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DEVELOPMENT OF SEED SOURCES AND ESTABLISHMENT METHODS FOR NATIVE UPLAND RECLAMATION

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Florida Institute of Phosphate Research
1855 West Main Street
Bartow, Florida 33830
(863) 534-7160
Fax: (863) 534-7165
http://www.fipr.state.fl.us

DEVELOPMENT OF SEED SOURCES AND ESTABLISHMENT METHODS FOR NATIVE UPLAND RECLAMATION

FINAL REPORT

Sharon Pfaff and Clarence Maura, Jr.
Principal Investigators

with

Mary Anne Gonter

United States Department of Agriculture
Natural Resources Conservation Service
PLANT MATERIALS CENTER
14119 Broad Street
Brooksville, Florida 34601

Prepared for

FLORIDA INSTITUTE OF PHOSPHATE RESEARCH
1855 West Main Street
Bartow, Florida 33830 USA

Project Manager: Dr. Steven G. Richardson
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DISCLAIMER

PERSPECTIVE

The use of native plant species in the revegetation of upland (non-wetland) sites on phosphate mined lands, has been hampered by the lack of seeds, especially of grasses and forbs (broadleaved herbaceous species). Bareroot or containerized transplants of several native trees and a few shrubs are available from several Florida nurseries, but only out-of-state seed sources have been commercially available for a few "native" (southeastern U.S.A.) upland grasses and forbs. The grass species most commonly (almost exclusively) used in reclamation in Florida have been the non-native grasses, bahiagrass and bermudagrass. These non-native species have several characteristics that make them valuable for use in reclamation, but they are inappropriate for use where restoration of a natural ecosystem is the desired goal. Recently, seeds have been harvested from native plant communities and planted on reclaimed lands, but the quantity of seed available from native plant communities is small and often unreliable.

The purpose of this research was to develop quality seed sources of Florida native upland plant species and to develop methodology for seed production and for field establishment of plants from seeds. The real hope is that commercial growers will use the technology and the seed sources that have been developed to produce larger quantities of native seeds. A “Florida Native Seed Production Manual,” based on this research, is also being produced (published by the Natural Resources Conservation Service) that provides guidelines for native plant seed collection, seed production and plant establishment. An earlier manual, “Florida Native Plant Collection, Production and Direct Seeding Techniques: Interim Report,” was published by the NRCS and FIPR in 1996.

Related research includes:

- Synthetic Seed Production of Florida's Indigenous Plants. FIPR Project No. 96-03-123.
- Rapid Production of Florida's Indigenous Plants Via Micropropagation. FIPR Project No. 99-03-139
- Managing Weed Competition and Establishing Native Plant Communities on Reclaimed Phosphate Mined Lands. FIPR Project No. 98-03-134.

Steven G. Richardson
FIPR Reclamation Research Director

ABSTRACT

There is a growing demand in Florida for native seed sources, which can be used to restore upland habitats. However, native species have inherent traits that make development of commercial sources difficult and costly. The purpose of this 5-year agreement was to develop seed sources, and associated establishment and production technology for selected native species. A four-fold approach was used, including seed collection, plant evaluation, researching seed production and establishment practices. A large number of collections were made throughout Florida and evaluated in laboratory, greenhouse and field trials. Methods to increase seed production of native grasses were investigated. Experiments were conducted on reclaimed mined lands, testing seeding methods, rates and dates for several native grasses. As a result, 8 species are under development, with several species being close to commercial release. A large volume of useful establishment and seed production technology was developed; the results of which are to be compiled into a manual for future growers. Currently, there is no commercial native seed production industry in Florida. Much opportunity exists in Florida to develop this industry, along with a greater diversity of seed sources and associated technology.

ACKNOWLEDGMENTS

Development of native seed sources is a long and expensive process. The support of the Florida Institute of Phosphate Research (FIPR) and the phosphate industry in Florida has been invaluable in rapidly moving this process forward. We especially thank Dr. Steven Richardson for his assistance in all phases of this work, and Rosemarie Garcia (Cargill Fertilizer Inc.) for providing excellent sites and support for field studies.

Native sources of seed were critical for the success of this work, and we gratefully thank personnel at Avon Park Air Force Range and Ft. Cooper State Park for allowing us to harvest with our Flail-Vac Seed Stripper. We also thank the State Forest Service, the Florida State Parks and the Florida Water Management Districts for opening up their lands for seed collection. The state of Florida is rich in native lands, and the staff from these many agencies are doing a tremendous job preserving and protecting Florida's natural resources.

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EXECUTIVE SUMMARY

Restoring a portion of reclaimed mined ands to native vegetation has long been the goal of the Florida phosphate industry. A native seed mix is desired, which could be mechanically seeded onto large tracts of reclaimed uplands. However, commercial varieties of Florida native seed were not available. Despite increasing demand, native species have inherent traits that make seed source development difficult and costly. First, many species have low seed production and viability. Secondly, seeds are often light, with awns or hairy appendages, and cannot be harvested or seeded with conventional equipment. Thirdly, desirable native species often lack seedling vigor, and are poor competitors with the many aggressive introduced species that have invaded Florida.

Florida lies on a climatic transition zone from temperate to tropical, and is host to thousands of native species. Under a previous agreement with FIPR, the Brooksville, Florida Plant Materials Center (PMC) 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; usefulness as a ground cover for erosion control and protection of water quality. A second agreement was developed to build upon this work and move towards meeting the goal of developing native seed sources along with establishment and production technology. The specific objectives of this agreement were as follows:

1. Identify and collect upland grasses, legumes and forbs, which show promise for use in a native seed mix. Do broad scale genetically diverse assemblies of those species identified as being good candidates for the seed source development program.

2. Evaluate seed and plants of collected species in the laboratory, greenhouse and field. Conduct field tests at both the PMC and on reclaimed mined ands. Evaluation criteria include seed viability, seedling vigor, ease of establishment, seed production, forage quality, persistence, drought, disease and insect resistance.

3. Establish production fields of accessions of selected species to test cultural practices for increasing seed production and viability.

4. Develop and test cultural practices for direct seeding native species on disturbed sites in monoculture and mixes, including one or more major experiments testing such things as seeding methods, rates, and dates.

Under this agreement, very rapid progress was made in assembling and testing several species. Over 25 native species were collected in the form of seed or plants for these studies. Large assemblies of six species, including lopsided indiangrass

(*Sorghastrum secundum*), chalky bluestem (*Andropogon capillipes*), eastern gammagrass (*Tripsacum dactyloides*), hairawn muhly (*Muhlenbergia capillaris*), switchgrass (*Panicum virgatum*), and wiregrass (*Aristida beyrichiana*) had been or were collected statewide in preparation for seed source development. Blue maidencane (*Amphicarpum muhlenbergianum*) was collected for vegetative source development. Each assembly contained from 80 to 150 accessions collected from a broad range of sites throughout Florida. Historically it takes an average of 14 years to develop and commercially release a species in the Plant Materials Program. To develop a proven cultivar with associated production and establishment technology commonly takes 25 years or more. Because of high demand, the Brooksville PMC used abbreviated development procedures under this agreement to speed the commercial release process for the seven selected species. The result has been that several species are nearing the end of the development process and are being increased for release onto the commercial market.

In addition to the work discussed above, a total of 23 species were screened for adaptation on reclaimed mined land overburden and sand tailing soils. Two accessions (*Liatris elegans* and *Andropogon ternarius*), were selected directly from these studies, and are being increased for commercial release. These accessions were among the few that could successfully establish on sand tailings despite extreme droughty conditions. Three more species (*Sporobolus junceus, Pityopsis graminifolia,* and *Schizachyrium stoloniferum*) also proved highly adaptable to reclaimed mined land soils, and were selected as candidates for future large-scale assembly and seed source development.

Even if a seed source is commercially available, establishment attempts may fail if seed quality is poor or seed has a high degree of dormancy. Two studies addressed this problem. In the first, different methods of storing switchgrass seed were studied, to see how they influenced seed germination. Cold dry storage may initially increase the level of seed dormancy, but between two and four years, there was no difference between seed stored at room temperature, and refrigerated seed. Seed stored under uncontrolled conditions held its viability for one year, but quickly expired thereafter.

Eastern gammagrass seed is also prone to dormancy. Different methods of breaking dormancy were tested on two Florida ecotypes. A combination of chilling and gibberellic acid promoted very rapid emergence and robust plants. Seed treated in this manner has the potential to dramatically increase field establishment success.

Another undesirable trait of eastern gammagrass is uneven seed ripening. An assembly of Florida ecotypes was screened for viable seed production. It was discovered that though seed is continually produced in the summer, greatest production and viability for most types occurred later in the season, around August 1. This information will help improve timing of harvests to obtain maximum amounts of viable seed.

Cultural management studies were conducted on two other grass species, to investigate ways to improve seed production and stand longevity. Lopsided indiangrass appears to be a short-lived perennial, with stands at the PMC surviving only three to four years. February and July burn and mow treatments were applied to an indiangrass stand, to study residue removal effects on seed production and plant persistence. Mowing during either month, or February burning, increased seed yields over untreated plants, though differences were not statistically significant. July burning severely hurt plant vigor and dramatically lowered seed production. Managers of native stands often burn between March and August to stimulate wiregrass seed production. In this study, burning during July was very detrimental to indiangrass, indicating that those managing stands of indiangrass for seed should only burn old residue in the winter before spring regrowth. Mowing to remove residue, even if plants are actively growing, caused less plant injury.

It has been shown that native stands of wiregrass need a growing season burn to produce viable seed. A series of three studies was conducted on stands of wiregrass at the PMC. In the first, response to burning verses mowing was investigated. In this study, plants that were mowed to a 1-2 inch height, to expose the plant crown, had the same seed production and viability as plants that had been burned. Mowing would allow seed growers greater flexibility in managing stands to obtain optimum production.

It would be economically desirable to harvest wiregrass fields annually, but annual burning may reduce plant vigor and stand life. The second study investigated response to different burn frequencies (one, two, or three years) in conjunction with fertilizer applications. It was discovered that mature plants do not necessarily need to undergo a growing season burn to produce viable seed. Unburned plants often flowered, though seed production and viability were not always as great as that found in burned plants. There was very little observable response the first two years to high levels of K applied after burning. In the third year, a combination of N and K was applied early in the year. This significantly increased either seed production or viability, depending on burn cycle. During this 3-year study, plant losses were similarly high in all treatments.

A third study specifically examined response to fertilizer application (no fertilizer, K & P, and N, K & P). The original premise used in this study was that wiregrass would have very little response or a negative response to N fertilization, since it had evolved in a nutrient poor environment. Other nutrients (namely K) are commonly found in the ash after a burn, and thought to be important for seed production. Initial applications were made to mimic the flush of nutrients released following a July burn. During the two years of this study, no significant response in viable seed production was seen between any of the fertilizer treatments. In all probability, the N fertilizer was applied too late in the growing season (July or August) to provide any real benefit to the plants. Further studies need to be conducted to determine if applications of N fertilizer at the initiation of spring growth can increase seed production. However, management practices can improve seed production only to a limited degree. Because viable seed production was highly diverse between plants, regardless of fertilizer treatment, genetic selection could potentially rapidly improve viable seed production in wiregrass.

Weed control was a serious problem in both the indiangrass and wiregrass studies. Better plant and row spacing strategies need to be developed to minimize weed competition. In these studies, plants were placed on two-foot centers, within and between rows. This allowed too much open space for weeds to become established. A better strategy may be to place plants one foot or less apart within double rows, to maximize plant density, and increase row spacing between sets of double rows to three to five feet, to allow for mechanical tillage. Herbicide control measures also need to be investigated.

Under the fourth objective of this agreement, studies were conducted to determine successful seeding methods, rates and dates for wiregrass and indiangrass on upland reclaimed mined lands. Broadcasting generally produced the highest plant densities for both species, whether planted alone or in a mixture. Initially, drilled seeding rates were the same as those used for broadcasting, but were most likely higher than necessary. Lopsided indiangrass established fairly well in drilled treatments. Drilling may be advantageous for species with seed that will flow through chaffy seed drills. Drilling normally requires lower seeding rates, which can reduce seed costs substantially.

Based on seeding rate tests, optimum broadcast seeding rate for indiangrass was 430 pure live seed per m^2 (pls/m^2) (40 pls/ft^2), [approximately 9 kg pls ha^{-1} (8 lb/A)]. Drill seeding rates were not precisely determined, but are generally half of broadcast rates. Optimum wiregrass broadcast rates could not be determined in these studies. Wiregrass could not establish under extreme dry, windy conditions, or when weed competition was high, no matter the rate. When conditions were favorable, adequate stands were produced from rates of 640 to 860 pls/m^2 (60 to 80 pls/ft^2), [approximately 3.5 to 4.7 kg pls ha^{-1} (3 to 4 lb/A)]. In terms of mixtures, adding up to 4.5 kg pls ha^{-1} (4 lb/A) of indiangrass did not appear to suppress wiregrass emergence.

No significant difference was found between January and May seeding dates for either species. However, March and April rains were well below normal when this study was seeded, while more favorable rains fell in May and June. Higher winter/spring rainfall at the time of planting may have produced different results.

Under this agreement, switchgrass, eastern gammagrass, chalky bluestem and common maidencane were successfully established on a reclaimed mined lands lake shoreline. A layer of nutrient-rich muck soils encouraged vigorous growth and establishment. Of the 4 species, switchgrass was the least susceptible to droughty conditions and provided the greatest cover. Although gammagrass had good emergence, establishment may have been more rapid in this study if seed had been pretreated to overcome dormancy. Chalky bluestem was the slowest to establish. It provided comparatively less early cover with which to control erosion than did the other grasses.

Development of quality seed sources is a very time-consuming and costly process. Under this agreement, rapid progress was made in developing species adapted to reclaimed mined land soils. Much useful seed establishment technology was developed for several native species, along with foundational seed production technology. Information gathered under this agreement is being compiled into a comprehensive Florida native seed production manual for future seed growers. Even though these seed sources will soon be available for growers, there is currently no native seed production industry in Florida to produce them. Great strides were made under this agreement, but much opportunity still exists in Florida to develop a native seed production industry, along with a greater diversity of seed sources and associated technology.

DEVELOPING SEED SOURCES OF FLORIDA NATIVE UPLAND SPECIES

INTRODUCTION

There has been a recent surge of interest in reclaiming Florida uplands to native species, in the phosphate industry as well as amongst many public and private conservation groups. Unfortunately, commercial sources of seed for Florida native species are lacking. Several factors have discouraged the development of Florida cultivars. Many of the desirable Florida native grasses and forbs have poor seed production and viability, especially those with rhizomatous root systems (Yarlett 1996; Pfaff and Gonter 1996). Florida upland species evolved under a regime of summer fires, and may require burns of fairly specific timing and intensity to produce viable seed (Platt and others 1994). In addition, native seedlings often lack vigor, and have difficulty competing with the abundant number of robust introduced weed species in Florida.

The Brooksville, Florida Plant Materials Center (PMC) began cooperating with the Florida Institute of Phosphate Research in the early 1990's to identify and develop those native species with the greatest potential for use in an upland seed mix. Early work included screening a broad range of candidates for seed production and growth characteristics on reclaimed upland mined lands. Several good candidates were found (Pfaff and Gonter 1996). The second stage of this work is to develop reliable, commercially available seed sources of these promising species. This includes developing cultural practices for stand establishment and seed production.

MATERIALS AND METHODS

The Plant Materials Program has historically used a multi-step process to develop proven plant materials for conservation uses. Development of superior cultivars can take decades. Because demand for native species is currently high, abbreviated procedures have been developed to shorten the time it takes to release plant materials onto the commercial market. These short cuts have strong advantages and disadvantages.

The first step in plant materials development is assembly. There is much controversy about the benefits of revegetating with only local ecotypes versus combining propagules from different populations to get more genetic diversity (Booth and Jones 2001; Havens 1998). Unless plant materials are being developed for a specific locale (e.g. a park or preserve), targeted species are assembled from as wide a genetic range as possible, while staying within the same ecoregion. If a species grows in only a limited area, and demand is great, material collected from a given site can be immediately released as a "Source Identified" commercial release. Seed gathered directly from the site or grown under cultivated conditions will carry this designation. The plants undergo no evaluation, therefore, very little is known about plant performance other than what is observed at the collection site. Nothing is known about establishment on other sites. Neither has any genetic manipulation occurred. Commercial growers and reclamationists take on a larger share of risk when they use “Source Identified Seed”. Collecting seed, establishing commercial production fields, and planting native seed on reclamation sites is extremely expensive. The chances of failure are high if the seed is not adapted, or appropriate planting and management technology is not available.

The second step is initial evaluation. Assembled materials are usually planted at the PMC in replicated trials, possibly on one or more soil types. Accessions are evaluated for establishment, growth and seed production characteristics for 1 to 4 years. Longer-term evaluations provide better information on persistence and disease resistance. One or more superior performers are then selected and increased. If demand is great, superior accessions can be increased at this point and released as a “Selected” commercial release. With this type of release, testing has not been conducted off-Center or on more than one generation. Therefore, accessions may or may not breed true, and desirable characteristics may not show up in all of the offspring. Cultural methods to promote viable seed production may not be known at this point either. Because of high demand, many native species are being released under the “Selected” class. However, growers and reclamationists still share a larger percentage of the risk using this class of materials, because a large amount of adaptability information and management technology is still missing. One other option at this phase of the program is to place all accessions with good performance in a polycross nursery, and develop a synthetic with a large amount of genetic diversity. Greater diversity potentially allows for a broader range of adaptability.

Selected plant materials must be increased to provide material for further testing. This is the third step in the process. The fourth step is advanced evaluations. Offspring from superior accessions are planted on multiple sites, usually in replicated plots, to verify performance and heritability of desirable characteristics. Trials typically last from 2 to 4 years. Advanced evaluation trials are designed to prove genetic superiority and determine whether heritability of distinctive traits is stable. Superior performers selected from advanced evaluation trials can be released as “Tested” materials.

If advanced evaluations are extended to include replicated studies of adaptation ranges, establishment, management, and/or production technology of two or more generations, then the selection can be released as a “Cultivar” or “Variety”. At this step, the heritability of superior traits, performance, and adaptation range has been proven. These are the highest quality releases available and carry the lowest risk for users. They include a great deal of technology to insure establishment and production success.

The final step is field planting. Large-scale plantings of the cultivar are established along with a standard of comparison (a commercially available cultivar of the same or a similar species with a well established performance record) under a variety of soils, climate and land use conditions. Field plantings are useful for gathering performance or cultural management information under actual use conditions. Field plantings add to the body of technology available for a cultivar, but are not necessary for release onto the commercial market.

RESULTS AND DISCUSSION

Between 1996 and 2001, rapid progress was made in developing proven seed sources of 1 forb and 8 native grasses. Species are listed below in order of nearness to commercial release.

Blazing Star

Blazing star is a showy perennial wildflower, with several species being found in a variety of sites throughout Florida. Deer browse the forage and the flowers are especially attractive to butterflies and other insects. In reclaimed mined land adaptation trials, an upland ecotype of blazing star [*Liatris elegans* (Walt.) Michx.] collected in Citrus County proved to be highly adaptable to sand tailings. This accession was planted in increase plots at the PMC in 2001 in preparation for commercial release.

Splitbeard Bluestem

Splitbeard bluestem (*Andropogon ternarius*) is a perennial bunchgrass adapted to droughty sandhills. It is useful for erosion control, wildlife cover and livestock forage. In adaptation trials on reclaimed mined lands, an accession collected from Ft. Cooper State Park in Citrus County proved to be highly adaptable to overburden and especially sand tailings. Splitbeard bluestem is a prolific seed producer. Seed size is relatively large, giving this species high seedling vigor even in adverse conditions. An increase plot of the Ft. Cooper ecotype was planted at the PMC in 2001 in preparation for commercial release.

Chalky Bluestem

Chalky bluestem (*Andropogon capillipes* Nash) grows in wet flatwoods and around fresh water bodies. It has excellent seed production and is useful for erosion control, livestock forage and wildlife cover. Seed from a total of 91 accessions was collected from 43 counties in Florida, in the fall of 1996. Initial evaluation trials were established on well and poorly drained irrigated sites at the PMC. Evaluations were conducted for 3 years, and 10 superior performers were selected in the fall of 1999. These accessions were planted in a polycross nursery at the PMC in 2001. Seed from this nursery will be used to establish a foundation seed field in preparation for commercial release.

Lopsided Indiangrass

Lopsided indiangrass [*Sorghastrum secundum* (Ell.) Nash] is an upland bunchgrass useful for erosion control, livestock forage and wildlife cover. It has relatively high seed production and seedling vigor, making it one of the best candidates for use in a native seed mix. In the fall of 1996, the PMC completed assembly of 138 accessions of lopsided indiangrass, collected from over 48 counties in Florida. Trials were established on irrigated and non-irrigated plots at the PMC in 1997. Evaluations were conducted for 3 years. All accessions survived only 2 years on the irrigated site, probably due to soil-borne pathogens. Several accessions persisted for 4 years on the non-irrigated site. No accession showed superior performance in all criteria. Twenty-four top performers were selected out of this assembly. In 2001, 3 of these accessions with very similar growth characteristics were placed in a polycross nursery. Twenty-one accessions were placed in a separate polycross nursery. Seed from these nurseries will be used to establish foundation seed fields in preparation for commercial release. Because demand is high, and the need for technology is great, seeding and cultural management trials have already been conducted for this species. Results are reported in 2 other papers in this publication. Further cultural management technology needs to be developed to make seed production more economically feasible.

Blue Maidencane

Several native grasses in Florida are desirable candidates for revegetation use, yet produce little or no viable seed. Instead, they have extensive rhizomatous root systems, and can be established by sprigging or disking rhizomes into prepared sites (Yarlett 1996). Such is the case with blue maidencane [*Amphicarpum muhlenbergianum* (Schult.) Hitchc.] Blue maidencane can typically be found in flatwoods and around fresh water ponds. Because of its extensive root system, it has tremendous potential for use in erosion control, which in turn helps maintain water quality. It also provides quality forage for livestock. Approximately 150 blue maidencane accessions gathered from around the state were placed in an initial evaluation trial at the PMC in 1999. Eleven superior performers were selected and increased in 2000. At the writing of this report, advanced evaluation trials were planted in 3 counties in Florida. More trials will need to be planted to identify superior accessions and establish adaptation ranges. Once trials have been completed, selected accessions will be increased for commercial release.

Eastern Gammagrass

Eastern gammagrass [*Tripsacum dactyloides* (L.) L.] has received intense scrutiny in the US as a high quality forage crop. It is found in moist fertile sites and along the edges of canals and freshwater bodies. It is very useful for wildlife food and cover. In recent years, gammagrass has gained popularity as a border or buffer around cropland. A PMC assembly of Florida ecotypes of eastern gammagrass was evaluated in 1996 and 1997 for seed production and plant performance. Four accessions with the greatest seed production and desirable growth characteristics were selected for advanced evaluation. These 4 accessions were planted in seed increase plots in 1999 at the PMC. Seed was collected and, at the writing of this paper, has thus far been used to establish advanced evaluation trials in 4 counties in Florida. A forage and seed production trial has also been planted at the PMC in cooperation with the Oklahoma Agriculture Research Service. More advanced evaluation trials will need to be planted throughout Florida to determine the range of adaptation. Further technology also needs to be developed to maximize seed production. Once this body of work is complete, it is expected that 2 of the accessions will be released onto the commercial market as cultivars.

Hairawn Muhly

Hairawn muhly [*Muhlenbergia capillaris* (Lam.) Trin.] is a perennial bunchgrass, which has recently become very popular among landscapers, because of its showy purple bloom. It grows on a variety of sites in Florida from very dry to marshy. It has fair seed production and seedling vigor under favorable conditions. Ninety-four accessions were assembled from around the state, and were planted in an initial evaluation trial at the PMC in March of 2000. Superior accessions are to be selected after 2 to 3 years of evaluation and increased for advanced evaluation.

Switchgrass

Switchgrass (*Panicum virgatum* L.) is a perennial bunchgrass, which has also 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 provides cover for wildlife; birds and other small animals eat the seed. The PMC has been working to develop Florida strains of switchgrass for many years. Several accessions have been selected with excellent forage production characteristics. The one limiting factor, however, has been reliable production of viable seed. A breeding program to improve seed production was developed in conjunction with University of Florida plant breeder, Dr. Ken Quisenberry in 2000. That same year, 104 accessions of switchgrass were assembled from throughout the state. Accessions collected as seed were started in the greenhouse, and plants were placed in a polycross nursery at the PMC in 2001. Accessions are to undergo intensive selection to develop one or more strains with high seed production characteristics. It is expected that this project will take an additional 5 to 7 years before a strain is developed and ready for advanced field evaluations.

Wiregrass

Wiregrass (*Aristida beyrichiana* Trin. & Rupr.) is often the dominant grass species in Florida uplands. Foresters have long preferred this species for pine forest understory because of its ability to carry fire. Even though growing season burns are now known to stimulate flowering, seed viability and seedling vigor are relatively poor. Much establishment and seed production technology has recently been developed for wiregrass, as discussed in other papers in this publication. Based on this work, it appears that cultural practices can only improve viable seed production to a small degree. If commercial seed production is to become economically feasible, genetic improvement will need to take place. An assembly of wiregrass from around the state of Florida was initiated by the PMC. More accessions need to be collected, and a comprehensive plant breeding program developed in conjunction with university plant breeders.

CONCLUSIONS

Over the past six years, the Florida PMC has been conducting extensive assembly and evaluation work to begin meeting the demand for native species. The pressing need for commercial sources, however, must also be balanced with technology development. Unlike many other states, Florida does not currently have a native seed production industry. Native species are typically more expensive and difficult to establish and maintain than introduced cultivars that have undergone decades of selective breeding. Although abbreviated release procedures allow seed sources to be quickly moved onto the commercial market, two to four additional years of testing can provide proven materials, along with vital information necessary for successful stand establishment and production.

PERFORMANCE OF SELECTED FLORIDA NATIVE SPECIES ON RECLAIMED PHOSPHATE MINED LANDS

INTRODUCTION

Commercial seed sources of a diversity of native species are desired for reclamation of phosphate mined lands. However, developing seed sources is a very expensive and time-consuming process. Before engaging in this process, some preliminary screening work needed to be conducted to determine which species were adaptable to reclaimed soils. Mining dramatically changes the soil substrate, and therefore the available nutrients and water holding capacity of the soil. The purpose of this research was to determine the adaptability of a broad range of Florida native grasses and forbs to reclaimed mined lands, and identify those species with the greatest potential for seed source development.

MATERIALS AND METHODS

In 1996 through 1998, seed from a variety of native species was hand collected, primarily from Ft. Cooper State Park in Citrus County and the Avon Park Air Force Base—sandhill and flatwood sites respectively. Other collections were made from various locations in Florida where promising species grew in abundance. Prior to planting, purity was determined, and germination tests were conducted to determine seed viability of all collections. A total of 23 species and 34 accessions were tested in this study using 2 planting dates over a period of 3 years. Due to the length of time necessary for conducting germination tests, winter plantings could not be made until early January. May was selected for the summer planting date so plots could be seeded just prior to the summer rainy season, before heavy rains could interfere with planting. Plantings were made in January and May of 1997, 1998 and 1999 on 2 types of reclaimed soils. Half of the study site was composed of sand tailings, which are generally consistently coarse and droughty. The other half of the study site was composed of sand tailings capped with overburden. Overburden soils are a heterogeneous mixture of sandy loam. A small clay component in these soils greatly increases water-holding capacity, however, it may also cause severe crusting. The study site was provided by Cargill Fertilizer Inc., and is located south of Bartow. Seed was hand-planted in 6 m (20 ft) rows, with 1 m between rows on both soils. Planting depth was generally 1 to 2 cm (½ to ¾ in). Seeding rate was generally 645 pure live seed (pls) per m^2 (60 pls/ft^2). The commercially available cultivar 'Alamo' switchgrass (*Panicum virgatum* L.) was planted each time as a standard of comparison. Due to a scarcity of seed, plots were not replicated. Plots were evaluated 6 months after planting and then annually to determine adaptability and performance. A final evaluation was made in May of 2001.

RESULTS AND DISCUSSION

The winter of 1997 was unusually wet, encouraging excellent establishment on both soil types (Tables 1 and 2). The winters of 1998, 1999 and especially 2000 and

2001 had periods of extreme wind and drought. Summer rains were not consistent between 1997 and 1999, and most species appeared to establish better from January verses May plantings. Many species that did emerge, especially from winter seedings, often died from lack of moisture, or were desiccated by blowing sand, particularly on sand tailings. Even many established plants were not able to survive under the droughty conditions. Therefore, it was a good opportunity to study species drought resistance. Despite unfavorable conditions, some species did establish quite vigorously, especially on sand tailings.

Weed competition was often a problem on the overburden soils but not on the sand tailings. Both soil types had very low fertility, which further reduced plant vigor. A few species consistently performed better than the standard of comparison, Alamo switchgrass. Following is a brief discussion on the performance of the better adapted species.

Splitbeard bluestem (*Andropogon ternarius*) was planted on all but the first planting date, so performance could be observed across various weather patterns and planting seasons. On overburden soils, plants were not as robust or vigorous as Alamo switchgrass, but densities were similar. On sand tailings, this species outperformed all other species in that it was able to consistently emerge and establish, despite extreme drought conditions. The accession of splitbeard bluestem used in this study was collected from Ft. Cooper State Park on a droughty sandhill site. It does not produce as much forage as some other species under upland conditions, however, it has good potential for use as an erosion control plant on droughty uplands. It also appears to have good persistence. This accession was selected for increase and release onto the commercial market.

Wiregrass (*Aristida beyrichiana* Trin. & Rupr.) performance varied depending on available moisture, planting season and ecotype. Upland ecotypes, such as those collected from Wekiwa Springs State Park, appeared to have better performance than flatwoods ecotypes such as those collected from the Avon Park Air Force Range. However, this would need to be verified in replicated studies. Generally, wiregrass had slightly better performance than Alamo switchgrass.

Blazing star [*Liatris elegans* (Walt.) Michx., *L. tenuifolia,* Nutt., and *L. gracilis* Pursh] performance varied depending on species, planting season and soil type. May, 1997 plantings of *L. elegans and L. tenuifolia* did not emerge. Florida ecotypes may be similar to mid western ecotypes, in that they require short day lengths to germinate. The droughty sandhill ecotype of *L. elegans* planted in this study performed extremely well on sand tailings. It did not persist on overburden soils, possibly because of susceptibility to soil-borne pathogens in the moister soils. *L. elegans* is a good candidate for adding diversity to extremely droughty sites, and was selected for increase and release onto the commercial market.

Sky blue lupine (*Lupinus diffusus* Nutt.) initially displayed tremendous vigor and drought resistance. However, within a few months, most plants began dying from what appeared to be soil-borne pathogens, especially on the overburden soils. Because of dormancy, seed continued to germinate over a period of years. A few plants lived long enough to produce seed, which may have also begun to germinate. Inoculating seed did not appear to increase disease resistance. One accession collected from back dunes along the Gulf coast in Bay County had better survival than did Hernando County accessions on sand tailings. Lupine is a member of the legume family, and therefore provides a sustainable source of nitrogen to native systems. It is toxic to livestock, but some types of wildlife eat the seeds. This species has tremendous potential for use in native plantings if disease resistant varieties can be developed. The role of beneficial soil organisms such as mycorrhizae on disease resistance should also be investigated.

Two Florida ecotypes of switchgrass (collected from Miami and Stuart) were crossed to obtain the seed used in this study. These plants consistently outperformed Alamo switchgrass, especially on sand tailings. It was concluded that Florida varieties of switchgrass have good potential for use on reclaimed mined land soils, lending further encouragement to the work of developing a variety with high viable seed production.

Grassyleaf goldenaster [*Pityopsis graminifolia* (Michx.) Nutt.] seed was only available for the 1999 plantings. Even though this accession was collected from a flatwoods site in Avon Park Air Force Range, it established well on overburden soils. During the extreme droughty conditions of 2000 and 2001, it was one of the few species in this study to remain green and robust. This species has tremendous potential for use in native plantings, as its rhizomatous growth habit is especially useful for controlling erosion. It was selected as a good candidate for seed source development.

Lopsided indiangrass [*Sorghastrum secundum* (Ell.) Nash] initially had very good performance, though it varied according to ecotype. Emergence was usually high on both soil types if there was sufficient moisture. Performance was much better than Alamo switchgrass, but plants did not persist on most sites more than 3 years. This species has good potential for early erosion control in native plantings. However, if conditions are not conducive to seed production, it may not persist in the landscape.

Creeping bluestem (*Schizachyrium stoloniferum* Nash) had surprisingly good performance on overburden soils, though not on sand tailings. The accession used in this study was collected from a sandhill site in Ft. Cooper State Park. During the extreme droughty conditions of 2000 and 2001, this species was one of the few able to persist and spread. Because of its rhizomatous growth habit, it is useful for erosion control in native plantings. Since creeping bluestem viable seed production is often relatively low, it was thought that it would be difficult to successfully direct seed. That was not the case with the accession used in this study, however. This species was selected as a good candidate for seed source development.

Table 1. Plant Densities of 34 Accessions of Grasses and Forbs Planted on Six Different Dates on Reclaimed Mined Land Overburden Soils, and Evaluated in May of 2001 (24 to 54 Months After Planting).

Species	Planting Date					
	1997		1998		1999	
	Jan.	May	Jan.	May	Jan.	May
	----------------------Plants/m^2----------------------					
Andropogon ternarius		<1	0	2	0	0
A. capillipes	0	0				
A. gyrans		0	0			
Aristida beyrichiana (Avon Park)	7		<1	0	0	<1
A. beyrichiana (Leon)						<1
A. beyrichiana (Wekiwa)					3	
Carphephorus corymbosus					0	0
Chamaecrista fasciculata (Citrus)			0	0		
C. fasciculata ('Comanche')			0		0	0
Chasmanthium laxum	0	0	0			
Ctenim Aromaticum	0	0	0			
Eragrostis spectabilis (Hernando)			<1	3		
E. spectabilis (Avon Park)			0			
Helianthus radula		0				
Liatris elegans (Floral City)	0	0	0		0	
L. gracilis (Avon Park)			0		0	
L. tenuifolia (Ft. Cooper)	7	0			0	
L. tenuifolia (Avon Park)					<1	
Lupinus diffusus (Croom)			0	0		
L. diffusus (Hernando) (noninoculat.)			0	0	0	0
L. diffusus (Hernando) (inoculated)						0
L. diffusus (Bay) (noninoculated)					0	0
L. diffusus (Bay) (inoculated)						0
Panicum anceps			0			
P. virgatum ('Alamo')	1	0	<1	<1	0	0
P. virgatum (Miami x Stuart)			7	2	1	<1
Pityopsis graminifolia					1	<1
Sorghastrum nutans ('Lometa')			0			
S. secundum (Ft. Cooper)	1			10	<1	<1
S. secundum (Croom)					0	0
Schizachyrium stoloniferum			3	0	20	<1
Sporobolus junceus		1	10	1	7	<1
Tridens flavus	0	0	0	0	0	
Tripsacum dactyloides (Clay Co.)		0	0	0	0	0

Table 2. Plant Densities of 34 Accessions of Grasses and Forbs Planted on Six Different Dates on Reclaimed Mined Land Sand Tailings, and Evaluated in May of 2001 (24 to 54 Months After Planting).

Species	Planting Date					
	1997		1998		1999	
	Jan.	May	Jan.	May	Jan.	May
	----------------------Plants/m^2----------------------					
Andropogon ternarius		<1	0	<1	1	2
A. capillipes	0	0				
A. gyrans		0	<1			
Aristida beyrichiana (Avon Park)	4		0	0	0	0
A. beyrichiana (Leon)						<1
A. beyrichiana (Wekiwa)					0	
Carphephorus corymbosus					0	0
Chamaecrista fasciculata (Citrus)			0	0		
C. fasciculata ('Comanche')			0		0	0
Chasmanthium laxum	0	0	0			
Ctenim Aromaticum	0	0	0			
Eragrostis spectabilis (Hernando)			0	0		
E. spectabilis (Avon Park)			0			
Helianthus radula		0				
Liatris elegans (Floral City)	3	0	3		0	
L. gracilis (Avon Park)			0		0	
L. tenuifolia (Ft. Cooper)	<1	0			0	
L. tenuifolia (Avon Park)					0	
Lupinus diffusus (Croom)			*sp	0		
L. diffusus (Hernando) (noninoculat.)			sp	sp	sp	<1
L. diffusus (Hernando) (inoculated)						<1
L. diffusus (Bay) (noninoculated)					sp	5
L. diffusus (Bay) (inoculated)						4
Panicum anceps			0			
P. virgatum ('Alamo')	10	0	<1	0	<1	0
P. virgatum (Miami x Stuart)			<1	2	0	<1
Pityopsis graminifolia					0	0
Sorghastrum nutans ('Lometa')			0			
S. secundum (Ft. Cooper)	3			1	1	3
S. secundum (Croom)					1	0
Schizachyrium stoloniferum			<1		0	0
Sporobolus junceus		0	0	<1	0	0
Tridens flavus	1	0	0	0	0	
Tripsacum dactyloides (Clay Co.)		0	0			

*sp = first plants that emerged died, but due to seed dormancy, new plants had sprouted.

Pinewoods dropseed [*Sporobolus junceus* (Beauv.) Kunth] consistently performed very well on overburden soils, establishing better from January plantings than from May plantings. Overall, it displayed the highest plant densities of any of the species tested. Plants persisted despite extreme droughty conditions, and even produced several seedheads. It appeared that a few seedlings emerged from this seed. Although it does not produce as much foliage as wiregrass, pinewoods dropseed had much better establishment and survival on overburden soils. It may be a valuable component in pine forest plantings, since it is easier to seed than wiregrass, and fills a similar role in understory burn programs. This species was selected as a good candidate for seed source development.

Two other species are worthy of mention, although they did not perform well in this study. Purpletop [*Tridens flavus* (L.) A.S. Hitchc.] emerged from most plantings if adequate moisture was available, and even persisted on the sand tailings where there was no weed competition. However, this species is better adapted to moist fertile hammock sites rather than droughty uplands like those in this study. Purpletop also appears to have a high nitrogen requirement. In increase plots at the PMC, unfertilized plants quickly died out, while those receiving fertilization were able to persist.

The second species of note is partridge pea [*Chamaecrista fasciculata* (Michx.) Greene]. Probably due to extreme droughty conditions, plants that did emerge in this study did not produce seed. Because it is a reseeding annual, this species did not persist. No difference was observed in performance between the Florida ecotype from Ft. Cooper State Park, and the Texas release 'Comanche'. Based on the results of this study, seed source development was considered to be low priority for this species. There appeared to be no advantage in developing seed sources of Florida ecotypes of partridge pea, unless more drought tolerant types could be found.

CONCLUSIONS

This study produced much useful species adaptation data. Based on the results, accessions of 2 species were identified for immediate increase and commercial release; 3 species are currently in seed source development programs; 3 other species were identified as being good candidates for future large-scale assembly and seed source development. Of these 8 species, 2 are forbs and 6 are grasses, providing a good foundation for a diverse seed mixture for native upland reclamation.

SEED STORAGE EFFECTS ON SWITCHGRASS GERMINATION

INTRODUCTION

Switchgrass (*Panicum virgatum* L.) is a native warm-season perennial grass with tremendous potential for use in conservation plantings. Switchgrass can be difficult to establish because of seed dormancy and slow seedling establishment (Beckman and others 1993). Storage methods can greatly influence dormancy of Midwestern switchgrass cultivars. Seed that has been stored at room temperature for several months or even years often has higher germination than when it was initially harvested (Zarnstorff and others 1994). Since Florida ecotypes of switchgrass evolved in a semitropical climate, it was not known whether the seed even underwent dormancy. The objective of this study was to evaluate the effect of different storage methods on switchgrass seed germination.

MATERIALS AND METHODS

Seed was collected from a crossing block of two Florida ecotypes of switchgrass released by the Brooksville PMC, ‘Miami Germplasm’ and ‘Stuart Germplasm.’ Harvest occurred in October of 1997 and seed was immediately placed in a refrigerated seed storage facility where temperature was maintained at 50-55^{o}F (10-13^{o} C) with 45-50% humidity. Initial seed germination tests were conducted in December of 1997. In January of 1998, samples of 2 lots of seed were placed in a building with no climate control and a building maintained at room temperature. Control samples were kept in the refrigerated seed storage facility. Each test consisted of 4 replicates of 100 seeds placed on 2 layers of filter paper in a petri dish, kept moist with H_2O and KNO_3 and placed in the germinator for 28 d. Alternating day/night temperatures (30/15^{o}C) and light (8h day/16 h night) were used according to guidelines in the *Association of Official Seed Analysts Rules for Testing Seeds* (AOSA 1993). Tests were periodically run between June of 1998 and March of 2001. Statistical analysis was conducted using MSTATC (Michigan State University 1988).

RESULTS AND DISCUSSION

Germination results were inconsistent between the 2 seed lots at 10 months (Table 3). In the first lot, there was no difference between any of the storage methods. In the second, highest germination occurred in seed from the uncontrolled environment, and lowest in the seed held in cold storage. By 20 months, germination of seed held in the uncontrolled environment had diminished dramatically, and seed had completely expired in both lots by approximately 2 years. Between 2 and 3.5 years, there was no difference in germination of seed held under cold storage, verses the room temperature treatment.

Table 3. Percent Germination of Two Lots of Switchgrass Seed Under Three Storage Methods.

Lot	Storage Method	Months After Harvest				
		2	10	20	26	42
		-------------------- % germination-----------------------				
97-U	Cold Storage	42	31	56	56	56
	Room Temperature		40	62	52	57
	Uncontrolled		39	15	0	0
	LSD		11.4	12.1	7.3	11.9
97-F	Cold Storage	33	12	38	37	35
	Room Temperature		23	38	39	40
	Uncontrolled		33	8	0	0
	LSD		5.7	9.4	8.2	7.6

CONCLUSIONS

Storing switchgrass seed in uncontrolled or at room temperature conditions did not improve initial germination. Storing seed dry under refrigeration may, however cause seed to go into dormancy for a period of time. It was clearly illustrated in this study that seed rapidly expired in an uncontrolled environment between 1 and 2 years. Over a period of 3.5 years, storing seed at room temperature was just as effective at maintaining germination as cold storage.

EASTERN GAMMAGRASS SEED STUDIES

INTRODUCTION

Eastern gammagrass [*Tripsacum dactyloides* (L.) L.] is a native perennial warm-season grass with tremendous forage production potential. In recent years, a great deal of research has been conducted on this species to develop improved lines and establishment technology. Gammagrass has several inherent traits that make it difficult to establish, including seed dormancy. Once established, it can be difficult to obtain a seed crop. Two studies were conducted to address these issues.

The objective of the first study was to investigate methods of stimulating seed germination of Florida populations of eastern gammagrass. One method developed to overcome dormancy is chilling seed on moist substrate. Maximum germination was obtained after chilling between 2 and 6 weeks, depending on the genetic population (Ahring and Frank 1968). Anderson (1985) found that treatment with gibberellin (GA) increased germination. Florida ecotypes of eastern gammagrass do display seed dormancy. However, since they evolved under a milder climatic regime than more northern ecotypes, it was not known if the seed would respond to cold stratification.

The second study considered some of the inherent reproductive characteristics of gammagrass that make it challenging to obtain a seed crop, including uneven seed ripening and poor seed fill. Not only is seed ripening uneven on the raceme, with upper fruitcases shattering before lower fruitcases have filled, but reproductive tillers emerge sporadically throughout the growing season. In Florida, accessions typically flower May through August, making it difficult to gauge the most favorable time to harvest. Productivity is highly variable within this species, so some progress can be made through genetic selection (Wright and others 1983). The purpose of this study was to identify accessions with high viable seed production in an assembly of Florida ecotypes of eastern gammagrass. Although it had not been one of the original objectives, the period of highest production for the selected accessions was also determined.

STUDY I—SEED TREATMENT METHODS FOR PROMOTING GERMINATION OF EASTERN GAMMAGRASS

Materials and Methods

Seed from 2 Florida native accessions of eastern gammagrass (9059213 and 9059264) was hand collected in July of 1999, from plots established at the Brooksville PMC. The seed was stored in a refrigerated storage unit at 50-55^{o} F (10-13^{o} C) with 45-50% humidity, until it was treated. The experiment included 3 treatments along with an untreated control. In the first treatment (GA/Chill), seed was soaked in a solution of GA and tap water [105 mg GA (A.I.)/liter water] for 24 hours. Seed was then rinsed and drained. Damp seed was placed in plastic bags and refrigerated for 4 weeks at 35-45^{o} F

(2-7^{o} C). For the second treatment (Chill), seed was soaked in tap water for 24 hours and drained, placed in plastic bags and refrigerated for 4 weeks. For the third treatment (GA), seed was soaked in GA solution for 24 hours before planting. Dry untreated seed stored in the cooler was used as a control. All treatments were replicated 4 times with 38 seed used per treatment. The seeds were planted in potting soil and placed in a greenhouse on September 22, 1999. Emergence was recorded every 7 to 10 days following planting for the first 4 months and monthly thereafter.

Results and Discussion

All treated seed had significantly higher germination than did untreated seed after 45 days (Table 4). Highest germination was obtained with the GA/Chill treatment. The 2 accessions used in this study responded differently to chilling or GA used alone. Chilling seed of accession 9059213 produced a similar response to the GA/Chill treatment, indicating that this accession is very sensitive to cold stratification. Response of 9059213 to GA alone was significantly less than chilling. Chilling and GA alone produced very similar responses in accession 9059264, both of which promoted significantly lower germination than the GA/Chill treatment at 45 days. This accession may not be as sensitive to cold stratification, and may be less prone to dormancy.

Table 4. Percent Emergence of Two Accessions of Eastern Gammagrass Seed at Two Dates Treated with Three Different Seed Treatments.

Treatment	9059213		9059264	
	45 Days	8 Months	45 Days	8 Months
GA/Chill	69a	70a	59a	61ab
Chill	57ab	65ab	39bc	50abc
GA	17de	57abc	34de	57abc
No Treatment	3e	29d	9e	42cd

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

A late seeding date and cooler winter temperatures in the greenhouse may have actually simulated a natural chill treatment. Emergence slowed greatly between December and April. At the inception of warmer spring temperatures, emergence increased rapidly in several treatments, especially in the untreated control. A final count was made 8 months after planting. Even though untreated seed had substantial emergence in the spring, it was significantly less than emergence from the other 3 treatments.

Not only did the GA/Chill treatment promote the highest germination it also promoted very rapid germination (Figure 1). Emergence of GA/Chilled seed was 97% complete 10 days after planting. Ten days after planting, emergence of the Chill seed and the GA seed was only 21% and 10% complete respectively. None of the untreated seeds had emerged within the first 10 days. The chilled GA seedlings were also taller and more robust than the other treatments, with many seedlings having double shoots.

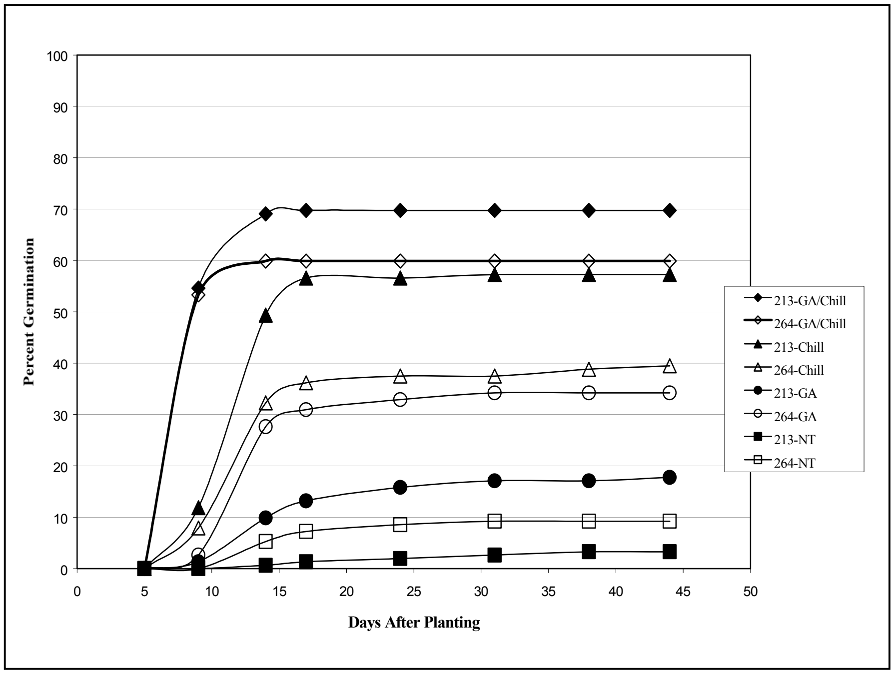

Figure 1. Germination of Two Florida Populations of Eastern Gammagrass Seed (9059213 and 9059264) from Four Seed Treatments: GA/Chill = Soaked in GA and Chilled for 4 Weeks; Chill = Chilled for 4 Weeks; GA = Soaked in GA; NT = No Treatment.

STUDY II—SEASONAL SEED RIPENING OF FLORIDA NATIVE EASTERN GAMMAGRASS

Materials and Methods

In 1996, an assembly of eastern gammagrasses collected from throughout Florida and established at the PMC was screened for viable seed production and desirable growth characteristics. Nine accessions were selected for further testing. Study protocol was developed through consultation with Chet Dewald, Research Agronomist at the USDA Agriculture Research Station in Woodward, Oklahoma. Ripe seed was collected every 7 to 10 days during the flowering and seed set period. Fruitcases of the ripe seed are dark bronze to brown in color, and separate easily from lower fruitcases. Gammagrass seed typically ripens from the top down. Once the upper tassel (male spikelets) mature and shatter, the lower female spikelets (fruitcases) begin ripening in succession. Mature seed shatters easily. Seed was hand collected in June through August 1996 and 1997. Collected seed was immediately stored in a refrigerated seed storage unit at approximately 45^{o} C and 45% humidity. The number and weight of seed gathered from each plot at each collection date was recorded. Viability was determined by dissecting the fruitcase to determine the presence or absence of a healthy caryopsis. One hundred seed were dissected in each sample if they were available.

Accessions were located on 2 diverse sites at the PMC. Soils on both sites are composed of Kendrick fine sands, however, site 1 (dry site) is well drained, and tends to be droughty and infertile. Site 2 (wet site) is more fertile and poorly drained. The water table is within 15 to 30 cm (6 to 12 in) of the soil surface during the growing season. Supplemental irrigation was applied at subsistence rates. Average number of plants per plot was 2 with 2 replicates on the dry site and 5 plants with 1 replicate on the wet site.

The eastern gammagrass accessions used in this study varied in chromosome ploidy levels. Two of the accessions (9059264 and 9059283) are triploid; five (9059213, 9059215, 9059266, 9059287, 9059338) are tetraploid; and the ploidy level of one accession (9059286) is unknown. However, based on the size of seed, it is most likely a tetraploid. Chet Dewald and his staff performed the chromosome counts. Seed from two additional accessions (9056069 and 9059278) was collected in 1997 only. Both accessions are diploid. It was observed that diploid strains produce smaller seeds than strains with multiple ploidy levels.

Results and Discussion

In both 1996 and 1997, flowering began in most accessions in May and tapered off in August. The majority of the seed ripened between mid June and late August. Seed weight varied between accessions and between collection dates, as seen in the 1996 wet site data for the 4 top producing accessions (Table 5). Lower viability would be expected to decrease seed weight. However, primary vegetative tillers were observed to have two or more rachis, while secondary tillers ripening later in the season (mid July) tended to have only a single rachis. Seeds from a multiple rachis tended to be smaller in size and weight than those coming from a single rachis. For example, seed collected from 9059213 on 6/28 with a viability of 52%, weighed 10.86 g/100 seed, while seed collected on 8/20 with a viability of 55% weighed 15.84 g/100 seed. The added weight was most likely due to larger fruitcases with heavier walls. Because of this, seed numbers were used to calculate production rather than seed weight.

Highest seed viability for the 4 accessions listed in Table 5 typically occurred in mid to late July or early August. At highest viability in 1996 on the wet site, a pound of 9059213 contained 2,638 seed; 9059264 contained 4,239 seed; 9059266 contained 3,380 seed; and 9059287 contained 2,885 seed. Ahring and Frank (1968) reported a pound of seed used in their seed germination experiments contained 5928 to 6387 seed with 66% having filled caryopsis. It is possible they were using diploid strains for their work, since diploids tend to produce smaller seeds than triploid or tetraploid strains.

Table 5. Viability and Weight per 100 Seed of Four Eastern Gammagrass Accessions Collected From the Wet Site in 1996.

Accession		1996 Collection Date								
		6/21	6/28	7/5	7/15	7/24	8/2	8/9	8/20	8/29
9059213	100 Sd. Wt. (g)	8.29	10.86	14.43	14.84	15.89	17.21	16.07	15.84	16.04
	% Viable	30	52	63	72	74	80	31	55	39
9059264	100 Sd. Wt. (g)	0.00	7.55	10.26	10.71	13.13	13.78	13.92	14.79	12.99
	% Viable		51	63	68	40	49	39	36	31
9059266	100 Sd. Wt. (g)	0.00	0.00	16.67	13.43	15.56	13.75	13.45	14.21	12.96
	% Viable			58	81	78	58	56	40	16
9059287	100 Sd. Wt. (g)	4.76	8.82	12.96	13.95	13.85	15.74	14.05	13.60	13.40
	% Viable	0	68	72	23	75	83	58	44	36

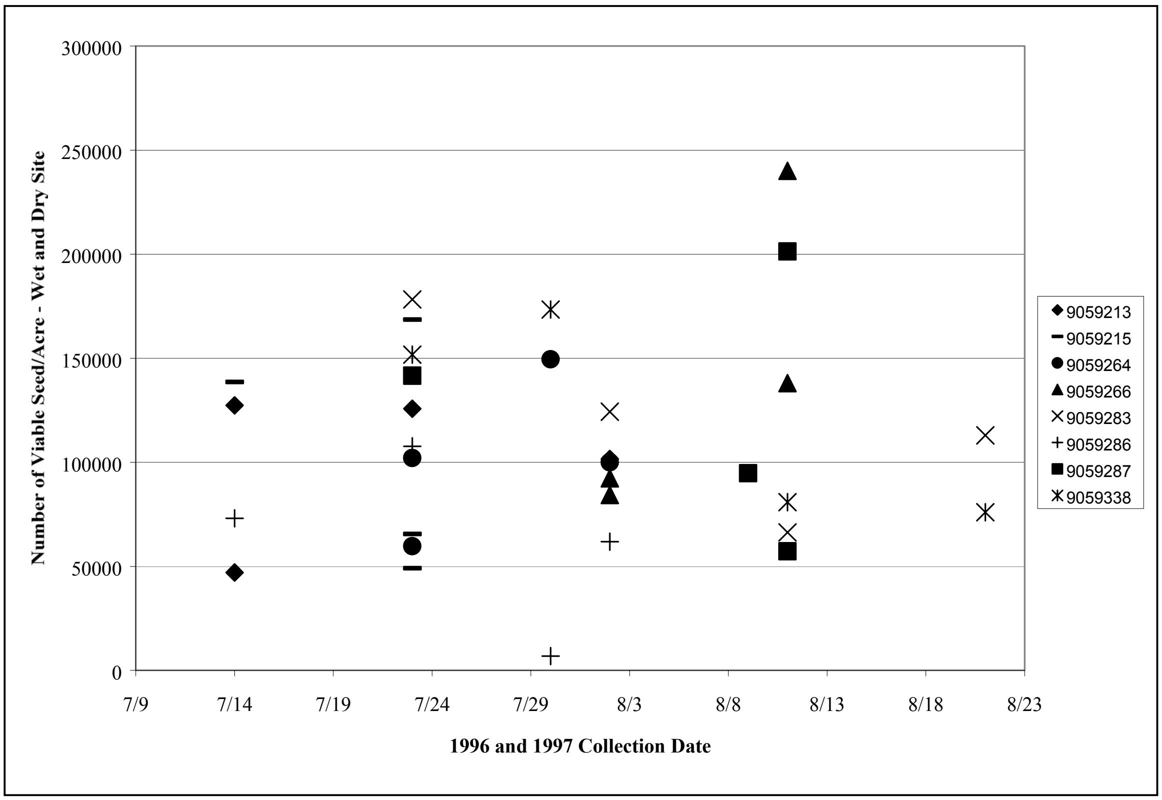

Figure 2. Peak Number of Viable Seeds Produced per Acre by Eight Accessions in 1996 and 1997 on Both Wet and Dry Sites.

The date of peak viable seed production for eight accessions on both sites in 1996 and 1997 is shown in Figure 2. For most accessions, peak production fell between 7/23 and 8/11 both years. For the 2 diploid accessions collected in 1997, peak production occurred between 6/16 and 6/26. Seed shattered quickly (in one week or less) once they were ripe.

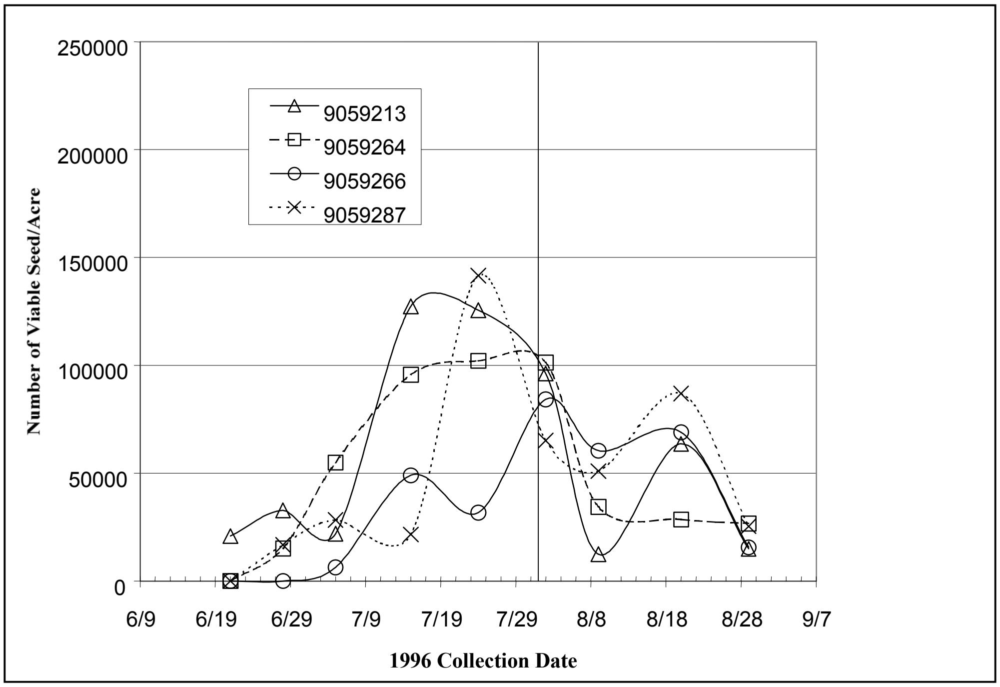

Figure 3. Number of Viable Seeds Produced per Acre During the 1996 Growing Season by Four Accessions on the Wet Site.

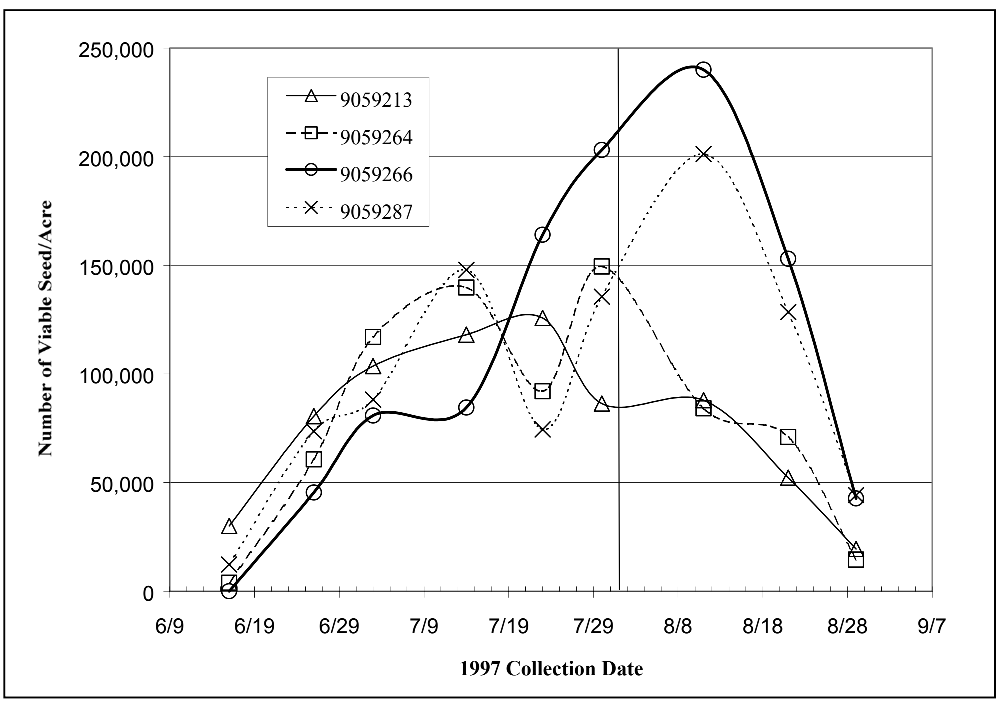

Figure 4. Number of Viable Seeds Produced per Acre During the 1997 Growing Season by Four Accessions on the Wet Site.

All accessions had higher production on the wet site than on the dry. Figures 3 and 4 show the pattern of viable seed production on the wet site for the 4 highest producing accessions in the study in 1996 and 1997. Production varied greatly between the 2 years even though precipitation was similar. May through August rainfall was 74 cm (29 in) in 1996 and 56 cm (22 in) in 1997. Even though viable seed was being produced as early as mid June, production typically rose sharply after July 1, and fell sharply after August 15. Early in the season, seed was observed to come ripe one at a time on the raceme. However, at the time of peak production several seeds would ripen simultaneously on the raceme. Accession 9059213 tended to mature the earliest of the four accessions with peak production occurring before August 1. The other three accessions tended to experience peak production on August 1 or later.

CONCLUSIONS OF EASTERN GAMMAGRASS STUDIES

Florida strains of eastern gammagrass do undergo seed dormancy. Chilling and GA both promoted germination in two Florida accessions, but a combination of these treatments produced the greatest germination. In addition, this dual treatment promotes very rapid emergence and robust plants. Seed treated in this manner has the potential to dramatically increase field establishment success if the process can be refined for large-scale plantings. In more northern climates, eastern gammagrass is often planted in the fall or winter to take advantage of natural stratification processes. Soaking seed in GA prior to planting may further increase spring seedling emergence in dormant plantings.

Valuable information was also gathered from these studies for maximizing seed production. There are large differences in viable seed production between Florida ecotypes. Although many of these ecotypes produce seed over a period of four months, it was discovered that peak production for most types occurred within 15 days of August 1. This information will help improve timing of harvests to obtain maximum amounts of viable seed.

THE EFFECT OF RESIDUE MANAGEMENT ON LOPSIDED INDIANGRASS SEED YIELD

INTRODUCTION

Lopsided indiangrass [*Sorghastrum secundum* (Ell.) Nash] is an important component of native uplands in Florida. It has relatively good seed production and seedling vigor compared to other Florida native grasses, and is a good candidate for use in a native seed mix. To encourage commercial production of this species, information relating to establishment and management of seed production fields is needed. Although lopsided indiangrass evolved under a fire dependant ecosystem, the effects of summer and winter burns on viable seed production had not been studied.

Burning removes mulch and plant debris. This reportedly increases the light reaching emerging shoots, thereby stimulating growth (Masters and others 1993). Burning native grasslands is a common practice in Florida. Sievers (1985) recommended that native sites in Florida 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 3 years, since desirable native grasses are sensitive to burning and populations are reduced under high frequency burn programs.

In the Midwest, early researchers found that burning and fertilization of cultivated stands of native warm-season grasses in late spring resulted in higher seed yields (Masters and others 1993). Masters and his associates studied the effect of burning native grasslands in Nebraska, including the response of yellow indiangrass [*Sorghastrum nutans* (L.) Nash]. When combined with fertilization and atrazine applications, late spring burns (mid-May) generally increased reproductive stem densities over earlier spring burns (March-April), or unburned treatments. Whether these practices would have a similar effect on indiangrass stands in Florida is not known. The objective of this study was to determine the effect of canopy removal on stand persistence, seed production and seed viability of lopsided indiangrass.

MATERIALS AND METHODS

A field of lopsided indiangrass was established on irrigated Kendrick fine sand soils at the Brooksville PMC, in 1997. Seed for this planting was collected from the Croom tract of the Withlacoochee State Forest in Hernando Co. Plants were started in the greenhouse in 15 cm (6 in) deep cone trays in 1996, and transplanted to the field in the September of 1997. Plants were placed on 0.6 m (2 ft) centers, with plot size being 2.4 m x 17 m (8 ft x 56 ft). Plants were allowed to establish for approximately 1.5 years before any residue treatments were applied. The study was a split-plot design, with main plots being the date of canopy removal. Subplots were canopy removal method. Treatments were winter burn (February); summer burn (July); winter mowing (February);

summer mowing (July); and an untreated control. Treatments were replicated 4 times. All treatments were applied in 1999. Mowed plots were cut with a forage harvester so that residue could be removed from the plots. Clipping height was 13 to 20 cm (6 to 8 in). Plants were dormant in February, and burned completely to the ground. In July, plants were green and did not burn well. Weeds were controlled chemically with 2,4-D and by hand hoeing. No fertilizer treatments were applied. The number of plants in each plot was counted in July of 1999 before summer treatments were applied and in Oct. just before seed ripening. Ripe seed was collected by hand, air-dried and weighed. Samples of 100 seed each with 4 replicates were placed in a germinator at 20 to 30^{o} C for 28 days to determine viability. Statistical analysis was done using MSTAT-C (Michigan State University 1988) factor program for split-plot designs.

RESULTS AND DISCUSSION

In 1998, before any treatments had been applied, the entire indiangrass field had a seed yield of 75 lb/A (84 kg ha^{-1}), with an average seed viability of 26%. By 1999 plant numbers had begun to decrease in all treatments (Table 6) and production had dropped substantially. Greatest plant losses occurred in the untreated and summer burn treatments. Summer burning dramatically decreased plant vigor and reproductive tillering. However, there was no statistical difference in seed viability between any of the treatments. Highest production in 1999 occurred in the summer mowed plots, which averaged 20.6 lb/A (23.1 kg ha^{-1}) with 13% viability. Percent seed viability was quite low compared to that of the previous year. Clearly other factors besides residue management were affecting viable seed production in this study.

Table 6. Lopsided Indiangrass Percent Plant Loss, Seed Production and Percent Seed Viability under 5 Residue Management Treatments.

Treatment	% Plant Loss Jan. to Oct.	Seed Produced kg ha^{-1} (lb/A)*	% Viable Seed
Winter Mow	29%	18.3 (16.3)ab	12a
Winter Burn	32%	19.5 (17.4)ab	11a
Summer Mow	25%	23.1 (20.6)a	13a
Summer Burn	37%	4.4 (3.9)b	11a
No Treatment	38%	11.5 (10.3)ab	10a

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

Soil-borne pathogens are one potential cause of the high plant losses that occurred in 1999, and residue management may have only marginally overcome the disease symptoms. Irrigated plots of lopsided indiangrass on other sites at the PMC tended to die out after 3 years. Lopsided indiangrass plants may not persist beyond 3 years, even in natural systems. This species may function as a short-term perennial, relying on high seed production to sustain population numbers. Several plants from the residue management study were sent to the state plant pathology lab for testing. Roots were reportedly moderately infested with lesion nematodes. This apparently made the plants more susceptible to invasion by other soil borne pathogens such as *Rhizoctonia* and *Fusarium.* 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 beneficial microorganisms may assist in increasing stand longevity.

CONCLUSIONS

Based on the results of this study, residue management appears to be important for lopsided indiangrass seed production. Removing residues by winter burning, or mowing in either the winter or summer, increased seed yields compared to untreated plants. However, differences were not statistically significant. Summer burning severely hurt plant vigor and seed production compared to summer mowing or winter burning and mowing. Residue management apparently could not overcome damage by soil-borne pathogens, with stands persisting no more than three years on this irrigated site. Further research needs to be conducted to determine if beneficial microorganisms can help increase stand longevity of lopsided indiangrass production fields.

WIREGRASS CULTURAL MANAGEMENT STUDIES FOR INCREASING SEED PRODUCTION

INTRODUCTION

Wiregrass (*Aristida beyrichiana* Trin. & Rupr.) is considered an important component of pineland habitats. In native systems, this species contributes significant amounts of fine fuels for understory burn management programs. Therefore, those wishing to reestablish pineland habitats often desire to first establish wiregrass. Dependable commercial supplies of seed are needed to meet this growing demand. One important step toward developing a commercial seed industry is finding economical ways for growers to establish and maintain production fields. Very little is known about growing wiregrass under cultivation, including the effects of basic practices like residue management and fertilization on viable seed production.

Removing mulch and plant debris reportedly increases the light reaching emerging shoots, thereby stimulating growth (Kirk and others 1974; Masters and others 1993). Originally, it was thought that wiregrass did not flower. However, further observation indicated that it will flower after burning, defoliation or minor soil disturbances (Clewell 1989). Researchers in Northwestern Florida found that stands burned during the growing season (April-July) produced more reproductive tillers than stands burned late in the year (September-November) (Seamon 1998). However Means (1997) observed that wiregrass under a dense pine canopy produced almost no reproductive tillers, despite being burned during the growing season. Conversely, plants under a more open canopy flowered prolifically. These findings support the premise that light is a key component in stimulating growth of reproductive tillers. Although burning is a proven seed production management tool, it is not always feasible. Mowing would be more practical in some situations, but it was not known if mowing would stimulate the production of viable seed as well as burning.

There is some evidence that annual burning reduces wiregrass plant vigor and stand longevity. To keep plant numbers from diminishing in native sites, land managers typically only burn every three years (Seamon 1998; Sievers 1985). Fertilizing cultivated fields could potentially sustain plant vigor and seed production under more intense burning cycles. However, because wiregrass evolved in a nutrient deficient community, response to nutrients such as N, were thought to be small. In fire-dependant systems, burning contributes to deficiencies in nitrogen and phosphorous in the soil (Clewell 1989). Nitrogen is volatilized by burning, and much of this nutrient, along with some of the phosphorous, is permanently lost (Harper and others 1957). Meanwhile, beneficial nutrients such as Ca, K and Mg are released in the ash. Soil pH may be increased for a brief period of time, making other nutrients more plant available. Anderson and Menges (1997) burned native wiregrass stands on a sandhill site, and measured soil nutrient levels one and four months after burning. They did not see any significant changes in pH levels on burned plots over a period of four months, although pH in unburned plots steadily decreased. Burned plots had significant increases in soil P, Ca and Mg, one month after burning, but not N or K. Wiregrass tissue samples from burned plants, however, showed significantly higher percentages of N, K and most micronutrients than did unburned plants. This would suggest that the availability of such plant nutrients as P and Ca help wiregrass become more efficient at extracting N and K. Kalmbacher (1983) reported that the highest percentage of K in wiregrass was found in the inflorescence. Wiregrass response to direct applications to N fertilizer have been mixed. Kalmbacher and Martin (1996) found that fertilizing native range actually eliminated wiregrass from test plots, possibly because of increased competition from other species. Outcalt and Associates (1999) found that applications of a slow release form of N significantly increased the growth rate of wiregrass transplants established in cultivated plots.

Three studies were developed to investigate how management practices affect wiregrass seed production. The purpose of the first study was to investigate effects of residue removal methods in conjunction with fertilization. The purpose of the second study was to investigate the effect of N and K on wiregrass seed production. The purpose of the third study was to investigate the effect of burn frequency and fertility on viable seed production and stand longevity in a cultivated stand of wiregrass.

STUDY I—EFFECT OF MOWING AND BURNING ON WIREGRASS SEED PRODUCTION

Materials and Methods

Seed was collected from a flatwoods site at the Avon Park Air Force Base, and planted into containers of potting soil in the Brooksville PMC greenhouse in 1996. Containers were 5.5 cm (2.25 in) tapering cones, 14.5 cm (6 in) deep. In 1997, transplants were placed in a cultivated irrigated field on 0.6 m (2 ft) centers. Soils were primarily well drained Kendrick and Sparr fine sands. Plants were allowed to established for two years before any treatments were imposed. Weeds were a serious problem in these study plots. Hand hoeing and herbicides were used (2,4-D, dicamba and imazapic were applied to the entire field, and glyphosate was sprayed with shielded sprayers between plants as needed; oryzalin, a preemergent was applied over entire field in June of 2001) to obtain some measure of control. The study design was a split-plot, with the main plots being canopy removal method (burn vs. mow). The subplots were fertilization treatments [none vs. 56 kg ha^{-1} (50 lb/A) K in the form of 0-10-20] applied just after canopy removal, to mimic the flush of nutrients released after a burn. The fertilizer formulation also contained several micronutrients important for plant growth. Nitrogen was not applied since it is not a major component of native wiregrass systems, and other researchers had not found it to be beneficial (Kalmbacher and Martin 1996). Plot size was 3 m x 12 m (10 ft x 40 ft) with 4 replicates. Soil samples were taken in 1999, and sent to a commercial laboratory for analysis.

In 1999, plots were mowed or burned July 8 between 1:00 and 4:00 p.m. High temperature was 34^{o} C (94^{o} F) at the PMC. Relative humidity reported at the Tampa

Airport was 68% at 1:00 p.m. For the mowing treatment, a riding lawnmower was used, which left a stubble height of 2.5 to 5.1 cm (1 to 2 in). 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. Fertilizer was applied with a hand-held fertilizer spreader 12 days later. Living and flowering plants were counted in each plot just prior to harvest. Plots were harvested with a Flail-Vac Seed Stripper on December 8. Seed samples were weighed and purity was determined. One hundred seed were placed in petri dishes on 2 layers of filter paper, with four replicates. Seed was kept moist with a mixture of KNO_3 and H_2O and placed in the germinator for 28 d. Alternating day/night temperatures (30/20^oC) and light (8h day/16 h night) were used according to guidelines for other native grasses in the *Association of Official Seed Analysts Rules for Testing Seeds* (AOSA 1993).

In 2000, plots were again mowed or burned on July 12 between 1:00 and 3:00 p.m. in the same manner outlined above. High temperature on that day was 34^{o}C (94^o F) at the PMC. Relative humidity at the Brooksville Airport was recorded as 65% at 3:53 p.m. Because no significant differences appeared in seed viability between fertilized and unfertilized treatments in 1999, fertilizer rates were tripled in 2000 in an effort to elicit a response. The fertilizer was applied in two applications, with 56 kg ha^{-1} (50 lb/A) of K (in the form of 0-10-20) applied on August 1 when plants had just begun to regrow. On August 23, 112 kg ha^{-1} (100 lb/A) of K was applied, after plants had put on a substantial amount of leaf tissue but had not yet begun to bloom. Plants were counted and plots were harvested on December 12. Bulk seed samples were weighed. Percent purity was again determined by hand separating smaller samples of seed from inert matter and weighing both. Germination tests were conducted as outlined above. Statistical analysis was conducted using MSTAT-C (Michigan State University 1988) Anova program for split plot designs.

Results and Discussion

Results from the soil analysis are shown in Table 7. Average levels of P were high, K and Ca low, and Mg medium. Very little N was detected in the samples.

Table 7. Average Soil pH, P, K, Ca and Mg in Wiregrass Mow Versus Burn Plots at 2 Depths.

Depth	pH	P	K	Ca	Mg
	--------------Parts per Million--------------				
0-15 cm (0-6 in)	6.2	170	5	352	35
15-30 cm (6-12 in)	5.7	149	1	451	18

In 1999, seed purity was estimated to be 42%. Seed weight averaged 2220 seeds/g or 1,007,880 seed/lb. Table 8 shows amount of seed obtained under each treatment, along with seed viability. There was no significant difference in amount of seed produced per residue or fertilizer treatment. Number of seed producing plants varied somewhat per plot, so plant numbers in each plot were used to more accurately determine actual production. Regarding seed viability, there were no differences between clipping and burning. Fertilization did not appear to affect viability either.

Table 8. Wiregrass Mow Versus Burn Study, 1999 Pure Seed Production and Percent Seed Viability.

Treatment*	Seed Produced kg ha^{-1} (lb/A).	Production/ Plant g	% Viable Seed
Burn/Fertilized	21.6 (19.3)	0.97	18
Burn/Unfertilized	27.2 (24.3)	1.21	21
Mow/Fertilized	24.3 (21.7)	1.05	21
Mow/Unfertilized	24.4 (21.8)	1.06	17
LSD (0.05)	8.8 (7.9)	0.51	8

* Burned or clipped on 7/8/99 and fertilized on 7/20 (56 kg K ha^{-1}).

In 2000 average seed purity was estimated to be 57%. Seed weight averaged 1,667 seeds/g or an average of 756,818 seed/lb. There was again no significant difference in amount of seed produced per residue or fertilizer treatment (Table 9). Average germination had increased somewhat over 1999 levels, but seed production decreased. Removing residue annually may have negatively impacted plants, and reduced plant populations, but without untreated controls this could not be verified. Burned fertilized and unfertilized treatment plant losses were 12% and 8% respectively between 1999 and 2000. Mowed fertilized and unfertilized treatment plant losses were 6% and 10% respectively.

Table 9. Wiregrass Mow Versus Burn Study, 2000 Pure Seed Production and Percent Seed Viability.

Treatment*	Seed Produced kg ha^{-1} (lb/A)	Production/ Plant g	% Viable Seed
Burn/Fertilized	17.5 (15.6)	1.0	28
Burn/Unfertilized	20.7 (18.5)	0.9	26
Mow/Fertilized	20.2 (18.0)	1.0	25
Mow/Unfertilized	19.6 (17.5)	1.0	25
LSD (0.05)	12.2 (10.9)	0.4	6

*Burned or clipped on 7/12/00. Fertilizer applications split, with 56 kg K ha^{-1} applied on 8/1 and 112 kg ha^{-1} on 8/23.

STUDY II -EFFECT OF NITROGEN AND POTASSIUM ON WIREGRASS SEED PRODUCTION

Materials and Methods

Seed for this study was obtained from the Florida State Department of Forestry, Andrews Nursery. The source was a xeric site in Wekiwa Springs State Park. Transplants were established in containers of potting soil in the Brooksville PMC greenhouse in 1996. Containers were 5.5 cm (2.25 in) tapering cones, 14.5 cm (6 in) deep. In 1997, transplants were placed in a cultivated irrigated field on 0.6 m (2 ft) centers. Soils are predominately Kendrick fine sand, which is well drained. Plants were allowed to establish for 2 years before any treatments were applied. Weeds were a serious problem in these study plots. Several herbicides (listed in Study I) and hand hoeing had to be used to obtain some measure of control. Soil samples were taken in 1999, and sent to a commercial laboratory for analysis. Study design was randomized complete blocks with 6 replications. Plot size was 3 m x 9 m (10 ft x 30 ft). Fertility treatments were N & K [56 kg ha^{-1} (50 lb/A) N and K in the form of 10-10-10]; K [56 kg ha^{-1} (50 lb/A) K in the form of 0-10-20], and an unfertilized control. The fertilizer formulations also contained several micronutrients important for plant growth. Fertilizer was applied just after canopy removal to mimic the natural flush of nutrients following a burn.

In 1999, all plots were burned on July 8 from 4:00 to 5:00 p.m., and July 9 between 1:00 and 4:00 p.m. Temperature highs on both days were 34^{o} C (94^{o} F) at the PMC. Relative humidity at the Tampa airport on July 8 and 9 during the burn time was 72% and 74% respectively. 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. Fertilizer was applied with a hand-held fertilizer spreader 12 days later. The number of living plants was recorded in each plot just prior to harvest. Plots were harvested with the Flail-Vac Seed Stripper on December 8. Seed samples were weighed and purity was determined. Four replicates of 100 seeds were placed in petri dishes on 2 layers of filter paper. Seeds were kept moist with a mixture of KNO_3 and H_2O and placed in the germinator for 28 d to determine viability. Alternating day/night temperatures (30/20^{o}C) and light (8h day/16 h night) were used according to guidelines for similar native grasses in the Association of Official Seed Analysts Rules for Testing Seeds (AOSA 1993).

In 2000, all plots were burned on July 12 between 3:00 and 5:00 p.m. in the same manner outlined above. High temperature was 34^{o}C (94^{o} F) at the PMC. Relative humidity at the Brooksville Airport was recorded at 65% at 3:53 p.m. Because no significant differences appeared in seed viability between fertilized and unfertilized treatments in 1999, fertilizer rates were tripled in 2000 in an effort to elicit a response. The fertilizer was applied in 2 applications, with 56 kg ha^{-1} (50 lb/A) of K and N & K being applied on August 1 when plants had just begun to regrow. On August 23, 112 kg ha^{-1} (100 lb/A) of K and N & K were applied, after plants had put on a substantial amount of leaf tissue but had not yet begun to bloom. Plants were counted and plots were harvested on December 12. Seed was weighed and purity was determined. Germination tests were conducted as outlined above. Statistical analysis was conducted using MSTAT-C (Michigan State University 1988) Anova program.

Results and Discussion

Results from the soil tests are shown in Table 10. The level of P was high, K low, Ca and Mg medium. Very little N was detected in the samples. Soil pH was relatively acid.

Table 10. Average Soil pH, P, K, Ca and Mg in Wiregrass Fertility Plots at Two Depths.

Depth	pH	P	K	Ca	Mg
	--------------Parts per Million--------------				
0-15 cm (0-6 in)	5.4	161	19	538	88
15-30 cm (6-12 in)	5.3	88	12	535	30

Seed purity was estimated to be 34% in 1999. Seed weight averaged 2,500 seed/g or 1,135,000 seed/lb. Seed production and viability is shown in Table 11. Because the number of plants varied in each plot, seed production was also calculated on a per plant basis. Although unfertilized plants had slightly lower seed production than did fertilized plants, amounts were not statistically significant. Plants fertilized with nitrogen had slightly higher seed viability than did the other 2 treatments, however differences again were not statistically significant. In comparison to seed viability obtained at the PMC in 1999, the original seed collected at Wekiwa State Park had a germination rate of 22%.

Table 11. Wiregrass Fertility Study, 1999 Pure Seed Production and Percent Seed Viability.

Treatment*	Seed Produced kg ha^{-1} (lb/A)	Production/ Plant g	% Viable Seed
K (56 kg ha^{-1})	23.4 (20.9)	1.32	27
K&N (56 kg ha^{-1})	25.8 (23.0)	1.35	29
No treatment	24.4 (21.8)	1.21	26
LSD (0.05)	7.7	0.36	8.5

*Burned on 7/8/99 and fertilized on 7/20.

Seed purity averaged 56% in 2000. Droughty conditions may have caused seed to be smaller and lighter in 2000, with there being an average of 1,667 seed/g or 756,667 seed/lb. Fertilizing did not appear to cause any differences in seed production or viability between any of the treatments (Table 12). Intensive annual burning appeared to stress the plants in the study. Plant numbers dropped an average of 31% in both fertilized treatments between 1999 and 2000, while unfertilized treatments lost an average of 37%.

Table 12. Wiregrass Fertility Study, 2000 Pure Seed Production and Percent Seed Viability.

Treatment*	Seed Produced kg ha^{-1} (lb/A)	Production/ Plant g	% Viable Seed
K (168 kg ha^{-1})	14.7 (13.1)	1.20	21
K & N (168 kg ha^{-1})	16.0 (14.3)	1.20	23
No treatment	14.1 (12.6)	1.10	23
LSD (0.05)	5.8	0.7	8

*Burned on 7/12/00. Fertilizer applications split, with 56 kg ha^{-1} applied on 8/1 and 112 kg ha^{-1} on 8/23.

During the two years of this study, seed germination rates within the given treatments varied between 12 and 21 percentage points of each other, indicating genetic diversity may have been influencing seed viability more than environmental factors. Management practices can only improve germination rates to a limited degree. Seed viability could potentially be improved rapidly with genetic selection.

STUDY III—EFFECT OF BURN FREQUENCY ON WIREGRASS SEED PRODUCTION

Materials and Methods

Seed was collected from a flatwoods site at the Avon Park Air Force Base, and planted into containers of potting soil in the Brooksville PMC greenhouse in 1995. Container size was 8 x 8 cm (4 x 4 in) tapering to 6.5 x 6.5 cm (2.5 x 2.5 in), 7.5 cm (3 in) deep. In 1996, transplants were placed in a cultivated irrigated field on 0.6 m (2 ft) centers. Soils were primarily well drained Kendrick and Sparr fine sands. Plants were allowed to established for three years before any treatments were imposed. Weeds were a serious problem in these study plots. Several applications of herbicides (listed in Study I) and hand hoeing had to be used to obtain some measure of control. Study design was a split-plot, with main plots being burn frequency (1, 2 and 3 years). Subplots were fertilization treatment [none vs. 56 kg ha^{-1} (50 lb/A) K in the form of 0-10-20] applied just after canopy removal, to mimic the natural flush of nutrients following a burn. Fertilizer was applied to all fertilizer treatment plots even if they were not burned. The fertilizer formulation also contained several micronutrients important for plant growth. Nitrogen was not applied the first 2 years, since it is usually deficient in native wiregrass systems, and other researchers had not found it to be beneficial (Kalmbacher and Martin 1996). Plot size was 3 m x 12 m (10 ft x 40 ft) with 4 replicates. Soil samples were taken in 1999, and sent to a commercial laboratory for analysis.

In 1999, all plots were burned July 8 between 1:00 and 4:00 p.m. High temperature was 34^{o} C (94^{o} F) at the PMC. Relative humidity reported at the Tampa Airport was 68% at 1:00 p.m. Plants were set on fire with a drip torch. Fertilizer was applied with a hand-held fertilizer spreader 12 days later. Plant counts were made in each plot just prior to harvest. Plots were harvested with a Flail-Vac Seed Stripper on

December 8, when seed had ripened on all plants in the study, and was easily stripped from the heads. Seed samples were weighed and purity was determined. Four replicates of 100 seed were placed in petri dishes on 2 layers of filter paper. Seed was kept moist with a mixture of KNO_3 and H_2O and placed in the germinator for 28 d. Alternating day/night temperatures (30/20^{o}C) and light (8h day/16 h night) were used according to guidelines for other native grasses in the *Association of Official Seed Analysts Rules for Testing Seeds* (AOSA 1993).

In 2000, one-year cycle plots were burned on July 12 between 1:00 and 3:00 p.m. in the same manner outlined above. High temperature was 34^{o}C (94^{o} F) at the PMC. Relative humidity at the Brooksville Airport was recorded at 65% at 3:53 p.m. Because no significant differences appeared in seed viability between fertilized and unfertilized treatments in 1999, fertilizer rates were tripled in 2000 in an effort to elicit a response. The fertilizer was applied to all fertilized treatment plots (burned and unburned) in two applications, with 56 kg ha^{-1} (50 lb/A) of K (in the form of 0-10-20) applied on August 1 when plants had just begun to regrow. On August 23, 112 kg ha^{-1} (100 lb/A) of K was applied, after plants had put on a substantial amount of leaf tissue but had not yet begun to bloom. Flowering plants were counted and plots were harvested on December 12. Seed was weighed and purity was determined. Germination tests were conducted as outlined above.

In 2001, one- and two-year cycle plots were burned August 6 between 1:00 and 5:00 p.m. in the same manner outlined above. Burning was delayed in 2001 for several reasons, including weather conditions, which were not conducive to burning until the beginning of August. Unfortunately, some plants had already begun to produce reproductive tillers by this date, and appeared to be severely set back by the later burn. High temperature on August 6 was 32^{o}C (92^{o}F) at the PMC. Relative humidity at the Brooksville Airport was recorded at 55% at 3:53 p.m. Since there had been very little response to the fertilizer treatments the previous two years, N was included in the fertilizer application in 2001, to attempt to increase plant vigor and reduce plant losses. Applications were made earlier in the season when plants had begun to actively grow. Fertilizer was applied to all fertilized treatments (burned and unburned) in two applications, with 56 kg ha^{-1} (50 lb/A) of N & K (in the form of 10-10-10) being applied on June 5 when plants were actively growing. On September 4, 56 kg ha^{-1} (50 lb/A) of 10-10-10 was applied, after burned plants had put on a substantial amount of leaf tissue but had not yet begun to bloom. Flowering plants were counted and plots were harvested when the entire stand was ripe on November 26. Seed was weighed and purity was determined. Germination tests were conducted as outlined above. Statistical analysis was conducted using MSTAT-C (Michigan State University 1988) Anova program for split plots.

Results and Discussion

Results from soil tests are shown in Table 13. The average pH was moderately acidic compared to soils on native Florida sites, which tend to be strongly acidic; levels of K were very low, P very high, Ca and Mg medium. Soil N tested very low.

Table 13. Average pH, P, K, Ca and Mg in Wiregrass Burn Frequency Plots at Two Depths.

Depth	pH	P	K	Ca	Mg
		--------------Parts per million--------------			
0-15 cm (0-6 in)	6.1	184	3	352	39
15-30 cm (6-12 in)	5.6	158	4	451	27

Seed purity was estimated to be 24% in 1999. Seed weight averaged 2,350 seed/g or 1,066,900 seed/lb. Since all plots were burned in 1999, the only treatment differences were fertilization. Unfertilized plots averaged 17.2 kg pure seed ha^{-1} (15.4 lb/A), fertilized averaged 16.8 kg ha^{-1} (15 lb/A). Production per plant in 1999 of the unfertilized plants was 0.79 g, fertilized was 0.76 g. Fertilization did not appear to significantly affect seed viability either, which was 25% and 26% for unfertilized and fertilized plots respectively.

Average seed purity was estimated to be 56% in 2000. Seeds were smaller and lighter than the previous year, averaging 2,000 seed/g or 908,000 seed/lb. Even though two- and three-year cycle plots weren't burned, many (but not all) unburned plants still flowered. This lends credence to the theory that flowering is related to the amount of residue shading the crown, or more specifically, the amount of light reaching the crown.

Table 14. Wiregrass Burn Frequency Study, 2000 Pure Seed Production, Production per Flowering Plant, and Seed Viability.

Treatment*	Pure Seed Produced kg ha^{-1} (lb/A)	Production/ Flowering Plant g	% Viable Seed
1 Year/Fertilized (burned)	17.4 (15.5)	1.0	26
1 Year/Unfertilized (burned)	17.0 (15.2)	0.9	17
1 & 2 Year/Fertilized (unburned)	9.6 (8.6)	0.7	15
1 & 2 Year/Unfertilized(unburned)	9.5 (8.5)	0.7	16
LSD (0.05)	4.9	0.4	9

*Burned 7/12/00, fertilized with 56 kg K ha^{-1} on 8/1 and 112 kg K ha^{-1} on 8/23.

Seed samples were taken from all treatments in 2000, whether burned or unburned. As would be expected, more plants flowered and therefore total seed production was higher in annually burned plots (Table 14). But differences were not as dramatic when placed on a per flowering plant basis. Fertilizer increased viability in the burned treatments, but not in the unburned treatments. Overall, fertilized treatments averaged a 13% plant loss between 1999 and 2000, while unfertilized plots averaged a 12% plant loss.

Average seed purity was estimated to be 44% in 2001. Seeds were heavier than the previous years, averaging 3,450 seed/g or 1,565,500 seed/lb. The increased weight may have been partially due to many of the seed being infected with a smut-like fungus commonly found on wiregrass.

The late timing of the 2001 burn severely reduced plant vigor in burned plots. Seed production and viability in burned plots was actually lower than in the three-year cycle unburned plots (Table 15). The use of N fertilizer in 2001 produced some significant but mixed results. In burned plots, there was no significant difference in seed production between fertilized and unfertilized treatments. However, fertilized burned treatments had significantly higher seed viability. This would indicate that additional N gave burned plants the energy to fill more of the seed they produced, even though it didn't stimulate greater overall vegetative tiller production.

Conversely, fertilized unburned plots had higher seed production compared to unfertilized unburned treatments, but seed viability was the same for both treatments. In this case, additional N may have stimulated greater growth and plant vigor in unburned plants, thus increasing total seed production, but not seed fill. The amount of seed produced by the unburned plants in 2001 was surprisingly high compared to yields in previous years. It is uncertain whether this was simply due to management factors or if environmental conditions had a greater influence.

Table 15. Wiregrass Burn Frequency Study, 2001 Pure Seed Production, Production per Flowering Plant, and Seed Viability.

Treatment*	Pure Seed Produced kg ha^{-1} (lb/A)	Production/ Flowering Plant g	% Viable Seed
1 Year/Fertilized (burned)	17.0 (15.2)	1.0	22
1 Year/Unfertilized (burned)	12.9 (11.5)	0.9	14
2 Year/Fertilized (burned)	15.2 (13.6)	0.9	16
2 Year/Unfertilized (burned)	12.9 (11.5)	0.9	8
3 Year/Fertilized (unburned)	28.4 (25.4)	1.6	29
3 Year/Unfertilized (unburned)	21.4 (19.1)	1.2	29
LSD (0.05)	4.6	0.4	6.6

*Burned 8/6/01, fertilized with 56 kg K&N ha^{-1} on 6/2 and 56 kg K&N ha^{-1} on 9/4.

In the short term, burn frequency did not appear to significantly affect plant persistence. Plant losses between 1999 and 2001 on both fertilized and unfertilized treatments averaged 19%, 20% and 21% for one-, two- and three-year cycles respectively. It was too early to determine if the use of N fertilizer slowed plant losses.

CONCLUSIONS FROM WIREGRASS SEED PRODUCTION STUDIES

A great deal of valuable information was gathered from these studies, concerning the response of wiregrass to various management factors. It was previously postulated that mowing would not be as effective as burning in stimulating production of viable seed. In these studies, plants that were mowed closely to expose the plant crown had the same seed production and viability as plants that had been burned. Mowing gives seed producers greater flexibility in managing stands to obtain optimum production.

The burn frequency study revealed that plants do not necessarily need to undergo a growing season burn to produce viable seed. A large percentage of plants in these studies were able to produce reproductive tillers without the physical stimulus of residue removal. The amount of residue shading the crown, or conversely the amount of light reaching the plant crown, may have more influence on the production of wiregrass reproductive tillers than any physical stimulus. In practical terms, seed growers may be able to forego burning their fields if old residues are below threshold levels. More research would need to be conducted to determine if this is in fact true, and what those threshold levels are. The early July burns employed in this study were well timed for seed production, but an early August burn occurred too late in the season, and interfered with seed production. Results may differ on stands with greater biomass that have not initiated flowering.

Concerning fertilizer application, the original premise used in these studies was that wiregrass would have very little response or a negative response to N fertilization, since it had evolved in a nutrient poor environment. Therefore, N was not initially applied in two of the three studies. Other nutrients (namely K) were applied, as they were commonly found in the ash after a burn, and thought to be important for seed production. Initial applications were made to mimic the flush of nutrients released following a burn. During the first two years, no significant response was seen from K fertilizer applications, even when rates were tripled. Meanwhile, plant losses were relatively high in the studies, 20% or more in some cases, regardless of treatment. In the fertility study, N & K application was specifically compared to application of only K. Applying even relatively high levels of N and K at the time of flowering did not significantly affect wiregrass seed production or viability during a 2-year period. In all probability, the N fertilizer was being applied too late in the growing season to provide any real benefit to the plants.

In 2001, N fertilizer was applied to plots in the burn frequency study (which ran for 3 years) early in the growing season (June) in an attempt to boost plant vigor and slow plant losses. This produced significant increases in seed viability or production between fertilized verses unfertilized treatments. Results suggest that wiregrass plants under cultivation will respond to N fertilizer. The general recommendation for fertilizing native seed production fields is to apply 34 to 112 kg ha^{-1} (30 to 100 lb/A) N fertilizer (if warranted by soil test recommendations) at the initiation of spring growth. Future wiregrass management studies should consider this type of fertilization program. However, cultural management practices can only influence seed production to a limited degree. Greater improvements may be made through genetic selection.

One other factor that needs to be considered in wiregrass seed production fields is weed control. Weeds were a serious problem in these studies, and their control required a tremendous amount of time and resources. Because wiregrass is such a slow growing, shallow rooted plant, it did not compete well under cultivation with weeds. Removing the plant canopy during the middle of the growing season encouraged further weed invasion. Plants in these studies were placed on 0.6 m (2 ft) centers within and between rows. Under the intense burning and harvest cycles, they were never able to develop a dense canopy. Yet plant spacings were too narrow to allow mechanical tillage between rows. A better planting scheme would have been to place plants in double rows on 0.3 m (1 ft) or less centers. Double rows would then be separated by 1 to 1.5 m (3 to 5 ft) alleys, which could be mechanically tilled. This type of planting scheme would allow for maximum shading and weed competition within rows, while minimizing between plant competition. Wide alleys would also allow space for tillage and harvest equipment.

Several herbicides were used to control weeds in the study plots. Dicamba and 2,4-D successfully controlled broadleaf weeds, if applied when weeds were in the 2 to 4-leaf stage. In tests on reclaimed mined lands, imazapic applied at a rate of up to 0.21 kg a.i. ha^{-1} (12 oz/A) did not injure wiregrass plants (Kluson and others 2000). This herbicide was therefore used for weed control in the PMC wiregrass studies, because it is very effective in controlling nutsedge (*Cyperaceae* spp.) The preemergent herbicide oryzalin was applied to study plots in 2001. Wiregrass plants did not appear to be injured by this herbicide, but it is uncertain how much weed control was obtained. Use of herbicides, especially preemergents, need to be further investigated in wiregrass seed production fields.

ESTABLISHING NATIVE LOWLAND GRASSES ON RECLAIMED MINED LANDS

INTRODUCTION

The phosphate mine industry is required to restore acre for acre, wetlands that are disturbed in the mining process. In natural environments wetlands are encompassed by lowland systems such as flatwoods and seasonally flooded marshes that contribute to the health of the wetlands. These mesic systems are characterized by a diversity of species that in turn host a diverse population of wildlife. Switchgrass (*Panicum virgatum* L.), eastern gammagrass [*Tripsacum dactyloides* (L.) L.], chalky bluestem (*Andropogon capillipes* Nash) and maidencane (*Panicum hemitomon* Schult.) are four perennial native grasses that are commonly found in mesic areas adjacent to wetlands. The Brooksville PMC has been working to develop proven sources of these beneficial grasses. The objectives of this study were to determine the adaptation of Florida ecotypes to mesic reclaimed mined lands, and develop successful establishment methods.

MATERIALS AND METHODS

In August of 1999, switchgrass, eastern gammagrass and chalky bluestem seed, and maidencane rhizomes were planted on a newly reclaimed lake shoreline site provided by Cargill Fertilizer, Inc. The study plots began within 30 cm (1 ft) of the water line, and extended 7.6 m (25 ft) up a 13% slope. Soils were sandtails and overburden topped with 15 to 30 cm (6 to 12 in) of muck soils. Plot size was 3 x 5.6 m (10 x 25 ft) with four replications in randomized complete blocks. Each species was planted both in monoculture and as part of a mixture. For monoculture plots, two Florida accessions of eastern gammagrass (9059213 and 9059264) were hand seeded in rows at a rate of 42 and 39 kg pure seed ha^{-1} (37 and 35 lb/A) respectively. Seed had been collected in 1999 from plots at the PMC. Three rows of each accession were planted in each half plot, with 30 cm (1 ft) between rows and 45 cm (1.5 ft) between accessions. Planting depth was 5 to 10 cm (2 to 4 in). The commercially available cultivar, 'Alamo' switchgrass, and a Florida switchgrass, accession number 9060500 (derived from crossing 'Miami Germplasm' and 'Stuart Germplasm'), were seeded in three rows per each half plot. Seeding rate was 645 pure live seed $(pls)/m^2$ ($60 pls/ft^2$) or 4 kg pls ha^{-1} (3.7 lb/A). Alamo was used as a standard of comparison. Planting depth was 1.5 to 2.5 cm (0.5 to 1 in). Chalky bluestem seed (collected from an assembly of chalky bluestem accessions at the PMC in 1998 with a forage harvester) was hand broadcast over plots at a rate of 645 pls/m^2 or 1.3 kg pls ha^{-1} (1.2 lb/A). Rhizomes of the Florida ecotype, 'Citrus Germplasm' maidencane, were hand planted in trenches 5 to 15 cm (2 to 6 in) deep with 30 cm between rows. Plots of the commercially available release, 'Halifax' maidencane from Mississippi were also established as a standard of comparison. Planting rate was approximately 30 bushels per acre. Plots were packed with a cultipacker before and after planting.

For mixture treatments, 3 rows of Citrus maidencane were planted in each plot and then hand broadcast with a mixture of gammagrass (9059213), switchgrass (9060500) and chalky bluestem seed. Seeding rate was 3.5 kg pure seed ha^{-1} (3 lb/A) gammagrass, 1.1 kg pls ha^{-1} (1 lb/A) switchgrass, and 0.3 kg ha^{-1} (0.3 lb/A) chalky bluestem. Soil was moist at the time of planting but not saturated. Meter square quadrats were used to evaluate plots at 6 months and 1 year, for establishment and growth characteristics. Within each plot, measurements were taken at the top of the slope, in the middle, and at the base of the slope next to the water line, to observe the effect of moisture on establishment. The upper end of the slope was 0.6 to 1 m (2 to 3 ft) above the water line, and much drier than the area adjacent to the water.

RESULTS AND DISCUSSION

All species established extremely well in this study despite a record-breaking drought in 1999 and 2000. This was partly due to timely summer rains that provided favorable soil moisture at the time of planting. Average percent canopy cover for each accession one year after planting is shown in Table 16. Dry conditions did reduce establishment of all species, except switchgrass, on the upper slope. Switchgrass produced the greatest cover at all levels, which in turn substantially suppressed weed competition. Because of its rhizomatous growth habit, Citrus maidencane had aggressively colonized the area next to the water within one year after planting. Florida ecotypes had better performance than Halifax and Alamo, which originated in other states.

Table 16. Percent Canopy Cover of Four Native Grasses at Three Elevations Above a Lake Shoreline, One Year After Planting.

Accession	Lower Slope	Middle slope	Upper Slope
	Average % Canopy Cover		
Halifax Maidencane	10	7	5
Citrus Maidencane	29	15	13
Chalky Bluestem	10	7	9
Gamma – 9059213	15	15	11
Gamma – 9059264	22	16	11
Switchgrass – Alamo	27	23	28
Switchgrass – 9060500	30	34	39

One of the factors that make eastern gammagrass difficult to establish is seed dormancy. General planting recommendations for gammagrass in the Eastern and Midwestern US call for a dormant winter seeding, in which seed is planted in the late fall. This allows seed to undergo a cold stratification period that stimulates germination in the spring. Seed used in this study germinated quickly, with a surprising number of seedlings emerging in the first five months after planting (Table 17). Since this seed had been harvested within one month of planting, dormancy mechanisms may not have yet engaged. There was some seed dormancy, however, because seedlings were still emerging at the time of the 1-year evaluation. Accession 9059264, had higher emergence shortly after planting than 9059213, indicating it experienced less dormancy.

Table 17. Seedling Emergence of Two Eastern Gammagrass Accessions at Three Elevations Above a Lake Shoreline, Five Months after Planting.

Accession	Lower Slope	Middle slope	Upper Slope
	Average Plants/m^2		
Gamma – 9059213	3	4	3
Gamma – 9059264	15	10	11

Chalky bluestem was the slowest species to establish, making it less suitable for use in controlling erosion. Chalky bluestem plants were generally smaller at one year of age than the other species (Table 18) with less canopy closure. Although not as tall as switchgrass, the gammagrass plants grew quickly in the first year. Nutrient-rich muck soils contributed greatly to the vigorous growth of this nitrogen-loving species.

Table 18. Plant Height of Four Native Grasses at Three Elevations Above a Lake Shoreline, One Year after Planting.

Accession	Lower Slope	Middle slope	Upper Slope
	Plant Height (cm)		
Halifax Maidencane	38	42	33
Citrus Maidencane	64	55	65
Chalky Bluestem	57	49	42
Gamma – 9059213	61	65	66
Gamma – 9059264	56	59	54
Switchgrass – Alamo	75	77	87
Switchgrass – 9060500	73	72	72

Table 19. Percent Canopy Cover of a Mixture of Four Native Grasses at Three Elevations Above a Lake Shoreline, One Year after Planting.

Accession	Lower Slope	Middle slope	Upper Slope
	Average % Canopy Cover		
Citrus Maidencane	12	11	12
Chalky Bluestem	6	6	
Gamma – 9059213			
Switchgrass – 9060500	25	18	17
Total	43	35	29

Gammagrass did not emerge from the mixture seedings (Table 19). Because seed was broadcast in the mixture treatments, it appears that planting depth was too shallow to promote emergence of gammagrass seed. Switchgrass and maidencane tended to dominate the mixture plots. Chalky bluestem established only on the middle and lower elevations. Competition from the other species may have inhibited chalky bluestem establishment.

CONCLUSIONS

Switchgrass, eastern gammagrass, chalky bluestem and maidencane established very successfully on the reclaimed mined lands lake shoreline in this study. An upper layer of nutrient-rich muck soils encouraged vigorous growth and establishment. Of the four species, switchgrass was the least susceptible to droughty conditions and provided the greatest cover. Although gammagrass had good emergence in this study, pretreating seed to overcome dormancy would provide quicker establishment. Gammagrass did not emerge from broadcast plots, so drilling may be necessary for successful stand establishment. Chalky bluestem was the slowest to establish and is not as useful for controlling soil erosion as switchgrass and maidencane.

SEEDING WIREGRASS AND LOPSIDED INDIANGRASS ON RECLAIMED PHOSPHATE MINED LANDS

INTRODUCTION

There is a movement in Florida to revegetate upland sites with native species, especially reclaimed phosphate mined lands. Direct seeding has the potential to be the most economical method for revegetation when compared to planting seedlings. However, several problems associated with native plants have hampered reseeding efforts. Seeds from native species are often light, with awns or hairy appendages that preclude harvest and planting with conventional equipment. Desirable native species often lack seedling vigor, and are poor competitors with weedy species. In addition, some native species may undergo seed dormancy and only germinate during a given season.

In 1995, under a previous agreement with the Florida Institute of Phosphate Research (FIPR), the Brooksville PMC established seeding methodology trials on two reclaimed mined land sites near Bartow, Florida, using wiregrass (*Aristida beyrichiana* Trin. & Rupr.) and lopsided indiangrass [*Sorghastrum secundum* (Ell.) Nash] (Pfaff and Gonter 1996). Plots were planted in May, 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 establish. Low plant densities were thought to be primarily due to the 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 potential for establishing indiangrass. However, the drill used in this study was not capable of handling light chaffy seed.

Bisset (1995) was able to successfully establish several native species, including wiregrass, by broadcasting mature chopped native material on a reclaimed mined land site near Bartow, Florida in December. Bisset estimated that wiregrass was distributed at a rate of 538 pure live seed/m^2 (50 pls/ft^2) (personal conversation). 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 3,200 pls/m^2 (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 had no seedling emergence. It appears that planting into disturbed bare mineral soils is important for successful wiregrass stand establishment.

The purpose of this study was to research the affect of seeding method, seeding rate and planting date on the establishment of wiregrass and lopsided indiangrass in monoculture and mix.

MATERIALS AND METHODS

Lopsided indiangrass seed was collected from Ft. Cooper State Park in 1995 through 1998, using a Flail-Vac Seed Stripper. Wiregrass seed was collected from Avon Park Air Force Base in 1995 through 1998 with the Flail-Vac. Initially, seed from both species was debearded using a Clipper debearder. Chaff was then removed using an air-screen cleaner. Purity obtained for the indiangrass was 95%. Purity of the wiregrass was approximately 50% due to broken seed. Wiregrass seed is very brittle, and the debearder caused a great deal of seed breakage. A hammermill was a better instrument for debearding wiregrass seed. Although awns aren't completely removed and some breakage occurs in the hammermill, the seed is not processed as long as in the debearder, therefore breakage is reduced. After it was determined in 1997 that debearding wiregrass was not economical, only the indiangrass seed was debearded. The wiregrass seed was still scalped with an air-screen cleaner to remove large sticks and stems.

The study site was near Bartow, Florida, on reclaimed mined lands provided by Cargill Fertilizer, Inc. It was composed of three acres of sand tailings, and an adjacent three acres of sand tailings capped with 15 cm (6 in) or more of overburden. Sand tailings are washed sands, predominately 0.1-0.5 mm in particle size, with poor water holding capacity (Mushinsky and McCoy 1996). Texture of the overburden varied greatly. On the west end of the study site, where the overburden cap was thinnest, the texture was sandy with low water holding capacity. On the east end, the overburden contained a larger loam and clay fraction, which had a higher water holding capacity, and crusted heavily when dry. Soil samples were taken at three depths and analyzed by a commercial laboratory for plant nutrient content.

The freshly reclaimed study site needed no weed control in January 1997. Vacant plots were disked and sprayed with glyphosate throughout the growing season in 1997-1999 to control weeds. However, heavy late summer rains often interfered with weed control and allowed crabgrass (*Digitaria sanguinalis*), natalgrass (*Rhynchelytrum roseum*) and hairy indigo (*Indigofera hirsuta*) to establish seed banks at the site.

All plots were rolled with a cultipacker before seeding. Plots were 3 x 15 m (10' x 50') in size. Generally, four replications were used on overburden plots and three replications on sand tailings. Winter and summer studies were planted in January and May 1997 through 1999, on both overburden and sand tailings. Each study built on the information gained from the previous year.

1997 SEEDINGS

The first winter study was planted on January 28, 1997, as a randomized complete block. Treatments included:

- Monocultures of debearded wiregrass and indiangrass seed were planted using an air drill built by Pounds Motor Company of Winter Garden, Florida. This drill was specifically designed to handle light chaffy seed and keep it from bridging in the drill. It has an aggressive brush system in the hopper, and forced air blows the seed through the drop tubes. Indiangrass seeding rate was 645 pls/m^2 (60 pls/ft^2). Wiregrass seeding rate was slightly higher, 800-860 pls/m^2 (75-80 pls/ft^2), due to the aggressive brush system of the air drill.

- An indiangrass/wiregrass/*Liatris* (primarily *L. elegans* and *L. tenuifolia*) seed mixture of debearded seed was drilled. Wiregrass and indiangrass were planted in this mix at a rate of 645 and 430 pls/m^2 (60 and 40 pls/ft^2) respectively. *Liatris* was included in the January mixture at a rate of 130 pls/m^2 (12 pls/ft^2).

- All monoculture broadcast treatments used debearded seed, and were planted using a hand-held Cyclone seeder. Both lopsided indiangrass and wiregrass seeding rates were 645 pls/m^2 (60 pls/ft^2).

- A seed mixture of beards-on wiregrass, debearded indiangrass and *Liatris* was broadcast using a seed blower. Seeding rate was the same as for the drilled mixture treatment. All broadcast plots were rolled with a cultipacker after seeding.

The first summer study was planted on May 20, 1997, using the procedure outlined above. However, drill treatments were planted using a Tye drill with a warm season grass attachment, borrowed from the Quicksand, KY PMC. Seeding rates were the same as for the January seeding, except that wiregrass was drilled at 645 pls/m^2.

1998 SEEDINGS

The second series of winter plots were broadcast seeded on January 21, 1998, with emphasis placed on seeding rates. Only indiangrass was debearded for this planting, and broadcast with a Cyclone seeder. Beards-on wiregrass was broadcast in monoculture and mix with a seed blower. Plots were rolled before and after seeding with a cultipacker. Treatments were replicated four times on overburden and three times on sand tailings in randomized complete blocks. Treatments included:

- Monoculture plots broadcast at 3 rates:

    - Wiregrass – high (860 pls/m^2), medium (645 pls/m^2), and low (430 pls/m^2).
    - Indiangrass – high (645 pls/m^2), medium (430 pls/m^2), and low (215 pls/m^2).

- Two seed mixtures (high and low) were broadcast in January, with both mixtures using a wiregrass seeding rate of 430 pls/m^2, and approximately 55 pls/m^2 for *Liatris*. The high rate mix included indiangrass at a rate of 215 pls/m^2. The low rate mix included indiangrass at a rate of 108 pls/m^2.

The summer series of plots were planted on May 11, 1998. Indiangrass and wiregrass were broadcast at one monoculture rate of 645 pls/m^2 in the same manner as above. Wiregrass and indiangrass were broadcast as a mixture at one rate of 430 and 215 pls/m^2, respectively. These three treatments were planted on vacant plots within the January 1998 study, so that planting date effects could also be studied.

An additional indiangrass seeding method study was planted in May of 1998. Treatments compared broadcasting indiangrass seed with a Cyclone seeder, versus planting with a Truax chaffy seed drill. Seed was drilled at the approximate rates of 215 and 430 pls/m^2, and broadcast at a rate of 430 pls/m^2. Slight modifications had to be made to the Truax to keep the seed from bridging in the drop tubes. Each treatment was replicated three times on both overburden and sand tailings in a randomized complete block design.

1999 SEEDINGS

The third series of winter studies were planted on January 12, 1999:

- To study the effect of seeding date on wiregrass and lopsided indiangrass establishment, both species were broadcast in monoculture at a seeding rate of 645 pls/m^2 in January in a split plot design. Main plots were species and subplots were planting date. Subplots included a January and May treatment. Plots were replicated three times on both overburden and sand tailings. Wiregrass seed was broadcast with a seed blower. Debearded indiangrass seed was broadcast with a cyclone seeder. Plots were rolled before and after seeding with a cultipacker.

- In a separate January study, the influence of indiangrass on wiregrass densities in mixture plantings was considered. Wiregrass was broadcast at 860 pls/m^2 in mixtures with three different rates of indiangrass (0, 108 and 215 pls/m^2) and 55 pls/m^2 *Liatris* seed. Seed was broadcast with a seed blower. Plots were replicated three times on both soil types in a randomized complete block design.

The third and final series of summer plots was planted on May 4, 1999, within the January 1999 split block design. Wiregrass and indiangrass were seeded using the same rate and methods as for the January plots.

Meter square quadrats (two per plot) were randomly established on all plots at six months. These were used to evaluate treatments for plant density, size, vigor, percent canopy and weed cover at 6, 12 and 24 months after seeding. A final evaluation was conducted on all plots in May of 2001. Statistical analysis was conducted using MSTAT-C (Michigan State University 1988).

RESULTS AND DISCUSSION

Weather patterns varied greatly among the three years of this study. Rainfall amounts as recorded by Cargill Fertilizer Inc. at Hooker's Prairie, which is located within five miles of the study site, are shown in Table 20. The spring of 1997 was unusually wet, with over seven inches of rainfall recorded at Hooker's Prairie in April. March and April precipitation is very critical for winter-planted seedlings. The first three months of 1998 were reported as being exceptionally wet at Hooker's Prairie. However, almost no rainfall was received in the critical month of April. This dry period was also accompanied by high winds. Rainfall amounts were very low the first four months of 1999. High winds accompanied the dry conditions, and new seedlings were literally sand blasted on the sand tailings. Precipitation adequate to sustain May planted seedlings did occur during the summer season in 1997, 1998 and 1999. Record-breaking drought conditions occurred in 2000 and early 2001. Indiangrass plant populations were especially hard hit. The unusually severe conditions provided the opportunity to study drought tolerance of wiregrass and indiangrass at this site.

Table 20. Inches of Monthly Rainfall at Hooker's Prairie from 1996 through 2001.

	1996	1997	1998	1999	2000	2001	Average*
	Inches of Precipitation						
January	5.18	0.93	2.50	2.50	0.7	0.38	2.41
February	1.74	0.86	2.58	0.44	0.42	0.00	3.46
March	5.45	2.17	6.84	0.45	1.07	5.82	3.40
April	0.73	7.12	0.37	1.52	1.35	0.03	2.52
May	10.38	1.87	2.07	4.34	0.60	2.47	5.12
June	3.32	6.00	0.83	8.87	3.97	5.71	7.13
July	4.39	9.49	7.31	5.51	4.01		8.46
August	9.62	2.41	4.29	7.87	4.60		7.52
September	4.89	8.05	13.01	10.07	8.26		6.75
October	3.43	3.32	0.30	2.26	0.00		2.76
November	0.86	5.94	3.11	2.18	0.00		2.11
December	1.67	8.51	1.94	2.16	0.80		2.27
Total	51.66	56.67	55.15	48.17	25.78		53.91

*Average rainfall recorded at Bartow, Florida between 1951 and 1984.

Analysis results for the overburden and sand tailing soils are shown in Table 21. Compared to native, undisturbed soils, levels of P, Ca and Mg tend to be higher on both sand tailings and overburden (USDA NRCS 1990). Higher levels of Ca buffer the soil, increasing pH, which in turn makes other nutrients more plant available. Native upland soils are generally strongly acid. The pH levels of overburden are similar to slightly less acid than native soils. Sand tailings tend to be higher in pH than overburden soils, ranging into the moderate acid level. Sand tailings also tend to increase the pH of overburden when the two soils become incorporated, as they did at this study site. As with native soils, N and K levels are low on reclaimed soils, and these are often the most limiting plant nutrients. However, no fertilizer was applied to the plots. Application of mineral fertilizer is not recommended when seeding natives, because it tends to stimulate weed competition, which in turn smothers out the less aggressive natives.

Table 21. Average and Range of 14 Soil Nutrients in Overburden and Sand Tailings at the Cargill Study Site.

	Overburden		Sand Tailings	
	Average	Range	Average	Range
Nutrient	parts per million			
Nitrate (NO_3-N)	10.5	8.7-14.9	10.3	8.6-12.1
Ammonium (NH_4-N)	0.1	0.0-0.9	0.3	0.0-0.9
Phosphorus (P)	302.9	110-773	237.7	147-365
Potassium (K)	11.6	0.0-29.7	10.2	0.0-48.9
Calcium (Ca)	583.1	32-1198	428.6	246-670
Magnesium (Mg)	151.7	7-554	25.2	14-58
Iron (Fe)	52.2	12-107	27.3	16-62
Manganese (Mn)	1.1	0.0-5.5	0.4	0.2-1.1
Boron (B)	0.2	0.0-1.6	0.1	0.0-0.9
Copper (Cu)	0.1	0.0-0.3	0.1	0.0-0.3
Zinc (Zn)	0.4	0.0-1.7	0.6	0.3-1.1
Molybdenum (Mo)	0.01	0.0-2.4	0.03	0.0-0.2
Sodium (Na)	10.9	0.0-28.2	7.2	0.0-12.9
Aluminum (Al)	611.4	51-1416	261.9	58-469
pH	5.4	3.6-6.7	5.7	5.0-6.2

SEEDING METHOD

Three types of drills were tested in this study, and 2 types of broadcast methods. In the January 1997 planting, the air drill designed by Pounds Motor Co. handled 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 blew the seed out of the furrows. Seeding depth was increased to offset this problem. Because of this, the planting depth of the drilled mix ended up being slightly deeper than the planting depth for the drilled 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 2 inches of the soil.

The Cyclone seeder distributed debearded wiregrass and indiangrass seed very uniformly. The seed blower handled the chaffy wiregrass seed mix very well, though weed distribution over the soil surface was uneven. The ideal seedbed for this method was a moist soil surface imprinted with grooves created by a cultipacker, in which the air-blown seed could collect.

Overall, broadcasting produced the greatest plant densities for both species (Table 22). Direct seeding success criteria for Florida soils have not been developed. On surface mined lands in the western U.S., 43 plants/m^2 is considered a satisfactory stand of seeded native plants (Cook and others 1974; Thornburg 1982). Coarse droughty soils in Florida may not be able to sustain such high seedling densities. In its natural environment in Florida, mature wiregrass averages 5 plants/m^2 (Clewell 1989). However, initially higher seedling densities would be needed to offset seedling mortality, and would also help reduce weed competition. Most of the January 1997 treatments exceeded the native wiregrass average of 5 plants/m^2 on both overburden and sand tailings.

Table 22. Average Plant Densities of January 1997 Monoculture Broadcast (BC) and Drilled (DR) Indiangrass and Wiregrass, on Overburden and Sand Tailings, Six Months after Planting.

Treatment	Overburden	Sand Tailings
	Plants/m^2	
Indiangrass–BC (645 pls/m^2)	177a	46ab*
Indiangrass–DR (645 pls/m^2)	96b	76a
Wiregrass–BC (645 pls/m^2)	65b	14bc
Wiregrass–DR (860 pls/m^2)	36b	5c

*Treatment means within the same column followed by different letters are significantly different by Tukey's HSD at P≤0.05.

A seeding rate of 645 pls/m^2 was actually too high for indiangrass. After two years, indiangrass densities in broadcast plots had diminished by approximately 60% on both soil types. Due to excessive competition between seedlings, plants in broadcast plots were smaller and less vigorous than those in drilled plots. Drilling provided better seed placement. After five years, including two years of extreme drought, no plants remained alive in the indiangrass broadcast plots. After five years, the drilled indiangrass treatment on overburden averaged 3 plants/m^2. On the sand tailings, broadcast and drilled plots averaged 2 and 5 plants/m^2 respectively.

Wiregrass, on the other hand, proved to be very persistent once established, even on broadcast plots with high seedling densities. After five years, wiregrass treatments on broadcast and drilled plots averaged 15 and 14 plants/m^2 respectively. On sand tailings, broadcast and drilled plots averaged 10 and 4 plants/m^2 respectively.

Wiregrass and indiangrass were also drilled and broadcast as a mixture in January of 1997 (Table 23). Even at a reduced seeding rate, indiangrass dominated the mix and inhibited wiregrass germination. After five years, however, indiangrass had almost completely died out, while wiregrass decreased by 60 to 65%. It appears wiregrass is very susceptible to competition at emergence, yet, once established, this species has excellent persistence.

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, because the debearded wiregrass seed was very light, the hopper had to be over half full for it to meter out efficiently. On this drill, 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, but placement was not precise. This system showed no advantages over broadcasting, except for placement of seed in rows. Seedlings within rows are placed on a more uniform basis. This allows for greater access to light, water and nutrients, while reducing competition among seedlings.

Table 23. Average Plant Densities of January 1997 Broadcast (BC) and Drilled (DR) Mixtures of Indiangrass and Wiregrass, on Overburden and Sand Tailings, Six Months after Planting.

Treatment	Overburden	Sand Tailings
	Plant/m^2	
Indiangrass–BC (430 pls/m^2)	88a	26b*
Indiangrass–DR (430 pls/m^2)	79ab	86a
Wiregrass–BC (645 pls/m^2)	39bc	4b
Wiregrass–DR (645 pls/m^2)	17c	3b
Total Plants - BC	127	30
Total Plants- DR	96	89

*Treatment means within the same column followed by different letters are significantly different by Tukey's HSD at P≤0.05.

Results for May 1997 monoculture treatments are shown in Table 24. Greatest densities for both species were again obtained by broadcasting. Indiangrass broadcast plant densities on overburden plots were excessively high. The Tye drill was not successful in seeding wiregrass, although seeding date may have been a contributing factor. Broadcast wiregrass treatment densities were low, but still met native stand averages of five plants/m^2. Weed competition was observed to be higher in May overburden plots than in January plots, though the plots were sprayed with glyphosate prior to planting. Weed competition undoubtedly contributed to low wiregrass emergence in overburden plots. Competing weeds were primarily crabgrass, natal grass, and hairy indigo.

Indiangrass again dominated mixture treatments in the May 1997 plantings (Table 25). However, all mixture treatments had poor emergence on sand tailings. A dry, windy August may have contributed to seedling desiccation. Almost no wiregrass emerged from any of the mixture treatments.

Table 24. Average Plant Densities of May 1997 Monoculture Broadcast (BC) and Drilled (DR) Indiangrass and Wiregrass, on Overburden and Sand Tailings, Six Months after Planting.

Treatment	Overburden	Sand Tailings
	Plants/m^2	
Indiangrass–BC (645 pls/m^2)	117a	34a*
Indiangrass–DR (645 pls/m^2)	57b	21a
Wiregrass–BC (645 pls/m^2)	7c	5a
Wiregrass–DR (645 pls/m^2)	1c	0.2a

*Treatment means within the same column followed by different letters are significantly different by Tukey's HSD at P≤0.05.

Table 25. Average Plant Densities of May 1997 Broadcast (BC) and Drilled (DR) Mixtures of Indiangrass and Wiregrass, on Overburden and Sand Tailings, Six Months after Planting.

Treatment	Overburden	Sand Tailings
	Plants/m^2	
Indiangrass–BC (430 pls/m^2)	28a	2a*
Indiangrass–DR (430 pls/m^2)	46a	7a
Wiregrass–BC (645 pls/m^2)	2b	0.3a
Wiregrass–DR (645 pls/m^2)	1b	0.2a
Total Plants-BC	30	2
Total Plants-DR	47	7

*Treatment means within the same column followed by different letters are significantly different by Tukey's HSD at P≤0.05.

In May of 1998, a Truax chaffy seed drill was used to compare drilling with broadcasting indiangrass. Among the advantages of drilling are that seed can be placed precisely at a given depth and row spacing. Seeding rates can also be reduced compared to broadcasting, which leaves approximately half of the seed on the soil surface. 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 sand tailings. The drop tubes of the chaffy seed box were positioned to open directly 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 further back. A few of the appendages on the indiangrass seed remained after debearding, causing enough resistance to keep the seed from flowing easily. This problem could be overcome in the future by increasing processing times in the debearder to more fully polish seed hulls. Leaving indiangrass seed in the debearder longer may cause more seed damage. However, better flowing seed would greatly increase consistent stand establishment.

Table 26. Average Plant Densities of May 1998 (DR) Drilled and (BC) Broadcast Indiangrass, on Overburden and Sand Tailings, Six Months after Planting.

Treatment	Overburden	Sand Tailings
	Plants/m^2	
BC- Medium Rate (430 pls/m^2)	84a	97a*
DR- Medium Rate (430 pls/m^2)	8b	17b
DR- Low Rate (215 pls/m^2)	9b	14b

*Treatment means within the same column followed by different letters are significantly different by Tukey's HSD at P≤0.05.

Broadcast treatments produced very high indiangrass densities on both soil types (Table 26). Drilled treatment densities were substantially lower, due primarily to poor seed flow. Doubling the drilled seeding rate to broadcast levels did not increase seedling densities. Future studies need to be conducted to precisely determine optimum drilled indiangrass seeding rates, once mechanical difficulties are overcome.

SEEDING RATE

Indiangrass and wiregrass were broadcast in monoculture at three seeding rates in January of 1998 (Table 27). Unfortunately, erratic rainfall and heavy weed competition caused much variability in the data. Rainfall was unusually heavy the first three months of 1998. This appeared to stimulate high weed competition early in the year, especially on overburden plots. Lack of any appreciable rainfall in April, coupled with high winds, decimated populations of the less vigorous native grasses that had emerged. Sandy overburden plots had lower weed competition than did the more loamy overburden plots. This resulted in relatively high seedling densities for both species on the sandy replications, graduating to virtually no surviving seedlings on the loamier soils. The net result was that density data on overburden plots was erratic, e.g., high seeding rates produced lower seedling densities than did medium, or low rates.

Table 27. Average Plant Densities of January 1998 Broadcast Indiangrass and Wiregrass in Monoculture at Three Seeding Rates, on Overburden and Sand Tailings, Six Months after Planting.

Treatment	Overburden	Sand Tailings
Indiangrass	Plants/m^2	
High Rate (645 pls/m^2)	32a	42a*
Medium Rate (430 pls/m^2)	38a	37a
Low Rate (215 pls/m^2)	13a	13a
Wiregrass		
High Rate (860 pls/m^2)	3b	4b
Medium Rate (645 pls/m^2)	3b	4b
Low Rate (430 pls/m^2)	5b	2b

*Treatment means within the same column followed by different letters are significantly different by Tukey's HSD at P≤0.05.

Some interesting observations could be made from the indiangrass treatments, however. This was the species most able to overcome unfavorable conditions, including drought and high weed competition. Indiangrass seedling densities were similar for the high and medium rates on both soil types. The low rate produced substantially lower plant densities than did the medium rate. If the western criteria of 43 plants/m^2 is used, then, based on these data, it appears that a 215 pls/m^2 broadcast seeding rate is too low. There is also no advantage in tripling the seeding rate to 645 pls/m^2. This high rate has in fact been observed to cause severe competition between seedlings, and high seedling mortality. High, medium and low indiangrass seeding rates equate to roughly 13.5, 9 and 4.5 kg pls ha^{-1} (12, 8 and 4 lb/A) respectively.

January 1998 planted wiregrass seedling densities were very low and generally did not reach the native stand average of 5 plants/m^2 at any of the seeding rates used in this study. This species appears to be extremely sensitive to weed competition and rainfall, which had a greater effect on seedling emergence than did seeding rate. Wiregrass high, medium and low seeding rates translated to roughly 4.5, 3.5 and 2.5 kg pls ha^{-1} (4, 3 and 2 lb/A) respectively.

Table 28. Average Plant Densities of Wiregrass Broadcast with Indiangrass at Three Rates in January 1999, on Overburden and Sand Tailings, Six Months after Planting.

Treatment	Overburden	Sand Tailings
	Plants/m^2	
Rate 1		
Wiregrass (860 pls/m^2)	11ab	0.3a*
Liatris (55 pls/m^2)	3bc	1a
Rate 2		
Wiregrass (860 pls/m^2)	9ab	1a
Indiangrass (108 pls/m^2)	5abc	2a
Liatris (55 pls/m^2)	3bc	2a
Rate 3		
Wiregrass (860 pls/m^2)	8ab	0.3a
Indiangrass (215 pls/m^2)	7ab	4a
Liatris (55 pls/m^2)	3bc	1a

*Treatment means within the same column followed by different letters are significantly different by Tukey's HSD at $P \leq 0.05$.

To test wiregrass seedling sensitivity to competition with other species in a native mix, wiregrass was broadcast with indiangrass at three rates in January 1999 (Table 28). Unfortunately, weather patterns were once again very erratic in 1999. Only 12.4 cm (4.9 in) of rain fell in the first four months of 1999, compared to an average of 39.4 cm (15.5 in) for the first four months of the previous three years. Droughty conditions were accompanied by high winds. Remarkably, wiregrass densities for all treatments on overburden plots were above the native standard of five plants/m^2. Fortunately, weed competition was low and had much less influence on seedling emergence compared to

1998. Indiangrass densities appeared to be too low to significantly affect wiregrass emergence under these droughty conditions at either rate. Stand densities on the January 1999 planted sand tailings plots were almost nil for all species. Droughty conditions and blowing sand decimated seedlings that did emerge.

After three years of severe drought, wiregrass numbers averaged three plants/m^2 on all treatments, while lopsided indiangrass numbers dropped to two or less plants/m^2. These studies provided a good opportunity to establish seeding rate thresholds for wiregrass and indiangrass in monoculture and mixtures. Further experiments may be necessary to develop data under less extreme conditions.

SEEDING DATE

Throughout these studies, seeding date often appeared to have a strong influence on seedling establishment. A final series of studies were planted in 1999 to specifically address the effect of planting date on wiregrass and indiangrass emergence. Droughty weather conditions in 1999 negatively influenced seedling emergence. However, much good data was still obtained. Weed competition was not a significant factor in this study. There was no significant difference between wiregrass stand densities in January versus May on overburden plots (Table 29). Had more rainfall been received in the winter and early spring of 1999, it is possible that January wiregrass seedling densities would have been much higher. This conclusion is based on wiregrass performance in the 1997 studies. Densities on both dates were well above the natural standard of five plants/m^2. Timely summer rains gave May seedlings a much needed boost to become established on overburden plots. However, soil moisture appeared to be too low and windy conditions too extreme, for wiregrass to establish on sand tailings at either seeding date. Indiangrass established relatively well on both soil types on both dates. It was able to take advantage of summer rains to become established on overburden plots.

Table 29. Average Plant Densities of Wiregrass and Indiangrass Broadcast in January and May 1999, on Overburden and Sand Tailings, Six Months after Planting.

Treatment	Overburden	Sand Tailings
	Plants/m^2	
Indiangrass - January	113b*	13a*
Indiangrass - May	236a	30a
Wiregrass - January	23c	0b
Wiregrass - May	10c	0b

*Treatment means within the same column followed by different letters are significantly different by Tukey's HSD at $P \leq 0.05$.

After three years, which included periods of extreme drought and winds, wiregrass numbers on overburden had dropped to an average of 8 plants/m^2 on both treatments, while indiangrass numbers had dropped to 7 and 30 plants/m^2 for the January and May treatments respectively. On sandtails, indiangrass plants averaged 11 plants/m^2

for both planting dates. Dry conditions inhibited seed production, so this species may not persist in these plantings. Lopsided indiangrass is a good candidate for a native seed mix, because of its ability to immediately colonize a site despite adverse conditions. Though it may not persist on all sites, it could act as a native "nurse crop" to help other species such as wiregrass become established. If adequate moisture is available, it is expected that this species would produce enough viable seed to persist on the site.

CONCLUSIONS

Based on these series of studies, broadcasting generally produced the highest plant densities for both species whether planted alone or in a mixture. Lopsided indiangrass established fairly well in drilled treatments. Drilling with a chaffy seed drill may be advantageous for planting this species if seed is adequately debearded. Drilling generally requires lower seeding rates, which can reduce seed costs substantially.

In the short term, optimum broadcast seeding rate for indiangrass was found to be 430 pls/m^2 (40 pls/ft^2) on overburden and sand tailings, which roughly equates to 9 kg pls ha^{-1} (8 lb/A). Drill seeding rates were not precisely determined. Typically, seeding rates for drilling are half of broadcast rates. Further research will be needed to verify this. Indiangrass did not persist longer than five years on many of the study plots. This species appears to be a short lived perennial, and may be most useful when used in a native mixture as a native nurse or cover crop, to help control wind erosion.

Optimum wiregrass broadcast seeding rates could not be established in these studies. Soil moisture and weed competition had a profound effect on wiregrass seedling establishment. Wiregrass could not establish under extremely dry, windy conditions, or when weed competition was high, no matter the seeding rate. When conditions were favorable, broadcast rates of 640 to 860 pls/m^2 (60 to 80 pls/ft^2) produced adequate stands on both soil types. This roughly equates to 3.5 to 4.7 kg pls ha^{-1} (3 to 4 lb/A). In terms of mixtures, adding up to 4.5 kg pls ha^{-1} (4 lb/A) of indiangrass did not appear to suppress wiregrass emergence.

Study data indicated there was no significant advantage to a winter seeding date for either species. However, during the time the seeding date study was established, winter/early spring rains were well below normal, while more favorable rains fell in May and June. Higher winter rainfall may have produced different results. Indiangrass emerged well at any date when adequate moisture was available. A winter seeding date may be more advantageous for wiregrass, due to lack of weed competition and higher soil moisture from timely winter rains.

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