that is not as readily leached into the environment. In order to maximize P uptake, the plants need to be managed for optimal and sustainable growth.

OBJECTIVE 2 (fertilizer omission plots)

Materials and Methods (Obj 2): Test plots (20 x 10 ft) were established at the Silver Spurs ranch (27.881 N, -81.052 W), April 01, 2016, to test and demonstrate fertilizer effects on pasture bahiagrass productivity. This approach was based upon site-specific nutrient management (SSNM), using omission plots that did not compare individual fertilizer nutrient additions against an untreated control, but rather, a single nutrient factor was omitted from plots receiving ample amounts of complete fertilizer. These replicated treatments were compared against a well-fertilized control treatment and a Class AA biosolids treatment. An untreated check plot was included, as well. This technique was developed to test and demonstrate on-farm rice fertilization effects and is a promising technique for on-farm use world-wide (Dobermann and Cassman, 2002).

The test location hosts flatwood soils or Spodosols. More specifically, the test site had Sandy, siliceous, hyperthermic Aeric Alaquods or Myakka series (NCSS, 2016), as described by Soil Survey Staff (2016). Soil characteristics are given in Table 1. Treatments consisted of the following: 1) A complete fertilizer treatment that received N, P, and K fertilizer (80 lbs N acre^{-1} as NH_4NO_3, 40 lbs P_2O_5 acre^{-1} as triple super phosphate, and 40 lbs K_2O acre^{-1} as a blend of KCl (75% K_2O) and KMag (25% K_2O rate). The KMag also provided 10 lbs S acre^{-1} and 5 lbs Mg acre^{-1}. The N-P-K rates were equivalent to those prescribed by UF-IFAS when soils test low for these nutrients, regardless of the actual measured fertility. The remaining treatments were: 2) -N treatment, 3) -P treatment, 4) -K treatment, 5) class AA biosolids plus K_2O, and 6) check (no fertilizer applications). This equated to a total of 6 treatments replicated 3 times (n=18). Fertilizers were reapplied after the first cutting in June, 2016, the first cutting in May, 2017, and the second cutting in July, 2017. A third and final cutting is scheduled for September, 2017.

Table 1. Soil characteristics from Omission test plot location, Kenansville, FL.

pH	CEC	P	K	Ca	Mg	S	B	Fe	Zn	Mn	Cu
	meq/100 g	----------	----------	----------	----------	----------	ppm	----------	----------	----------	----------
4.9	8.51	19	64	790	49	8	0.44	60	0.30	1	0.40

The site was managed as pasture until the time of testing. At that time, temporary electrical fencing was installed, in order to better assess bahiagrass yields due to fertilizer inputs without short-term interference by cattle. During the winter, prior to spring green-up, cattle broke into the study area for a time. The forage was harvested 06/15/2016, 08/24/2016, 5/18/17, and 7/11/17, to assess forage yield differences. Harvest 1 consisted of 2 composited samples from a 0.25 m^2 square, while the second and third samplings were taken from a single 0.25 m^2 square per plot. The fourth sampling was taken by mowing a 48” long by 21” strip from each plot, using a manual mower and bag. Following sampling, the remaining forage was cut with a hay cutter, manually raked, and removed. A push mower with bag attachment was used to stage the area to 3 inch stubble height across the entire field site and plots re-fertilized with amounts, as listed above. The sampled forage was dried (60 C for 7 days), weighed, and ground to pass through a 2mm sieve. Tissue samples were sent to a commercial lab (Waters Agricultural Laboratories, Camilla, GA) for crude protein and nutrient composition.

Two piezometers (pressure transducers, auger with extensions, and casings) were purchased but were not installed, as of 08/31/2016. Standing water early in the season and other activities near and at the site, made it somewhat impractical for installation during the summer. The piezometers will be situated in line of expected subsurface flow (10 ft depth) this fall. One will be stationed near the omission plots or P trial and the other southeast by at least 200 ft. The actual installation locations will be coordinated with the Silver Spurs staff, as they plan for drain tile and other land disruptive activities. The data from both types of equipment can complement related activities related to assessing water quality and its movement by staff.

Data were analyzed using PROC MIXED in SAS (SAS for Windows V 9.4, SAS Institute, 2009, Cary, NC, USA). Fixed effects included fertilizer treatment and harvest date. Since there was fertility treatment x harvest date interactions, harvest dates were analyzed independently. Blocks were considered as random effect. The LSMEANS were compared using the PDIFF procedure adjusted for Tukey’s test. Differences were declared significant at $P \leq 0.05$.

Results (Obj 2): Bahiagrass forage responded to lack of some fertilizers with reduced growth ($P < 0.001$), by the first harvest in June, 2016 (Fig. 2-1). The lowest yields were with the Check (no fertilizer) and –N plots, while other treatments were similarly greater in yield (Fig. 2-1). Plots receiving biosolids had yields that straddled the higher and lower yielding plots. Again, the lowest yielding plots in August were the Check and –N treatments, while all other treatments were similarly greater, by over 100% (Fig. 2-2).

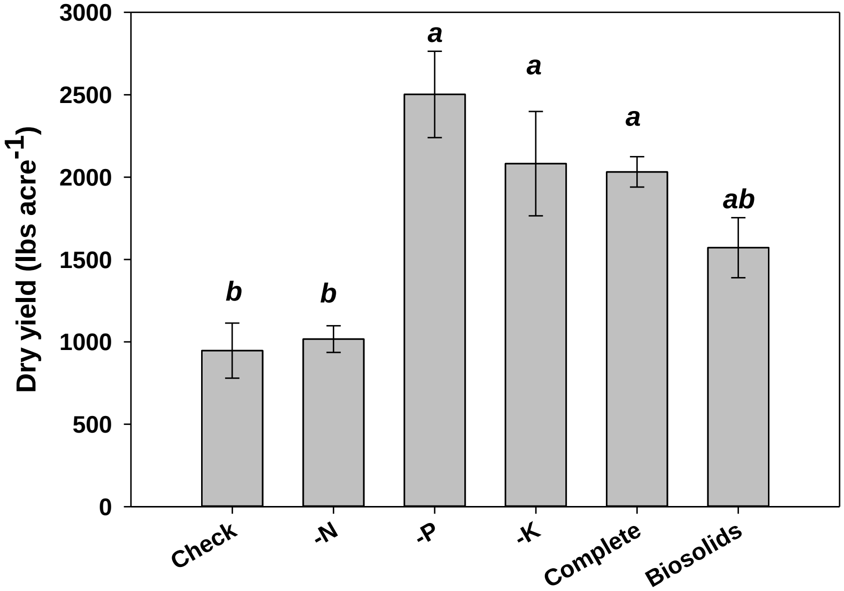

Fig. 2-1. Dry forage yields from 6/15/2016, as affected by fertility treatments. Bars represent means ± standard errors. Bars sharing the same letters are not significantly different.

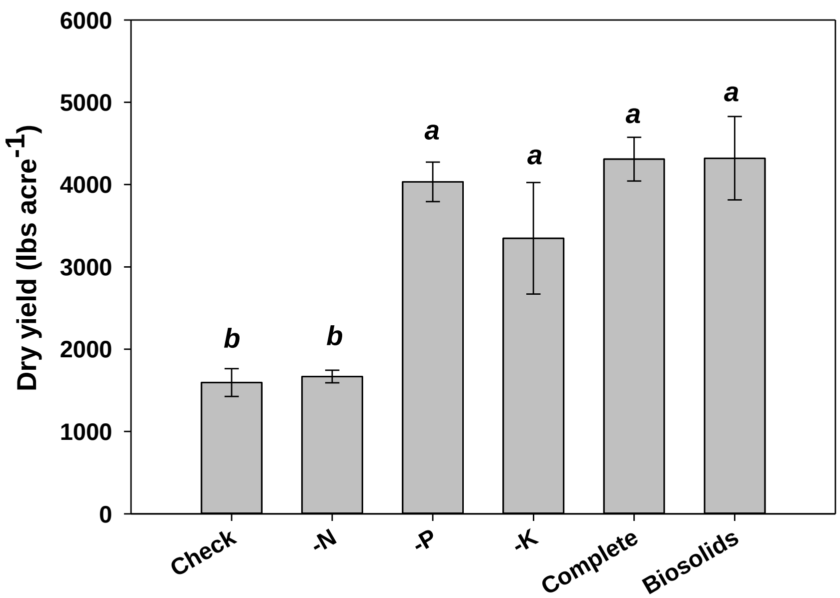

Fig. 2-2. Dry forage yields from 8/24/2016, as affected by fertility treatments. Bars represent means ± standard errors. Bars sharing the same letters are not significantly different.

Since the August, 2016 harvest until the May, 2017 harvest, the forage had not been intentionally grazed (cows/horses broke to the plots for a short time during the winter). Yields with the May harvest relied on over-wintering nutrients in the soil. With the May harvest, the –K treatment resulted in less forage than the –P treatment, that was among the most productive (Fig. 2-3). By the July, 2017 harvest, it was becoming clear that the K depleted plots (-K treatment) were beginning to lose significant forage production (Fig. 2-4). It is expected that this trend will continue with the next (final) forage harvest scheduled for September, 2017.

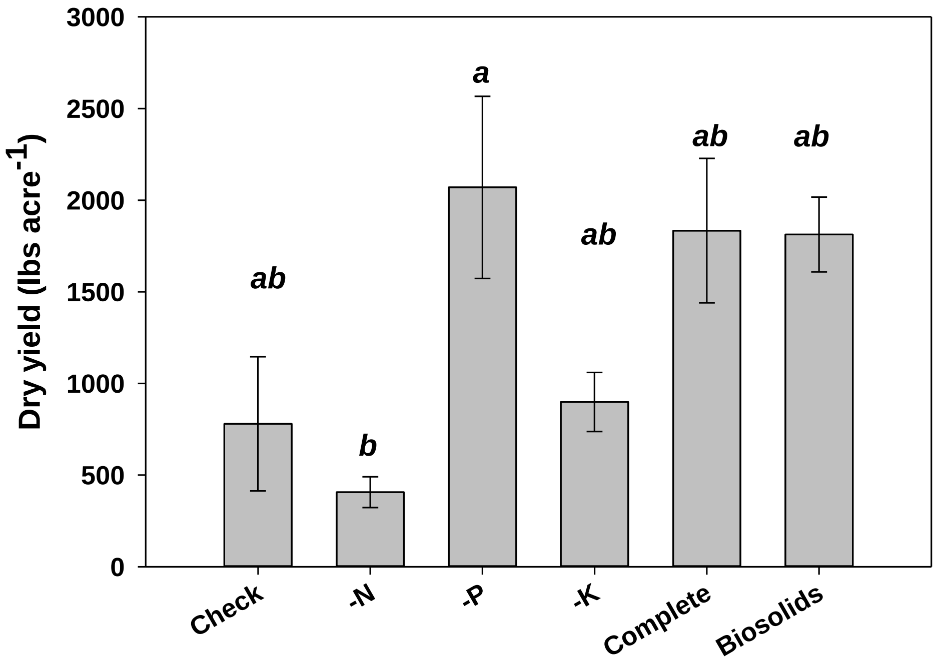

Fig. 2-3. Dry forage yields from 5/18/2017, as affected by fertility treatments. Bars represent means ± standard errors. Bars sharing the same letters are not significantly different.

Tissue N, P, and K concentrations were graphed and compared to suggested sufficiency levels (levels that support at least 80% production). There is no official sufficiency values available specifically for bahiagrass, so for purposes of this discussion (other than P at 1.5 mg kg^{-1} or 0.15%), values for similar grasses were used as guides. Often times major (macro) nutrient deficiencies can be assessed by tissue analyses. However, there are situations where conditions other than low soil fertility result in low tissue nutrient concentration values and sometimes even high values can occur that is not related directly to excess soil fertility.

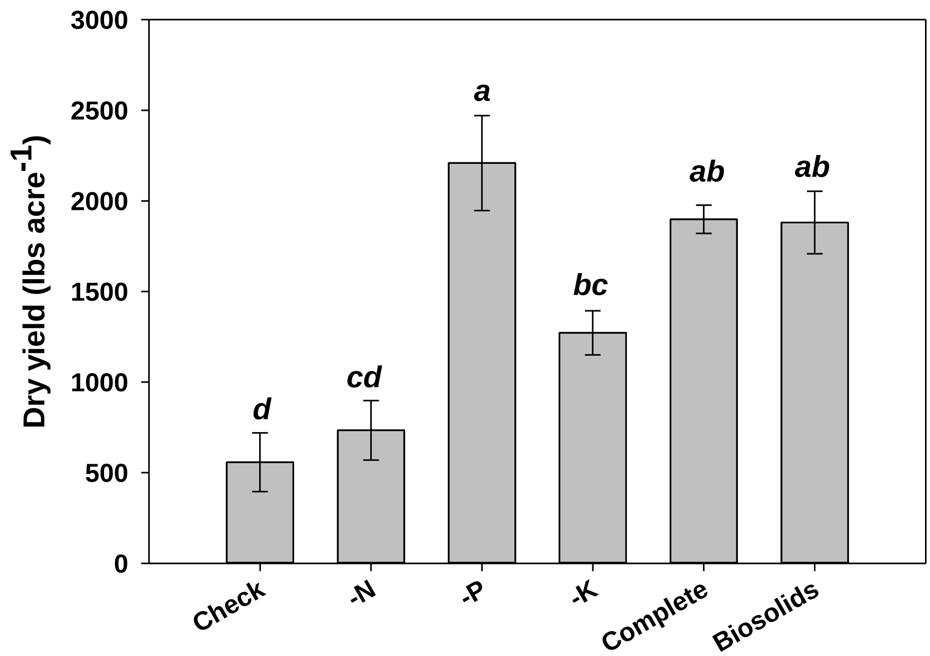

Fig. 2-4. Dry forage yields from 7/11/2017, as affected by fertility treatments. Bars represent means ± standard errors. Bars sharing the same letters are not significantly different.

A N sufficiency of 15 g kg^{-1} (1.5% N or 9.37% crude protein) was used to represent productive bahiagrass. Tissue N was similar among fertility treatments in June, 2016 and May, 2017, when all treatments were well below 15 g N kg^{-1} (Fig. 2-5). In August, 2016 tissue values represent approximately 5 to 6% crude protein and hardly adequate to maintain livestock. In comparison, tissue N concentrations increased in June 2016 and July 2016, when bahiagrass is actively growing. The Check (unfertilized) and –N treatments remained similarly low in tissue N and it was reflected in the lower production, which is not surprising. Grasses respond to N fertilization with increased growth, as N is the most limiting nutrient to plant growth under many different environments.

The lack of P fertilization via the –P treatment increasingly resulted in lower tissue P concentrations with harvests after June, 2016 (Fig. 2-6). This suggests that the plants had mined the more easily accessible P that was available to them. By May, 2017, the –P treatment had tissue values of <1 g kg^{-1} (or 0.1%). However, it had no deleterious impact on forage production and even without P fertilization, the –P treatment increased its tissue P content to values above critical sufficiency of 1.5 g P kg^{-1} or 0.15% (Fig. 2-6).

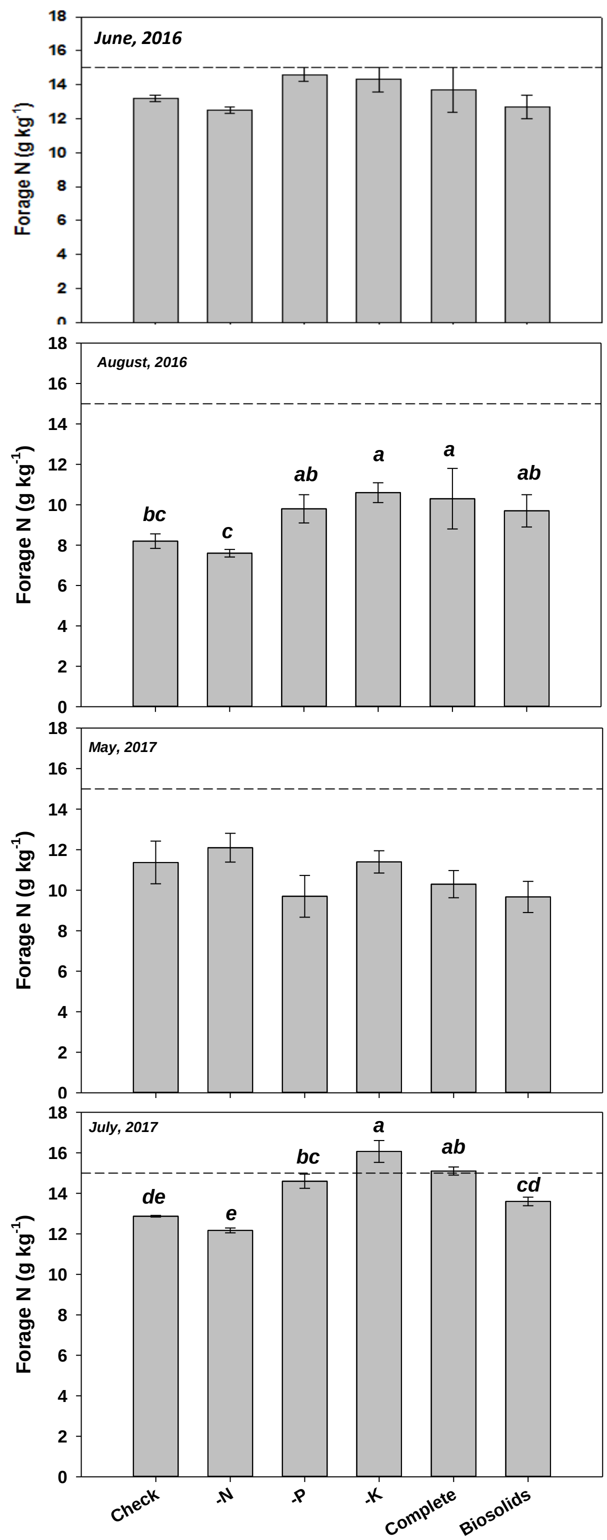

Fig. 2-5. Forage N concentrations from 2016 and 2017, as affected by fertility treatments. Shaded bars represent means ± standard errors. Bars sharing the same letters are not significantly different within a given harvest. The dash reference line provides an estimate of a potentially low sufficiency limit at 15 g N kg^{-1}.

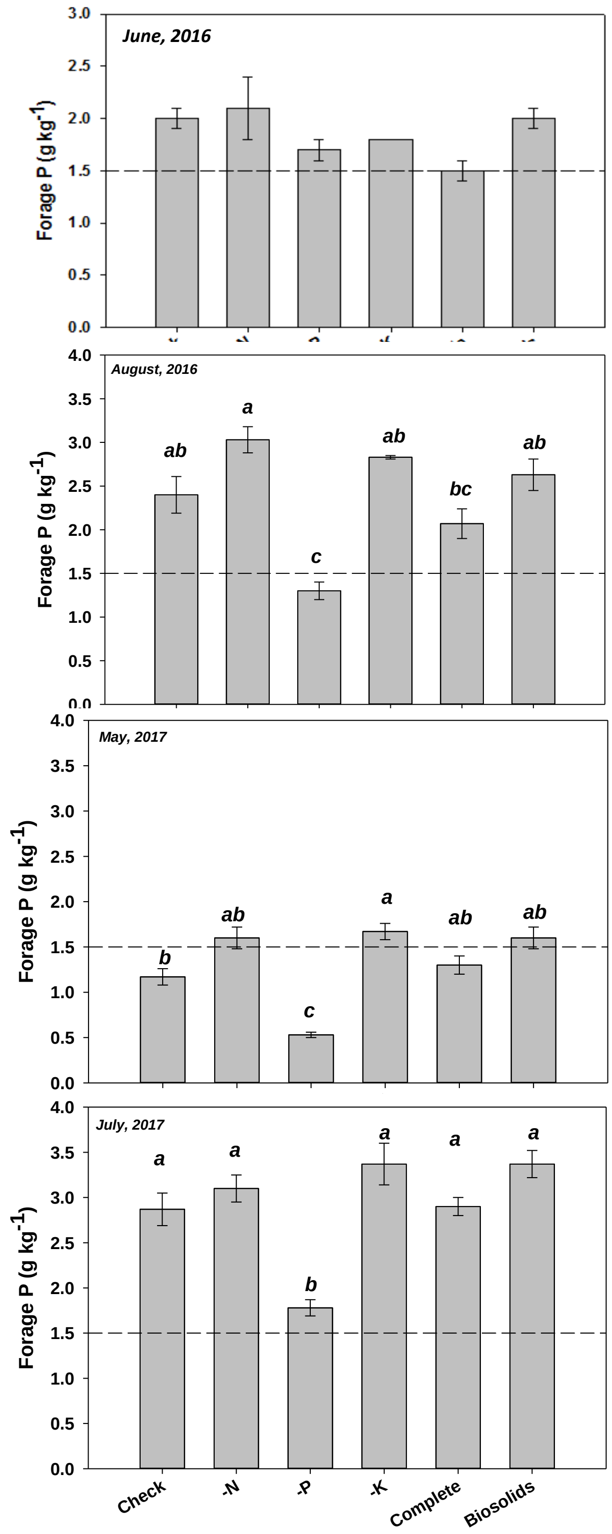

Fig. 2-6. Forage P concentrations from 2016 and 2017, as affected by fertility treatments. Shaded bars represent means ± standard errors. Bars sharing the same letters are not significantly different within a given harvest. The dash reference line provides an estimate of a potentially low P sufficiency limit of 1.5 g P kg^{-1}.

The lack of K fertilization via the –K treatment greatly lowered tissue K concentrations over time (Fig. 2-7). However, with the May, 2017 harvest, tissue from all fertilized plots had forage tissue K far below the sufficiency value of 12 g kg^{-1} (or 1.2%). Unlike N, the production losses from lack of K fertilization were slower to express itself, but with increasing soil depletion, it became clear that low K soil fertility was impacting yield with increasing harvests.

Discussion (Obj 2): For a second year, the omission plots clearly show that at this test location, N was the most limiting nutrient for forage production. In comparison, a lack of K fertilization often impacted yield but not to the same extent as a lack of N fertilization had, nor was it as severe. In contrast, depleted tissue P had absolutely no negative impact on forage yields, even at times when forage P fell below suggested sufficiency levels. It is interesting to note that with the May sampling, N, P, and K tissue content was low, regardless of fertilization treatment. The harvested tissue was from forage that had not been cut since the previous August. Additionally, it had been a dry winter and the grass did not grow. Old, weathered leaves (rank grass) are noted to lose nutrition over time if they are not cut or grazed to promote new growth.

It is interesting to note that a lack of P fertilizer often expressed itself as lower tissue P content but it never reduced forage production. In fact, it trended as one of the most productive treatments. Even without P additions, the plants seemed to have access to soil P reserves. In the greenhouse column study, we found as much total P in plants not receiving inputs as plants that received P inputs. The same response seems to have happened in the field. There is a small amount of P in the surface soils but a much larger reserve in the Spodic horizon, which is within 20 inches of the soil surface at this location. However, based upon the almost consistently lower tissue P values in plants with access to the Spodic P source, it suggests at least two different conditions, 1) the critical P sufficiency value is set higher than is necessary to support high bahiagrass production and 2) this bahiagrass is limited to how much P it can capture from the Spodic horizon and must rely more on P reserves closer to the soil surface. Grasses, as well as many other forage species, concentrate the majority of their root mass near the soil surface. Traditionally, it was accepted that plants predominantly took up soil P near the soil surface. It is only more recently that the lower soil depths have been considered major sources of P nutrition for bahiagrass. Further study is required to better assess P limits on long-term bahiagrass growth and sward longevity.in the field. However, it is becoming increasingly clear that for this location, greater forage growth can be obtained through increasing N and perhaps K fertilization practices.

Other plant essentially nutrients were measured and plots receiving Class AA biosolids tended to have higher tissue S concentrations. Although all plots received additional S via mineral fertilizer, tissue S sometimes dropped below sufficiency, but not so for the biosolids treatment. Sulfur helps protect against disease and helps with N nutrition.

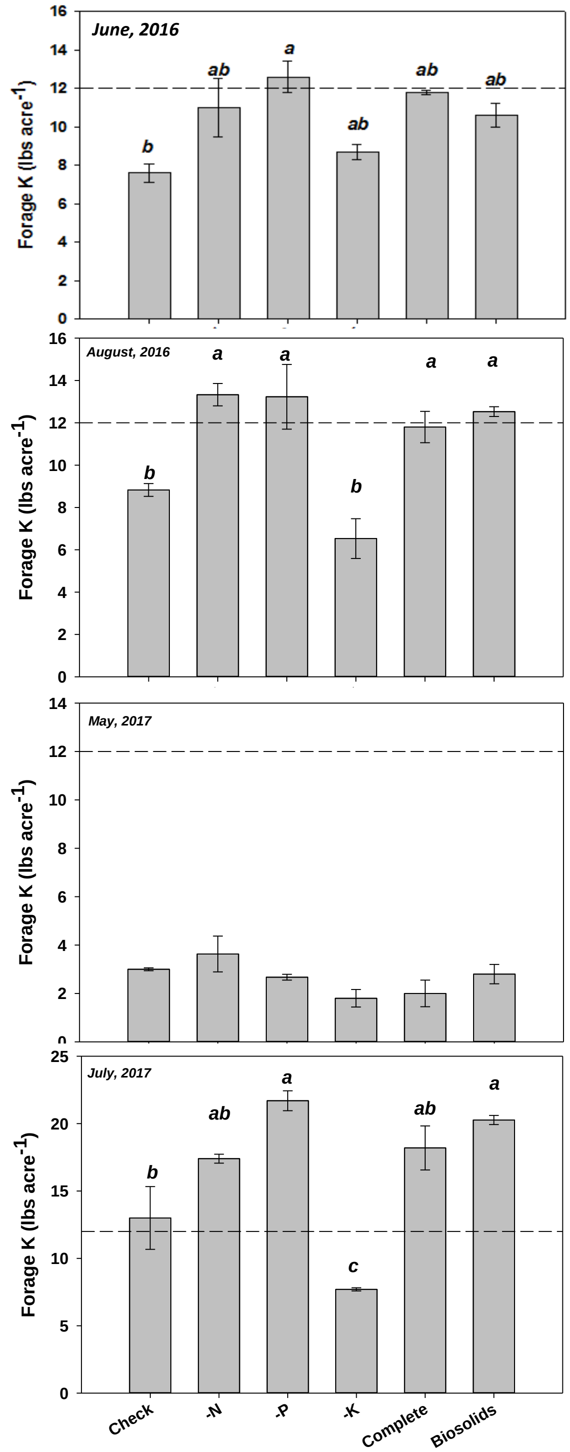

Fig. 2-7. Forage K concentrations from 2016 and 2017, as affected by fertility treatments. Shaded bars represent means ± standard errors. Bars sharing the same letters are not significantly different within a given harvest. The dash reference line provides an estimate of a potentially low sufficiency limit at 12 g K kg^{-1}.

Objective 3 (P and N fertilizer dose-responses)

Materials and Methods (Obj 3): We tested 'UF Riata' response to 0, 30, 60, and 120 lbs P_2O_5 ac^{-1} and 0, 60, and 120 lbs N ac^{-1}, using 1 kg pots filled with two of the same soil types that were used for the greenhouse column study (Objective 1). The soils were Ultisol at low inherent P fertility (Tifton series), Ultisol at high inherent P fertility (Orangeburg series), and a Spodosol A horizon with a low inherent P fertility (Myakka series). Other major (macro) nutrients were applied as a solution to ensure there were no other interfering nutrient limitations. Soil micronutrient fertility was not adjusted. The N fertilizer was applied as ammonium nitrate and the P as TSP. Fertilizers were thoroughly mixed with the soil and allowed to incubate in the greenhouse for a week prior to transplanting bahiagrass, cv Riata seedlings that were germinated in soilless potting mix. A plastic saucer was placed under each pot to limit the potential for nutrient loss from watering events. Greenhouse temperature averaged 24 C day/ 20 C night and RH averaged 70% day/75% night. Plants were grown over several weeks prior to destructively harvesting to gather biomass production and soil composition data.

The tissue was weighed, dried (60 C for 7 days) and dry mass determined. The tissue was ground to pass through a 2-mm screen, digested in concentrated HNO3 and 30%H2O2 (Jones, 1989), and analyzed for plant essential nutrients, including P via ICP-OES. Roots were rinsed with deionized water to removed surface soil, prior to drying. The air-dried soils were analyzed for Mehlich-3 extractable nutrients (including P, Fe, and Al).

Data were analyzed using PROC MIXED in SAS (SAS for Windows V 9.4, SAS Institute, 2009, Cary, NC, USA). A 4 x 3 factorial experimental design was used. Fixed effects included P and N treatments. Blocks were considered as random effect. The LSMEANS were compared using the PDIFF procedure adjusted for Tukey's test. Differences were declared significant at $P \le 0.05$.

Results (Obj 3):The was a clear relationship between P and N fertilization on plant growth response, where increasing P or N resulted in increasing forage biomass for all three test soils (Fig. 3-1, left panels). In the case of the low inherent P Spodosol, increasing P fertilization all the way to 120 lbs P ac^{-1} (listed as P in Fig. 3-1), had no effect on forage yield, even as N fertilizer rates increased. However, by applying 30 lbs P_2O_5 ac^{-1} (P in Fig. 3-1, left panel), forage production increased significantly. Increasing N fertilization from 60 to 120 lbs N ac^{-1}, resulted in no greater forage production unless P was also increased to 120 lbs P_2O_5 ac^{-1}.

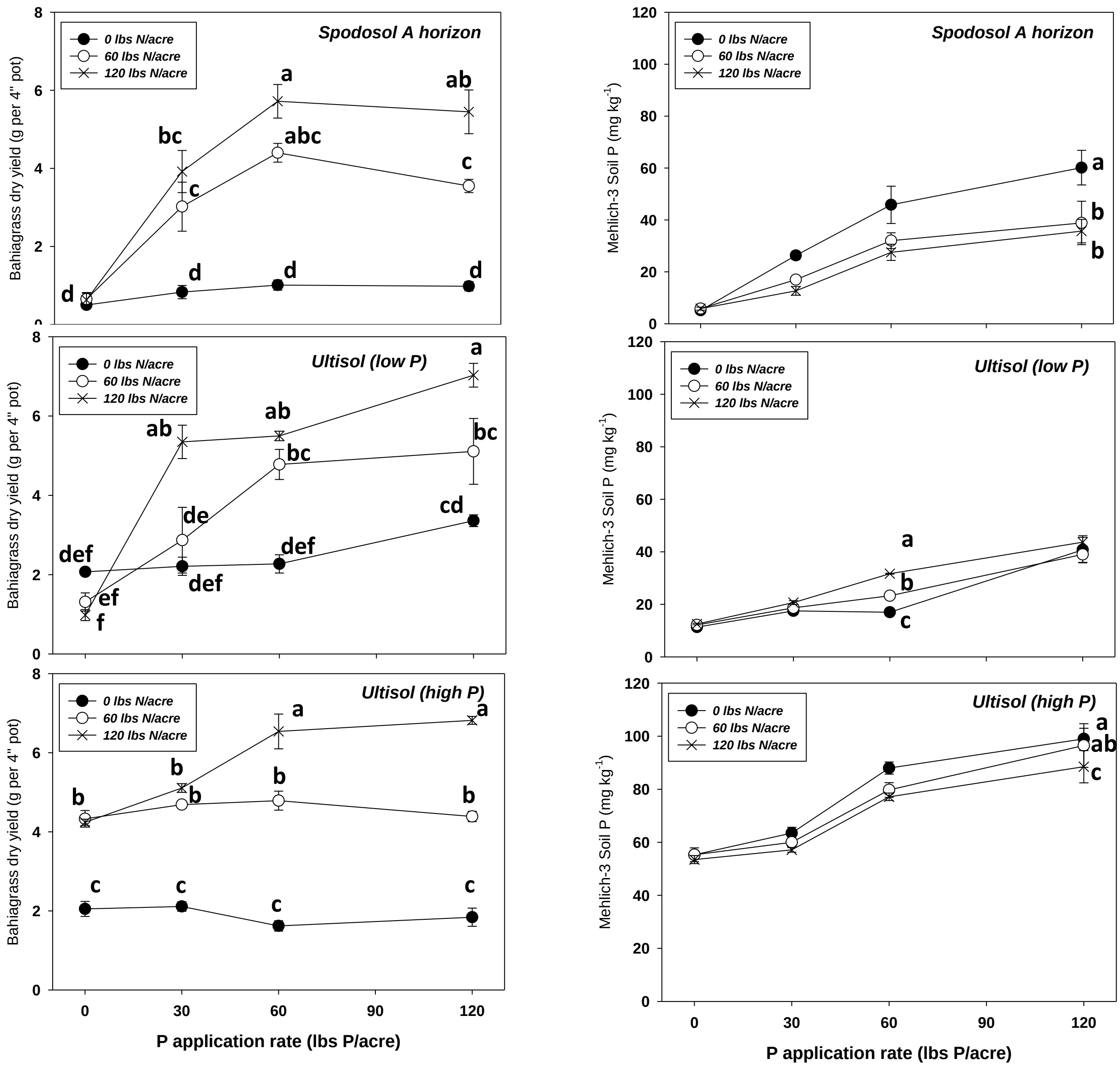
Spodosol A horizon
Ultisol (low P)
Ultisol (high P)
0 lbs N/acre
60 lbs N/acre
120 lbs N/acre
Bahiagrass dry yield (g per 4" pot)
Mehlich-3 Soil P (mg kg^{-1})
P application rate (lbs P/acre)
0
30
60
90
120
a
ab
bc
abc
c
d
def
de
cd
ef
f
b

Fig. 3-1. Phosphorus by N fertilizer rate effects on forage production (left panels) and soil P fertility (right panels), using three three different Florida soil types. Each syymbol represents the mean of 3 replicates ± standard errors. Symbols sharing the same letters are not significantly different N rate at each P rate. Where there is one letter near two or more symbols, they all share the same letter or level of significance (left panels). The letters on the right panels represent differences assessing the N main effects only, rather than differences among N rates at each tested P rate.

Forage grown in the low inherent P Ultisol resulted to fertilization rate responses similarly to the Spodosol, where increasing P rates had no effect on forage growth without concomitant additions of N fertilizer (Fig. 3-1, left panels). The Higher P Ultisol had a similar response, as well. However, forage growth under zero N application rates was twice as great with the two Ultisol soils than the Spodosol soil type. The 60 lbs P_2O_5 ac^{-1} application rate resulted in the greatest forage production when N was applied at 60 or l20 lbs N ac^{-1} for either Ultisol soil type. Increasing P fertilization rates further, to 120 lbs P_2O_5 ac^{-1}, resulted in no additional forage production under any of the soil types, even when N fertilization was increased to 120 lbs N ac^{-1}. It cannot be determined from this experiment if higher N application rates would have increased forage production further. It is likely that it would, but fertilizer use efficiency (FUE) would drop considerably and often such high N rates are economically limiting.

As one might expect, there was generally a negative relationship between forage growth response and soil P concentrations at the end of the study period, except all soil types accumulated soil P with increasing P fertilizer application rates (Fig. 3-1, right panels). Greater forage production resulted in greater soil P uptake. The low soil P Spodosol and had similar inherent M-3 P values (0 P application rate), but the relative rates of P remaining in the soil with increasing N additions were more clearly defined in the Spodosol system. The high inherent P Ultisol also performed much like the Spodosol soil, except that it had inherently more P to begin with (merely a shift in response).

Discussion (Obj 3): These data demonstrate that applying P fertilizer without adequate N fertility will likely not increase bahiagrass yields. Unfortunately, it is not always easy to know if your N soil fertility is adequate, since Florida labs do not analyze for soil N fertility. However, plants are visually responsive to N fertilizer and one can, with practice, become familiar with the signs that the forage may benefit from additional N fertilizer applications. Additionally, UF-IFAS has provided N recommendations for many different crops, including bahiagrass. Following these recommendations will likely provide adequate guidance towards productive forage nutrient management. The heavier soils demonstrated some production benefit by increasing N application rates from 60 to 120 lbs N ac^{-1}. However, it should be noted that it comes at an economical and environmental cost. In many Florida pasture systems, N application rates are targeted at approximately 50 lbs ac^{-1}. This is a good baseline since it lessens the risk of N leaching from a single high application rate and it won't break the pocketbook.

We proposed to further address P and N fertility interactions in the greenhouse with different bahiagrass cultivars (Pensacola, Argentine, and Riata) and soil types (Spodosol A horizon with inherent low P, Spodosol A horizon with inherent medium P, Ultisol A horizon with inherent low P, and Ultisol A horizon with inherent medium P). To better understand the response to fertility.

Objective 4 (On-farm soil P source and rate trial)

Materials and Methods (Obj 4): This study was initiated in 2017 at the Silver Spurs Ranch in Kenansville, FL, where the Omission plot testing is located (Objective 2). This location has a Myakka (Spodosols) soil series with low soil test P in the A horizon and medium soil test P in the spodic (Bh) horizon that resides within two feet of the soil surface. This site illustrates the risks many ranches in the region face when fertilizing with P. Data from FCA funded column study demonstrated that P source affected both, yield and soil P storage capacity (SPSC). Additionally, plants in the column study significantly increased the SPSC through P uptake. Forage production is maximized from June through July, when day-lengths are longest. It seems reasonable that bahiagrass may gain the most benefit from nutrient inputs during that period of maximum forage growth, particularly when applying a sparingly available nutrient, such as P.

The treatments were as follows: 4 P sources (40 lbs P_2O_5 application) 1) triple super phosphate or TSP, 2) struvite (recycled from municipal waste water treatment, 3) Class AA biosolids, and 4) biochar from biosolids, which equates to a total of 39 plots. We also included a check treatment (no P additions). The 3 P application times were as follows: 1) single application in May (Early), 2) single application after the first cutting in July (Late), and 3) split application of 50% in May and 50% after first cutting in July. Other macronutrients (N, K, S, Mg) will be normalized among treatments, based upon respective fertilizer nutrient content, to supply 50 lbs N, 40 lbs K_2O, 20 lbs S, and 11 lbs Mg per acre.

Initial soil samples were collected from each 10 ft x 20 ft plot at 3 soil depths (A horizon or 0-6 inces), E horizon (6-12 inches) and upper Bh horizon (approximately 18 to 24 inches (taking a 6 inch depth sample). Soils were air-dried and passed through a 2-mm screen. The samples were analyzed for soil fertility and Al as M-3 extracts.

Over the coming year, we will develop a set of sequential soil P extractions to better assess soil P forms, impact on soil P fertility and environmental impact. This will aid in our understanding of P contributions from the various P sources by identifying the P forms in the soil pre and post fertilization. Soils will be sampled again in the fall, following the final seasonal harvest of 2017 and 2018.

The site was managed as pasture until the time of testing. At that time, temporary electrical fencing was installed, in order to better assess bahiagrass yields due to fertilizer inputs without short-term interference by cattle. The forage was harvested 7/11/17 and will again in Sep, 2017, to assess forage yield differences. The forage sampling was taken by mowing a 48” long by 21” strip from each plot, using a manual mower and bag. Following sampling, the remaining forage was cut with a hay cutter, manually raked, and removed. A push mower with bag attachment was used to stage the area to 3 inch stubble height across the entire field site and plots re-fertilized with amounts, as listed above. The sampled forage was dried (60 C for 7 days), weighed, and ground to pass through a 2mm sieve. Tissue samples were sent to a commercial lab (Waters Agricultural Laboratories, Camilla, GA) for crude protein and nutrient composition. At the end of Year 2, rhizomes + roots (approximately 1 square foot and 4 inches deep) will be sampled for dry yield and nutrient content.

Data were analyzed using PROC MIXED in SAS (SAS for Windows V 9.4, SAS Institute, 2009, Cary, NC, USA). Fixed effects included fertilizer treatment, harvest date, and soil depth. Blocks were considered as random effect. The LSMEANS were compared using the PDIFF procedure adjusted for Tukey’s test. Differences were declared significant at $P \leq 0.05$.

Results (Obj 4): As of the time of the first forage sampling, the late P application had not been applied, as it was scheduled for after the first forage harvest, which happened on 7/11/17. Therefore, the late P application plots should have biomass yields similar to the Check (no P applied) plots for the July harvest (Fig. 4-1). There were no P treatment effect differences among P sources or timing. This is not unusual, as the response to P fertilizer typically takes longer than a few weeks.

Nitrogen fertilization as total N was equivalent among P treatments, and this is reflected in the tissue concentrations, where averaged approximately 15 g kg^{-1} or 1.5% (9.4% crude protein). Crude protein above 9% is generally considered adequate for bahiagrass pastures. The forage P concentrations also did not differ significantly among the P fertilizer treatments, which is somewhat similar to what we experienced with early plot sampling in previous P application studies, such as the Omission plot study (Objective 2). Even so, there seems to be a trend of slightly higher tissue P from the TSP early and split applications and perhaps a trend of lower P in the biochar treatment. If this holds, then tissue P concentrations will reflect this in later samplings.

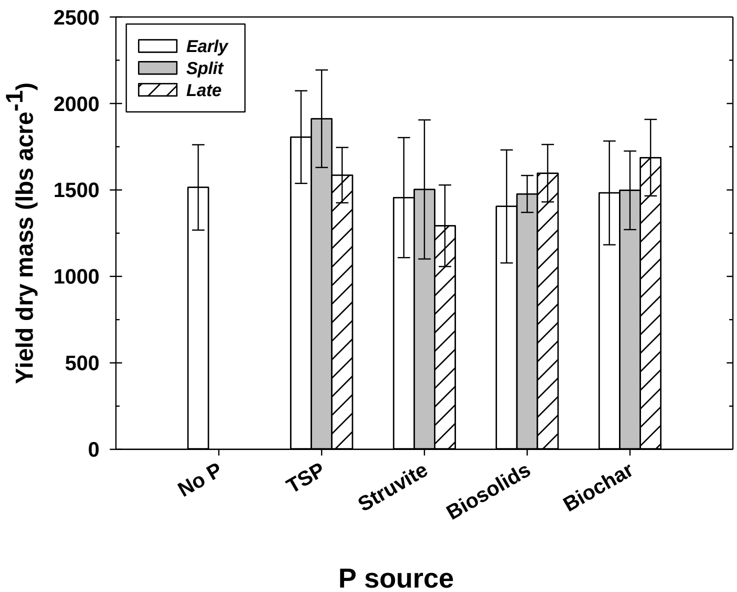

Fig. 4-1. Forage yield from 7/11/17 harvest, as affected by fertility treatments. Broad bars represent means ± standard errors.

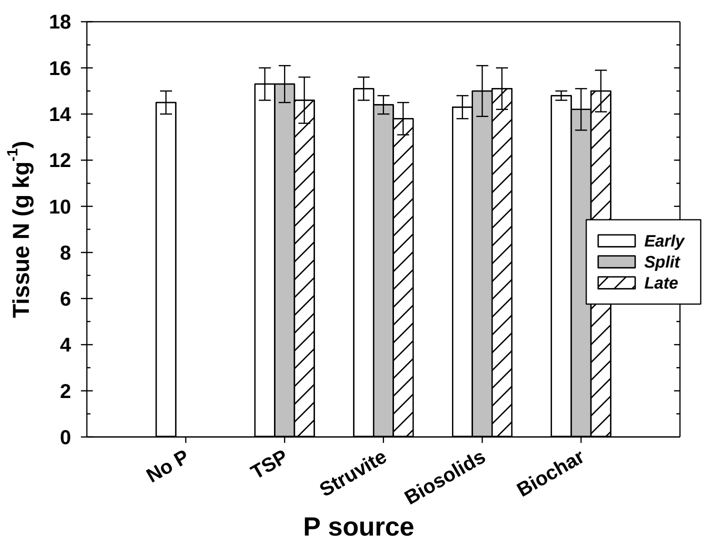

Fig. 4-2. Forage tissue N concentrations from 7/11/17 harvest, as affected by fertility treatments. Broad bars represent means ± standard errors.

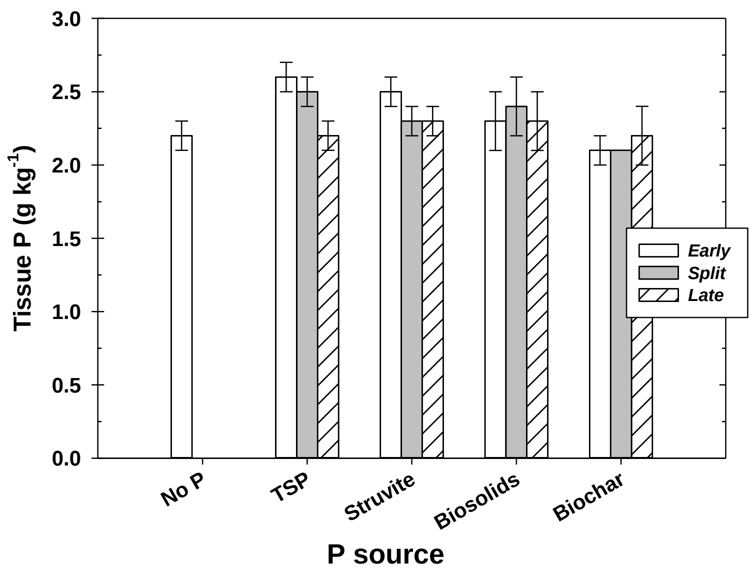

Fig. 4-3. Forage tissue P concentrations from 7/11/17 harvest, as affected by fertility treatments. Broad bars represent means ± standard errors.

The forage K concentrations were similar among fertilizer treatments, as one would expect, since all treatments received the same quantity of K. The late Biochar treatment K value appears to trend higher but statistically it is no higher than the other treatments. Since at this stage it received no more nutrients than the No P control.

The initial soil M-3 extracted soil nutrients were as follows: In the A horizon (0-6 inch depth), P and K were 31.0 ± 13.9 and 44.4 ± 42.0 ppm, respectively. In the E horizon (6-12 inch depth), P and K were 16.3 ± 22.5 and 15.0 ± 15 ppm, respectively. In the Bh (spodic) horizon (18 or greater depth), P and K were 243 ± 120 and 15.8 ± 9.9 ppm, respectively. Soil pH at all sampling depths were between 5 and 5.5.

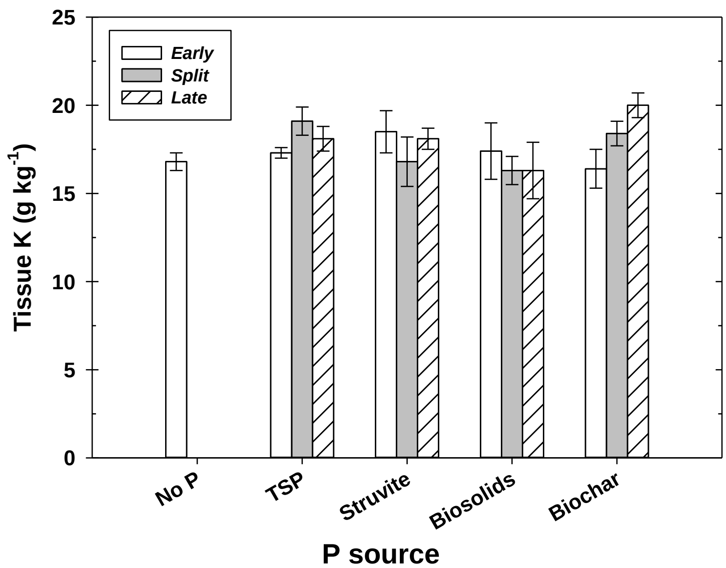

Fig. 4-4. Forage tissue K concentrations from 7/11/17 harvest, as affected by fertility treatments. Broad bars represent means ± standard errors.

Discussion (Obj 4):

At this early stage, there is not much to ponder about results, other than response to P fertilizer applications in the field typically take several months to express itself, as we have observed with past field studies. The soil samples were collected from each plot to better monitor fertility variability. It is noted by the relatively high standard deviation values, that there is a fair amount of nutrient variability in the surface soils (0-6 inches). The relative variability decreases in the Bh horizon, where distubances are less. We look forward to the second 2017 harvest and those planned for 2018.

DELIVERABLES

Objective 1: The final samples were analyzed as planned and data is being compiled into publications to refereed journals. In addition, data from this objective was presented as a poster at the UF Soil and Water Sciences Department annual symposium last September This was followed by an abstract that was submitted to Soil Science Society of America meetings in Phoenix AZ last November (see Appendix for details).

Objective 2: Omission plot testing has nearly completed its second and final season. Forages were sampled 4 times, with a final sampling scheduled for September, 2017, along with final soil samplings with depth. Results from this work will be developed into an EDIS publication to aid county agents and others on how they might test for suspected, chronic nutrient deficiencies in their fields and pastures.

Objective 3: We completed the sampling and analyses of three soil types and 1 bahiagrass cultivar at different rates of P and N fertilization in the greenhouse. Due to labor shortages and a delay in funding, we were late in initiating a second study. However, over the next year, we will be able to meet our objectives and complete all four testing schemes. When completed, we will have a thorough response surface to better understand the interaction of P and N fertilization and its potential effects on the three main bahiagrass types grown in Florida (a low-input, diploid, a low-input tetraploid, and a highly productive diploid). These data will be published in research and extension publications over the course of the next 12 to 18 months.

Objective 4: We initiated the P source and rate field trial at Silver Spurs as projected. However, we were unable to recruit a MS student to the project since the supporting funding was not expected to cover beyond 2017. We will continue to look for opportunities to fund a student to help with this work and also rely on Oseola extension staff to assist with work at the Silver Spurs Ranch. An extension meeting is planned for this fall, where updates on our efforts being funded by FCA and particularly the work at Silver Spurs Ranch will be highlighted.

Budget Expenditure Summary

The large majority of the anticipated budget for 2017 was to be used to support a MS student to address the proposed objectives. Due to funding complications we were unable to develop that position. The FCA funding did not get into place until April, 2017. Additional staffing changes in my program and a university-level hiring freeze led to more delays in hiring new labor to support the project. Most of the labor deficit has been resolved over the past couple of months. This has led to a large surplus in budgetary funds to be returned to the sponsor.

Of the approximately $21,300 in expenditures for 2017, roughly 60% was used towards labor costs, another 30% was used for materials and supplies, including analyses, and the remaining 10% was used for travel to Silver Spurs and trips related to trainings and associated FCA forage-related interests in the region. See Table 2.

Further Reading

Chakraborty, D., V.D. Nair, W.G Harris, and R.D. Rhue. 2011. The potential for plants to remove phosphorus from the spodic horizon. EDIS SL359/SS560. https://edis.ifas.ufl.edu/ss560.

Mackowiak, C. L., A.R. Blount, E.A. Hanlon, M.L. Silviera, M. B. Adjei, and R.O. Myer. 2008. Getting the Most out of Bahiagrass Fertilization. Florida Cooperative Extension Service, IFAS, 6 pp. SL249. http://edis.ifas.ufl.edu/pdffiles/SS/SS46900.pdf

Nair,V.D., K.M. Portier, D.A. Graetz, and M.L. Walker. 2004. An environmental threshold for degree of phosphorus saturation in sandy soils. J. Environ. Qual. 33:107–113.

Nair, V.D., and W.G. Harris. 2014. Soil phosphorus storage capacity for environmental risk assessment. Adv. Agric. Doi:10.1155/2014/723064.

NCSS. 2016. National Cooperative Soil Survey. National Cooperative Soil Characterization Database. Available online. Accessed 02/15/2016.

Soil Survey Staff. 2016. National Resources Conservation Service, United States Department of Agriculture. Official Soil Series Description. Available online. Accessed 02/15/2016.

Appendix . Presentations related to Objective 2.

Abstract and poster to UF Soil and Water Sciences Symposium, September 2016.

Use of biosolids in reducing phosphorus loss from Florida agricultural soils

Biswanath Dari[1], C.L. Mackowiak[1], Vimala Nair[2], J.P. Shirley[1]

[1]University of Florida, North Florida Research and Education Center, Quincy, FL-32351

[2]University of Florida, Soil and Water Sciences Dept., Gainesville, FL-32611

Alternate sources of phosphorus (P) fertilizer are needed to secure the potential supply shortage of global P reserves. Biosolids, a by-product of municipal wastewater treatment, is an attractive source of slow-release fertilizer P but there are concerns that biosolids are being over-applied on grazing lands in central and south Florida, and thereby impacting water resources. A five-month column experiment was conducted in a greenhouse with two Florida soils, a Spodosol (Myakka) and an Ultisol (Orangeburg) and six different P sources (triple super phosphate or TSP, struvite, Class AA1 and Class AA2 biosolids, Class B biosolids, and biochar made from Class B biosolids). The soil P storage and release patterns in the two soils were determined. A P-loss risk assessment, based on a threshold P saturation ratio (PSR; a molar ratio of Mehlich-3 extractable P to [Fe+Al], beyond which P release increases sharply) was determined. The soil P storage capacity (SPSC) was calculated using the threshold PSR to assess potential environmental P-loss risk. Mehlich-3 P, Fe and Al, and water soluble P (WSP) at a 1:10 soil: solution ratio was analyzed at experiment termination (20 weeks). The amount of releasable P was lower in columns receiving biosolids than the two inorganic P fertilizers (TSP and struvite) and P loss from struvite was lower than from TSP. The soils receiving Class B biosolids retained more P than soils receiving Class AA biosolids or biochar made from Class B biosolids, regardless of soil type. This study confirms that release of P from agricultural soil can be reduced by substituting biosolids and other recoverable P (biosolids-derived biochars and struvite from wastewater treatment) for conventional P fertilizers. Increasing their use may help reduce reliance on global P reserves.

Abstract and poster to Soil Science Society of America, November, 2016.

Soil phosphorus storage capacity in Florida soils receiving fertilizer alternatives

Biswanath Dari[1], C.L. Mackowiak[1], Vimala Nair[2], J.P. Shirley[1]

[1]University of Florida, North Florida Research and Education Center, Quincy, FL-32351

[2]University of Florida, Soil and Water Sciences Dept., Gainesville, FL-32311

Global phosphorus (P) supplies are dwindling and thus there is a need to identify and develop alternative P fertilizer sources. Even so, P-impacted soils are also a concern and threaten water resources in some agricultural regions of the U.S., including south Florida. Slow-release, P fertilizer recovered from municipal waste water treatment as biosolids, have been used in the past and new products, such as struvite, are being developed. Assessing their impact on land found in Florida agricultural areas will help in the continued development of Best Management Practices (BMPs) and provide data for land and water managers tasked with minimizing P impacts in sensitive areas. A column experiment was conducted in greenhouse using two different agricultural soils (Spodosols and Ultisols) at Quincy, Florida. The aim of this study was to test Class B, Class AA, and biochar prepared from class B biosolids as organic P sources, compared to inorganic P fertilizer sources (struvite and triple super phosphate) mixed with two different soils on P retention and ortho-P release in unplanted soil columns. A P loss risk assessment, using a threshold P saturation ratio (PSR; a molar ratio of Mehlich-3 extractable P to [Fe+Al], beyond which P release increases sharply) was also determined. The soil P storage capacity (SPSC) was calculated using threshold PSR to assess potential environmental risk. After 12 weeks, the unplanted columns were analyzed for Mehlich-3 P, Fe, Al, and water soluble P (WSP). The PSR and SPSC values were calculated. Water soluble P, an indicator of releasable P in soil following rainfall/irrigation events was: TSP>struvite>biosolids>control (unfertilized soil). Results suggest that biosolids and biochar derived from biosolids might make a suitable P fertilizer alternative, due to reduced short-term P availability in soils.

Table 2. Summary of expenditures and percent completion for 2017.

BUDGET FOR FLORIDA CATTLE ENHANCEMENT FUND APPLICATION					
PROJECT TITLE & FCEB #: Options for Phosphorus Fertilization and Retentionin Bahiagrass Pastures #24122					
DETAILED LINE ITEM DESCRIPTION	QTY	% Complete	TOTAL	EXPLANATION/JUSTIFICATION OF DELIVERABLE	COMPLETION DATE
Sample preparation and chemical analysis (Objective A)	258	100	$ 6,330.87	Expenses associated with tissue preparation (grinding) and analyses (plant essential nutrients in tops and roots)	9/01/2017
Sample preparation and chemical analysis (Objective B)	90	65	$ 4,259.87	Expenses associated with harvests, tissue preparation (grinding) and analyses (plant essential and soil fertility). A final, season-end (September 2017) forage harvest, soil collection (2 depths), and analysis is anticipated.	9/01/2017
Experiment initiation, management, and chemical analysis (Objective C)	135	60	$ 4,698.32	Expenses associated with harvests, tissue preparation (grinding) and analyses (plant essential nutrients in tops and roots), and soil anaylyses for P, Fe, Al. One of two expected 2017 trials was completed. Second was initiated.	9/01/2017
Experiment initiation, management, and chemical analysis (Objective D)	195	100	$ 6,023.81	Expermiental site was prepared, initial soil samples(3 depths) collected and two forage harvests completed.	9/01/2017
Final Research Project Report		100		Project report detailing research, which includes results, conclusions and future research needs	9/01/2017
GRAND TOTAL: (equal to percentage of completion)			**$21,312.87**		