Fertilisation of creeping signalgrass and bahiagrass under grazing in Florida

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Abstract
Creeping signalgrass (*Urochloa humidicola*, syn. *Brachiaria humidicola*) is adapted to central and south Florida and shares many of the desirable characteristics of bahiagrass (*Paspalum notatum*), the main pasture grass in the state. Signalgrass has not been utilised in Florida and little is known about its management. Our first study (1997–98) was at Deseret ranch on land recently converted to pasture where 7 annual fertiliser treatments, using 56, 29 and 56 kg/ha N, P and K, respectively, were applied to signalgrass: 1) no fertiliser; 2) N in March; 3) N and P in March; 4) N and K in March; 5) N, P and K in March; 6) N in March & June (112 kg/ha N); and 7) N, P and K in March & June (112, 58, 112 kg/ha N, P and K).

A second study was conducted at Ona (2000–01) with 7 treatments (1, 2, 5, 6 and 7 as above, plus N in June and N, P and K in June) applied to signalgrass and bahiagrass both recently sown on an area under pasture for 50 years. Signalgrass was unproductive in April–May, and there was little response to fertiliser. In April–June, yield of bahiagrass increased with N, but P and K had little effect. During July–October, signalgrass responded strongly to June-applied N with an additional increase in yield from P and K. Annual forage yields of both grasses were greatest in the NPK March & June treatment, which also resulted in the greatest annual uptake of N (232 kg/ha N). Recovery of N was greatest for signalgrass in the NPK June (168%) and N June (140%) treatments and averaged 93% and 73% for signalgrass and bahiagrass, respectively.

Introduction
The Florida cow-calf industry has historically been based on relatively large ranches with minimal pasture input. While several perennial grasses are commonly grown in pasture, bahiagrass (*Paspalum notatum*) fits well in a system of extensive management and is the major perennial pasture grass with ~1 M ha state-wide (Chambliss 1999). However, the loss of ~40 000 ha of bahiagrass in the mid-1990s to tawny mole cricket (*Scapteriscus vicinus*) highlighted the need to identify other grasses with qualities similar to bahiagrass (Adjei et al. 2001).

Creeping signalgrass (*Urochloa humidicola*, syn. *Brachiaria humidicola*) shares many of the desirable characteristics of bahiagrass. It produces moderate yield with low soil fertility, establishes from seed and withstands close grazing. Although it does not tolerate the wide range of soil conditions and temperatures that bahiagrass does, it is adapted to the wet, infertile soils of the warmer central and south Florida, where the majority of the state’s cattle are produced.

Signalgrass was tested in clipping trials at the Range Cattle Research and Education Centre (REC) in the 1950s (E.M. Hodges, personal communication) and in mob-grazing trials in the 1990s (Mislevy et al. 1996). Compared with bahiagrass, it was persistent, produced relatively high yield and had similar nutritive value.
Since bahiagrass has been used for grazing in Florida for > 60 years, it has been the subject of several small-plot fertilisation trials (McCaleb et al. 1966; Blue 1966, 1971; Blue and Graetz 1977; Snyder and Kretschmer 1985). All of these trials demonstrated that bahiagrass was very responsive to N fertiliser, but its response to P and K was variable under clipping. The differences in nutrient requirements of experimental plots managed by grazing and clipping techniques (Blue and Gammon 1963) make it difficult to relate these trials to ranch conditions. Based on fertilisation trials conducted under grazing (Sumner et al. 1991; Rechcigl et al. 1992), the University of Florida recommends late winter or early spring application of 56–67 kg/ha N for central and south Florida (Chambliss 1999). With this level of N and under grazing on well established pasture, no P or K fertiliser is recommended.

There has been no fertilisation research on creeping signalgrass in Florida, most having been conducted in Brazil on P-fixing Oxisols (Gomide 1989; Guss et al. 1990; Nara et al. 1995; Arnaldo de Alencar et al. 1996).

The purpose of our investigation was to establish guidelines for N, P and K fertilisation of signalgrass pastures. Fertiliser treatments were based on recommendations for bahiagrass, and 2 fertility situations were considered. The first was a low fertility site on pasture that had recently been established, replacing the native vegetation (Deseret Cattle and Citrus; ~28°20’N, 80°W). The second was a site which had been under pasture for >50 years with a history of N, P and K fertilisation (Range Cattle REC at Ona; 27°26’N, 81°55’W).

**Materials and methods**

**Deseret**

Native vegetation was removed by logging, chopping and disking in 1995, and in May 1996, a 125 ha pasture (Unit 10, pasture 7) was sown to signalgrass (Naterra Seed Co., Brazil) at 5 kg/ha of seed mixed with fertiliser (37, 29 and 31 kg/ha N, P and K, respectively). No lime or micronutrients were applied. The soil was a Spodosol (Deseret was not soil-surveyed) with a spodic horizon at ~1 m below the soil surface. In June 1996, 56 and 24 kg/ha N and K was applied, and the pasture was grazed periodically through the summer. In January 1997, the pasture was burned, and a representative area of 1 ha was selected for test plots. On March 19 and June 17, 1997 and March 31 and June 24, 1998, 4 replicates of 7 fertiliser treatments, in a completely randomised design, were applied by hand to 15 m × 15 m plots. Treatments were: 1) an unfertilised control; 2) 56 kg/ha N applied in March; 3) 56 kg/ha N and 29 kg/ha P applied in March; 4) 56 kg/ha N and 56 kg/ha K applied in March; 5) 56, 29 and 56 kg/ha N, P and K, respectively, applied in March; 6) 56 kg/ha N in March and June (112 kg/ha N annually); and 7) 56, 29 and 56 kg/ha N, P and K, applied in March and June (112, 58 and 112 kg/ha N, P and K annually). The pasture, including the experimental area, was rotationally grazed by cow-calf pairs during May-October of each year under the control of ranch management.

One wire cage (1.22 × 1.22 × 1.22 m) was secured by stakes in each plot to exclude cattle grazing. Forage inside the cage was sampled every 42 days (5 times annually) by mowing to 5-cm stubble, and the cage was moved to an adjacent area, which was mowed to 5-cm stubble on the day of sampling. Forage was weighed in the field, and a representative subsample (~500 g) was weighed before and after drying to determine dry matter percentage. On the day of sampling, a sample of hand-cut grass similar to what cattle were observed to be eating was collected from outside the cage. This sample was used to determine N, P and K concentrations in grass being consumed.

Soil was sampled (0–15 cm depth) on March 18, 1997 (before fertilisation), October 21, 1997, April 1, 1998 (before fertilisation) and March 18, 1999. Three samples from the spodic horizon were taken on July 15, 2003. Tissue N was determined at the Forage Evaluation Laboratory of the University of Florida, and tissue P and K, soil pH and Mehlich I-extractable P, K, Ca and Mg at the University of Florida Analytical Research Laboratory (Hanlon and Devore 1989). Rainfall was not recorded at Deseret due to the remoteness of the site, and rainfall measured at Orlando, FL (~30 km north) was used.

**Ona**

Six 2 ha paddocks (3 for each grass) were selected at random and sown to ‘Pensacola’ bahiagrass and creeping signalgrass (Naterra Seed Co., Brazil).
Fertilisation of creeping signalgrass and bahiagrass under grazing in Florida

Co., Brazil) at 20 and 10 kg/ha, respectively, on a Pomona fine sand (sandy, siliceous, hyperthermic Ultic Alaquod) on June 15, 1998 for a comparative grazing trial in which this fertilisation trial was conducted. Pastures were fertilised with 37, 6 and 31 kg/ha N, P and K, respectively, in July 1998 and 56 kg/ha N as ammonium nitrate in March 1999. Pastures were grazed as needed during establishment in 1998 and 1999, and during the trial they were grazed in a 4-paddock rotation with 1 week grazing followed by 3 weeks rest. During 2000 and 2001, pastures (except for the fertilisation study) were fertilised with 56 kg /ha N.

On March 15 and June 15, 2000 and March 15 and June 8, 2001, 7 fertiliser treatments were applied by hand to 15 m × 15 m plots. Treatments used at Ona were modified based on results at Deseret. Treatments 1, 2, 5, 6 and 7 as described above were included plus 2 new treatments: 56 kg/ha N applied in June; and 56, 29 and 56 kg/ha N, P and K, respectively, applied in June. Forage from a single cage (same size as Deseret) in each plot was sampled by mowing and collecting at 28-day intervals (8 times annually) for dry matter yield. Prior to mowing, forage was cut from inside the cage by hand to obtain an unsoiled sample of grass for N, P and K analyses. Forage sampling and laboratory procedures at Ona were the same as those at Deseret. Recovery of applied N, P and K was calculated as: (total uptake of N, P or K on a particular treatment minus uptake of N, P or K by the control) divided by N, P or K applied, expressed as a percentage. These calculations were done only for Ona where the grasses could be compared. Soil was sampled (0–15 cm) in each plot on April 17 and July 14, 2000 (0–15 cm and spodic horizon) and January 10, 2001. Methods of soil analyses were the same as those for Deseret.

Results

Climate

Deseret. Rainfall totalled 1059 mm for April–October 1997 (167 mm more than 50-year mean), and was especially high for July (292 mm) and August (203 mm). The plot area was briefly covered with 7–20 cm of water at the July 29, 1997 sampling, so no yield data were obtained on that date, but hand-cut samples were taken for forage analyses. Forage accumulated under cages between June 17 and September 9, 1997. The winter of 1997–1998 was mild with no frost (El Niño). The 1998 growing season was dry (647 mm for April–October) compared with 1997. June was very dry with 40 mm rain (148 mm less than normal), but July (219 mm) and August (142 mm) rainfall was typical, and the soil was saturated, with short-term flooding.

Ona. Annual rainfall for 2000 was a 59-year record low. Total rainfall for April–October 2000 was 674 mm (375 mm less than 59-year mean). In 2001, rainfall for April–October was 1457 mm (401 mm greater than 60-year mean). In spite of excessive rain, the site did not flood due to better drainage than at Deseret. During the 2000–2001 winter, there were 9 days when temperature at the soil surface was ≤0°C with the extreme low at −5°C. There were 13 instances of frost with one occurrence as late as April 19. Signalgrass was severely injured by this cold, and visual estimates of ground cover indicated ~50% ground cover from living signalgrass in May 2001.

Data analyses

The completely random design at Deseret and the randomised complete block design at Ona were analysed with a mixed linear model using the MIXED procedure (SAS 1999). At Deseret, fertiliser treatments formed whole plots and years were subplots, which were fixed effects along with their interactions. At Ona, there was a split plot with grasses as whole plots, fertiliser treatments as subplots, years as sub-subplots, and sample dates as sub-sub-subplots. These were all fixed effects. For both experiments, error terms, except the residual, were random effects. When significant third-order interactions involving grass, fertiliser treatment, year and sample date in year occurred, analyses were conducted by year and sample date. Annual yield was analysed in a general linear model with grasses as whole plots, fertiliser treatments as subplots and years as sub-subplots (SAS 1999). Means for main effects of fertiliser treatments and grass × treatment interactions were separated by the DIFF (LSD) option (SAS 1999). Contrasts were used to compare means of treatments containing P or K with means of those without P or K, and contrasts were also used to compare means in grass × fertiliser treatment interactions for P and K recovery. Where significance is indicated in the text, this will be at P ≤ 0.05 unless stated otherwise.
Soils

Deseret. The level of nutrients in the soil prior to application of fertiliser treatments in April 1997 was low (Table 1). Soil was essentially in the native condition at the start of the experiment as the only fertiliser applied was that at the time of sowing. Soil pH was in a range (5.0–5.5) considered adequate for perennial grasses in Florida (Chambliss 1999). This was known when signalgrass was sown in 1996, so no liming materials were applied.

Concentrations of P and K in the soil were affected by a fertiliser treatment × sampling date interaction. There were no treatment effects in October 1997, which was 6 months after the first treatment application (P = 6.3 and K = 14.9 ppm; data not shown). In April 1998 and 1999, mean P concentrations for plots receiving P were greater (5.8 and 12.3 ppm for 1998 and 1999, respectively) than the means of plots not receiving P (4.6 and 9.1 ppm). Likewise, mean soil K levels in plots receiving K were greater (12.9 and 36.9 ppm for 1998 and 1999, respectively) than the means of plots not receiving K (9.2 and 21.0 ppm). Even after 2 years of fertilisation at the highest levels of P and K, levels of these elements were very low according to University of Florida interpretation (<10 ppm of Mehlich I-extractable P and <20 ppm of K are very low) (Kidder et al. 2002) as were mean P (6 ppm) and K (<1 ppm) concentrations in the spodic horizon.

Ona. The level of nutrients in the soil prior to application of fertiliser treatments in April 2000 was relatively high compared with levels at Deseret (Table 1). Fertiliser treatment had no effect on levels of P and K in soil at any sampling date, but date did have an effect on K. Concentrations of K in the soil increased over sampling dates from 41 ppm initially in April 2000 to 51 and 76 ppm in July 2000 and January 2001, respectively (data not shown). Levels of P and K in the spodic horizon were not affected by fertiliser treatment, with means of 54 and 15.6 ppm, respectively.

Annual yield

At Deseret, fertiliser treatment affected signalgrass yield, while at Ona there was a grass × fertiliser treatment interaction (Table 2). The control generally had the lowest yield and applying N in March increased yield over the control for signalgrass at Deseret and bahiagrass at Ona. Signalgrass yield at Ona was improved significantly when N was applied in June with no benefit from applying N in March. Inclusion of P and K with N produced responses only when N was applied in both March and June. With both grasses, the NPK March & June treatment yielded more than all other treatments. Signalgrass yielded more than bahiagrass in most treatments where fertiliser was applied in June.

Yield at individual sampling dates

Deseret. There was a fertiliser treatment × year × sampling date interaction for signalgrass yield. In 1997 (data not shown), there were no differences among treatments on May 6 (mean = 500 kg/ha),

**Table 1.** Concentrations of elements (Mehlich I-extractable) in soil (0-15 cm) at Deseret and Ona prior to application of fertiliser treatments.

<table>
<thead>
<tr>
<th>Element</th>
<th>Deseret</th>
<th>Ona</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>5.9</td>
<td>29.0</td>
</tr>
<tr>
<td>K</td>
<td>10.5</td>
<td>41.0</td>
</tr>
<tr>
<td>Ca</td>
<td>260</td>
<td>715</td>
</tr>
<tr>
<td>Mg</td>
<td>18</td>
<td>59</td>
</tr>
<tr>
<td>Zn</td>
<td>0.49</td>
<td>2.80</td>
</tr>
<tr>
<td>Mn</td>
<td>0.19</td>
<td>1.83</td>
</tr>
<tr>
<td>Cu</td>
<td>1.19</td>
<td>0.43</td>
</tr>
<tr>
<td>pH</td>
<td>5.4</td>
<td>5.2</td>
</tr>
<tr>
<td>Organic matter (%)</td>
<td>2.0</td>
<td>3.4</td>
</tr>
</tbody>
</table>

**Table 2.** Mean annual yields of creeping signalgrass at Deseret (1997 and 1998) and of bahiagrass and creeping signalgrass at Ona (2000 and 2001) as affected by fertilisation treatments.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Deseret</th>
<th>Ona</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Signalgrass</td>
<td>Signalgrass</td>
</tr>
<tr>
<td>NPK Mar &amp; June</td>
<td>11 320 a</td>
<td>12 350 a</td>
</tr>
<tr>
<td>N Mar &amp; June</td>
<td>9 750 b</td>
<td>9 960 bc</td>
</tr>
<tr>
<td>NPK June</td>
<td>—</td>
<td>10 010 b</td>
</tr>
<tr>
<td>N June</td>
<td>—</td>
<td>10 350 b</td>
</tr>
<tr>
<td>NPK March</td>
<td>8 540 c</td>
<td>9 400 bc</td>
</tr>
<tr>
<td>NK March</td>
<td>8 050 c</td>
<td>—</td>
</tr>
<tr>
<td>NP March</td>
<td>8 190 c</td>
<td>—</td>
</tr>
<tr>
<td>N March</td>
<td>7 800 c</td>
<td>8 850 cd</td>
</tr>
<tr>
<td>Control</td>
<td>6 320 d</td>
<td>8 210 d</td>
</tr>
</tbody>
</table>

1 N = 56, P = 29 and K = 56 kg/ha; March and June are application dates. N in the June treatments was applied after the June sampling date.
2 Means within columns followed by the same letter are not different (P > 0.05).
3 Treatments were not applied at this location.
4 Compares grasses at Ona.
but by June 17, the NPK March and NPK March & June treatments (mean = 1850 kg/ha) yielded more than all other treatments (1500 kg/ha). In September 1997, N March & June and NPK March & June (mean = 9850 kg/ha) yielded more than all other treatments (mean = 7580 kg/ha). In 1998, the only significant responses were in August when NPK March & June yielded more than all other treatments, and in September when yield was ranked: NPK March & June > N March & June > all other treatments (Figure 1).

**Ona.** There was a grass × year × sampling date interaction for yield (Figure 2). Bahiagrass yielded more forage than signalgrass (no measurable yield) in April 2000, and the reverse occurred in June, July and August with no differences at the remaining harvests. The pattern was similar in 2001, with bahiagrass yielding more than signalgrass (no measurable yield) in April–June and signalgrass reversing the situation in July. During August–October, yields were similar for both grasses.

![Figure 1](image1.png)

**Figure 1.** Means for the fertiliser treatment × sampling date interaction for dry matter yield of creeping signalgrass under grazing at Deseret in 1998. Fertiliser was applied on March 30 and June 24 (F).

![Figure 2](image2.png)

**Figure 2.** Means for the grass × sampling date × year interaction for dry matter yield under grazing at Ona.
There were differences among fertiliser treatments in April, July and August 2000 and 2001. In April of both years, bahiagrass yield was lowest in the control and June-applied fertiliser treatments, which were not different from each other (April data not shown). In April 2000, the inclusion of P and K with N in March (430 kg/ha) did not increase bahiagrass yield over N alone (340 kg/ha). In April 2001, NPK in March (810 kg/ha) resulted in more bahiagrass than N alone (550 kg/ha).

On July 6, 2000 there was a grass x fertiliser treatment interaction (Table 3). Yield of signalgrass was greater than that of bahiagrass for all treatments except the control and N March treatments. Signalgrass responded to fertiliser application with yield in the control < N March, NPK March < N June, N March and June < NPK June < NPK March and June. Bahiagrass yield on July 6, 2000 was lowest in the control and (inexplicably) in the NPK March treatment. Addition of N in March, June or March and June increased bahiagrass yield, but addition of P and K produced no further response.

On July 5, 2001, application of N in March produced no significant increase in grass yield, while applying N in June or March and June did increase yield over the control. There was no benefit from including P and K at any time.

On August 3 and August 30, 2000 and August 2, 2001, there were significant treatment effects but no interaction with grasses (data not shown). At all dates, yields of both grasses were lowest in the control (mean = 1700 kg/ha), and yields were not increased with application of N or NPK in March (mean = 2060 kg/ha). Applying N in June increased yield over the control only on August 30, 2000 (2310 kg/ha). At all August dates, NPK June, N March and June and NPK March & June treatments were not different (mean = 2470 kg/ha), but these treatments increased yield over all the previous treatments.

### Tissue N, P, and K

Deseret. There was a fertiliser treatment × sampling date interaction for N concentration in signalgrass tissue (Figure 3). Concentrations of N in the N, NP, NK and NPK March treatments were similar throughout and exceeded those in the control in May and June. Concentration of N in the N March & June treatment exceeded that in treatments receiving N in March only at the August sampling. Applying NPK in March & June increased N above the N March & June treatment at May and August sampling dates.

There was a fertiliser treatment × year × sampling date interaction for concentration of P in signalgrass tissue (Figure 3). Two groups emerged for P concentrations corresponding with treatments with and without P fertiliser. When no P was applied, the changes in P over dates were very similar in 1997 and 1998, and these 4 treatments are shown as their mean over years at each date. In both years, mean P concentrations for treatments supplying P were greater than means for the group supplying no P at May and September sampling dates.

There was a fertiliser × sampling date interaction for concentration of K in signalgrass tissue

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**Table 3.** Mean dry matter yields of signalgrass and bahiagrass from various fertilisation treatments on July 6, 2000 and treatment means on July 5, 2001 at Ona, FL.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>July 6, 2000</th>
<th>July 5, 2001</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Signalgrass</td>
<td>Bahiagrass</td>
</tr>
<tr>
<td>NPK Mar &amp; June</td>
<td>4680 a²</td>
<td>1510 a</td>
</tr>
<tr>
<td>N Mar &amp; June</td>
<td>2470 c</td>
<td>1520 a</td>
</tr>
<tr>
<td>NPK June</td>
<td>3010 b</td>
<td>1140 b</td>
</tr>
<tr>
<td>N June</td>
<td>2300 c</td>
<td>1360 ab</td>
</tr>
<tr>
<td>NPK March</td>
<td>1690 d</td>
<td>730 c</td>
</tr>
<tr>
<td>N March</td>
<td>1390 d</td>
<td>1230 ab</td>
</tr>
<tr>
<td>Control</td>
<td>980 e</td>
<td>840 c</td>
</tr>
</tbody>
</table>

1 N = 56, P = 29 and K = 56 kg/ha; March and June are application dates. N in the June treatments was applied after the June sampling date.

2 Means within columns followed by the same letter are not different (P > 0.05).

3 Compares grasses.
The N March, NP March and N March & June treatments were not different from each other at any sampling date and are shown as their mean. Fertiliser treatments supplying no K produced higher K concentrations than the control in May, June and August, with higher levels still in treatments supplying K.

Ona. Fertiliser treatment affected concentrations of N, P and K in bahiagrass tissue during April–June 2000 and 2001 (Table 4). Concentrations of N were greater in treatments where N had been applied in March compared with application in June only or the control. Concentrations of P were greater in the NPK March & June and NPK March treatments than in other treatments. Concentration of K was greatest in the NPK March & June treatment.

During July–October 2000 and 2001, fertiliser treatments affected N concentrations of both grasses similarly (Table 4). N concentrations in
treatments where N was applied in June were greater than in treatments where N was applied only in March and in the control.

There was a grass × sample date × year interaction for N concentration during July–October (Figure 4). On August 30, 2000, which was comparatively wet, N concentrations in signalgrass tissue declined to lower levels than in bahiagrass, and concentrations remained very low through to October. In 2001, which was the drier of the 2 years, N concentrations in grasses were similar over most sampling dates.

There was a grass × fertiliser treatment interaction for P concentration during July–October 2000 and 2001 (Table 4). Signalgrass always contained higher levels of P than bahiagrass. Treatments did not affect concentrations of P in bahiagrass, but affected P concentrations in signalgrass. Applying N alone to signalgrass lowered P concentrations, the effect being greater with applications in March and June. With dual applications of P and K, P concentration was increased above all other treatments.

There was a grass × sample date × year interaction for P concentration during July–October (Figure 4). Concentrations of P in bahiagrass were the same in each year, and there was little change over sample dates, remaining at about 0.3%. In signalgrass, P concentrations declined with time in 2000 from about 0.8% P in July to 0.5% in August with minor fluctuations in this value for the remainder of the sampling period. In 2001, the drier year, P in signalgrass increased with time from 0.3% in July to 0.7% in October.

Concentrations of K during July–October displayed a fertiliser treatment × sample date interaction (Figure 4). In July, the NPK June and NPK March & June treatments had greater concentrations than other treatments. Over time, concentration of K in the NPK June treatment became similar to that in the other treatments while the NPK March & June treatment remained higher.

N, P and K uptake and recovery at Ona. Annual uptake of N did not differ between grasses and was affected by fertiliser treatment only (Table 5). Order of N uptake was: NPK March & June > NPK June, N June and N March & June > NPK March and N March > control. Mean N uptake by signalgrass with P and K fertiliser (195 kg/ha N) was greater (P = 0.004) than N uptake without P and K (148 kg/ha N), whereas P and K did not affect (P = 0.35) N uptake in bahiagrass (mean = 166 kg/ha N).

Recovery of applied N was affected by a grass × fertiliser treatment interaction (Table 6). Signalgrass recovered more N than bahiagrass in the NPK June and N June treatments, but there were no differences between grasses for other treatments. For signalgrass, recovery was generally improved by applying N in June, but there were no differences among treatments for N recovery in bahiagrass.

Uptake of P in all treatments was greater for signalgrass than for bahiagrass (Table 5). Uptake of P by signalgrass was increased when P was applied with highest uptakes with 2 applications. For bahiagrass, P uptake in the NPK March & June treatment exceeded that in all other treatments. Uptake of K by signalgrass was increased by virtually all fertiliser treatments, with highest values with applications of K in March and June.
For bahiagrass, K uptake was increased over control for all fertiliser treatments with the highest value for the NPK March & June treatment.

There was a grass × fertiliser treatment interaction for recovery of P and K (Table 6). Recovery of P by signalgrass was greater than recovery by bahiagrass in all treatments where recovery could be measured, but recovery of K by signalgrass was greater than by bahiagrass only in the NPK June treatment. Recovery of P by signalgrass was greater in the NPK June treatment than in other treatments. Recovery of K by signalgrass was greater for NPK June than for NPK March with NPK March & June intermediate. For bahiagrass, there were no differences among treatments for P or K recovery.

**Discussion**

Differences in temperature and rainfall between years and between sampling dates within years brought out the weaknesses and strengths of each grass. Signalgrass produced essentially no forage...
in the dry, cool spring or during periods of drought, such as occurred in June 1998 at Deseret or in spring 2001 at Ona. Rain in April–May 1998 at Deseret and April–May 2000 at Ona did provide some signalgrass growth, but responses to fertiliser were only modest.

To obtain best results, the timing of fertilisation of signalgrass should be close to the beginning of the rainy season, which is late May or early June in central and south Florida. There is a sharp spike in production at this time even without fertiliser, but it is made dramatic with N fertiliser and is enhanced with P and K. Both grasses are long-day plants and flower in July, but signalgrass appears to put more resources into reproductive growth than bahiagrass. Much of the abundant growth in July comes from culms and inflorescences. Ranchers who manage fertilised signalgrass must be prepared to increase stocking rates rapidly to utilise the sharp increase in forage from signalgrass at this time.

Bahiagrass will provide limited forage from March to May when forage is in short supply. Fertilisation enhances production, especially if it is accompanied by rain. Blue (1971) was the first to advocate application of N to bahiagrass in spring, and later research by Sumner et al. (1991) supported the earlier recommendations, which are intended to provide spring forage.

Table 5. Fertiliser treatment main effect means for annual uptake of N and grass x fertiliser treatment means for uptake of P and K by signalgrass and bahiagrass. Means of 2000 and 2001 at Ona, FL.

lactation and weight gain after winter (Pate et al. 2000). Although concentrations of N in both grasses were improved briefly by application of N in June, this is less critical than improvement of forage in spring.

During mid-to late summer in Florida, bahiagrass declines in nutritive value with corresponding declines in cattle weight gain (Sollenberger et al. 1988; Williams et al. 1991). The minimum level of crude protein suggested for lactating cows is ~10% (NRC 1996), which is the level obtained by both grasses (1.6% N × 6.25) in August–September 2001 at Ona (Figure 4). For signalgrass at Deseret (Figure 3) and Ona in 2000 (Figure 4), crude protein was below the critical 10% level even with June-applied fertiliser.

In spite of low production and little rainfall during April–May, which (if high) would remove N by uptake and leaching, respectively, forage production in summer was slight from a single application of N in March. This was especially true for signalgrass (Table 2). The additive effect from 2 applications of N was also slight, as concentrations of N in tissue during July–October from a single application of 56 kg/ha N in June were not different from those following application of 56 kg/ha N in both March & June (112 kg/ha total) (Table 4).

Levels of N recovery by bahiagrass forage (57–93%) under grazing in this study were somewhat higher than values reported by others under clipping conditions. Blue (1970; 1974) found recovery of applied N by bahiagrass forage on a Spodosol ranged from 40–50% during the first 4 years, but increased to ~80% in the subsequent 6 years of a clipping trial. The increases in recovery rates with time were attributed to the root-stolon system, which is capable of absorbing relatively large amounts of N. Blue and Graetz (1977) reported N recovery in bahiagrass forage at 64–79% and Sveda et al. (1992) reported recovery of applied N in bahiagrass forage averaging 52% in a greenhouse trial.

Our N-recovery values for signalgrass in June-applied treatments that exceed 100% are unusual, and no comparable values have been found in the literature. Signalgrass recovery of N from treatments where N was applied in March is comparable with those for bahiagrass and those reported for signalgrass. Loureiro and Boddey (1988) determined that signalgrass fertilised with 40 kg/ha N had a 57% N recovery. Arnaldo de Alencar et al. (1996) found recovery of applied N in signalgrass ranged from 14% with 50 kg/ha N to 46% with 150 kg/ha N. Uptake and recovery can increase with rate of N applied (Scarsbrook 1970; Blue 1974).

Nitrogen recoveries calculated by subtracting N uptake in a control from that in a treatment are apparent values that can be misleading if N from mineralisation of organic matter or biological N fixation (BNF) is not considered. Impithuska and Blue (1978) applied $^{15}$N to bahiagrass on a Myakka soil (Aeric Alaquod) and found that, in the first half of the growing season, N uptake was from $^{15}$N, but later, non-fertiliser N, presumably from mineralisation of organic matter, was the major source of N. In their study, non-fertiliser N in bahiagrass forage amounted to 26, 55 and 97 kg/ha with applied N at 0, 100 and 200 kg/ha, respectively. There is information to suggest that there are root-associated BNF systems in both grasses. Day et al. (1975) measured 127 kg/ha N assimilated in the leaves of Pensacola bahiagrass from Azotobacter paspali after 4 months, and Boddey and Victoria (1986) estimated BNF in signalgrass amounted to 30–45 kg/ha annually from root-associated BNF. Blue (1979) estimated that a Spodosol gained almost 800 kg/ha N over 25 years, or 31 kg N/ha/year from an unknown source.

Applying P and K with N in June can result in more signalgrass forage in August–September than applying N alone. Perhaps rapid growth in late June and early July creates a demand for P and K, which produces a response to added P and K. In excessively wet years, such as 1997 at Deseret, or following winter injury and drought as was the case at Ona in 2001, a response to P and K was not observed within the growing season. At both locations in both years, treatments including N, P and K applied in June increased annual yield over respective N levels without P or K (Table 3).

The fact that signalgrass established and grew at Deseret, where soil P was about 6 ppm, is a testament to its ability to tolerate low levels of P in the upper 15 cm of soil. Nara et al. (1995) found no yield response in signalgrass to rates (0–26 kg/ha P) or methods of application (banded or broadcast) of P on a sandy soil containing 5 ppm P. Guss et al. (1990), working in 5 P-fixing Oxisols, found that signalgrass yield increased with P rates, and that the critical value of P in the soil was 46–80 ppm P (Mehlich I-extractable). Critical soil P was 90% of the soil P.
concentration that resulted in maximum forage production on that soil.

The lack of a yield response in bahiagrass to P and K when applied with N as a single application at 56 kg/ha N compared with responses to P and K when applied with split applications of N (112 kg/ha N total) at Ona in both years is consistent with earlier reports from central and south Florida (McCaleb et al. 1966; Sumner et al. 1991; Rechcigl et al. 1992). The higher N rate (112 kg/ha) appeared to create a demand for P and K over the demand when N fertilisation was 56 kg/ha.

Concentrations of P in signalgrass tissue at Ona, where soil P averaged 25 ppm, were usually twice those in bahiagrass, and uptake of P by signalgrass was greater than for bahiagrass for all fertiliser treatments. Guss et al. (1990) and Gomide (1989) reported that signalgrass had higher “critical internal” concentrations of P (0.33–0.5%) than 3 other Brachiaria (Urochloa) spp. “Critical internal” concentrations were defined as the concentrations of P in tissue that resulted in 90% of maximum growth. Since tissue P was higher and yield lower than for the other 3 grasses, Guss et al. (1990) considered that signalgrass was not an efficient user of P. However, at Deseret where soil test P averaged 6 ppm, tissue P in signalgrass forage was about 0.09% with no P fertiliser and 0.18% where P was applied. Considering the yields obtained at Deseret, it would seem that signalgrass was efficient in use of P.

At Ona, concentrations of P in signalgrass with and without P fertiliser averaged 0.61% and 0.45% P, respectively, compared with 0.33% and 0.29% in bahiagrass. These values are above the 0.22–0.26% of P in diet dry matter that is recommended for lactating cows (NRC 1996). Cattle are likely to consume more P by grazing signalgrass than bahiagrass. We noted that cattle grazing signalgrass ate less than half as much mineral supplement annually as cattle grazing bahiagrass.

In the control, uptake of P averaged 40 kg/ha for signalgrass and 20 kg/ha for bahiagrass. When P was applied to signalgrass in June (29 kg/ha) or in March & June (58 kg/ha), P uptake was 66 and 82 kg/ha P, respectively. Recovery of applied P was 90 and 72%, respectively. For bahiagrass, greatest P uptake was 36 kg/ha P in the NPK March & June treatment where 58 kg/ha P was applied. Uptake of P by bahiagrass receiving P in March (25 kg/ha uptake, 18% recovery) or June (28 kg/ha uptake, 29% recovery) was not different from treatments receiving no P. Our recovery values for applied P are lower than the 63 and 46% recovery by bahiagrass in 2 years with 24 kg/ha P applied by Rechcigl et al. (1992). Signalgrass could possibly have a role in removing P from the soil where high levels of soil P could produce run-off that may threaten environmentally sensitive areas such as near Lake Okeechobee.

Conclusion

Creeping signalgrass fits well into an extensive management system with low soil fertility and poor drainage such as that at Deseret. However, it may be harder to manage than bahiagrass because of its low production in spring and higher production in summer. Unlike bahiagrass, which will produce some forage with March-applied N fertiliser, fertilisation of signalgrass should not be undertaken until the rainy season is imminent, perhaps late May or early June in central Florida. Fertilisation of signalgrass should include P and K, especially on soils that contain low levels of available P (<25 ppm) and K (<50 ppm). Without N fertiliser, N concentration in signalgrass may be low and crude protein may be less than that needed for lactating cows.

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References


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