DEVELOPMENT OF SEED SOURCES AND ESTABLISHMENT METHODS FOR NATIVE UPLAND RECLAMATION

1999 ANNUAL REPORT

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INTRODUCTION

There is a pressing demand in Florida for native plant materials for use in reclamation of upland habitats. Direct seeding has the potential to be the most economical method for revegetation. However, there are currently no commercial seed sources of native Florida upland species. Several problems associated with native plants have hampered reseeding efforts. First, many species have low seed production and viability. Secondly, seeds are often light and chaffy, and cannot be harvested or seeded with conventional equipment. Thirdly, desirable native plant species often lack seedling vigor, and are poor competitors with weed species.

Under a previous five-year agreement with FIPR, the Brooksville, Florida Plant Materials Center (FLPMC) collected and tested seed from a large spectrum of upland native grasses, forbs and woody species. From this initial work, several species were identified as having potential for use in a native seed mix. Selection criteria included production of substantial quantities of viable seed which could be mechanically harvested and direct seeded; persistence; usefulness for livestock forage, wildlife food and habitat; provide ground cover for erosion control and increased water quality. Under the present five-year agreement, the FLPMC is working to develop seed sources, seed production, harvesting, seed cleaning and planting technology for these targeted species, as well as continuing to study other native species for potential use in a native seed mix.

The objectives of this five-year agreement are as follows:

1. **Identify and collect upland grasses, legumes and forbs, which show promise for use in a native seed mix**: Seed from 2 to 4 new promising species will be collected, (in addition to those species targeted for further study under the previous agreement). Also, 1 to 3 species identified as being good candidates for the cultivar release program will undergo state-wide assembly and be entered into initial evaluation trials.

2. **Evaluate seed and plants of collected species**: All collections will be tested at the FLPMC in the laboratory. Greenhouse and field tests will be conducted if an accession warrants further testing, and seed materials are available. Evaluation criteria include seed viability, seedling vigor, ease of establishment, seed production, forage quality, persistence, and drought, disease and insect resistance.

3. **Establish production fields of selected species**: Fields of 2 to 4 selected species (in addition to those species established under the first agreement) will be planted at the FLPMC, to increase seed supplies and test cultural practices which will increase seed production and viability.

4. **Develop and test cultural practices for direct seeding native species on disturbed sites in monoculture and mixes**: One or more major experiments testing such things as seeding rates, depths and dates will be established on reclaimed mined lands.

SEED COLLECTION

OBJECTIVE # 1: Identify and collect upland grasses, legumes and forbs, which show promise for use in a native seed mix

Native Site Hand Collections:

Seed of several native species was collected from Ft. Cooper State Park and Avon Park Bombing Range in the fall of 1998. Both of the collection sites received growing season burns in 1998. This appeared to stimulate viable seed production of the species that were collected. Seed germination test results are shown in Table 1. Sky Blue Lupine (*Lupinus diffusus*) was collected from one site in Citrus Co. in 1999. Germination tests have not yet been conducted on this species

Switchgrass (*Panicum virgatum*) was collected vegetatively from three sites in Florida. The types collected and purpose for these collections will be discussed in detail under the "Testing Cultural Management Practices" section of this report.

Native Site Flail-Vac Collections:

Wiregrass seed was collected from Avon Park Bombing Range using the Flail Vac seed harvester Nov. 31 through Dec. 4, 1998. Approx. 50 pounds of bulk material was obtained. Besides wiregrass, the seed also contained a percentage of toothachegrass, *Liatris tenuifolia*, *L. gracilis,* and several *Andropogon* species. The wiregrass had an average germination rate of 40%. Purity ranged from 12% to 82%.

SEED AND PLANT EVALUATIONS

OBJECTIVE #2: Evaluate seed and plants of collected species.

Laboratory Tests:

In addition to native site collections, seed was collected from several native species established at the FLPMC. Germination test results are included in Table 1. *Andropogon arctatus* collected from the burned site at Ft. Cooper State Park had 35% seed germination. A plot of this species was established at the PMC in 1997 on an irrigated site. The transplants did very well and produced a prolific amount of viable seed in the fall of 1997. However, plant vitality diminished rapidly in 1998, and seed production and viability was almost nil. This is a promising species for upland restoration; however, further research will need to be conducted to develop practices for maintaining production stands.

Similar results can also be seen with *Pityopsis graminifolia*. Native site collections had 25% seed germination, but plants in a non-irrigated plot at the PMC had only 3%. The PMC plot was not burned.

Liatris species from native collections had seed germination rates from 39 to 68%. This species has good potential for commercial production once cultural practices are developed. *Sporobolus junceus* collected from PMC plots had germination rates of 47 to 60%. This species also has good potential for commercial production.

Seed from a type of creeping bluestem was collected from a sandhills site in Ft. Cooper State Park. This species only seems to produce viable seed when it receives a growing season burn. It is a highly rhizomatous species with low seed viability (only 3%). However, it has such good potential for use in erosion control and native upland restoration, that it warrants further study. Dr. Wunderlin identified a sample as being *Schizachyrium scoparium*. In discussing this species with Dr. David Hall, he suggested that it met the description of *S. scoparium* var. *polycladus*. Transplants of this species were established in an irrigated plot at the PMC in 1997. It was not burned in 1998, and although seed was produced, none of it was viable.

Table 1. 1998 Native Site Seed Collections and Laboratory Germination Results

Species	Common Name	Acc. Number	Origin	Collection Date	Method	Lab Germ %	Hard Seed %
Andropogon arctatus		9060084	PMC	11/24/98	Hand	<1	0
		9060084	Ft. Cooper	11/23/98	Hand	35	7
Aristida stricta	wiregrass	9060445	Avon Park 1	12/3/98	Flail-Vac	40	0
		9060445	Avon Park 2	11/30/98	Flail-Vac	42	0
		9059733	PMC	12/8/98	Flail-Vac	6	0
		9060086	PMC	12/8/98	Flail-Vac	3	0
		9060086	PMC	11/24/98	Forg. Har.	1	1
Ctenium Aromaticum	toothache grass		Avon Park	12/3/98	Flail-Vac	30	9
Carphephorus		9059729	Ft. Cooper	11/23/98	Hand	37	0
Liatris elegans	gayfeather	9059730	Floral City	11/23/98	Hand	39	1
		9059730	Cargill study	12/16/98	Hand	45	1
L. tenuifolia		9059731	Ft. Cooper	11/23/98	Hand	46	0
			Cargill study	12/17/98	Hand	44	1
L. gacilis		9060447	Avon Park	12/2/98	Hand	68	1
L. tenuifolia		9060449	Avon Park	12/1/98	Hand	62	1
Lupinus diffusus	lupine	9060101	Hernando C.	5/20/98	Hand	21	12
		9060417	Bay Co.	6/23/98	Hand	8	40
Muhlenbergia capillaris	hairawn muhly	9059717	PMC	11/24/98	Hand	3	0
Pityopsis graminifolia	grassleaf goldenaster	9060446	Avon Park	12/1/98	Hand	25	0
		Native plot	PMC	11/27/98	Hand	3	0
Schizachyrium	creeping	9060083	Ft. Cooper	11/23/98	Hand	3	0

Species	Common Name	Acc. Number	Origin	Collection Date	Method	Lab Germ %	Hard Seed %
scoparium	bluestem						
Sporobolus junceus	Pinewoods dropseed	9060098	PMC	8/14/98	Hand	47	3
		9060099	PMC	7/2/98	Hand	60	1
Sorghastrum secundum	lopsided indiangrass	9059727	Ft. Cooper 1	10/28/98	Flail-Vac	18	2
		9059727	Ft. Cooper 2	10/27/98	Flail-Vac	20	2
		9059727	Ft. Cooper 3	10/29/98	Flail-Vac	24	6
		9059727	Ft. Cooper 4	10/30/98	Flail-Vac	28	3
		9059450	PMC (Croom field)	10/98	Hand	26	4
Tridens flavus	purple top	9059735	PMC (Pasco holding blk)	10/16/98	Hand stripped	45	1
		9059726	PMC (Hern-ando hld blk)	11/24/98	Hand stripped	75	0
		9059732	PMC (Sumter holding blk)	11/24/98	Hand stripped	26	0
		9059735	PMC (Pasco field)	11/27/98	Clipped & screened	66	1

PMC 1999 Field Plantings:

In January of 1999, several species were direct seeded on a clean-tilled well-drained non-irrigated site at the PMC for the purpose of seed production. This included *Liatris elegans, L. tenuifolia, Andropogon arctatus, Schizachyrium scoparium* and two accessions of *Lupinus diffusus.* Seed was hand planted ½ to ¾ inches deep in 20' rows. One to five rows of each accession were planted per species, depending on available seed stocks. The winter and spring of 1999 was very dry and windy, and only three of the species established. All but the lupine species were established in trays in the greenhouse in January also, along with *Carphephorous corymbosus, Liatris gracilis,* and another accession of *L. tenuifolia.* These seedlings were transplanted to an irrigated well-drained site on the PMC in August.

Best establishment in the non-irrigated plots was obtained with *Liatris elegans.* This species is very drought tolerant and seems to thrive in extremely dry coarse sandy soils. However, it is not tolerant of finer wetter loamy soils, and rapidly dies out on these sites. Cultural management research must be conducted to determine how to maintain seed production stands of this species. Blank areas in the plots were filled in with seedlings from the greenhouse in August, but these were not robust enough to bloom the first year. Direct-seeded plants bloomed prolifically in October. Deer often nibbled off the tips of this species during the summer, causing the plants to produce multiple seedheads. Clipping during the summer may be one method of increasing seed production. Seed viability tests are not yet available.

Only two direct-seeded plants of *Liatris tenuifolia* managed to establish on the non-irrigated site. Deer also nibbled off the ends of this species and caused a profusion of seedheads to form. Vacant rows were planted with greenhouse transplants in August, but these were not robust enough to bloom by October.

One accession of *Lupinus diffusus* collected from Hernando Co. emerged well, and grew rapidly. By June, however, all plants were dead from an unknown soil-borne disease. This same problem has occurred on plants seeded on the Cargill minedland test site. Samples of diseased plants and healthy plants were taken from the Cargill site and sent to the Plant Pathology laboratory in Gainesville. Results are not yet available. This plant has great potential for use as a sustainable source of nitrogen in native revegetation efforts. It is a very hardy, drought resistant annual or biennial, but seed production will be difficult if disease problems cannot be overcome.

Andropogon arctatus came up sporadically in the PMC plots. Those plants that did emerge bloomed prolifically in the fall of 1999. Vacant areas in the direct seeded plots were planted with greenhouse seedlings. Even very small transplants put up at least one seed head in October. Although forage production is relatively low, this species is very hardy and drought resistant. It is a prolific seed producer, and the seed is relatively large compared to other bluestem species, making it a very good candidate for use in an upland seed mix. Persistence, disease resistance and the role of fire in seed production need to be studied to develop cultural management guidelines for this species.

Direct seeded *Schizachyrium scoparium* did not emerge from the non-irrigated site. Greenhouse seedlings were transplanted to the field in August. Although soil moisture was high at this time, establishment has been slow.

Minedland Field Plantings:

If adequate seed was available, those native collections with potential for use on reclaimed minedlands were put in field trials. Plantings were made in Jan. and May of 1997, 1998 and 1999, on both overburden and sand tails soils. Seed was hand-planted in 20' rows, with 3 feet between rows on both overburden and sand tails soils. Planting depth was generally ½ to ¾ inches. Seeding rate was generally 60 pure live seed (pls) per acre. 'Alamo' switchgrass (*Panicum virgatum*) was planted each time as a standard of comparison. Due to scarcity of seed, plots were not replicated. Evaluation results from May 5, 1999 are outlined in the tables below. Results from May 1999 plantings are not yet available.

The winter of 1997 was unusually wet, encouraging excellent establishment on the both soil types, but especially on the sand tails soils. The winters of 1998 and 1999 were extremely windy and dry. Species that did emerge often died from lack of moisture or were desecrated by blowing sand, especially on sand tails. These harsh conditions provided an opportunity to study emergence under unfavorable conditions. Some species actually did establish quite vigorously.

Summer rains provided a fair amount of moisture all three years, however, it usually was not enough to promote good emergence on the sand tails soils. Weed competition was often a problem on the overburden soils but not on the sand tails. Both soils types had very low fertility. 'Alamo' swithchgrass was able to establish consistently on the overburden soils (Table 2), but plants were small and lacked vigor. Droughty conditions discouraged 'Alamo' establishment on sand tails soils. Successful stands on reclaimed minedlands in the West are thought to have at least 4 plants per square foot. Initial emergence often exceeded this amount, however, droughty winter conditions and lack of nutrients reduced stand densities. Only two of the 'Alamo' test plantings met this criterion at the May 1999 evaluation. Switchgrass requires a fairly high level of nutrients to sustain growth.

Table 2. Direct seeded 'Alamo' switchgrass performance of 1997-1999 plots on reclaimed minedland overburden and sandtails soils at May 5, 1999 evaluation.

Year	Month	Overburden		Sandtails	
		Avg. Plants/ft	Vigor (1 to 9)*	Avg. Plants/ft	Vigor (1 to 9)*
1997	January	<1	5	9	5
	May	1	5	0	
1998	January	3	5	2	5
	May	<1	5	0	
1999	January	7	5	<1	5

*1= greatest vigor, 9 = a dead plant

Pinewoods bluestem (*Andropogon arctatus*) is one of the few species tested that managed to establish on both soil types on all planting dates (Table 3). Although only the Jan. 1999 planting met the success criteria of 4 plants/ft^2, a few seedlings always managed to establish at every planting date. Performance was often better than that of the standard, 'Alamo' swithchgrass, especially on the sand tails soils. Some plants managed to produce seedheads in 1997 and 1998, and a few seedlings managed to establish in areas adjacent to the study plots. As noted in the section above, this species is a prolific seed producer and seed are relatively large compared to other bluestem species. The accession used for these plantings came from a sandhills site in Ft. Cooper State Park. Based on its performance in these study plots, it has good potential for use in revegetating native uplands, especially droughty sites.

Table 3. Direct seeded *Andropogon arctatus* performance of 1997-1999 plots on reclaimed minedland overburden and sandtails soils at May 5, 1999 evaluation.

Year	Month	Overburden		Sandtails	
		Avg. Plants/ft	Vigor (1 to 9)*	Avg. Plants/ft	Vigor (1 to 9)*
1997	May	<1	5	<1	4
1998	January	3	4	<1	6
	May	1	5	<1	5
1999	January	7	5	<1	5

*1= greatest vigor, 9 = a dead plant

Chalky bluestem was planted on both soil types in 1997 and 1998. High precipe in Jan. 1997 encouraged a few seedlings to establish on overburden soils. Some of these seedlings have managed to survive, but vigor was very poor. This species is not suited to low fertility upland soils prone to drought.

Elliot bluestem (*Andropogon gyrans*) is a minor component in drier native upland sites. Initially, it was able established on the minedlands soils, however, plant density was severely reduced by the droughty conditions. This species may have some potential for use if resources are available to develop it.

Table 4. Direct seeded *Andropogon gyrans* performance of 1997-1999 plots on reclaimed minedland overburden and sandtails soils at May 5, 1999 evaluation.

Year	Month	Overburden		Sandtails	
		Avg. Plants/ft	Vigor (1 to 9)*	Avg. Plants/ft	Vigor (1 to 9)*
1997	May	0		0	
1998	January	<1	7	<1	6

*1= greatest vigor, 9 = a dead plant

Paintbrush (*Carphephorus corymnbosus*) collected from a sandhills site in Ft. Cooper was planted on the minedlands site in Jan. of 1999. No seedlings had emerged by the May evaluation. This species appears to lack seedling vigor and be difficult to establish. Even PMC greenhouse plantings had low emergence. However, once a plant has become established in the field, it has fairly good persistence.

Spike chasmanthium (*Chasmanthium laxum*) was planted in 1997 and 1998. Emergence was good on overburden soils in Jan. plantings. However, seedlings rapidly perished. Chasmanthium prefers moist fertile soils under open canopy forests, with low light intensities. Conditions at the minedland test site were much too harsh for it to become established. Because viable seed production is high, spike chasmanthium may have potential for use in seeding lowlands and forest understories. Addition research would be needed to determine adaptation range and establishment techniques.

Toothachegrass (***Ctenium aromaticum***) was planted in 1997 and 1998, but never emerged on either soil.

Lovegrass (***Eragrostis spectabilis***) established well on overburden soils only, in 1998 (Table 5). Plant densities did not meet the 4 plants/ft^2 success criteria, however, performance was as good as or better than the standard, 'Alamo'. Lovegrass generally colonizes disturbed sites, and has good potential for use as an erosion control plant, however, wildlife value is not known.

Table 5. Direct seeded *Eragrostis spectabilis* performance of 1997-1999 plots on reclaimed minedland overburden and sandtails soils at May 5, 1999 evaluation.

Year	Month	Overburden		Sandtails	
		Avg. Plants/ft	Vigor (1 to 9)*	Avg. Plants/ft	Vigor (1 to 9)*
1998	January	3	5	0	
	May	2	6	0	

*1= greatest vigor, 9 = a dead plant

Liatris elegans is a very vigorous, drought-resistant species. A number of seedlings established on both soil types, but persisted over the long term only on the sand tails (Table 6). This species does not tolerate moist soil, but seems to thrive in extremely droughty conditions. Plants on sand tails plots produced a good quantity of viable seed in

1998 (44% germ.). *L. elegans* has good wildlife value and very good potential for use in restoration of droughty sandhill sites.

Table 6. Direct seeded *Liatris elegans* performance of 1997-1999 plots on reclaimed minedland overburden and sandtails soils at May 5, 1999 evaluation.

Year	Month	Overburden		Sandtails	
		Avg. Plants/ft	Vigor (1 to 9)*	Avg. Plants/ft	Vigor (1 to 9)*
1997	January	<1	6	7	4
	May	0		0	
1998	January	5	4	4	5
1999	January	<1	5	0	

*1= greatest vigor, 9 = a dead plant

Liatris tenuifolia did not establish as well or as vigorously as *L. elegans* on sand tails soils (Table 7). However, seedlings on overburden soils persisted longer than did those of *L. elegans*. This species also has good potential for use in a native seed mix if conditions are not too droughty. It also appears that the *Liatris* species must be planted during the winter months for the seedlings to germinate.

Table 7. Direct seeded *Liatris tenuifolia* performance of 1997-1999 plots on reclaimed minedland overburden and sandtails soils at May 5, 1999 evaluation.

Year	Month	Overburden		Sandtails	
		Avg. Plants/ft	Vigor (1 to 9)*	Avg. Plants/ft	Vigor (1 to 9)*
1997	January	3	7	<1	5
	May	0		0	
1999	January	<1	6	0	

*1= greatest vigor, 9 = a dead plant

Liatris gracilis and spicata collected from a flatwoods site were planted in Jan. of 1998 and 1999. Neither species emerged. Conditions of the planting site were undoubtedly too dry for these species to germinate.

Sky blue lupine (*Lupinus diffusus*) is a hard-seeded native legume with tremendous vigor and drought resistance. Seed emergence and establishment was excellent for all planting dates on both soils (Table 8). Robust lupine seedlings established on the sand tails, despite extremely droughty conditions. Unfortunately, once plants became established, they often became chlorotic, wilted and eventually died. Samples of healthy and chlorotic plants were sent to a plant pathology lab to determine the disease affecting this species. Lab results indicate that *Fusarium solani* was isolated from discolored vascular tissue, this disease in ubiquitous and difficult to control. Some types of biological control, such as green manure crops, which increase the levels of bacterial and fungal antagonists, or increasing levels of other antagonists such as mycorrhizal fungi, have met with some success. Unless the disease can be controlled or resistant strains found, this species will have limited value in a native seed mix.

Table 8. Direct seeded *Lupinus diffusus* performance of 1997-1999 plots on reclaimed minedland overburden and sandtails soils at May 5, 1999 evaluation.

Year	Month	Overburden		Sandtails	
		Avg. Plants/ft	Vigor (1 to 9)*	Avg. Plants/ft	Vigor (1 to 9)*
1998	January	<1	4	0.5	5
	May	3	3	4	4
1999	January	3	4	3	2

*1= greatest vigor, 9 = a dead plant

Beaked panicum (*Panicum anceps*) planted in Jan. of 1998 had some emergence on overburden soils but none on sand tails. Surviving seedlings were poor, and lacked vigor. This species is typically found in flatwood sites, and does not appear to be adapted to droughty upland sites.

Seed obtained from crossing two native Florida switchgrass accessions ('Miami' and 'Stuart') was planted at the study site in 1998 and 1999. Plant performance was slightly lower than that displayed by 'Alamo' (Table 9). Seedlings were yellower and slightly less robust than 'Alamo' seedlings, although once established, persistence was good. This species is better adapted to moister, more fertile soils.

Table 9. Direct seeded Miami X Stuart switchgrass performance of 1997-1999 plots on reclaimed minedland overburden and sandtails soils at May 5, 1999 evaluation.

Year	Month	Overburden		Sandtails	
		Avg. Plants/ft	Vigor (1 to 9)*	Avg. Plants/ft	Vigor (1 to 9)*
1998	January	7	5	<1	6
	May	1	6	<1	6
1999	January	7	6	0	

*1= greatest vigor, 9 = a dead plant

Pityopsis graminifolia was planted in Jan. of 1999, but no seedlings emerged. Extreme droughty conditions did not encourge emergence of this small-seeded species.

Table 10. Direct seeded *Schizachyrium scoparium* performance of 1997-1999 plots on reclaimed minedland overburden and sandtails soils at May 5, 1999 evaluation.

Year	Month	Overburden		Sandtails	
		Avg. Plants/ft	Vigor (1 to 9)*	Avg. Plants/ft	Vigor (1 to 9)*
1998	January	2	5	<1	6
	May	0			
1999	January	5	6	<1	6

*1= greatest vigor, 9 = a dead plant

An upland accession of creeping bluestem (*Schizachyrium scoparium*) collected from Ft. Cooper managed to establish on both soils types (Table 10). With adequate seeding rates, this drought-resistant species may be a good candidate for direct seeding. However, problems with poor seed production will need to be overcome.

Pinewoods dropseed (*Sporobolus junceus*) established well on overburden soils (Table 11), but not on sand tails. Some plants produced viable seed during the spring of 1999. This species fills the same role as wiregrass in the ecosystem, however, forage production is usually not as high as that of wiregrass. It has fair seed production, and good potential for use in a native seed mix.

Table 11. Direct seeded *Sporobolus junceus* performance of 1997-1999 plots on reclaimed minedland overburden and sandtails soils at May 5, 1999 evaluation.

Year	Month	Overburden		Sandtails	
		Avg. Plants/ft	Vigor (1 to 9)*	Avg. Plants/ft	Vigor (1 to 9)*
1997	May	<1	5	0	
1998	January	4	4	0	
	May	<1	6	0	
1999	January	1	5	0	

*1= greatest vigor, 9 = a dead plant

Pupletop (*Tridens flavus*) was planted in 1997 through 1999. Although it generally had good emergence, even on sand tailing soils, vigor was very poor. Like chasmanthium, this species prefers wet fertile woodlands with partial shade. Soils on the site were too infertile to maintain initial stand densities.

Several accessions of eastern gamagrass (*Tripsacum dactyloides*) were planted 1997 through 1999. Although several plants emerged on both soil types, their vigor was very poor. This species requires moist fertile soils for best growth, and is better adapted to lowlands, than uplands.

Initial Evaluations for Cultivar Selections:

Lopsided Indiangrass: Lopsided indiangrass (*Sorghastrum secundum)* was assembled in the form of seed from 48 of the 67 counties in FL, in the fall of 1996. When combined with the accessions collected under the previous FIPR agreement, the assembly totaled 138. These accessions were then planted in the greenhouse in January of 1997. Greenhouse seedlings were transplanted to replicated field plots in early November of 1997. The planting site is an irrigated well-drained field of predominately Kendrick fine sand.

In addition, those accessions with adequate seed were direct seeded on two PMC sites in late January of 1997. The first site is an irrigated well-drained field of predominately Kendrick fine sand. The second site is a non-irrigated well-drained field of predominately Kendrick fine sand and Sparr find sand. Established plots were evaluated 1997 through 1999 for forage production, vigor, drought and disease resistance, bloom and seed maturity dates, seed production and viability. Weeds were controlled by hand hoeing, tilling and with chemical herbicides. 'Lometa' yellow indiangrass was used as the standard of comparison.

Most accessions on the irrigated site died after two years, once they reached maturity. Plants on the non-irrigated site persisted longer, but plant densities diminished. Diseased plants from an irrigated plot were sent to a plant pathology lab. They reported that the roots were infested by the lesion nematode, *Pratylenchus zeae*, and that the association of this nematode with pathogenic fungi can stunt several grasses, including sorghum. In the case of lopsided indiangrass, it appears these pathogens can actually kill the plants after they reach a certain level of maturity. In native situations, lopsided indiangrass is a very short-lived perennial, and stand densities vary greatly from year to year. This is offset by prolific seed production and good seedling vigor. No accessions were found with marked disease resistance, although several accessions scored high in forage and seed production. Evaluation data is currently being analyzed. Superior accessions are to be selected and increased at the beginning of 2000.

Based on 1997 evaluation results, 10 superior accessions were selected and planted in January of 1998 on overburden and sand tailing reclaimed minedland soils. Plots were replicated three times on each soil type in 7-foot rows. A seeding rate of 40 pls/ft^2 was used in most accessions.

The dry windy spring of 1998 provided an opportunity to observe if any of the indiangrass accessions had superior establishment capabilities under droughty conditions. Most had emerged in March. However, by the July 1998 evaluation, many of these seedlings had perished under the harsh conditions. Other seedlings germinated between July and December of 1998. Once established, many seedlings were able to persist, despite severe drought conditions in early 1999. Results from the May 1999 evaluation on overburden plots are shown in Table 12. Highest average number of seedlings per 20' row on overburden was approx. 7. Only three accessions had seedlings in all three reps. All 10 accessions had similar vigor.

Table 12. Eighteen month performance of 10 lopsided indiangrass accessions planted on overburden soils in January of 1998.

	Number of Plants / 20' Row				Vigor (1 to 9)*			
Accession	**Rep 1**	**Rep 2**	**Rep 3**	**AVG**	**Rep 1**	**Rep 2**	**Rep 3**	**AVG**
9059450	2	0	0	0.6	5			5
9059727	5	7	2	4.7	4	5	5	5
9060118	1	14	0	5.0	6	4		5
9060129	4	4	0	2.6	6	5		5
9060144	1	0	0	0.3	5			5
9060164	5	0	0	1.7	6			6
9060169	4	0	0	1.3	5			5
9060187	1	8	14	7.7	6	5	4	5
9060191	1	4	9	4.7	5	5	5	5
9060198	1	4	0	1.7	4	5		5
Mean				3.0				5.1

* 1= greatest vigor, 9 = a dead plant

Eighteen-month performance of the ten lopsided indiangrass accessions on sand tailing soils is shown in Table 13. Only 7 of the 10 accessions survived. Only three accessions had seedlings in two reps. Vigor was moderate to fair. No single accession consistently had superior performance on both soil types.

Table 13. Eighteen month performance of 10 lopsided indiangrass accessions planted on sand tailings in January of 1998.

	Number of Plants / 20' Row				Vigor (1 to 9)*			
Accession	**Rep 1**	**Rep 2**	**Rep 3**	**AVG**	**Rep 1**	**Rep 2**	**Rep 3**	**AVG**
9059450	3	0	2	1.7	5		5	5
9059727	1	0	1	0.7	6		5	6
9060118	1	0	0	0.3	5			5
9060129	2	1	0	1.0	5	6		6
9060144	0	0	0	0				
9060164	0	0	2	0.7			5	5
9060169	0	0	0	0				
9060187	2	0	0	0.7	6			6
9060191	0	3	0	1.0		5		5
9060198	0	0	0	0				
Mean				0.9				5.4

* 1= greatest vigor, 9 = a dead plant

Chalky Bluestem: Chalky bluestem (*Andropogon glomeratus* var. *glaucopsis*) was assembled in the form of seed from 43 counties in FL, in the fall of 1996. A total of 91 accessions were collected. All accessions were established in the greenhouse in January of 1997. These seedlings were then transplanted into replicated field trials in September of 1997. The planting site is a poorly drained irrigated field of predominately Blichton loamy fine sand.

Those accessions with adequate seed were also direct seeded on two sites in early February of 1997. The direct seeding trials were tremendously successful. Many accessions emerged and were vigorous enough to produce seedheads in 1997. The first site is a well-drained irrigated field of predominately Kendrick fine sand. The second site is a poorly drained irrigated field of predominately Blichton loamy fine sand. The poorly drained site is subject to severe weed competition. Many accessions were able to emerge and become established on this site despite pressure from aggressive weed species. Weeds were controlled as much as possible by hand hoeing, tilling and with chemical herbicides. Established plots were evaluated in 1997 through 1999 for forage production, vigor, drought and disease resistance, bloom and seed maturity dates, seed production and viability. Many accessions had good persistence during the three years of initial evaluation. Seed was collected from all surviving accessions in 1998. Germination ranged from 4 to 75%. Evaluation data is currently being analyzed. Superior accessions will be selected and increased in 2000.

Based on 1997 evaluation data, 11 superior accessions were selected for planting on reclaimed minedland soils in Jan. of 1998. Due in large part to the dry conditions, no seedlings emerged from any of the plots.

Eastern Gamagrass: In an effort to develop a seed source for a Florida ecotype of eastern gamagrass, a collection of over 75 gamagrass accessions at the PMC were screened in 1996 for seed production potential. Twelve accessions were selected for further study. One to three replicates of each accession is growing at the PMC on two different soil types. Both sites are irrigated, however, the first site is coarse soils which are well drained and droughty in nature. Fertility is low on these soils. Irrigation was only enough to maintain the stand. The second site is irrigated at the same level, however it is composed of poorly drained soils. These soils tend to be higher in fertility. These two sites provided a fair range of the types of sites gamagrass is found in in natural systems. In 1996 through 1998, ripe seed was hand collected every 7-10 days, beginning in mid June and ending in late August. Collected seed was then counted and cut open to determine presence of viable seed. This method was used instead of germination tests because gamagrass is known to undergo dormancy. It was observed that the exterior appearance of the fruit case is not necessarily a good indicator of seed viability. Viable seed per acre was calculated, and those accessions with the greatest overall seed production, and desirable growth characteristics, were selected and increased in 1999. Increased seed stock is to be used for advanced field evaluations. Selected accessions are 9059213 (Clay Co.), 9059264 (Dixie Co.), 9059266 (Polk Co.), and 9059287 (Citrus Co.). All four accessions have either triploid or tetraploid chromosome levels, and therefore will not out-cross. Increase fields were established by planting seed in conetainers in the greenhouse in January, and transplanting the seedlings to irrigated plots at the PMC in July.

During the summer of 1999, seed from the four accessions continued to be collected from the initial evaluation plots at the PMC. This seed was used for advanced studies. The purpose of field evaluations is to study plant performance in actual field situations, determine adaptation range, and develop cultural management techniques for cultivars. After two to three years of advanced field evaluations, one or more of the selected accessions is slated to be released onto the commercial market.

In the first study, seed from all four accessions was planted in replicated plots near a pond on private land in Citrus Co. The site was a reclaimed rock mine, and a heavy clay soil had been used as fill. The site is subject to flooding. Sixty seed were planted in 15' long rows, with four feet between rows. Plots were replicated four times. It was very difficult to dig trenches with consistent depths, because of the tremendously heavy nature of the clay soils. Seeds were planted ¼ to 2 inches deep. Planting took place on September 1, 1999. Due to seed dormancy, it is expected that seedlings will not emerge until the following spring.

In the second study, seed from 9059213 and 9059264, were planted along a shoreline of a Cargill reclaimed mineland site in Polk Co. Due to lack of seed, only these two accessions were used in the study. Details of this project are reported in the reclaimed minedland direct seeding research portion of this report.

Eastern gamagrass is known to undergo seed dormancy, however, it was not known whether this held true for Florida accessions. Seed stratification by chilling, and use of growth hormones, are the treatments typically used to overcome dormancy in gamagrass. A study was conducted, beginning in August of 1999, at the PMC, to determine the effect of several seed treatments on germination. Seed from accessions 9059213 and 9059264 was used for this study. Treatments included soaking seed in a gibberellin-based plant growth regulator, ProVide, for 24 hours then chilling for one month; rinsing in water then chilling for one month; and soaking in gibberellin for 24 hours. Untreated seed was used as a control. All seed was collected in 1999 and had been stored in the seed cooler until treated. Chill-treated seed was placed in the refrigerator, at temperatures of 35 to 45^{o} F. All seed was planted in conetainers in the greenhouse on September 22, 1999. Thirty-day percent emergence is shown in Table 14.

Treating seed with gibberellin then chilling, significantly increased germination of both accessions. Chilling alone also significantly increased germination compared to untreated seed. Unchilled gibberellin-treated seed had greater emergence than did untreated seed, but according to Tukey's HSD test the difference was not statistically significant. Gamagrass seed germination may be influenced by day length and soil temperature. Therefore, performance of untreated seed may be different if this test were conducted in the summer, or if the seed was more than one-year old. It is apparent from the results of this test, that Florida accessions of gamagrass do have dormancy mechanisms, which can be overcome by chilling and treating with gibberellin. In addition, this dual treatment also promotes very rapid emergence. An average of 83% of the gibberellin + chill seeds that would emerge in 30 days had already done so after 10 days, while only 21% of the chilled seed and 10% of the gibberellin-treated seed to germinate in 30 days had done so within the first 10 days after planting. None of the untreated seeds had emerged within 10 days.

Table 14. Thirty-day greenhouse emergence of eastern gamagrass seed treated with four different seed treatment.

Accession No.	Treatment	30 Day % Emergence*
9059213	Gibberellin + Chill	69.8a
9059213	Chill	56.5ab
9059213	Gibberellin	17.3bc
9059213	No Treatment	2.8c
9059264	Gibberellin + Chill	61.0a
9059264	Chill	36.8abc
9059264	Gibberellin	34.3abc
9059264	No Treatment	9.5c

*Means followed by different letters are different ($P<0.05$) according to Tukey's HSD Test

TESTING CULTURAL MANAGEMENT PRACTICES

OBJECTIVE #3: Establish production fields of selected species

Cultural management technology for native species must be developed, in order to make establishment and harvest of production fields economically feasible. This is necessary if dependable seed sources of native species are to be available on the commercial market. Fire, fertility and available moisture play an important role in seed production and viability in many species in native habitats. Therefore, the FLPMC has been in the process of establishing production fields of several native species for the purpose of testing such practices as irrigation, fertility, burning and clipping on seed production. Establishment methods and weed control practices are also being considered. To date, production fields of one legume and four grasses were established.

'Croom Source' Lopsided Indiangrass:

Lopsided indiangrass is an important component of native uplands in Florida. It is also one of the species that has been successfully used to revegetate upland sites. Commercial sources are needed if adequate supplies of seed are to be available on the commercial market. It must be economically feasible for commercial producers to establish and maintain production fields of indiangrass. However, very little is known about growing this species under cultivation. Cultural methods, which will maximize viable seed production and stand longevity, need to be developed. Very little is known about how factors such as burning and fertility affect seed viability of lopsided indiangrass.

Lopsided indiangrass typically has low seed viability. Seed collected from native stands in Ft. Cooper State Park, Citrus Co., had germination rates ranging from 20 and 28% between 1996 and 1998. Seed collected from the 'Croom Source' increase field at the FLPMC in 1997 and 1998 averaged 25% germination. In addition, it has been observed in lopsided indiangrass initial evaluation plantings at the FLPMC, that larger indiangrass plants on irrigated fields tend to die after they have produced seed. These plants were usually 2 years in age, and examination revealed that roots were infested with lesion nematodes, which apparently made the plants susceptible to invasion by *Rhizoctonia* and *Fusarium* species. There are no economic chemical controls for these soil-borne pathogens in the field. However, biological controls such as crop rotation, residue management and introduction of antagonistic fungi may assist in increasing stand longevity. The objective of this project is to study the effects of canopy removal, the method of canopy removal, and the timing of such removal on stand persistence, seed production and seed viability of lopsided indiangrass.

Burning removes mulch and plant debris. This reportedly increases the light reaching emerging shoots, thereby stimulating growth (Masters *et al*., 1993). Burning native grasslands is a common practice in Florida, which has been studied by several researchers. Sievers (1985) recommended that native sites in FL be burned in late winter (Jan. – Mar.) while desirable grasses such as lopsided indiangrass were dormant. He also recommended that native sites should not be burned more frequently than every three years. This is due to the fact that desirable native grasses are sensitive to burning and populations are reduced under high frequency burn programs.

In the Midwest, early researchers reportedly found that burning and fertilization of cultivated stands of warm-season grasses resulted in higher seed yields (Masters *et al*., 1993). Masters and his associates studied the effect of burning native grasslands in Nebraska, including the response of yellow indiangrass (*Sorghastrum nutans*). They found a combination of burning, fertilization and atrazine applications increased reproductive stem densities in comparison to no treatment or one of these treatments used alone. Late spring burns (mid-May) generally increased reproductive stem densities over earlier spring burns (Mar. – April), or unburned treatments. However, fertilization and atrazine applications were also included in these treatments.

Looking at the effects of fertilization on FL native flatwoods, Kalmbacher and Martin (1996) found that fertilization encouraged the proliferation of annual herbs and early successional species. Fertilization actually seemed to decrease populations of such species as wiregrass (*Aristida stricta*), creeping bluestem (*Schizachyrium scoparium*) and maidencane (*Panicum hemitomon*), especially after annual fertilizer applications over a period of years. In Oklahoma, yellow indiangrass populations were reduced by fertilization in native warm-season grass CRP seedings (Berg, 1995). Weedy species tended to dominate the fertilized seedings. However, on pure stands of yellow indiangrass in the Ozarks, Brejda and his associates (1995) found that fertilization increased forage production. Rates of up to 150 lb./ac. were used for a period of three years in split applications. The stands were burned in April of each year, but weed control methods were not discussed. Based on the above research results, it would appear that fertilization may only be beneficial on pure stands if weed competition is controlled. However, if competition is controlled, then fertilization may enhance a burn program.

A field of lopsided indiangrass was established on an irrigated site at the FLPMC in March of 1996. Seed came from the Croom tract of the Withlacoochee State Forest in Hernando Co. Transplants raised in the greenhouse were planted on 2' centers. Many plants were choked out by weed competition during the 1996-growing season. Therefore, the field was reestablished in the fall of 1997 with transplants. The study is a split-plot design. Main plots are the date of canopy removal. Subplots are canopy removal method. Treatments were as follows: Winter burn (Feb.), summer burn (July), winter clipping (Feb.), summer clipping (July), and an untreated control. Plots were clipped with a forage harvester so that residue could be removed from the plots. Clipping height was 6-8". Plants burned to the ground in the Feb. burn treatment because they were dormant. However, most plants were very green in July, and would not burn well. Each plot contained four rows of plants (approx. 104 plants/plot). Approx. plot size is 8' x 56'. Each treatment was replicated 4 times. Weeds were controlled chemically and by hand hoeing. No fertilizer treatments were applied due to severity of weed competition. Statistical analysis was done using MSTATC Factor program for split-plot designs.

The number of plants in each plot was counted in July of 1999 before treatments were applied and in Oct. just before seed ripening. It was also noted whether plants had green shoots or if all leaf material looks brown and dead. Percent plant loss during the 1999 growing season and treatment effects on seed production are shown in Table 15.

There is very little difference between plant population numbers of the various treatments. However, summer burning reduced the size and vigor of plants severely. It is interesting to note that untreated plots had the greatest plant losses. Most untreated plants looked brown and dead by Oct. Managing residue apparently does affect stand longevity.

In 1998, the newly established 'Croom' indiangrass field produced 75 pounds of seed per acre. Average seed viability was 26%. Highest production in 1999 occurred in the summer clipped plots, which averaged 20.6 lbs./ac. It is possible that soil-borne pathogens had severely reduced plant vigor by 1999, and residue management only marginally overcame disease symptoms. Statistically, there was no difference between any of the treatments except summer clipping and summer burning. Most summer burned plants did not produce seedheads. Those that did probably did not actually burn because of too much green matter. Seed viability information is not yet available.

Table 15. 'Croom Source' lopsided indiangrass 1999 percent plant loss and seed production (lbs./ac.) under 5 residue management treatments.

Treatment	% Plant Loss (Jan. to Oct.)	Seed (lbs./ac.)*
Winter Clip	29%	16.3ab
Winter Burn	32%	17.4ab
Summer Clip	25%	20.6a
Summer Burn	37%	3.9b
No Treatment	38%	10.3ab

*Means followed by different letters are different (P<0.05) according to Tukey's HSD Test

Based on the results of this study, it appears that removing indiangrass residue to ground level while the plants are dormant (as in the case of the Feb. burn) does not hurt plant productivity. Neither does clipping above growing points (6") in early July. Summer burning, however, severely hurt plant productivity. Residue management is important for maintaining stand productivity. Of greater impact though are soil-borne pathogens. If seed production is to be commercially feasible, more research needs to be conducted on controlling pathogens in lopsided indiangrass production fields.

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'Avon Park Source' Wiregrass:

Wiregrass is considered an important component of pineland habitats, because of its ability to carry fire. In native situations, wiregrass contributes a large percentage of the fuel for understory burn management programs. Many public agencies and private conservation groups, among others, are interested in using wiregrass to revegetate native habitat. Dependable supplies of seed need to be available on the commercial market to meet this growing demand. In order to do this, it must be economically feasible for commercial producers to establish and maintain production fields of wiregrass. However, very little is known about growing this species under cultivation. Cultural methods, which will maximize viable seed production and stand longevity, need to be developed. It has been shown that wiregrass requires a growing season burn to produce viable seed. There is also some evidence that the hotter the fire, the greater will be the subsequent seed viability. The effect of other factors such as burn frequency and fertility on seed viability is not well understood.

Although wiregrass requires fire to produce viable seed, burning is not always feasible. Clipping would be more practical in some situations, but it is not known if clipping will have the same effect as burning. Secondly, some research indicates that burning annually decreases stand vitality of native species. There presently is no research to suggest whether fertilization can offset this trend in wiregrass. The objectives of this study are first, to study the effects of method of canopy removal and fertility on seed production and seed viability of wiregrass. Secondly to study the relationship between burn frequency and fertility as it relates to seed production and viability.

Wiregrass has been observed to flower after burning, defoliation and minor soil disturbance. It was not recorded whether viable seed was subsequently produced by defoliation or soil disturbance (Clewell, 1989). However, late spring and summer burns are known to promote the production of viable seed. Wiregrass is more tolerant of burning than other native grass species in Florida. For instance, annual burning of a central Florida flatwoods site did not appear to decrease wiregrass stand density over a 5-year period (Kirk *et al*, 1974). The effects of annual burning on viable seed production have not been documented, however.

Wiregrass has a very dense but shallow root system. This allows plants to take advantage of the flush of nutrients released following a burn. Nitrogen is volatilized by burning, therefore, much of this nutrient, along with some of the phosphorous, is permanently lost. On the other hand, beneficial nutrients such as Ca, K and Mg are released in the ash, and may be important for stimulating production of viable seed. Kalmbacher (1983) reported that the highest percentage of K in wiregrass was found in the inflorescence. Wiregrass does not appear to respond positively to nitrogen fertilizer. Kalmbacher and Martin (1996) found that fertilizing native range actually eliminated wiregrass from test plots. Wiregrass was only a minor component in the test plots, however, so this data had only limited application.

A field of 'Avon Park Source' wiregrass was established on an irrigated site at the FLPMC with 4" tubelings in February of 1996. Transplants were planted on 2' centers. The field was extended with 6" tubelings planted in October of 1997. The entire field measures 40' x 390' (0.35 acres). Soils on this site are predominately Kendrick fine sand which is well drained, and some Sparr find sand on one end of the field, which is poorly drained. Plants were allowed to become well established, and the field was then divided into subplots in 1999, in preparation for the studies.

Almost all of the original transplants flowered in the fall of 1996. Seed was collected using the Flail-Vac Seed Stripper. One pound of seed was obtained. Germination rate was 18%. Most of the plants flowered again in 1997, but were not harvested, to avoid damaging the recently transplanted seedlings. Most new transplants flowered in 1998 also. However, older plants with more dry matter did not flower or had fewer seedheads.

Two separate studies were applied to the field. The first study is a split-plot design. Main plots are canopy removal method (burn vs. clip). Subplots are fertilization treatment (none vs. 50 lbs/ac of 0-10-20 applied just after canopy removal). Plots were clipped and burned 7/8/99 between 1:00 and 4:00 p.m. High temperature that day was 94^{o} F. Humidity was not recorded at the PMC, however, for the sake of comparison, relative humidity at the Tampa Airport on 7/8 was 68% at 1:00 p.m. The clipping treatment was done with a Grasshopper mower, which cut the stubble to a height of 1 to 2". Residue was left on the plots. For the burn treatment, plants were set on fire with a drip torch. Most plots were not dense enough to carry fire across the entire plot, so plants often had to be individually burned. Burning and clipping treatments are to be reapplied annually depending on condition of plants. Fertilizer was applied with a hand-held fertilizer spreader. Plot size is 10' x 40' and each treatment is replicated 4 times. Study duration is to be for 3 to 5 years depending on results and funding. Statistical analysis will be conducted using MSTATC Anova program for split plots.

The second study is also a split-plot design. Main plots are burn frequency (annual, every 2 years or every 3 years). Subplots are fertilization treatment (none vs. 50 lbs/ac of 0-10-20 applied after canopy is removed or during the growing season on unburned plots). Plots were burned 7/8/99 as outlined above. Fertilizer was applied with a hand-held fertilizer spreader. Plot size is 10' x 40' with four replications. Study duration will be 3 to 6 years depending on results and funding.

Random soil tests were taken from plots in both studies, and number of plants in each plot was counted prior to canopy removal. Plant counts were again made prior to harvest, to determine treatment effects on stand populations. Seed is to be harvested from each plot upon ripening with the Flail – Vac Seed Harvester. Seed gathered from each plot will be weighed, and seed germination tests conducted. Weeds were controlled chemically and by hand hoeing.

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'Wekiwa Source' Wiregrass:

Ecotype compatibility is one of the issues native site reclamationists are struggling with. There is some thought in the scientific community that wiregrass seed collected from, for example, a xeric ecotype will establish better on xeric sites than will a mesic ecotype. To test this hypothesis, and also to determine if a xeric ecotype responds differently to cultural management practices, the FLPMC sought to obtain seed from a xeric habitat. However, it soon became apparent that this would not be a simple matter. Nearby State forests and parks had large acreage's of wiregrass dominated sites. However, despite summer burns, production of viable seed was low on these sites (0-13%). The State Department of Forestry had been successful in harvesting viable wiregrass seed (germination rate was 22%) from a xeric site in Wekiwa Springs State Park. Tim Pittman of the DOF Andrews Tubeling Nursery graciously sent us enough of this seed to establish a production field.

Seed was planted into six-inch tubeling trays in the greenhouse in 1996. In October of 1997, 2000 tubelings were transplanted into an irrigated field at the FLPMC which had been kept clean tilled for two years. Within and between row spacing was two feet. Plot size is approximately 0.2 acres. The site is predominately Kendrick fine sand, which is well drained. Transplants in this production field established very well in 1998 and bloomed profusely during the fall. Seed was collected on 12/8/98 with a forage harvester and with the Flail-Vac Seed Stripper. Germination rates were 1% and 3% respectively. The field was divided into subplots in 1999, to test the effects of various fertilizer treatments on viable seed production of this upland ecotype. As discussed in the 'Avon Park' wiregrass section, the effect of nitrogen and other plant nutrients on wiregrass seed production is not well understood. The objective of this study is to determine the effect of N, P and K on seed viability, with K hypothesized to be the most essential nutrient to seed viability.

The study is a randomized complete block design comparing fertilization treatments (none vs. 50 lbs. K/ac. of 0-10-20, vs. 50 lbs. K/ac. 10-10-10) applied after canopy is removed. Plot size is 10' x 30', with 6 replications. The field was partially burned on 7/8 from 4:00 to 5:00 p.m., with the remainder being burned on 7/9/99 between 1:00 and 4:00 p.m. Temperature highs on both days was 94^{o} F. Relative humidity at the Tampa airport on 7/8 was 72%, although it was probably higher than that at the FLPMC because a thunderstorm was moving in. Humidity at the Tampa Airport on

7/9 between 1:00 and 4:00 p.m. was 74%. Plants were fired with a drip torch. The canopy was not dense enough to carry the fire over the entire field, so many plants were burned individually. Some plants were too green, and would not completely burn. Plant counts were made prior to burning and prior to harvest in each plot. Plots will be harvested with the Flail-Vac Seed Stripper. Plots are to be burned annually and study duration is to be 3 to 5 years depending on plant response and funding. Weeds are controlled chemically and by hand hoeing. Statistical analysis will be conducted using MSTATC Anova program.

'Miami Source' - 'Stuart Source' Switchgrass Crossing Block:

Switchgrass has received a great deal of attention as a forage grass for livestock. It produces a tremendous amount of high quality, palatable forage in the early part of the growing season. It is also being studied for use in filter strips and windbreaks, because of its value for wildlife food and habitat. The switchgrass cultivar, 'Alamo', from Texas performs well in Florida. However, there is a demand for upland species native to Florida. The purpose of this project is to develop a seed source for a superior Florida native switchgrass.

The FLPMC has recently released (vegetatively) two strains of Florida native switchgrass, selected from an assembly, which had undergone initial and advanced evaluation. Both strains have excellent forage production and persistence. Both flower prolifically every year. However, seed viability is very low because the caryopsis rarely fills. This has been a common problem in switchgrass throughout Florida. Even 'Alamo', a cultivar released from Texas, produces less viable seed when grown at the FLPMC, then when grown further north.

In 1991, vegetative material of three Florida accessions (including 'Miami' and 'Stuart') were sent to PMC's in Georgia, Louisiana, east and south Texas, to determine if seed viability would increase in a colder climate. Percent germination of new seedlings ranged from 25 to 56% at the FLPMC in 1991. It ranged from 53 to 71% at the other locations. In 1992, percent germination dropped to a range of 1 to 9% at the FLPMC. It ranged from 1 to 37% at the other locations. These results indicate that it may be possible to increase seed viability of Florida accessions by growing them in a colder climate. However, germination rates dropped dramatically once the plants became established, indicating that other factors are involved.

Both 'Miami Source' and 'Stuart Source' breeders blocks had been increased from a single plant. Since switchgrass plants are self-incompatible, it was thought that crossing these two accessions might stimulate seed production. After consulting with Ken Vogel, ARS Research Geneticist at University of Neb., a plan to install a crossing block was developed. Root stock of both accessions was established in the greenhouse. Tubelings were then transplanted to an irrigated field at the FLPMC on 5/3/96. Soils on this site are predominately Kendrik fine sand, which is well drained. The two accessions were randomly mixed, and placed on three and one-half foot centers. The wider spacing allowed the field to be tilled every year, to trim plants and keep them from growing together. Total plot size is 42' x 54' (0.05 ac.) Half of the plot was fertilized in 1997 and

1998 with 10-10-10 at a rate of 100 pounds per acre. No fertilizer was applied to the crossing block in 1999.

Crossing the two Florida strains of switchgrass did indeed stimulate viable seed production compared to isolated breeders blocks. Seed was hand collected from fertilized and unfertilized plants in 1997 through 1999. Plots were also harvested with the combine in 1997 through 1999. Seed germination tests were conducted on all samples. The 1997 and 1998 results are shown in Table 16. Seed viability data for 1999 is not yet available. 'Miami' and 'Stuart' breeder blocks were fertilized over half the plots in 1998, and harvested with the combine and by hand. Seed viability data is included in Table 16.

Table 16. Laboratory seed germination results for 1997 and 1998 'Miami' X 'Stuart'; 'Mi x Stu' progeny; and 'Miami' and 'Stuart' switchgrass breeder blocks.

Collection Method & Treatment	% Viable Seed 1997	% Lab Germ. 1998	% Hard Seed	% Viable Seed 1998
Crossing Blk Hand Collections:				
Unfertilized	46	12	2	14
Fertilized	27	10	2	12
Crossing Blk. Combined & Cleaned				
Unfertilized	42	27	9	36
Fertilized	33	11	0	11
9060500 – Mi x Stu Progeny Hand Col.				
Unfertilized		13	2	15
Breeders blocks Hand Collected:				
Miami Unfertilized	5	0	0	0
Miami Fertilized		0	0	0
Stuart Unfertilized	0	2	1	3
Stuart Fertilized		2	0	2
Breeder Blks. Combine & Cleaned				
Miami Unfertilized		3	3	6
Miami Fertilized		0.5	0	0.5
Stuart Unfertilized		4	1	4
Stuart Fertilized		7	2	9

The switchgrass seed harvested from the crossing block in 1997 was planted in test plots on reclaimed minedlands in 1998 and 1999. Seedling performance was reported in the Seed and Plant Evaluation section of this report. Seed was also direct seeded in 6 rows in a 16' x 20' block at the PMC on 3/23/98. The plot received irrigation and was kept clean tilled between the rows throughout the summer. Most plants had matured and produced seedheads in 1998. Seed was hand collected from the progeny block in 1998 and 1999.

Overall, seed viability was lower in samples taken from the crossing block in 1998 compared to 1997. Reasons for this are uncertain. It is interesting to note that unfertilized plants usually produced more viable seed than did fertilized plants. This is probably due to the fact that fertilized plants put more energy into forage production than seed production. This trend needs to be investigated further in order to develop management criteria that will maximum seed production. Highest seed viability in the isolated breeder blocks in 1998 was 3% for ‘Stuart’ but was 0% for ‘Miami’. Combined collections probably had higher germination rates because the screening process had removed empty seed hulls.

The ‘Miami’ x ‘Stuart’ progeny samples had only 15% viable seed in 1998. One of the reasons for such low seed production may be inbreeding depression. It would be expected that the first generation of seed from the crossing block would have good seed viability because of hybrid vigor. However, because of limited genetic variability, the following generations may revert back to the parent stock, and seed viability would again decrease. Consultations with a plant breeder in 1999 confirmed that this would indeed happen. He recommended starting with an original population of at least 40 individuals to limit inbreeding depression. In order to develop a seed source that would have more consistent seed viability through future generations, the FLPMC attempted to locate the original parent stock of ‘Miami’ and ‘Stuart’. Unfortunately, ‘Miami’ was collected from a park in downtown Miami in the 1965, and none of the original parent stock remains. ‘Stuart’ was collected from native grasslands near Stuart, FL in 1959. The original collection site was not pinpointed, however, the So. Fla. Water Management District has several acres of native lands near Stuart, and they have agreed to let PMC personnel collect switchgrass there. Once obtained, these plants will be crossed with the original ‘Miami’ and ‘Stuart’ breeder stock, to attempt development of a Florida switchgrass cultivar with consistent seed production.

A second ongoing study concerning switchgrass has been to determine how seed storage method affects switchgrass seed germination. Seed dormancy is very common in switchgrass. One method of breaking this dormancy is to allow seed to “age”. The effects of different storage regimes on seed germination was studied using the ‘Miami’ X ‘Stuart’ switchgrass crossing block seed harvested in 1997. Samples of switchgrass seed harvested in 1997 were placed in the seed cooler, the air-conditioned office building, and in a portion of the seed storage barn, which is not air-conditioned. Samples were placed in the different locations four months after harvest. All seed had initially been stored in the seed cooler immediately after harvest, where the temperature is maintained at 45 to 55^{o} F, and the humidity at 45 to 55%. Germination tests were conducted at 2, 10 and 20 months after harvest. Each test used 100 seed replicated 4 times. Results are shown in Table 17.

One of the problems with this study is that seed fill is highly variable, making it difficult to compare affects of storage time. Therefore, the amount of seed that germinated relative to the total percent of viable seed was also calculated. Initially, the amount of seed that germinated from seed stored in the seed cooler was lower than from the other two storage methods. However, after almost two years, over 90% of the viable seed from the cooler still germinated. Germination rates consistently increased between 10 and 20 months on the seed stored in the seed cooler. Germination rates of seed stored in the air-conditioned office between 10 and 20 months varied between the two types of seed. Aging decreased germination of the first type and increased germination of the second type. Seed stored in the seed barn had begun to lose viability compared to the other two treatments after almost two years. Germination rates consistently decreased between 10 and 20 months for both types of seed. Based on this data, peak germination of switchgrass seed can be maintained and possibly even increased if seed is stored in a non air-conditioned building for a year. However, to maintain maximum viability over the long term, it is better to store switchgrass seed in an air-conditioned facility.

Table 17. Seed germination results for 1997 'Miami' X 'Stuart' switchgrass seed 2, 10 and 20 months after harvest, under different storage regimes. Amount of seed that germinated relative to the total amount of viable seed also included.

Collection Method & Treatment	Date of Test	Storage Regime	% Lab Germ.	% Hard Seed	Total %	Rel. % Germ.
Combine collection Cleaned seed:						
Unfertilized	12/4/97	Cooler	42	34	76	55
Unfertilized	7/15/97	Cooler	31	7	38	82
Unfertilized	6/4/99	Cooler	56	5	61	92
Unfertilized	7/15/97	Office	40	1	41	98
Unfertilized	6/3/99	Office	62	8	70	89
Unfertilized	7/15/97	Seed Barn	39	13	52	75
Unfertilized	6/3/99	Seed Barn	15	6	21	71
Fertilized	12/4/97	Cooler	33	23	56	59
Fertilized	7/15/97	Cooler	12	7	19	63
Fertilized	6/3/99	Cooler	38	2	40	95
Fertilized	7/15/97	Office	23	9	32	72
Fertilized	6/3/99	Office	38	9	47	81
Fertilized	7/15/97	Seed Barn	33	5	38	87
Fertilized	6/3/99	Seed Barn	8	6	13	62

RECLAIMED MINEDLAND DIRECT SEEDING STUDIES

OBJECTIVE #4: Develop and test cultural practices for direct seeding native species on disturbed sites in monoculture and mixtures.

Reclaimed Upland Minedlands Planting Date - Seeding Methodology Trials:

In 1995, under the previous agreement with FIPR, the FLPMC established seeding methodology trials on two reclaimed minedland sites, using wiregrass and lopsided indiangrass. Plots were planted in the early summer, at the beginning of the rainy season. Despite problems with severe competition from introduced pasture species, much information was gathered from these studies. Indiangrass readily established, although plant densities were low. Wiregrass did not readily establish.

The cause of the low plant densities in these studies was thought to be primarily due to the following factors: Season of seeding, seeding rate and weed competition. Problems associated with the three seeding methods employed in this study also contributed to poor stand establishment. Drilling showed good potential for use in establishing indiangrass. However, the drill used in the initial study was not capable of handling light chaffy seed.

The objective of the current study is to research the effect of planting date and seeding method on the establishment of wiregrass and indiangrass in monoculture and mix.

Literature Review: Prior to the 1995 FLPMC study, Bisset and associates had successfully established several native species by broadcasting chopped native seed material on a reclaimed minedland site in December of 1994 (Bissett, 1995). Wiregrass established very well in this study. Season of seeding, seeding rate and less weed competition may have had the greatest influence on establishment success, since soils and seeding methods were similar in the 1995 FLPMC study.

In north Florida, Seamon (1998) reported successful wiregrass establishment, when a wiregrass mix collected with a Flail-Vac Seed Stripper was broadcast on plots of bare mineral soils with a hay blower. The seed was planted in February. Possibly due to a dry spring, most seedlings did not emerge for two years. Seeding rate was estimated to be over 300 pls/ft^2. Wiregrass seedlings emerged well from plots that had been disked prior to seeding. However, plots that were simply burned off or were not disturbed at all had no seedling emergence. It appears that planting into bare mineral soils is very important for successful wiregrass stand establishment.

In the FLPMC study, an indiangrass seeding rate of 20 pls/ft^2 produced about half of the desired plant density in the drill treatment and one quarter in the broadcast treatment on overburden soils. Therefore, a seeding rate of 40 to 80 pls/ft^2 should be adequate to produce a successful stand. The wiregrass broadcast method used by Bisset applied approximately 50 pls/ft^2 (personal conversation). Other published research will continue to be reviewed as it comes available.

1997 Plantings: The first series of wiregrass and lopsided indiangrass direct seedings were made in 1997. Plots were seeded 1/28/97 and 5/20/97. The planting site was reclaimed minedland provided by Cargill Fertilizer, Inc. It is composed of three acres of sand tailings, and an adjacent three acres of sand tailings capped with 6 or more inches of overburden soils. A cross section of soils was tested on each series of plots as they were established. Soils were tested for pH, and macro and micro nutrients at 0-6, 6-12 and 12-24 inches. Testing was conducted by a private testing facility.

Lopsided indiangrass seed was collected from Ft. Cooper State Park in 1995 and 1996, using the Flail-Vac Seed Stripper. Wiregrass seed was collected from Avon Park A. F. Bombing Range in 1995 and 1996 with the Flail-Vac. The '95 wiregrass material contained a large percentage of *Liatris tenuifolia*.

Seed from both species was debearded using a Clipper debearder. Seed was then screened and aspirated several times to remove chaff. Purity obtained on the indiangrass was 95%. Purity of the wiregrass was approx. 50%. Low purity in the wiregrass was due to broken seed. Wiregrass seed is very brittle, and the debearder caused a great deal of seed breakage. Although much of the chaff could be screened out of the wiregrass, the broken seed could not be removed. The hammermill appears to be a better instrument for debearding wiregrass seed. Although breakage also occurs in the hammermill, the seed is not processed as long as in the debearder, therefore breakage is reduced.

A clean weed-free seedbed was prepared prior to planting. All plots were freshly reclaimed in January of '97, so no further preparation was necessary. However, in order to prepare for the May seeding, the planting site was sprayed with chemical herbicides in April, and then again in May just prior to planting. The site was relatively clean except for the presence of crabgrass (*Digitaria sanguinalis*) on the overburden site. All plots were packed before seeding with a cultipacker. Plots are 10' x 50' in size with 4 reps on overburden soils and 3 reps on sand tailing soils.

For the January planting, monocultures of both grass species were seeded using an air drill built by Pounds Motor Company of Winter Garden, FL. This drill was specifically designed to handle light chaffy seed. A Tye drill with a warm season grass attachment was used for the May drill treatments. The Tye drilled was borrowed from the Quicksand, KY PMC. An indiangrass/wiregrass/*Liatris* mixture of debearded seed was also drilled at each planting date.

All monoculture broadcast treatments used debearded seed, and were planted using a hand held Cyclone seeder. All drilled treatments also used debearded seed. A mixture of beards-on wiregrass, debearded indiangrass and *Liatris* were broadcast at each planting date, using a seed blower to distribute the material over the plot. All broadcast plots were packed with a cultipacker after seeding.

Lopsided indiangrass and wiregrass seeding rate in drilled and broadcast monoculture treatments was 60 pls/ft^2, for both seeding dates. The exception to this was the January wiregrass drill treatment. It was seeded at a rate of 75 - 80 pls/ft^2, due to the aggressive brush system of the air drill. In broadcast mix treatments, wiregrass and indiangrass were planted at an approximate rate of 60 and 40 pls/ft^2 respectively. *Liatris* was also added to the January mix treatments at a rate of 12 pls/ft^2. Normally a mix would be planted at a 50:50 ratio. However, wiregrass appears to be less aggressive than indiangrass, and more seed was planted to obtained the desired plant densities.

In the January 1997 planting, the air drill was able to handle the debearded indiangrass and wiregrass seed fairly well. It has an aggressive brush system, which pulls the seed to the drop tube openers. The seed is then sucked into the drop tubes and blown through to prevent bridging or clogging. However, the air pressure through the tubes was so great that it actually blew the seed out of the furrows. Seeding depth was increased to offset this problem, and the planting depth of the drilled mix was deeper than the planting depth for the monoculture treatments. The air pressure could be adjusted to some extent, however decreasing the air pressure decreased the amount of seed output. Depth placement using this drill was difficult to determine because seed was distributed throughout the upper two inches in the soil.

The Cyclone seeder and the seed blower both handled the seed well. However, the seed blower did not produce even distribution over the surface of the plots. Broadcasting produced the greatest plant densities on overburden soils for both species. Six, 12 and 24-month plant density results on overburden soils are shown in Table 18.

The Tye drill used for the May 1997 planting could not handle the seed as well as the air drill used in January. The Tye drill operated on a gravity flow system. It was able to meter out debearded indiangrass seed fairly efficiently. However, the drop tubes are placed behind the double disk openers. The furrow partially closed up before the seed could fall into it, causing a large percentage of the seed to be left on the soil surface. Planting depth was increased to overcome this problem, however placement was not precise. This system showed no advantages over broadcasting. In addition, debearded wiregrass seed was very light, and the hopper had to be over half full for it to meter out efficiently.

Meter square quadrants (two per plot) were randomly established on the January and May seeded plots at six months. These were used to evaluated treatments for plant density, size, vigor, percent canopy cover, and percent weed cover at 6, 12 and 24 months after seeding. All treatments will continue to be evaluated for the next two years.

Table 18. Plant densities of January 1997 seeded indiangrass and wiregrass on overburden soils at 6 months, 1 year and 2 years after planting.

Treatment	6 months	1 year	2 years	% Seedling Loss
	Plants/m^2			
Indiangrass – Broadcast (60 pls/ft^2)	177	106	63	64
Indiangrass – Drilled (60 pls/ft^2)	96	75	42	43
Indiangrass in Mix – Broadcast (40 pls/ft^2)	89	64	33	63
Indiangrass in Mix – Drilled (40 pls/ft^2)	91	68	47	51
Wiregrass – Broadcast (60 pls/ft^2)	65	63	58	11
Wiregrass – Drilled (80 pls/ft^2)	36	36	32	11
Wiregrass in Mix – Broadcast (60 pls/ft^2)	39	32	37	5
Wiregrass in Mix – Drilled (60 pls/ft^2)	17	18	15	12
Mix - Indiangrass & Wiregrass - Broadcast	128	96	70	
Mix - Indiangrass & Wiregrass - Drilled	108	86	62	

The spring of 1998 was very dry and windy at the Cargill site, with summer rains not arriving until June. Stand densities of indiangrass treatments from the January 1997 overburden plantings were substantially reduced after two years. Broadcast treatments, which initially had the highest densities, also had the highest losses (64%). This would indicate that initial seeding rates were too high for all indiangrass treatments. After two years, drilled indiangrass plants were an average 4 cm taller and 2 cm wider than broadcast indiangrass plants. Drilled indiangrass plants also looked healthier and more robust than did broadcast plants. Drilled plants are spaced wider, reducing competition between plants. The established indiangrass was also suffering heavy losses in the wiregrass/indiangrass mix treatment. Once wiregrass became established, it was very hardy and drought resistant, and very competitive with other species. Wiregrass densities were initially much lower in all treatments than for indiangrass. However, after two years, wiregrass losses have been very low in all treatments. Wiregrass plants also looked healthy on overburden soils, with several plants producing seedheads in 1998. Many indiangrass plants produced seedheads in 1998 and 1999. However, plants in denser stands were too small to develop seedheads.

Weed competition was substantially reduced in all treatments containing wiregrass in the January 1997 overburden plots (Table 19). Only in the broadcast indiangrass treatment did weed competition increase slightly.

Table 19. Percent weed canopy cover in January 1997 seeded indiangrass and wiregrass on overburden soils at 6 months1 year and 2 years after planting.

Treatment	6 months	1 year	2 years	% Points
	% Weed Cover			Changed
Indiangrass - Broadcast	8	6	10	2
Indiangrass - Drilled	11	6	5	-6
Indiangrass & Wiregrass in Mix - Broadcast	13	4	3	-10
Indiangrass & Wiregrass in Mix - Drilled	7	4	5	-2
Wiregrass - Broadcast	12	7	4	-8
Wiregrass - Drilled	11	10	3	-8

Indiangrass stand densities declined substantially on the January 1997 sand tails plots two years after planting (Table 20). Highest losses occurred in the drilled treatments (up to 80%). This was due to blowing sand getting trapped in the drill rows and smothering the plants. Broadcast plants were spaced more randomly, and held less blowing sand. Although wiregrass stand densities were initially much lower in all treatments compared to indiangrass, wiregrass seedling losses were very low after two years. Once established, wiregrass plants on sand tails are very hardy, robust and drought tolerant. Several plants produced seed heads in 1998. Many indiangrass plants produced seed heads in 1998 and 1999. Weed competition was less than 1% on all January 1997 treatments.

Table 20. Plant densities of January 1997 seeded indiangrass and wiregrass on sand tailings at 6 months, 1 year and 2 years after planting.

Treatment	6 months	1 year	2 years	% Seedling

	Plants/m²			Loss
Indiangrass – Broadcast (60 pls/ft²)	47	23	20	57
Indiangrass – Drilled (60 pls/ft²)	77	49	19	75
Indiangrass in Mix – Broadcast (40 pls/ft²)	26	15	11	58
Indiangrass in Mix – Drilled (40 pls/ft²)	86	41	17	80
Wiregrass – Broadcast (60 pls/ft²)	15	14	14	7
Wiregrass – Drilled (80 pls/ft²)	5	5	5	0
Wiregrass in Mix – Broadcast (60 pls/ft²)	4	5	4	0
Wiregrass in Mix – Drilled (60 pls/ft²)	3	1	1	67
Mix - Indiangrass & Wiregrass - Broadcast	30	30	15	
Mix - Indiangrass & Wiregrass - Drilled	89	42	18	

One-year evaluation results for May 1997 overburden treatments are shown below in Table 21, with weed canopy data in Table 22.

Table 21. Plant densities of May 1997 seeded indiangrass and wiregrass on overburden soils at 6 months, 1 year, and 2 years.

Treatment	6 months	1 year	2 years	% Seedling
	Plants/m²			Loss
Indiangrass - Broadcast	117	117	81	-31
Indiangrass - Drilled	57	47	35	-38
Indiangrass in Mix - Broadcast	28	26	23	-19
Indiangrass in Mix - Drilled	46	38	36	-22
Wiregrass - Broadcast	7	8	7	-7
Wiregrass - Drilled	1	1	1	0
Wiregrass in Mix - Broadcast	2	2	2	0
Wiregrass in Mix - Drilled	1	1	1	0
Mix - Indiangrass & Wiregrass - Broadcast	30	28	25	
Mix - Indiangrass & Wiregrass - Drilled	47	39	37	

Table 22. Percent weed canopy cover in May 1997 seeded indiangrass and wiregrass on overburden soils at 6 months, 1 year and 2 years after planting.

Treatment	6 months	1 year	2 years	% Points
	% Weed Cover			Changed
Indiangrass - Broadcast	7	14	17	10
Indiangrass - Drilled	11	4	17	6
Indiangrass & Wiregrass in Mix - Broadcast	8	9	16	8
Indiangrass & Wiregrass in Mix - Drilled	9	8	13	4
Wiregrass - Broadcast	15	17	31	17
Wiregrass - Drilled	12	12	27	15

After two years of growth, and especially two very droughty springs, there was some seedling mortality in the lopsided indiangrass on the overburden soils. However, plant densities were still quite high, and plants were fairly vigorous. Based on successful stand establishment criteria used in the Western US (43 plants/m²) only the broadcast indiangrass treatment would be considered successful on overburden plots. Wiregrass densities were very low to begin with, but mature plants were quite competitive. Weed competition had at least doubled in most plots, even in the indiangrass broadcast plots, which had relatively high plant densities. Competing weeds were primarily crabgrass (*Digitaria sanguinalis*), natal grass (*Rhynchelytrum roseum)*, and hairy indigo (*Indigofera hirsuta*).

Initial establishment on the May '97 sand tailing plots had been poor, and subsequent seedling losses were high. The droughty springs of 1998 and 1999 were accompanied by severe winds and blowing sand. The area around the plots and the plots themselves were almost completely devoid of vegetation. Wind erosion was extreme, and the sand blasting effects of the blowing sand scoured out existing plants. Indiangrass especially was not able to withstand these harsh conditions. Plant densities are shown in Table 23. The exception to this was the two plots that had an overburden layer a few inches below the surface. Indiangrass plants in these plots had tremendous growth, most likely due to additional moisture.

Weeds have had a hard time establishing on May '97 sand tails plots, because of the severe conditions mentioned above. Weed competition had risen only slightly from 0% to only 2 or 3% in two years.

Table 23. Plant densities of May 1997 seeded indiangrass and wiregrass on sand tailings at 6 months, 1 year, and 2 years after planting.

Treatment	6 months	1 year	2 years	% Seedling
		Plants/m^2		Loss
Indiangrass - Broadcast	34	19	14	-60
Indiangrass - Drilled	21	11	9	-59
Indiangrass in Mix - Broadcast	1	1	0	-100
Indiangrass in Mix - Drilled	7	4	4	-48
Wiregrass - Broadcast	5	5	5	0
Wiregrass - Drilled	0	0	0	0
Wiregrass in Mix - Broadcast	0	0	0	0
Wiregrass in Mix - Drilled	0	0	0	0
Mix - Indiangrass & Wiregrass - Broadcast	1	1	0	
Mix - Indiangrass & Wiregrass - Drilled	7	4	4	

1998 Plantings: A second series of seeding date study plots were established in 1998. Materials and methods were similar to those used in 1997, except where noted. Wiregrass and lopsided indiangrass were again harvested from the same sources in 1997. Wiregrass and indiangrass were broadcast in monoculture and mix in January. For the monoculture treatments, only indiangrass was debearded for this planting, and broadcast with a Cyclone seeder. Wiregrass was broadcast in monoculture and mix with a seed blower. Wiregrass seed was not debearded for the 1998 plantings. It was found that up to 50% of the seed was lost to breakage in the debearding process. Thus debearding was not considered economical or practical for direct seeding endeavors.

January wiregrass monoculture plots were broadcast at three rates, high (80 pls/ft^2), medium (60 pls/ft^2) and low (40 pls/ft^2). Indiangrass monoculture plots were also broadcast at three rates, high (60 pls/ft^2), medium (40 pls/ft^2), and low (20 pls/ft^2). Wiregrass/indiangrass mixtures were broadcast at a high rate (40 and 20 pls/ft^2 respectively) and a low rate (40 and 10 pls/ft^2 respectively). Mixtures contained approx. 5 pls/ft^2 of *Liatris* species. Treatments were replicated four times on overburden soils and three times on sand tails soils in randomized complete blocks.

A second series of plots was planted in May of 1998. Indiangrass and wiregrass were again broadcast in the same manner, in monoculture and together as a mix. These were planted on vacant plots within the January 1998 plantings on overburden and sand tailing soils. The two planting dates were incorporated into one block to provide greater statistical integrity. In the overburden block, soils range from very coarse sands on the west end to hardpan soils with a higher clay component on the east end. It is possible that crusting in these heavier soils may dramatically decrease wiregrass emergence. In the case of the sand tails plots, some areas have overburden substrata within 6 inches of the soil surface. This causes a dramatic increase in plant density and size, as was discovered in one plot in the May 1997 plots.

In May 1998, only one indiangrass monoculture treatment was broadcast. The seeding rate was 60 pls/ft^2. One wiregrass monoculture treatment was broadcast at 60 pls/ft^2. Wiregrass and indiangrass were broadcast as a mixture with seeding rates of 40 and 20 pls/ft^2 respectively. *Liatris* was not included in the May planting as it has been shown that this species will not germinate from a summer planting. Treatments were replicated 4 times on overburden soils and 3 times on sand tailings. Plot size was 10' x 50'. Vacant plots were kept clean by disking. This helped eliminate some of the weed competition, however, it also had a tendency to dry out the soil. Soil conditions were extremely dry at the time of planting, and most of the seed was placed into a dust mulch. All plots were packed before planting, and broadcast plots were packed again after seeding.

An additional lopsided indiangrass seeding method study was planted on both sand tails and overburden soils in May of 1998. Treatments compared broadcasting versus drilling indiangrass. The FLPMC purchased a Truax drill, which arrived in April of 1998. Seed was drilled at the approximate rates of 20 and 40 pls/ft^2. Seed was broadcast at a rate of 40 pls/ft^2. Each treatment was replicated 3 times on both soil types. Plot size was 10' x 50'.

The Truax drill was able to handle the chaffy indiangrass seed fairly well. It has a very vigorous auger system that keeps the seed from bridging, and aggressively pulls it into the drop tubes. As with all new equipment however, some problems had to be overcome. The disk openers would not turn in the dry sand tailing soils. The drop tubes of the chaffy seed box were positioned to open right over the point where the two blades of the disk openers met. If these did not turn, the seed would collect there and not be metered out evenly. This problem was overcome by moving the drop tubes back to another hole. In the future, an effort needs to be made to remove more of the appendages on the indiangrass seed, so that seed will flow better. This will necessitate leaving seed in the debearder longer and may cause more seed damage. However, better flowing seed would greatly increase consistent stand establishment.

Seed depth placement was the second problem that needed to be overcome. Due to the dry conditions, seed was placed as close to moisture as possible. Depth bands generally prevented seed placement from being any deeper than 2" in the overburden soils. However, sand tailing soils were dry down to 4" and very soft. They tended to push up in front of the drill, so seeding depth was not consistent.

Six month and one year evaluation results for January 1998 overburden plantings are shown in Tables 24 and 25. The study was designed to compare seeding dates and rates. However, the droughty, windy spring of 1998 and excessive weed competition caused tremendous static in the data. Although vacant plots had been sprayed and disked previous to planting, wet conditions late in 1997 allowed enough weeds to produce seed and establish a sizeable seed bank. Weed competition was very severe on the overburden soils, but not necessarily consistent throughout the plots. Lighter, sandier soils on the west end of the overburden site, and especially heavy claypan areas on the east end had lower weed competition. It was observed that wiregrass emerged from those sites that had lower weed canopies, but not at all from sites that had heavy weed canopies. Increasing the seeding rate did not help wiregrass overcome the weed competition. In fact, the lowest wiregrass seeding rate actually had slightly higher stand densities than did the higher rate, but it also had approximately half the weed competition. Primary weed competition came from natalgrass (*Rhynchelytrum roseum*), crabgrass (*Digitaria sanguinalis*) and, later in the summer, hairy indigo (*Indigofera hirsuta*).

Table 24. Percent weed canopy cover of January 1998 broadcast indiangrass, wiregrass and *Liatris* on overburden soils at 6 months and 1 year after planting.

Treatment	6 months	1 year
	% Weed Canopy	
Indiangrass - High Rate (60 pls/ft^2)	23	36
Indiangrass - Medium Rate (40 pls/ft^2)	15	16
Indiangrass - Low Rate (20 pls/ft^2)	25	32
Wiregrass/Indiangrass Mix – High IG Rate (20 pls/ft^2)	21	31
Wiregrass/Indiangrass Mix – Low IG Rate (10 pls/ft^2)	16	29
Wiregrass - High Rate (80 pls/ft^2)	23	41
Wiregrass - Medium Rate (60 pls/ft^2)	21	44
Wiregrass - Low Rate (40 pls/ft^2)	11	24

Initial 1998 indiangrass overburden stand densities were much lower than those obtained in January of 1997. Subsequently, competition between 1998 indiangrass seedlings, even at the highest seeding rate was low (Table 25). Indiangrass stand densities in most treatments remained the same after one year or even increased slightly. The medium indiangrass seeding rate (40 pls/ft^2) actually produced higher average stand densities than did the high rate (60 pls/ft^2). However, weed competition on the medium rate plots happened to be half that experienced by the high rate plots. Although indiangrass appears to be able to compete with weedy species better than wiregrass, higher seeding rates of indiangrass could still not overcome the weed competition.

Table 25. Plant densities of January 1998 broadcast indiangrass, wiregrass and *Liatris* on overburden soils at 6 months and 1 year after planting.

Treatment	6 months	1 year
	Plants/m^2	
Indiangrass - High Rate (60 pls/ft^2)	32	33
Indiangrass - Medium Rate (40 pls/ft^2)	38	44
Indiangrass - Low Rate (20 pls/ft^2)	13	14
Indiangrass in Mix - High Rate (20 pls/ft^2)	6	6
Indiangrass in Mix - Low Rate (10 pls/ft^2)	3	5
Wiregrass - High Rate (80 pls/ft^2)	3	3
Wiregrass - Medium Rate (60 pls/ft^2)	3	4
Wiregrass - Low Rate (40 pls/ft^2)	5	5
Wiregrass in Mix - High Indiangrass Rate (40 pls/ft^2)	1	0
Wiregrass in Mix - Low Indiangrass Rate (40 pls/ft^2)	0	0
Liatris in Mix - High Indiangrass Rate (10 pls/ft^2)	2	2
Liatris in Mix - Low Indiangrass Rate(10 pls/ft^2)	2	1
Mix - Indiangrass, Wiregrass and *Liatris* - High Rate	9	8
Mix - Indiangrass, Wiregrass and *Liatris* - Low Rate	5	6

Indiangrass established well on the overburden in May of 1998 (Table 26). Timely summer rains helped the plants to become well established. Seedling mortality was relatively low after one year, despite the droughty spring of 1999. The wiregrass did not establish well on the overburden plots in May of 1998. Weed competition was heavy and continues to be so. Weed competition in plots with indiangrass decreased significantly between the 6 months and 1 year evaluations (Table 27) as the plants became established.

Table 26. Plant densities of May 1998 seeded indiangrass and wiregrass on overburden soils at 6 months and 1 year.

Treatment	6 months	1 year	% Seedling
	Plants/m^2		Loss
Indiangrass – High Rate (60 pls/ft^2)	110	99	-10
Indiangrass in Mix – High Rate (20 pls/ft^2)	15	17	10
Wiregrass in Mix – High Indiangrass Rate	1	1	0
Wiregrass – Medium Rate (40 pls/ft^2)	1	1	0

Table 27. Percent weed canopy cover in May 1998 seeded indiangrass and wiregrass on overburden soils at 6 months and 1 year after planting.

Treatment	6 months	1 year	% Points
	% Weed Canopy		Changed

Indiangrass – High Rate (60 pls/ft^2)	37	16	-21
Indiangrass & Wiregrass in Mix – High Rate	34	21	-13
Wiregrass – Medium Rate (40 pls/ft^2)	28	25	-3

Percent weed canopy cover of January 1998 sand tails treatments are shown in Table 28. Weed competition was lower on sand tails than on overburden soils, and it was also fairly consistent. However, because of the droughty nature of the sand tails soils, even low levels of weed competition severely reduced stand densities compared to 1997 levels.

Table 28. Percent weed canopy cover of January 1998 broadcast indiangrass, wiregrass and *Liatris* on sand tailings at 6 months and 1 year after planting.

Treatment	6 months	1 year
	% Weed Canopy	
Indiangrass - High Rate (60 pls/ft^2)	7	8
Indiangrass - Medium Rate (40 pls/ft^2)	7	10
Indiangrass - Low Rate (20 pls/ft^2)	9	10
Wiregrass/Indiangrass Mix – High IG Rate (20 pls/ft^2)	7	10
Wiregrass/Indiangrass Mix – Low IG Rate (10 pls/ft^2)	6	12
Wiregrass - High Rate (80 pls/ft^2)	7	10
Wiregrass - Medium Rate (60 pls/ft^2)	9	13
Wiregrass - Low Rate (40 pls/ft^2)	10	16

Stand densities of January 1998 sand tails treatments are shown in Table 29. Although conditions were dry in the spring of 1998, there was apparently enough soil moisture for the wiregrass and indiangrass to become established. There was little difference between the high and medium seeding rates for indiangrass. Indiangrass densities from these two seeding rates were slightly below the success criteria level of 42 plants/m^2. They changed very little between 6 months and one year after planting. Apparently adequate summer moisture minimized competition between surviving seedlings.

There was very little apparent difference between stand densities of for the different wiregrass seeding rates. None of the seeding rates was high enough to overcome the weed competition on sand tails. Monoculture stand densities averaged 3 to 4 plants/m^2. This was much lower than the 65 plants/m^2 obtained in the January 1997 plantings. Based on this data, it is difficult to determine whether a higher indiangrass seeding rate suppressed wiregrass emergence. Weed competition and soil moisture had a more profound effect on seedling establishment. *Liatris elegans* emerged well on the sand tails in the mix treatments. Persistence for this species is yet to be determined however.

Table 29. Plant densities of January 1998 broadcast indiangrass, wiregrass and *Liatris* on sand tailings at 6 months and 1 year after planting.

Treatment	6 months	1 year
	Plants/m^2	
Indiangrass - High Rate (60 pls/ft^2)	42	42

Indiangrass - Medium Rate (40 pls/ft^2)	37	35
Indiangrass - Low Rate (20 pls/ft^2)	13	14
Indiangrass in Mix - High Rate (20 pls/ft^2)	6	6
Indiangrass in Mix - Low Rate (10 pls/ft^2)	5	5
Wiregrass - High Rate (80 pls/ft^2)	4	4
Wiregrass - Medium Rate (60 pls/ft^2)	4	4
Wiregrass - Low Rate (40 pls/ft^2)	2	3
Wiregrass in Mix - High Indiangrass Rate (40 pls/ft^2)	0	0
Wiregrass in Mix - Low Indiangrass Rate (40 pls/ft^2)	2	1
Liatris in Mix - High Indiangrass Rate (5 pls/ft^2)	4	2
Liatris in Mix - Low Indiangrass Rate(5 pls/ft^2)	4	2
Mix - Indiangrass, Wiregrass and *Liatris* - High Rate	10	8
Mix - Indiangrass, Wiregrass and *Liatris* - Low Rate	11	8

Lopsided indiangrass established very well on the sand tailings plots in May of 1998, due in large part to timely summer rains. Losses were relatively low after 1 year, despite the droughty spring of 1999 (Table 30). Wiregrass did not establish as well. Weed competition was relatively high on these plots (Table 31), a factor which may have influenced wiregrass establishment.

Table 30. Plant densities of May 1998 seeded indiangrass and wiregrass on sand tails soils at 6 months and 1 year.

Treatment	6 months	1 year	% Seedling
	Plants/m^2		Loss
Indiangrass – High Rate (60 pls/ft^2)	181	167	-8
Indiangrass in Mix – High Rate (20 pls/ft^2)	8	9	15
Wiregrass in Mix – High Indiangrass Rate	1	1	0
Wiregrass – Medium Rate (40 pls/ft^2)	2	2	0

Table 31. Percent weed canopy cover in May 1998 seeded indiangrass and wiregrass on sand tails soils at 6 months and 1 year after planting.

Treatment	6 months	1 year	% Points
	% Weed Canopy		Changed
Indiangrass – High Rate (60 pls/ft^2)	5	2	-3
Indiangrass & Wiregrass in Mix – High Rate	10	6	-4
Wiregrass – Medium Rate (40 pls/ft^2)	14	8	-6

Evaluations were also conducted on the indiangrass planting method study, established on both overburden and sand tails soils in May of 1998, in which drilling was compared to broadcasting. There was some initial difficulty getting the new Truax drill to feed properly when the overburden plots were planted. Therefore, drill plant densities were lower than expected (Table 32). Drilled densities were higher on the sand tails soils (Table 33), but still not even close to the emergence obtained from the broadcast treatment. Based on this study, broadcasting was the better method of establishment.

Poor drilled stands are due in large part to poor seed flow through the drill. Better seed conditioning would make drilling more feasible and require less seed.

Table 32. Plant densities of May 1998 drilled and broadcast indiangrass on overburden soils at 6 months and 1 year.

Treatment	6 months	1 year	% Seedling
	Plants/m^2		Loss
Indiangrass Broadcast - Medium Rate (40 pls/ft^2)	84	79	-6
Indiangrass Drilled - Medium Rate (40 pls/ft^2)	8	9	13
Indiangrass Drilled - Low Rate (20 pls/ft^2)	9	9	0

Table 33. Plant densities of May 1998 drilled and broadcast indiangrass on sand tailing soils at 6 months and 1 year.

Treatment	6 months	1 year	% Seedling
	Plants/m^2		Loss
Indiangrass Broadcast - Medium Rate (40 pls/ft^2)	97	91	-6
Indiangrass Drilled - Medium Rate (40 pls/ft^2)	17	15	-11
Indiangrass Drilled - Low Rate (20 pls/ft^2)	14	14	0

1999 Plantings: A third series of plantings were made in January and May of 1999. The first study focused on the effect of seeding date on wiregrass and lopsided indiangrass establishment. Wiregrass and indiangrass were broadcast in monoculture at a seeding rate of 60 pls/ft^2 in January and again in May. Plots were replicated three times on both overburden and sand tailing soils in a split-plot design. Wiregrass seed was not debearded, and was broadcast with a seed blower. Debearded indiangrass seed was broadcast with a cyclone seeder. Plots were packed before and after seeding with a cultipacker. Seed sources and other materials and methods were the same as used for the 1997 and 1998 plantings.

In the second study, the effect of various rates of indiangrass on wiregrass emergence was considered. Plots were planted in January on both soil types. Wiregrass was broadcast at 80 pls/ft^2 with three different rates of indiangrass (0, 10 and 20 pls/ft^2). Seed was broadcast with a seed blower and also contained a small percentage of *Liatris* seed. Plots were replicated three times on both soil types in a randomized complete block design.

In addition, alleys between the 1997 through 1999 plots were seed in January of 1999. Indiangrass was drilled into the alley on the north side of the plots with the Truax drill at a rate of 20 pls/ft^2. A wiregrass/indiangrass mix was broadcast into the middle and south alleys with a seed blower at a rate of approx. 100 and 10 pls/ft^2 respectively. A small portion of the alleys adjoining the 1999 seeding date study plots were left open for packing the May planted plots, after which these alleys were also seeded.

Six-month plant densities and weed competition for January 1999 seeding date study plots on both soils are shown in Table 34. Overburden soils in 1999 experiments have a large sand tails fraction, and texture tend to be lighter and coarser than overburden soils found in plots on the east end of the Cargill site. Weed competition was also much lower than that on the eastern overburden sites. Both species established well on the overburden soils despite the droughty spring. However, indiangrass establishment on the sand tails soils was poor, and wiregrass did not establish. Dry conditions and blowing sand desecrated seedlings that did manage to emerge.

Table 34. Plant densities and percent weed canopy cover of January 1999 indiangrass and wiregrass seeding date study on overburden and sand tails soils at 6 months after planting.

Treatment	Plants/m^2	Weed Canopy %
Overburden Soils:		
Indiangrass - Broadcast (60 pls/ft^2)	113	7
Wiregrass - Broadcast (60 pls/ft^2)	23	10
Sand Tails Soils:		
Indiangrass - Broadcast (60 pls/ft^2)	13	1
Wiregrass - Broadcast (60 pls/ft^2)	0	0

Six-month plant densities and weed canopy cover for the seeding rate studies are shown in Tables 35 and 36. *Liatris tenufolia* and *L. gracilis* were used in the overburden mixture. *Liatris elegans* was seeded with the sand tails mixture.

Table 23. Plant densities and percent weed canopy cover of January 1999 broadcast seeding rate study overburden plots at 6 months after planting.

Treatment	Plants/m^2	Weed Canopy %
Rate 1:		
Wiregrass (80 pls/ft^2)	11	5
Liatris (5 pls/ft^2)	3	
Rate 2:		
Wiregrass (80 pls/ft^2)	9	4
Indiangrass – Medium Rate (10 pls/ft^2)	5	
Liatris (5 pls/ft^2)	3	
Rate 3		
Wiregrass (80 pls/ft^2)	8	6
Indiangrass – High Rate (20 pls/ft^2)	7	
Liatris (5 pls/ft^2)	3	

The droughty spring of 1999 severely decreased emergence of all species on both soil types, but especially on the sand tails soils. It is difficult to determine how much competition the indiangrass gave emerging wiregrass, since so little wiregrass germinated. Under the climatic conditions of this study, it would appear that the higher rate of indiangrass (20 pls/ft^2) may reduce wiregrass establishment to some degree. However, it also provides some additional cover, so that wind erosion can be minimized.

Table 24. Plant densities and percent weed canopy cover of January 1999 broadcast seeding rate study sand tails plots at 6 months after planting.

Treatment	Plants/m^2	Weed Canopy %
Rate 1:		
Wiregrass (80 pls/ft^2)	0	2
Liatris (5 pls/ft^2)	1	
Rate 2:		
Wiregrass (80 pls/ft^2)	1	4
Indiangrass – Medium Rate (10 pls/ft^2)	2	
Liatris (5 pls/ft^2)	1	
Rate 3		
Wiregrass (80 pls/ft^2)	0	4
Indiangrass – High Rate (20 pls/ft^2)	4	
Liatris (5 pls/ft^2)	1	

All plots will be evaluated for one to two more years to monitor persistence and weed competition.

Thus far, direct seeding research results indicate that lopsided indiangrass emerges well any time of the year it is planted, as long as there is adequate moisture. Indiangrass is somewhat competitive with annual weedy species. Persistence of indiangrass has yet to be determined. Once established, it does not appear to be as drought tolerant as wiregrass. A broadcast seeding rate of 40 pls/ft^2 has produced adequate stands, depending on weed competition and available moisture.

Wiregrass appears to be extremely sensitive to weed competition. Therefore, seedbed preparation is critical to a successful stand. Low weed competition and good spring moisture produced excellent wiregrass stands in January of 1997. High weed competition and poor moisture in January of 1998 produced poor stands. In many overburden plots, wiregrass did not establish. Weed competition was lower on 1999 plots, and wiregrass was able to establish on overburden soils. However, dry windy conditions kept wiregrass from establishing on sand tails in 1999. Although evaluations have not yet been conducted on May 1999 plantings, a large percentage of wiregrass was observed in those plots. This would indicate that seeding date is not as critical to wiregrass establishment as is weed competition and moisture. Winter wiregrass plantings may establish better than summer plantings because there is less competition from annual weeds. Once wiregrass is established, it is very hardy and drought tolerant. Ideal seeding rate data is yet to be established for this species.

Reclaimed Lowland Minedlands Native Species Direct Seeding Trials:

The FLPMC is working with several native grasses that are adapted to mesic environments. Site adaptation and establishment technology needs to be developed for these species. In August of 1999, three grass species were direct seeded, and one was established with rhizomes on a newly reclaimed lake shoreline site provided by Cargill Fertilizer, Inc. The study plots began within one foot of the water line, and extended 25' up a relatively steep bank. Soils were sandtails and overburden topped with 6 to 12" of muck soils. Plot size was 8' x 25', and plots were replicated four times. Two Florida accessions of eastern gamagrass (9059213 and 9059264) were seeded in rows at a rate of 4 seeds per linear foot. Three rows of each accession were planted in each plot, with row spacing between plots being approx. 1.5'. Planting depth was 2 to 4". 'Alamo' switchgrass and the Florida switchgrass accession 9060500 ('Miami' x 'Stuart' parent stock) were seeded in 3 rows each per plot, at a rate of approx. 60 pls/ft^2. Planting depth was 1 to 2". Chalky bluestem seed (collected from several initial evaluation plots at the PMC in 1998 with a forage harvestor) was hand broadcast over plots. Rhizomes of 'Halifax' maidencane (*Panicum hemitomon*) from Mississippi, and the FLPMC released Florida accession 'Citrus' maidencane, were hand planted in trenches. Maidencane planting depth was 2 to 6" with approx. 5 rows per accession. In addition to these treatments, 3 rows of 'Citrus' maidencane were established in a plot that was then hand broadcast with a mixture of gamagrass (0.25 seed/ft^2), switchgrass and chalky bluestem at a rate 15 pls/ft^2 each. All plots were packed with a cultipacker before and after seeding. Trenches were dug with a tractor but plots were planted and covered by hand because of their small size.

Heavy rains caused some erosion after plots were established. However, all species had emerged within 2 months. The maidencane was very well established. Gamagrass seedlings had emerged from the rows but not from the broadcast mix plots. The planting depth may have been too shallow in broadcast plots to promote germination. Most gamagrass plants were 6 to 12" tall. Both switchgrass accessions had emerged and were performing similarly. The chalky had emerged but was the least robust of the four grass species. Seedlings averaged less than 1" in height. This study is scheduled to be evaluated within 6 to 12 months for seedling density and persistence.

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