

**Final Report for the Florida Department of Agriculture
and Consumer Service Projects:**

**Verification of Interim BMPs for Nitrogen Fertilization of Hayfields
Within the Suwannee River Water Management District**

and

**Confirmation of Interim BMP for Maximum Nitrogen Fertilization of
Hayfields in the Suwannee River Water Management District**

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Executive Summary

In the Lower Suwannee River Basin (LSRB), elevated nitrate concentrations in groundwater have been linked to agricultural production activities. Bermudagrass [*Cynodon dactylon* (L.) Pers.] hay production is a major industry that provides forage for numerous dairy and beef cattle (cow-calf) operations in the basin. Our objective was to determine the environmental impact of applying 100 lb/acre of fertilizer N per growth interval of 'Coastal' bermudagrass, the most commonly grown cultivar for hay production in the LSRB. This N rate was the maximum quantity allowed by an interim measure adopted for hay production in the region by the Florida Department of Agriculture and Consumer Services (FDACS) in 2000. Three 10-acre Coastal bermudagrass hayfields located in northwest Gilchrist County were selected for the project. Within each hayfield, ten suction lysimeters were installed to collect soil water from below the rooting zone (5-ft depth). Also, five wells were installed to monitor nitrate-N levels within the upper water table which ranged from 33 to 44 feet in depth. The hayfields were harvested three times during each of the 2003, 2004, and 2005 warm-growing seasons. Soil water and well water were sampled at 14- and 21-day intervals, respectively, from April 2003 to March 2006. Each hayfield was fertilized with a different fertilizer N source. The designated 'tobacco barn' hayfield (TB_L) received a liquid N source (21% N). The granular N source, ammonium nitrate, was applied to the 'highway' hayfield (HW_G). Both hayfields were fertilized with the 100-lb/acre N rate per growth period. The 'home place' hayfield (HP_{AG}) was fertilized in the spring with anhydrous ammonia at a N rate of 125 lb/acre. This quantity of N was considered to be a 100-lb equivalent rate, allowing for 20% loss of N via surface volatilization. A target N rate of 100 lb/acre was applied at the beginning of each of the second and third growth periods at HP_{AG}, using ammonium nitrate.

The 3-year average dry matter (DM) yield was 4.6, 5.0, and 6.2 ton/acre for the HP_{AG}, HW_G, and TB_L hayfields, respectively. Corresponding average hay yield (12% moisture) was 5.2, 5.7, and 7.0 ton/acre, respectively. Forage N concentration ranged from 1.3 to 1.7% DM. The average annual quantity of N removed in the hay ranged from 145 to 171 lb/acre. Apparent N recovery ranged from 48 to 54% during the 3-year period.

The lowest nitrate-N concentration in soil water below the rooting zone was recorded at TB_L. From April 2003 to March 2006, there were only two sampling dates where nitrate-N levels exceeded 10 mg/L. The highest peak concentration was near 20 mg/L. At HW_G, there were two concentration peaks that exceeded 40 mg/L and one that was near 20 mg/L. At HP_{AG}, there were three major peaks, one exceeding 30 mg/L and two near 20 mg/L. There was no obvious relationship between nitrate-N leaching patterns in soil water and the relatively constant nitrate levels found in well water over the 3-year project. Nitrate-N concentration in well water ranged from 3 to 6 mg/L in all hayfields. The relatively few concentration peaks observed in soil water occurred mostly over short time periods, indicating that the moisture fronts leaving the rooting zone were narrow in thickness. We suggest that as these nitrate-concentrated moisture fronts moved downward toward the water table, they became more diffuse and merged with less concentrated fronts, which caused their effects on well water concentration to be diminished. Based on well water nitrate-N concentration measured over three years, the environmental impact of the 100-lb N rate per growth interval was within acceptable limits of Florida's groundwater standard.

Abbreviations: DM, dry matter; FDACS, Florida Department of Agriculture and Consumer Services; HP_{AG}, home place hayfield with applied N sources, anhydrous ammonia and granular ammonium nitrate; HW_G, highway hayfield with granular N source applied; LSRB, Lower Suwannee River Basin; SRWMD, Suwannee River Water Management District; TB_L, tobacco barn hayfield with liquid N source applied; UFA, Upper Floridan Aquifer;

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BUDGET SUMMARY

Budget summaries for the previous (Contract no. 0006755, project # 4) and current (Contract no. 0009508) projects are presented in Table 1.

INTRODUCTION

The historic Suwannee River originates from the Okefenokee Swamp in southeastern Georgia and flows through northern Florida to the Gulf of Mexico. Basins surrounding the Lower Suwannee River (Fig. 1) have become an environmental concern. In 1999, the Florida Department of Environmental Protection designated the Lower Suwannee River Watershed as 'Category 1', a watershed in greatest need of restoration (Florida Unified Watershed Assessment, 1999). The primary reason for the designation was elevated nitrate levels in the river's surface water and groundwater of the Upper Floridan Aquifer (UFA) beneath the basins surrounding the river. The upper part of the LSRB (i.e., Reach 3 basins) was of particular concern. Over a 3-year period, the average annual load of nitrate-N originating from these basins and reaching the Gulf through the Suwannee River system was 965 Mg or 37% of the total load (SRWMD, 2000, 2002, 2003).

The types of soils and underlying hydrogeology in the LSRB, make the UFA vulnerable to nitrate contamination. This area has high potential recharge to the UFA because surface soils are deep sands that overlie karst limestone. Also, the UFA is relatively close to the land surface and the layers above it are thin and unconfined (Andrews, 1992). These characteristics coupled with relatively high annual rainfall increase the possibility that nitrate originating from commercial fertilizers used on farms, will reach groundwater. The 30-year average annual rainfall (1961-1990)

for eight locations within the Suwannee River area in northern Florida ranged from 52 to 57 inches (National Climatic Data Center, Asheville, NC). The Suwannee River is also vulnerable to nitrate contamination. During low flow, it is supplied with water from the UFA through springs and seeps (Andrews, 1992).

Commercial fertilizers have been identified as a predominant source of nitrate in the LSRB (Katz and DeHan, 1996; Asbury and Oaksford, 1997; Berndt et al., 1998; Maddox et al., 1998). The gross N input from different N sources was estimated for the Suwannee River Water Management District (SRWMD). Commercial fertilizer contributed an average of 42% of the total N input (SRWMD, 1997).

The LSRB is a major bermudagrass forage production area where growers provide hay for local beef (mostly cow-calf) and dairy operations. Bermudagrass hay is produced almost entirely without irrigation. According to 1999 inventory estimates, there were 42,000 milk and 50,000 beef cows in Gilchrist, Lafayette, Levy, and Suwannee Counties (Florida Dep. of Agric. and Consumer Serv., 1999). In 2000, interim BMPs for N fertilization of bermudagrass hayfields within the SRWMD, were adopted by the Florida Department of Agriculture and Consumer Services (FDACS). The primary objective of the following projects were to verify the environmental impact of the interim BMP for the maximum amount of N (100 lb/acre) applied per growth interval. The major N sources applied to hayfields within the SRWMD were used in the evaluation.

MATERIALS AND METHODS

During the first year of the project, about 30 hay producers were visited in Gilchrist, Lafayette, and Suwannee counties to identify a location for the project. Criteria for selection included soil type, topography, N inputs in surrounding areas, bermudagrass cultivar, level of

management, eagerness of producer to cooperate, and other factors. Most of the producers interviewed as well as others within the Suwannee River Water Management District (SRWMD), participated in a survey to determine (i) N sources used most often for hay production, (ii) average number of bermudagrass harvests made per season without irrigation, (iii) range of N fertilization rates applied, and (iv) percentage of producers testing their hay for nutritive value. ‘Coastal’ bermudagrass was the predominant cultivar used for hay production in the SRWMD. Coastal was first introduced in the 1940s and later became a principle cultivar used for hay production in the southern United States. It is a F1 hybrid that is vegetatively propagated (Burton et al., 1988).

Mr. Bill Rush was selected as project cooperator (3219 N.W. 50th Ave, Bell, Florida). He has several well-managed, Coastal bermudagrass hayfields near the Suwannee River in northwest Gilchrist county. Three 10-acre sites were selected for the project, each in the northeast corner of an existing hayfield. The soil at the sites is an excessively drained, Penney fine sand with < 5% slope (thermic, uncoated Typic Quartzipsammments). Permeability is very rapid and surface runoff is slow. The water table varies from 33 to 44 feet below the soil surface, depending on location and rainfall. Rainfall totals for 15-day intervals over the 3-year period are presented for each hayfield (Fig. 2).

The three hayfields were designated as the ‘tobacco barn’ (**TB_L**; 29° 47' 00.139" N, 82° 54' 05.670" W), ‘home place’ (**HP_{AG}**; 29° 47' 13.584" N, 82° 53' 36.374" W), and ‘highway’ (**HW_G**; 29° 47' 40.304" N, 82° 52' 20.946" W) sites. Five monitor wells (53-66 feet in depth) and 10 suction lysimeters (5-ft depth) were installed within each hayfield (Fig.3). Wells were made of 4-inch diameter polyvinyl chloride pipe connected to 20 feet of slotted pipe. The water table averaged 32.9, 37.2, and 43.5 feet below the land surface at TB_L, HP_{AG}, and HW_G, respectively. Suction lysimeters were constructed by attaching a round-bottom, porous ceramic cup (5.1-cm

o.d. x 6-cm length, one bar high flow; Soil Moisture Equipment Corporation, Santa Barbara, CA) to the end of 4.9-cm-o.d. polyvinyl chloride tubing. Two days prior to sampling, any water contained in the lysimeter was evacuated before a suction (40 to 45 kPa) was placed on it. At sampling, suctions were released.

At the beginning of each of three growth periods per year, N was applied at a target rate of 100 lb/acre with the exception of the first growth period at HP_{AG} where anhydrous ammonia was applied at a target N rate of 125 lb/acre (Table 2). This was considered a 100 lb/acre equivalent N rate, assuming an average of 20% loss of N via volatilization of ammonia. In the two succeeding growth cycles at HP_{AG}, a granular N source (ammonium nitrate; 34% N) was applied. The TB_L hayfield received a liquid formulation (21% N) as a sole N source while HW_G received ammonium nitrate. The 21% liquid N source was a commercial formulation made up of ammonium nitrate dissolved in water. To increase uniformity of distribution of granular and liquid fertilizers, one half the N rate was applied across the field in a N-S pattern and one half in an E-W pattern. Phosphorus, potassium, and minor elements were applied using a blended fertilizer (0% N - 10% P₂O₅ - 20% K₂O). The target rate for the fertilizer was 300 lb/acre applied at the start of each growth cycle, for a seasonal total of 900 lb/acre. The actual total amount applied was 900, 895, and 985 lb/acre in 2003, 2004, and 2005, respectively. The total amount of elemental P applied was 39, 39, and 43 lb/acre, respectively. For elemental K, the annual rate was 150, 149, and 164 lb/acre.

In all seasons, the first harvest of bermudagrass occurred between June 21 and July 9. The second harvest took place between August 13 and 29 and the third harvest between October 14 and November 7. During harvest, bale counts and weights were recorded and hay samples were collected for nutrient analyzes. Hay samples were dried at 140° F in a forced-air oven, to determine dry matter concentration. Forage samples were then ground in a Thomas-Wiley mill (1-

mm screen) for N and P determinations. The analysis for N and P concentrations involved a modification of the standard Kjeldahl procedure (Gallaher et al., 1975), followed by semiautomated colorimetry (Hambleton, 1977) using a Technicon Auto Analyzer. Crude protein concentration was calculated as N concentration multiplied by 6.25. Apparent N recovery was computed as: $(\text{N removed in forage} / \text{actual fertilizer N applied}) * 100$. Apparent P recovery was computed as: $(\text{P removed in forage} / \text{actual fertilizer P applied}) * 100$.

Sampling of suction lysimeters occurred at 14-day intervals throughout the year. Monitor wells were sampled every 21 days. Each well had a dedicated pump. The sampling procedure for wells involved purging three times the volume of the water in the well. After purging, the pump was raised to within three feet of the well water surface. An additional 3 gallons of water was purged, then samples were taken. Nitrate plus nitrite N concentration in soil water (lysimeters) and well water was determined by EPA method #353.2 (USEPA, 1983) using a Flow IV, air-segmented, automated spectrophotometer (O-I Analytical, College Station, TX). In this report, it will be referred to as nitrate-N. Phosphorus concentrations in soil water and well water were determined by inductively coupled argon plasmo spectroscopy (EPA method 200.7; USEPA, 1994), utilizing a Model 61-E analyzer (Thermo Jarrell Ash Corporation, Franklin, MA).

RESULTS AND DISCUSSION

Producer Survey

The survey showed that liquid and granular commercial N sources were used most often by hay producers in the SRWMD (Table 3). Two of the 34 producers surveyed used anhydrous ammonia while three applied broiler litter, however other N sources were also applied in their operations. The number of harvests per growing season ranged from two to five. Only two producers reported two harvests per season while two reported five harvests. The most common

response was three and four harvests per season. For commercial sources, the fertilizer N rate ranged from 56 to 97 lb/acre per harvest. Nitrogen rates were generally higher when broiler litter was used. The seasonal N rate for commercial sources ranged from 171 to 388 lb/acre. Most hay producers did not test their hay for nutritive value.

Dry Matter Yield, Forage N, and N Removal

Over the 3-year period, annual dry matter (DM) yield ranged from 3.9 to 6.6 ton/acre for all hayfields (Table 4). Hay yield (12% moisture) ranged from 4.4 to 7.5 ton/acre. The greatest average yield was obtained from the TB_L hayfield. It is unknown whether the higher yield was due to N source or location or both. Hayfields adjacent to TB_L appeared to be more productive than those near the HP_{AG} and HW_G hayfields. Therefore, we suspect there was an effect of location on annual yield. The lowest annual yield of 3.9 ton/acre was recorded at HP_{AG} in 2003. Forage N averaged from 1.2 to 1.7 % DM among hayfields (Table 4). The corresponding range for crude protein concentration was 7.5 to 10.6 % DM. Among all sites and years, N removal ranged from 119 to 171 lb/acre per growing season. The lowest apparent N recovery in harvested forage (36%) was measured at HP_{AG} in 2003, a result of low forage yield. With this value excluded, N recovery ranged from 48 to 54% at all sites over the 3-yr period.

In a 2-yr study conducted in North Central Florida, Ruelke and Prine (1968) reported annual DM yield of 4.8, 5.1, and 6.8 ton/acre for Coastal bermudagrass fertilized with annual N rates of 120, 240, and 480 lb/acre, respectively. They reported a forage N concentration of 1.3%. The study continued for an additional three growing seasons. In the final season, DM yield was 4.0 ton/acre at the 240 lb/acre N rate (Ruelke and Prine, 1971). Average forage N was 2.0% and the apparent recovery of applied N was 65%. In a study involving increasing N fertilization rates applied to 'Tifton 85' bermudagrass, Woodard et al. (2002) reported higher yield, forage N percentage, and apparent N recovery, compared to those of the current project. One of two sites

included in their study was located within five miles of the current project and on a similar soil. Though the study did not include the 100 lb/acre N rate, forage responses were estimated from reported polynomial equations. Over a 2-yr period (1999-2000), the estimated annual DM yield, average forage N concentration, and average apparent N recovery were 8.9 ton/acre, 1.7%, and 83%, respectively. In two separate experiments, Mandebvu et al. (1999) reported that Tifton 85 bermudagrass produced 7 and 34% higher DM yield than Coastal.

Nitrate in Soil Water Below the Rooting Zone

During the 2003-04 cycle, nitrate-N in soil water was maintained at low levels in the TB_L hayfield (Fig. 4a). There was only one sampling date where the average nitrate-N concentration (12 mg/L) exceeded Florida's groundwater standard (10 mg/L). There were eight sampling dates at HW_G and nine at HP_{AG} where the mean concentration exceeded the groundwater standard. This was consistent with the lower yield and N removal measured for these two hayfields in 2003, compared to TB_L. At each of the two sites, these samples dates were associated with two distinct concentration spikes, one occurring in the summer and one in winter.

Over the next two years, average nitrate-N concentration exceeded 10 mg/L on three sampling dates at HP_{AG} (Fig. 4b and 4c). There was a concentration spike in the summer of 2005 reaching near 20 mg/L. Dry matter yield and N removal were greater at HP_{AG} in the 2004 and 2005 growing seasons than the previous season which was probably in part responsible for the lower nitrate-N levels. There were four dates exceeding the standard at HW_G, three of which were involved in a major concentration spike of 44 mg/L in October 2004. Nitrate-N concentrations continued to be low during the latter two 12-mo cycles at TB_L. There was only one sampling date with an average concentration over 10 mg/L.

Over the three growing seasons, the highest nitrate-N peaks (36 to 51 mg/L) occurred during the second and third harvest intervals and were preceded by heavy rainfall (Fig. 2a and 2b).

In northern Florida, leaching events of this magnitude during the wet season (June to September), will likely be unavoidable in some years. Another vulnerable time for leaching to occur is the winter season. Nitrogen remaining in the upper soil profile at the end of the growing season is particularly susceptible to leaching during winter because surface evaporation following rainfall events is less due to cooler temperatures and water usage by the dormant bermudagrass is nil. Therefore, major leaching events in winter can occur following modest amounts of rainfall. Leaching patterns have shown that most of the N remaining in the upper soil profile at the end of the growing season will have moved out of the rooting zone by the start of spring growth (Fig. 4a; Woodard et al., 2001).

To avoid excess residual N, we suggest that the 100-lb N rate be applied no later than September 1 in the LSWB. Hay producers need to be aware of the reduction in growth rate of Coastal bermudagrass that occurs in late summer and fall, so that they will not overestimate the 'effective' length of the final growth interval. The growth rate will decline regardless of adequate water, fertilizer, and temperature. Research has shown that daylength (most important) and solar radiation were factors associated with slower growth of Coastal bermudagrass in late summer and fall (Burton et al., 1998). If fertilization occurs after September 1, the N rate needs to be reduced.

Nitrate in Well Water

At all sites, average nitrate-N concentration in well water gradually increased throughout most of the 2003 growing season (Fig. 5a). The increase was more pronounced at TB_L. However, soil water data from TB_L showed that nitrate-N leaching out of the rooting zone was maintained at low levels throughout the 2003-04 cycle (Fig. 4a). Also, soil water nitrate-N peaks at HP_{AG} and HW_G did not occur until July and August at which time nitrate-N levels in well water were starting to plateau. Therefore, the increase in well water nitrate-N concentration during the 2003 growing season (April- October), was not a consequence of the 2003 fertilizer N applications.

During the 2004-05 and 2005-06 cycles, average nitrate-N levels in well water ranged from 3 to 6 mg/L at all hayfields (Figures 5b and 5c). There were minor fluctuations over time but it was unknown whether they were related to previous nitrate-N patterns in soil water. We suggest that the moisture fronts containing peak nitrate-N concentrations became diffuse and merged with other moisture fronts as they moved downward toward the water table, thereby attenuating their effect on well water.

Phosphorus in Forage, Soil Water, and Well Water

Though phosphorus (P) was not the primary focus of this project, its concentration was measured in forage, soil water, and well water. Over the 3-year period, forage P concentration among hayfields, ranged from 0.13 to 0.18% (Table 5). The greatest annual P removal (3-yr avg: 21 lb/acre) occurred at TB_L. It was the result of greater DM yield rather than greater forage P concentration. Phosphorus removal averaged 15 lb/acre for the other two hayfields. Apparent P recovery ranged from 32 to 58%. For Coastal bermudagrass, Ruelke and Prine (1971) reported an average forage P concentration of 0.34% and an annual P removal of 26 lb/acre.

During the project, soil water P concentration was ≤ 0.03 mg/L. For well water, the average P concentration was 0.04 mg/L. Phosphorus levels among sampling dates ranged from near zero to 0.09 mg/L. The low P concentration in soil water from below the rooting zone suggests that fertilizer P not taken up by the bermudagrass was retained in the upper soil profile. The deep sandy soils within the LSRB generally have the capacity to retain considerable amounts of P. The P retention capacity is mostly associated with moderate to high concentrations of aluminum within the upper soil profile (Woodard et al., 2003). Our results show that the fertilizer P rates used on the hayfields did not impact groundwater quality.

CONCLUSIONS AND RECOMMENDATIONS

The quantity and distribution of rainfall received during a 12-mo cycle, not only affect the amount of soil water moving out of the rooting zone at a given time, but greatly impact bermudagrass production and therefore its capacity to remove nutrients from the soil. With the 100-lb N rate, moisture fronts containing high nitrate-N concentration will at times move below the rooting zone, given the variable nature of rainfall patterns in Florida. However, this study suggests that the environmental impact of this rate will be within the limits of Florida's groundwater standard. Over the 3-yr period, the relatively few high nitrate-N concentration peaks in soil water at five feet below the soil surface, did not appear to have a direct effect on subsequent well water concentrations. Our explanation was that moisture fronts containing the higher nitrate-N concentrations became more diffuse and merged with other less concentrated fronts, before reaching the water table. Nevertheless the leaching events that did occur in some hayfields in some years, could be an indication that the 100-lb N rate is near the upper environmental limit for unirrigated Coastal bermudagrass hayfields in the LSRB. With N rates above this level, increased frequency and magnitude of major leaching events would be expected, thereby increasing the chances of significant environmental impact on groundwater. Also, the greater loss of fertilizer N via leaching below the rooting zone, would undoubtedly increase production costs for hay growers. Furthermore, we caution hay producers not to apply the 100-lb N rate too late in the growing season. This project, as well as other studies, has shown that residual N will be leached out of the rooting zone during the winter season. We recommend that the 100-lb N rate for the last growth interval be applied no later than September 1 in the LSRB.

REFERENCES

- Andrews, W.J. 1992. Reconnaissance of water quality at nine dairy farms in North Florida, 1990-1991. U.S. Geological Survey, Water Res. Invest. 92-4058.
- Asbury, C.E., and E.T. Oaksford. 1997. A comparison of drainage basin nutrient inputs with instream nutrient loads for seven rivers in Georgia and Florida, 1986-90. U. S. Geological Survey, Water Res. Invest. 97-4006.
- Berndt, M.P., H.H. Hatzell, C.A. Crandall, M. Turtora, J.R. Pitman, and E.T. Oaksford. 1998. Water quality in the Georgia-Florida coastal plain, Georgia and Florida, 1992-1996. U. S. Geological Survey, Cir. 1151.
- Burton, G.W., J.E. Hook, J.L. Butler, and R.E. Hellwig. 1988. Effect of temperature, daylength, and solar radiation on production of Coastal bermudagrass. *Agron. J.* 80:557-560.
- Gallaher, R.N., C.O. Weldon, and J.G. Futral. 1975. An aluminum block digester for plant and soil analysis. *Soil Sci. Soc. Amer. Proc.* 39:803-806.
- Hambleton, L.G. 1977. Semiautomated method for simultaneous determination of phosphorus, calcium, and crude protein in animal feeds. *J. Assoc. Off. Anal. Chem.* 60:845-852.
- Florida Department of Agriculture and Consumer Services. 1999. Florida Agricultural Facts, 1999 Edition. FDACS, Tallahassee, FL.
- Florida Department of Environmental Protection. 1996. Ground water classes, standards, and exemptions. Chapter 62-520, Fla. DEP, Tallahassee, Florida.
- Florida United Watershed Assessment. 1999. State of Florida united watershed assessment and watershed restoration priorities. FDEP, Tallahassee, FL.
- Katz, B.G. and R.S. DeHan. 1996. The Suwannee River basin pilot study: Issues for watershed management in Florida. U. S. Geological Survey, Fact Sheet FS-080-96.

- Maddox, G., C. Cospers, P. Craig, R. Copeland, and D. Ouellette. 1998. Ground-water quality and agricultural land use in the Lafayette County very intense study area (VISA). Florida Department of Environment Protection, Div. of Water Facilities, Ambient Monitoring Program, AMR 1998-1.
- Mandebvu, P., J.W. West, G.M. Hill, R.N. Gates, R.D. Hatfield, B.G. Mullinix, A.H. Parks, and A.B. Caudle. 1999. Comparison of Tifton 85 and Coastal bermudagrasses for yield, nutrient traits, intake, and digestion by growing beef steers. *J. Anim. Sci.* 77:1572-1586.
- Ruelke, O.C., and G.M. Prine. 1968. Preliminary evaluation of yield and protein content of six hybrid bermudagrasses, Pensacola bahiagrass, and pangolagrass under three fertilization regimes in North Central Florida. *Soil Crop Sci. Soc. Fla. Proc.* 28:123-129.
- Ruelke, O.C., and G.M. Prine. 1971. Performance of six hybrid bermudagrasses, pangola digitgrass, and pensacola bahiagrass at three fertility levels in North Central Florida. *Soil Crop Sci. Soc. Fla. Proc.* 31:67-71.
- Suwannee River Water Management District. 1997. Surfacewater quality and biological monitoring annual report. Suwannee River Water Management District, Live Oak, FL.
- Suwannee River Water Management District. 2000. Surfacewater quality and biological monitoring annual report. SRWMD, Live Oak, FL.
- Suwannee River Water Management District. 2002. Surfacewater quality and biological annual report. SRWMD, Live Oak, FL.
- Suwannee River Water Management District. 2003. Surfacewater quality and biological annual report. SRWMD, Live Oak, FL.
- United States Environmental Protection Agency. 1983. Methods for chemical analysis of water and wastes. EPA-600/4-79-020. USEPA, Cincinnati, OH.

- U.S. Environmental Protection Agency. 1994. Methods for the determination of metals in environmental samples-supplement 1. EPA-600/R-94/111. U.S. EPA, Washington, DC.
- Woodard, K.R., E.C. French, L.E. Sollenberger, D.A. Graetz, G.M. Prine, B. Macoon, and L.A. Sweat. 2002. Best management practices for nitrogen fertilization of high quality forage grass in the middle Suwannee River area. Final Report. Florida Dep. of Agriculture and Consumer Services, Tallahassee, 44 pp.
- Woodard, K.R., L.E. Sollenberger, L.A. Sweat, S.J. Rymph, V.D. Nair, D.A. Graetz, H.H. Van Horn Jr., and Yongsung Joo. 2003. Degree of phosphorus saturation and leaching potential in soils of the middle Suwannee River area under varying application rates of dairy effluent and cropping systems. Final Report for Project WM740, Florida Department of Environ. Protection, Tallahassee, 47 pp.

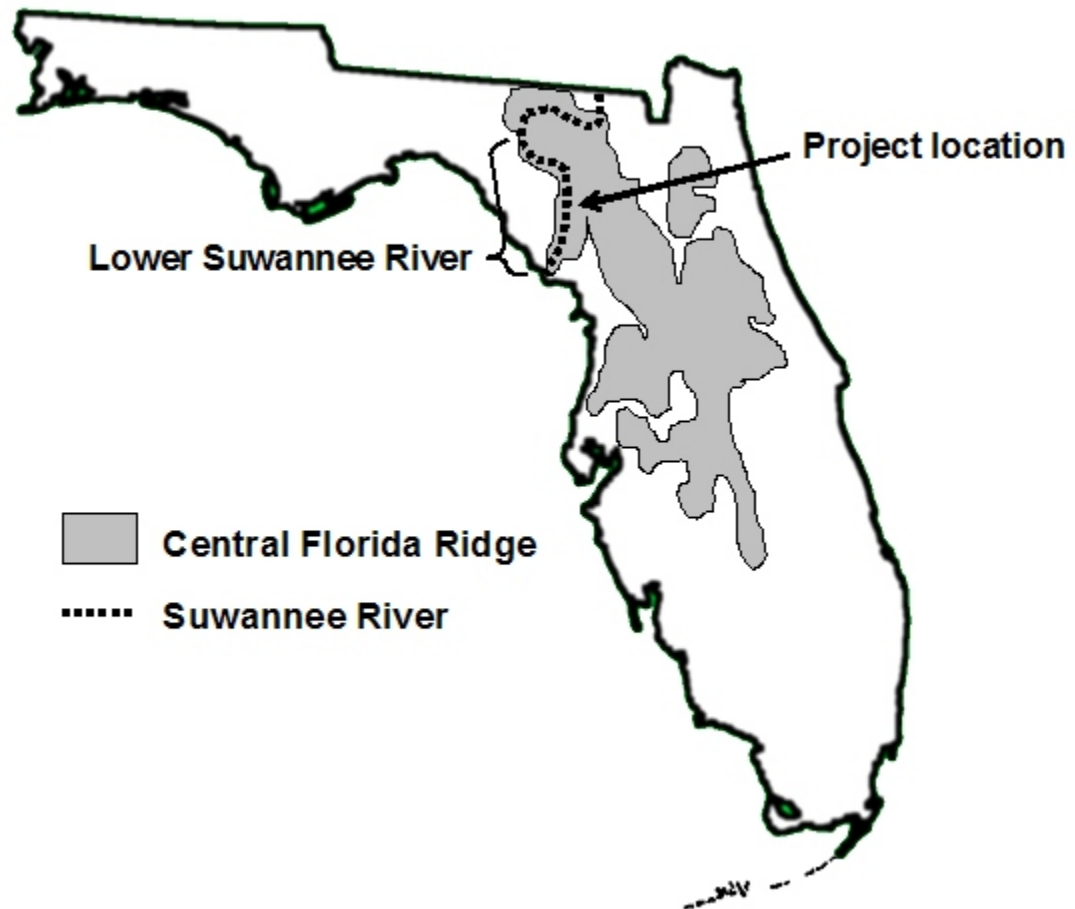


Fig. 1. The Central Ridge region and Suwannee River in Florida. The Central Florida Ridge is dominated by well- to excessively-drained sandy soils.

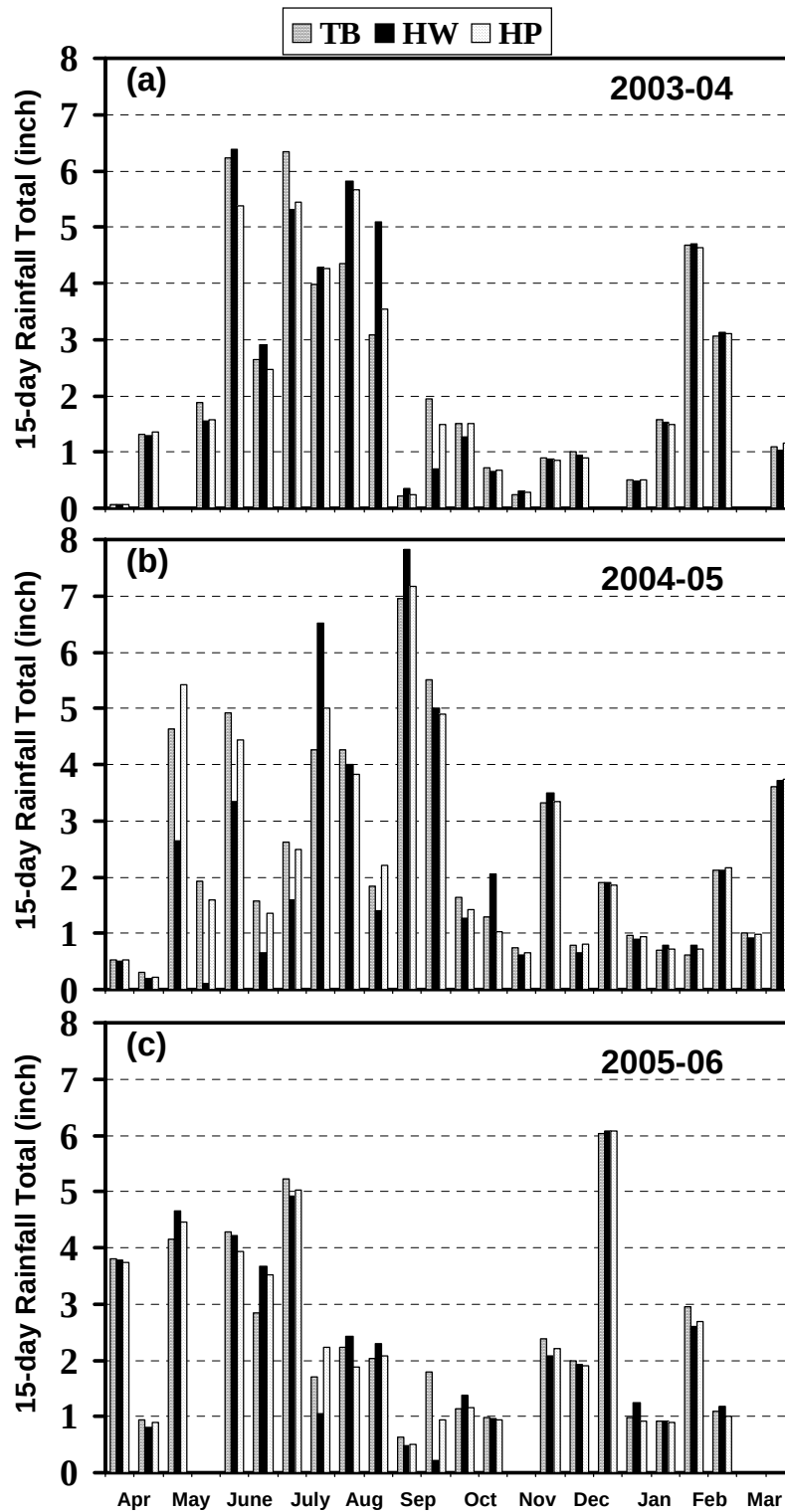


Fig. 2. Rainfall totals for 15-day periods from April 1, 2003 through March 31, 2006 at three Coastal bermudagrass hayfields in northwest Gilchrist County, Florida. Hayfields include the tobacco barn (TB), highway (HW), and home place (HP) sites.

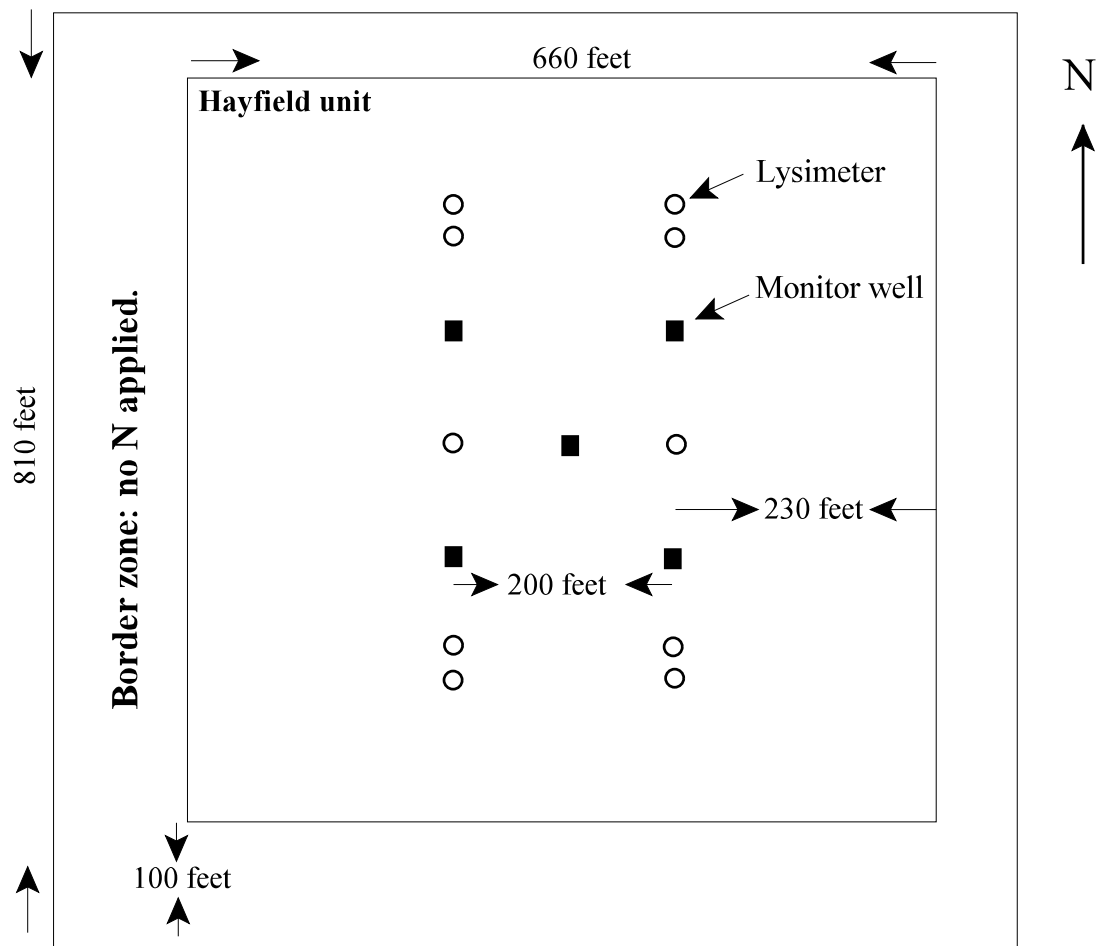


Fig. 3. The layout of a typical 10-acre hayfield showing the placement of suction lysimeters and monitor wells.

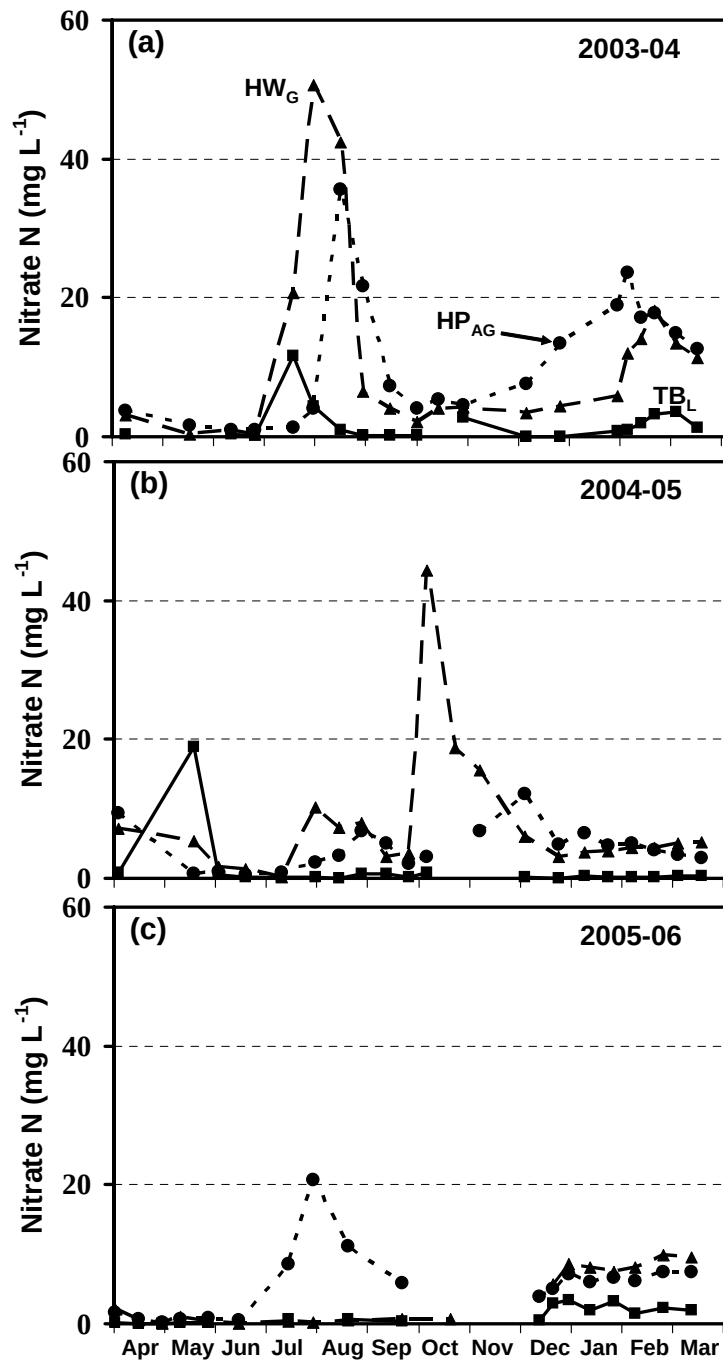


Fig. 4. Nitrate-N concentration in soil water (5-ft depth) from April 2003 through March 2006 in three Coastal bermudagrass hayfields in northwest Gilchrist County, Florida. The hayfields were designated as the highway (HW_G), home place (HP_{AG}), and tobacco barn (TB_L) sites.

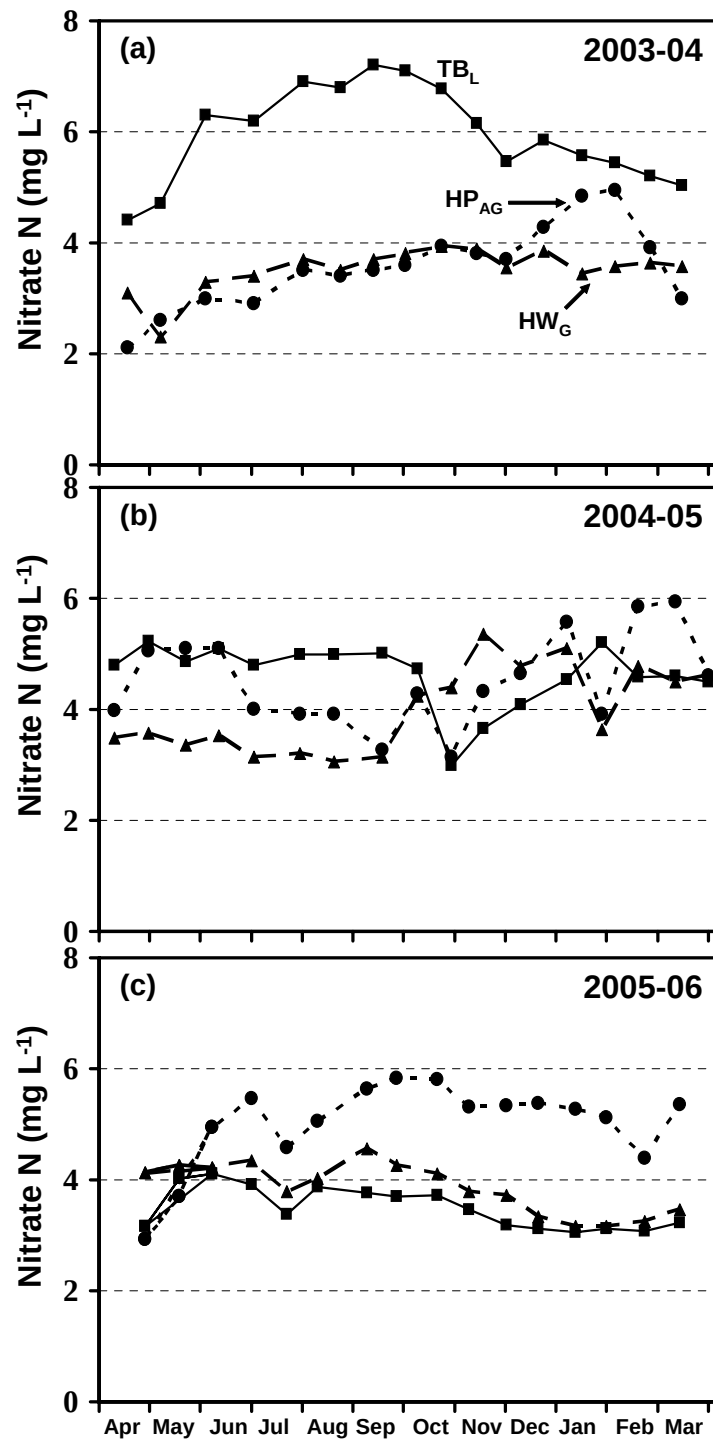


Fig. 5. Nitrate-N concentration in water from monitor wells sampled from April 2003 through March 2006 in three Coastal bermudagrass hayfields in northwest Gilchrist County, Florida. The hayfields were designated as the tobacco barn (TB_L), home place (HP_{AG}), and highway (HW_G) sites.

Table 1. Budget summaries for projects no. 0006755 (2/7/2002 - 2/6/2005) and no. 0009508 (2/7/2005 - 5/6/2006).

Expense category	Funds released	Expenditures	Funds remaining
----- \$ -----			
<u>Project 0006755</u>			
Personnel expense	188,492.55	188,492.55	0.0
Operating expense	106,892.45	106,892.45	0.0
Indirect costs	14,770.00	14,770.00	0.0
Total:	310,155.00	310,155.00	0.0
<u>Project 0009508</u>			
Personnel expense	64,516.39	64,516.39	0.0
Operating expense	25,959.80	25,959.80	0.0
Indirect costs	4,523.81	4,523.92	-0.11
Total:	95,000.00	95,000.11	-0.11

Table 2. Target and actual N rates applied during the 2003, 2004, and 2005 growing seasons on three Coastal bermudagrass hayfields near the Suwannee River in northwest Gilchrist County. The bermudagrass was harvested three times during the growing season.

Hayfield	Target†	Actual N applied		
		2003	2004	2005
		----- lb/acre of N -----		
Tobacco barn	300	307	316	305
Home place	325	332	331	324
Highway	300	303	308	309

† The target rate for the tobacco barn and highway hayfields was 100 lb/acre of N for each of three growth intervals within a warm season, using 21% liquid and granular (ammonium nitrate) N sources, respectively. The annual target rate for the home place hayfield included 125 lb/acre of N from anhydrous ammonia for the first growth period and 100 lb/acre of N from ammonium nitrate for each of the second and third growth periods. Also during each of the three growth periods, each hayfield received 30 lb/acre of P_2O_5 and 60 lb/acre of K_2O via blended fertilizer.

Table 3. Results of a survey to determine nitrogen fertilization practices of bermudagrass hay producers within the Suwannee River Water Management District in Florida†.

Hay producer ID	County	Average N rate per growth cycle	Number of harvests per season	Seasonal N rate	Forage tested	Primary N source (s) used ‡
no.		lb/acre	no.	lb/acre	yes/no	
1	Alachua	85	4	340	Yes	L
2	Alachua	79	4	316	No	G
3	Columbia	97	4	388	No	L
4	Columbia	64	3	192	No	L
5	Dixie	70	2-3	175	No	G
6	Gilchrist	73	3-4	256	No	G
7	Gilchrist	79	3	237	No	G
8	Gilchrist	57	3	171	No	G
9	Gilchrist	91	4	364	No	L, A
10	Gilchrist	56	3	168	Yes	L
11	Gilchrist	89	4	356	No	L, G, A
12	Gilchrist	69	3	207	No	G
13	Gilchrist	72	2-3	180	No	L
14	Gilchrist	84	3	252	No	L
15	Gilchrist	68	3-4	238	Yes	G
16	Gilchrist	64	3	192	No	L
17	Gilchrist	57	3	171	No	G
18	Gilchrist	72	3	216	No	G
19	Lafayette	81	4	324	Yes	L
20	Lafayette	73	3	219	No	G, L
21	Levy	62	4	248	No	G
22	Madison	80	4	320	Yes	G
23	Suwannee	132	3	396	No	L, B§
24	Suwannee	82	5	410	Yes	L, B
25	Suwannee	72	4-5	324	No	L

Table 3. Continued

Producer ID #	County	Average N rate per growth cycle	Number of cuttings per season	Seasonal N rate	Forage tested	Primary N source (s) used ‡
no.		lb/acre	no.	lb/acre	yes/no	
26	Suwannee	74	4	296	No	L,G
27	Suwannee	95	4	380	No	G
28	Suwannee	129	3	387	No	L,G,B
29	Union	64	4	256	No	L
30	Union	78	3	234	No	L
31	Union	94	3-4	329	No	L
32	Union	94	3	282	No	L
33	Union	94	4	376	No	L
34	Union	76	4	304	No	L

† Survey was conducted by K. R. Woodard and L. A. Sweat, Agronomy Department, Univ. of Florida, Gainesville, Florida.

‡ Nitrogen sources included: A, anhydrous ammonia; G, granular; L, liquid; and B, broiler litter.

§ It was assumed that one ton of broiler litter contained 55 lb of N.

Table 4. Annual dry matter (DM) yield, forage N percentage, and N removal of Coastal bermudagrass hayfields in northwest Gilchrist County over three growing seasons.

Hayfield †	DM yield‡				Forage N§				N removal			
	2003	2004	2005	Avg.	2003	2004	2005	Avg.	2003	2004	2005	Avg.
	----- ton/acre -----				----- % DM -----				----- lb/acre -----			
Tobacco barn	6.2	6.6	5.7	6.2	1.2	1.3	1.5	1.3	152	171	165	163
Home place	3.9	5.1	4.9	4.6	1.5	1.6	1.7	1.6	119	164	169	151
Highway	4.6	4.7	5.7	5.0	1.6	1.6	1.4	1.5	145	152	161	153

† The target rate for the tobacco barn and highway hayfields was 100 lb/acre of N for each of three growth intervals within a warm season, using 21% liquid and granular (ammonium nitrate) N sources, respectively. The annual target rate for the home place hayfield included 125 lb/acre of N from anhydrous ammonia for the first growth period and 100 lb/acre of N from ammonium nitrate for each of the second and third growth periods.

‡ Dry matter yield was based on an oven drying temperature of 140° F.

§ Annual forage N means were weighted according to DM yield measured for each harvest within a season.

Table 5. Forage phosphorus (P) percentage in dry matter (DM), P removal, and apparent P recovery for three Coastal bermudagrass hayfields in northwest Gilchrist County over a three growing seasons.

Hayfield †	Forage P‡				P removal				Apparent P recovery§			
	2003	2004	2005	Avg.	2003	2004	2005	Avg.	2003	2004	2005	Avg.
	----- % DM -----				----- lb/acre -----				----- % -----			
Tobacco barn	0.18	0.15	0.16	0.16	23	21	19	21	58	53	43	51
Home place	0.18	0.15	0.17	0.17	14	15	16	15	36	39	38	38
Highway	0.15	0.13	0.15	0.14	14	13	17	15	36	32	40	36

† A total of 39, 39, and 43 lb/acre of elemental P was applied to each hayfield during 2003, 2004, and 2005, respectively. The target rate for the tobacco barn and highway hayfields was 100 lb/acre of N for each of three growth intervals within a warm season, using 21% liquid and granular (ammonium nitrate) N sources, respectively. The annual target rate for the home place hayfield included 125 lb/acre of N from anhydrous ammonia for the first growth period and 100 lb/acre of N from ammonium nitrate for each of the second and third growth periods.

‡ Forage P means are weighted according to DM yield measured for each harvest within a season.

§ Apparent P recovery was computed as: (P removed in forage / actual fertilizer P applied) *100.