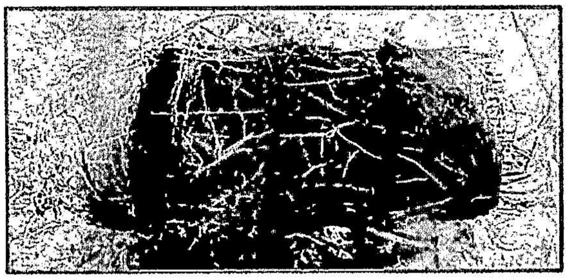
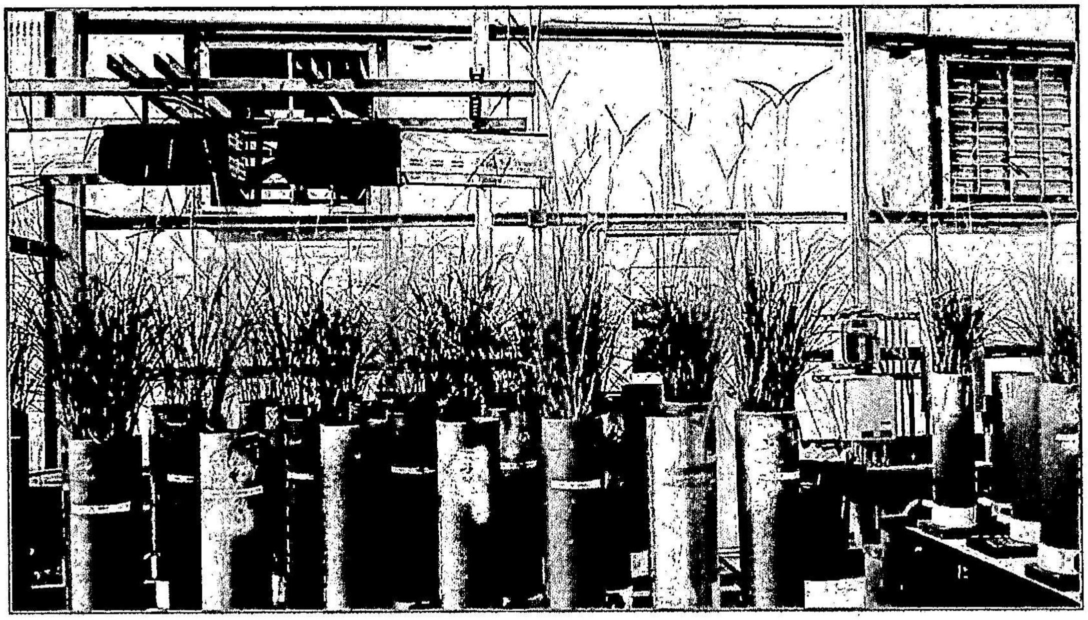
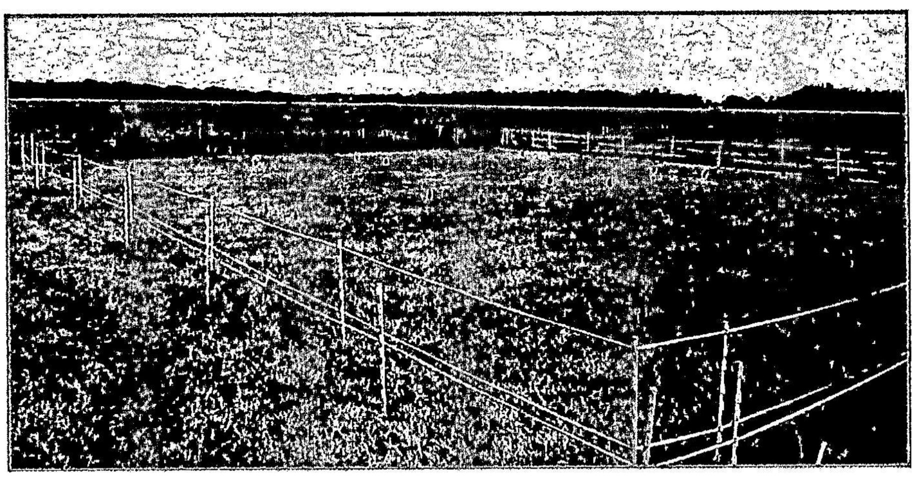





Biosolids options for phosphorus fertilization and its effect on P retention in pasture soils

FDACS Contract No. 22963, 2016 Final Report

UF | UNIVERSITY of FLORIDA



Biosolids options for phosphorus fertilization and its effect on P retention in pasture soils

Florida Department of Agriculture and Consumer Services

Office of Agricultural Water Policy

FDACS Contract No. 22963, 2016 Final Report

Investigators: Dr. Cheryl Mackowiak (Lead PI); Dr. Vimila Nair (Co-PI); Dr. Jose Dubeux (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 08, 2016

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 proposal addressed Florida's cow/calf BMPs and more specifically, the following Florida Cattlemen's Association (FCA) 2015 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.

OBJECTIVES

1. Determine if different biosolids affect bahiagrass P uptake, P retention, and leaching loss by testing six different P sources on a representative flatwoods pasture soil (Spodosol) in south-central Florida.
2. Evaluate bahiagrass performance under current fertilizer practices, compared to abundant N, P, and K soil fertility, by establishing omission test plots at the Silver Spurs Ranch, Kenansville, FL.
3. Determine where future omission plot demonstrations and soil P calibration testing may benefit Florida stakeholders, by creating a preliminary assessment of soil P storage capacity (SPSC) at nine Florida ranches, representing three soil orders (Spodosols, Entisols, and Ultisols).

OBJECTIVE 1

Materials and Methods (Obj 1): We deviated slightly from the proposed objective by testing two instead of one soil type, in order to determine if heavier soils typical of pastures in the northern part of the state would respond similarly to P fertilization as many of the central and south Florida ranches. 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 BA 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 slitted 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, only the A horizon was used.

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 (BAAT), 4) class AA biosolids from Jacksonville (BAAG), 5) class B biosolids from Tallahassee (BioB), 6) biochar created from class B Tallahassee biosolids (Biochar), and 7) struvite (a recovered mineral from wastewater treatment, Ostera, Vancouver, CA). The act of pyrolyzing (burning under moderate heat (~400 °C) 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 wastewater of human (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 and soil type to assure 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 be 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 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 from this first harvest 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. Tissue was also analyzed for nutrients from the final harvest, while only dry mass was determined from harvests 2 and 3.

At the final harves, 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 3 inch depth sections. Roots were separated from each section and measured separately. The root data is still being processed. 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.

An ANOVA was used to analyze the 2 x 2 x 4 x 7 (planted vs unplanted, 2 soils, 4 soil depths, 7 fertilizer treatments) factorial design (soils) and 2 x 2 x 7 (planted vs unplanted, 2 soils, 7 fertilizer treatments) factorial design (forage).

Results (Obj 1): Dry matter yields were affected early, with the first harvest and significant differences continued through each harvest, until the last (Figs. 1-4). Triple Super Phosphate always performed well, while the control (no added P) performed relatively poorly. Class B biosolids resulted in higher yields early on, while it dropped by the final harvest (Fig. 4). Plants grown in the Ultisols grew larger at each harvest, compared to the Spodosols.

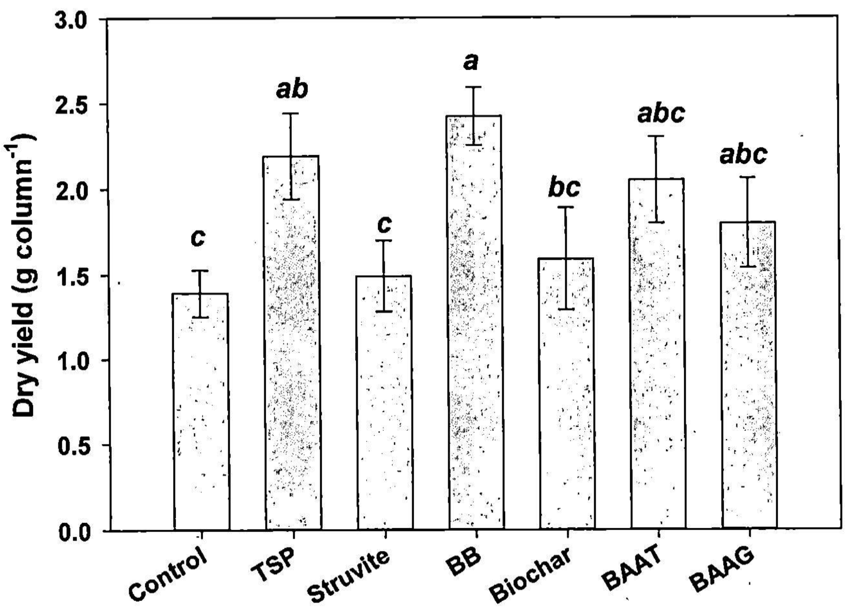


Fig. 1. Dry forage yields from 4/13/2016, as affect by fertility treatments. BB= class B biosolids, BAAT= class AA biosolids from Tallahassee, and BAAG=class AA biosolids from Jacksonville. Bars represent means ± standard errors. Bars sharing the same letters are not significantly different.

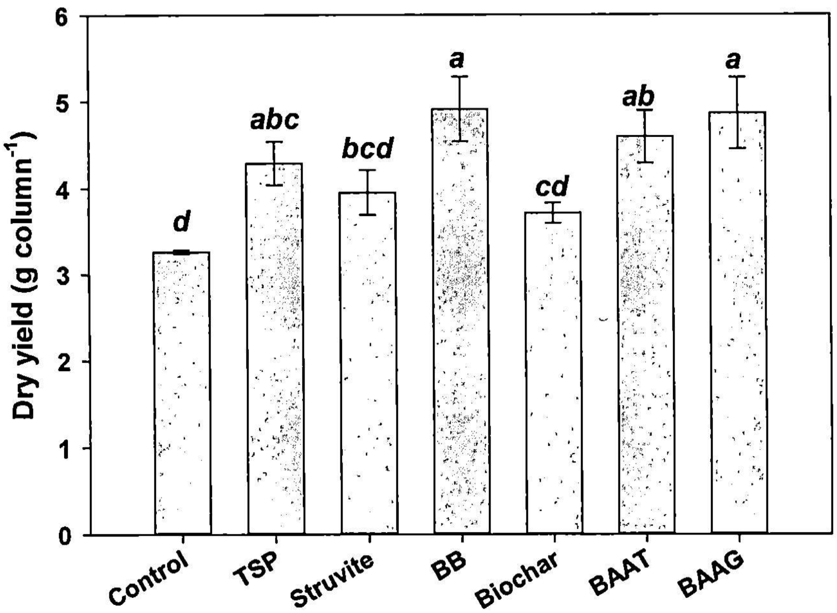


Fig. 2. Dry forage yields from 5/25/2016, as affect by fertility treatments. BB= class B biosolids, BAAT= class AA biosolids from Tallahassee, and BAAG=class AA biosolids from Jacksonville. Bars represent means ± standard errors. Bars sharing the same letters are not significantly different.

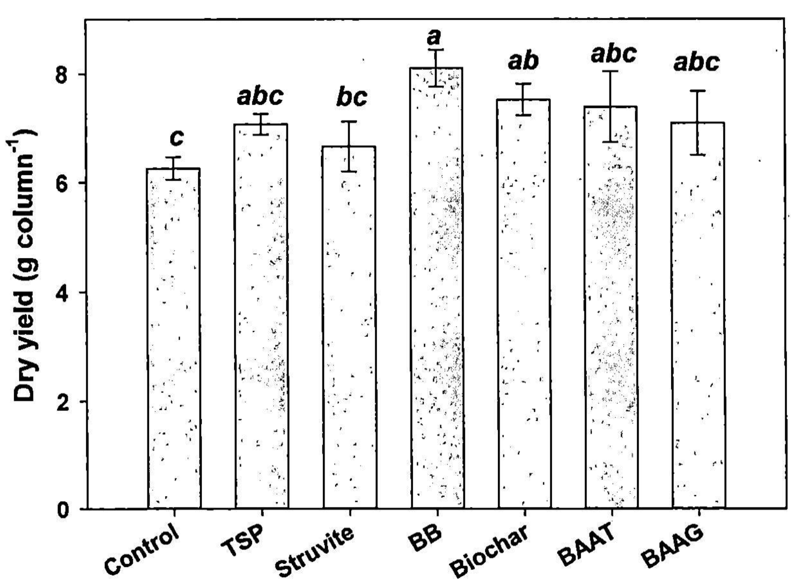


Fig. 3. Dry forage yields from 6/15/2016, as affect by fertility treatments. BB= class B biosolids, BAAT= class AA biosolids from Tallahassee, and BAAG=class AA biosolids from Jacksonville. Bars represent means ± standard errors. Bars sharing the same letters are not significantly different.

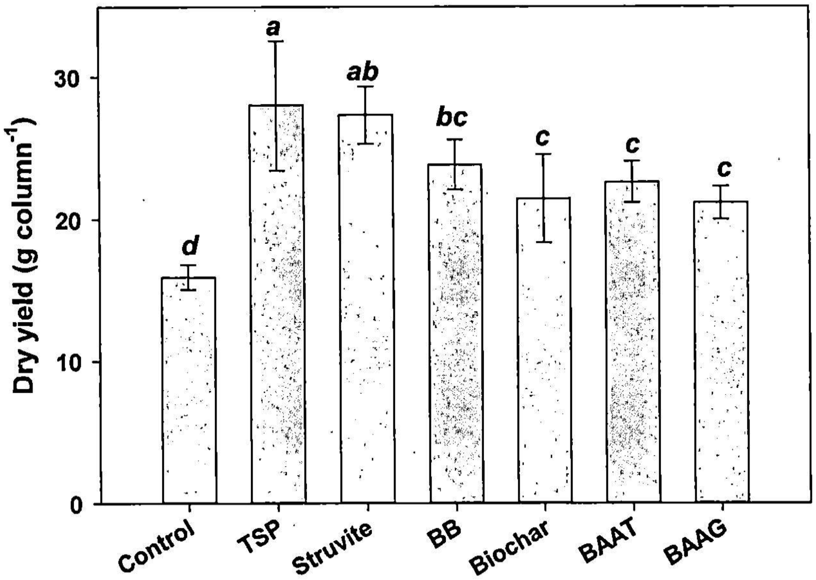


Fig. 4. Dry forage yields from 6/15/2016, as affect by fertility treatments. BB= class B biosolids, BAAT= class AA biosolids from Tallahassee, and BAAG=class AA biosolids from Jacksonville. Bars represent means ± standard errors. Bars sharing the same letters are not significantly different.

There were interactions among planting type, soil type, soil depth and treatment. Soil data from the columns are being completed and an update report will be delivered to the FCA at their third quarterly meeting in December, 2016. As expected, the Spodosols columns had greater water soluble P (WSP) and Mehlich-3 P in the Bh horizon, while these values were often not significantly different in the Ultisol soils, with depth. Planting the columns greatly reduced Mehlich-3 P in all columns, regardless of soil type. There was a concomitant increase (positive SPSC values) in SPSC in planted columns, as well. The TSP treatment trended towards lower SPSC, deeper in the soil profiles.

Discussion (Obj 3): Based on the early column study results, it appears that bahiagrass plants can take up P originating from any of the P fertilizers, which allowed those treatments to often outperform the Control, which received all the same fertilizer, except P. The more labile TSP seemed often to result in greater biomass than the other treatments. There seems to be a benefit to have readily bioavailable P near the plant during growth. It may not be possible to supply all the plant demand for bioavailable P while also protecting the environment from excess P loss in some production systems. Tissue nutrient content and further analysis of the soil composition and root partitioning should lead to interesting findings. We will have these additional data summarized by the end of 2016. Tissue content from the first clipping (Appendix 1) is provided to show relative differences among treatments. Tissue P concentration remained above 0.15% (1.5 g kg^{-1}) lower sufficiency limit. Preliminary results seem to suggest additional P might be beneficial to bahiagrass growth (under our controlled conditions). Objective 2. Looked at this further in the field.

OBJECTIVE 2

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. 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).

This 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).

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

Monthly air and soil temperatures, rainfall, and evapotranspiration data from the Florida Automated Weather Network (FAWN) is given in Table 2. The site was managed as pasture until the time of the test. 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 06/15/2016 and 08/24/2016, to assess forage yield differences. Harvest 1 consisted of 2 composited samples from a 0.25 m^2 square, while the second sampling was taken from a single 0.25 m^2 square per plot. 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 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 from the first harvest were sent to a commercial lab (Waters Agricultural Laboratories, Camilla, GA) for crude protein and nutrient composition. The August harvest was not analyzed but the tissue remains in storage for analysis at a later date, as funds permit. A final season (October) harvest is scheduled to complete the growing season. At the end of the season (October, 2016), surface and lower profile soil samples will be collected and stored for future fertility and SPSC analyses. The study will be repeated in Year 2, pending funding. During the test period, the fencing had been disabled once in June, but there was no sign of livestock grazing. An ANOVA (alpha = 0.05) was conducted on yield and tissue nutrient content using Proc Mixed (SAS version 9.4, Cary, NC). When significant, means were separated using Tukey.

Table 2. Monthly environmental conditions at the test plot location, Kenansville, FL.

Month	Air Temp	Soil Temp	Rainfall	ET^Z
	(°C at 24 inches)	(°C at -4 inches)	--------------(inches)---------	
Jan	58.2	63.2	5.77	1.55
Feb	59.8	65.2	1.29	2.32
Mar	68.5	73.9	5.16	3.41
Apr	69.8	78.3	1.75	4.20
May	74.3	81.9	10.74	4.96
Jun	79.2	86.2	5.74	5.10
Jul	81.0	89.0	4.86	5.58
Aug	79.7	86.7	5.09	4.65

^{Z}ET = Evapotranspiration. These values are an estimate of monthly water vapor loss from soil due to a combination of soil evaporation and plant transpiration processes.

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 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 lysimeter installations later this year. The data from both types of equipment can complement each other in assessing water quality and its movement.

Results (Obj 2): Bahiagrass forage responded to fertilizer treatments ($P < 0.001$), by the first harvest in June, 2016. The lowest yields were with the Check (no fertilizer) and –N plots, while other treatments were similarly greater in yield (Fig. 5). Plots receiving biosolids were had yields that straddled the higher and lower yielding plots.

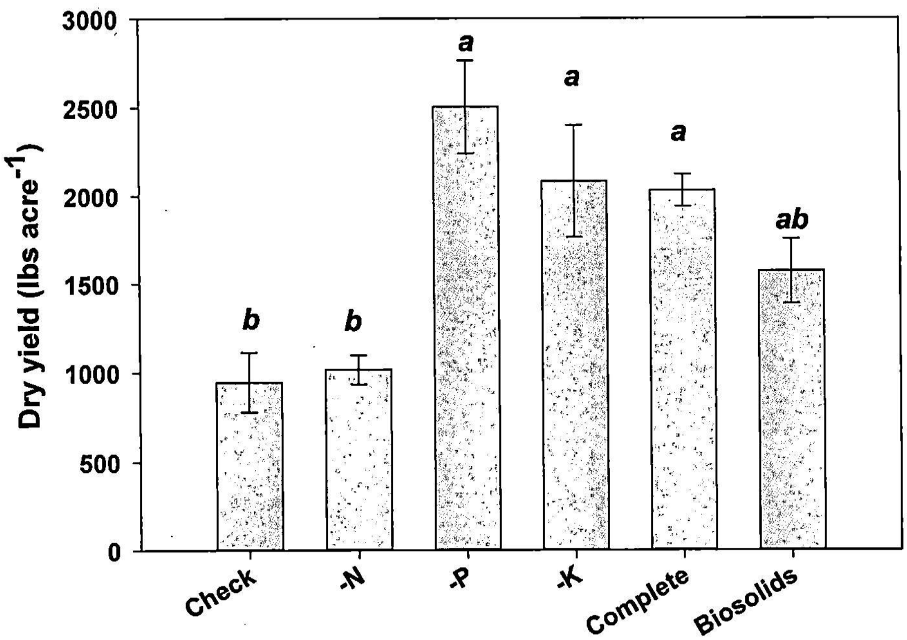


Fig. 5. Dry forage yields from 6/15/2016, as affect by fertility treatments. Bars represent means ± standard errors. Bars sharing the same letters are not significantly different.

Again, in August, the lowest yielding plots were the Check and –N treatments, while all other treatments were similarly greater, by over 100% (Fig. 6).

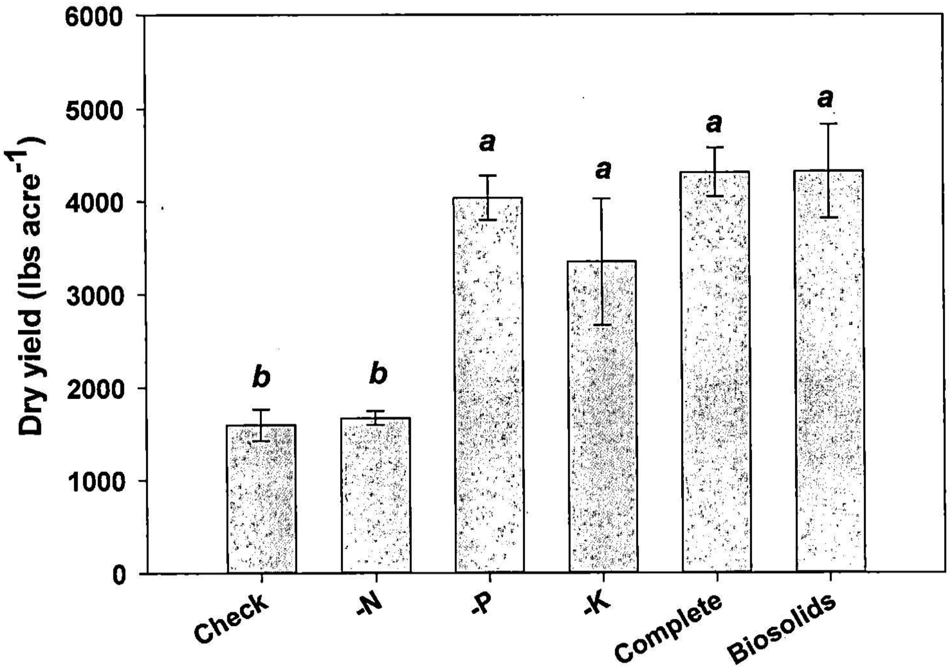


Fig. 6. Dry forage yields from 8/24/2016, as affect by fertility treatments. Bars represent means ± standard errors. Bars sharing the same letters are not significantly different.

Tissue N, P, and K concentrations were graphed from the first forage harvest. If nutrients are limiting, they may measure lower in the forage, as well, although sometimes interactions with other nutrients and reduced plant growth or expansion may mask deficiencies. Tissue N was similar among fertility treatments, although the Check, -N and Biosolids treatments had numerically lower values (Fig. 7). Tissue P also was similar among treatments (Fig. 8). In comparison, tissue K differed among treatments, where the Check had a lower tissue K value than the –P treatment (Fig. 9) and the –K treatment was somewhat intermediate to the lowest highest value treatments (Fig. 9).

Other plant essential nutrients were measured, as well and their concentrations and treatment comparisons are provided in Table 3. These nutrients play important roles in bahiagrass nutrition but they are not a focus of this project, other than their responses to treatments.

Table 3. Bahiagrass nutrient concentrations at 6/15/2016.

Treatment	Ca	Mg	S	B	Fe	Mn	Zn	Cu
	---------------g kg^{-1}	-------------		-----------------------	---mg kg^{-1}	------------------------		
Check	5.03a^Z	3.27ab	1.47ab	4.31ab	43	46abc	11.05	3.94
-N	4.17ab	2.27c	1.47ab	4.87ab	42	37c	9.95	3.73
-P	3.73b	2.60bc	1.30b	3.34ab	44	55ab	12.22	3.60
-K	4.83a	3.53a	1.77a	5.21a	46	56a	14.47	5.05
Complete	3.90b	2.47ab	1.40ab	2.36b	43	46abc	13.15	4.86
Biosolids	3.57b	2.37ab	1.63ab	4.36ab	41	39bc	10.49	3.66
Suggested								
Low sufficiency^Y	*3.0*	*1.6*	*1.8*	*3.0*	*50*	*20*	*20*	*2 to 4*

^{Z}Columns sharing the same letters are not significantly different.
^{Y}Values adapted from Mackowiak et al., 2015.

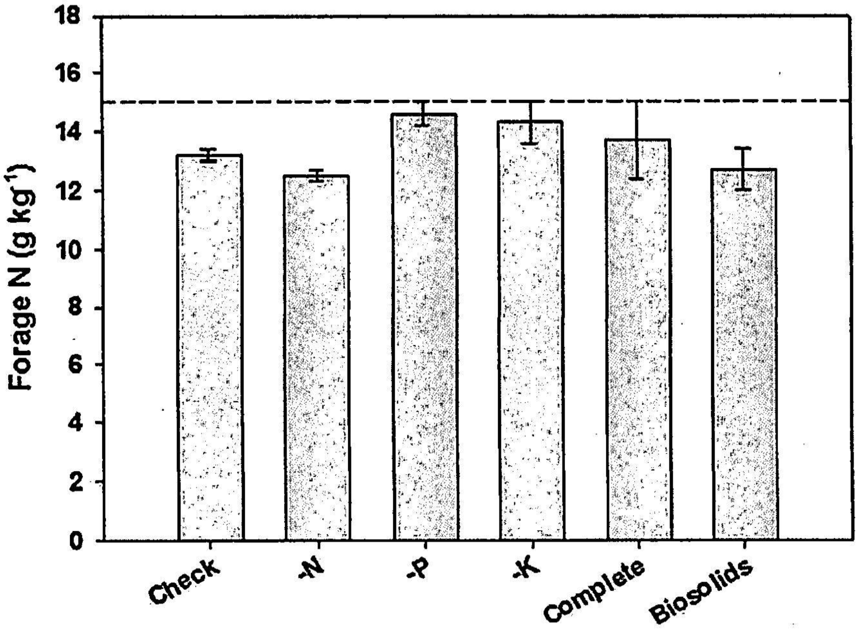


Fig. 7. Forage N concentrations from 6/15/2016, as affect by fertility treatments. Bars represent means ± standard errors. The dash reference line provides an estimate of potentially low sufficiency limit at 15 g kg^{-1}.

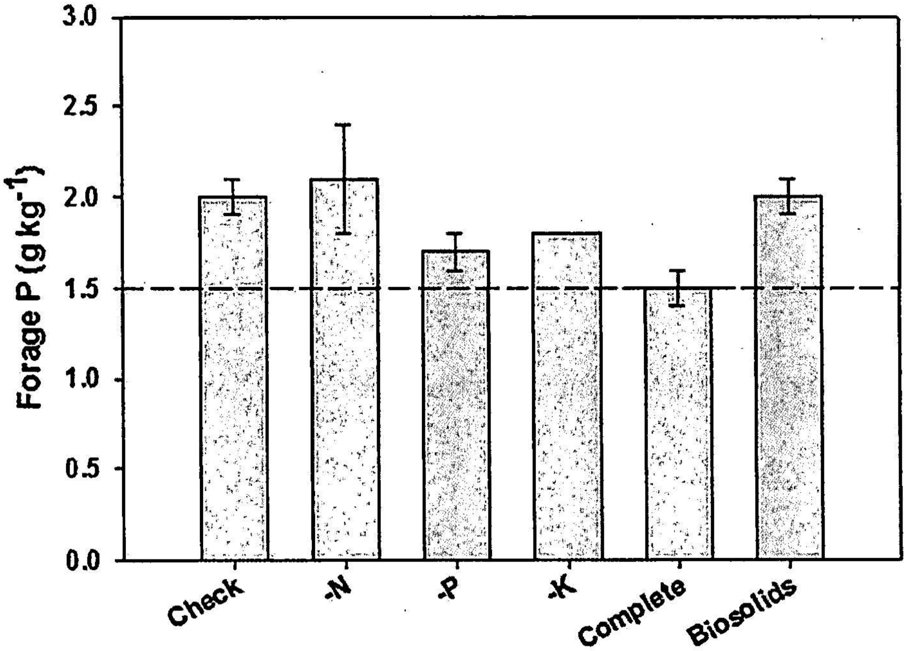


Fig. 8. Forage P concentrations from 6/15/2016, as affect by fertility treatments. Bars represent means ± standard errors. The dash reference line provides an estimate of potentially low sufficiency limit at 1.5 g kg^{-1}.

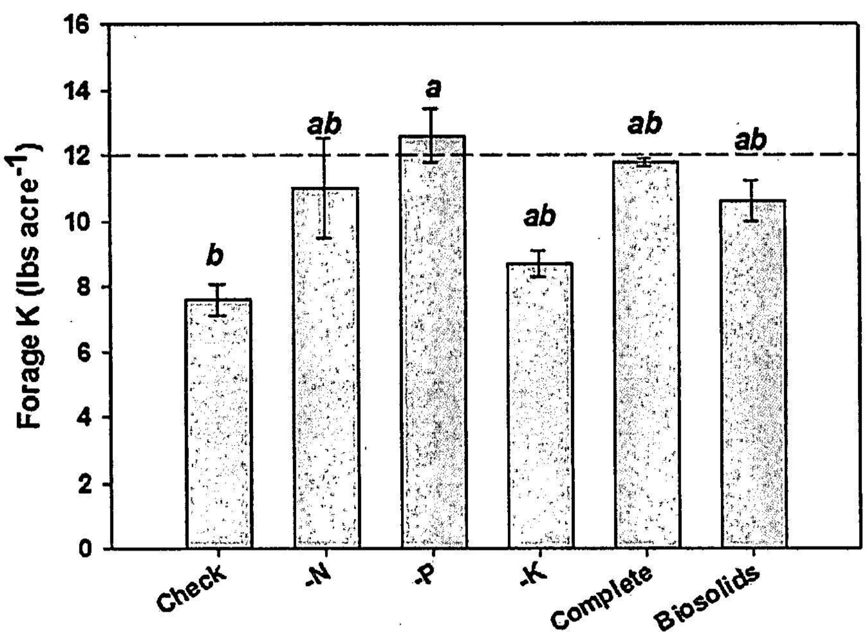


Fig. 9. Forage K concentrations from 6/15/2016, as affect by fertility treatments. Bars represent means ± standard errors. Bars sharing the same letters are not significantly different. The dash reference line provides an estimate of potentially low sufficiency limit at 12 g kg^{-1}.

Discussion (Obj 2): Even though it is early in testing, the omission plots clearly show that for this test location, N is the most limiting nutrient for same-season forage yields. It is far too early to assess the interactions of other nutrients and environment on depleted P or K soil reserves. A continuation through 2017 may provide longer-term effects on forage stand, disease interactions, etc. Forage N content was not affected, although there appeared to be a pattern of somewhat lower tissue N in forages not receiving N and from Biosolids, which has slower N release.

As with N, tissue P content was not significantly different among treatments. It is interesting to note that although soil test P was low (19 mg kg^{-1}) by UF-IFAS standards (low is ≤ 25 mg P kg^{-1}), forage P was adequate (1.5 mg kg^{-1}) in most cases. Only the Complete treatment approached a critical low concentration. It is well described that bahiagrass is often N limited for yield, but we do not have sufficient reporting of what happens to forage quality and yield when challenged with chronic deficiencies.

Other plant essential nutrient concentrations differed among treatments. Cations that compete with K for uptake were affected by the –K treatment, where those plots not receiving K had higher tissue Ca and Mg content. We have observed this response in bahiagrass and bermudagrass throughout the state in previous studies. Manganese and S also trended higher in forage grown on the –K treatment. Sulfur was applied to the –K plots via $MgSO_4$ $6H_2O$, whereas S was applied as KMag to all plots receiving K fertilizer. Tissue S, Fe, Zn, and Cu approached or were below suggested sufficiency for bahiagrass. There are few to no reports of verified nutrient sufficiency ranges for bahiagrass, so there might be interest in developing ranges or at least test further, one or more nutrients that consistently measure low in the UF-IFAS extension soil testing lab's (ESTL) database. One of the purposes of the Biosolids treatment was to determine if more micronutrients might become available to the plants. As of the first sampling, this did not seem to be the case. Longer-term sampling will be needed to address this question.

Completing the harvests through the remainder of this year, soil sampling and continuing the study through 2017 or longer, will provide much greater insight into the effects deficiencies beyond N, may have on our bahiagrass pastures. A better assessment of nutrient depletion effects will also help us in better identifying future research needs and improve our soil calibrations for bahiagrass using the Mehlich-3 extraction method. This or similar testing should be funded to help garner answers to our producers' questions about bahiagrass fertilization and nutrient requirements.

OBJECTIVE 3

Materials and Methods (Obj 3): An article was published in the January 2016 issue of Florida Cattleman Magazine addressing biosolids applications and effects on soil P. It also included an online survey to identify volunteers who want to participate in soil and forage sampling on their land for this project. Survey response was poor, and it became difficult to identify ranches that were enthusiastic about having their soils and forages tested. Eventually we located one large ranch in south-central Florida where we sampled Spodosols and Alfisols over six locations. The Alfisols were not part of the original sampling list, but as they presented themselves, we decided that it was an opportunity to assess and compare with the Spodosols that were in relatively close proximity. Three different ranches were represented by Ultisols (1 location per ranch) located in northwest and north Florida. Additionally, two ranches in north Florida were used to represent Entisols. Although Entisols were represented by only one soil series, it provided some comparison of fertility variation within a single soil series. The soil series and description are given in Table 4.

Table 4. General descriptions and descriptions of soils collected in Florida. Numbers following series name were used to distinguish locations having the same series.

Soil order	Series	Description	Coordinates
Entisols	Alpin1	Thermic, coated Lamellic Quartzipsamments	30.2, -83.1
	Alpin2	Thermic, coated Lamellic Quartzipsamments	30.2, -83.2
	Alpin3	Thermic, coated Lamellic Quartzipsamments	30.2, -83.2
Alfisols[Z]	Pineda1	Loamy, siliceous, active, hyperthermic Arenic Glossaqualfs	28.1, -80.9
	Pineda2	Loamy, siliceous, active, hyperthermic Arenic Glossaqualfs	28.1, -80.9
	Riviera	Loamy, siliceous, active, hyperthermic Arenic Glossaqualfs	28.1, -80.8
Spodosols	Immokalee	Sandy, siliceous, hyperthermic Arenic Alaquods	28.1, -80.9
	Myakka	Sandy, siliceous, hyperthermic Aeric Alaquods	28.0, -80.9
	Wabasso	Sandy over loamy, siliceous, active, hyperthermic Alfic Alaquods	28.1, -80.8
Ultisols	Clarendon	Fine-loamy, siliceous, semiactive, thermic Plinthaquic Paleudults	30.9, -854
	Dothan	Fine-loamy, kaolinitic, thermic Plinthic Kandiudults	30.7, -85.3
	Blanton	Loamy, siliceous, semiactive, thermic Grossarenic Paleudults	30.4, -83.5

[Z]These soils were not part of the original list but were collected in order to provide a larger variety of soil types.

Sampling at all locations consisted of collecting a composite soil sample with a soil probe (0 to 6 inch depth) within a small (10m2 area). In addition, a single augered core was collected and divided into 0 to 6 and 6 to 12 inch segments. The deeper sampling was used to help determine changes in soil P with depth. Along with the composite soil samples, forages were sampled in the same 10m^2 area and composited (sampled from the upper 50% of canopy). Soil samples were air-dried, passed through a 2-mm sieve and stored until they were analyzed. Forage samples were oven-dried (60 C for 7 days), ground to pass through a 2-mm sieve and stored until they were analyzed. Due to the sampling schedule, only the Spodosols and Alfisols were analyzed, to date. The remaining samples will be analyzed in 2016 in time to present information at the FCA December quarterly meeting. The soil probed samples were analyzed for soil fertility and the augered soils were analyzed for nutrients and Al, to help determine SPSC with soil depth. The forages were analyzed for plant essential nutrients.

Results (Obj 3): Soils collected in south-central Florida had high forage P content well above the low P sufficiency value of 1.5 g kg^{-1}.The Wabasso soil had the lowest forage P concentration and it also had the lowest soil P concentration with depth. The Wabasso location also corresponded to the highest SPSC value. Although the some (Riviera, and all the Spodosols) declined in soil P with depth, the resulting SPSC was negative in all cases. Negative SPSC values equate to P impacted soils.

Table 5. Phosphorus survey of two different soil orders from Florida ranches.

Soil Series	Tissue P	Soil P	Soil P		SPSC^Z	
	(g kg^{-1})	--------(mg kg^{-1})--------				
Alfisols		Probe (0-6")	(0 to 6")	(6 to 12")	(0 to 6")	(6 to 12")
Pineda1	4.6	670	629	668	-20	-21
Pineda2	3.7	161	210	222	-6	-7
Riviera	3.1	295	407	46	-13	-1
Spodosols						
Immokalee	4.6	151	163	36	-4	-1
Myakka	3.5	92	77	29	-2	-1
Wabasso	2.4	118	96	56	-2	-1

[Z]*SPSC = soil phosphorus storage capacity.*

Comparing the soil probe P values with a single auger core, resulted, in most cases to similar P values (within 20% of one another). In two cases, the values were within 30% of one another.

Discussion (Obj 3): A negative SPSC provides warning when soils are containing more P than is required for forage production, and additional P applications will likely not be retrained, leading to P losses to nearby surface and groundwater. Since soil differ in their mineralogy and ability to fix P, it is often difficult to determine quickly whether any particular soil is P impacted. In comparison, the SPSC provides a simpler approach. If the SPSC is negative, then soils within that depth increment will release P to the environment. Deeper sampling will tell you to what depth are the soils impacted. In the case of Spodosols, with their uncoated surface sands, they often become impacted within close proximity to the the shallow water table.

Soil P measurements can be quite variable in agricultural systems. The comparison of the soil probe P with the single auger method provided similar results in most cases, suggesting that in these examples, a single augered core likely provides fairly good representation of the pasture, at least within several meters. The additional nutrients that were measured are given in Appendix 2. Data from the other measured parameters may help with data interpretation as data is collected from more cites and as we learn more from the omission plot data from Objective 2.

DELIVERABLES

Objective 1:Soils were collected and the greenhouse column study initiated. We completed well past the first harvest and presented data from all yield harvests and the initial tissue composition. The P sources were described and even further information will be forthcoming, as we summarize the completed study.

Objective 2: Omission plots were established and data collected and presented through 2 harvests (only required one harvest). The piezometers are ready to be installed, following coordination with Silver Spurs and their plans for complementary lysimeter installations.

Objective 3: An article (Appendix 3) was published in the Florida Cattlman magazine in January, 2016 containing education on soil P in pastures and a P survey. We located several ranches and collected soil and forage from them. Half the samples were reported on, while the remaining samples are being analyzed. We actually sampled an additional soil order to better help with this objective. Fertility and P species, including SPSC was presented in this report.

REFERENCES

Mackowiak, C. L., A.R. Blount, E.A. Hanlon, M.L. Silveira, 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

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 1. Tissue composition from first column clipping (April13, 2016).

Block	Soil	Treatment	N (%)	P (%)	K (%)	Mg (%)	Ca (%)	S (%)	B (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)
1	Spodosols	Control	2.57	0.15	1.36	0.3	0.69	0.21	6.5	45.25	111	71.75	7.19
2	Spodosols	Control	1.92	0.12	1.46	0.18	0.51	0.15	6.99	23.79	88.23	60.96	5.05
3	Spodosols	Control	2.06	0.20	1.89	0.18	0.57	0.18	5.76	23.18	107.50	60.78	4.6
1	Spodosols	TSP	2.16	0.16	1.56	0.25	0.57	0.24	20.57	29.14	102.00	116.70	5.99
2	Spodosols	TSP	2.45	0.18	1.78	0.27	0.57	0.25	20.82	47.90	117.30	81.21	7.25
3	Spodosols	TSP	2.43	0.18	1.91	0.24	0.56	0.30	24.32	49.91	124.90	76.74	7.7
1	Spodosols	Struvite	2.09	0.17	1.71	0.24	0.58	0.23	18.98	25.37	101.50	113.30	4.58
2	Spodosols	Struvite	2.29	0.15	1.30	0.24	0.54	0.15	6.78	31.50	87.03	65.31	5.76
3	Spodosols	Struvite	2.21	0.18	1.93	0.22	0.56	0.18	3.81	22.47	102.00	66.97	5.6
1	Spodosols	BAAG	2.31	0.16	1.45	0.22	0.60	0.21	7.43	29.16	92.07	69.07	4.46
2	Spodosols	BAAG	2.23	0.17	1.31	0.30	0.68	0.21	6.89	36.01	101.00	78.46	6.38
3	Spodosols	BAAG	2.62	0.17	1.71	0.26	0.50	0.25	6.40	51.73	97.36	76.91	7.99
1	Spodosols	BAAT	2.39	0.18	1.44	0.3	0.69	0.22	8.66	48.82	117.8	80.37	7.38
2	Spodosols	BAAT	2.46	0.18	1.70	0.27	0.59	0.19	8.07	43.16	86.09	79.39	7.22
3	Spodosols	BAAT	2.35	0.19	1.83	0.23	0.56	0.24	12.37	44.57	106.80	71.36	5.95
1	Spodosols	BB	2.61	0.17	1.44	0.25	0.65	0.21	8.3	37.19	108	77.75	8.31
2	Spodosols	BB	2.30	0.19	1.56	0.27	0.57	0.20	5.44	28.25	85.20	65.51	6.41
3	Spodosols	BB	2.22	0.15	1.47	0.22	0.47	0.21	6.82	30.44	89.90	65.30	5.92
1	Spodosols	Biochar	1.94	0.18	1.55	0.20	0.53	0.17	7.53	23.24	77.71	61.11	4.1
2	Spodosols	Biochar	2.16	0.24	1.87	0.28	0.61	0.20	8.14	29.63	92.14	71.57	5.72
3	Spodosols	Biochar	2.13	0.26	1.96	0.25	0.57	0.18	5.59	27.88	92.33	66.26	5.15
1	Ultisols	Control	2.92	0.18	1.72	0.32	0.79	0.32	14.8	70.45	152.5	97.03	7.93
2	Ultisols	Control	2.16	0.16	1.19	0.30	0.53	0.19	5.64	39.53	110.00	74.79	7.99
3	Ultisols	Control	2.64	0.17	1.89	0.25	0.55	0.26	12.14	54.75	120.70	78.03	7.5
1	Ultisols	TSP	3.51	0.15	1.22	0.24	0.81	0.27	36	65	134	91	9.8
2	Ultisols	TSP	2.45	0.17	1.42	0.31	0.67	0.23	8.39	55.29	121.10	84.67	7.3
3	Ultisols	TSP	2.56	0.16	1.95	0.23	0.53	0.25	18.01	45.15	125.20	74.05	7.75
1	Ultisols	Struvite	2.78	0.18	1.58	0.29	0.68	0.26	8.18	58.21	133.7	88.25	7.85
2	Ultisols	Struvite	2.51	0.16	1.61	0.26	0.54	0.18	7.28	42.95	82.91	83.63	6.77
3	Ultisols	Struvite	2.32	0.17	1.92	0.20	0.50	0.28	21.84	43.27	119.00	71.12	6.76
1	Ultisols	BAAG	2.68	0.13	1.43	0.25	0.59	0.2	6.82	43.61	120.9	76.05	8.4
2	Ultisols	BAAG	2.55	0.19	1.67	0.26	0.60	0.19	6.11	43.91	93.27	75.59	6.21
3	Ultisols	BAAG	2.90	0.19	2.01	0.29	0.52	0.23	3.96	53.96	113.20	73.31	7.81
1	Ultisols	BAAT	2.34	0.19	1.56	0.25	0.52	0.17	5.58	37.42	85.10	65.92	6.57
2	Ultisols	BAAT	2.40	0.16	1.41	0.31	0.63	0.26	9.00	54.18	125.60	84.66	7
3	Ultisols	BAAT	2.78	0.18	1.67	0.32	0.53	0.21	6.22	50.22	124.30	70.41	7.28
1	Ultisols	BB	3.03	0.17	1.22	0.37	0.65	0.2	6.41	65.06	120.7	81.75	9.57
2	Ultisols	BB	1.96	0.12	1.29	0.23	0.50	0.16	5.85	30.38	113.70	67.20	6.09
3	Ultisols	BB	2.19	0.18	1.62	0.25	0.60	0.21	8.58	41.62	112.30	68.89	5.61
1	Ultisols	Biochar	2.12	0.16	1.64	0.23	0.55	0.19	10.17	28.25	82.41	86.85	5.17
2	Ultisols	Biochar	2.54	0.17	1.44	0.30	0.61	0.25	7.99	53.77	116.90	85.59	9.34
3	Ultisols	Biochar	2.62	0.18	1.78	0.25	0.52	0.24	7.45	56.55	107.40	71.69	6.97

Appendix 2. Soil fertility and bahiagrass forage nutrient characterization from pastures in south-central Florida.

	Soil fertility				mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	meq/100 g	(%)	(%)	(%)	(%)
Soil	Location	Depth	pHw	pHb	P	K	Mg	Ca	S	B	Zn	Mn	Fe	Cu	CEC	K	Mg	Ca	H
Alfisol	Pineda 1	0-6	6.6	7.75	629	28	107	2294	25	1.02	29.72	3	175	12	14.4	0.5	6.2	79.5	13.9
Alfisol	Pineda 1	6-12	7.2	7.95	668	12	45	2269	21	0.73	14.39	3	150	7	12.1	0.3	3.1	93.4	3.3
Alfisol	Pineda 2	0-6	6.8	7.75	210	33	150	2927	21	1.25	22.96	3	156	7	18.0	0.5	7.0	81.4	11.1
Alfisol	Pineda 2	6-12	7.2	7.95	222	13	119	3188	38	1.15	13.14	1	155	5	17.4	0.2	5.7	91.8	2.3
Alfisol	Riviera	0-6	7.5	7.85	407	126	159	2673	201	1.83	16.41	4	152	7	16.2	2.0	8.2	82.5	7.4
Alfisol	Riviera	6-12	6.6	7.9	46	18	40	1032	66	0.49	1.50	3	65	1	6.3	0.7	5.2	81.4	12.6
Spodosol	Immokalee	0-6	5.4	7.7	163	13	68	681	12	0.24	15.50	4	77	9	6.4	0.5	8.8	53.2	37.5
Spodosol	Immokalee	6-12	5.9	7.95	36	6	26	376	5	0.10	2.75	1	19	2	2.5	0.6	8.5	75.0	16.0
Spodosol	Wabasso	0-6	7.7	7.9	96	17	52	1467	19	0.41	4.22	3	88	3	8.6	0.5	5.0	85.2	9.3
Spodosol	Wabasso	6-12	7.5	7.95	56	11	32	1051	16	0.21	1.91	2	66	2	5.9	0.5	4.4	88.4	6.7
Spodosol	Myakka	0-6	5.9	7.65	77	23	67	1109	7	0.17	4.62	2	60	3	9.0	0.6	6.2	61.9	31.2
Spodosol	Myakka	6-12	5.7	7.6	29	17	27	1076	5	0.12	1.94	1	41	1	8.8	0.5	2.5	60.8	36.2
Alfisol	Pineda 1	soil probe	7.1	7.85	670	22	109	2606	24	0.93	22.19	3	161	9	15.2	0.4	6.0	85.8	7.9
Alfisol	Pineda 2	soil probe	6.7	7.85	161	17	95	1619	45	0.50	11.77	1	122	4	10.1	0.4	7.8	79.9	11.8
Alfisol	Riviera	soil probe	7	7.9	295	19	101	2107	105	0.94	8.17	2	114	3	12.2	0.4	6.9	86.2	6.5
Spodosol	Immokalee	soil probe	6	7.8	151	17	61	920	17	0.23	12.53	2	65	5	6.7	0.6	7.5	68.2	23.7
Spodosol	Wabasso	soil probe	7.5	7.95	118	20	57	1534	25	0.47	4.81	2	78	3	8.6	0.6	5.5	89.2	4.7
Spodosol	Myakka	soil probe	6.4	7.85	92	15	67	1295	7	0.22	4.74	2	51	2	8.3	0.4	6.8	78.3	14.5
	Bahiagrass			N	P	K	Mg	Ca	S	B	Zn	Mn	Fe	Cu					
	Forage			%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm					
Alfisol	Pineda 1			2.5	0.46	0.84	0.53	0.57	0.35	8.92	50.45	36.96	91.32	10.26					
Alfisol	Pineda 2			2.24	0.37	0.8	0.41	0.49	0.34	7.27	41.53	16.23	66.71	8.65					
Alfisol	Riviera			2.07	0.31	0.89	0.27	0.78	0.28	11.74	48.81	17.48	62.72	8.48					
Spodosol	Immokalee			2.69	0.42	0.97	0.49	0.65	0.26	7.67	74.68	45.52	66.79	8.89					
Spodosol	Wabasso			1.56	0.24	0.79	0.21	0.72	0.18	4.52	22.09	12.46	60.94	5.25					
Spodosol	Myakka			1.72	0.35	0.93	0.33	0.66	0.16	6.12	20.76	11.4	61.91	5.66					

Appendix 3. Article published in January 2016 issue of Florida Cattleman Magazine.

Phosphorus fertilization from biosolids and its effect on P retention in pasture soils

Cheryl Mackowiak, NFREC, Soil fertility and water quality

Judicial use of biosolids as a slow-release phosphorus (P) fertilizer can save ranchers fertilization costs, depending on the land's fertilizer requirements and fertilizer prices at the time of application. For example, the slow-release characteristics of class AA biosolids may translate to lower P application rates and/or reduced trips to the pasture to spread fertilizer. This may results in greater environmental protection compared to soluble mineral fertilizers.

Differences in soil type, land-use, management, and water table depth make it challenging to design P application recommendations that maintain a healthy agriculture economy while protecting the state's natural resources, particularly water. To better understand when the land might be a source or sink for soil P, technologies are needed to assess soil P storage capacity in Florida soils. 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). The SPSC performs well, in part, because 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.

The P fertilizer source that one chooses (quick-release minerals vs. slow-release manures, litters, biosolids, etc.) also will impact the SPSC (Rew et al., 2007), with slower releasing products often having less impact on the SPSC than quick-release P fertilizers. The SPSC was even shown to be influenced by differences among biosolids source materials (Fig. 1). Further testing is required to better estimate P release and storage in our Florida soils using different P fertilizer inputs, particularly biosolids.

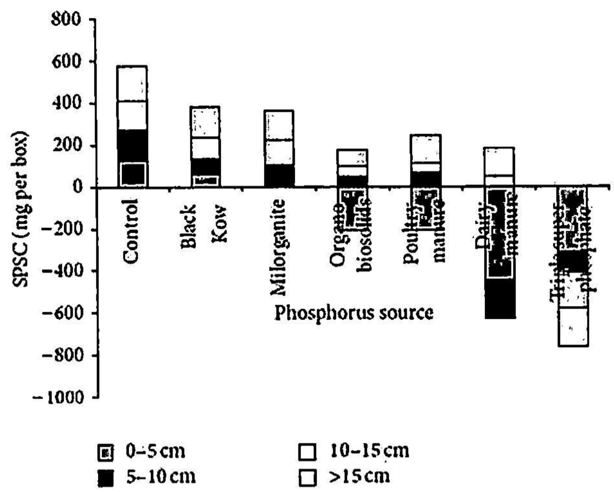


Fig. 1. Relationship between soil P storage capacity (SPSC) and different soil nutrient amendments (equivalent total P additions). Negative SPSC values equate to potential P environmental losses. Taken from Rew et al. (2007).

In cooperation with the Florida Cattlemen and the state legislature, funds will allow us the opportunity to begin determining if different biosolids affect bahiagrass P uptake, soil P retention, and leaching loss. Additionally, we want your assistance in determining where future soil P calibration testing may benefit our stakeholders (Florida Cattlemen), by creating a preliminary assessment of soil P storage capacity (SPSC) at nine Florida ranches, representing three major soil orders (Spodosols, Entisols, and Ultisols). Equally important is our desire to learn more about our stakeholders' needs and expectations.

The following survey has been created to assist us in understanding the scope of soil P fertility concerns and related agricultural challenges. One might call this an example of citizen science, where your input and on-farm support provides advisory feedback into our research and it may also hasten discoveries that benefit the Florida cattle producer. We thank you in advance!

There are three options for taking this survey: 1) type in the NFREC homepage link http://nfrec.ifas.ufl.edu/ and one of the scrolling pictures at the top of the page will take you directly to the electronic survey; 2) email answers to the 10 questions. You do not need to include the questions, as long as the answers are in order; 3) fill out the survey in your magazine and mail, fax, or email sheets to:

Cheryl Mackowiak, NFREC, 155 Research Rd., Quincy, FL 32351, echo13@ufl.edu 850-875-7188 (fax).

References:

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.