

## Effect of dolomite and sowing rate on plant density, yield and nutritive value of *Paspalum atratum*

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### Abstract

Three experiments were conducted with the perennial pasture grass *Paspalum atratum* cv. Suerte at Ona, Florida. In Experiment I, Suerte was evaluated in 1992–1993 on a Pomona fine sand for responses to dolomite (0, 1.1, 2.2, 3.4, 4.5 and 6.7 t/ha) and broadcast-sowing rates (5.6, 13.6 and 20.5 kg/ha pure, live seed [PLS]). Dolomite increased soil pH ( $4.5 + 0.22X$ ,  $X = \text{t/ha}$ ), Suerte density ( $\text{plants/m}^2 = 32.7 + 7.3X - 0.99X^2$ ) and mean 42-d forage yield ( $\text{kg/ha} = 2904 + 248.0X - 25.1X^2$ ). Dolomite did not affect crude protein (6.1%), but did increase IVOMD ( $\% = 53.6 + 0.65X$ ). A target pH for Suerte should be about 5.0, which was achievable with about 3.0 t/ha dolomite on this sandy Florida soil. Initially, density increased with increasing sowing rate ( $\text{plants/m}^2 = 18.6 + 1.7X$ ,  $X = >5.6 \text{ kg/ha PLS}$ ), but there was no difference in density after 2.5 years (33 plants/m<sup>2</sup>).

In Experiment II, Suerte was broadcast-sown at 1.5, 3.0, 4.5 and 6.0 kg/ha PLS on March 1, May 1, July 1 and September 1, 1995. Average density in the 84-d period after sowing from March and May increased with increasing sowing rates ( $\text{plants/m}^2 = 11.3 + 2.3X$ ,  $X = >1.5 \text{ kg/ha PLS}$ ), whereas July and September sowings failed due to flooded soil. Mean yield in June and July 1996 from March and May 1995

sowings increased with increasing sowing rate ( $\text{kg/ha} = 1200 + 240X$ ). When broadcast, seed should be sown at 5–6 kg/ha PLS.

In Experiment III, Suerte seed was flooded for 0, 2, 4, 6, 8, 10, 14, 21 and 28 d, drained, and incubated for 28 d. Suerte seed lost about 2% germination for each day it was flooded.

### Introduction

*Paspalum atratum* cv. Suerte was introduced to Florida from Brazil in 1990 (Kretschmer *et al.* 1994). It is established from seed, is adapted to seasonally wet soil, and is a productive and palatable perennial bunchgrass. Nothing was known about sowing rates for Suerte or its response to soil pH at the time of its introduction. Although tropical grasses are generally adapted to acid soils, Al<sup>3+</sup> toxicity resulting from pH below 5.5 (Zelazny and Fiskell 1971) and low P availability in Florida soils usually necessitate the addition of liming materials, which increases pasture establishment cost. The objective of the first experiment was to measure plant density, forage yield, crude protein, digestibility and mineral concentrations of Suerte over a range of dolomite and broadcast-sowing rates. This led to 2 additional experiments to investigate lower sowing rates, and the effects of flooding on Suerte germination.

### Materials and methods

#### Experiment I

At the University of Florida, Range Cattle Research and Education Centre (27°25'N, 81°55'W), an unlimed (initial pH = 4.3), unfertilised Pomona fine sand (sandy, siliceous, hyperthermic Ultic Alaquod) was disked in 1987 to remove native vegetation. The following 6 dolomite treatments were applied in November 1987 in 4 replicates in a randomised, complete block

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design: 0, 1.12, 2.24, 3.36, 4.48 and 6.72 t/ha. Dolomite was rotovated into the top 15 cm of the soil in  $2.2 \times 4.6$  m plots, and its effect on ryegrass (*Lolium multiflorum*) was measured (Rechcigl and Payne 1988). On August 26, 1991, dolomite at these 6 rates was reapplied (dry matter basis) and rotovated (15 cm) into respective plots. This dolomite was 58.4%  $\text{CaCO}_3$  and 34.3%  $\text{MgCO}_3$  with a  $\text{CaCO}_3$  equivalence of 100%. At least 90, 80 and 50% passed 2.38, 0.841 and 0.297 mm sieves, respectively.

On September 24, 1991, Suerte was broadcast-sown by hand on to  $2 \text{ m}^2$  subplots within each dolomite plot at 5.6, 13.6 and 20.5 kg/ha pure, live seed (PLS). These PLS rates were calculated as percent germination/100  $\times$  kg sown seed/ha. The seedbed was well prepared by rotovating, and it was rolled several times to pack soil after sowing. The seed had been hand-harvested from experimental plots in October 1990 and had 85% germination (February 1991) after 28-d incubation on a regimen of 9 h at 35°C (light) and 15 h at 20°C (dark).

Fertilisation consisted of 56:5:47 kg/ha of N:P:K applied at the beginning of the growing season on March 19, 1992 and March 4, 1993. The same rates of N:P:K were applied at each sampling date.

Soil was sampled (0–15 cm) on August 16, 1991 (before dolomite application), March 2, 1992, February 2, 1993, and February 7, 1994, and analysed for extractable Ca, Mg, P and K (Mehlich I [0.05 M HCl and 0.01 M  $\text{H}_2\text{SO}_4$ ]) (Hanlon and DeVore 1989). Soil pH was determined in a 1:2 soil:water slurry. Exchangeable  $\text{Al}^{3+}$  was determined in a 1:10 soil:1 M KCl extraction on the sample taken in March 1992, and concentration of  $\text{Al}^{3+}$  was measured by the aluminon procedure (Jayman and Sivasubramaniam 1974). Organic carbon was determined from the March 1992 sampling (Hanlon and DeVore 1989).

Plant density was determined by counting plants in a  $1 \text{ m}^2$  quadrat in each subplot on November 4, 1991 and March 3, 1994. To facilitate determination of plant density in March, plant residue on the plots was burnt on January 11, 1994. Percentage ground cover of weeds was determined visually on May 14, 1992.

Winter growth was removed by cutting on April 3, 1992 and by burning on February 27, 1993. Forage yield was then determined by hand-clipping  $1 \text{ m}^2$  quadrats to a 10 cm stubble height

on May 14, June 17, July 22 and August 26, 1992, and on May 18, June 21, July 26 and August 30, 1993. Forage was weighed in the field and a subsample was weighed, dried (60°C for 96 h) and reweighed for dry matter determination. Yields reported are Suerte with no weeds. Crude protein (Gallaher *et al.* 1975; Hambleton 1977), *in vitro* organic matter digestion (IVOMD) (Moore and Mott 1974), and tissue Ca, Mg, P and K were determined on subsamples in 1992. Tissue was ashed at 500°C for 5 h, and minerals were extracted using 0.3 M HCl. Solutions were analysed for Ca, Mg and K using an atomic absorption spectrophotometer and for P using a spectrophotometer and colorimetric method (Murphy and Riley 1962).

#### Experiment II

A previously limed Pomona fine sand with pH = 6.0 and concentrations of extractable Ca = 880, Mg = 200, P = 16 and K = 70 mg/kg was rotovated on January 30, 1995. Suerte was hand-sown, raked and packed in  $2 \text{ m}^2$  plots at 1.5, 3.0, 4.5 and 6.0 kg/ha PLS on March 1, May 1, July 1 and September 1, 1995. There were 5 replicates of each sowing rate at each date. Certified seed, which was harvested on October 30, 1994, had 80% germination (March 1995) under the test conditions described above.

Each sowing was fertilised after seedling emergence with 56, 5 and 46 kg/ha of N, P and K, respectively. Seedling density was determined at 28, 56 and 84 d after each sowing date and final plant density on August 12, 1996. On May 20, 1996, plots were hand-clipped to a 10 cm stubble height and fertilised with 56 kg/ha N. Suerte yield was determined on June 24 and July 30, 1996 by hand-clipping forage in a  $1 \text{ m}^2$  quadrat. Plots were refertilised with 56 kg/ha N on June 24.

#### Experiment III

Lots of 100 certified seeds were placed in petri dishes between layers of blotter paper and dishes were filled to the top with distilled water. After 0, 2, 4, 6, 8, 10, 14, 21 and 28 d, dishes were drained and excess water was removed by blotting. There were 3 replicates of each treatment. At the end of each flooding period, seed was incubated for 28 d with a daily regimen of 9 h at 35°C (light) and

15 h at 20°C (dark). Dishes were examined every other day and seed that had the radicle protruding from the seed coat were counted and removed. After the 28-d incubation period, remaining seed was examined under a dissecting microscope to distinguish dormant (firm) and spoiled (soft) seed.

#### Experimental analyses

Data were analysed using Generalised Linear Models procedures (SAS 1985). When soil amendment treatments in Experiment I were significant ( $P < 0.05$ ), relationships between dolomite and sowing rates and the various responses were determined with regression analyses. Plateau analysis was used to define the relationship between plant yield and dolomite rates (Dahnke and Olson 1990). Experiments II and III were completely randomised designs and were analysed by analysis of variance. In Experiment II, the model contained effects due to sowing date and rate and their interaction. Effects due to days after sowing were determined with the repeated measures option of SAS. In both of these later studies, relationships between germination and sowing rates or length of flooding period were determined with regression analyses. All  $R^2$  ( $r^2$ ) values were calculated as the ratio sum of squares of regression: treatment + error sum of squares.

## Results

### Experiment I

Initial soil pH (August 16, 1991) changed linearly ( $\text{pH} = 4.4 + 0.17X$ ,  $r^2 = 0.85$ , where

$X = \text{t/ha dolomite}$ ) as a result of the November 1987 dolomite application. After the August 26, 1991 dolomite application, soil pH was significantly affected by sampling date and dolomite treatment, but there was no interaction. Averaged over 1991–1994 (4 sampling dates), dolomite increased soil pH linearly ( $\text{pH} = 4.5 + 0.22X$ ,  $r^2 = 0.86$ ). Exchangeable  $\text{Al}^{3+}$  decreased quadratically with increasing dolomite rates ( $\text{mg/kg Al}^{3+} = 18.1 - 1.09X + 0.113X^2$ ,  $R^2 = 0.77$ ).

Concentrations of Ca, Mg, P and K in soil depended on a year  $\times$  dolomite rate interaction. The 4-year average dolomite effect is used to document the overall response. Increasing the dolomite rate linearly increased concentrations of Ca and Mg and quadratically increased concentrations of P in the soil (Table 1). Soil K was affected by dolomite rate only in 1993 when it decreased quadratically with increasing dolomite rates.

Increasing dolomite rate linearly increased mean concentrations of Ca and Mg in plant tissue (Table 1). Concentration of K decreased linearly with increases in dolomite, while P concentration in tissue was not affected by dolomite rates.

Sampling date did not affect ( $P = 0.06$ ) concentrations of Ca in tissue (mean = 5.47 g/kg). Concentrations of Mg were affected by sampling date ( $\text{g/kg} = 5.5 + 2.1X - 0.49X^2$ ,  $R^2 = 0.69$ , where  $X = 1 - 4$  for May 14, June 17, July 22 and August 26, 1992, respectively). Tissue P ( $\text{g/kg} = 1.0 + 0.7X - 0.14X^2$ ,  $R^2 = 0.75$ ) and K ( $\text{g/kg} = 1.8 + 11.4X - 1.98X^2$ ,  $R^2 = 0.84$ ) were also affected by sampling date. Sampling date did not interact with dolomite rate for any of these minerals.

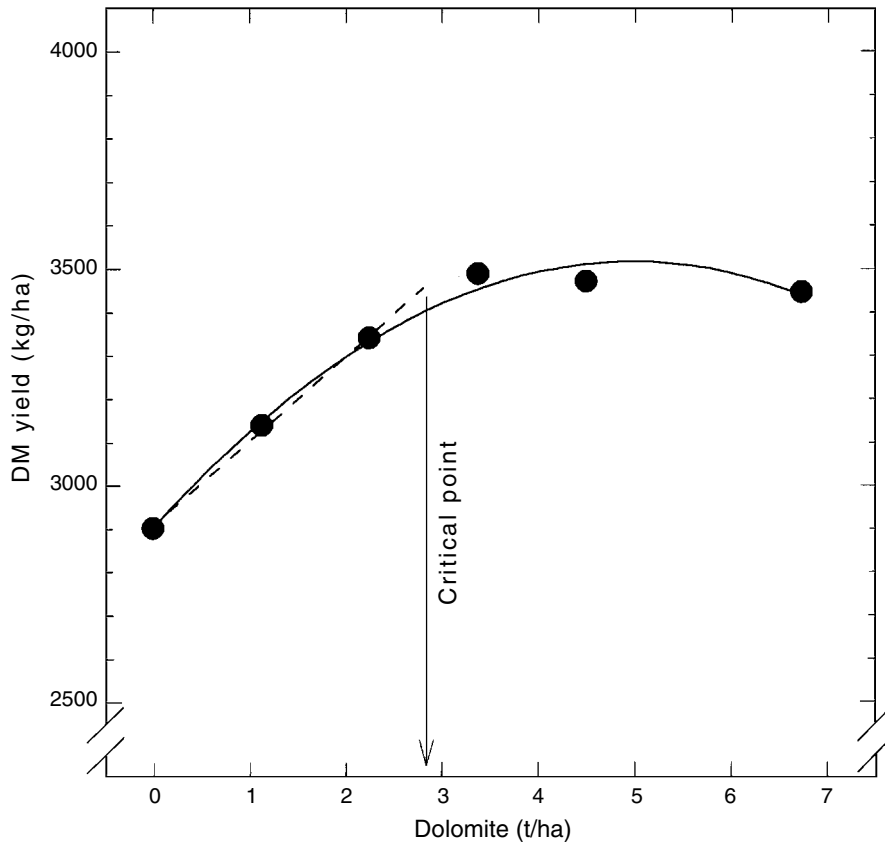
**Table 1.** Regression of concentrations of Ca, Mg, P and K in soil (1991–1994) and plant tissue (1992) at 6 dolomite rates (0–6.72 t/ha).

Element	Source	Year	Equation <sup>1</sup>	$r^2$ or $R^2$
Ca	Soil	mean <sup>2</sup>	$\text{mg/kg} = 207.3 + 124X$	0.94
Ca	Tissue	1992	$\text{g/kg} = 3.8 + 0.56X$	0.69
Mg	Soil	mean	$\text{mg/kg} = 19.2 + 23.7X$	0.93
Mg	Tissue	1992	$\text{g/kg} = 5.8 + 0.47X$	0.55
P	Soil	mean	$\text{mg/kg} = 5.7 - 0.35X + 0.15X^2$	0.77
P	Tissue	1992	mean 1.6 g/kg	
K	Soil	1993 <sup>3</sup>	$\text{mg/kg} = 63.6 - 9.46X + 0.73X^2$	0.72
K	Tissue	1992	$\text{g/kg} = 17.0 - 0.56X$	0.38

<sup>1</sup>X is dolomite (t/ha).

<sup>2</sup>Mean of 1991–1994.

<sup>3</sup>Dolomite did not affect soil K in other years.



**Figure 1.** Regression of Suerte dry matter yield (mean of eight 42-d regrowth intervals over 1992–1993) on rate of dolomite. Observed means = d, predicted kg/ha =  $2904 + 248.02X - 25.06X^2$ ,  $R^2 = 0.53$ . Plateau analysis (broken line) indicated yield increased (kg/ha =  $2909 + 196X$ ,  $r^2 = 0.40$ ) up to a critical point of 2.9 t/ha dolomite.

Forage yield was affected by dolomite rate in June (kg/ha =  $1181 + 634.7X - 66.10X^2$ ,  $R^2 = 0.71$ ) and July 1992 (kg/ha =  $3269 + 839.0X - 78.79X^2$ ,  $R^2 = 0.75$ ). Forage yield was not affected by dolomite rates on other dates. When averaged over all 8 sampling dates, dolomite affected ( $P = 0.003$ ) forage yield (Figure 1). Plateau analysis indicated that more than 2.9 t/ha of dolomite resulted in no further (significant) increase in yield. The increase in yield (2910–3470 kg/ha) represents an average 560 kg/ha for each 42-d sampling date interval. The relationship between soil pH and forage yield (kg/ha =  $1200 + 325X$ ,  $r^2 = 0.26$ ) was not strong. Sowing rates did not affect forage yield at any sampling date.

Ground cover from weeds on May 14, 1992 decreased as dolomite rate increased (cover % =  $68 - 22.5X + 2.25X^2$ ,  $R^2 = 0.53$ ). Weeds prevalent at low dolomite rates were acid-tolerant

*Dichanthelium* spp. and *Pterocaulon pycnostachyum*, both of which are common on native areas. Increasing the sowing rate decreased ground cover from weeds (cover % =  $43 - 3.5X$ ,  $r^2 = 0.30$ , where  $X = 5.6 - 20.5$  kg/ha PLS). This effect was independent of the effect of dolomite.

Dolomite rates had no effect on crude protein concentrations, which averaged 6.1% over 8 sampling dates. *In vitro* organic matter digestion increased slightly with dolomite rates (IVOMD% =  $53.6 + 0.65X$ ,  $r^2 = 0.28$ ) with an observed range of 54.7–57.6% for 0–6.7 t/ha dolomite, respectively. Both crude protein and IVOMD were also affected by sampling date, but date did not interact with dolomite rates. Sowing rates did not affect either crude protein or IVOMD, and there were no interactions with dolomite rates.

On November 4, 1991, which was 41 d after sowing, plant density increased from 35 to 48 plants/m<sup>2</sup> at 0–3.36 t/ha dolomite, then declined

at higher rates ( $\text{plants/m}^2 = 32.7 + 7.34X - 0.99X^2$ ,  $R^2 = 0.50$ ). On March 3, 1994, there was no difference in plant density over dolomite rates (mean = 33  $\text{plants/m}^2$ ).

Plant density increased linearly with sowing rate on November 4, 1991 ( $\text{plants/m}^2 = 18.6 + 1.7X$ ,  $r^2 = 0.51$ , where  $X = 5.6\text{--}20.5$  kg/ha PLS). Observed means were 28, 43 and 53  $\text{plants/m}^2$  at 5.6, 13.6 and 20.5 kg/ha PLS, respectively. On March 3, 1994, there was no effect of sowing rate on plant density (mean = 33  $\text{plants/m}^2$ ).

#### Experiment II

After the March sowing, plant density (averaged over sowing rates) increased linearly over the following 84-d period ( $\text{plants/m}^2 = 11.5 + 0.14X$ ,  $r^2 = 0.14$ , where  $X = 28\text{--}84$  days after sowing). Observed mean density increased from 14.5  $\text{plants/m}^2$  at 28 d to 22.1  $\text{plants/m}^2$  at 84 d. The increase in plant density with time after the March sowing was attributed to cool temperatures which resulted in slower, progressive germination.

At the May, July and September sowings, plant density did not change over the 84-d period and averaged 16.4, 5.3 and 1.6  $\text{plants/m}^2$ , respectively. Soil was very dry on July 1, and there was no rain for 1 week after sowing, during which time there was no germination. By July 31, plots were under water after 315 mm rain, and throughout August and early September, soil varied between water-logged and flooded. The September 1 sowing was postponed until September 20 because of flooded soil. Seedlings were beginning to emerge when 191 mm rain fell over 8 d (October 4–11). It seems that water-logged soil prevented germination or flooding killed many seedlings in both the July and September sowings.

Disregarding the July and September sowings, average plant density during the 84-d periods after sowing on March 1 and May 1, 1995 increased linearly over sowing rates ( $\text{plants/m}^2 = 7.9 + 2.7X$ ,  $r^2 = 0.48$ , where  $X = 1.5\text{--}6.0$  kg/ha PLS). Observed mean densities were 9.9, 18.1, 21.1 and 22.2  $\text{plants/m}^2$  for the 1.5, 3.0, 4.5 and 6.0 kg/ha PLS sowing rates. On August 12, 1996, plant density was affected by sowing rate ( $\text{plants/m}^2 = 6.4 + 1.2X$ ,  $r^2 = 0.56$ ).

Forage yield in June or July 1996 was the same for the March and May 1995 sowing dates. Yield from 35-d regrowth increased with increasing

sowing rates in June 1996 ( $\text{kg/ha} = 700 + 163X$ ,  $r^2 = 0.36$ ) and in July ( $\text{kg/ha} = 1700 + 322X$ ,  $r^2 = 0.38$ , where  $X = 1.5\text{--}6.0$  kg/ha PLS).

#### Experiment III

Germination decreased linearly from 65.0% (not including 11% dormant seed) with no flooding to 23.7% with 28-d flooding (germination % =  $71.0 - 1.8X$ ,  $r^2 = 0.77$ , where  $X = \text{days flooded}$ ). Spoiled seed increased linearly from 24.0% to 74.5% as duration of flooding increased from 0 to 28 d (spoiled % =  $20.8 + 2.1X$ ,  $r^2 = 0.81$ ). There was less than 1% germination during the flooding period, and seedlings that did germinate under water soon died.

## Discussion

### Dolomite rates

Suerte's response to dolomite can be viewed only as a collective response to several soil-related factors. The 4-year mean linear increase in pH observed here (0.2 pH units/t of dolomite) was a typical response for this Florida soil. It was the same as that observed from the addition of 0–6.6 t/ha  $\text{CaCO}_3$  on a Pomona fine sand (Rechcigl 1992) and was similar to a linear increase of 0.1 pH unit/t dolomite in an earlier study on a Pomona fine sand (Kalmbacher *et al.* 1992). Although soil pH increased with dolomite, the reduction in exchangeable soil  $\text{Al}^{3+}$  probably did not play a great part in Suerte's response. Without dolomite (pH 4.5), exchangeable  $\text{Al}^{3+}$  was about 18 mg/kg, which was low compared with 35.4 mg/kg in 0–15 cm of an unlimed Ona fine sand (sandy, siliceous, hyperthermic Typic Alaquod), a soil comparable with the Pomona fine sand used in the present study (Rechcigl *et al.* 1993). About 60%  $\text{Al}^{3+}$  saturation is generally considered detrimental to most tropical forage grasses (Kamprath 1984). Low ionic strength (estimated to be 2–3 mM; Rechcigl *et al.* 1993) and low organic carbon (ours was 17.0 g/kg) suggest that  $\text{Al}^{3+}$  would not be bound in the soil. It may have been coincidental that yield ceased to increase with more than 3.0 t/ha dolomite (pH 5.0 and  $\text{Al}^{3+} < 16$  mg/kg). Exchangeable soil Ca, Mg and P were affected by dolomite, but this alone probably had little to do with Suerte's response.

### Seeding rates

Sowing Suerte at 5.6–20.5 kg/ha PLS in Experiment I resulted in 28–53 plants/m<sup>2</sup> at 41 d after sowing, and had no effect on yield in the following year. Sowing bahiagrass (*Paspalum notatum*) from 5.6–50.4 kg/ha made only small contributions to yield (Gates and Mullahey 1997). Without interspecific competition, yield increases with plant density, then levels off or decreases due to self-thinning (Drew and Flewelling 1979 as cited by Pyke and Archer 1991). In Experiment II, where Suerte density was 10–22 plants/m<sup>2</sup>, yield increased linearly with increased density, suggesting a self-thinning density had not been attained.

Although seemingly high yields of Suerte can be obtained at low densities, it may not be advisable for pasture. At 4 plants/m<sup>2</sup> and a 40-d cutting interval so that Suerte achieved nearly 100% ground cover, yield averaged 2180 kg/ha (Kalmbacher *et al.* 1997a). At 13.5 plants/m<sup>2</sup> with 60–75% ground cover, presentation yield of Suerte grazed by 6.6 steers/ha averaged 2720 kg/ha (Kalmbacher *et al.* 1997b). However, low sowing rates that result in 4–13 plants/m<sup>2</sup> increase the probability of undesirable plants coming into a sward, especially if overgrazed. Grasses that spread vegetatively can be sown at low rates (Stanley 1990), but Suerte sown at low rates will not fill in interplant spaces. Larger Suerte plants resulting from low density would be more susceptible to overgrazing than smaller plants characteristic of high density stands.

The sowing rates in Experiment I and Experiment II (1.5, 3.0, 4.5, 5.6, 6.0, 13.6 and 20.5 kg/ha PLS) could result in about 60 (19%), 130 (17%), 170 (13%), 210 (14%), 220 (10%), 500 (9%) and 760 (7%) plants/m<sup>2</sup> with  $3.7 \times 10^5$  PLS/kg. The numbers in parenthesis indicate Suerte plants we observed as a percentage of potential plants. Each 1 kg/ha PLS increase in sowing rate resulted in 1.7 and 2.7 plants/m<sup>2</sup> in Experiments I and II, respectively. While our percentages seem low, they reflect losses that occur in a difficult environment. Rickert (1974) observed 4 and 9% field emergence after 21 d in 2 experiments with no mulch under rainfed conditions with green panic (*Panicum maximum*) that had 41.5% germinability. High sowing rates (11–22 kg/ha; 400–800 seed/m<sup>2</sup>) are recommended for bahiagrass in the south-eastern USA (Stephens and Marchant 1960; Ball *et al.* 1991 as

cited by Gates and Mullahey 1997). Since most Florida pastures are sown by broadcasting seed on to a prepared seedbed, we consider plant densities resulting from the low sowing rate in Experiment I (5.6 kg/ha PLS = 28 plants/m<sup>2</sup>) or the high rate in Experiment II (6.0 kg/ha PLS = 24 plants/m<sup>2</sup>) appropriate broadcast-sowing rates for pasture.

Suerte is well adapted to seasonally water-logged soil. However, based on the stand failures due to water-logged soil at the July and September sowings in Experiment II and on the decline in seed germination due to flooding in petri dishes in Experiment III, this may not apply to seeds and seedlings. Soil in central and south Florida can change quickly from a dry to a water-logged condition at any time of the year, except perhaps in April and May, which is the dry season. As indicated by Experiment II, sowing between March and June may have less risk of flooding compared with sowing between July and September.

### Conclusions

Suerte yield and plant density increased with addition of up to about 3 t/ha dolomite on a Pomona fine sand with initial pH of 4.5 and exchangeable Al<sup>3+</sup> of 18 mg/kg. Concentrations of Ca and Mg in Suerte tissue and IVOMD increased with increasing rate of dolomite, while tissue K decreased. Broadcast-sowing 6.0 kg/ha PLS resulted in about 25 plants/m<sup>2</sup>. Suerte failed to establish in soil that became water-logged or flooded within 28 d of sowing 1.5–6.0 kg/ha PLS. Suerte germination declined about 2% for every day it remained flooded in petri dishes. It is recommended that Suerte be sown at 6.0 kg/ha PLS in sandy soil limed to pH 5.0. This recommendation applies to broadcast-sowing, not drilling. In south and central Florida where water-logged soil occurs, sowing in March, (April and May are usually too dry), late May through June, or after mid-September may reduce the risk of stand failure due to water-logged soil.

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