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Plant Materials Adaptation Study

Final Report

Belleview - Perry Sprayfield

Plant Materials Center
Brooksville, Florida

BELLEVIEW - PERRY SPRAYFIELD
PLANT MATERIALS ADAPTATION STUDY

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U. S. Department of Agriculture
Natural Resources Conservation Service
Plant Materials Center
Brooksville, Florida

In Cooperation With

Marion Soil and Water Conservation District

and

The City of Ocala, FL

April 2000

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PMC Crew Harvesting Mott Dwarf Elephantgrass at Belleview Sprayfield

INTRODUCTION

The state of Florida is undergoing a period of tremendous urban expansion. This has meant city managers must find methods of disposing of additional quantities of municipal wastewater. The practice of disposing of secondary municipal wastewater by land application (referred to as a sprayfield) is expanding rapidly. Initially, it was thought that this practice would provide great agronomic benefits, while disposing of thousands of gallons of domestic wastewater in a manner which would sustain groundwater quality. Instead, researchers and sprayfield managers have been faced with unique problems and challenges, and are searching for plant materials that can help to solve these problems.

Extremely large volumes of effluent water continuously applied cause the most serious problems associated with sprayfields. Generally, this effluent water has been purified until it contains only low levels of nutrients beneficial for plant growth. However, nondesirable minerals such as sodium, boron and magnesium are present, and can build up to toxic levels or leach into the groundwater if they are not removed by living filters. Effluent irrigation is often applied at a rate that rapidly leaches nutrients beyond rooting depth. This problem is further compounded by the nature of the sandy soils on which most sprayfields in Florida are located. Coarse soils do have the ability to filter large quantities of water without ponding. However, sorption capacity is minimal, creating an environment low in fertility. These factors also cause serious problems with weed competition.

The purpose of this study is to identify plant materials that are adaptable to the sprayfield environment. They must be quick to establish, able to tolerate excessive irrigation and low fertility, and competitive with invading weed species. These plant materials must provide maximum uptake of effluent nutrients and be commercially marketable as well. Because sprayfields need to stay in operation throughout the year, selected species should also provide water uptake singly or in rotation with other species throughout the entire year.

LITERATURE REVIEW

The primary goal of a sprayfield is to recycle large volumes of wastewater and associated nutrients without negatively impacting the environment, especially in terms of water quality. A secondary goal is to produce commercially marketable crops that use the maximum amount of effluent water and nutrients (Roberts and Vidak, 1994). The use of sprayfields to process secondary effluent is a relatively new practice for most municipalities in Florida, and associated research is minimal. High rainfall, a long growing season, and highly leachable coarse soils make sprayfield operations in Florida unique from those in other areas. Also, domestic water use may actually increase in Florida during the winter months, due to tourism and return of winter residents. Sprayfields must continue disposing of effluent wastewater during the winter months, even though many crop and forage species are dormant at this time. Forage grasses such as Coastal bermudagrass, used in rotation with winter rye, are reported as being among the most desirable sprayfield crops, because they can tolerate excessive water application and have high nutrient use (Vidak and Roberts, 1991; Kardos and Sopper, 1973). In addition, they require less management and fewer inputs than more intensive row crop rotations.

Since the inception of sprayfields, plant managers have found ways to decrease the amount of nitrogen in effluent water. This has created an environment low in fertility. Also, many nutrients are quickly leached past the rooting zone by heavy effluent application rates, and excessive rainfall. Results from research conducted at a Tallahassee, Florida sprayfield showed that application of nitrogen, potassium, sulfur and trace minerals is necessary for maintaining crop production. Calcium ions from effluent water appear to displace other nutrients, further enhancing deficiencies, especially in the micronutrients. However crops could not be managed according to standard production guidelines because of greater potential for nutrient leaching (Vidak and Roberts, 1991; Overman, 1979). The phosphorus in the effluent water appears to be of adequate quantity to meet crop needs, being sorbed to soil particles within the rooting zone (Flaig *et al* 1986).

Although sprayfields can apply almost unlimited amounts of water to a field, application rates are limited by the crop's ability to efficiently recover nitrogen. Research results using ryegrass, bermudagrass and other forages, show best nitrogen recovery efficiency occurred at approximately 2 inches per week, applied at an intensity of no greater than 0.5 in/hr (Overman, 1979; Overman and Ku, 1976, Kardos and Sopper, 1973). Another management practice which can be employed is to withhold water at certain stages of crop growth in order to encourage the development of more extensive rooting systems, thus promoting greater nutrient uptake (Roberts and Vidak, 1994). Due to high irrigation and precipitation, weeds flourish in the sprayfield environment. Despite earlier thoughts to the contrary, results of recent research confirm that fertility and weed management is necessary for maximum efficiency of a sprayfield operation.

PREVIOUS WORK BY THE FLORIDA PMC

During 1990 through 1993, the City of Ocala provided the FLPMC a plant adaptation study site at the Pine Oaks Golf Course effluent disposal site. A large variety of grasses and forbs were planted and evaluated for performance and nutrient uptake. However, high-pressure rotating guns were used to water this site, and application rates were not consistent. In 1993, a study site was developed at the Perry Reuse facility, near Belleview (henceforth referred to as the Belleview Sprayfield). This site is watered by an overhead sprinkler system, which is controlled independently from the main center pivot sprinkler systems. In 1994, a broad range of grasses and forbs were evaluated. Results from this early work were analyzed. Species that showed the greatest capacity for adaptation and nutrient removal, as well as having high commercial value, were selected for more intensive study.

MATERIALS AND METHODS

In 1995, all plant materials from previous studies were removed from the research site at the Belleview Sprayfield, in preparation for establishment of the current study in 1996. Millet was planted on the entire field in the summer of 1995, to take up any residual nitrogen left from legume plots. The millet residue was removed from the field in the fall of 1995.

The plant materials selected for this study were 'Coastal' bermudagrass (*Cynodon dactylon*);'Pensacola' bahiagrass (*Paspalum notatum*); Eastern gamagrass (*Tripsacum dactyloides*), FLPMC accession no. 9055975; 'Alamo' switchgrass (*Panicum virgatum*); Defuniak source switchgrass (*Panicum virgatum*), PMC accession no. 9059616; 'Floralta' limpograss (*Hermarthria altissima*); 'Mott' dwarf elephantgrass (*Pennisetum purpureum*); and 'Sharp' marshhay cordgrass (*Spartina patens*). 'Florigraze' perennial peanut (*Arachis glabrata*) was also included in this study because of its ability to fix nitrogen. Since the sprayfield environment is actually low in nitrogen, a sustainable, slow release form of nitrogen such as that produced by perennial peanut may be preferable to applying chemical fertilizers. Bermudagrass and bahiagrass were included as standards, since they are so widely used in Florida. Due to the climate and the predominantly livestock-based local agriculture economy, only forage grasses and legumes were used in this study.

The climate at the research site is warm and humid, with 55 inches average annual precipitation and an average growing season of 260 days. Soils are predominately sand and sandy loam (Candler sand). The water table is six feet deep or more. Soil samples were taken before initial establishment, and once a year in each plot at 0-6", 6-12", 12-24", 24-36" increments. Samples were sent to a soil testing facility to determine presence of NO3-N, NH4-N, P, K, Ca, Mg, Fe, Mn, B, Cu, Zn, Na and Al. Soil samples were analyzed by Micro-Macro International, Inc. in Athens, GA. Tests were conducted according to the procedures outlined in "Handbook on Reference Methods for Soil Analysis", 1992, by the Soil and Plant Analysis Council, Inc., Athens, GA. Mehlich No. 3 was the extractant used for the mineral elements, according to Mehlich (1981).

Plants were pre-established at the FLPMC so that all species would be placed in the field at the same stage of growth. All species were established in six-inch deep cone tubeling trays, and placed in the PMC shadehouse (except for gamagrass, which was established in six-inch pots). Both switchgrasses and bahiagrass were established in the conetainers using seed. The other six species were established in conetainers from plant propagules.

In April of 1996, seven grass species were planted in the field. There were several killing frosts in the winter of '95-'96. This caused the plant materials in the FLPMC shadehouse to become dormant. The peanut and 'Defuniak Source' switchgrass had not recovered sufficiently for planting in April. Therefore, these two species were not planted in the field until July of 1996. Weeds were controlled in all plots in 1996 and 1997, by hand weeding and with chemical herbicides.

The Sharp marshhay cordgrass had not established well in the field by 1997, so maidencane (*Panicum hemitomon*), PMC accession no. 421993, was established on half of the Sharp plots in the summer of 1997, to better utilize the space. Although maidencane will not be analyzed with the other species, information will be gathered on the adaptability of this wetland native grass species to a sprayfield environment. The maidencane was established by placing vegetative material in shallow trenches.

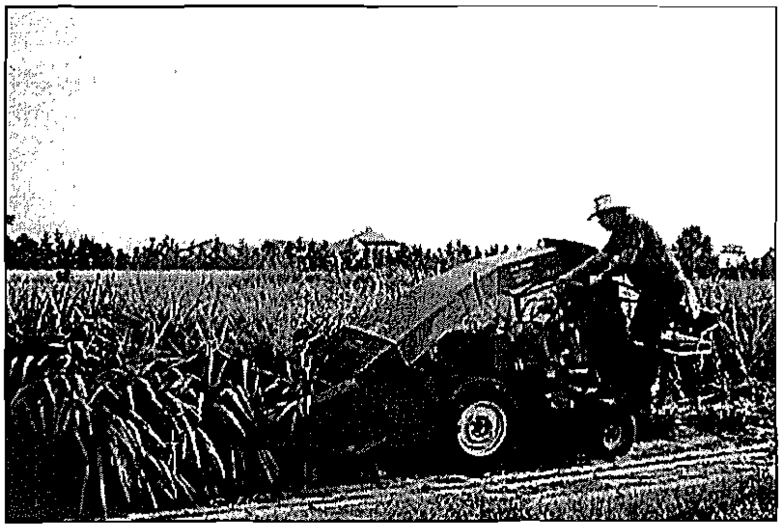
Plots were 34'x 34' in size, in a randomized complete block design with four reps per treatment (except Sharp and maidencane plots, which were 14'x 34'). Effluent water was applied approximately three times a week, depending on rainfall. The management goal was to irrigate the site throughout the growing season so that combined rainfall and irrigation was approximately 2 inches per week.

Tissue samples were taken approximately every 45 days beginning in late April or early May from all species except switchgrass. Switchgrasses were clipped more often in an effort to slow growing point extension in the stems. Once the growing point extended beyond 14 inches, clipping ceased. Clipping below the growth point removes too much leaf tissue, which stresses the plant and rapidly decreases stand density. Tissue samples were taken with a Carter forage plot harvester.

Tissue samples were weighed wet in the field. Grab samples were used to determine percent moisture, then ground in preparation for testing. Tissue testing (TKN, P, K, Ca, Mg, Na, Fe, Zn, Al, B, and Cu) was also conducted by Micro-Macro International, Inc. Tests were conducted according to procedures presented by Jones (1977). All material from plots was clipped and removed at each sampling date.

Clipping heights were 2-4 inches for peanut, bahiagrass and bermudagrass; 6 inches for limpograss and maidencane, 8 inches for marshhay cordgrass, eastern gamagrass, switchgrass, and dwarf elephant grass. Switchgrass clipping heights increased with the extension of the growing point to 14 inches. The length of this study was four years, including establishment year.

The MSTATC (Michigan State Univ., 1988) statistical package was used to conduct analysis of variance on dry matter yields of each species. Comparisons were made between means using Tukey's Honestly Significantly Different test at a significance level of $P<0.05$.



Harvesting Mott Dwarf Elephantgrass

RESULTS AND DISCUSSION

ESTABLISHMENT AND MAINTENANCE

All grass species except Sharp marshhay cordgrass established well in 1996. The perennial peanut was slower to establish and did not provide complete canopy cover in the plots until the 1997 growing season. Because the switchgrasses and gamagrass have a bunch-type growth habit, weeds tend to grow between the plants, even after they are well established. Weed competition was fairly severe in all species in 1996. Weeds were controlled through an intensive hand weeding and herbicide application program. By the 1997 growing season, most species except Sharp were established well enough to suppress weed competition. However, herbicide weed control was still conducted on most plots, to suppress weeds completely. Mott dwarf elephantgrass had developed such a dense canopy by the 1997 growing season, that all weed competition was suppressed, negating the use of chemical herbicides.

Plants were allowed to grow without clipping in 1996. Winter frosts caused all species to go dormant during the winter. In March of 1997 all plots were mowed to the designated height. Excess residue was then removed by burning. Defuniak switchgrass, peanut and Sharp plots did not have enough residue to require burning. Plots were harvested during the 1997 growing season as outlined above.

The winter of 1998 was very warm, and most species at the Belleview site did not go completely dormant. Excess top growth was clipped and physically removed in February of 1998. Plots weren't burned because there was too much green material, which would have inhibited burning.

Winter frosts caused plants to go dormant in the winter of 1999. Plots were mowed and then burned in February of 1999 to remove dead material. Peanut, bahia and maidencane plots did not have enough dormant material to burn.

PRECIPITATION AND IRRIGATION

The quantity of effluent water and precipitation the study site received monthly during the 1997 growing season is shown in Table 1. The primary growing season for most species began in March and ended in October. The irrigation meter was read every two to three weeks, so application rates were averaged across the given time period. The goal was for the study site to receive a total of 2 inches of moisture weekly, through both irrigation and precipitation. Due to the coarse nature of the soils at this site, applying less than two inches of water appeared to cause plants to undergo drought stress.

Table 2 shows the irrigation and precipitation amounts received on the study site in 1998. The irrigation amounts applied to the study site were not consistent, due to change of personnel operating the system. During several months in 1998, more irrigation water was applied to the plants than is recommended for efficient use. This also occurred in 1999 (Table 3).

Table 1. Inches of rainfall and irrigation received per month at the Belleview study site in 1997.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
							Inches					
Irr.	0.00	2.64	4.80	7.00	7.20	4.82	12.02	7.44	7.36	5.52	0	0
Precip.	2.00	0	2.75	3.75	2.70	4.90	3.50	3.50	1.75	0	4.50	10.50
Total	2.00	2.64	7.55	10.75	9.90	9.72	15.52	10.94	9.11	5.52	4.50	10.50

Table 2. Inches of rainfall and irrigation received per month at the Belleview study site in 1998.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
							Inches					
Irr.	0	0	0.06	9.69	10.00	5.65	3.90	27.25	5.93	10.40	10.00	10.40
Precip.	4.00	8.75	3.25	1.50	1.80*	*	2.00*	4.25	18.50	1.50	2.00	1.25
Total	4.00	8.75	3.31	11.19	12.00	5.65	5.90	31.50	24.43	11.90	12.00	11.60

*Missing rainfall data

Table 3. Inches of rainfall and irrigation received per month through Oct. 7 at the Belleview study site in 1999.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
							Inches					
Irr.	6.63	7.30	13.42	16.23	7.96	9.78	18.95	9.11	8.81	2.06		
Precip.	6.50	0.50	2.00	1.25	1.75	9.50	3.00	0.75*	*	*		
Total	13.13	7.80	15.42	17.48	9.71	19.28	21.95	9.86	8.81	2.06		

*Missing rainfall data

SOIL SAMPLING

Initial soil samples were taken in 1993, 1994 and 1996 from the study site. In Appendix A, Table 9 displays the ranges of nutrients in the soil in reference to plant needs. When the study began in 1996, soil test results showed that phosphorous was in the high range, and potassium was in the low range for plant requirements (Table 10). The micronutrients calcium and magnesium were also in the low range (Table 11). Nitrate levels were also tested, and were fairly high in the lower profiles. However, nitrates are highly susceptible to leaching in coarse soils, and fluctuate too rapidly to be accurately followed through soil testing. The pH levels were very strongly acid in 1997 (Table 13). By early 1999, pH had climbed to the moderate or even mildly acidic level. Greatest change occurred on the surface, however, pH increased at all levels down to 36".

Soil samples were taken from four depths from each plot in 1997, 1998 and 1999, at the beginning of the growing season. Results are shown in Tables 14 through 24 in Appendix A. Nutrient levels in 1999 are compared to 1996 levels in Tables 25 and 26 to track nutrient loading trends. Overall, P increased or stayed level in the upper 12 inches under most species. Some species may have been extracting P from below 12 inches. Effluent water appeared to contain enough K to meet plant needs, as soil levels increased over three years. Excessive irrigation may have caused leaching of K in 1998 and 1999.

Micronutrient levels were adequate to meet plant needs during the three years of the study. Levels of Ca increased two to three times over the three years, and are probably responsible for increasing pH. If Ca levels continue to increase at present levels, this element may begin to interfere with uptake of other nutrients. Levels of Mg generally doubled or tripled under most species but were still in the low range. Iron levels were slightly reduced, while B and Cu levels were substantially reduced. In the long term, it may be necessary to supplement these nutrients if deficiencies are observed in the crops. Zinc levels increased substantially, as did Na, while Al levels decreased slightly. However, Al levels were excessively high at the beginning of the study, so the decrease was minimal.

TISSUE SAMPLING

Total Dry Matter Production

Table 4. Average lbs./ac. total dry matter production for nine forage species grown at the Belleview sprayfield in 1997-1999.

	Dry Matter (lbs./ac.)			
Species	**1997**	**1998**	**1999**	**Average**
Mott	10,489*a**	13,866*ab*	18,156*b*	14,170*a*
Bermuda	8,785*b*	14,247*a*	22,860*a*	15,297*a*
Limpo	7,812*b*	13,311*ab*	12,284*cd*	11,136*b*
Peanut	5,072*c*	12,626*ab*	13,734*cd*	10,477*bc*
Bahia	5,356*c*	10,597*bc*	15,369*bc*	10,441*bc*
Gama	5,356*c*	8,358*c*	10,428*d*	8,047*de*
Alamo	2,492*d*	12,249*ab*	11,295*cd*	8,679*cd*
Defuniak	2,144*de*	7,371*c*	5,923*e*	5,146*f*
Sharp	786*e*	7,305*c*	9,955*de*	6,015*ef*
Mean	5,365	11,103	13,087	9,934

*Total DM amounts followed by the same letter are not significantly different according to Tukey's HSD at $P<0.05$.

Total dry matter production for 1997 through 1999 is shown in Table 4. Mott dwarf elephantgrass had highest dry matter production the first year after establishment. By the second and especially the third year, bermudagrass surpassed Mott in total production. Limpograss performed comparably to bermudagrass the first two years, but production diminished in 1999. The Floragraze perennial peanut was slow to establish. Low soil pH in the first year no doubt contributed to lower initial production. As pH levels increased, peanut production increased substantially. More favorable soil conditions and increased moisture also allowed bahiagrass production to increase substantially by 1999. Two of the eastern gamagrass plots suffered high plant losses for unknown reasons. For comparison, dry matter production based on averages of the two best replicates was 10,000 lbs./ac. in 1998 and 11,800 lbs./ac. in 1999, a difference of almost 1,500 lbs./ac. Other strains of gamagrass may have had higher forage production at the Belleview site, and the species warrants further testing.

Switchgrass tended to have relatively high production early in the season. However, by early June Alamo plants had extended their growth points beyond the height at which they could be safely clipped. The Florida ecotype from Defuniak Springs had lower production than Alamo, and a smaller growth habit. It could usually be clipped until July. In 1998 and 1999, both switchgrasses were sampled in October, at the last clipping date. Although the material was dormant and of very low quality, this allowed total yearly production to be calculated. Unless it can be used in a rotation to provide early spring forage, switchgrass does not appear to be adaptable to a sprayfield environment.

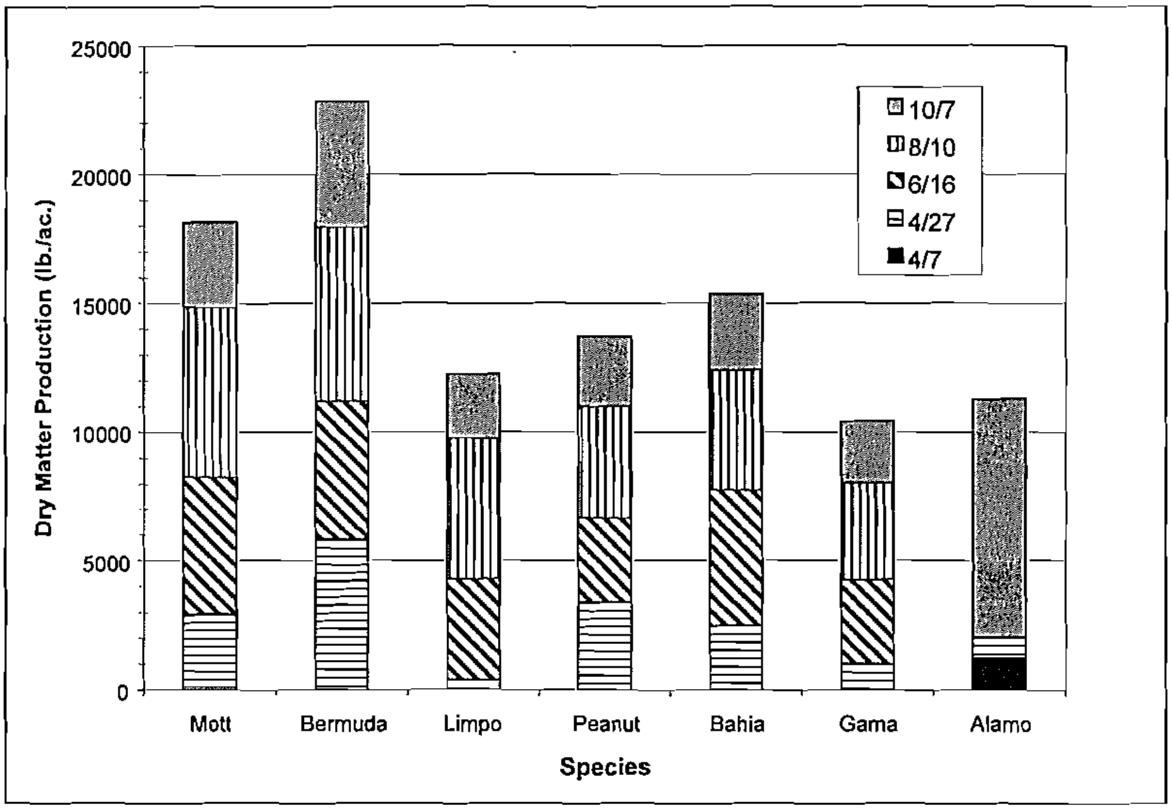


Figure 1. Average dry matter production per clipping date in 1999 for 7 species grown at the Belleview sprayfield.

Dry matter production per clipping date in 1999 is shown in Figure 1. Alamo had the highest production in March, compared to the other six species. By mid April, most of the other species had rapidly surpassed Alamo. Although Alamo continued on to produce almost 5 ton of dry matter during the growing season, it was of very poor quality by Oct., and not suitable for haying or grazing. Switchgrass is highly palatable to livestock when the forage is young. If temperatures remain above freezing, switchgrass will grow several inches high during the winter months. This species may have potential for a niche winter forage crop. However, it is not as cold tolerant as winter rye, which will continue growing at temperatures near freezing.

The primary growing season for the other six species in the study occurred between mid April and the end of September. Mott had greatest production during June, July and August, while Bermudagrass had a longer growing season, with high production occurring from April through September. Obtaining year round production on a sprayfield would require planting a mixture of cool and warm season crops. Of the species used in this study, bermudagrass, bahiagrass and peanut best lend themselves to being interseeded with a winter cover crop such as rye. Mott has coarse, cane-like stems and produces a very dense ground cover that would not easily host a winter cover crop.

Macro and Micro Nutrient Uptake

Total pounds per acre of nitrogen taken up by the nine species in 1997 through 1999 are shown in Table 5. Mott dwarf elephantgrass far surpassed bermudagrass in total N uptake, despite higher dry matter production by bermudagrass. An excessive amount of effluent water was applied in 1999. Mott was able to capture almost twice as much N (730 lbs. /ac.) out of this water compared to bermudagrass, which took up 406 lbs./ac. Mott consistently displayed substantially higher N use compared to all other species during the three years of the study. Limpograss, perennial peanut and bahiagrass had similar uptake, with gamagrass N uptake being only slightly less.

Table 5. Pounds per acre of total N, harvested in nine species grown at the Belleview sprayfield 1997 - 1999.

	Total N (lbs./ac.)			
Species	**1997**	**1998**	**1999**	**Average**
Mott	270*a**	546*a*	730*a*	515*a*
Bermuda	219*b*	364*b*	406*b*	329*b*
Limpo	187*b*	343*bc*	236*cd*	256*c*
Peanut	125*c*	326*bcd*	297*bc*	249*c*
Bahia	134*c*	248*cde*	254*cd*	212*cd*
Gama	135*c*	220*de*	192*cde*	182*de*
Alamo	68*d*	223*de*	122*e*	138*ef*
Defuniak	44*de*	161*e*	102*e*	102*f*
Sharp	20*e*	158*e*	158*de*	112*f*
Mean	134	287	273	233

*Amounts followed by the same letter are not significantly different according to Tukey's HSD at P<0.05.

Mott had substantially higher P uptake than any of other species (Table 6). Bermudagrass had significantly lower P uptake than Mott despite having higher dry matter production in 1998 and 1999. Uptake of P by limpograss, peanut, and bahiagrass was similar, with gamagrass uptake being only slightly less.

Table 6. Pounds per acre of P uptake by nine species grown at the Belleview sprayfield in 1997 through 1999.

	P (lbs./ac.)			
Species	**1997**	**1998**	**1999**	**Average**
Mott	52	51	80	61*a**
Bermuda	28	36	58	41*b*
Limpo	27	36	41	35*bc*
Peanut	19	38	46	34*bc*
Bahia	18	26	44	29*cd*
Gama	17	24	35	25*de*
Alamo	9	23	22	18*ef*
Defuniak	7	21	24	17*f*
Sharp	2	20	33	18*ef*
Mean	20	30	42	31

*Amounts followed by the same letter are not significantly different according to Tukey's HSD at $P<0.05$.

Of the nine species, Mott also had substantially greater potassium use than any other species (Table 7). Despite this high use by Mott, soil tests indicate that the effluent water was supplying adequate K to meet plant needs (Table 23, Appendix A). Uptake of K in the other eight species followed similar trends as for P uptake.

Table 7. Pounds per acre of K uptake by nine species grown at the Belleview sprayfield in 1997 through 1999.

	K (lbs./ac.)			
Species	**1997**	**1998**	**1999**	**Average**
Mott	495	485	734	571
Bermuda	168	212	399	260
Limpo	176	232	237	215
Peanut	120	238	299	219
Bahia	106	145	241	164
Gama	95	125	194	138
Alamo	61	129	106	99
Defuniak	31	92	97	73
Sharp	12	109	159	93

Three-year average uptake of other micronutrients by the nine species is shown in Table 8. Perennial peanut had highest Ca, Mg, Fe and B use of all the species. Effluent water appeared to have supplied adequate amounts of these nutrients; however, B may become deficient in peanut plots over time. Sharp marshhay cordgrass had greatest Na uptake (45.1 lbs./ac.). This is to be expected since marshhay cordgrass grows in coastal areas where it is adapted to being inundated by saltwater. It is somewhat surprising that gamagrass had the second highest uptake of Na (31.6 lbs./ac.). This would indicate that gamagrass has fair tolerance of saline soils.

Table 8. Three year average pounds per acre of uptake of micronutrients by nine species grown at the Belleview sprayfield (total S averages from 1998 and 1999 only).

	(lbs./ac.)								
Species	**Ca**	**Mg**	**Cu**	**Fe**	**B**	**Zn**	**Na**	**Al**	**S**
Mott	69	28	0.09	1.82	0.09	0.36	11.7	2.09	31
Bermuda	63	20	0.04	2.31	0.07	0.32	10.4	6.29	28
Limpo	32	26	0.05	0.90	0.07	0.24	18.4	1.20	20
Peanut	165	58	0.04	2.62	0.46	0.28	8.3	7.75	21
Bahia	49	25	0.03	1.56	0.08	0.26	8.9	3.64	20
Gama	25	12	0.04	0.80	0.09	0.18	31.6	1.02	15
Alamo	28	18	0.02	0.80	0.04	0.13	9.2	0.76	15
Defuniak	14	9	0.02	0.58	0.04	0.10	9.8	0.65	9
Sharp	28	13	0.02	0.58	0.03	0.11	45.1	0.75	13

Maidencane plots were sampled with the other species during the 1999 growing season. Total dry matter production was.10,870 lbs./ac., which was similar to gamagrass. However, total N uptake was 237 lbs./ac., which was closer to the performance for bahiagrass. Uptake of P and K was 34 and 233 lbs./ac. respectively. Uptake of the micronutrients was very similar to that of gamagrass.

CONCLUSIONS

Of the nine species studied at the Belleview sprayfield, Mott dwarf elephantgrass displayed the greatest macronutrient uptake. Bermudagrass had the highest average forage production of the nine species, however, Mott far surpassed bermudagrass in N, P and K uptake. Limpograss, perennial peanut and bahiagrass performed similarly, and ranked third in production and uptake. The Florida ecotype of eastern gamagrass used in this study experienced some disease problems, which decreased production. Other more adapted strains may have had better performance. Switchgrass produced forage earlier than the other eight species, however, the forage it produced after April was largely unusable. Switchgrass is not well adapted to the sprayfield environment unless it is used in a niche type system for winter grazing. Marshhay cordgrass, ranked on the bottom end of forage production and nutrient uptake, and is not well adapted to the sprayfield environment either.

All of the species used in this study except Mott required regular applications of herbicides to control weeds. Once established, Mott required no weed control. Its dense canopy successfully shaded out most weed competition. Concerning continuous use of fields for effluent application, winter rye could be interseeded into several of the species used in this study to provide year round water use. However, it would be difficult to interseed into Mott because of the dense canopy.

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APPENDIX A

Table 9. Pounds per acre of P, K, Ca and Mg in 6" of soil at low medium and high levels. Ranked according to plant availability in terms of pounds per acre (Mehlich, 1981).

Cation	Low	Medium	High
		lbs/ac	
P	0-30	31-60	61+
K	0-70	71-120	120-250
Ca	0-800	801-1600	1600+
Mg	0-30	30-60	61+

Table 10. Soil pH, and lbs./ac. nitrogen, phosphorous and potassium per sampled depth from samples taken at the Belleview sprayfield in 1993, 1994 and 1996.

	Depth (inches)	pH	NH4 (lb/ac)	NO3 (lb/ac)	P (lb/ac)	K (lb/ac)
1993 Samples	0-4	4.4	1.2	5	49	55
	4-12	4.3	0.0	7	20	22
	24-30	4.4	0.0	7	12	17
1994 Samples	0-4	4.8	0.0	13	109	46
	4-12	4.8	10.8	0	184	63
	24-30	4.9	3.9	0	14	23
1996 Samples	0-6	4.4	0.1	12	97	28
(Avg. of 6 plots)	6-12	4.5	0.0	12	77	23
	12-24	4.3	0.8	24	135	37
	24-36	4.2	1.4	24	154	46

Table 11. Average pounds per acre of Ca, Mg, Na and Fe per sampled depth from soil samples taken at the Belleview sprayfield in 1993, 1994 and 1996.

	Depth (inches)	Ca (lbs/ac)	Mg (lbs/ac)	Na (lbs/ac)	Fe (lbs/ac)
1993 Samples	0-4	382	77	16	30
	4-12	201	26	16	19
	24-30	117	16	16	18
1994 Samples	0-4	963	145	75	13
	4-12	820	109	49	19
	24-30	294	53	29	14
1996 Samples	0-6	181	21	20	110
(Avg. of 6 plots)	6-12	121	16	19	116
	12-24	108	22	36	238
	24-36	231	32	38	198

Table 12. Average pounds per acre of Aluminum, Boron, Copper and Zn per sampled depth from soil samples taken at the Belleview sprayfield in 1993, 1994 and 1996.

	Depth (inches)	Al (lbs/ac)	B (lbs/ac)	Cu (lbs/ac)	Zn (lbs/ac)
1993 Samples	0-4	417	0.10	0.84	2.70
	4-12	449	0.06	0.36	1.76
	24-30	305	0.04	0.20	0.80
1994 Samples	0-4	412	0.92	0.52	2.66
	4-12	552	0.58	0.84	1.32
	24-30	322	0.28	0.46	0.24
1996 Samples	0-6	1153	1.34	1.67	0.94
(Avg. of 6 plots)	6-12	1124	0.83	1.37	0.57
	12-24	2142	1.62	2.06	0.58
	24-36	1976	1.38	0.90	1.29

Table 13. Soil pH, per sampled depth. Numbers are averages of 4 reps per depth, taken at the Belleview sprayfield in 1997, 1998 and 1999.

		pH		
Species	**Depth**	**1997**	**1998**	**1999**
Mott	0-6	4.9	5.6	5.8
	6-12	4.4	4.8	5.3
	12-24	4.3	4.4	5.2
	24-36	4.2	4.2	4.6
Bermuda	0-6	4.9	5.6	5.9
	6-12	4.5	5.0	5.6
	12-24	4.3	4.7	5.3
	24-36	4.5	4.6	5.2
Limpograss	0-6	4.8	5.5	5.7
	6-12	4.3	4.7	5.4
	12-24	4.2	4.4	5.2
	24-36	4.2	4.4	5.1
Bahia	0-6	5.1	5.5	5.8
	6-12	4.7	4.8	5.5
	12-24	4.4	4.6	5.4
	24-36	4.4	4.3	5.2
Peanut	0-6	5.0	5.1	5.9
	6-12	4.5	5.0	5.4
	12-24	4.6	4.4	5.2
	24-36	4.3	4.2	4.8
Gama	0-6	5.0	5.6	5.5
	6-12	4.4	4.5	5.4
	12-24	4.2	4.3	4.8
	24-36	4.4	4.2	4.9
Alamo	0-6	5.1	5.3	5.6
	6-12	4.5	4.8	5.3
	12-24	4.3	4.8	5.1
	24-36	4.4	4.2	4.7
Defuniak	0-6	4.8	5.1	5.5
	6-12	4.3	4.9	5.7
	12-24	4.5	4.5	5.4
	24-36	4.6	4.3	5.0
Sharp	0-6	5.2	5.5	5.8
	6-12	4.5	4.6	5.5
	12-24	4.4	4.6	5.1
	24-36	4.4	4.4	5.1

Table 14. Soil lbs./ac. of NO_3 per sampled depth. Numbers are averages of 4 reps taken at the Belleview sprayfield in 1997, 1998 and 1999.

	NO_3 (lbs./ac.) in 1997								
Depth	Mott	Bermuda	Limpo	Peanut	Bahia	Gama	Alamo	Defuniak	Sharp
0-6	13	12	12	13	12	13	12	12	13
6-12	12	12	12	13	13	12	12	12	12
12-24	24	24	24	24	25	24	24	23	24
24-36	26	24	24	24	24	25	24	25	23
	NO_3 (lbs./ac.) in 1998								
0-6	19	21	18	20	19	18	21	18	20
6-12	19	20	19	20	17	19	18	22	21
12-24	37	38	37	32	37	39	38	39	39
24-36	39	39	38	38	37	42	43	43	40
	NO_3 (lbs./ac.) in 1999								
0-6	5	4	5	4	4	5	5	3	4
6-12	4	4	4	3	5	4	4	4	4
12-24	8	8	9	7	12	8	7	8	6
24-36	13	9	9	8	7	7	7	8	7

Table 15. Soil lbs./ac. of P per sampled depth. Numbers are averages of 4 reps taken at the Belleview sprayfield in 1997, 1998 and 1999.

	P (lbs./ac.) in 1997								
Depth	Mott	Bermuda	Limpo	Peanut	Bahia	Gama	Alamo	Defuniak	Sharp
0-6	209	212	231	266	222	194	212	228	212
6-12	79	152	125	164	131	123	98	95	99
12-24	133	139	117	167	136	127	165	124	129
24-36	113	156	141	144	134	132	136	132	129
	P (lbs./ac.) in 1998								
0-6	132	165	147	101	120	136	93	153	131
6-12	44	109	47	107	69	24	54	51	31
12-24	34	98	60	77	90	40	41	56	36
24-36	52	69	50	51	39	45	47	40	34
	P (lbs./ac.) in 1999								
0-6	110	194	153	258	133	89	161	70	94
6-12	74	98	74	105	137	91	53	163	71
12-24	91	143	75	220	129	102	266	366	206
24-36	72	80	64	66	107	140	145	267	212

Table 16. Soil lbs./ac. of K per sampled depth. Numbers are averages of 4 reps taken at the Belleview sprayfield in 1997, 1998 and 1999.

K (lbs./ac.) in 1997									
Depth	**Mott**	**Bermuda**	**Limpo**	**Peanut**	**Bahia**	**Gama**	**Alamo**	**Defuniak**	**Sharp**
0-6	74	77	82	51	71	74	54	60	54
6-12	35	56	27	33	39	23	30	28	34
12-24	13	51	48	42	64	40	40	41	53
24-36	18	47	45	34	48	39	24	38	48
K (lbs./ac.) in 1998									
0-6	57	46	104	83	59	84	37	52	61
6-12	43	49	23	28	38	30	35	47	35
12-24	31	66	69	23	64	28	70	82	86
24-36	91	66	75	44	50	45	49	50	44
K (lbs./ac.) in 1999									
0-6	72	66	62	86	66	55	60	46	39
6-12	59	51	47	50	50	58	26	70	42
12-24	108	104	99	119	112	81	72	113	100
24-36	61	111	59	67	73	84	91	79	125

Table 17. Soil lbs./ac. of Ca per sampled depth. Numbers are averages of 4 reps taken at the Belleview sprayfield in 1997, 1998 and 1999.

Ca (lbs./ac.) in 1997									
Depth	**Mott**	**Bermuda**	**Limpo**	**Peanut**	**Bahia**	**Gama**	**Alamo**	**Defuniak**	**Sharp**
0-6	806	652	875	776	763	735	681	723	651
6-12	227	293	214	300	287	268	161	175	174
12-24	150	109	155	242	275	148	117	142	162
24-36	102	121	158	126	187	127	93	125	108
Ca (lbs./ac.) in 1998									
0-6	864	924	906	321	705	880	642	843	799
6-12	270	468	249	430	228	142	245	167	167
12-24	62	289	118	91	171	52	236	111	140
24-36	38	79	70	37	40	45	40	41	54
Ca (lbs./ac.) in 1999									
0-6	829	1401	914	915	664	606	787	324	476
6-12	469	557	501	364	845	645	262	767	345
12-24	532	839	436	909	696	650	1251	1224	945
24-36	191	402	312	218	550	681	683	783	1175

Table 18. Soil lbs./ac. of Mg per sampled depth. Numbers are averages of 4 reps taken at the Belleview sprayfield in 1997, 1998 and 1999.

				Mg (lbs./ac.) in 1997					
Depth	Mott	Bermuda	Limpo	Peanut	Bahia	Gama	Alamo	Defuniak	Sharp
0-6	107	76	110	94	91	107	95	85	82
6-12	29	36	24	38	32	37	21	22	21
12-24	27	23	28	42	46	33	25	26	32
24-36	23	23	32	25	36	27	23	25	24
				Mg (lbs./ac.) in 1998					
0-6	111	95	109	46	79	108	70	88	85
6-12	43	62	39	50	32	25	31	25	25
12-24	31	56	34	27	44	25	51	33	35
24-36	21	30	25	16	23	23	19	25	25
				Mg (lbs./ac.) in 1999					
0-6	53	55	55	56	40	35	46	22	31
6-12	33	32	32	23	50	38	17	41	22
12-24	44	54	35	64	49	48	66	67	58
24-36	22	33	33	20	44	51	42	49	70

Table 19. Soil lbs./ac. of Fe per sampled depth. Numbers are averages of 4 reps taken at the Belleview sprayfield in 1997, 1998 and 1999.

				Fe (lbs./ac.) in 1997					
Depth	Mott	Bermuda	Limpo	Peanut	Bahia	Gama	Alamo	Defuniak	Sharp
0-6	115	110	133	137	118	119	115	113	102
6-12	90	117	126	121	106	110	109	97	90
12-24	251	281	229	259	230	266	244	251	227
24-36	258	288	296	250	276	283	246	257	241
				Fe (lbs./ac.) in 1998					
0-6	83	72	95	74	69	131	77	74	70
6-12	76	108	82	84	66	72	67	61	55
12-24	189	232	222	183	189	188	150	176	134
24-36	228	461	222	175	181	205	161	171	157
				Fe (lbs./ac.) in 1999					
0-6	93	113	86	137	95	90	97	105	84
6-12	89	97	89	122	97	96	70	128	101
12-24	178	196	192	205	196	195	201	238	194
24-36	203	200	212	185	184	201	196	238	175

Table 20. Soil lbs./ac. of B per sampled depth. Numbers are averages of 4 reps taken at the Belleview sprayfield in 1997, 1998 and 1999.

B (lbs./ac.) in 1997									
Depth	**Mott**	**Bermuda**	**Limpo**	**Peanut**	**Bahia**	**Gama**	**Alamo**	**Defuniak**	**Sharp**
0-6	0.63	0.54	2.28	0.52	0.94	0.75	1.01	2.25	0.53
6-12	0.39	0.45	0.73	0.38	0.38	0.32	0.38	0.49	0.27
12-24	0.71	0.60	0.79	0.58	0.67	0.89	0.62	0.66	0.46
24-36	0.49	1.21	0.87	0.48	0.69	0.55	0.38	0.62	0.44
B (lbs./ac.) in 1998									
0-6	0.26	0.22	0.59	0.20	1.96	0.35	0.86	0.30	0.36
6-12	0.06	0.96	0.28	0.21	0.42	0.19	0.58	0.15	0.21
12-24	0.18	0.53	0.27	0.27	0.64	0.37	0.65	0.31	0.36
24-36	0.13	0.44	0.23	0.23	0.54	0.29	0.60	0.23	0.50
B (lbs./ac.) in 1999									
0-6	0.45	0.48	0.38	0.44	1.54	0.34	0.46	0.32	0.25
6-12	0.33	0.33	0.27	0.31	0.48	0.41	0.28	0.36	0.30
12-24	0.61	0.62	0.51	0.55	0.69	0.62	0.72	0.70	0.52
24-36	0.56	1.62	0.63	0.40	1.28	0.59	0.47	0.61	0.78

Table 21. Soil lbs./ac. of Cu per sampled depth. Numbers are averages of 4 reps taken at the Belleview sprayfield in 1997, 1998 and 1999.

Cu (lbs./ac.) in 1997									
Depth	**Mott**	**Bermuda**	**Limpo**	**Peanut**	**Bahia**	**Gama**	**Alamo**	**Defuniak**	**Sharp**
0-6	0.78	0.57	0.79	0.92	0.85	0.76	0.65	0.83	0.95
6-12	0.59	0.42	0.56	1.00	0.63	0.55	0.54	0.37	1.14
12-24	0.45	0.52	0.65	0.58	0.62	0.53	0.53	0.57	0.69
24-36	0.42	0.32	0.29	0.40	0.54	0.39	0.42	0.34	0.50
Cu (lbs./ac.) in 1998									
0-6	0.41	0.34	0.54	0.32	0.53	0.46	0.51	0.44	0.43
6-12	0.28	0.38	0.23	0.42	0.32	0.20	0.28	0.56	0.19
12-24	0.63	0.36	0.45	0.51	0.56	0.45	0.61	0.53	0.48
24-36	0.41	0.68	0.28	0.26	0.28	0.20	0.44	0.22	0.27
Cu (lbs./ac.) in 1999									
0-6	0.10	0.27	0.18	0.28	0.27	0.23	0.82	0.25	0.07
6-12	0.14	0.21	0.16	0.09	0.30	0.23	0.27	0.52	0.08
12-24	0.29	0.55	0.00	0.25	0.24	0.17	0.21	2.13	0.28
24-36	0.38	0.18	0.11	0.28	0.17	0.49	0.30	1.04	0.33

Table 22. Soil lbs./ac. of Zn per sampled depth. Numbers are averages of 4 reps taken at the Belleview sprayfield in 1997, 1998 and 1999.

Zn (lbs./ac.) in 1997									
Depth	**Mott**	**Bermuda**	**Limpo**	**Peanut**	**Bahia**	**Gama**	**Alamo**	**Defuniak**	**Sharp**
0-6	2.92	2.51	3.32	2.96	3.10	2.76	2.52	2.67	2.86
6-12	0.90	1.09	1.13	1.40	0.86	1.01	0.69	1.08	1.00
12-24	0.37	0.49	0.53	1.03	0.77	0.33	0.41	0.52	0.74
24-36	0.38	0.43	0.35	0.40	0.59	0.37	0.53	0.54	0.35
Zn (lbs./ac.) in 1998									
0-6	1.57	1.28	1.59	0.71	1.05	1.14	1.27	1.71	1.72
6-12	0.56	0.60	0.42	0.85	0.38	0.29	0.42	0.39	0.32
12-24	0.27	0.55	0.26	0.29	0.38	0.28	0.33	0.38	0.27
24-36	0.25	0.38	0.25	0.21	0.30	0.24	0.32	0.32	0.26
Zn (lbs./ac.) in 1999									
0-6	1.49	1.44	1.42	1.86	1.36	1.13	1.54	0.54	0.87
6-12	0.97	0.79	0.98	0.87	1.42	1.34	0.59	1.66	0.83
12-24	1.28	1.18	0.70	2.31	1.17	0.93	2.46	3.09	1.14
24-36	0.48	0.74	0.59	0.75	0.80	1.04	1.08	2.32	1.84

Table 23. Soil lbs./ac. of Na per sampled depth. Numbers are averages of 4 reps taken at the Belleview sprayfield in 1997, 1998 and 1999.

Na (lbs./ac.) in 1997									
Depth	**Mott**	**Bermuda**	**Limpo**	**Peanut**	**Bahia**	**Gama**	**Alamo**	**Defuniak**	**Sharp**
0-6	78	46	64	67	67	92	60	59	55
6-12	57	38	39	48	43	64	37	36	30
12-24	74	44	50	53	64	68	48	52	48
24-36	59	40	54	47	53	62	41	47	46
Na (lbs./ac.) in 1998									
0-6	21	17	36	22	22	69	28	21	25
6-12	30	26	28	18	30	42	26	28	26
12-24	42	36	46	37	54	53	41	47	41
24-36	39	36	39	29	38	50	38	49	44
Na (lbs./ac.) in 1999									
0-6	42	50	53	52	45	41	47	39	37
6-12	39	39	41	39	45	42	27	45	35
12-24	70	76	71	71	67	68	73	84	75
24-36	50	60	66	50	65	65	62	73	80

Table 24. Soil lbs./ac. of Al per sampled depth. Numbers are averages of 4 reps taken at the Belleview sprayfield in 1997, 1998 and 1999.

Depth	Mott	Bermuda	Limpo	Peanut	Bahia	Gama	Alamo	Defuniak	Sharp
Al (lbs./ac.) in 1997									
0-6	956	875	1136	1131	1052	1050	1069	1031	950
6-12	1120	1199	1308	1256	1148	1179	1262	1106	1027
12-24	2298	2325	2175	2115	2258	2351	2300	2269	2034
24-36	2162	2379	2624	2067	2304	2493	2114	2213	2124
Al (lbs./ac.) in 1998									
0-6	698	645	841	683	547	645	598	636	530
6-12	915	1085	898	701	699	851	756	660	576
12-24	1801	2013	2104	1669	1766	1774	1421	1627	1153
24-36	2036	1889	1974	1479	1537	1863	1501	1543	1297
Al (lbs./ac.) in 1999									
0-6	857	1005	909	1103	809	832	886	1097	833
6-12	967	974	982	1135	854	933	650	1039	893
12-24	1826	1896	1970	1871	1727	1915	1667	1846	1693
24-36	1894	1741	1966	1699	1658	1952	1840	2033	1622

Table 25. Soil P, K, Ca and Mg in 1999 expressed as a percent of 1996 levels.

Depth	Mott	Bermuda	Limpo	Peanut	Bahia	Gama	Alamo	Defuniak	Sharp
P as % of 1996 levels									
0-6	113	198	157	264	136	92	165	72	97
6-12	96	127	96	136	177	118	68	210	91
12-24	67	106	56	163	95	75	197	270	152
24-36	47	52	42	43	69	90	94	173	137
K as % of 1996 levels									
0-6	250	228	214	296	228	192	207	161	136
6-12	248	215	198	209	211	242	107	292	176
12-24	292	281	266	320	302	218	194	305	270
24-36	133	240	128	145	158	182	196	172	271
Ca as % of 1996 levels									
0-6	459	775	506	506	367	335	435	179	263
6-12	387	459	414	301	697	533	217	633	285
12-24	492	776	403	841	644	601	1158	1133	874
24-36	83	174	135	94	238	295	296	339	508
Mg as % of 1996 levels									
0-6	258	266	268	272	192	170	221	105	149
6-12	211	199	205	148	318	242	111	260	139
12-24	200	245	158	290	220	215	296	300	263
24-36	69	102	102	61	136	160	131	153	219

Table 26. Soil Fe, B, Cu, Zn, Na, and Al in 1999 expressed as a percent of 1996 levels.

Depth	Mott	Bermuda	Limpo	Peanut	Bahia	Gama	Alamo	Defuniak	Sharp
Fe as % of 1996 levels									
0-6	84	103	78	125	86	81	88	96	77
6-12	77	84	76	105	84	83	60	110	87
12-24	75	82	81	86	83	82	85	100	82
24-36	103	101	107	94	93	102	99	120	89
B as % of 1996 levels									
0-6	34	36	29	33	115	25	35	24	18
6-12	40	39	32	37	58	49	33	43	36
12-24	38	38	31	34	43	38	45	43	32
24-36	41	117	46	29	93	43	34	44	57
Cu as % of 1996 levels									
0-6	6	16	11	16	16	14	49	15	4
6-12	10	15	12	6	22	16	20	38	6
12-24	14	27	0	12	12	8	10	103	14
24-36	42	20	12	31	19	54	34	115	36
Zn as % of 1996 levels									
0-6	158	152	150	197	144	119	163	58	93
6-12	169	137	171	151	247	234	102	290	145
12-24	219	202	121	397	202	160	422	530	196
24-36	37	57	45	58	62	80	83	179	142
Na as % of 1996 levels									
0-6	206	245	260	253	218	201	230	190	183
6-12	206	207	220	206	238	225	144	239	186
12-24	195	214	198	198	186	189	203	234	209
24-36	130	157	172	130	170	170	162	192	211
Al as % of 1996 levels									
0-6	74	87	79	96	70	72	77	95	72
6-12	86	87	87	101	76	83	58	92	79
12-24	85	89	92	87	81	89	78	86	79
24-36	96	88	99	86	84	99	93	103	82