FLORIDA NATIVE TURFGRASS INVESTIGATION II

Final Report to the Florida Department of Transportation

Contract No. BC-354, University Project Number 99041213

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Doria R. Gordon, Amy A. Miller, Michael T. Renda, Jodi L. Slapcinsky, and David A. Jones

Department of Botany, University of Florida
and
The Nature Conservancy, Hobe Sound, Florida

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NOTICE:

Since we completed this research and report, we have learned that some researchers suspect that *Paspalum vaginatum* is not native to Florida. The genetic research needed to evaluate this hypothesis has not yet been conducted. However, we wish to caution readers that we do not know whether the coarse-leaved *P. vaginatum* ecotype is indeed a native substitute for non-native turfgrasses. We suggest that this species be used only experimentally until the origin can be identified. We apologize for the confusion that this clarification causes.

Doria Gordon, Amy Miller, and Michael Renda, The Nature Conservancy 2002

Project Summary

Florida DOT has committed to increasing the use of native plant species along rights-of-way (FDOT 1983). Typically, non-native turfgrasses are commonly planted along highways, as well as in retention ponds and lawns, for soil stabilization and landscaping purposes. This research was designed to identify and examine native species that might be as effective in areas of special concern. Such areas include natural lands where non-native species are not desirable. If native species are planted in areas that border native communities, particularly those designated as conservation areas, land managers would reduce costs in the control of some non-native, invasive sod species in natural areas. For example, managers are controlling St. Augustine grass (*Stenotaphrum secundatum*) in scrub and coastal strand communities (Dick Roberts, DEP, Hobe Sound, FL, pers. comm.).

Vegetative communities in inland and coastal areas of the state vary in their salt exposure and salt-tolerance (Johnson et al. 1990). Therefore, we selected an inland and coastal site for our tests of salt-intolerant and salt-tolerant species, respectively (Figure 1). The Disney Wilderness Preserve (DWP), the inland site, is comprised of wetland, flatwoods and scrub communities, and neutral to acidic soils. Blowing Rocks Preserve (BRP) has halophytic vegetation, alkaline soils and frequent saltwater spray from the adjacent Atlantic Ocean. Both preserves are owned and managed by The Nature Conservancy (TNC).

We endeavored to address two objectives, both continuing the work started under Contract No. BB-533. Objective 1 continued our research into the potential turf development of native inland flatwoods grasses. Objective 2 developed recommendations from this research for the use of native turfgrasses in roadside revegetation and for future research needs. Since we were also continuing to collect data on the experiments established on native coastal grasses as well, we divided Objective 2 into two sections. The first, Objective 2a, integrates the additional year of data for Experiments A, B, and C of Contract BB-533 with the original two years of data, updating our final report (Gordon et al. 2000b). The second, Objective 2b, includes recommendations as described in the original Objective 2.

When Contract BB-533 was initiated in 1998, minimal research and implementation on the potential for developing native turfgrasses existed in Florida. While two native Florida grass species, within the same genus as bahiagrass, seashore paspalum (*Paspalum vaginatum*) and knotgrass (*Paspalum distichum*), are cultivated and planted in other states and countries (Malcolm and Lang 1969, Wong et al. 1983, Duncan 1996), neither are utilized by FDOT. Today, two native Florida grasses, *P. vaginatum* and *Sporobolus virginicus,* are commercially available as sod and planted in a few locations around the state.

We developed several conclusions about the potential for using native grasses in situations where turfgrass is desired, some of which are highlighted below:

- *Paspalum vaginatum* and *S. virginicus* are coastal species that have potential for use as native turfgrass.

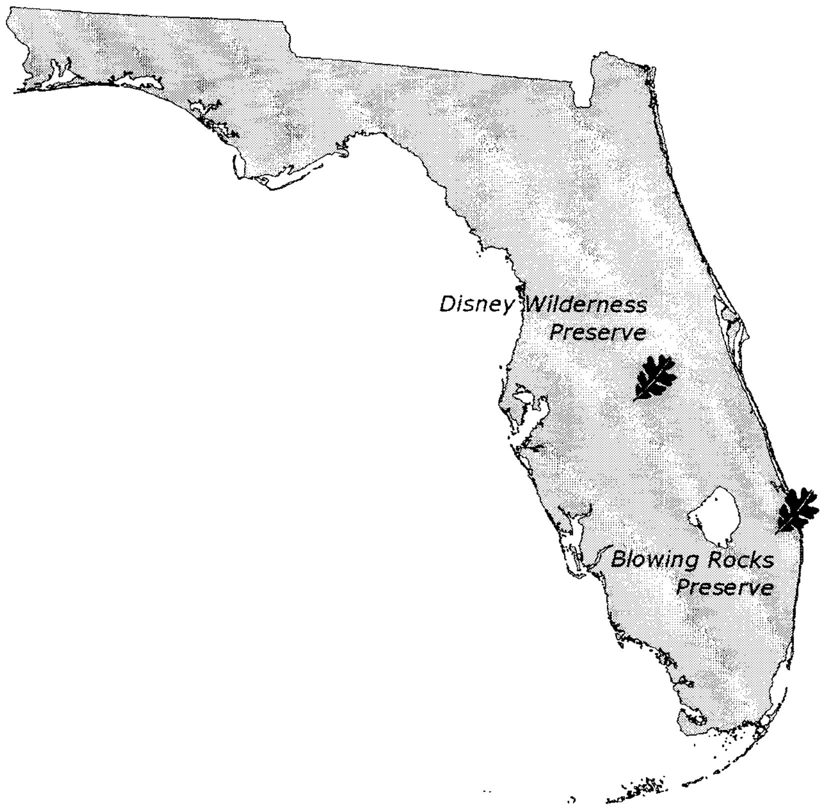

Figure 1. State of Florida map with the two project site locations: Blowing Rocks Preserve, Martin County, and Disney Wilderness Preserve, Polk and Osceola Counties.

Both are promising candidates when planted as sod. *S. virginicus* may not require mowing, while *P. vaginatum* would need regular mowing to maintain dense growth and be within FDOT standards for roadside grass heights. Both species have acceptable green color during the growing season. *P. vaginatum* tends to turn brown in the dry, winter season.

Retention of color during the dry, winter months and a low-growth form suggests that *S. virginicus* is the more promising of the two species for use on saline rights-of-way.

Both species also developed well when planted as sprigs or plugs. Vegetative cover from plugs was initially higher, however over time the cover converged despite differences in mortality.

- For inland flatwoods and prairie conditions, *P. distichum* has promising potential as a turfgrass.

  Irrigated sprigs were successful in two experiments and did not suffer from the effects of being planted on a roadside. *Paspalum distichum* should also be explored for sod development.

- *Eustachys petraea* is another inland species with turfgrass potential and is among several other species that should be further investigated.

  Eustachys petraea and *Eragrostis refracta* established well when directly seeded into plots in the pasture experiment. In the roadside experiment, *E. petraea* produced very high cover when directly seeded and was not negatively impacted by roadside conditions. However, *E. petraea* started turning brown in September 2000. We do not know whether this was premature initiation of winter dormancy because of the drought, or if this species has a shorter green period than would be desirable for aesthetic reasons.

  Eragrostis refracta did not establish as well on the roadside, perhaps because of the timing of sowing. Although *Panicum anceps* and *Paspalum setaceum* did not germinate sufficiently in the pasture plots to produce good cover, they had the highest germination of the seeded species in the shadehouse and could still have good potential as turfgrasses if better methods of direct seeding were researched.

  Because of low germination rates of most species, we recommend the relatively high sowing rates of 20-30 lbs seed/acre unless methods for enhancing germination are developed.

- Planting sod appears to be the most successful method for establishing native species as turf, particularly where other aggressive species are already present.

  Paspalum vaginatum and *Sporobolus virginicus* are salt-tolerant species now currently grown commercially as sod. Currently there are no salt-intolerant species grown commercially as sod. *Paspalum distichum*, already available as plugs, may be the easiest new species to develop for commercial sod production.

- Site preparation is an essential step in revegetating roadsides and establishing native turfgrasses when a seedbank may be present. Frequent and lengthy site preparation can reduce the seedbank of undesirable, non-planted species from competing with planted species.

  We observed a decrease in non-planted species and higher success of planted species in the two experiments where site preparation was conducted for longer periods of time and with more frequent disking and herbicide application.

However, leaving bare soil exposed adjacent to road edges may not be feasible because of erosion concerns. More effective pre-emergent herbicide applications may be necessary in those situations.

- Extensive seed preparation efforts appear unnecessary for most of the native species.

  In the seed germination trials, *Panicum anceps* and *Paspalum setaceum* had high germination percentages. Most species did not show increased germination after pre-germination treatment, except for *P. setaceum,* which showed increased seed germination when treated with sulfuric acid.

Acknowledgements

Many people around the state assisted with this research, and we are grateful for their expertise. Staff of The Nature Conservancy's Blowing Rocks Preserve, Disney Wilderness Preserve, the Florida Chapter, and the Gainesville offices have helped tremendously on this project. These include: Teri Jabour, Bruce Beh, Linda Finch, Ralph Johnson, Chris Bason, Bob Nelson, Krisann Kosel, Jon White, Sandy Woiak, Laura Butterfield, Rob Dent, Jean McCollom, Mike Duever, Alba Castrillon, Laura Robinson, and Bridgette Clements. Nancy Bissett also provided invaluable assistance. Volunteers donated 1044 hours of time to the project. They are too numerous to name but we appreciate their dedicated hard work. We also thank Dr. Sherlie West, Dr. Betsy Lamb, and Judy Gersony at the University of Florida Institute of Food and Agricultural Sciences for their help in facilitating the seed viability testing and seed treatments. Sharon Pfaff and Mary Anne Gunter at the USDA Plant Materials Lab in Brooksville, Florida assisted us with seed cleaning techniques. Jim Anderson of Anderson Nurseries in Ruskin, FL donated one palette of *P. vaginatum* sod and provided expertise on sod installation and maintenance. Finally, we thank FDOT for their assistance and support, especially Gary Henry and Jeff Caster. This work was funded by Contracts No. BB-533 and BC-354 to D.A. Jones and D.R. Gordon.

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<u>Disney Wilderness Preserve (DWP) resource description</u>

Location and setting

The Disney Wilderness Preserve is a 11,846 acre off-site wetland mitigation project owned and managed by TNC. The preserve is located on the north side of Lake Hatchineha, at the base of the Reedy Creek/Lake Marion Creek watershed in Osceola and Polk Counties in central Florida. The nearest metropolitan area is Kissimmee, located approximately 12 miles north. Land use surrounding the preserve varies from a large, rapidly growing residential community to agricultural land to lake frontage. See descriptions of climate, soils, and native community types in our final report on Contract No. BB-533 (Gordon et al. 2000b).

The objectives of the DWP project are identified in detail in the documents "A Management Plan for Walker Ranch" (The Nature Conservancy 1992a) and "Walker Ranch Wetland Mitigation Program" (The Nature Conservancy 1992b).

Experiment A. Investigate the effects of several cultural treatments on turf establishment and cover by several native grass species in mesic and wet flatwoods habitats.

<u>Introduction</u>

This experiment investigates the potential of native grasses to develop turf or continuous cover. In some situations native grasses may be more desirable than commonly used, often persistent and invasive, non-native turfgrasses. This experiment continued our efforts to evaluate several inland native grasses for their turf-forming potential and for growth and establishment under different management treatments. The research was conducted at TNC's Disney Wilderness Preserve (DWP).

Through literature investigation, field identification, advice from experts like Nancy Bissett (The Natives, Davenport, FL) and the availability of seed, five species were chosen for study in the inland experiments at DWP: *Eragrostis refracta; Panicum portoricense; Panicum anceps; Axonopus furcatus;* and *Paspalum distichum.* These species are native to central Florida, DWP and pine flatwoods. Many of them were growing along roads near DWP, making them prime candidates for use. Some of these species are also commercially available. These five species were selected for Experiment D of the Florida Native Turfgrass Investigation (Contract BB-533, see Gordon et al. 2000b). This experiment was implemented in June 1998 but was discontinued following the serious drought that summer. No germination of sown species was ever recorded and we saw high mortality in the *P. distichum* sprigs. Because the unusually dry summer resulted in germination and growth that was not likely indicative of performance during a more normal year, we recommended that the project be repeated (see Gordon et al. 2000b).

Under the current contract, Experiment A was initiated as a repeat of the terminated experiment. Planting and sowing occurred in February 1999 to correspond with the timing of natural seedfall and germination (Nancy Bissett, pers. comm.). Because seed were collected in the fall, we substituted some of the species used in the first experiment with species that we hypothesized were better candidates for roadside growth (Table 1). We substituted *Paspalum setaceum* and *Eustachys petraea* for *Axonopus furcatus* and *Panicum portoricense* (from Experiment D of Contract BB-533). The substituted species have been observed to withstand roadside conditions (Nancy Bissett, pers. comm.) but were not available as seed in 1998. We again sowed *Panicum anceps* and *Eragrostis refracta*, and planted sprigs of *Paspalum distichum* as no seed was available. Repeating this experiment also enabled us to complete more extensive site preparation prior to sowing.

Table 1. Species included in the investigation of inland flatwoods grasses.

Species	Growth Habit and Characteristics	Commercial Availability
Panicum anceps Beaked panicum	• clumping grass, low growing • drought tolerant • bright green color	• can be contract-grown if seed are provided (The Natives, Davenport, FL)
Eragrostis refracta Coastal lovegrass	• clumping grass • attractive flowering stalk	• can be contract-grown if seed are provided (The Natives, Davenport, FL)
Paspalum distichum Knotgrass	• spreads by rhizome, fairly rapidly • forms dense mats • bright green color	• available as plugs or sprigs in the central Florida area (Horticultural Systems Inc., Parish, FL)
Paspalum setaceum Thin paspalum	• low-growing, clumping grass • found on roadsides around DWP	• not commercially available at this time
Eustachys petraea Pinewoods fingergrass	• spreads by rhizome, fairly rapidly • found on roadsides with high cover all over Central and S. Florida, including I-95 and The Florida Turnpike • light bluish-green color	• not commercially available at this time

The species were sown under a variety of cultural treatments across a hydrological gradient within bahiagrass pasture at DWP. The pastures are analogous to roadsides in that planted species must successfully compete with undesirable species. As a result, the experiment included investigation of management methods to reduce competition with non-planted species. We also tested whether irrigation would enhance establishment of the species planted.

Methods

Site Selection

The fenced sites used in Experiment D of Contract BB-533 (see Gordon et al. 2000b) were again used in this experiment. Three sites in pastures on the preserve were selected in 1998. The sites are located roughly 100 m from three of the existing upland restoration plots in pastures at DWP (see Contract no. BA-523; Gordon et al. 2000a). Utilizing the well data from 1997 in these six sites, we selected the wettest, driest, and an intermediate site for this experiment. The sites are referred to as: Stump Pasture, Visitor Center, and Work Center, respectively. Pasture history and soils have been previously described for these sites (The Nature Conservancy 1996). The sites varied slightly in species composition but essentially were all improved bahiagrass pastures.

Site Preparation

Much of the following site preparation and experimental set-up for this experiment was completed in 1998, before the first trial. Three plots, 25 x 50 m (1250 m^2; 82 x 164 ft), were marked and treated with herbicide (3% Roundup Super Concentrate®). Due to heavy rainfall, the initial application of herbicide in two of the plots (Work Center and Visitor Center) was only mildly effective. These two plots were treated again two weeks later. The plots were then disked at a depth of 15 - 25 cm (6-10 inches) with a disk harrow pulled behind a tractor. Previous upland restoration research suggests that multiple treatments of both herbicide and disking are most effective in removing bahiagrass (The Nature Conservancy 1996, Gordon et al. 2000a).

In 1998 clumps of dead bahiagrass remained on the soil surface after repeated disking of the sites. These clumps were further fragmented using a rotovator pulled behind a tractor. The sites were disked again six to nine more times. All of the dead bahiagrass pieces were removed from the plots with garden rakes to leave a relatively smooth planting surface. Hog and barbed wire fences were constructed around each site to prevent cattle and feral hog damage to the plots.

When the first experiment was terminated in August 1998, all three sites (Stump Pasture, Visitor Center, and Work Center) were again treated with herbicide (3% Roundup Super Concentrate®) to eliminate weeds. Two weeks after the treatment the sites were disked twice. After five weeks the sites were disked twice and rolled to reduce the furrows caused by the disking. The roller weighed approximately 215 lbs. This step was included to decrease disturbance caused by soil preparation prior to sowing, such as raking. At the end of December, spot treatment of Roundup® herbicide was applied to control the remaining weeds. The mounds of soil that remained from disking were raked smooth. A final broadcast application of Roundup® was applied on January 26, 1999 because weeds (primarily *Cyperus* spp.) persisted.

Experimental Design

Experiment A is a split plot design with the main split on irrigation. Irrigated plots were watered every third day for a month following the onset of summer rains; non-irrigated plots received no supplemental water. Sixty sub-plots were located within each of the split plots. Sub-plots were 1 x 1 m (3.3 x 3.3 ft) with a 1-m buffer separating each from adjacent sub-plots. These sub-plots supported factorial combinations of the five species (*Eragrostis refracta*, *Eustachys petraea*, *Panicum anceps*, *Paspalum setaceum* and *Paspalum distichum*), three weed control (hand weeding, application of 3% Roundup® herbicide, or 0.05% Plateau® herbicide), two fertilization (none and twice a year), and two mowing (none and once a month starting in the third month of growth) treatments (5 species x 2 irrigation x 3 weed control x 2 mowing x 2 fertilizer = 120 sub-plots per site). Placement of the treatments was randomized among the sub-plots within each half of the site.

The Roundup® treatment killed the remaining weeds and potentially killed weed seeds at the soil surface. However, this herbicide can inhibit seed germination of some native species (J. Norcini, University of Florida, Monticello, FL, pers. comm.). Plateau® is being tested in uplands and is marketed to target fast-growing pioneer species (mainly weedy or non-native species) and kill them both as a contact herbicide and as a pre-emergent on the seeds. A two-ounce per acre concentration controls *Cyperus* spp. (N. Bissett, pers. comm.), and was used in this experiment. These treatments all occurred the week before planting and sowing to minimize disruption and fatality of seed and sprigs used in the experiment. (See the *Flatwoods Seed Experiment* (Gordon et al. 2000b) for an evaluation of herbicide effects on seed germination.).

Planting and sowing

Seeds of all species to be direct-seeded, except *E. petraea* were hand-collected at DWP. *Eustachys petraea* seed was collected along Pleasant Hill Road on the northern boundary of DWP. All seed was collected in November and December of 1998. Volunteers cleaned the seeds by stripping them off the stalks and removing the chaff. This effort ensured that each sub-plot contained an equal amount of seed by weight.

Due to the low germination percentages observed in our previous trials with *E. refracta* and *P. anceps*, the amount of seed used in this experiment was increased from 3.6 kg/ac (8 lb/ac) (used in Experiment D of Contract BB-523) to 9.08 kg/ac (20 lb/ac). This amount is the upper limit of the sowing density recommended for native seed (Harper-Lore 1998), and resulted in the sowing of 2.24 g (0.005 lb) of seed per 1 m^2 sub-plot.

Shadehouse germination tests were conducted in 1998 and 1999 for all sown species. Two hundred seeds of each species were sown in flats in the nursery at BRP. These flats were placed in the shadehouse and irrigated twice daily. Trial results showed variable, but positive germinability of all the species (Table 2).

Planting occurred on February 27, 1999 with the assistance of 28 volunteers (Figure 2). The sub-plots of the four seeded species were prepared by raking the plots to create small grooves for the seeds. Seed was then evenly sown by hand throughout each 1 m^2 sub-plot and rolled into the soil with a 68 kg (150 lb) hand roller (Figure 3). Rolling after sowing increases seed germination rates (Gordon et al. 2000a). This sowing procedure also mimics the action of a seeder used by FDOT. The FDOT seeder drops the seed between soil grooves that it creates, and then follows with a roller to press the seeds into the soil.

Table 2. Germinability of seed from DWP in flats of soil in the shade house at BRP with daily irrigation.

Species	Percent Germination	Year
Panicum anceps	24	1998
Eragrostis refracta	6.6	1998
Paspalum setaceum	12	1999
Eustachys petraea	67	1999

Although *Paspalum distichum* was located at two sites on the preserve, it was not flowering and seed collection was not possible. As before (Gordon et al. 2000b) sprigs were purchased (Horticultural Systems, Parish, FL), cut to 10 cm (4 in.) pieces with no fewer than three nodes each, and stored in water. Sprigs were planted by volunteers with hand trowels on the third day post-harvest. At least 50% of each sprig was buried horizontally under the soil to increase soil contact with the nodes. Having found high sprig mortality in the 1998 trial (mean=87.6%), we increased the planting density from six-inch centers (36 sprigs/plot) in 1998, to five-inch centers (64 sprigs/plot) in 1999. Because of low rainfall, we watered the sprigs with 0.76 cm (0.3 in.) of water every forth day for ten weeks. Watering occurred with a gas powered pump and water tank.

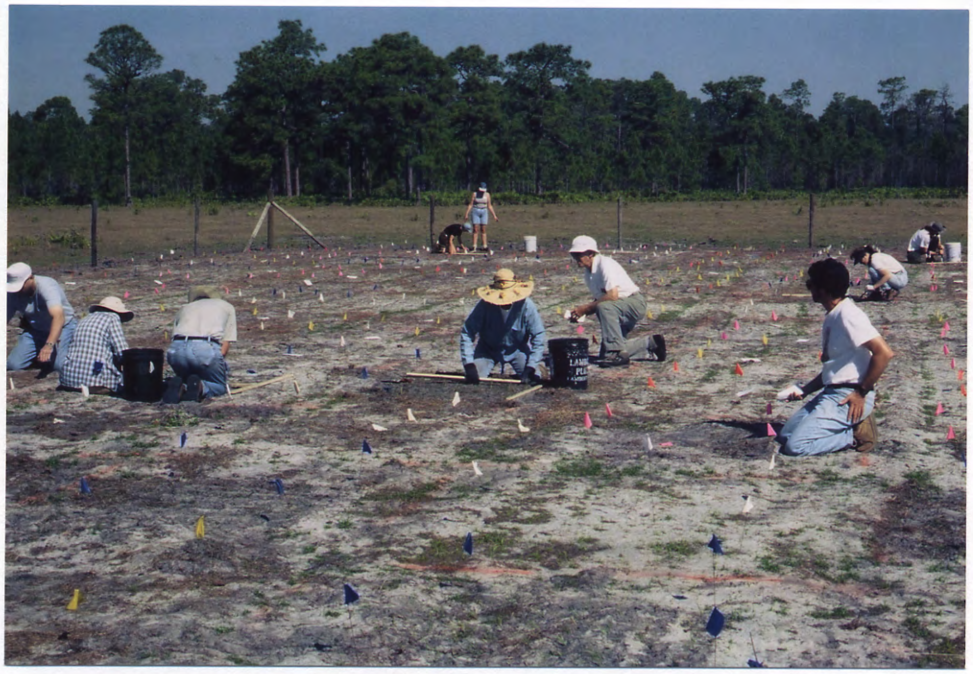

Figure 2. Volunteers sow seed and sprigs in the sub-plots. Flag color indicates the species sown.

Cultural Treatments

Irrigation of the watered-half of each site began on June 21, 1999 and continued every third day for four weeks. The designated half of each site received 0.30 inches (0.76 cm) of water per irrigation session using overhead sprinklers attached to a tractor and gas-powered water pump. The mowing treatment was initiated in June and accomplished with a spin trimmer. The specified sub-plots were mowed on a monthly basis according to FDOT standards (FDOT 1990). Fertilizer treatment was initiated in Spring 1999 and applied every spring and fall thereafter. FDOT uses fertilizer made by Howard Fertilizer Company (Orlando, Florida) composed of 12-8-8 (N, P, K). This fertilizer was selected under the nitrogen application recommendation in Duncan (1997). The Howard Fertilizer Company donated 400 lbs of this fertilizer for the research. The same fertilizer was used in all experiments with a fertilizer treatment. At each application, 90 grams of the fertilizer was applied to each specified plot.

Figure 3. Hand-rollers filled with water were rolled over the plots following sowing to increase seed contact with the soil.

Monitoring

Monitoring of the plots began in April and was conducted monthly for the first seven months and then bimonthly through November 2000. Percent cover within four cover categories (sown species, non-planted species, bare soil, and litter) was ocularly estimated using Daubenmire Cover Classes (Bonham 1989). Maximum height of vegetation in each sub-plot was also recorded. Percent mortality was recorded for the *P. distichum* sprig sub-plots after one month.

Plateau® Herbicide

Weeds continued to germinate and compete with seedlings and sprigs after planting (A. Miller, pers. obs.). Plateau® herbicide (0.05%) was applied to the areas around the sub-plots to reduce weed germination. Through this application we were able to make observations about species controlled by this herbicide at the rate applied (Gordon et al. 2000b, Table 3): 1) the Plateau® primarily controlled non-native or weedy native species, with the exception of the non-native *Panicum repens* (torpedo grass), and 2) two grasses not impacted, *Paspalum laeve* and *Panicum portoricense,* are desirable flatwoods species, while *Chamaecrista fasciculata* is considered ruderal (Wunderlin 1998). Since weedy species such as *Cyperus* spp. tend to invade first in plots of this nature, Plateau® may be important for site preparation. This herbicide has great potential for future use on roadsides that are being revegetated with native grasses. An added benefit of Plateau® is that it also appears to have pre-emergent effects on seeds of the same species that it kills as a contact herbicide (A. Miller, pers. obs.).

Table 3. Species that were and were not controlled by 0.05% Plateau® herbicide within the three pasture plots (from Gordon et al. 2000b).

Species controlled by Plateau®	**Species not controlled by Plateau®**
Scoparia dulcis	*Paspalum laeve*
Digitaria serotina	*Panicum portoricense*
Digitaria ciliaris	*Chamaecrista fasciculata*
Cyperus spp.	*Panicum repens* *
Paspalum notatum *	
Axonopus affinis (syn. *A. fissifolius)*	

* not-native to Florida according to Wunderlin (1998)

Data Analysis

Analysis of variance for a split plot design was used to compare the treatment effects on sprig mortality, and cover of sown species, non-planted species, bare soil, and litter. We compared the effects of the irrigation, non-planted species control, mowing, pasture site (block) and species treatments on cover of planted species, non-planted species, bare soil and litter over time using repeated measures analysis of variance. Analyses included all the main and interactive effects of the treatments. Sown and sprigged plots were analyzed separately, so the among-species comparison was made for sown plots only.

All cover data were arcsine square root transformed to increase consistency with the assumptions of parametric statistics. While the cover data remained skewed after the transformation, the analysis is relatively robust to non-normally distributed data (Kirk 1982). The sprig mortality data did not require transformation. Poor germination caused small sample sizes for *P. setaceum*, *P. anceps* and for all sown species at the Work Center site. The analyses for seeded species presented exclude those species and that site (Table 4, Gordon et al. 2000b). This exclusion reduces the power of the site test and results in species comparisons of only two sown species. We have presented the raw data for all sites and species in the figures below.

Table 4. Percent of sub-plots with germination of sown species by site in September 2000.

Plot	Species	Percent of Sub-Plots with Germination
Stump Pasture	*Eustachys petraea*	87.5
	Eragrostis refracta	100.0
	Panicum anceps	16.6
	Paspalum setaceum	0
Visitor Center	*Eustachys petraea*	33.3
	Eragrostis refracta	58.3
	Panicum anceps	8.3
	Paspalum setaceum	4.2
Work Center	*Eustachys petraea*	4.2
	Eragrostis refracta	0
	Panicum anceps	0
	Paspalum setaceum	0

We were able to compare mortality and cover changes in *P. distichum* over the two years of the two experiments. Analysis of variance was used to examine site and year effects on sprig mortality. These data were included in Gordon et al. (2000b) and are presented again for clarity.

Results

Sprig mortality

Sprig mortality was higher in 1998 than in 1999 ($F=78.6$, $df=1$, $p<0.0001$), where it averaged between 50% and 70% across the blocks. Mortality varied significantly by pasture ($F=6.33$, $df=69$, $p=0.003$), with a site by year interaction ($F=5.49$, $df=2$, $p=0.005$). Mortality was higher at the Work Center than at the Visitor Center block (Tukey $p<0.05$); mortality in the Stump Pasture did not differ from that at either of the other sites (see Figure 34 in Gordon et al. 2000b).

Percent cover - sprigged sub-plots

Planted species

Results of the repeated measures analysis of variance indicate that percent cover of *P. distichum* within the sprigged sub-plots was only significantly influenced by site (Table 5). With the exception of the first month, the Stump Pasture consistently had the highest percent cover of *P. distichum* in every month monitored (Figure 4). Although not significant ($p<0.3362$), the hand weeded sub-plots tended to demonstrate the highest percent *P. distichum* cover of the three weed control treatments in the Stump Pasture and the Work Center during most months (Figure 4a, c).

In the Visitor Center, the Plateau® treated sub-plots tended to have the highest percent cover of *P. distichum* over time, but this response was not significant (Figure 4b).

Table 5. P-values of Wilks' Lambda from repeated measures analysis of cover of *P. distichum*, non-planted species, bare soil, and litter for all sprig sub-plots from April 1999 through November 2000. Significant ($p<0.05$) and near significant ($p<0.07$) effects are bolded. Factors where no significant P-values were found for any cover category were omitted.

		P-Value			
Factor	**df**	**Planted species**	**Non-planted species**	**Soil**	**Litter**
Herbicide	22	0.3362	**0.0072**	0.1105	**0.0002**
Site	11	**0.0001**	**0.0001**	**0.0012**	**0.0001**
Site x Herbicide	22	0.6226	**0.0110**	0.0843	**0.0009**
Irrigation x Herb	22	0.5122	0.4942	0.7435	0.0915
Herb x Mow	22	0.7095	0.7566	0.2628	**0.0538**
Site x Mow	11	0.2320	0.5100	0.4368	**0.0219**

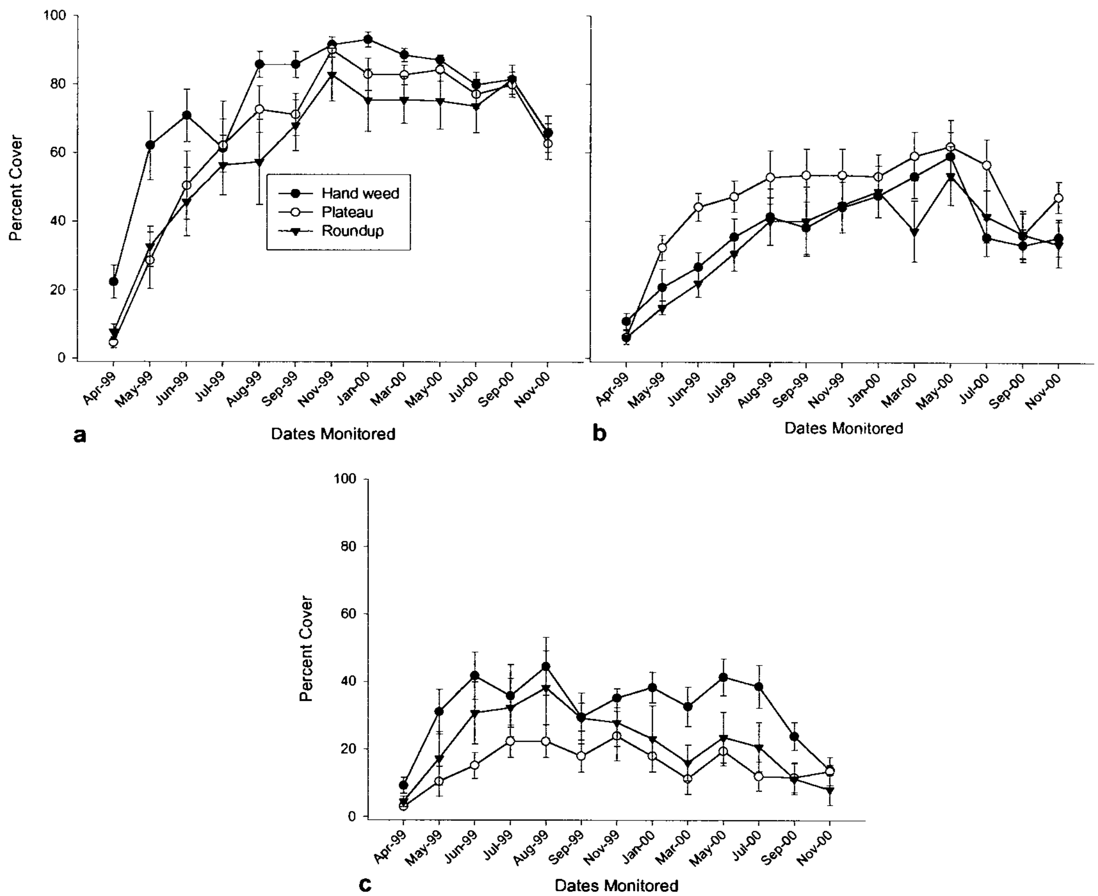

Figure 4. Mean percent cover (± 1 SE, n=8) of *P. distichum* sub-plots in the (a) Stump Pasture, (b)Visitor Center, and (c)Work Center sites from April 1999 through November 2000.

Non-planted species

Percent cover of non-planted species in *P. distichum* sprigged sub-plots was significantly affected by the herbicide treatment, site, and their interaction (Table 5). For all months monitored, the consistently dry Visitor Center had a significantly higher percentage of non-planted species in the sprigged plots than did the wetter Stump Pasture, which had the lowest percentage of non-planted species overall (Figure 5a, b). The Work Center showed a steady increase of non-planted species over time (Figure 5c). The herbicide treatment had a significant effect on cover of non-planted species over time but none of the three treatments were consistently and significantly most effective in decreasing non-planted species (Figure 5). In the Stump Pasture and the Work Center the three weed control treatments resulted in similar covers of non-planted species over time, while in the Visitor Center, which had the highest percentage of non-planted species, the treatment effects were temporally variable (Figure 5). The Stump Pasture and Work Center sites showed significant decreases in non-planted species cover in November 2000, probably because of dry weather (see Appendix B, Figure B-1) and winter dormancy (Figure 5).

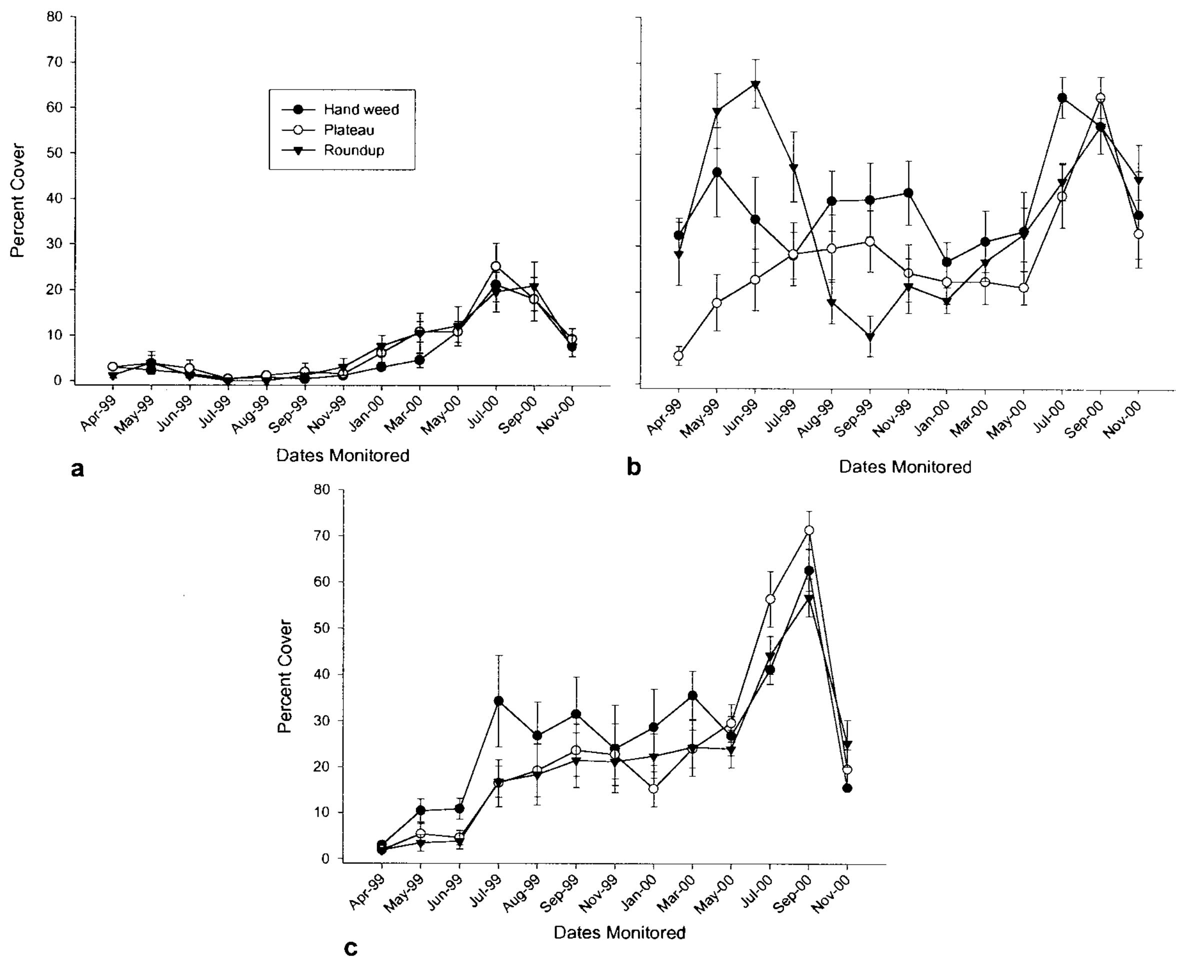

Figure 5. Mean percent cover (± 1 SE, n=24) of non-planted species in sprigged *P. distichum* sub-plots in the (a) Stump Pasture, (b) Visitor Center, and (c) Work Center sites.

Soil

Soil cover within the sprigged sub-plots was only significantly influenced by site over time (Table 5). Of the two sites analyzed, the Stump Pasture had the significantly highest percentage of bare soil each month until July 1999, when the bare soil at the Visitor Center increased and was highest from March through September 2000 (Figure 6a, b). In all three sites, bare soil decreased over time (Figure 6).

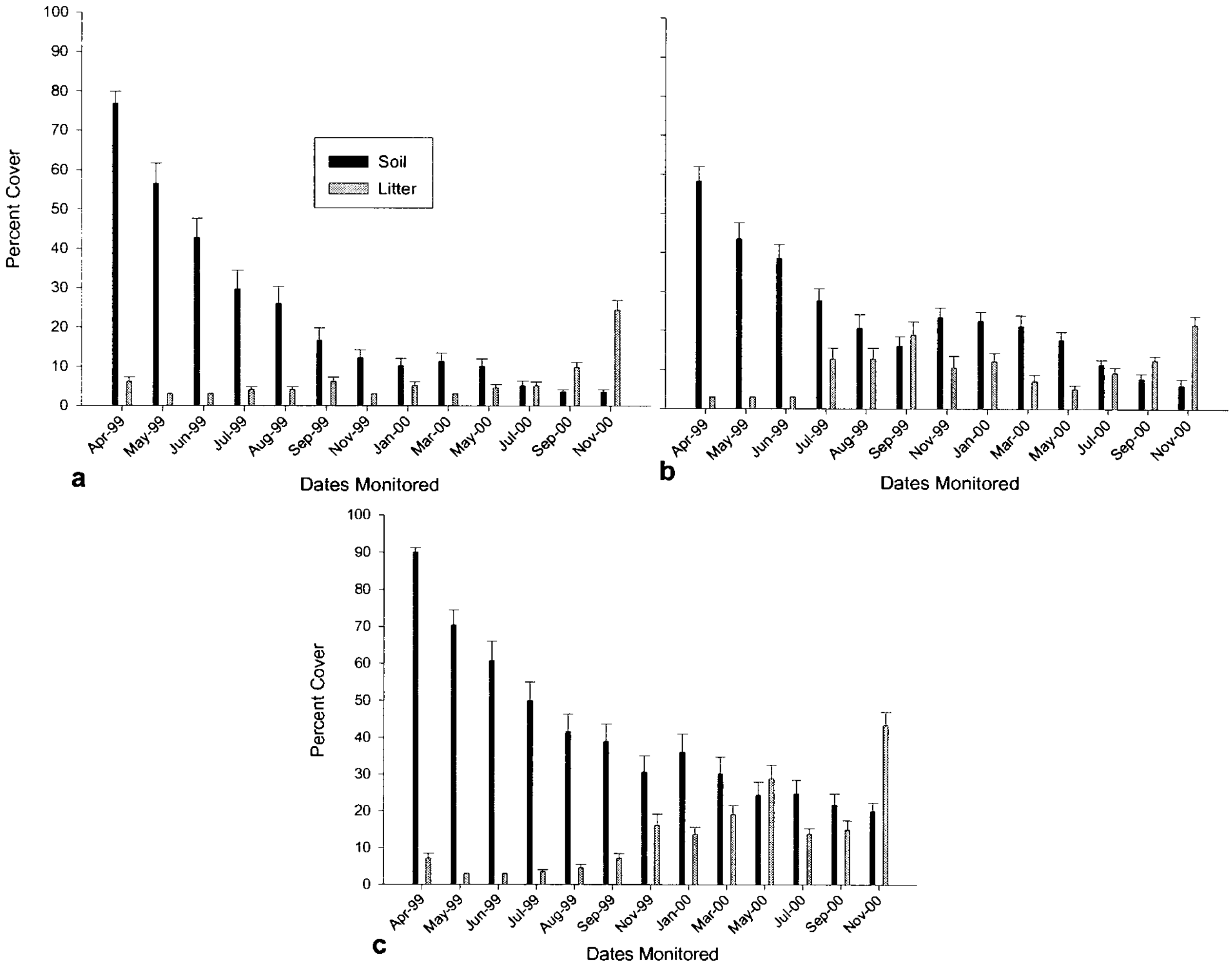

Figure 6. Mean percent cover (+1 SE, n=24) of bare soil and litter within the (a) Stump Pasture, (b) Visitor Center, and (c) Work Center sites.

Litter

Percent cover of litter was significantly affected by herbicide treatment, site, and several interactions (Table 5). While site and herbicide significantly influenced litter cover over time, no one site or herbicide treatment consistently increased litter cover in the sprigged sub-plots. In all three sites, litter constituted only a minor proportion of the total cover of the plots and tended to slightly increase over time, especially in November 2000 (Figure 6). This increase parallels the decrease in living tissue during that same period.

Percent cover - seeded sub-plots

Planted Species

Results of the repeated measures ANOVA indicate that cover of sown species was significantly affected by irrigation, species, herbicide, site, and several interactive effects (Table 6). Site significantly influenced the cover of these planted species (Figure 7): the drier Work Center site consistently had the lowest cover of the three sites. In the initial months neither the Stump pasture nor the Visitor Center were consistently different from one another, but in every month following January 2000, the Stump Pasture showed significantly higher cover (Figure 7a, b). Irrigated sub-plots of *Eragrostis refracta* and *E. petraea* in the Stump Pasture and the Visitor Center had significantly higher cover than non-irrigated sub-plots in every month after the irrigation treatment was initiated until September 2000 (Figure 8). *Eustachys petraea* had the highest cover of the species every month except September and October 2000 (only some months significantly higher), when *E. refracta* had the highest cover (Figure 7a, b) in the Stump Pasture and Work Center. Although the mowing and herbicide treatments significantly influenced cover of the sown species, there were no consistent patterns in the effects. Cover of sown species in all three sites decreased in November 2000.

Table 6. P-values of Wilks' Lambda from repeated measures analysis of cover of sown and non-planted species, bare soil and litter for all *E. petraea* and *E. refracta* sown sub-plots from April 1999 through November 2000. Significant ($p<0.05$) and near significant ($p<0.07$) effects are bolded. Non-significant factors for all cover categories were omitted.

		P-Value			
Factor	**df**	**Sown species**	**Non-planted species**	**Soil**	**Litter**
Irrigation	11	**0.0590**	**0.0031**	**0.0538**	**0.0224**
Species	11	**0.0001**	0.1282	0.0851	0.3000
Herbicide	22	**0.0017**	**0.0001**	**0.0001**	**0.0582**
Site	11	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Irrigation x Species	11	0.6222	0.4131	**0.0454**	**0.0266**
Irrigation x Spp x Herb	22	0.9570	0.7479	0.1562	**0.0130**
Species x Herb x Mow	22	**0.0063**	0.9280	0.7466	0.8749
Site x Species	11	**0.0004**	0.1511	0.0750	0.3369
Site x Irrigation	11	0.7007	**0.0426**	0.2357	0.1812
Site x Mow	11	**0.0155**	0.6809	0.0899	0.8481
Site x Herbicide	22	0.3031	**0.0001**	**0.0001**	**0.0026**
Site x Spp x Mow	11	**0.0512**	**0.0316**	0.6341	0.3767
Site x Irr x Spp x Herb x Mow	22	0.4112	0.7914	0.6965	**0.0208**
Site x Irr x Spp x Mow	11	**0.0512**	0.8574	0.5684	0.8872
Site x Spp x Herb x Mow	22	0.9775	0.3283	**0.0562**	0.2931

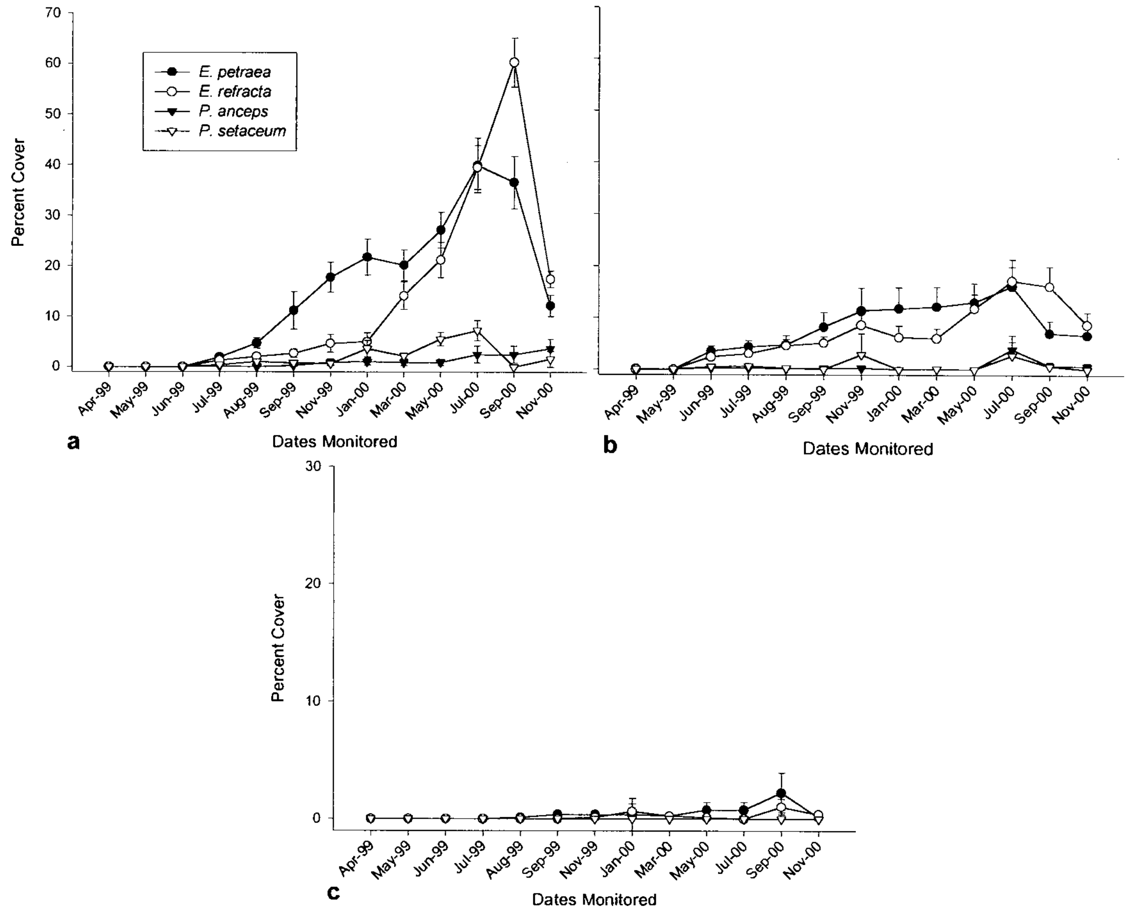

Figure 7. Mean percent cover (± 1 SE, n=24) of seeded species in the (a) Stump Pasture, (b) Visitor Center and (c) Work Center sites.

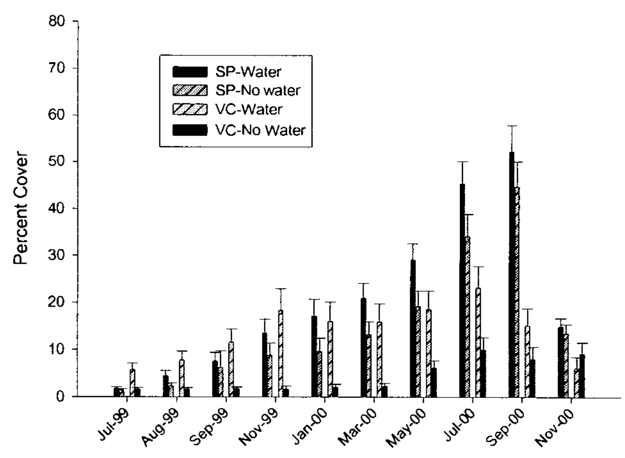

Figure 8. Mean percent cover (+1 SE, n=24) of both *E. petraea* and *E. refracta* in irrigated and non-irrigated sub-plots within the Stump Pasture and the Visitor Center sites.

Non-planted species

Percent cover of non-planted species within the seeded sub-plots were significantly influenced by irrigation, herbicide treatment, site and several interactive effects (Table 6). Of the two sites analyzed (Stump Pasture and Visitor Center), the Visitor Center site had significantly higher cover of non-planted species for every month monitored (Figure 9a, b). Sub-plots receiving supplemental irrigation showed a lower percent cover of non-planted species than did non-irrigated sub-plots, a significant difference in many months (Figure 9a, b). Although not statistically tested (because of low germination), this pattern did not hold for the Work Center where there was no consistent response until November 1999, when the irrigated section had the higher percentage of non-planted species for the remainder of the monitored months (Figure 9c). Herbicide treatment had a significant but inconsistent effect; we could not identify an optimal method for reducing non-planted species over time through the statistical analysis.

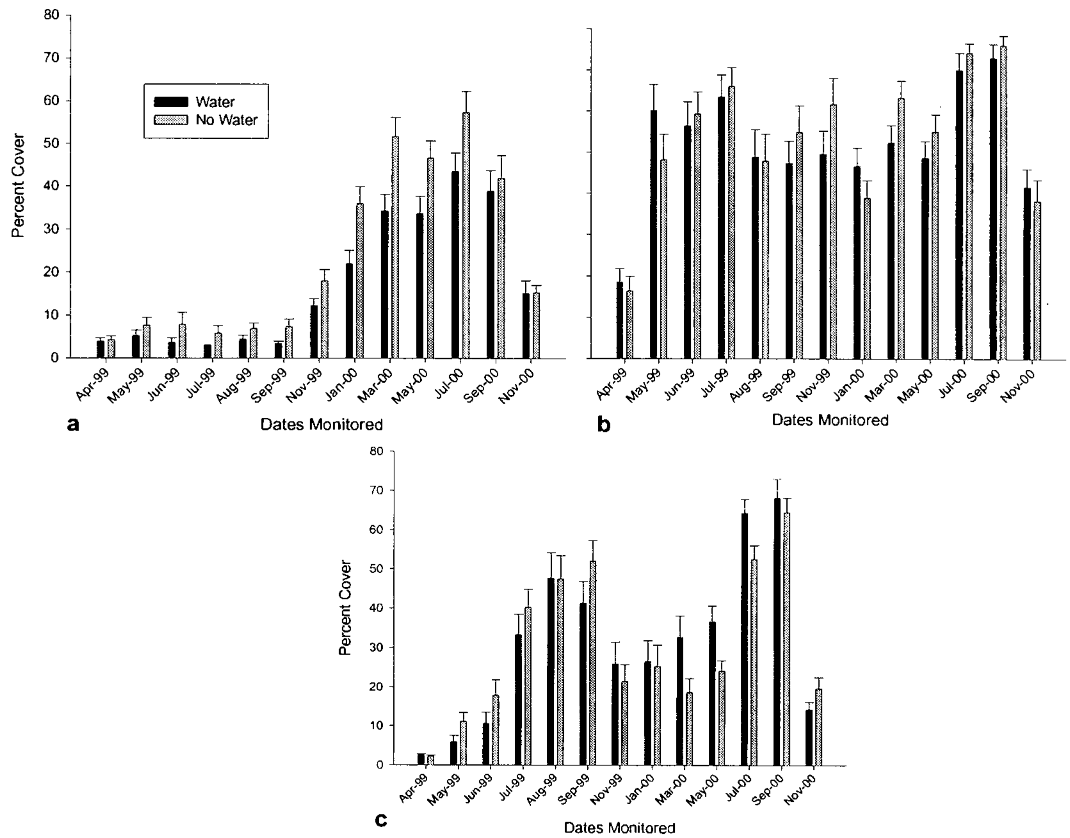

Figure 9. Mean percent cover (+1 SE, n=24) of non-planted species within both *E. petraea* and *E. refracta* sub-plots in the (a) Stump Pasture, (b) Visitor Center and (c) Work Center sites.

Bare Soil

Cover of bare soil was significantly influenced by irrigation, herbicide treatment, site and several interactive effects (Table 6). Of the two sites tested, the Stump Pasture had significantly higher cover of bare soil until March 2000 (Figure 10). In most months the non-irrigated sub-plots had a higher percentage of soil than the irrigated sub-plots. The Plateau® treatment resulted in a significantly higher percent of bare soil every month through September 1999, and this effect was greater in the Visitor Center than the Stump Pasture (Figure 10). In both sites, bare soil cover decreased over time.

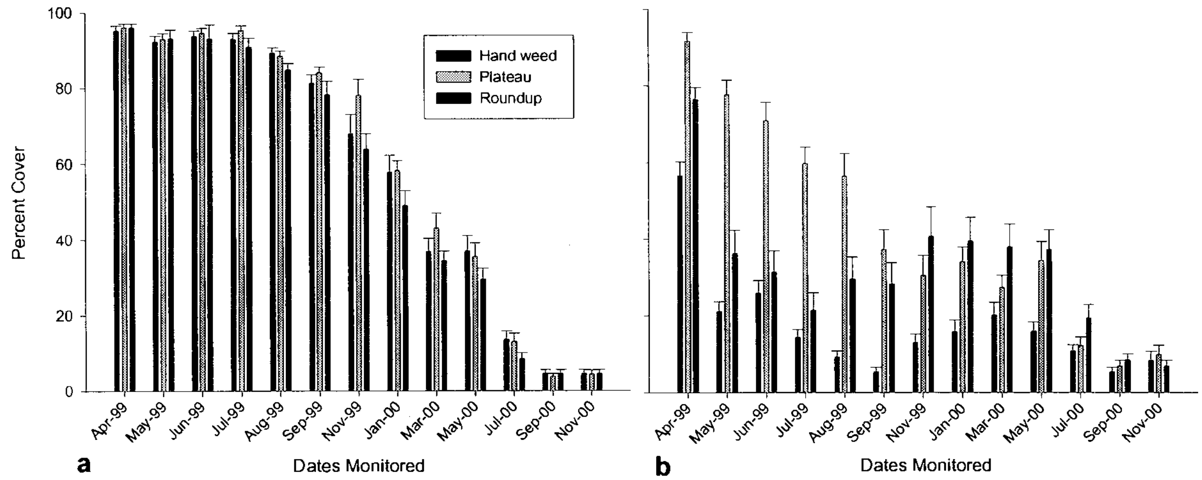

Figure 10. Mean percent cover (+1 SE, n=16) of bare soil in the seeded sub-plots (*E. petraea* and *E. refracta* only) for the (a) Stump Pasture and (b) Visitor Center sites.

Litter

Litter cover within the sown sub-plots was significantly affected by irrigation, herbicide treatment, site and many interactive factors (Table 6). No site or herbicide treatment had significantly more cover of litter consistently over time.

Discussion

Paspalum distichum

As discussed in Gordon et al. (2000b), differences in *P. distichum* mortality among pasture blocks appear to result from differences in water availability and temperature at the time of planting. The initial pasture selection was designed to include a gradient of hydrologic regimes. Additionally, precipitation levels varied significantly across the sites (see Appendix B, Figure B-1). Planting this species in cooler months, rather than in June as we did in 1998, may have enhanced survival because cooler temperatures and less intense sun exposure should have made root establishment less stressful for the sprigs and decreased the rate of desiccation. Perhaps the significant difference between the two years is an indicator that the timing of the sprig planting is critical.

For restoration efforts and roadside use, even the lower mortality seen in the 1999 trial is likely to be too high. Many other methods could be investigated to reduce mortality such as increased irrigation, mulch or hay, rooting hormones, fungicides, and water polymers. We anticipate that further information on the propagation and establishment of this species will be available from research conducted by Ann Blount of the UF Experiment Station in Quincy, Florida. We are optimistic that this species may be used on rights-of-way after methods to reduce mortality are identified because cover development was dramatic in some sub-plots (see Figure 37 in Gordon et al. 2000b).

Decreased cover of *P. distichum* in November 2000 in the Stump Pasture and the Work Center sites was probably due to winter dormancy. We do not know whether this is the normal dormancy pattern for *P. distichum* or whether it was accentuated by the extremely dry year.

Seeded species

Irrigation was a significant factor in cover development of *E. petraea* and *E. refracta*. The increased cover may have resulted from enhanced germination, growth, or both. *Eustachys petraea* had the highest percent cover in most months, while *E. refracta* had lower cover, but showed an increasing trend over time until it reached higher cover in September 2000 (Figure 7). In contrast, *E. petraea* decreased after September 2000 (Figure 7a, b), likely because of seasonal changes. In fact, *E. petraea* plots were already starting to show signs of dormancy in September 2000 with a slightly browning color. We also observed this change in naturally occurring roadside patches of this species adjacent to the preserve (A. Miller pers. obs.).

Paspalum setaceum and *P. anceps* had little to no germination in the field. We observed germination of both species in the seed germination experiments (see Objective 2a, Experiment C). This may indicate that direct sowing of these species without attention to water availability or some pre-germination treatment is not be advisable.

The reduced cover of non-planted species in the Stump Pasture could be the result of a smaller weed seed bank in that pasture, or more effective herbicide activity there. However, we did not detect consistent differences in the effectiveness of the different species control approaches tested. The fluctuations in cover of the non-planted species in the Visitor Center could be due to the high turnover rates of annual and weedy species observed in that pasture. Percent cover of soil decreased over time and corresponded to increases in cover of planted and weedy species.

The dramatic decrease in percent cover of seeded and non-planted species in all sites in November 2000 was due to winter dormancy of the sown species and most of the non-planted species within the plots (A. Miller, pers. obs.). As for the *P. distichum*, the extremely dry weather could also be a contributing factor (See Appendix B, Figure B-1).

Unexpectedly, these result do not suggest a recommendation for the most effective herbicide with the least negative effects on the planted species. We had anticipated, because of effectiveness elsewhere (N. Bissett, pers. comm.), that Plateau® would be most effective in this experiment. Further work will be required to identify whether herbicide effectiveness might vary under different levels of water or other resource availability. However, because both herbicides reduced germination of the four native grass species when applied at the rates used in this experiment (Gordon et al. 2000b), use of herbicides post-sowing may reduce the effectiveness of restoration efforts.

As described in Gordon et al. (2000b) these results led us to select *P. distichum* sprigs and seed of *E. petraea* and *E. refracta* for the roadside trial Experiment B.

Conclusions

Our experience gained from the drought-impacted Experiment A (Contract BB-533; see Introduction) and the additional site preparation incorporated into this experiment has contributed to its success. Increased sowing rates of more appropriate species and sowing in the winter probably contributed to the increased seed germination of sown species (compared with 0% in Contract BB-533). Any or all of these factors could be vital to the success of directly seeded restoration projects.

We recommend investigation of more efficient seed collection and seed cleaning techniques because our methods were time-consuming. All seed for this experiment was hand collected and hand separated from the stalks and chaff. An alternative seed treatment would be necessary for these species in any large-scale project.

Experiment B. Conduct roadside trials with the most successful native salt intolerant grass species determined from the flatwoods study.

Introduction

The successful establishment of species in the pastures may not reflect their success on roadsides. Roadsides have unusual characteristics like increased wind and impact due to car movement and increased heat from the blacktop surface. Further, the soils on those edges are generally significantly altered, with lower organic matter content, different compaction, nutrient levels, and texture than the native soils (Harper-Lore 1998) and higher concentrations of heavy metals and other contaminants (Warren 1987). As a result, species proposed for road rights-of-way should be tested in those locations.

Construction of a new paved road leading to the Conservation Learning Center at DWP gave us the opportunity to test the three species that showed the highest percent cover in Experiment A on a protected roadside. The road is the public entrance to the preserve and is very visible to visitors. Bahiagrass (*Paspalum notatum*) was sown on the roadside in January 1999 prior to the establishment of this experiment. Thus, as on public roads and in the pastures, we needed to remove the non-native turfgrass prior to planting the experimental species.

We incorporated the information gained from the two pasture experiments in this pilot experiment. We learned that extensive site preparation is an essential part of reducing weed seed germination and thus competition with desired species, especially when seeds or cuttings are used (see above and Gordon et al. 2000b). Repeated herbicide application and disking are necessary to remove the pasture vegetation. Although a year of site preparation was not possible for this trial, what was done was intensive. We also learned that the seeding rates for these species to form turf is not known and could potentially be increased. An increased seeding rate was tested in this roadside trial. Lastly, we tried a new, more time-efficient method of cleaning the *Eragrostis refracta* seed. Since fertilizer did not have a significant impact in Experiment A (Tables 5, 6) it was omitted in this experiment.

We generated interest in and understanding of the project by using signage along the road that reads: "Several plots on the road shoulder, at the turnouts, and in the center road islands are native turfgrass and vegetation research projects funded by the Florida Department of Transportation". A sign reading "Research Plots" was also posted by the plots.

Methods

Site Preparation

Bahiagrass was removed from the road shoulder with a combination of Roundup® herbicide application and multiple disking that began in August 1999 and continued with repeated disking until the time of planting. The site was raked and rolled just before sowing to smooth the loose soil. A final spot herbicide treatment was applied to germinated weed seedlings two weeks prior to planting.

Experimental Design

Three 11 x 2 m (36 x 6.5 ft) blocks were established in a randomized complete block design parallel to the roadside. Three 3 x 2 m (10 x 6.5 ft) plots, each separated by 1 m (3.3 ft), were established within each block, one per species. Species were randomly assigned for planting into one plot per block. Each plot was measured and flagged with a color that corresponded to the species.

Species

The three species tested for roadside use were *Eragrostis refracta, Eustachys petraea*, and *Paspalum distichum*. The first two species were sown as seed, which was collected by hand at DWP in November 1999. *Eragrostis refracta* seed was time-consuming to remove from the stems in 1998 and 1999. In 2000, seed removal was accomplished using a Hammermill® machine at the USDA Plant Materials Center in Brooksville, Florida. This machine has dull blades that separate the seed and grind the stems into tiny pieces. Following that separation, another machine with very fine screens was used to sift the seed from chaff. The result was a collection of almost all seed and a small amount of chaff. The *E. petraea* seed could more easily be directly pulled off the stalks by hand. *Paspalum distichum* sprigs were again planted as seed was not available.

Direct-seeded Plots

Plots of *E. refracta* and *E. petraea* were sown on December 9, 1999. Before sowing, the area was rolled to smooth and compact the soil. Each plot received the equivalent of 30 lbs of seed per acre (20.1 g of seed per plot). The seeding rate was increased from 20 to 30 lbs per acre because of the low germination and cover found in Experiment A. The seed was evenly hand-sown over the raked and rolled soil. A flat roller was pulled over the seed to improve contact between the soil and seeds. The roller was filled with water and weighed approximately 150 lbs. Pine straw was spread approximately 0.75 in. (2 cm) thick over the surface to hold the seed in the plots. The plots were rolled again to compact the straw. Since pine straw and seed are easily blown away by wind (as experienced with the flatwoods seed plots in 1998, see Gordon et al. 2000b), thin plastic netting was installed over the pine straw and stapled into the soil with six inch metal or plastic staples. The netting was removed as soon as seedlings began germinating to prevent any potential interference with seedling growth.

Paspalum distichum Sprig Plots

Paspalum distichum sprigs were purchased from Horticultural Systems in Parish, Florida. Sprigs were stored overnight in water and then cut into pieces 10 cm (4 in.) long with no fewer than three nodes each. These sprigs were planted into the three roadside plots on February 25, 2000 (postponed three months because of frost threats). All weeds were removed by hoe prior to planting. Sprigs were planted on 12.5 cm (5 in.) centers (360 sprigs per plot). Volunteers planted the sprigs using hand trowels, ensuring that 50% of the horizontally placed sprig was covered with soil. This sprig placement increased the number of nodes in contact with the soil from which roots could develop.

Paspalum distichum plots were irrigated during the initial establishment period with a water tank and pump. Plots received 0.77 cm (0.3 in.) of water every third day for two months depending on rainfall. Watering occurred longer than we anticipated because of the extended period of dry weather (see Appendix B, Figure B-1c).

Monitoring

These plots were monitored for cover and height monthly for the first six months, then bimonthly until February 2001. Cover was estimated using the point intercept method. Points were dropped every 20 cm (8 in.) along two randomly placed lines within each plot, parallel to the road. Cover was estimated within four cover categories: sown or planted species, non-planted species, bare soil or litter, and bare soil caused by vehicle disturbance. The height of the tallest planted and non-planted species was recorded at every third point. No vehicular disturbance was recorded through the duration of this contract.

Maintenance

We hand-weeded the plots periodically during the first three months to reduce competition with non-planted species. Mowing with a spin trimmer started in June 2000 and continued monthly until September 2000, when we started using a Ransomes® Bob Cat mower set at a 5 inch (12.7 cm.) height. Roundup® herbicide application was carefully applied to the edges of the plots for weed control.

Data Analysis

A repeated measures analysis of variance (GLM procedure in SAS®) was performed to determine if percent cover or height changed over time. Each cover category was analyzed separately. Data on cover of *E. petraea* data were transformed (arcsine of square root) to increase consistency with the assumptions of the test. The data were normally distributed for all other categories and species. Block and time were the only main factors tested as there were no cultural treatments in this experiment. We did not analyze the *E. refracta* results because of poor germination.

Results

Cover

Cover of all categories changed significantly over time in the *E. petraea* and *P. distichum* plots (Table 7). Cover of *P. distichum* was fairly consistent from May to October 2000, at around 45%, and then decreased steadily in the final winter months of monitoring (Figure 11a). Non-planted species cover within the *P. distichum* plots increased until June 2000 but has decreased each month since then, while bare soil remained fairly constant through October 2000 and then increased in cover in the remaining months (Figure 11a). *Eustachys petraea* increased in cover each month until August 2000, when it decreased to 40% by February 2001. Cover in the non-planted species category decreased over time (Figure 11b). Bare soil increased from October 2000 to February 2001 and seemed to correspond with the decrease in *E. petraea* (Figure 11b). *Eragrostis refracta*, which showed no germination before August, increased from 2% to 15% from August to October, 2000 and then slightly decreased again through February 2001 (Figure 11c). Non-planted species within the *E. refracta* plots increased until August and then decreased in December 2000, while bare soil decreased over time until a drastic increase in December 2000 and February 2001 (Figure 11c).

Table 7. P-values from repeated measures analysis of cover *of Paspalum distichum, Eustachys petraea,* non-planted species, and bare soil for Experiment B, from January 2000 through February 2001. All values are significant ($p<0.05$).

Plot	df	Planted species	Non-planted species	Bare soil
E. petraea	9	0.0001	0.0001	0.0001
P. distichum	9	0.0003	0.0039	0.0001

Height

Planted Species

The heights of *E. petraea* and *P. distichum* changed significantly over time (Table 8). In most months, *P. distichum* was the tallest of the three species, with increasing heights through August 2000, when it decreased to a mean of 5 cm by February 2001 (Figure 12a). *Eustachys petraea* also increased each month until October when it substantially decreased in height as well through February 2001. *Eragrostis refracta* was not present in the plots until June 2000. The *E. refracta* plots, therefore, had zero height until June 2000 and increased significantly in height in October

2000 then substantially decreased in the winter months (Figure 12a). The average maximum height of the three species has not reached above 12 inches (30 cm) to this point in the experiment, although monthly mowing did occur.

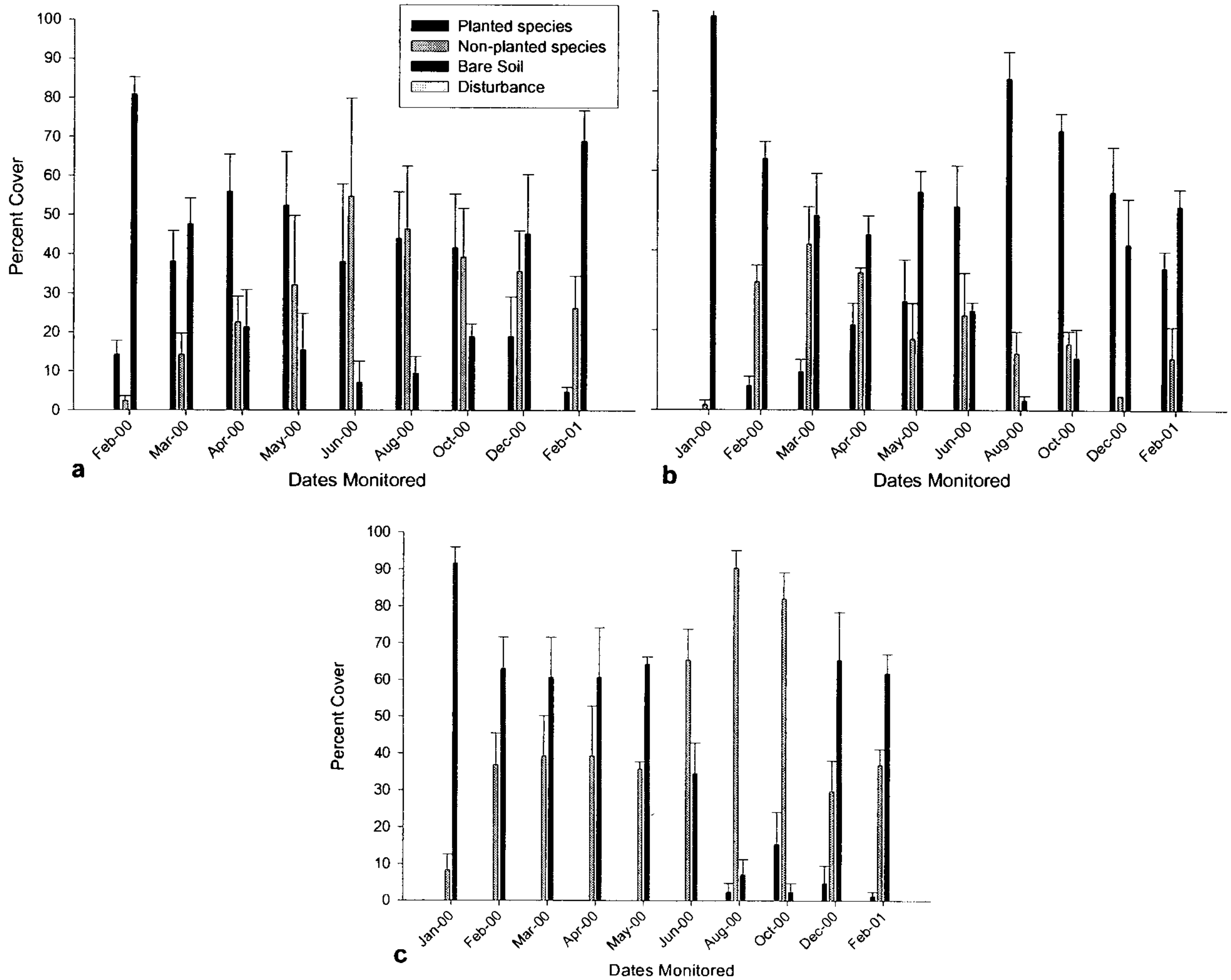

Figure 11. Mean percent cover (+1 SE, n=3) of planted species, non-planted species, bare soil, and vehicular disturbance in (a) *P. distichum* (sprigged), (b) *E. petraea* (seeded), and (c) *E. refracta* (seeded) plots along the roadside in Experiment B.

Table 8. P-values from repeated measures analysis of height of *Paspalum distichum, Eustachys petraea* and non-planted species for Experiment E from February 2000 through February 2001. All values are significant ($p<0.05$).

Plot	df	Planted species	Non-planted species
E. petraea	8	0.0001	0.0011
P. distichum	8	0.0001	0.0001

Non-planted species

We also found significant increases in the heights of the non-planted species within the *E. petraea* and *P. distichum* plots over time through August 2000 and then consistent decreases from October 2000 to February 2001 (Table 8, Figure 12b). However, height of non-planted species was not consistently greatest in any one species (Figure 12b).

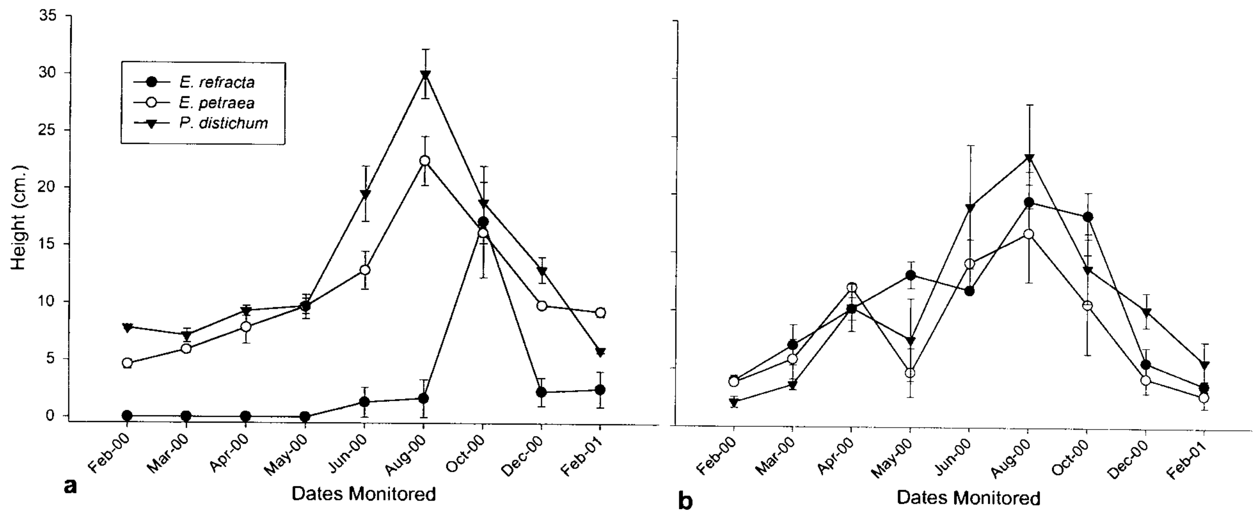

Figure 12. Mean height (±1 SE, n=3) of (a) planted species and (b) non-planted species for *P. distichum, E. petraea*, and *E. refracta* plots along the roadside in Experiment B.

Discussion

Cover

Paspalum distichum has good potential for roadside use when planted as sprigs (Figure 13). *Eustachys petraea* continues to have very high cover even in very dry conditions at DWP (Figure 13). This species also has good potential for roadside use but seed is not presently commercially available. An increase in percent cover of *E. petraea* was directly related to the decreases of bare soil and non-planted species in those plots (Figure 11b).

Cover of *P. distichum* and *E. petraea* both decreased in December 2000 and February 2001. This change probably due to normal dormancy, caused by extremely dry weather (see Appendix B, Figure B-1), and several freezes in the area during January. The increases in bare soil result from the decreases in planted and non-planted cover.

Height

The substantial decrease in height of the planted species in October 2000 seen in both *E. petraea* and *P. distichum* could have resulted from daylight and seasonal changes causing the grasses to slow in growth. The *E. petraea* plots were already starting to show signs of dormancy in October

2000, with a slightly browning color that was also observed in naturally occurring roadside patches of this species adjacent to the preserve (A. Miller, pers. obs.). The same browning was observed in Experiment A. The significant increase in height of the *E. refracta* plots in October 2000 is due to the continued germination of the species in the plots (A. Miller, pers. obs.). With monthly mowing these species displayed acceptable heights for use on roadsides (always <12 in. (30 cm)). We did not investigate whether reduced mowing frequency would be possible.

While not part of the regular monitoring program, we did make observations on the color of these plots. *Eragrostis refracta* and *P. distichum* have good green color registering "2" on our color scale and *E. petraea* had a lighter bluish-green color registering "3" on the scale (A. Miller pers. obs., see Figure 15 for color scale). *Eustachys petraea* also tended to turn brown early in fall 2000. *Eustachys petraea* is promising as a turfgrass but may have a short green season. We need to better understand the factors that stimulate dormancy in this species.

Eustachys petraea and *P. distichum* tolerated the roadside conditions in this experiment. There was no vehicular disturbance recorded (probably due to our signage), therefore recovery from disturbance was not determined. *P. distichum* is a promising species for use as turf on roadsides and we recommend further investigation to clarify whether these results would persist in other locations and over a longer period of time. We have been cautioned that *P. distichum* may not always grow well after several years (D. Hall, pers. comm.), but have seen no data.

Figure 13. Roadside plots at DWP. The front plot is *Eustachys petraea* and the back plot is *Paspalum distichum.*

In this roadside trial, direct seeding worked well for *E. petraea*, but it is unclear why the germination of *E. refracta* was so delayed. Perhaps the increased germination and cover of *E. petraea* was due to the increased seeding rate. Although the Hammermill® was very effective at cleaning the seeds of *E. refracta* off of the stalks, investigation into whether seeds were damaged by the machine is necessary because of the low germination seen in this trial. Further investigation into direct seeding for both of these species is warranted.

Conclusions

We believe that investigation into the production of *P. distichum* sod could be beneficial to inland areas around the state. The growth habit of this species supports dense sod production (A. Miller, pers. obs.). *Paspalum distichum* reproduces quickly with rhizomes and has dense vegetative cover. Like its coastal relative, *P. vaginatum*, we believe this inland congener has tremendous commercial potential as sod. We are unaware of any commercial source of *P. distichum* sod.

Site preparation is clearly a crucial step in revegetation of roadsides and other areas (Harper-Lore 1998). Site preparation for at least one year is recommended (N. Bissett, pers. comm.). This includes the steps we took in this experiment: herbicide application of Roundup® until all green vegetation is dead, repeated disking throughout the year, and spot treatments of herbicide as needed. Although not a full year, the site preparation for this experiment was very intensive and we believe this contributed to the success of the planted species in this experiment.

Objective 2: Develop recommendations from this research for the use of native turfgrasses in roadside revegetation and for future research needs.

Because the extension of Contract No. BB-533 allowed us to collect an additional year of data on Experiments A, B, and C that were established during that earlier contract, we have divided our reporting on this Objective into two sections. The first, Objective 2a, includes the three years of data now collected for those experiments, integrating the third year with the first two. The second, Objective 2b, includes the recommendations as described in the original Objective 2.

Objective 2a: Examine the potential for use of native salt tolerant turfgrasses.

Blowing Rocks Preserve (BRP) resource description

Location and setting

Blowing Rocks Preserve (BRP) is a 73-acre coastal preserve owned and managed by The Nature Conservancy (TNC) since 1968. The preserve is located on Jupiter Island, a 16-mile barrier island in southern Martin County on the southeast coast of Florida (Figure 1). The city of West Palm Beach is located 20 miles south of the preserve and the city of Stuart is 20 miles to the north.

County Road 707, constructed in the early 1950's, bisects the Preserve and Jupiter Island and provides access to the approximately 1000 residences of the island (The Nature Conservancy 1997). This road is narrow and seasonally very busy with commercial trucks and passenger cars. The preserve itself has over 50,000 visitors per year arriving predominantly by car. The east side of County Road 707 was planted with a 4.6 m (15 ft) wide bahiagrass sod edge about ten years ago. The grass was mown and irrigated regularly but no fertilizer or pesticides were applied. The west side of the road was never planted, contains a sidewalk and some crushed stone, but mostly sand and weeds for about 4.6 m (15 ft) from the road edge.

The most recent management and restoration plan for BRP was written in 1997 (The Nature Conservancy 1997). This and prior documents directed the restoration of over 25 acres within the preserve. Extensive removal of non-native species and propagation and planting of natives was involved. Descriptions of soils, climate, alterations, and native communities of BRP are included in the final report for the Florida Native Turfgrass Investigation (Gordon et al. 2000b).

BB-533 Experiment A: Investigate the effects of several cultural treatments on turf establishment and cover by three salt tolerant native grass species in a roadside setting.

Introduction

We investigated the growth responses of three grass species native to coastal Florida in this experiment, which was conducted along County Road 707 adjacent to BRP. Our objective was to test whether these species might develop turf and survive the roadside conditions. As previously discussed, roadside conditions include higher wind, runoff, and heat than found in more intact plant communities. The roadside soil on County Road 707 is primarily compacted, high pH, Intracoastal Waterway dredge material. The species we recommend for roadside use should be able to withstand these conditions. This experiment also tested a suite of cultural treatments: fertilizer, mowing, and propagule type.

Salt tolerant species

As described in Gordon et al. (2000b), the species selected for roadside trials at BRP were *Paspalum vaginatum, Sporobolus virginicus* and *Distichlis spicata*. These species are all native to BRP either in wetlands, on the dune, or on the shoreline of the Indian River Lagoon. In Florida, all of these species are native to both the east and west coasts (Wunderlin 1998). *Paspalum vaginatum* has recently been studied and installed on golf courses in Florida as an alternative to *Paspalum notatum* (bahiagrass) and *Cynodon dactylon* (Bermuda grass) (Duncan 1996, 1997). However, as discussed below, the cultivar used on golf courses originated in Africa. Our results are relevant only to the ecotype of *P. vaginatum* native to Florida. *Sporobolus vaginatum* and *D. spicata* are less studied; all are commercially available as plugs (Table 9).

Methods

Experimental design

Six blocks (three each on the east and west sides of CR 707) with factorial treatments of: 3 species (*P. vaginatum, D. spicata,* and *S. virginicus*) x 2 propagule (sprig or plug) x 2 mowing (mow or not) x 2 fertilizer (fertilizer or none) were established in a completely randomized block design in 1998. This design resulted in 72 plots on each side of the road. Propagules of either type were planted on 12 cm (4.7 in) centers (150 plugs or sprigs/plot). Some of the methods written below are repeated from Gordon et al. (2000b) to ensure clarity; greater detail is found in the earlier report.

Plant material

We purchased 3,600 plugs each of *D. spicata* and *S. virginicus* from D.R. Bates Seeds (Loxahatchee, Florida). The 3,600 *P. vaginatum* plugs were propagated under shadecloth in the native nursery at BRP from sprigs collected at the preserve. Sprigs of all three species were cut by hand from the plugs prior to planting. Sprig cuttings were collected from the stem or stolon and had at least three nodes each. One sprig was cut per plug, and soaked in water for 24 to 72 hours prior to planting.

Table 9. Species included in the investigation of salt-tolerant grasses (Table 1 in Gordon et al. 2000b).

Species	Growth Habit and Characteristics	Commercial Availability
Paspalum vaginatum Seashore paspalum	• spreads by rhizome, fairly rapidly • drought tolerant • studied for and used on golf courses • bright green color	• available by plug in many locations around the Florida coast • available as sod in Tampa and Port Orange, FL
Sporobolus virginicus Seashore dropseed	• spreads by stolon • low growing, very fine bladed • bright bluish green color	• available by plug in many locations around the Florida coast • soon to be available as sod in Ruskin, FL
Distichlis spicata Saltgrass	• spreads by stolons • light green color	• available by plug in many locations around the Florida coast

Site preparation

Sites for the experiment were chosen approximately 300 m (328 yd) north of the Hawley Education Center along County Road 707 on both the east and west sides of the road. Plots (blocks) are across the road from each other and 1 m (3.28 ft) inside of the road edge. A total of

151 m (165 yd) parallel to the road on the east side and 161 m (176 yd) on the west side was used for this experiment. Plots are 1.2 x 1.8 m (4 x 6 ft) and separated by 0.3 m (1 ft) to avoid unintended mixing of cultural treatments.

Roadside vegetation was treated with 3% Roundup Super Concentrate® (41% Glyphosphate, 59% inert ingredients), with two weeks between application dates. Two weeks following the final herbicide application the site was disked to a depth of 15-25 cm (6 - 10 in.) to promote germination of seeds in the seed bank. Where Australian pine roots were present in the plots (west side of road), the soil was scraped with a scraping blade and roots were removed by hand prior to disking. Both roadsides were rototilled to 15 cm (6 in.) to further loosen the soil and remove weeds in preparation for planting. Each roadside was then hand-raked by volunteers to remove rocks, shells, and dead *P. notatum* (bahiagrass) on the surface of the soil.

Soils

A 10 cm (4 in.) deep surface soil sample was collected from each of the blocks (n=6) and sent to the University of Florida Soil Testing Laboratory in Gainesville, Florida to be analyzed for pH, P, K, and Mg. The results were presented in Gordon et al. (2000b). Significant differences in soil chemistry were found between the east and west sides of the road (see Table 4 of Gordon et al. 2000b). Mean soil pH was 8.4 (s.d.=0.2) on the east side of the road and 8.6 (s.d.=0.1) on the west side. East side plots were elevated in phosphorus relative to the west side, and lower in magnesium and calcium. No soil amendments were added.

Planting

Planting of sprigs and plugs occurred at the end of April 1998. Planting involved many volunteers from the preserve and the local community, totaling 320 volunteer hours for the whole planting (Figure 14). Each plot was planted with 150 propagules (sprigs or plugs) on 12-cm (4.75 in.) centers. Plugs were buried slightly deeper than the soil associated with the plug. Sprigs were planted horizontally with at least 50% of the sprig covered with soil. This positioning increased the number of nodes in contact with the soil from which roots could develop. The plots were planted block by block from south to north, alternating sides of the road. All together 21,600 propagules were planted within the 15-day period.

Irrigation and Weeding

Plots were watered the day of planting. Due to the ensuing dry spell, the plots were watered with 0.3 inches (0.76 cm) of water daily for eight weeks unless it rained. Irrigation was decreased weekly and no watering occurred after the eleventh week.

The plots were weeded as necessary to ensure proper establishment of plants and decrease competition. Hand-weeding within the plots and careful herbicide application on the borders of the plots continued throughout the experiment. The herbicide application to the borders of the plots helped reduce edge effects.

Figure 14. Volunteers planting *Sporobolus virginicus* plugs at the Blowing Rocks Preserve.

Mowing

Mowing occurred monthly on the plots with that treatment according to FDOT standards for rural areas (FDOT 1990). The mowing height was six inches (15.3 cm.), and not more than one third of the plant excluding the flower stalk was removed (FDOT 1990). Plots were mown with a Ryobi® spin trimmer with two six-inch cords.

Fertilizer

Each plot received 0.08 lbs of the Howard Fertilizer 12-8-8 (N, P, K) blend per year. For the initial nine months the fertilizer was distributed monthly. However, the application schedule was changed in April 1999 to biannual applications in the spring and fall to correspond with the recommended cool-season grass fertilization protocol recommended for *P. vaginatum* (Duncan 1997). The total annual amount of fertilizer did not change: equal amounts were applied in April and October. Duncan (1997) also warns against applying more than 5 lbs of nitrogen fertilizer per 1000 ft^2 (93 m^2) per year to prevent scalping. No references were found on fertilization requirements for any of the other species.

Monitoring

Plants were monitored monthly for the first six months and bimonthly for the remainder of the project. Monitoring included survival, cover, height, and color. Percent mortality was measured after one month in each plot; subsequently the individual plants could not be distinguished. Percent cover was determined within four categories: planted species, non-planted species, undisturbed bare soil and litter, or bare soil caused by obvious vehicle disturbance. Cover data were collected using the point intercept method along two 2.4 m (8 ft) lines parallel to the road. Location of the lines was restricted to randomly fall within each of the 0.6 m (2 ft) sections of the 1.2 m (4 ft) plot width. The category of cover first encountered by a vertical point dropped from a 1-m height every 20-cm along each line was recorded. Maximum height of the nearest vegetation to every third point was recorded for two categories: planted species and non-planted species. Missing plants within a 20 cm circle around the dropped point were recorded as zero height. Lines were randomized again at every sampling date.

Overall color in each plot was assessed using the Munsell Plant Tissue Color Chart (1977). Seven colors were chosen from the Munsell Chart for use in this experiment (Figure 15). The chosen colors ranged from brown to dark green including yellowish greens and bluish greens. We chose seven colors from the Munsell Chart: 5GY 5/4, 5GY5/10, 7.5 GY 6/4, 2.5 GY 7/6, 2.5 GY 8/6, 2.5 Y 8/4, 5 Y 7/4.

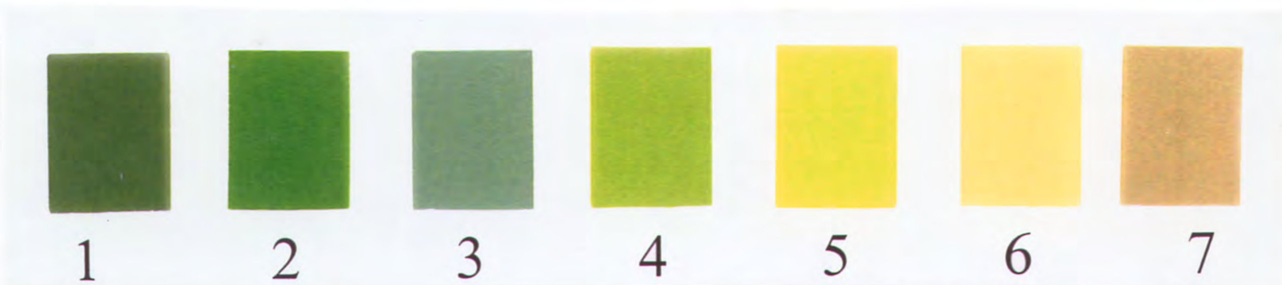

Figure 15. Color scale used. Darkest green = 1 through brown = 7. For colors not distorted through the reproduction process refer to the Munsell Plant Tissue Color Chart (1977). See text for the code identification of the shades used.

Disturbance

Disturbance to the plots occurred regularly. Many cars and trucks drove off the road onto the plots. These impacts were recorded during the monthly monitoring. Soil moisture at the time of the disturbance influenced the severity of the scar and the ability of the grass to recover. On August 18, 1999 three plots in Block 1 (east side) and four plots in Block 4 (west side) were completely destroyed when a tractor trailer truck attempted a U-turn on County Road 707 (see

Gordon et al. 2000b). Analyses were conducted on five blocks of each treatment following loss of the seven plots.

Data analysis

Differences in the percent mortality of plugs and sprigs of each species were examined using analysis of variance (GLM procedure in SAS®). Analyses of cover and height of planted and non-planted were conducted using repeated measures analysis of variance (MANOVA). For all repeated measures analyses, we examined the main and interactive effects of block, species, propagule type, mowing, and fertilizer on growth over time. Planted and non-planted species were analyzed separately. For cover, analysis was completed on three of the four categories: planted species, non-planted species, litter, and bare soil. Litter was never a significant proportion of any plot. Each category was analyzed independently. All cover data for non-planted species and bare soil were arcsine square root transformed to increase consistency with the assumptions of the MANOVA. Cover for planted species was log-transformed. The height data did not require transformation to meet the assumptions of the MANOVA.

Because of variation in annual monthly rainfall over the course of this experiment, we examined the relationship between cover of planted and non-planted species and monthly rainfall at the preserve using Spearman's rank correlations. Species were tested separately.

Results

Percent Mortality

These results were reported in Gordon et al. (2000b) and are included here for completeness. All three species had low mortality rates when planted as plugs (Table 6 of Gordon et al. 2000b). In general, mortality was higher on the east side of the road. *Paspalum vaginatum* plugs had the lowest mortality of the three species. Significant differences in sprig survival among species ($df=2$, $F=18.82$, $p<0.001$) resulted from higher mortality of *D. spicata* sprigs than of *S. virginicus* and *P. vaginatum* sprigs, which were not significantly different from one another (Table 7 of Gordon et al. 2000b). Overall, plugs had significantly lower mortality than sprigs ($df=1$, $F=54.43$, $p<0.0001$). Higher variation in sprig than in plug survival between the two roadsides was evident.

Cover

Planted Species

Cover of planted species was significantly affected by all main and several interactive factors (Table 10). Although cover varied by block, we found no consistent significant difference between the blocks on the east and west sides of the road. *Sporobolus virginicus* produced the highest cover in all months after November 1998 (Figures 16-17). This species remained at about 50% cover for several months (Figure 17a). *Paspalum vaginatum* and *D. spicata* decreased during the sampling period (Figures 17b, c).

For all species, differences in cover by sprigs or plugs changed over time. Plugs initially generated higher cover, which subsequently decreased, while the sprig cover remained fairly constant (Figure 17). As a result, by September 1999 any significant differences in cover developed by plugs or sprigs had disappeared. In all months except September 2000, unmown plots had higher cover than mown plots, although the difference was not always significant (Figure 17).

Table 10. P-values of Wilks' Lambda from repeated measures analysis of variance for percent cover of planted and non-planted species and bare soil from July 1998 through November 2000. Significant (p<0.05) and near significant (p<0.07) are bolded.

Factor	df	P-Values		
		Planted species	**Non-planted species**	**Soil**
Block	70	**0.0001**	**0.0001**	**0.0001**
Species	28	**0.0001**	**0.0002**	**0.0001**
Propagule type	14	**0.0001**	**0.0001**	**0.0001**
Mowing Treatment	14	**0.0001**	0.6400	**0.0095**
Block x Spp x Prop	350	**0.0001**	0.3439	**0.0062**
Species x Prop x Mow	6570	**0.0224**	0.8848	0.1778

Figure 16. *Sporobolus virginicus* plug plot in September 2000.

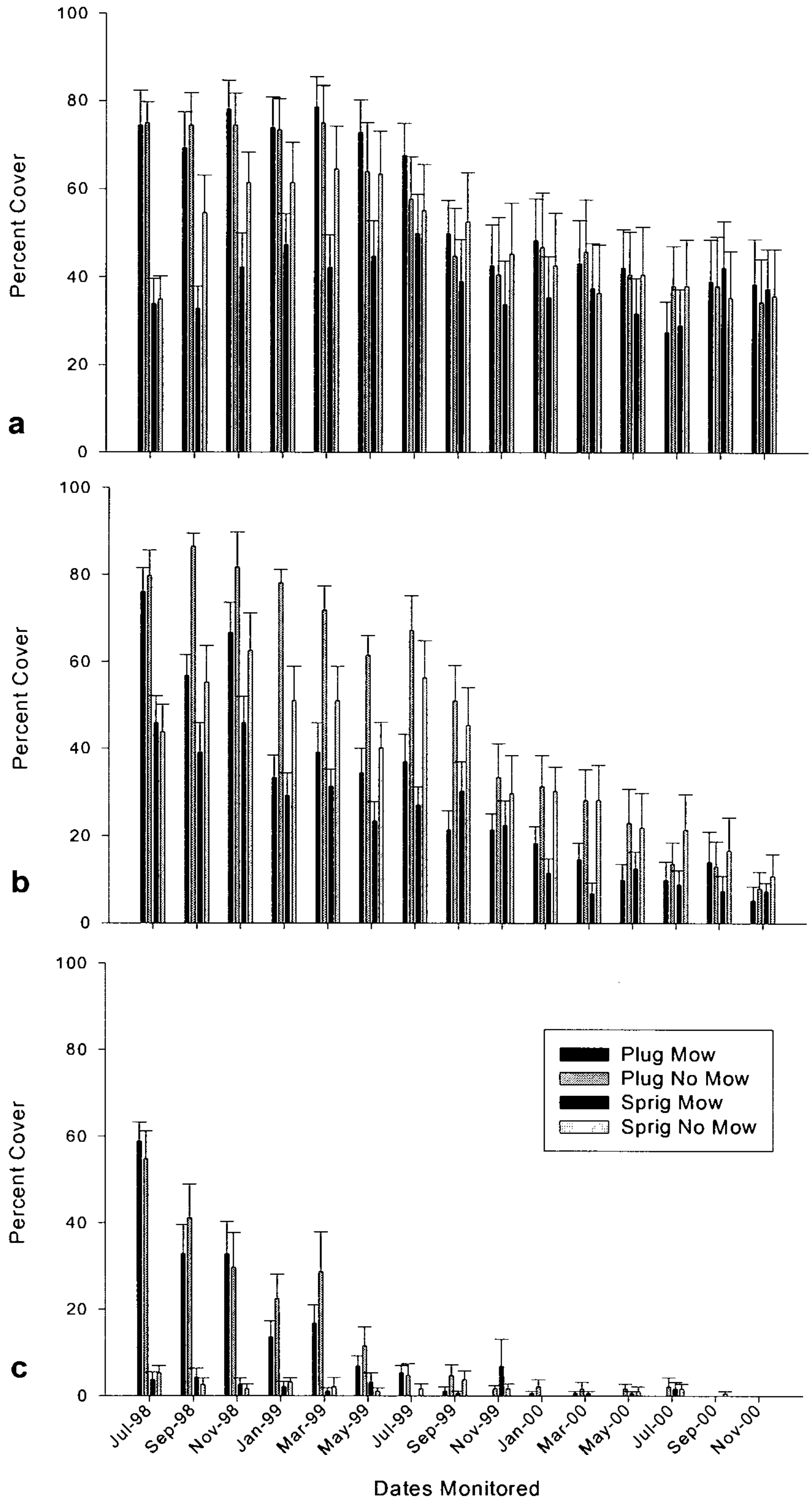

Figure 17. Mean percent cover (+1 SE, n=12) of planted species in (a) *S. virginicus*, (b) *P. vaginatum* and (c) *D. spicata* plots.

Non-planted species

The percent cover of non-planted species was similarly dependent on the main factors tested except mowing (Table 10). Again, there was no significant pattern in the response of blocks on the east or west side of the road. *Distichlis spicata* plots had the highest percentage of non-planted species in every month, significantly so in most months (Figure 18a, b). *Sporobolus virginicus* plots generally had the lowest percentage of non-planted species present (Figure 18a, b). Changes in trends among plots planted in plugs and sprigs over time demonstrated that there was no consistent pattern of lower weed growth in either propagule type across the planted species (Figure 18a, b).

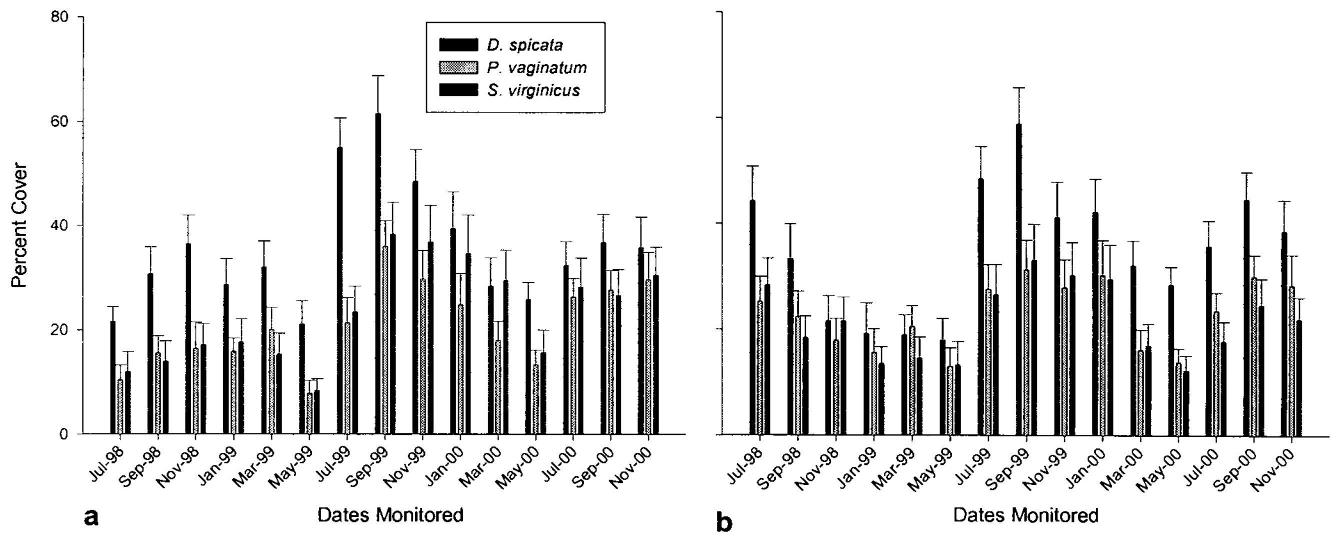

Figure 18. Mean percent cover (+1 SE, n=48) of non-planted species within *D. spicata, P. vaginatum*, and *S. virginicus* (a) plug and (b) sprig plots from July 1998 through November 2000.

Bare Soil

Percent cover of bare soil in the plots was significantly influenced by block, species, propagule type, mowing treatment and the interactive effect of block, species and propagule type (Table 10). *Distichlis spicata* plots had the highest percent cover of bare soil in every month monitored (Figure 19). After January 1999, *P. vaginatum* plots had significantly higher cover of bare soil than did *S. virginicus* plots in every month (Figure 19). Sprigged plots had significantly higher cover of bare soil than plugged plots until September 1999, when differences were no longer significant (Figure 19). Mown plots had significantly higher cover of bare soil every month until January 2000 (Figure 19).

Disturbance

The disturbance that could clearly be attributed to vehicles was analyzed separately from the other cover categories. Only 38 plots of the 144 were disturbed during the monitoring between June 1998 and May 2000. Thirty-one of these plots were not seriously damaged. When percent cover of the planted species in disturbed plots four months after the damage occurred was compared to the average value for cover in undisturbed plots of the same species and treatment in the same month, there was no significant difference between the covers ($t=-0.242$, $df=30$, $p<0.40$). The seven plots that were irretrievably damaged were excluded from the analyses, as discussed above.

Precipitation

Monthly rainfall was not strongly correlated to planted species cover. We found a weak but significant correlation between monthly precipitation and percent cover of planted and non-planted species in the *P. vaginatum* and *D. spicata* plots, respectively, but very little of the variation in cover was explained by this relationship ($p<0.0337$ and $r<0.20$ in all cases).

Height

Planted species

Height of planted species was significantly influenced by block, species, propagule type, mowing treatment, and the interactive effect between block, species, and propagule type (Table 11). *Paspalum vaginatum* grew taller (significant in many months) than did the other two species in every month until July 2000 (Figure 20). *Sporobolus virginicus* was tallest in July and September 2000 but was only significantly taller than *D. spicata*, which was the shortest in every month (Figure 20). Plugs had greater heights than sprigs every month, a difference that was only significant in some months (Figure 20). Not surprisingly, plants in unmown plots were taller in every month (significant some months) (Figure 20).

Table 11. P-values of Wilks' Lambda from repeated measures analysis of variance for height of planted and non-planted species from January 1999 through November 2000. P-values of significant factors ($p<0.05$) are bolded.

Factor	df	P-Value: Planted species	P-Value: Non-planted species
Block	55	**0.0007**	**0.0001**
Species	22	**0.0001**	**0.0001**
Propagule type	11	**0.0005**	**0.0030**
Mowing treatment	11	**0.0073**	**0.0030**
Fertilizer treatment	11	0.1490	**0.0001**
Species x Prop x Mow	55	0.8548	**0.0632**
Species x Prop x Fert	55	0.8497	**0.0153**
Block x Spp x Propagule	275	**0.0001**	**0.0346**

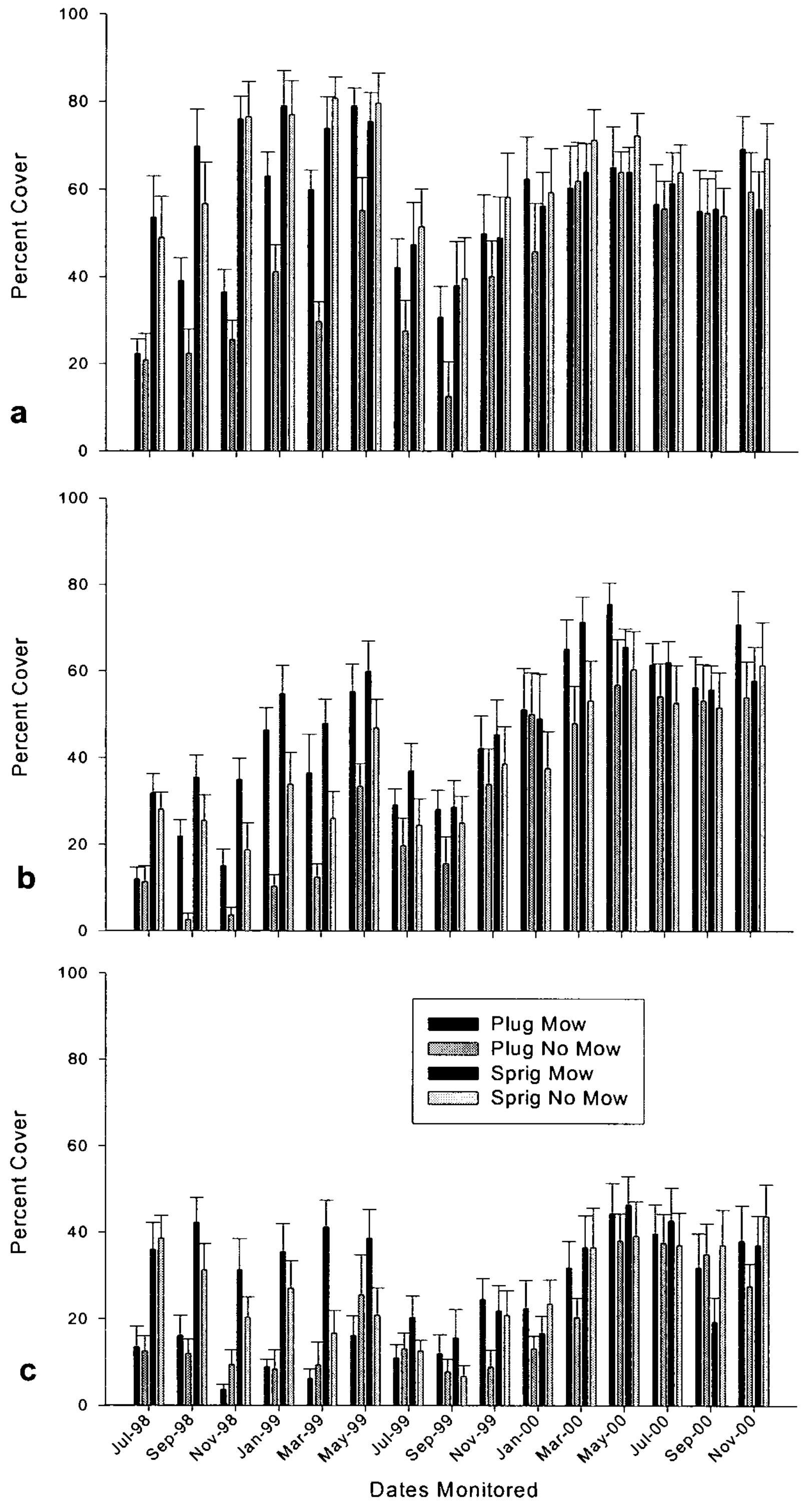

Figure 19. Mean percent cover (+1 SE, n=12) of bare soil in (a) *D. spicata*, (b) *P. vaginatum*, and (c) *S. virginicus* plots from July 1998 through September 2000.

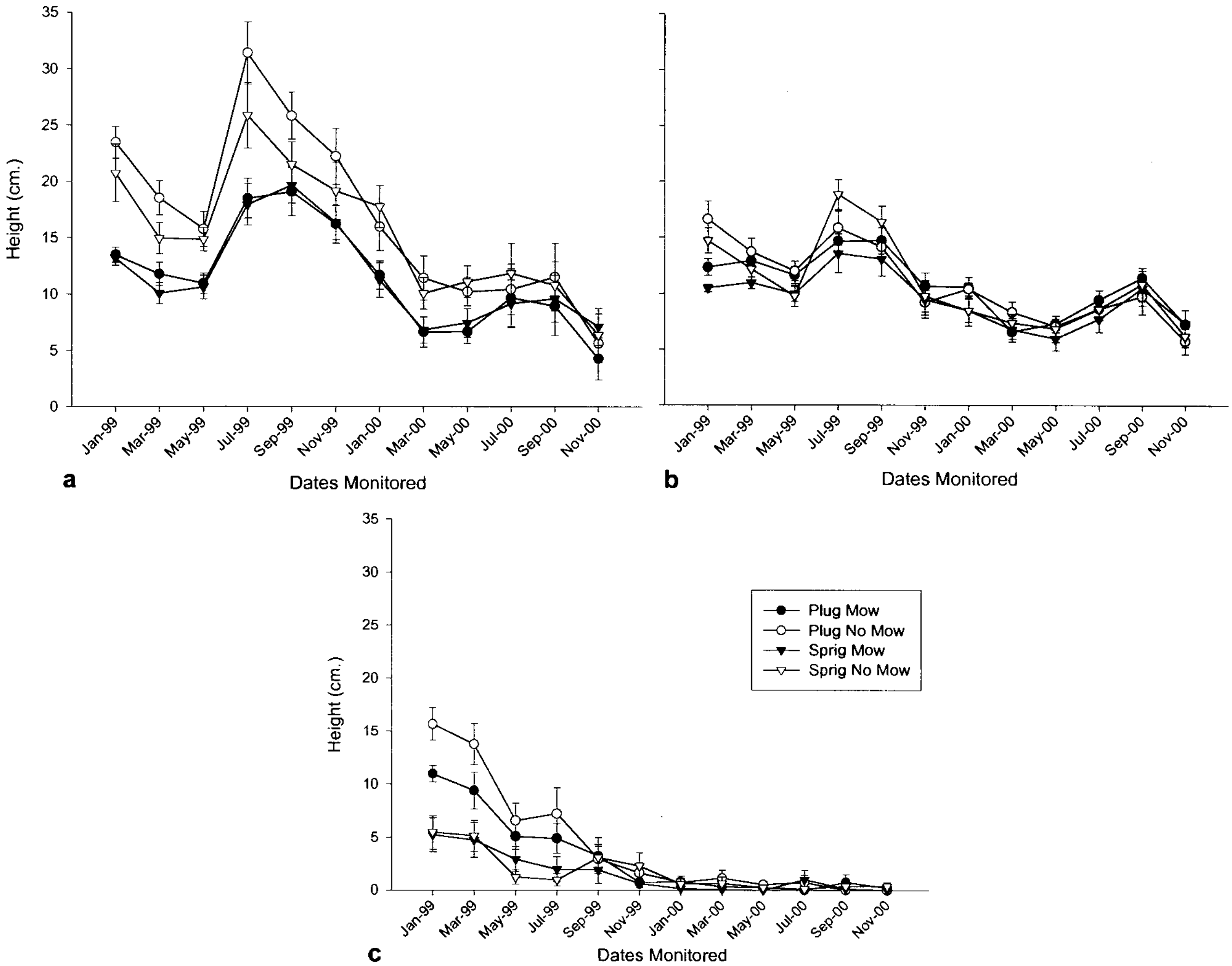

Figure 20. Mean height (± 1 SE, n=12) of (a) *P. vaginatum*, (b) *S. virginicus*, and (c) *D. spicata* from January 1999 through November 2000.

Non-planted Species

Height of non-planted species within the plots responded similarly to that of planted species with an additional dependence on fertilization and significant response by the interaction of species, propagule type, and mowing treatment (Table 11). No species or mowing treatment consistently resulted in the tallest non-planted species. Plots planted with plugs had taller non-planted species in them than did those planted with sprigs, but the difference was not significant in every month (Figure 21). The fertilized plots supported taller non-planted species every month until May 2000; plants were significantly taller from March 1999 through September 1999 (Figure 21).

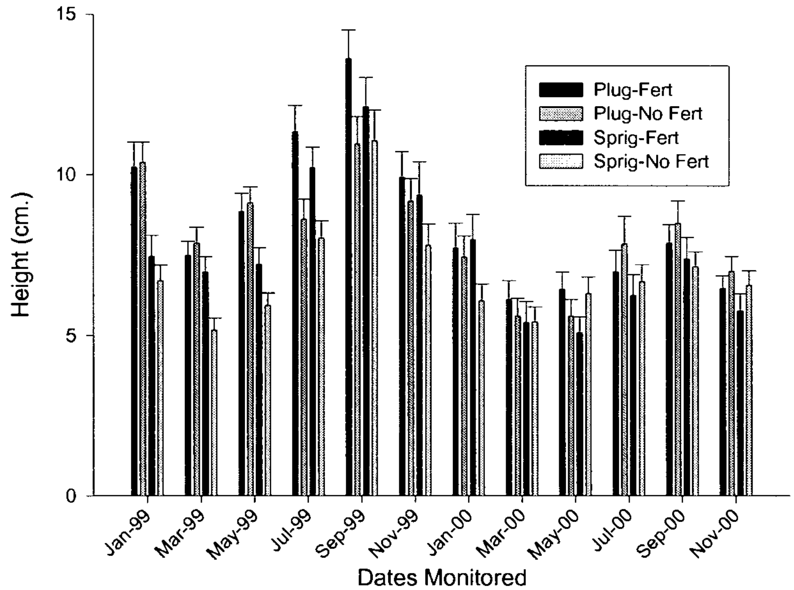

Figure 21. Mean height (+1 SE, n=36) of non-planted species with the fertilizer by propagule type interaction across species from January 1999 through November 2000.

Color

Although not quantitatively assessed, we observed a difference in color among the species (Figures 15, 22). *Sporobolus virginicus* had a more consistent bluish-green color over the monitoring period (with the exceptions of the winter of 1999) while *P. vaginatum* had a strong tendency toward brown in winter months, became more green immediately in the spring but has become browner again subsequently under drought conditions (Figures 15, 22a, b). The color of *D. spicata* became increasingly brown over time (Figures 15, 22c). We saw no obvious treatment effects in the color responses of each species (Figures 15, 22). All three species became more brown in winter 2001 (Figure 15, 22).

<u>Discussion</u>

Percent Cover

Planted species

During the sampling period, plugs and sprigs of *S. virginicus* maintained around 50% cover while the other two species showed a decrease in cover over time (Figure 16, 17a). We believe that abnormally dry weather (see Appendix B, Figure B-2) is a likely reason for the decreases in *P. vaginatum* and *D. spicata* cover over time and the drastic decrease in *S. virginicus* plug plots in summer 1999. The nursery-grown plugs of *S. virginicus* and *P. vaginatum* may have required more water because of acclimation to more mesic conditions in the nursery environment. Conversely, the response may result from a constrained rooting volume compared to the sprigs,

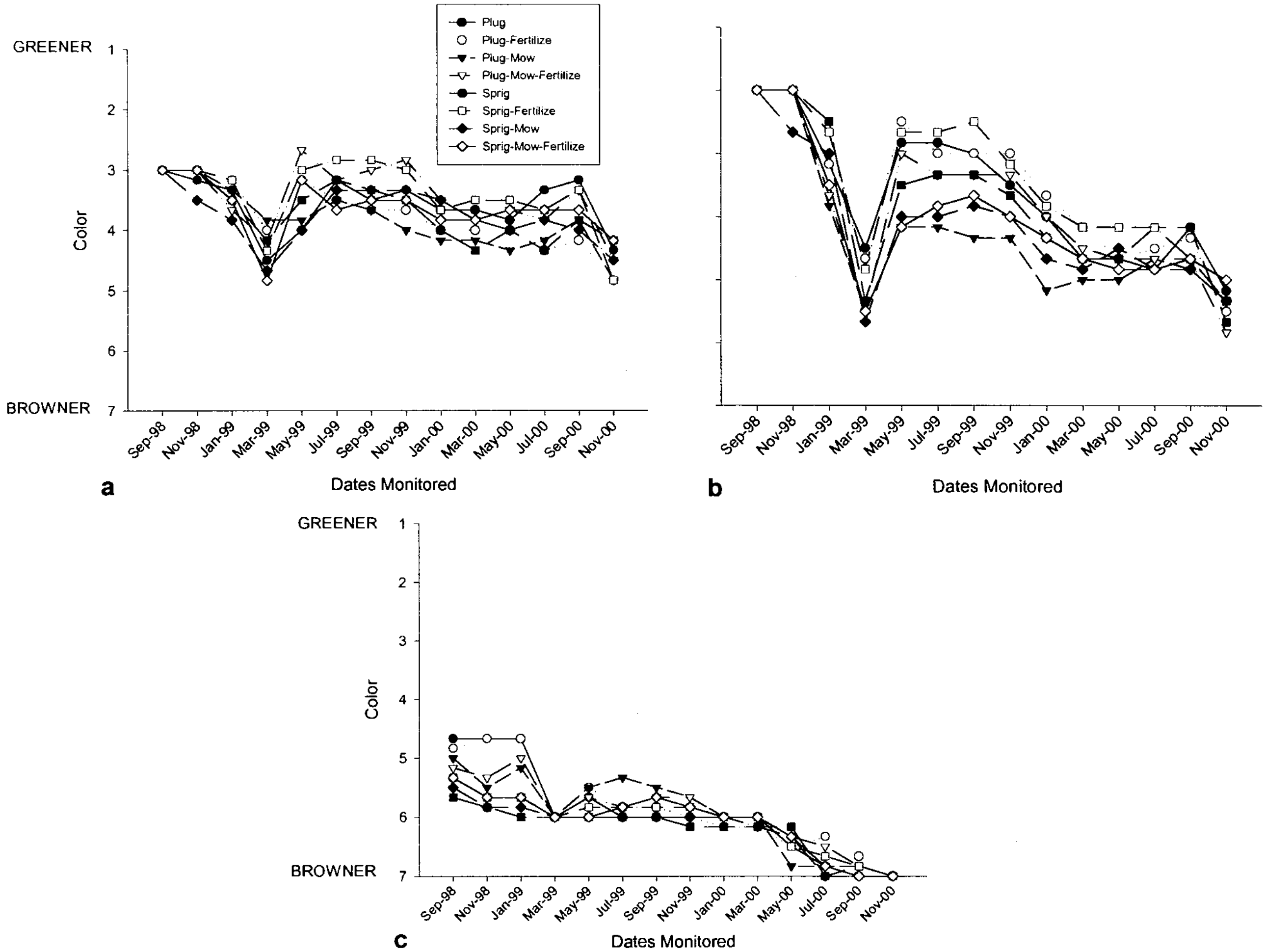

Figure 22. Mean color (n=6) of (a) *S. virginicus*, (b) *P. vaginatum*, and (c) *D. spicata* over time. Refer to Figure 15 for colors coded here.

which formed all roots under field conditions. More extensive rooting would have given the sprigs an advantage during the drought periods. At the end of December 2000, for example, Martin County was 14.9 inches below the average annual precipitation level (South Florida Water Management District 2000).

Distichlis spicata sprigs and plugs never developed significant cover because of their high mortality and inability to survive over time on the roadside. The species decreased in cover every month and was not present in most of the plots by September 2000. We do not recommend *D. spicata* for use as an alternative turfgrass.

The *P. vaginatum* genotype present at BRP seems to be less tolerant to mowing than we had anticipated. Jim Anderson reported that his commercial *P. vaginatum* sod requires frequent mowing to keep the sod dense (pers. comm.). In this experiment, mowing consistently decreased cover of this species (Figure 17b). However, many commercially selected and available genotypes apparently withstand mowing at extremely low heights (Duncan and Carrow 2000, see

Paspalum vaginatum Investigation below). These (non-native) genotypes are currently being used and mown at heights as low as 80/1000 in. around the world by golf courses in saline environments (M. Henderson, Gulfstream Golf Course, pers. comm.). Selection of native genotypes that can tolerate the FDOT mowing protocol (FDOT 1990) would be necessary if this species were adopted for use within the clear zone.

Non-planted species

Non-planted species, primarily *Dactyloctenium aegyptium* (crowfoot grass), *Digitaria* sp. (crabgrass), *Cynodon dactylon* (Bermuda grass), and *Sida acuta* (broomweed), negatively impacted the growth and cover of the planted species and in some plots dominated the cover. We may have been able to reduce this competition with a longer and more intensive period of site preparation. Non-planted species increased in cover during and right after summer 1999, when planted species showed decreases in cover.

Height

Sporobolus virginicus consistently had the lowest heights of the three species and perhaps would not need mowing if planted on a roadside because it does not grow taller that about 20 cm (8 in.) (A. Miller pers. obs.). Height results for *D. spicata* are irrelevant since it appears to be an inappropriate species for roadside use. The significant decrease in *P. vaginatum* height in all treatments was a result of high mortality (missing plants that were recorded as having no height). However, we observed that *P. vaginatum* was taller than the other species and tended to reach heights of about 61 cm (2 ft) and then collapse to a more horizontal growth form.

Color

Sporobolus virginicus reflected acceptable color (see Figures 15, 22a) for use as turf on roadsides. *Paspalum vaginatum* became brown in winter 1999 (much like bahiagrass) then recovered until mortality shifted color back toward the browner side of the scale (Figures 15, 22b). While the brown color of *D. spicata* was influenced by the high mortality the species suffered, even healthy plants tended to be on the yellowish side of the scale and were probably less acceptable in color.

Conclusions

Our conclusions are consistent with those drawn from one year of data collection (Gordon et al. 2000b). We recommend that *P. vaginatum* and *S. virginicus* be further investigated as potential native turfgrasses. Further investigation would clarify whether our promising results for both species would hold in other locations and over a longer time-frame. We have been warned by David Hall (pers. comm.) that *S. virginicus* may not always grow well after a few years. Steve Beeman, of Beeman Nurseries (Port Orange, FL), notes that this is only the case when *S. virginicus* is not exposed to salt water (pers. comm.). When salt water irrigation is present the species persists longer (S. Beeman pers. comm.). This suggests that *S. virginicus* has a salt water requirement; we do not know if exposure to salt spray in coastal locations is sufficient to maintain healthy growth. However, we are pleased to see that commercial sources of these species may be increasingly available. We do advise caution using *P. vaginatum* unless the source genotypes are confirmed to be native. We have conducted some additional research on this issue, which is reported below.

Paspalum vaginatum Investigation

During the course of this work, we learned that *P. vaginatum* has a global distribution. Movement of different genotypes of this species into North America from other continents has reduced our ability to broadly recommend this species as indigenous. We have proceeded in investigating this matter to further clarify questions we have concerning the origin and history of this species in Florida. *Paspalum vaginatum* is native to the southeastern United States; however it is also native to at least Africa, Argentina, Brazil, and Australia. Non-indigenous genotypes were introduced to the United States via slave ships in the 1700-1800's (Duncan and Carrow 2000).

According to R. R. Duncan of the University of Georgia, the indigenous genotypes may be distinguished from non-indigenous ones phenotypically (pers. comm.). Both fine textured and coarse textured ecotypes of *P. vaginatum* are currently found in Florida (Figure 23). The native Florida stock is all a coarse textured type (Fig. 24). Finer-leaved types are commercially available in Florida, but are non-native genotypes of this species that have been selected for characteristics desired by golf courses such as thin blades, fine texture, and very low growth habit (Figure 23b, c).

Dr. Duncan, who has studied this species extensively, states that there is no vegetative key available to distinguish between the native Florida stock and the ecotypes (pers. comm.). This led us to investigate different golf courses that had planted commercially available and locally collected *P. vaginatum* for use as turf.

We visited Ron Andrews, Golf Course Superintendent at Grand Harbor Golf Course in Vero Beach, FL. He has used *P. vaginatum* in several situations, both as a rough turf and in drainage areas and salt marshes. He has planted sprigs that he either collected on his site (thought to be of native stock) or purchased from Ecoshores, Inc. (now Southern Turf Nurseries) in Port Orange, FL (unknown genotype). Mr. Andrews has been unsuccessful in sprigging *P. vaginatum* in areas where there is not a salt water influence (R. Andrews, pers. comm.). He suggests that this species (as well as *S. virginicus*) are obligate halophytes and are poor competitors in fresh water situations. All of the *P. vaginatum* that we visited on his property looked vegetatively similar to both the plants we are growing at BRP and the sod we acquired from Anderson Nurseries (A. Miller and M. Renda, pers. obs.). Sprigged areas he showed us (off the fairway) never grew densely, had exposed soil areas, and were not considered successful (Figure 25). Mr. Andrews suggests using sod for better maintenance of cover and density (pers. comm.).

Figure 23. Morphological differences between *Paspalum vaginatum* (a) unmown coarse-textured, native Florida stock (collected at BRP), (b) unmown fine-textured, non-native "Salam" ecotype (collected at Gulf Stream Golf Course), and (c) mown (to 5/8 in.) fine-textured, non-native "Salam" ecotype (collected at Gulf Stream Golf Course).

We also observed some of the *P. vaginatum* ecotypes at the Gulfstream Golf Course in Gulfstream, FL. Mark Henderson, course superintendent, showed us the "Salam", "AP 10", and unknown genotypes of *P. vaginatum,* the former two purchased from Southern Turf Nurseries, that had been planted on the golf course greens and fairways. These two genotypes had very different growth habits than the plants at BRP (Figure 23). They were thin bladed, dense and cut at 80/1000 in. (Figure 26). Henderson said that "Salam" only requires 2-3 lbs of nitrogen fertilizer per year, which is significantly less than Bermuda grass requires, and when unmown for five months only grew to a maximum of about two inches (pers. comm.) (Figure 23b, c). These genotypes are very distinguishable from the native genotypes in characters that appeared not to result from mowing (A. Miller and M. Renda, pers. obs.).

Figure 24. *Paspalum vaginatum* at the Blowing Rocks Preserve. These are native coarse-textured Florida genotypes.

Figure 25. *Paspalum vaginatum* planted as sprigs on the roadside at Grand Harbor Golf Course.

Figure 26. *Paspalum vaginatum* at Gulfstream Golf Course. "Salam" is the lighter colored grass toward the back of the photo and "AP 10" is the darker green color toward the front.

The potential for interbreeding of the non-native and native genotypes is unknown. Dr. Duncan suggests it is highly unlikely and estimated a 0.05% probability of getting a viable seed. Interbreeding is further inhibited by the different photoperiod responses of the fine-textured and the coarse-textured (native stock) genotypes (Duncan, pers. comm.). Prolonged cold stratification may also be required for seed germination of some genotypes, another reason why mixed source genotypes may not succeed in Florida (Duncan and Carrow 2000; see below). Nevertheless, if interbreeding does occur, local genotypes may acquire deleterious traits like cold stratification requirement from non-native genotypes used in revegetation efforts. Similar negative effects have been seen when non-native species have hybridized with native closely related species (e.g. *Spartina alterniflora* (native) and *S. foliosa* (non-native) (Antila et al. 1998)). Both the identities of different cultivars and populations of *P. vaginatum* and their potential for interbreeding should receive further research. However, we believe the promise of the native ecotypes/genotypes of this species for further development as a native turfgrass is clearly good.

BB-533 Experiment B: Investigate the potential for sod development by the three salt tolerant native grass species.

<u>Introduction</u>

Turfgrass species used in Florida for soil stabilization and cover are generally available as sprigs, plugs, seed, and sod. This experiment focused on the potential of these species to develop a turf that may be harvested and planted as sod. In many sites sod is the only option for turfgrass installation, such as extremely sloped areas or other areas with a threat of severe erosion. For these reasons and because sod is the fastest, easiest way to get turf established, we decided to investigate the potential for these species to form sod. Following initiation of this research, we discovered *P. vaginatum* sod was already being commercially produced. As discussed above, only one vender (Anderson Nurseries, Ruskin, FL) appeared to have native genotype sod.

As described in Gordon et al. (2000b), we examined whether sod could be developed in a nursery setting from sprig plots. The same three salt tolerant species that were investigated in Contract BB-533 Experiment A: *P. vaginatum, D. spicata,* and *S. virginicus,* were selected for testing. This experiment also investigated whether the nursery grown sods could be cut with a sod cutter and transplanted successfully to a roadside. Sod was grown for a year prior to transplanting. As seen on the roadside, *D. spicata* suffered higher mortality and cover of non-planted species than did the other two species, and did not form a sod that could be transported. While we had some difficulty moving the loose sod of the *P. vaginatum* and *S. virginicus*, those two species successfully established on the right-of-way. The one-year continuation of this research project allowed us to follow development of the sod along the roadside.

Methods

Site preparation, planting of sprigs (or plugs for *D. spicata*), cultural treatments, monitoring, and transplantation methods were all described in Gordon et al. (2000b). Here we will cover the new methods and results, repeating the transplantation methods for clarity.

Sod Transplantation

The selected roadside for the sod was on CR 707, just north of the Hawley Education Center at BRP. The site was prepared about two months prior to transplanting. The existing bahiagrass and weeds were treated with 3% Roundup®. Two weeks following the treatment, the area was rototilled at a depth of six inches. The soil was then raked by hand and approximately two inches of existing soil was removed to accommodate the sod. A sprinkler irrigation system was installed.

The *D. spicata* sod trial was discontinued because of low vegetative cover and high cover of non-planted species (see Table 11 in Gordon et al. 2000b). The other two plots of sod were transplanted on September 29, 1999. We mowed the sod to a 10.4 cm (4 in.) height and weeded prior to transplanting. Sod was harvested using a Ryan® 7 hp sodcutter set to cut at a depth of four inches (10.4 cm) to minimize soil loosening (Figure 27). However, the action of the sodcutter under the grass caused the sandy soil to separate from many of the roots. Because of low root density and the sandy soils, the sod could not be directly lifted out once cut. We supported the pieces by sliding them onto boards which were carried to the planting site. Once the sod was laid on the roadside, it was watered and then rolled with a 240 lb roller to increase root contact with the soil. The plots were watered twice a day for the initial establishment period and then several times after that during periods of no rain.

Figure 27. Cutting the sod of *Paspalum vaginatum* using a Ryan® sodcutter.

Results

Cover of the two sod plots was monitored a few days after transplanting. Both species covered approximately 50-75% of their plots, respectively, with 1-6% non-planted species and 25-50% bare soil (Figures 28, 29). No mortality was observed as a result of the transplanting. Results from the post-transplant, bimonthly ocular estimates showed few changes over time. Results from the second month post transplant were identical to the earlier results. At present, both species have between 50-75% cover of planted species, 6-25% cover of non-planted species and 6-25% cover of bare soil. Neither plot has had any vehicular disturbance that caused obvious decrease in cover or increase of bare soil. These cover estimates have not changed since the second month after transplanting with the exception of weed cover which increased slightly over time.

Color results for the sod experiment were similar to that of Contract BB-533 Experiment A. *Sporobolus virginicus* showed the most consistent color over time while *Paspalum vaginatum* shifted toward brown in the winter months (Figure 15, Appendix B, Figure B-2).

Discussion

Prior to transplantation and after one year of growth, *P. vaginatum* and *S. virginicus* had virtually identical cover (see Table 11 of Gordon et al. 2000b). *Sporobolus virginicus* maintained its green color more consistently than did *P. vaginatum*. The *P. vaginatum* sod was visually more open and had more bare soil than the thicker *S. virginicus* sod, which had less visible bare soil. As

Figure 28. *Sporobolus virginicus* sod on the BRP roadside in June 2000.

Figure 29. *Paspalum vaginatum* sod on BRP roadside in June 2000.

discussed above, *D. spicata* had high mortality and high colonization of non-planted species and was not cut or transplanted to the road. The *D. spicata* also had a yellowish green color that shifted toward brown with increased mortality.

Transplanting these species was difficult, apparently because of low root density. The combination of insufficient root development and sandy soils meant that sod could not be lifted without additional support. Perhaps one year of growth in sandy soils is insufficient for dense root establishment of *P. vaginatum* and *S. virginicus*. Phosphorous fertilizer application may improve root development. As both species are currently or soon to be commercially available as sod, this difficulty may already have been satisfactorily addressed. These problems during transplant did not, however, result in increased death of the sod after transplant.

Conclusions

Paspalum vaginatum and *S. virginicus* formed a loose but functional sod when planted as sprigs in the nursery setting. Cultural techniques, such as fertilizer or a mowing regime designed to decrease internode lengths, may result in even more successful sod development. Plastics and fabrics are also widely used in nurseries and may be installed below ground to assist in lifting the sod (J. Anderson, Anderson Nurseries, pers. comm.). Overall this experiment demonstrates that both *P. vaginatum* and *S. virginicus* show high potential for large scale use as sod. Retention of color during the winter and dry months and a low growth form suggests that *S. virginicus* is the most promising for use on rights-of-way of the species studied.

Tests with commercially grown sod

Interest in the use of these native species for sod throughout the state has caused two commercial sod farms in Florida to initiate growth of *P. vaginatum* sod. The commercial sources are Anderson Nurseries in Ruskin, FL (West coast) and Southern Turf Nurseries in Port Orange, FL (East coast). The genetic source material for these operations is unknown because *P. vaginatum* has been horticulturally bred and even transported among continents for purposes of golf course sod development (Duncan and Carrow 2000). Further investigation on the origins of commercially grown sods and differences from local genotypes is recommended (see *Paspalum vaginatum* Investigation page 42).

This interest and commercial availability prompted us to start a small additional project. Three hundred square feet of commercially grown *P. vaginatum* sod were donated to the project by Anderson Nurseries. This donation enabled us to investigate the growth rates, drought resistance, and appearance of these commercially grown sods. According to Jim Anderson (pers. comm.), this sod was started from sprigs that were collected along the shoreline of Tampa Bay in southwest Florida. To the best of Mr. Anderson's knowledge, this was a naturally occurring patch of *P. vaginatum*.

The sod was installed on the BRP roadside on March 1, 2000 (Figure 30). Growth was dense, with approximately 75-95% cover and a bright green color that registered as a "2" on our color scale (Figure 15). We recorded no mortality after transplanting. The sod was irrigated weekly and mowed regularly. Unfortunately, several areas of *Cynodon dactylon* (Bermuda grass) contamination were identified in the sod (0-5% cover). This is a concern because *C. dactylon* is a non-native, invasive species. We already have records of *C. dactylon* invading disturbed sites throughout the BRP (M. Renda, pers. comm.).

Figure 30. Commercially grown *Paspalum vaginatum* sod installed on County Road 707 adjacent to BRP.

Due to the drought in 2000, the sod did not become established as rapidly as we initially expected (see Appendix B, Figure B-2). We continued to irrigate weekly through July 13, 2000, with the exception of one section of the sod plot that received no irrigation after May 10, 2000, to compare its growth and survival with that in the irrigated areas. This non-irrigated section turned brown. Weekly irrigation of the watered portion was resumed in August for three weeks, again to carry the sod through the dry weather.

The watered portion of the commercial sod was very dense with approximately 75-95% cover of *P. vaginatum*. Weed contamination remained at 1-5% cover. With increased rain in September 2000 the non-watered section started to grow back but only covered 25-50% of the plot.

Cynodon dactylon (Bermuda grass), several broadleaf species, and one small stem of *Panicum repens* (torpedo grass) contaminated the sod. On the irrigated section, salt water was sprayed from a pump sprayer twice a week for three weeks in an attempt to burn and kill the broadleaf species (<5% cover). No weed death, and only minor wilting of *Bidens alba* (Spanish needles) was observed. On the non-irrigated section, the weeds were sprayed with Ortho Weed B Gone® (0.2% 2,4-D, dimethylamine salt). This chemical did kill weedy species, but also caused browning of the sod, which took about a month to regreen (A. Miller, pers. obs.). The following herbicides have been tested by Duncan and Carrow (2000) and apparently are safe to use on *P. vaginatum* for weed control: Kerb®, Dimension®, Drive®, Prograss®, Vanquish®, Manage®, Trimec Southern®, Mecomec®, and Basagran®.

Discussion

The commercial *P. vaginatum* sod showed denser growth and could be transported with only minor fragmentation. The sod established well, but was sensitive to the dry conditions we had in summer 2000. At this time, whether the sod can recover from browning is unknown. We will know more after the sod has been present for a longer time period.

Inclusion of non-native and weedy species in the *P. vaginatum* sod suggests that tighter standards need to be developed if this native turfgrass is to be used as an alternative to non-native species. We were unable to successfully control the contaminants without negatively impacting the *P. vaginatum*. However, we did not try the herbicides suggested for use with this species by Duncan and Carrow (2000). In areas where irrigation is possible or where browning during winter and droughts is tolerable, this species forms commercial-quality sod.

Conclusions

To our knowledge, *P. vaginatum* sod of a coarse bladed type (assumed to be native stock) is currently available only at Anderson Nurseries in Ruskin, Florida. This ecotype has maintained good cover and color at BRP when irrigated through this extended dry year. Anderson Nurseries also tested a 1.5 acre plot of *S. virginicus* sod in 1999 and suggests that this species also has very high potential as a native sod. The *S. virginicus* fared much better through the extremely dry summer than did the *P. vaginatum* sod (J. Anderson, pers. comm.), as was seen in our experimental sod plots as well. This *S. virginicus* sod should be commercially available soon (J. Anderson, pers. comm.).

If *S. virginicus* sod becomes commercially available, land managers in coastal areas would have another option for native turfgrass sod. This species has great potential for areas where maintenance is not possible or desirable because it never grows very tall according to Jim Anderson (pers. comm.). However, long-term survival of this species, like *P. distichum*, requires further investigation.

Implementation of this research

Demand has been increasing for *P. vaginatum* sod from Anderson Nurseries (J. Anderson, pers. comm.). His nursery has sold all of their *P. vaginatum* sod for the year and is producing 20 additional acres of the sod for the coming year. This sod has been used in several locations, including adjacent to the BRP, some of which we detail below.

- Through our recommendation, Martin County and the Town of Jupiter Island installed approximately 10,000 ft^2 of *P. vaginatum* sod along the roadside at BRP (Figure 31). This application is a direct result and application of our FDOT-funded experimental work.

The road that bisects BRP was due for repaving and some shoulder work. Instead of planting *Stenotaphrum secundatum* (St. Augustine 'Floratam'), which is invasive in coastal strand communities (M. Renda, pers. obs.), or *Paspalum notatum* (Bahiagrass) sod, we recommended that they plant *P. vaginatum* despite the slightly higher cost. We also encouraged them to purchase the native Florida sod from Anderson Nurseries. The Town and County agreed to our recommendations and the sod was installed on September 15, 2000. The sod did not hold together as well as traditional sod and installation involved more labor than would a more traditional sod species. Potential reasons for this problem could be that the species does not have dense enough roots to hold the soil together or that the growing conditions in the sod fields (at that time) were too dry and the soil could not hold to the sod pieces. Future installations of this sod should anticipate this problem.

The sod was irrigated twice a week for the first two weeks and then once a week for the next five weeks. It is mowed once a week with a ride-on mower set at a four inch height. Two months post installation, the sod is attractive, dense, dark green, and survived well even though it fragmented in sections during installation. It browned in color slightly this winter but continues to hold dense cover with no additional irrigation (A. Miller, pers. obs.).

Figure 31. Martin County *Paspalum vaginatum* sod project on County Road 707 in October 2000.

- The Department of Environmental Protection in Tampa is also using *P. vaginatum* sod from Anderson Nurseries on road shoulders. This sod has been planted successfully on the edges of mangrove swamps and other salt water wetlands (Figure 32). We are very encouraged by these implementation activities, and will continue to monitor the sod at BRP.

Figure 32. Department of Environmental Protection *Paspalum vaginatum* sod project in Tampa, Florida.

- Jim Anderson (pers. comm.) listed several other projects that used this *P. vaginatum* sod: Pinellas County has used the *P. vaginatum* sod in several county parks. Additionally, 480,000 ft^2 of *P. vaginatum* sod was purchased by a condominium association in Naples to stabilize a berm between the condominium and Naples Bay. Bill Linton with Port Tampa used *P. vaginatum* sod at a boat ramp on Cockroach Bay. Large boulders bordered each side of the ramp. Sod was planted in filled spaces between the boulders.

BB-533 Experiment C. Conduct seed germination trials of four salt tolerant native grass species.

<u>Introduction</u>

Direct seeding is the most economical and one of the most predominantly used methods of establishing turfgrass on rights-of-way. In many remote areas where irrigation of sprigs, plugs or sod is not possible, direct seeding grass species is the only feasible method available. Therefore, we investigated whether several of the native grasses in this study have germination rates high enough to warrant large-scale use by FDOT.

Many grass species exhibit seed dormancy (Voight and Tischler 1997). Dormancy can hinder restoration efforts and cause seeds to be exposed to predators for longer periods of time (Bonner et. al. 1974). For some grass species seed treatments have focused on reducing the dormancy caused by hard seed coats.

Investigation of seed viability of the species used in all the experiments was included in the previous report (Gordon et al. 2000b). Germination trials at the IFAS Indian River Research and Education Center (Ft. Pierce, FL) were generally unsuccessful (see Table 12 of Gordon et al. 2000b). As a result, further investigation was conducted in the BRP shadehouse. We examined the effects of seed pre-germination treatments and sowing depth on germination of each of the species. Timing and percent germination were evaluated.

Methods

Seed germination trials were established in the shadehouse at BRP (Figure 33). The salt-tolerant species tested were *S. virginicus* and *P. vaginatum,* and the salt intolerant species were *E. refracta, E. petraea, P. anceps*, and *P. setaceum.* As in the earlier tests (Gordon et al. 2000b), seed were not available for *D. spicata* and *P. distichum*.

Figure 33. Seed germination experiment setup in the BRP shadehouse.

Four replicates of 100 seeds each of each combination of: six species x four pre-germination treatments (none, mechanical scarification, acid wash, and heat treatment) x 2 sowing depths (surface and 3 mm (0.117 in.) deep) were established for all species except *P. vaginatum*. Because of limited seed availability, 50 seeds were used for each replicate of this species. The treatments were then applied to the replicates as follows.

Heat Treatment

Heat has increased germination in Lehmann lovegrass (*Eragrostis lehmanniana*) (Haferkamp and Jordan 1977). Seeds in this treatment were placed in an oven at 70° C for 24 hours. This work was done in an incubating oven in Ft. Pierce at the University of Florida, Institute of Food and Agricultural Sciences (IFAS) lab and education facility.

Mechanical Treatment

Mechanical treatment was accomplished using sandpaper (see Hartmann 1990). Seeds were placed between two pieces of 180A grade sandpaper. The two pieces were gently rubbed together eight times. The number of strokes was determined by examining the seed under a microscope for nicks in the seed coat. Eight strokes appeared to nick the seed coat without destroying the seed (A. Miller, pers. obs.).

Acid Treatment

Sulfuric acid is used as a scarification method because it can pit hard seed coats (Fulbright 1987). Seeds for this treatment were soaked in 98% H_2SO_4 for 10 minutes (Association of Official Seed Analysts 1993). This treatment was again accomplished at the IFAS lab in Ft. Pierce. Acid was poured over the seed in a glass beaker in a fume hood. The mixture was stirred gently several times with a glass rod during the ten minute period. The mixture was diluted with water and strained with a metal mesh strainer. Seeds were rinsed in cool water for ten minutes and then rinsed in water with a small amount of baking soda to neutralize any remaining acid. All seeds were spread out to dry on paper towels. Seeds were observed under a microscope after treatment and seed coats of all species were either pitted or dissolved (A. Miller, pers, obs.).

Sowing

All of the pots (50 in^3 = 720 cm^3) were labeled by treatment and then randomly placed on tables in the shadehouse at BRP. Soil used for the experiment was 25% coarse sand, 25% pine bark, 45% Florida peat, 5% perlite, and one-half bag of minors and Dolomite to bring pH to 7.0. Soil was sifted through a flat with holes of 1.0 cm (0.39 in.) diameter to remove any large pieces of bark. All pots were filled with soil and the corresponding seed was hand-sown into each pot. Seeds of replicates with surface sowing depths were placed on top of soil; seeds of replicates with 3 mm (0.117 in.) deep sowing depths were sown on top of the soil and covered with 3 mm of soil. The pots were irrigated twice daily for six minutes.

Monitoring and Data Analysis

Weekly monitoring started at the first sign of germination, two weeks after sowing. The seedlings in each pot were counted, recorded and then removed from the pots to prevent duplicate counting. Thus far, the last recorded germination was on August 21, 2000. An analysis of variance (ANOVA) was used to determine differences in germination rates among species, treatments, and sowing depths. Data for each species were also analyzed separately to determine significant differences among the treatments.

Results

We found significant differences among the pre-germination treatments in germination by species, but no significant effect of sowing depth (Table 12). *Panicum anceps* had the highest percent germination of all species (Figure 34), while *P. vaginatum* had no germination. The literature suggests that the only method of enhancing germination of some *P. vaginatum* genotypes is long exposure to sub-freezing temperatures (Duncan and Carrow 2000). It seems unlikely that genotypes native to Florida would require this cold exposure. However, we clearly did not include an effective dormancy-breaking treatment for this species in this experiment. Seed treatment effects varied by species but, with the exception of *P. setaceum*, the control group had the highest germination of all the treatments for the remaining species (Figure 35). Thus, these pre-germination treatments were not necessary for most of these species. Germination of *P. setaceum* germination was significantly enhanced through an acid treatment (Figure 35).

Table 12. Significant ($p<0.05$) and near significant ($p<0.07$) results (in bold) from a full factorial analysis of variance of percent germination of all species except *P. vaginatum* (no germination recorded).

Factor	df	All species	*E. refracta*	*E. petraea*	*P. anceps*	*P. setaceum*	*S. virginicus*
Species	4	**0.0001**	n/a	n/a	n/a	n/a	n/a
Treatment	3	**0.0001**	**0.0006**	**0.0001**	**0.0088**	**0.0004**	**0.0001**
Depth	1	0.3225	0.2597	0.3980	0.2867	0.6857	0.1848
Spp*Treat	12	**0.0001**	n/a	n/a	n/a	n/a	n/a
Treat*depth	3	0.2020	0.9927	0.5987	0.8877	**0.0774**	0.5031

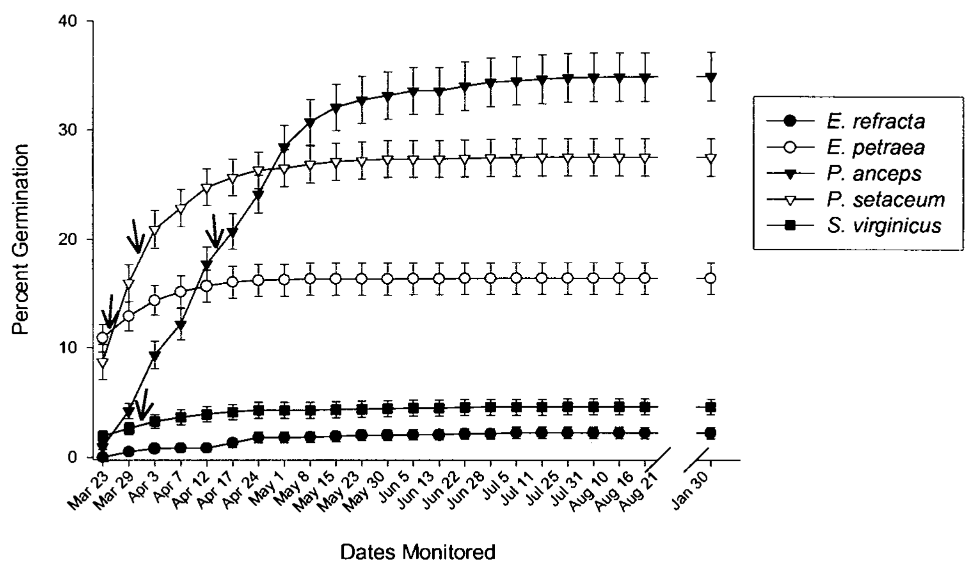

Figure 34. Mean cumulative percent germination (±1 SE, n=32) for each species. Arrows indicate mean date at which 50% germination was reached (insufficient data to calculate for *E. refracta*).

Timing of germination varied by species. We calculated the number of days until 50% germination was reached for all species that had some germination. This calculation was added to the ANOVA as a covariate to determine whether the speed of germination influenced total germination among the species. Speed of germination did not influence final germination results, but did differ among the species (p=0.01). *Panicum anceps* had the highest total germination, but reached 50% germination in 36 days, while the other three species took less than 22 days (Figure 34). Therefore, rapid germination did not mean higher total germination across the species; the relationship between total germination and speed differed among the species.

Discussion

These results indicate that the seed of *E. petraea*, *P. anceps*, and *P. setaceum* used in the field experiments was viable and was collected at proper maturity. For *S. virginicus* and *E. refracta*, perhaps this was not the case. Not surprisingly, the best technique to increase germinability is species-dependent. *Eustachys petraea* and *P. anceps* had fairly good germination percentages when sown directly with no pre-germination treatment (Figure 35). However, germination of *P.*

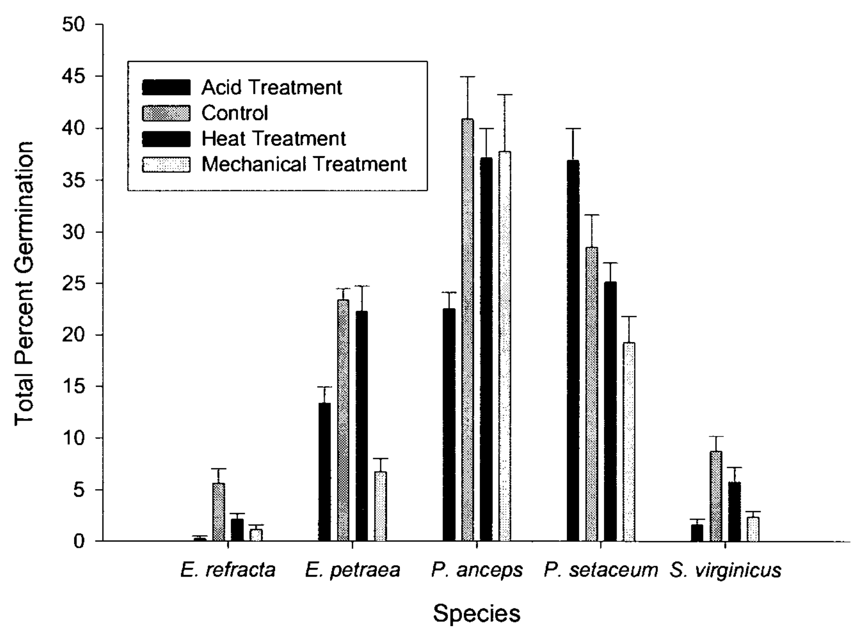

Figure 35. Mean percent germination (+1 SE, n=8) of each treatment by species. *Paspalum vaginatum* was not included due to no observed germination.

anceps seed from North Carolina was increased from no germination in untreated seed to 66% when treated with 0.5% KNO_3, damp storage for 42 days at 5°C, and then dried and stored at room temperature for 6 months (Matthews 1947). This difference might reflect genetic difference between seed stock from Florida and North Carolina, but further investigation might reveal similar treatments that would increase germination rates. *Eragrostis refracta*, *S. virginicus,* and *P. vaginatum* had inadequate germination for use on a large scale, and perhaps other scarification methods should be evaluated. *Paspalum setaceum* showed significantly higher germination when treated with an acid bath than in any other treatment in the study (Figure 35). Further investigation would clarify field germination success of *P. setaceum* treated with H_2SO_4.

We did not evaluate germination in *P. distichum* because no seed was available. Huang and Hsiao (1987) researched seed dormancy in *P. distichum* collected in California (of unknown seed origin) and found that this species does exhibit seed dormancy. These authors found that germination of *P. distichum* was also increased through environmental treatments, such as H_2SO_4 scarification and light exposure (Huang and Hsiao 1987).

These shadehouse tests help to explain the results we obtained from the field experiments. However, while *E. refracta* appeared not to respond with high germination in these trials, this species was one of the more promising in the field. Thus, both types of trials will be necessary to identify the species likely to establish on roadsides. Those species that do not require seed pre-treatment prior to sowing are likely to be more efficient for large-scale use.

Conclusions

Through the field experiments in Experiment A (Objective 1), where *E. refracta* and *E. petraea* showed good germination rates, and this shadehouse Experiment, where *P. anceps* and *P. setaceum* had good germination rates, we can conclude that all of these flatwoods seed tested are germinable by one of our methods. While we had selected the species that appeared to be most promising for the roadside trial of Experiment A, other species might also be useful on rights-or-way and in restoration efforts when planted as seed.

Objective 2b: Develop recommendations from this research for the use of native turfgrasses in roadside revegetation and for future research needs.

Many recommendations drawn from this research were made at the conclusion of Contract No. BB-533 (Gordon et. al. 2000b). Unless modified here, those original recommendations are still valid. Here we present modifications to the original recommendations in that report, some new recommendations that can now be made, and several future research needs.

Modifications to recommendations made in Contract No. BB-533

As mentioned under Contract BB-533 (Gordon et al. 2000b), there has been a growing interest around the state for native turfgrass sods, especially *P. vaginatum*. Many land managers are increasingly interested in native sods for roadsides and erosion control needs in natural areas (J. Anderson, Anderson Nurseries, pers. comm.). We previously recommended availability of *P. vaginatum* sod from Anderson Nurseries and Southern Turf (formerly Ecoshores Inc.). At this time we only recommend the use of *P. vaginatum* sod grown from native Florida sources. To our knowledge, this indigenous sod, as well as *S. virginicus* sod, is only available from Anderson Nurseries in Ruskin, Florida. We believe that the demand for these species would support greater availability of regional ecotypes from across the state. However, we again caution that consumers question whether native material is being propagated and must confirm that it is coarse-textured.

New Recommendations

Flatwoods graminoids

After the first two years of experimentation, we concluded that planting sprigs of *Paspalum distichum* was more promising than sowing seed of any of the species we tested for development of turf. However, the roadside trial that included *Eustachys petraea* suggests that direct-seeding may be more successful than we once thought. These two species clearly deserve further examination and development. Further, several of the other species demonstrated healthy establishment from seed, although they were not consistent across germination and sowing trials: *Eragrostis refracta, Paspalum setaceum,* and *Panicum anceps*. The likelihood of identifying several more species of native turfgrass that might be propagated for use on rights-of-way seems high.

While most recommendations for sowing rates for native species are for 7-20 lbs/ac (Harper-Lore 1998), we used 20-30 lbs/ac in these experiments because of low germination rates seen in previous trials (Gordon et al. 2000b). The seed cleaning and pre-germination treatments tried did not increase germination to levels that would suggest lower sowing rates would be successful. It is unclear whether *E. refracta* had such low germination in Experiment B (Objective 1) because of the seed cleaning technique (Hammermill®) we used, negative effects from roadside conditions, or other unknown factors. Since this species showed good germination and cover in Experiment A (Objective 1), we suggest that it be further investigated.

Paspalum distichum has good potential for sod development. Successful sod production of this species could be very beneficial for land managers in inland portions of the state. To our knowledge, *P. distichum* is not currently being commercially produced as sod. As suggested for the coastal species, propagation of regionally collected ecotypes for use in north, central, and southern Florida would likely find local markets. However, the ability of this species to persist over several years has been questioned and would need longer-term study to evaluate.

Fertilization was not an important treatment in any of our experiments. In our other research on restoration and revegetation with native species, we have found that fertilization provides greater benefits to the undesirable non-native and weedy species than to the natives targeted for establishment (The Nature Conservancy 2000). While fertilization may be beneficial in some situations, for development of a compact native sod for example, the standard N-P-K mix is unlikely to be optimal for many native species, especially when they are established from seed.

Salt tolerant graminoids

We continue to be optimistic about the potential for use of *Sporobolus virginicus* and *Paspalum vaginatum* on rights-of-way. This use is currently expanding, partially because of this research. *S. virginicus* may not require mowing in most situations, as heights never exceeded eight inches during our research. However, like *P. distichum*, persistence of *S. virginicus* over time requires further evaluation. Our caution about *P. vaginatum* stems from its global distribution. We recommend that local ecotypes, with coarse-texture be propagated and sold for use on rights-of-way.

We found native and non-native weedy species contamination in the commercially available sod. As with all propagated material and seeds, contamination of these species could have a highly destructive impact on revegetation efforts. Both standards and vigilance will be necessary to ensure that unclean material is not introduced.

Overall, this research demonstrates that Florida's native flora has many species that would likely produce continuous cover on rights-of-way. We encourage FDOT and others to continue pursuing this promising direction. As discussed above, some of the research products are clearly at the implementation stage, while additional research is necessary for several of the other species. The speed at which interest has been generated in these results suggest large-scale demand for native grass propagules. We hope that the horticultural and agronomic community will continue this line of research and implementation.

Research Needs

Many new research questions and further investigation of some questions we experimented on have come out of this project. As mentioned above, there is need for further investigation of the potential for *S. virginicus* and *P. distichum* to persist in a restoration setting for more than a few years. For *S. virginicus*, the amount of salt water exposure (ranging from salt spray to actual salt water irrigation or flooding) required for successful growth is unclear at this point.

Further research on the genetic variation of the *P. vaginatum* ecotypes is needed (especially ecotypes commercially available as sod) to determine the potential of the non-native ecotypes to interbreed with the native Florida type. This is necessary as the use of African *P. vaginatum* ecotypes such as "Salam" is increasing on golf courses in coastal areas, many of which have natural areas included on their property. Clarification of the differences among native and non-native ecotypes for easy field identification and determination of those native ecotypes that can tolerate mowing are also critical.

We believe seed collection, cleaning, and germination techniques on the directly-seeded species tested could be improved with investigation of different methods and improvement on the methods we tried. For example, we suggest field trials of acid-scarified *P. setaceum* seed and shadehouse trials of the mechanically cleaned *E. refracta* seed. This further research should improve the feasibility of direct seeding the flatwoods species tested and may reduce the sowing rate recommended.

The differences in germinability we observed among species and experiments suggest that further research on factors that control germination may produce more choices for revegetation with native grasses. These factors may include the timing of sowing, as we saw significant differences among the species in the timing of germination in the field.

Timing appeared to also be influential in several other ways. We saw significant differences in the establishment of the *P. distichum* sprigs among the repeated experiments, perhaps because of differences in the planting dates. Color changes in the different species also appeared to respond to different cues. For example, *E. petraea* started to turn brown in September 2000. Because of the drought conditions, we are unable to distinguish whether these differences are seasonal and linked to day length, or were dominated by drought effects or by other factors. Responses of these species in different years would clarify this ambiguity.

We also need better understanding of the effects of different herbicides on both sown or planted and undesirable species. We had anticipated that Plateau® would be the most effective of the weed-control methods tested. While Plateau® did seem to most effectively control non-native and weedy native species on the edges of the plots, it was less effective in controlling the weeds in the plots than we had hoped. Further, we found earlier (Gordon et al. 2000b) that Plateau® has some pre-emergent effects even on the sown species. Testing of this and other herbicides at different concentrations to identify the most effective treatments would be useful.

If a more effective pre-emergence herbicide could be identified that would not have residual negative effects on the sown seeds, the duration and perhaps cost of site preparation could be reduced. Evaluation of available herbicides for their ability to control the species that continue to germinate after the site has been disked to reduce existing vegetation and loosen the soil might result in identification of a more effective treatment than the ones tested here.

In summary, more research is necessary. We would recommend that implementation and research be conducted simultaneously so as to speed the use of native species on rights-of-way and learn more in the process. We also hope that these results will stimulate the horticultural industry to explore development of more of these species for landscaping purposes. Our experience during these two research projects is that the demand is already present.

Technology transfer accomplished during the course of the project.

Presentations

Miller, A. The Florida Native Turfgrass Investigation. May 2000. Florida Native Plant Society Annual Conference. Miami, Florida.

Miller, A. The Florida Native Turfgrass Investigation. May 2000. The Nature Conservancy's Upland Restoration Workshop. Disney Wilderness Preserve, Kissimmee, Florida.

Gordon, D.R. Native Species for Use along Rights-of-Way. September 2000. FDOT 2000 Environmental Management Workshop. St. Petersburg, Florida.

Renda, M.T. Native Plant Propagation. March 16, 2000. Florida Native Plant Society. Eugenia Chapter meeting. Vero Beach, Florida.

Field Trips

Field trips to Grand Harbor Golf Course in Vero Beach, FL and Gulfstream Golf Course in Gulfstream, FL to observe *P. vaginatum* ecotypes in golf coarse setting. June 2000. Amy Miller and Mike Renda.

Field trip at DWP with Jonas Stewart of Volusia County Mosquito Control to view *Paspalum distichum* for potential use in mosquito ditches. April, 2000.

Field trip with a group of secondary teachers associated with the Adopt-A-Watershed Workshop at DWP. June, 2000. 20 participants.

Publications about this project

The Nature Conservancy. 2000. Proceedings of the upland restoration workshop. Disney Wilderness Preserve, Kissimmee, Florida. 74 pp.

The Nature Conservancy. Winter 2000. Seashore Paspalum planted on preserve roadside. Blowing Rocks Preserve newsletter. p. 4. The Nature Conservancy, Hobe Sound, Florida.

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Andrews, Ron. Grand Harbor Golf Course. Vero Beach, FL.
Beeman, Steve. Beeman Nurseries. Port Orange, FL.
Bissett, Nancy. The Natives Nursery. Davenport, FL.
Blount, Ann. University of Florida, NFREC. Quincy, FL.
Burk, Kathy. DEP, Bureau of Invasive Plant Management. Tallahassee, FL.
Duncan, Ronald. University of Georgia Experiment Station. Griffin, GA.
Hall, David. Botanist. Gainesville, FL.
Henderson, Mark. Gulfstream Golf Coarse, Gulfstream, FL.
Lamb, Betsy. University of Florida, IFAS. Ft. Pierce, FL.
Pfaff, Sharon. USDA Plant Materials Lab. Brooksville, FL.
Roberts, Dick. DEP, Florida State Park Service. Hobe Sound, FL.
West, Sherlie. University of Florida, IFAS. Gainesville, FL.

Appendix A. TNC newsletter article on the native turfgrass research.

Seashore Paspalum Planted on Preserve Roadside

The preserve's three-year study to find the best native grass species for roadside use, funded by the Department of Transportation, is nearing completion. We recently found that seashore paspalum, one of the top grasses from the study, is being commercially grown at a sod nursery near Tampa. Martin County agreed to purchase this sod for the preserve as part of their roadwork on Jupiter Island, and about 10,000 square feet of sod has been installed on the roadside adjacent to the education center. We will water the grass until it becomes established, at which point the grass will need no additional care.

Figure A-1. The Nature Conservancy. Winter 2000. Seashore Paspalum planted on preserve roadside. Blowing Rocks Preserve newsletter. p. 4. The Nature Conservancy, Hobe Sound, Florida.

Appendix B. Precipitation data for Disney Wilderness and Blowing Rocks Preserves during the research period.

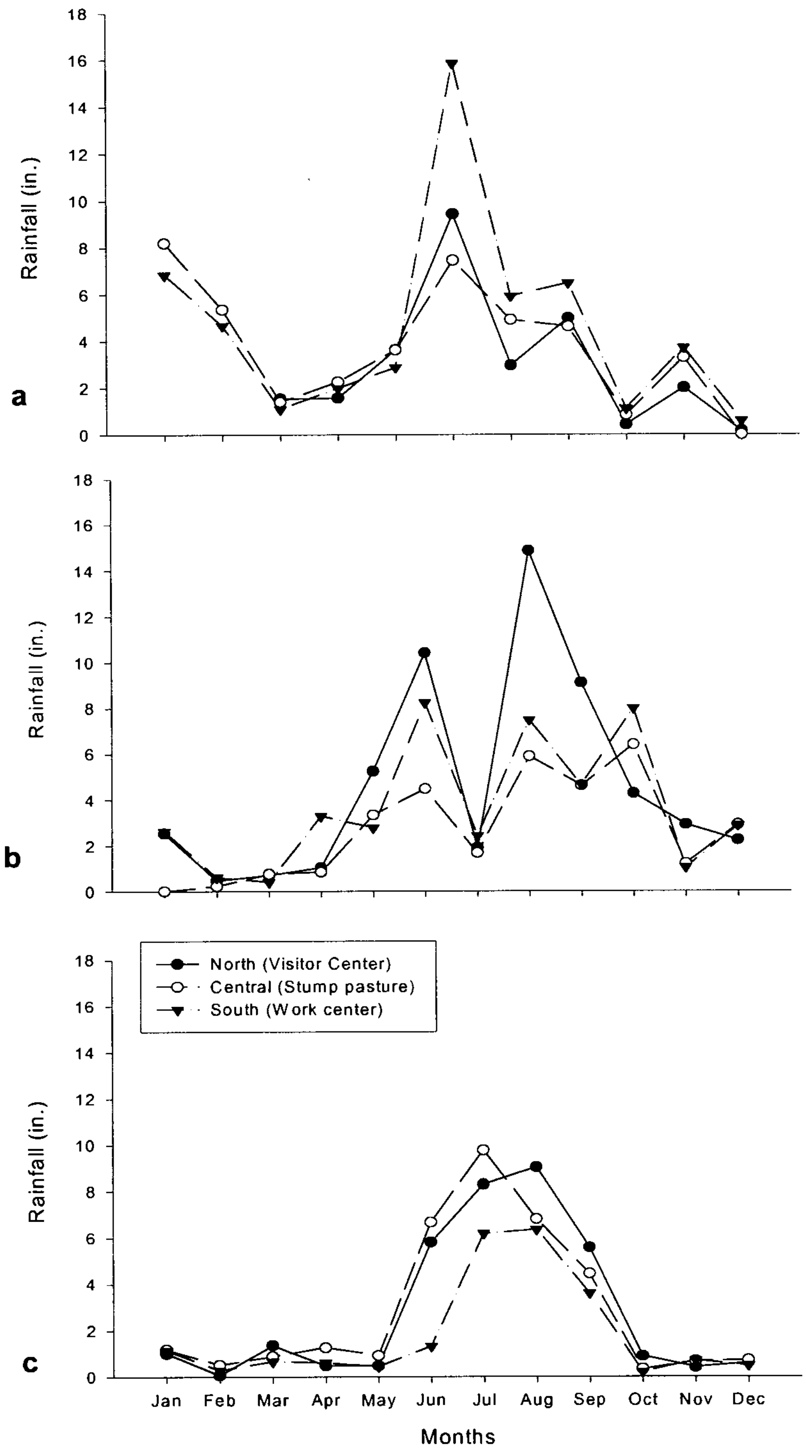

Figure B-1. Monthly rainfall at DWP from three remote weather stations in (a) 1998, (b) 1999, and (c) 2000. The north recorder was installed on 4/01/98. Gaps in data for: North 7/13/99 and 8/14/99, Central 2/10/99, 9/99, 10/99, and 11/99, and South 9/99, 10/99, 11/99, and 6/00 are due to mechanical malfunctions.

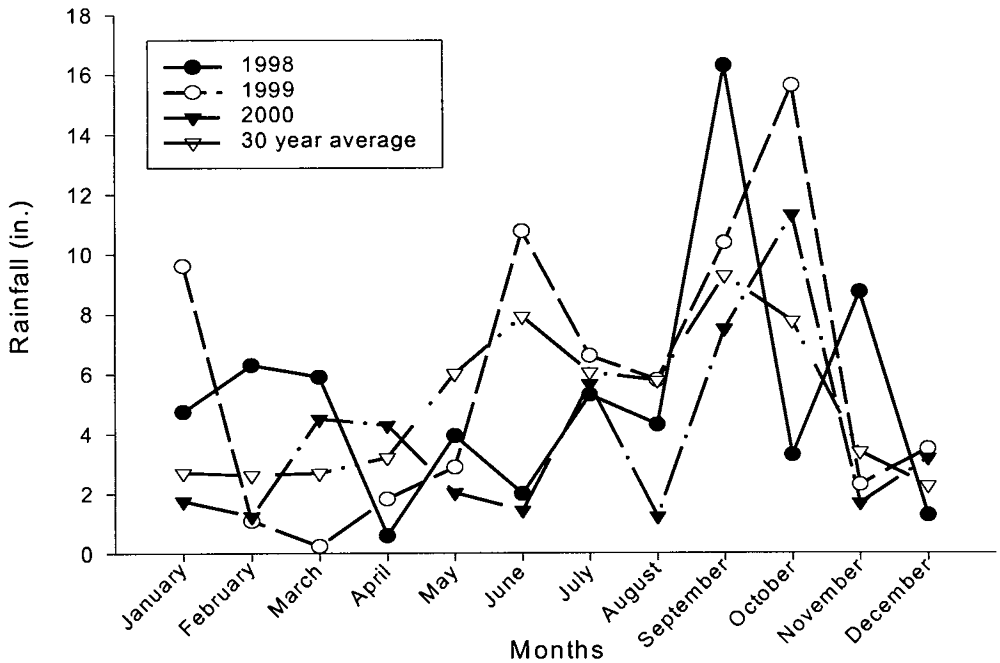

Figure B-2. Monthly rainfall at BRP for 1998-2000 and the thirty-year average for West Palm Beach Weather Bureau Station.