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CONTROL AND MANAGEMENT OF COGONGRASS AND OTHER EXOTIC GRASSES ON DISTURBED LANDS IN FLORIDA: RESEARCH REPORT

Prepared by

FLORIDA INDUSTRIAL AND PHOSPHATE RESEARCH INSTITUTE

May 2013

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PERSPECTIVE

Steven G. Richardson, Ph.D. – Research Director, Reclamation

Invasive exotic plants are major problems in natural areas and on reclaimed mined lands in Florida. Even some native plants can be highly competitive when re-establishing plant communities on disturbed lands, and they have been included in the term "nuisance plants" by the Florida Department of Environmental Protection. The control of invasive exotic and native nuisance plants (also referred to as weeds in this report) is a major contributor to reclamation costs on mined lands and also to management and restoration costs on non-mined lands in Florida. The management of a wide array of invasive exotic and nuisance plants was addressed in Florida Industrial and Phosphate Research Institute (FIPR Institute) Publication 03-160-248, "Management of Nuisance and Exotic Vegetation on Phosphate Mined Lands in Florida" (available online at the FIPR Institute website http://www.fipr.state.fl.us). The information in that manual was based on more than 20 years of research and demonstration projects conducted by FIPR Institute staff and cooperators, plus published reports and the experience of other researchers and reclamation/restoration practitioners. The Florida Exotic Pest Plant Council (FLEPPC) maintains a list of invasive exotic plants in Florida and is a source of information on the characteristics and management of these plants.

Some of the most widespread and problematic weeds are exotic grasses, such as cogongrass (*Imperata cylindrica*), torpedograss (*Panicum repens*), smutgrass (*Sporobolus indicus*), natalgrass (*Melinis repens,* synonym: *Rhynchelytrum repens*), bermudagrass (*Cynodon dactylon*) and bahiagrass (*Paspalum notatum*). This report summarizes some of the research and demonstration work conducted by FIPR Institute personnel on control of invasive weeds, with an emphasis on these exotic grasses. The purpose of this research has been to develop and evaluate cost-effective weed control strategies to enhance establishment and growth of native plants on reclaimed phosphate mined lands and other disturbed or weed-infested lands in Florida. Emphasis has been on selective weed control measures that aid early establishment of multiple-species native plant communities or renovation of native plant communities that have become infested with non-native weeds, including cogongrass and other non-native grasses.

One of the first research projects on weed ecology and management conducted by the FIPR Institute (formerly the Florida Institute of Phosphate Research [FIPR]) began in 1989. The initial research examined competitive interactions between various weeds and upland or wetland trees (see Richardson and others 1994). Early emphasis was on primrose willow and cattail competition with several wetland tree species (see Richardson and Johnson 1998, Richardson and Kluson 2000). FIPR funded a University of Florida research project on the ecology and management of cogongrass in 1993, which was published in 1997 (Shilling and others 1997). In 1998, FIPR Staff began a series of studies on competitive interactions of several non-native grasses and other weeds with native plants in uplands plus studies on selective herbicidal weed control, i.e., killing certain weeds with minimal or no injury to various native plants (Kluson and others 2000, Richardson and others 2003). Over the next several years, FIPR provided funding to help support several graduate students under the direction of Dr. Greg MacDonald at the University of Florida, and FIPR Staff expanded research efforts on control of cogongrass and other weeds, plus tolerance of native plants to various herbicides.

Some of the research findings have been presented at various national and regional professional meetings (American Society of Mining and Reclamation, Society for Ecological Restoration, Florida Exotic Pest Plant Council, Southern Weed Science Society, Florida's Annual Regional Phosphate Conference, Florida Vegetation Management Association, etc.). Presentations about weed ecology and management from the 2008 Ecosystem Restoration Workshop are available online at the FIPR Institute website (http://www.fipr.state.fl.us). Several presentations were published as full papers or as abstracts in various conference or symposium proceedings. Graduate student theses have also been published through the University of Florida.

ABSTRACT

Invasive exotic plants are major problems on disturbed lands, such as reclaimed mined lands, but also in natural areas in Florida. The control of exotic nuisance plants is a major contributor to reclamation, restoration and management costs in natural areas and on disturbed lands. This report summarizes research and demonstration projects conducted by FIPR Institute Staff on the management of cogongrass (*Imperata cylindrica*) and other exotic grasses: torpedograss (*Panicum repens*), smutgrass (*Sporobolus indicus*), natalgrass (*Melinis repens,* synonym: *Rhynchelytrum repens*), bahiagrass (*Paspalum notatum*), and bermudagrass (*Cynodon dactylon*). The research included studies of competitive interactions with native plants, improving the effectiveness and efficiency of herbicides for control, and selective herbicidal control of weeds (including native plant tolerances to herbicides). The report also includes guidelines and recommendations for managing the exotic grasses based on FIPR Institute research and experience plus the available literature. Bibliographies are included at the end of each chapter for those who wish to delve into various topics in greater detail.

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EXECUTIVE SUMMARY

Invasive exotic plants are major problems in natural areas and on reclaimed mined lands in Florida. The control of invasive exotic and native nuisance plants (exotic and native nuisance plants often referred to simply as "weeds" in this report) is a major contributor to reclamation costs on mined lands and also to management and restoration costs on non-mined lands in Florida. Some of the most widespread and problematic weeds are exotic grasses, such as cogongrass (*Imperata cylindrica*), torpedograss (*Panicum repens*), smutgrass (*Sporobolus indicus*), natalgrass (*Melinis repens,* synonym: *Rhynchelytrum repens*), and bermudagrass (*Cynodon dactylon*). Bahiagrass (*Paspalum notatum*) is a valuable and often-planted pasturegrass, but as a non-native plant, it is considered undesirable in native plant communities. This report summarizes some of the research and demonstration work conducted by FIPR Institute personnel on control of invasive weeds. Much of our research effort has been aimed at cogongrass, and the research results on cogongrass management are reported in the first chapter. The second chapter includes research and demonstration studies involving the other grasses listed above.

COGONGRASS

Cogongrass is a tall, highly competitive, rhizomatous grass. A dense tree canopy was observed to exclude invasion by cogongrass. Although cogongrass inhibited growth of young laurel oak, live oak and other trees, wax myrtle competed well against cogongrass and even "shaded it out" as the canopy developed.

Several chemical herbicides exhibited some value in controlling cogongrass, including imazapyr (e.g., Arsenal, Habitat), glyphosate (e.g., Roundup, Rodeo), fluazifop-p-butyl (Fusilade), and sulfometuron-methyl (e.g., Oust). Imazapyr was the most effective herbicide for cogongrass and is known to have both foliar and soil activity, including soil residual. Imazapyr at higher rates (e.g., 0.75 to 1.0 lb active ingredient [a.i.] per acre or 1.5 to 2.0 qt Habitat or Arsenal per acre) tended to be non-selective (killed virtually all vegetation), but at lower rates (e.g., 0.094 to 0.125 lb a.i. per acre or 12 to 16 fluid oz Habitat or Arsenal per acre) it was shown to be selective, meaning some plants (e.g., *Aristida, Andropogon, Eragrostis, Liatris, Pityopsis, Helianthus, Galactia, Pinus*) exhibited greater tolerance than cogongrass. Glyphosate was the next most effective herbicide available for non-selective control when applied at 4 to 5 lb a.i./acre. Although glyphosate is non-selective, it has no soil residual. Fluazifop-p-butyl is a foliarly applied grass herbicide that has little to no effect on most broadleaved plants. Fluazifop was not as effective as imazapyr or glyphosate in controlling pure stands of cogongrass but showed value for selective control of cogongrass in stands of young trees or other broad-leaved plants. The fluazifop severely injured cogongrass without any injury to trees and broadleaved herbaceous plants, thus tipping the competitive balance in favor of the trees and herbaceous broadleaved plants, which in turn then helped further suppress the cogongrass. Sulfometuron-methyl was shown in our research to enhance the effectiveness of glyphosate when tank-mixed. Imazapyr added to glyphosate enhanced control of cogongrass, but glyphosate added to imazapyr did not enhance cogongrass control over imazapyr alone. Suboptimal rates of imazapyr were more effective than high rates of glyphosate. There is generally little value in mixing imazapyr and glyphosate; it is better to use imazapyr alone.

Where possible in solid stands of cogongrass, we recommend burning in late summer to remove the standing dead matter and promote a flush of fresh green growth. The regrowth should be sprayed in the fall when it reaches a height of about 18 to 30 inches. The effectiveness of imazapyr and glyphosate on cogongrass has been shown to be greater in the fall than at other times of the year (successful control of cogongrass August through December in central peninsular Florida). This is hypothesized to be related to greater translocation of the absorbed herbicide to the rhizomes in conjunction with greater translocation of photosynthate to rhizome storage in the fall. We have had greater success when spraying taller cogongrass regrowth (up to 48 inches) than shorter (8-12 inches). We presume this is related to greater herbicide uptake because of greater leaf area and also to greater translocation to rhizomes from fully expanded mature leaves versus young expanding leaves which may initially draw reserves from the rhizomes. We recommend imazapyr rates of 0.75 to 1.0 lb of a.i./acre and 4.0 to 5.0 lb glyphosate a.i./acre. This is equivalent to 1.5 to 2.0 qt of Habitat (or Arsenal) or 4.0 to 5.0 qt of Round-up Pro (3.0 to 3.7 quarts Rodeo) per acre (or equivalent rates of other brands with equivalent ingredients). Fusilade (fluazifop-p-butyl) should be applied in the summer (July to September) at the highest labeled rate. We used 1.0 fluid oz Fusilade per gallon for spot spraying.

The main value of fire is as a pretreatment to remove the standing dead matter often found in a field of mature cogongrass and to promote the production of green leaf tissue that is more susceptible to effective herbicide uptake. Mowing has been tried as a pre-treatment before applying herbicide to the regrowth; however, our research has shown that herbicidal control was better without mowing, even for a tall, old stand of cogongrass. Our hypothesis is that the large amount of thatch or "trash" following mowing may intercept herbicide and keep it from reaching the soil (important for root uptake with imazapyr) and may shield newer shoots and reduce foliar uptake of glyphosate or imazapyr.

NATALGRASS

Natalgrass behaves much like an annual plant. It grows rapidly from seed and is a prolific seed producer. However, in central and southern Florida it may also behave like a short-lived perennial. A hard frost may kill the plants, but with a slightly milder winter, the plants may resprout from roots and stem nodes. It can also spread vegetatively by producing roots and new shoots at stem nodes. Natalgrass was shown in our research to strongly inhibit growth of native plants such as wiregrass (*Aristida beyrichiana*), lopsided indiangrass (*Sorghastrum secundum*) and sand live oak (*Quercus geminata*).

The key to controlling natalgrass is to prevent seed production and to inhibit seed germination. Natalgrass can be killed by higher rates of glyphosate (e.g., 3-4 qt Round-up), imazapyr (1-2 qt Habitat or Arsenal/acre) and hexazinone (e.g., 1 qt Velpar L/acre). Fluazifop is not very effective on natalgrass even at the higher labeled rates, except on very young seedlings. Diquat is a contact herbicide that can kill natalgrass, but it is more effective on younger plants at the higher labeled rates and with greater carrier water volumes (e.g., 40 gal/acre or more) to provide complete foliar coverage. Several pre-emergent herbicides commonly used in agriculture, such as pendimethalin (Pendulum) and oryzalin (Surflan), effectively inhibit seed germination of natalgrass in greenhouse tests. Imazapyr and imazapic at lower rates (e.g., 12 fluid oz Habitat or Plateau per acre) can control seedlings or young plants and also inhibit seed germination of natalgrass. Hexazinone not only killed mature natalgrass plants but also inhibited natalgrass seed germination (1.0 to 1.5 qt Velpar L per acre).

A renovation technique used effectively on a natalgrass-infested xeric scrub reclamation site involved burning the site in June and applying pre-emergent herbicides to the bare ground to inhibit germination of natalgrass seeds in the soil. Natalgrass germination was effectively controlled by pendimethalin, with no effect on the resprouting perennial species. Hexazinone, imazapyr and imazapic also gave good pre-emergent control of natalgrass following the burn. These three herbicides also have post-emergent activity, but because of virtually no herbaceous leaf area after a burn, the uptake would be via roots. Fortunately, many native species in the legume and composite families, plus wiregrass and beardgrasses (*Andropogon* spp.) have some tolerance to imazapyr or imazapic at lower rates (12 to 16 fluid oz Habitat [also Arsenal] or Plateau per acre). Wiregrass, beardgrasses and pines have some tolerance to hexazinone (1.0 to 1.5 qt Velpar L per acre).

TORPEDOGRASS

Imazapyr (2 qt Habitat per acre) applied in October was very effective in controlling torpedograss in a wetland. Glyphosate was less effective than imazapyr. Imazamox (Clearcast), in our preliminary tests, provided some control of torpedograss at the highest rates listed on the label. Imazamox is tolerated by several wetland tree species, but we observed some injury to some broadleaved wetland herbaceous species. Fluazifop (Fusilade) is a grass herbicide that has little or no activity on non-grasses, including most trees and broadleaved herbaceous species. Our preliminary tests indicated fluazifop has good potential to kill or suppress torpedograss and encourage growth of broadleaved wetland plants that further compete with the weakened torpedograss. CAUTION: Current Fusilade labels do not allow application to standing water in wetlands (apparently because of concerns about fluazifop effects on fish and other aquatic organisms). Application to torpedograss in fringe areas around wetlands without standing water or perhaps to seasonally dry wetlands might be possible, but clarification from the Florida Department of Agriculture and Consumer Services, the USEPA and the manufacturer is needed. Maidencane was successfully planted in the summer following fall application of imazapyr and may be a good competitor to retard or prevent reinfestation of torpedograss. The propensity of maidencane to go dormant in the winter may also allow a window of opportunity to selectively control torpedograss, which tends to remain active at slightly lower temperatures than maidencane.

SMUTGRASS

Smutgrass can be controlled with high rates of imazapyr and glyphosate. It can be selectively controlled by applying 1.0-1.5 qt Velpar L (hexazinone) per acre during the rainy season. Wiregrass, pines, beardgrasses (*Andropogon* spp.) and bahiagrass are tolerant of hexazinone at these rates.

BAHIAGRASS

Seed germination is inhibited and seedlings and young plants can be selectively killed by imazapic (Plateau) or imazapyr (Habitat) at rates near 12 oz of product (Plateau or Habitat) per acre. More mature bahiagrass requires higher rates of imazapyr (32 to 48 oz/acre of Habitat) or glyphosate (3-4 qt Roundup Pro per acre) for control. Bahiagrass is most susceptible to imazapyr or imazapic in the spring or early summer before it flowers and is most tolerant in late fall or winter. Bahiagrass is more tolerant of imazapyr (12 fluid oz Habitat/acre) than is cogongrass, which allows selective control of cogongrass in a bahiagrass stand. Selective control is most effective in December when the bahiagrass is more dormant while the cogongrass is still metabolically active (early December in one test and early January in another test produced good control of cogongrass with only minor injury to bahiagrass). Bahiagrass is tolerant of hexazinone at rates of 1.0-1.5 quart Velpar L per acre, which allows selective control of smutgrass in a bahiagrass stand (most effective in the summer rainy season).

BERMUDAGRASS

Although we didn't include bermudagrass as a primary focus in our research plots, we did learn something about its control while managing weeds on our research sites. Bermudagrass is best controlled before other vegetation is planted. Tillage alone does not effectively control bermudagrass but may serve to spread rhizomes and stolons. It can be killed with higher rates of imazapyr or glyphosate, and imazapyr is more effective than glyphosate. As we learned with cogongrass, imazapyr alone does a better job than when glyphosate is applied in tank-mix with imazapyr (Boyd and Rogers 1999). Bermudagrass has some tolerance to imazapyr, imazapic and hexazinone. Fluazifop can be used to selectively control it without harming broadleaved plants. Triclopyr, a broadleaf and brush killer, causes some injury and suppresses bermudagrass (McCullough 2011; also our experience).

GENERAL INTRODUCTION

Invasive exotic plants are major problems in natural areas and on reclaimed mined lands in Florida. Even some native plants can be highly competitive (included in the term "nuisance plants") when re-establishing plant communities on disturbed lands. There are regulatory requirements to control invasive exotic and nuisance plants on reclaimed mined lands in Florida. The control of exotic and native nuisance plants (often referred to simply as "weeds" in this report) is a major contributor to reclamation costs on mined lands and also to management and restoration costs on non-mined lands in Florida. Management of a wide array of invasive exotic and nuisance plants is addressed in FIPR Institute Publication 03-160-248, "Management of Nuisance and Exotic Vegetation on Phosphate Mined Lands in Florida." Some of the most widespread and problematic invasive plants (or weeds) are exotic grasses, such as cogongrass (*Imperata cylindrica*), torpedograss (*Panicum repens*), smutgrass (*Sporobolus indicus*), natalgrass (*Melinis repens,* synonym: *Rhynchelytrum repens*), and bermudagrass (*Cynodon dactylon*). Bahiagrass (*Paspalum notatum*) is a valuable and often-planted pasturegrass, but as a non-native plant, it is considered undesirable in native plant communities. This report summarizes some of the research and demonstration work conducted by FIPR Institute personnel on control of invasive weeds. Much of our research effort has been aimed at cogongrass, and the research results on cogongrass management are reported in the first chapter. The second chapter includes research and demonstration studies involving the other grasses listed above. Some of the studies (especially the selective herbicide tests) have involved multiple plant species, including control of targeted weeds but also herbicide tolerance of various desirable native plant species.

GOALS

The purpose of this research has been to develop and evaluate cost-effective weed control strategies to enhance establishment and growth of native plants on reclaimed phosphate mined lands in Florida. Emphasis has been on selective weed control measures that aid early establishment of multiple species native plant communities or renovation of native plant communities that have become infested with non-native weeds, including cogongrass. The results are not only relevant to reclaimed phosphate mined lands but to restoration efforts on non-mined lands as well.

- Develop and evaluate strategies for control and management of cogongrass and other weeds, especially on lands reclaimed as native habitat, including:
    - Identify and evaluate selective and nonselective herbicides and optimize rates and times of application; and,
    - Evaluate cover crops (trees and herbaceous ground cover) for their abilities to compete with and suppress cogongrass and other weeds.

CHAPTER 1: COGONGRASS MANAGEMENT

INTRODUCTION

Invasive exotic weeds are major problems not only on reclaimed phosphate mined lands but on non-mined lands as well. Invasive and competitive native weeds also cause problems during the establishment of native plant communities or other desired vegetation. These native invasive weeds have been designated as “nuisance plant species” by the Florida Department of Environmental Protection (FDEP or DEP) and are required to be controlled or limited to only a very small percentage of total plant cover on reclaimed mined lands. The general aim of our research has been to improve our understanding of practices that enhance successful establishment of native plant communities on reclaimed phosphate mined lands, including effective and efficient means for managing invasive exotic and native nuisance plants.

Cogongrass (*Imperata cylindrica*) is among the world’s worst weeds. It infests thousands of acres in the southeastern United States, especially Florida, Alabama and Mississippi. It is a vigorous, rhizomatous perennial grass that is adapted to a wide range of soil fertility and moisture conditions in tropical and subtropical climates. It spreads by seed and by rhizomes.

Cogongrass is a fast growing, rhizomatous, perennial grass from southeast Asia that in recent years has become one of the most troublesome weeds in non-agricultural areas in Florida (Shilling and others 1997). Cogongrass is not a serious problem on intensively managed agricultural lands where the normal operations include repeated tillage and herbicide application. However, it has become a serious problem on less intensively managed lands such as rangelands, pastures, roadsides, reclaimed phosphate mines, and natural areas. MacDonald (2004 and 2009) has published reviews of the literature on the biology, ecology and management of cogongrass. In November 2007, a conference devoted to the cogongrass problem in the southeastern U.S. was held, and the proceedings were published as “A Cogongrass Management Guide” (Loewenstein and Miller 2007). Richardson and Murawski (2012) have recently published a guidance manual entitled *Management of Nuisance and Exotic Vegetation on Phosphate Mined Lands in Florida* (FIPR Publication No. 03-160-248), which provides guidelines for control and management of cogongrass and many other weeds.

This chapter contains the following sections:

- Competition (cogongrass interaction with trees);
- Improving effectiveness and efficiency of cogongrass control with herbicides;
- Studies of selective herbicidal control of cogongrass (killing or severely injuring cogongrass with minimal injury to desirable plants);
- Cogongrass management guidelines and recommendations (including use of fire, mowing, tilling, competition, chemicals, etc., singly and in combination).

COGONGRASS COMPETITION

Cogongrass Competition with Trees

Sites used in an earlier study to examine various factors affecting tree establishment (Richardson and others 1994) eventually became infested with cogongrass. However, we later observed that plots containing dense stands of wax myrtle (*Myrica cerifera*) with nearly complete canopy coverage were effective in excluding cogongrass. Mixed stands of laurel oak (*Quercus laurifolia*), red maple (*Acer rubrum*), and sweetgum (*Liquidamber stryaciflua*) also excluded cogongrass (Figure 1). A eucalyptus plantation on mined land in Florida suppressed cogongrass (Rockwood and others 2008, Tamong and others 2008), and trees have been tested for control of cogongrass in Africa and Asia (MacDicken and others 1997, Otsamo 2002). We wondered how well wax myrtle, laurel oak and live oak (*Quercus virginiana*) might compete with cogongrass if the cogongrass was present at the time of tree planting. We also wanted to know if these shrub and tree species could eventually eliminate the cogongrass as their canopies developed.

Figure 1. Cogongrass Suppressed or Excluded Under Mixed Hardwood (Laurel Oak, Red Maple, Sweetgum) Canopy.

The Tenoroc Fish Management Area, managed by the Florida Fish and Wildlife Conservation Commission, is publicly owned property northeast of Lakeland in Polk County, Florida. The area was formerly mined for phosphate. An area of dense cogongrass growth on an overburden slope (about 4 horizontal to 1 vertical) was burned (August 30, 2001) followed by application of 3 qt/acre of Roundup Pro (November 19, 2001) with a boom sprayer mounted on an ATV. The herbicide application was only temporarily effective, and much of the cogongrass had regrown, along with hairy indigo, by the summer of 2002. The area was mowed on July 18, 2002. Various zones at the site were sprayed with backpack sprayers in August with one of three herbicide treatments: (1) Garlon 3A (3 oz/gal + 0.3% NIS) to remove broadleaves and recreate pure stands of cogongrass; (2) Fusilade DX (2 oz/gal + 0.3% NIS) to control cogongrass but allow broadleaves such as hairy indigo and dogfennel to dominate; and (3) Roundup Pro (3 oz/gal) to control all vegetation. The site was planted on September 4, 2002, with sack (root mass 12 inch deep × 4 inch diameter) nursery stock of live oak, laurel oak, and wax myrtle. Trees were spaced on 7 foot centers (889 trees per acre). Garlon was *not* applied after tree planting (cogongrass dominated). The Fusilade treatment was applied twice per year from 2002 through 2004 to control cogongrass (including encroachment from adjacent plots), which resulted in plots dominated by hairy indigo (*Indigofera hirsuta*) the first year and dog fennel (*Eupatorium capillifolium*) and saltbush (*Baccharis halimifolia*) in subsequent years. The Roundup treatment was applied twice per year from 2002 through 2004, and the treatment also included mowing with a power trimmer to reduce height of tall weeds to avoid overspray of Roundup on the trees. Thus, three competition treatments were created: (1) nearly weed free (Roundup), (2) broadleaf weeds (Fusilade), and (3) cogongrass.

Tree height and crown diameter (mean of north-south and east-west diameters) of each tree were measured each year at the end of the growing season from 2003 to 2007. Percent cover of cogongrass was visually estimated within the 7 ft × 7 ft zone centered on each tree from 2005 to 2007.

Table 1 shows the effects of the three vegetation management treatments on growth of live oak, laurel oak and wax myrtle through 2007. Initially, the vegetation in the Fusilade treatment was hairy indigo, but by 2004 it was primarily tall dog fennel, and later, saltbush became abundant. Height growth of live oak and wax myrtle were inhibited about as much by the dogfennel and other broadleaved weeds in the Fusilade treatment as it was by cogongrass when compared to the Roundup/mowing treatment. However, laurel oak was inhibited more by cogongrass than by dog fennel and other broadleaves. Wax myrtle appears to be much less affected by cogongrass or broadleaves than the oaks. The long-term purpose of this study was not only to evaluate the effects of the treatments on tree growth but also to evaluate the effects of the tree species on cogongrass.

Table 1. Tree Heights and Crown Diameters at Tenoroc as Affected by Cogongrass Presence or Control with Herbicides.

Species/Treatment	Height (cm)					Crown Diameter (cm)				
Live Oak	'03	'04	'05	'06	'07	'03	'04	'05	'06	'07
Roundup	112a	200a	288a	353a	391a	43a	99a	157a	176a	188a
Fusilade	101a	157b	218b	267b	325b	31b	55b	87b	116b	129b
Cogongrass	103a	152b	204b	240b	298b	30b	52b	85b	112b	126b
Laurel Oak										
Roundup	77d	145d	239d	369d	470d	30d	69d	121d	176d	187d
Fusilade	72d	107e	203d	310d	423d	26d	35e	73e	123e	137e
Cogongrass	73d	91e	150e	238e	349e	26d	30e	57e	90e	116e
Wax Myrtle										
Roundup	104g	172g	278g	355g	442g	51g	112g	178g	234g	247g
Fusilade	67g	147g	267g	352g	415g	33g	72g	139g	204g	211g
Cogongrass	91g	159g	267g	355g	398g	42g	90g	155g	199g	218g

Trees planted September 2002. Roundup (and mowing) treatment reduced competition from all weeds. Fusilade treatment resulted in competitive stands of broadleaves: hairy indigo, dog fennel, saltbush. Treatment means by year within tree species followed by the same letter are not significantly different at the .05 level by Dunn's test.

Table 2 shows the effect of wax myrtle on cogongrass cover. Percent cover of cogongrass was estimated visually in an area 7 ft × 7 ft centered on each tree (only plots in the "cogongrass" treatment of Table 1 were included). The column on the left shows several cover categories (ranges of cover) from high percent cover at the top to low at the bottom. The numbers in the table under each year show the number of 7 ft × 7 ft plots that fell within the various cover categories. The data clearly show a decrease in the number of plots in the high cover categories and an increase in the number of plots in the lower cover categories with time in the wax myrtle plots. Table 3 shows the effect of laurel oak on cogongrass cover. The trend for reduced cover of cogongrass with time is also apparent under the developing laurel oak canopy, but the effect is less at this time than with wax myrtle. Live oak effects were similar to laurel oak (data not shown). Figure 2 shows dying cogongrass beneath the wax myrtle canopy in 2007.

Table 2. Effect of Wax Myrtle on Cogongrass Cover: Number of Plots per Cover Category by Year.

Cogongrass Cover (%)	2005	2006	2007
75-100	44	15	0
50-74	33	33	1
25-49	15	30	0
10-24	3	12	5
1-9	2	6	28
0	0	1	63

Table 3. Effect of Laurel Oak on Cogongrass Cover: Number of Plots per Cover Category.

Cogongrass Cover (%)	2005	2006	2007
75-100	55	42	11
50-74	17	24	19
25-49	3	10	20
10-24	1	0	19
1-9	0	0	6
0	0	0	1

Figure 2. Cogongrass Dying Under Wax Myrtle Canopy in 2007.

Cogongrass Shade Cloth Study

Shade cloth (woven black polyethylene rated at 51% and 73% shade) was installed December 14, 2004, on the top and sides of 10 ft × 10 ft × 5 ft high frames (plastic coated clothesline wire tautly suspended from braced 4-inch diameter PVC corner posts) in a stand of cogongrass on a sand-capped portion of a clay settling area at the IMC-Agrico Peace River Park (now the Mosaic Peace River Park) near Homeland, Florida. The 0% shade controls did not have shade cloth. There were three replicate plots per shade treatment. A zone around the outside of each plot was treated with glyphosate periodically to minimize possible effects of cogongrass plants outside the plots from contributing rhizomes to the plots or translocating photosynthate to plants in the plots. Shoot and root (mainly rhizomes) samples were collected March 26-28, 2007, and again on March 10-12, 2008. Tops were clipped at ground level from three 15 cm × 15 cm subplots per plot, and soil plus roots and rhizomes were collected from three 15 cm × 15 cm × 30 cm deep subplots per plot. Soil was washed from roots and rhizomes with a hose and screen. Shoots (above ground biomass) were bagged and dried over night in an oven at 75 °C, then cooled to room temperature and weighed. The roots and rhizomes were dried and weighed in the same manner.

Measurements of photosynthetic photon flux density (PPFD) made with a quantum sensor in March 2008 showed that the 51% shade treatment reduced PPFD by 56.3% compared to the unshaded check, and the 73% shade treatment reduced PPFD by 75.8% compared to the unshaded check.

Above-ground ("shoot") biomass was greater in March 2008 than in March 2007, but below-ground ("root") biomass was similar both years, especially in the shaded plots (Table 4). The results illustrate how shade can greatly reduce the below-ground rhizome and root biomass of cogongrass but also how cogongrass can persist under lower light conditions. It should be remembered that a real canopy of trees not only competes for light but also for soil water and nutrients. Leaf litter and roots may also produce inhibitory chemicals (allelopathy), which is particularly thought to be important with wax myrtle.

Table 4. Effect of Shade Cloth on Root and Shoot Biomass (Oven-Dry Weight g/sq m) of Cogongrass.

		Percent Shade		
		0	51%	73%
2007	Shoot	3278 (901)	1523 (425)	416 (90)
	Root	889 (136)	373 (32)	257 (47)
	Shoot:Root	3.69	4.08	1.62
2008	Shoot	4188 (689)	2120 (18)	914 (361)
	Root	712 (98)	407 (10)	268 (53)
	Shoot:Root	5.88	5.21	3.41

Means of 3 replicates (standard error in parentheses).

COGONGRASS CONTROL WITH HERBICIDES

Imazapyr and Glyphosate Herbicides for Cogongrass Control on a Sand Tailings Site Following Burning

The Tenoroc Fish Management Area, managed by the Florida Fish and Wildlife Conservation Commission, is a publicly owned property northeast of Lakeland in Polk County, Florida, that was formerly mined for phosphate. An area of dense cogongrass growth on a large sand tailings hill was burned on September 10, 2003, for removal of thatch and standing dead material. Glyphosate at 4.0 lb/acre (Roundup Pro 4 qt/acre) or imazapyr at 1.0 lb/acre (Arsenal 2 qt/acre) were applied with a tractor-mounted boom sprayer on November 13, 2003, to four large plots per treatment (each plot measured approximately 60 feet by 185 feet). Roundup Pro already contains a surfactant, but 0.5 oz surfactant (Activate Plus) per gallon was added to the Arsenal spray solution. On July 22, 2004, a line-point intercept cover survey was conducted to quantify regrowth of vegetation within the plots. A 200 foot measuring tape was stretched between two diagonal random points within each plot. At 2 ft intervals along the tape, plants intercepted by a point (the intersection of the foot marker and the edge of the tape) projected upward or downward was noted, resulting in a total of 100 data points per plot for percent cover estimates. The plots were subsequently reassessed using the same line-point intercept method on November 19 and 22, 2004.

Imazapyr (Arsenal) was clearly more effective in controlling cogongrass than was glyphosate (Roundup) (Table 5). Imazapyr has some soil residual, and the imazapyr treated plots were still nearly bare in mid July 2004 except for a small amount of hairy indigo. In contrast, several species, including cogongrass, were growing in the glyphosate treated plots. By November 2004, cogongrass cover was nearly 26% with the glyphosate treatment but less than 1% with imazapyr. Hairy indigo (*Indigofera hirsuta*), which appears to have some tolerance to imazapyr, had similar percent cover near 27% with either treatment. There was less natalgrass (*Melinis repens*) and torpedograss (*Panicum repens*) with imazapyr than with glyphosate.

Table 5. Percent Cover by Species at the Tenoroc Sand Tailings Hill Following Burning September 10, 2003, and Spraying with Glyphosate (4.0 lb/acre) or Imazapyr (1.0 lb/acre) November 13, 2003.

	July 2004		November 2004	
	Glyphosate	Imazapyr	Glyphosate	Imazapyr
Cogongrass	10.5 (3.8)	0.0 (0.0)	25.5 (4.2)	0.8 (0.8)
Hairy Indigo	7.8 (3.5)	3.3 (1.4)	26.8 (9.2)	27.0 (8.5)
Natalgrass	4.0 (2.7)	0.0 (0.0)	7.0 (2.6)	1.0 (0.7)
Passion Vine	5.3 (1.9)	0.0 (0.0)	4.8 (1.7)	3.0 (2.7)
Rustweed	3.3 (2.6)	0.0 (0.0)	2.3 (1.7)	5.3 (5.3)
Torpedograss	0.8 (0.8)	0.0 (0.0)	2.3 (1.9)	0.8 (0.5)

Data are means of 4 replicates (standard error in parentheses).
Glyphosate 4 lb/acre = 4 qt Roundup Pro/acre; imazapyr 1 lb/acre = 2 qt Arsenal/acre.

Fall Application of Herbicides to Cogongrass Regrowth Following Mowing at a Sand-Capped Clay Settling Area

The previous experiment examined the effects of glyphosate and imazapyr herbicides sprayed in November on cogongrass that had been burned in September. At a different site, imazapyr, glyphosate and fluazifop herbicides were sprayed at various rates in November on cogongrass that had been mowed in October. The mowing was done because the cogongrass was too tall to spray with a tractor drawn boom sprayer, and we also wondered how spraying regrowth following mowing would compare with spraying regrowth following burning.

Small Plots

An area of cogongrass on the southern end of a sand-capped clay settling area at the Mosaic Peace River Park (east of Homeland, Florida) was selected for a fall herbicide application of Fusilade DX (2.0 lb fluazifop butyl/gal) at 0.75, 1.0, 1.5 and 2.0 qt/acre (fluazifop butyl 0.375, 0.5, 0.875, 1.0 lb a.i./acre), Roundup Pro (4.0 lb glyphosate/gal) at 3, 4, and 5 qt/acre (glyphosate 3, 4, 5 lb a.i./acre) and Arsenal (2.0 lb imazapyr/gal) at 1, 2, and 3 qt/acre (imazapyr 0.5, 1.0, 1.5 lb a.i./acre). A nonionic surfactant at 0.5 oz per gallon was added to the Fusilade and Arsenal spray solutions but not to the Roundup Pro solutions because the Roundup product already contained a surfactant. The area had been burned in March 2003, but by the fall following the fire, cogongrass was considered to be too tall to spray with a boom sprayer. The cogongrass was mowed in October 2003 with the intention of spraying the regrowth. Herbicides were applied on November 13, 2003 to plots measuring 6.3 feet wide by 20 feet long by means of a CO_2 backpack sprayer (R&D Sprayers, model T), using a 4-nozzle boom (nozzle type XR0002; 18 inch spacing) calibrated using a flow rate of 40 gal/acre at 32 PSI pressure. The spray boom was held at a height of approximately 18 inches above the foliage. All treatments were replicated three times. Areas immediately to the south of each herbicide strip were untreated and designated as "check plots" for later comparisons with the sprayed vegetation. On June 17, 2004, line-point intercept data was collected on all plots for percent cover of regrowth. Three fiberglass reel measuring tapes were stretched along the 20 foot axis of each plot. Vegetation point intercepts at each whole foot mark were recorded, resulting in 60 data points per plot.

Although the herbicides initially appeared to kill the aboveground cogongrass foliage, by June of the following year the control was generally poor (Table 6). However, imazapyr was better than glyphosate, and glyphosate was better than fluazifop. The poor herbicide performance following mowing, compared to following a burn, may have been related to the abundant layer of cogongrass thatch after mowing, which intercepted the herbicide and protected any shoots that had not penetrated up through the grass clippings. In the case of Arsenal, which has both foliar and soil activity, the grass clippings may also have prevented much of the herbicide from reaching the soil. There is no thatch layer following a burn. In addition, the time between mowing and spraying in this trial was less than the time between burning and spraying in the previous experiment, so a difference in the regrowth may also have been a factor. It is usually recommended that Fusilade be applied to actively growing grasses in the summer for best results (see Table 16 for an example of better cogongrass control when Fusilade was sprayed in July).

Table 6. Percent Cover of Cogongrass in June 2004 Following Mowing in October 2003 and Spraying in November 2003 at the Peace River Park Clay Settling Area (Small Plots).

Rate (lb a.i./acre)	Check	Fluazifop	Glyphosate	Imazapyr
0	80.0 (2.7)	--	--	--
0.375	--	80.6 (2.0)	--	--
0.50	--	67.8 (2.2)	--	36.1 (8.6)
0.875	--	68.9 (3.1)	--	--
1.0	--	56.1 (3.1)	--	29.4 (9.4)
3.0	--	--	45.6 (6.3)	23.9 (2.9)
4.0	--	--	37.2 (9.4)	--
5.0	--	--	38.9 (6.4)	--

Means of 3 replicates (standard error in parentheses).

Large Plots

An area of cogongrass on the southern end of a sand-capped clay settling area at the Mosaic Peace River Park (near Homeland, Florida) was selected for a fall herbicide application of Roundup and Arsenal. The area was initially burned on March 19, 2003, as part of a controlled burn of the entire clay settling area. Subsequent cogongrass regrowth was mowed by Polk County Parks and Recreation staff in October 2003. Roundup Pro (4 lb glyphosate/gal) at 4 qt/acre or Arsenal (2 lb imazapyr/gal) at 2 qt/acre were applied with a tractor-mounted boom sprayer on November 21, 2003, to four large plots per treatment (each plot measured approximately 60 feet by 185 feet). The Arsenal spray solution also contained 0.5 oz nonionic surfactant (Activate Plus) per gallon.

On June 2 and 3, 2004, line-point intercept data were collected on all plots to estimate percent cover of regrowth. A fiberglass reel measuring tape was stretched along the long axis of each plot three separate times in three non-repetitive locations at a slight angle to avoid obvious tractor wheel tracks. Vegetation intercepts every three feet were recorded, resulting in 100 data points per plot.

Results in the large plots were similar to those of the small plots treated with the same rates of imazapyr or glyphosate in an adjacent area of the Peace River Park clay settling area. Cogongrass cover in June 2004 (following mowing in October 2003 and spraying in November 2003) was 36.8% with imazapyr (1.0 lb a.i./acre) and 42.0% with glyphosate (4.0 lb a.i./acre).

Efficient Use of Herbicides for Cogongrass Control

Imazapyr (Arsenal, Habitat, etc.) has been shown to be more effective in controlling cogongrass than has glyphosate (Roundup, Rodeo, etc.). However, imazapyr is much more expensive than glyphosate. To reduce cost, could the amount of imazapyr applied be reduced and the effectiveness of glyphosate increased (perhaps in a mixture of the two herbicides)? We had observed in preliminary studies on weed control in slash pine that sulfometuron (Oust, etc.) has some activity on cogongrass. Also, various herbicide labels and reports in the research literature suggest that use of a methylated seed oil (MSO) additive could, under some conditions (more mature leaf tissue, greater environmental stress), enhance effectiveness of imazapyr and glyphosate, compared to a non-ionic surfactant (NIS). In addition, we had observed in previous experiments that mowing prior to spraying of cogongrass regrowth was not as effective as burning prior to treatment of regrowth. What would be the difference between treating regrowth after mowing versus treating unmowed cogongrass?

On November 7, 2005, at the Peace River Park, cogongrass that had been mowed about 1.5 months earlier and unmowed cogongrass were sprayed with a two-person, hand-held 12 ft boom sprayer. Treatments are indicated in Tables 7 through 9. Percent cover was measured using the line-point method in June 2006 and in December 2006.

In June 2006 on the mowed plots, cogongrass control was greatest (percent cover least) in the 2 qt/acre Arsenal (1.0 lb/acre imazapyr) treatment, with no difference between the MSO or NIS additives (Table 7). The next best cogongrass control came from two treatments: (a) 1 qt/acre Arsenal + 2.2 qt/acre Rodeo (0.5 lb/acre imazapyr + 3.0 lb/acre glyphosate) treatment with 1% MSO or (b) 3.7 qt/acre Rodeo + 4.0 oz/acre Oust (5.0 lb/acre glyphosate + 3.0 oz/acre sulfometuron) with 1% MSO. Rodeo at 3.7 qt/acre (5.0 lb/acre glyphosate) with MSO gave the poorest cogongrass control. Hairy indigo was suppressed most by the 2 qt Arsenal treatment. The 3.7 qt/acre Rodeo + 4.0 oz/acre Oust treatment suppressed hairy indigo more than the 1 qt/acre Arsenal + 2.2 qt/acre Rodeo treatment. Fireweed (*Erechtites hieracifolia*) was most abundant following the 3.7 qt/acre Rodeo treatment, and the slight suppression of hairy indigo was probably due to greater competition from the more abundant cogongrass and perhaps the fireweed. There were no visual differences among treatments in the unmowed plots, so cover was not measured in June, but cogongrass control appeared to be more complete and broadleaf weeds were much fewer in the unmowed plots than in the previously mowed plots.

By December 2006 (13 months after treatment), cogongrass (48 to 90% cover) and hairy indigo control (88 to 95% cover) was poor in all treatments in the unmowed plots (Table 8), although cogongrass cover was lower with imazapyr treatment than with glyphosate. A comparison of Tables 8 and 9 clearly shows that control of cogongrass and hairy indigo was greater on the unmowed plots (Table 9) versus the previously mowed plots (Table 8) when evaluated 13 months after treatment. In the mowed plots (Table 8), cogongrass had nearly completely grown back in the Rodeo alone treatment. All the other treatments still showed some suppression of cogongrass (48-61% cover compared to 90% for Rodeo alone). Hairy Indigo cover was high with all treatments on the mowed plots. In the unmowed plots (Table 9), hairy indigo was only a minor component in any of the treatments. For the treatments with MSO additive, cogongrass control in the unmowed plots was still substantial (low cover) in the Arsenal treatment. The Arsenal + Rodeo treatment was the next best treatment after the Arsenal treatment, followed by Rodeo + Oust and the Rodeo alone treatments. Arsenal with MSO was better than the Arsenal plus NIS treatment in the unmowed plots (Table 9), but there was no difference with the MSO or the NIS in the mowed plots (Tables 7 and 8). Perhaps the NIS and MSO were equal in effectiveness on the more-lush regrowth following mowing, but the MSO may have been more effective on the older growth of the unmowed cogongrass.

Table 7. Effect of Herbicides Sprayed November 7, 2005, on Percent Cover of Cogongrass and Other Weeds in June 2006 at the Peace River Park (Mowed Mid-September 2005, 18-24 Inches Tall When Sprayed).

Rate (per acre)	Cogon-grass	Hairy Indigo	Fireweed	Litter + Bare
Arsenal 2 qt	8.9 (2.2)	25.6 (10.9)	0.0 (0.0)	65.6 (10.6)
Arsenal 1 qt + Rodeo 2.2 qt	20.0 (1.9)	78.9 (2.9)	0.0 (0.0)	13.3 (5.1)
Rodeo 3.7 qt	43.3 (1.9)	57.8 (4.4)	14.4 (2.9)	14.4 (2.9)
Rodeo 3.7 qt + Oust 4 oz	18.9 (4.8)	56.7 (5.8)	0.0 (0.0)	33.3 (0.0)
*Arsenal 2 qt + NIS	7.9 (2.9)	20.0 (3.3)	1.1 (1.1)	71.1 (4.8)

Means of 3 replicates (standard error in parentheses). *All treatments with 1% MSO in spray solution, except with 0.3% NIS, instead of MSO, as noted with asterisk (*).
3.7 qt Rodeo = 5 lb glyphosate. 2.2 qt Rodeo = 3 lb glyphosate. 2.0 qt Arsenal = 1.0 lb imazapyr. 1.0 qt Arsenal = 0.5 lb imazapyr. 4.0 dry oz Oust XP = 0.188 lb sulfometuron.

Table 8. Effect of Herbicides Sprayed November 7, 2005, on Percent Cover of Cogongrass and Hairy Indigo in December 2006 at the Peace River Park (Mowed Mid-September 2005, 18-24 Inches Tall When Sprayed).

Rate (per acre)	Cogon-grass	Hairy Indigo	Litter	Bare
Arsenal 2 qt	47.9 (4.2)	85.1 (13.2)	2.5 (1.4)	2.5 (1.4)
Arsenal 1 qt + Rodeo 2.2 qt	60.6 (10.6)	95.2 (2.8)	0.0 (0.0)	0.0 (0.0)
Rodeo 3.7 qt	90.1 (1.5)	88.4 (7.9)	0.0 (0.0)	0.8 (0.8)
Rodeo 3.7 qt + Oust 4 oz	51.6 (11.1)	87.9 (4.8)	3.2 (2.1)	0.0 (0.0)
*Arsenal 2 qt + NIS	54.2 (14.0)	93.2 (2.2)	1.7 (0.8)	0.0 (0.0)

Means of 3 replicates (standard error in parentheses).
*All treatments with 1% MSO in spray solution, except with 0.3% NIS, instead of MSO, as noted with asterisk (*). See Table 7 for product and active ingredient information.

Table 9. Effect of Herbicides Sprayed November 7, 2005, on Percent Cover of Cogongrass and Hairy Indigo in December 2006 at the Peace River Park (Unmowed Cogongrass, 36-42 Inches Tall When Sprayed).

Rate (per acre)	Cogon-grass	Hairy Indigo	Litter	Bare
Arsenal 2 qt	7.8 (2.0)	2.4 (2.4)	75.0 (0.9)	0.8 (0.8)
Arsenal 1 qt + Rodeo 2.2 qt	17.1 (6.3)	6.4 (3.0)	59.1 (4.1)	0.0 (0.0)
Rodeo 3.7 qt	39.1 (4.5)	4.7 (3.6)	59.3 (4.1)	1.6 (0.8)
Rodeo 3.7 qt + Oust 4 oz	39.1 (12.6)	2.4 (1.4)	51.2 (7.9)	0.0 (0.0)
*Arsenal 2 qt + NIS	28.7 (2.4)	3.8 (2.0)	63.7 (3.2)	0.0 (0.0)

Data are means of 3 replicates (standard error in parentheses). *All treatments with 1% MSO in spray solution, except with 0.3% NIS, instead of MSO, as noted with asterisk (*). See Table 7 for product and active ingredient information.

Herbicide and Adjuvant Effects on Cogongrass

The two main herbicides for control of cogongrass are imazapyr and glyphosate. New formulations of the herbicides plus various adjuvants or additives (surfactants, emulsified oils, water conditioners, or even other herbicides) may enhance their effectiveness for controlling cogongrass. Experiments at several sites were conducted to test various rates and combinations of chemicals on cogongrass control.

Peace River Park Cogongrass 2008-2009

The experimental area was selected on a sand-capped portion of a clay settling area at the Peace River Park, near Homeland, Florida, where cogongrass had grown to about 3 to 4 ft in height. Plot sizes were 12 ft wide by 40 ft long, with three replicates per treatment. Herbicide treatments included 5.0 lb glyphosate/acre, 0.75 lb imazapyr/acre and a tank mix of 4.0 lb glyphosate plus 0.5 lb imazapyr per acre. The glyphosate (AquaStar) and imazapyr (Arsenal) formulations used in the tests did not contain a surfactant. Different adjuvant systems, i.e., “Induce” non-ionic surfactant (NIS), “Agridex” crop oil concentrate (COC) or Agridex + water conditioner (“Quest”), were applied with the herbicides to compare the efficacy of different adjuvants versus our standard adjuvant treatment of 0.3% NIS alone. The treatments were applied with a two person 12 ft boom and CO_2 backpack sprayer at 32 PSI pressure, delivering 40 gal/acre. The experimental treatments were applied on July 22, 2008. Cogongrass cover was visually estimated on August 17, 2009. Cover in untreated areas was nearly 100%.

Previous research has indicated that cogongrass control is generally better if herbicide treatments are applied in the fall. In this experiment, control of cogongrass was good (low cover) 13 months after treatments containing imazapyr were applied in July (Table 10). Control (% cover of check minus % cover of treatment) was 95 to 99% (5% to 1% cover) with 0.75 lb imazapyr/acre or with 0.5 lb imazapyr + 4.0 lb glyphosate per acre, and there were no differences in the effects of the adjuvants with these treatments.

Control with 5.0 lb glyphosate per acre ranged from 78 to 94% (22% to 6% cover), depending on adjuvant. In this experiment, control with glyphosate was better with the non-ionic surfactant than with the crop oil concentrate. The water conditioner appeared to improve control (lower cover) when added to glyphosate + the crop oil concentrate. The apparent positive effect of the water conditioner on glyphosate efficacy in this experiment is in contrast to the lack of effect at the Chito Branch site (see Table 12 below); however, a higher rate of Quest water conditioner was used at the Peace River Park than at Chito Branch.

Table 10. Percent Cogongrass Cover at Peace River Park August 17, 2009, As Affected by Imazapyr and Glyphosate with Various Additives Sprayed July 22, 2008.

Rate (lb per acre)	Adjuvant %	% Cover
0.75 Imazapyr	0.3 NIS	4.7 (2.3)
0.75 Imazapyr	1.0 COC	1.0 (0.0)
0.75 Imazapyr	1.0 COC + 2.0 Quest	5.3 (1.7)
0.50 Imaz. + 4.0 Glyph.	0.3 NIS	1.2 (0.4)
0.50 Imaz. + 4.0 Glyph.	1.0 COC	4.7 (2.7)
5.0 Glyphosate	0.3 NIS	10.3 (2.6)
5.0 Glyphosate	1.0 COC	21.7 (4.4)
5.0 Glyphosate	1.0 COC + 2.0 Quest	6.0 (2.1)
Check		100

Unmowed cogongrass (40 inches tall).
Sprayed July 22, 2008.
Means of 3 replicates (standard error in parentheses).

Imazapyr and Glyphosate Formulation Effects on Control of Cogongrass (Hookers Prairie 2009-2010)

A site on overburden capped sand tailings was selected at the Mosaic Hookers Prairie Mine (Mosaic HP-2 Phase 1) located in Polk County about 1.5 miles southwest of the intersection of CR 630 and CR 555. Plot size was 15 ft × 20 ft (300 sq ft or 0.006887 acre). The cogongrass had not been mowed or burned and was about 36 inches tall. Plots were sprayed with a backpack sprayer using water with a pH of 7.7 and applied at the rate of 40 gallons per acre on September 28-29, 2009. There were three replicates of each treatment. Visual estimates of percent cogongrass cover were made on May 28 and on August 20, 2010. Cogongrass cover in adjacent non-treated areas was nearly 100%.

Eleven months after treatment, cogongrass cover was less (control was better) with imazapyr at 0.5 or 0.75 lb a.i./acre (1.0 qt or 1.5 qt Habitat/acre) than with glyphosate at 4 lb a.i./acre (3 qt AquaStar/acre) (Table 11). The effect of the Arsenal Powerline formulation did not differ from that of the Habitat formulation of imazapyr. When 4 lb glyphosate was added to 0.5 lb imazapyr per acre, cover appeared greater (control appeared less) than with 0.5 lb imazapyr per acre alone, although variability (as indicated by the standard error) was higher with this treatment, making a conclusion less certain. It is safe to say that adding glyphosate did not enhance control compared to imazapyr alone. Radiate, which contains kinetin and IBA hormones, had no effect on results of the glyphosate treatment.

Table 11. Percent Cogongrass Cover May or August, 2010, After Spraying Unburned Cogongrass on September 28, 2009, with Various Formulations of Imazapyr and Glyphosate and Additives.

Treatment (per acre)	5/28/10	8/20/10
1.5 qt Arsenal Powerline + 2.0% MSO (pH 6.7)	0.3(0.3)	0.3(0.3)
1.5 qt Habitat/acre + 2.0% MSO (pH 6.5)	0.3(0.3)	0.7(0.7)
1.0 qt Habitat/acre + 2.0% MSO (pH 6.5)	0.7 0.3)	2.7(1.2)
3 qt AquaStar + 1.0 qt Habitat + 2.0% MSO (pH 4.5)	2.0(1.5)	11.7(9.3)
3 qt AquaStar + 1.0% Phase II (pH 4.5)	7.7(2.3)	11.7(4.4)
3 qt AquaStar + 1.0% Phase II (pH 4.5) + Radiate 4.8 oz	8.0(7.0)	11.0 9.0)

Means of 3 replicates (standard errors in parentheses).
Unburned cogongrass approx. 36 inches tall when sprayed.
Solution pH values are indicated in parentheses.
Radiate contains IBA and kinetin.
3 qt AquaStar = 4 lb glyphosate/acre.
1.5 qt Habitat or Arsenal Powerline = 0.75 lb imazapyr/acre.
1 qt Habitat = 0.50 lb imazapyr/acre.

Glyphosate and Imazapyr Formulations and Adjuvants Effects on Control of Cogongrass (Chito Branch 2009-2010)

A cogongrass-infested site on former flatwoods soil that had been used for vegetable production was selected at Southwest Florida Water Management District's (SWFWMD) Chito Branch area, located in Hillsborough County about 4 miles southeast of Lithia, Florida. Plot size was 15 ft × 20 ft (300 sq ft or 0.006887 acre). The cogongrass had been burned on August 8, 2009, and had regrown to a height of about 30 inches when sprayed. Plots were sprayed on October 8, 2009, with a backpack sprayer using water with a pH of 7.7 and applied at the rate of 40 gallons per acre. There were three replicates of each treatment. Visual estimates of percent cover of cogongrass and broadleaved weeds were made in July, 2010, and estimates of cogongrass cover alone were made in October, 2010.

After twelve months, the treatments containing imazapyr (Arsenal Powerline or Habitat) generally had lower cogongrass cover (greater control) than did the glyphosate (AquaStar) treatments (Table 12). There were no differences between the Arsenal Powerline or Habitat formulations of imazapyr. The 0.5 lb imazapyr treatment (1.0 qt Habitat/acre) was similar to the 0.75 lb imazapyr treatment (1.5 qt Habitat/acre) and to the combination of 4 lb glyphosate (3 qt AquaStar) plus 0.5 lb imazapyr per acre. All the additives (0.3% NIS, 1% MSO, 2% MSO) resulted in the same cogongrass control with Arsenal Powerline. Radiate, which contains kinetin and IBA hormones, appeared to slightly enhance control with glyphosate in this trial, but it had no effect in a previous trial (see Table 11). The 1.0% Phase II adjuvant appeared to slightly enhance glyphosate efficacy compared to the 0.3% Induce NIS in the October assessment, although there was no difference in July.

Table 12. Effects of Glyphosate and Imazapyr Formulations and Adjuvants on Percent Cover (Visual Estimates) of Cogongrass and Broadleaf Weeds in July 2010 and Cogongrass in October 2010, Following Spray Treatments on October 8, 2009.

Treatment (per acre)	Broadleaf	7-12-10 Cogon.	10-4-10 Cogon.
AquaStar 3 qt + 0.3% NIS (pH 4.5)	68.3(3.3)	15.7(8.1)	23.3(6.7)
AquaStar 3 qt + 1.0% Phase II (pH 4.5)	73.3(4.4)	10.7(7.4)	14.3(8.5)
AquaStar 3 qt + Radiate 4.8 fl oz + 1.0% Phase II (pH 4.5)	71.7(6.0)	3.0(1.2)	8.0(4.0)
AquaStar 3 qt + Habitat 1 qt + 2% MSO (pH 4.5)	60.0(12.6)	0.3(0.3)	1.0(1.0)
Habitat 1 qt + 2% MSO (pH 6.5)	40.0(2.9)	0.0	2.0(1.2)
Habitat 1.5 qt + 2% MSO (pH 6.5)	31.7(9.3)	0.3(0.3)	1.3(0.7)
Arsenal Powerline 1.5 qt + 2% MSO (pH 6.7)	23.3(8.3)	0.0	1.3(0.9)
Arsenal Powerline 1.5 qt + 1% MSO (pH 6.7)	33.3(9.3)	0.0	1.3(1.3)
Arsenal Powerline 1.5 qt + 0.3% NIS (pH 6.7)	16.7(1.7)	0.0	1.7(0.9)

Means of 3 replicates (standard error in parentheses).
Cogongrass burned 8-8-09, approx. 30 inches tall when sprayed 10-8-09.
Solution pH values are indicated in parentheses.
3 qt AquaStar = 4 lb glyphosate/acre.
Radiate contains IBA and kinetin.
1.5 qt Habitat or Arsenal Powerline = 0.75 lb imazapyr/acre; 1 qt Habitat = 0.50 lb imazapyr/acre.

Effect of Water Conditioner on Glyphosate and Imazapyr Control of Cogongrass (Chito Branch 2009-2010)

A cogongrass-infested site on former flatwoods soil that had been used for vegetable production was selected at Southwest Florida Water Management District's (SWFWMD) Chito Branch area, located in Hillsborough County about 4 miles southeast of Lithia, Florida. The cogongrass had been burned on August 8, 2009, and had regrown to a height of about 36 inches when sprayed on October 29, 2009. Glyphosate (AquaStar 3.6 qt/acre) or imazapyr (Arsenal Powerline 1.8 qt/acre) with or without a water conditioner (0.5% Quest) were sprayed with an ATV mounted boom sprayer, and plot sizes were 10 ft × 80 ft. There were four replicates of each treatment. Percent cogongrass cover was visually estimated on each of four 10 ft × 20 ft subplots per treatment plot on July 29 and November 30, 2010.

All treatments gave good control of cogongrass (as indicated by low cover values) nine and thirteen months after treatment, but the imazapyr treatment was better than the glyphosate treatment (Table 13). The water conditioner (added to the solution before the herbicide) had no effect on herbicide performance at the rates applied. The solution pH values (included in parentheses after each treatment listed in the table) show that the water conditioner did reduce pH; however, the AquaStar formulation by itself reduced pH of the water from 7.7 to pH 4.5. Water conditioners have been shown in other research to enhance performance of lower rates of glyphosate by reducing deactivation effects of hard water. The relatively higher rates of glyphosate in this experiment plus the reduction in pH from the AquaStar formulation alone may have allowed sufficient active glyphosate in solution to make the water conditioner unnecessary.

Table 13. Percent Cogongrass Cover on July 29 and November 30, 2010, Following Treatment on October 29, 2009, with Glyphosate or Imazapyr (with or without a Water Conditioner; Cogongrass 36 Inches Tall).

Treatment (per acre)	July 29	November 30
AquaStar 3.6 qt (pH 4.5)	3.8 (0.7)	9.0 (1.5)
AquaStar 3.6 qt + 0.5% Quest (pH 4.0)	3.7 (0.7)	8.1 (1.4)
Arsenal 1.8 qt (pH 6.7)	0.6 (0.2)	2.4 (0.5)
Arsenal 1.8 qt + 0.5% Quest (pH 4.3)	0.2 (0.1)	1.1 (0.4)

All treatments with 1% MSO.
Mean values of 4 replicates per treatment and 4 subplots per replicate (standard error in parentheses).
Solution pH values are indicated in parentheses.
3.6 qt AquaStar = 4.86 lb glyphosate/acre.
1.8 qt Arsenal Powerline = 0.93 lb imazapyr/acre.
Quest is a water conditioner (pH buffer + ammonium sulfate).

Effects of Herbicide Tank Mix Partners on Glyphosate Control of Cogongrass (Chito Branch 2009-2010)

A cogongrass-infested site on former flatwoods soil that had been used for vegetable production was selected at the Southwest Florida Water Management District's (SWFWMD) Chito Branch area, located in Hillsborough County about 4 miles southeast of Lithia, Florida. Plot size was 15 ft × 20 ft (300 sq ft or 0.006887 acre). The cogongrass had been burned on August 8, 2009, and had regrown to a height of about 36 inches when sprayed. Plots were sprayed on November 16, 2009, with a backpack sprayer using water with a pH of 7.7 and applied at the rate of 40 gallons per acre. There were three replicates of each treatment. Percent cogongrass cover was visually estimated in May and July, 2010.

Adding Oust (sulfometuron) to glyphosate improved cogongrass control over the same rate of glyphosate alone (Table 14), which has also been observed in other experiments at the Alafia River State Park and at the Mosaic Peace River Park. The other herbicide additives did not improve glyphosate efficacy. Control with either rate of MAT 28 (aminocyclopyrachlor) alone was less than with glyphosate alone. In contrast, at the Alafia River State Park (see Table 15), MAT 28 at 4.5 oz/acre enhanced glyphosate activity, and MAT 28 at 9 oz/acre alone gave greater control than glyphosate alone. Quick observation at Chito Branch on November 30, 2010, indicated cover of cogongrass was about 40% with the Oust + AquaStar treatment and 80-95% with other treatments. Cogongrass control in this experiment was generally worse than in other experiments. The lower rate of glyphosate and perhaps the extended time after the burn may have been factors.

Table 14. Effect of Herbicide Additives to Glyphosate on Percent Cogongrass Cover (Visual Estimates) May 28 or July 29, 2010, Following Treatment on November 16, 2009 (36 Inches Tall).

Treatment (per acre)	5/28 Cover	7/29 Cover
Oust 4.5 oz + AquaStar 2.25 qt	2.3 (1.3)	11.7 (4.4)
Overdrive 4.5 oz + AquaStar 2.25 qt	14.3 (2.3)	41.7 (13.6)
AquaStar 2.25 qt	16.0 (2.1)	31.7 (9.3)
Mat 28 - 4.5 oz + AquaStar 2.25 qt	19.3 (0.7)	43.3 (12.0)
Mat 28 - 9 oz	41.7 (8.3)	71.7 (6.0)
Mat 28 - 4.5 oz	47.5 (2.5)	90.0 (5.8)

Means of 3 replicates (standard error in parentheses), all treatments with 1% MSO.
2.25 qt AquaStar = 3 lb glyphosate/acre.
MAT 28 = 50% aminocyclopyrachlor dry granular by weight.
Overdrive = 21.4% diflufenzopyr + 55.0% dicamba dry granular by weight.
Oust = 75% sulfometuron dry granular by weight.

Herbicide Additive Effects on Glyphosate and Imazapyr Control of Cogongrass (Alafia River State Park)

A cogongrass-infested site was selected on phosphate mined lands at the Alafia River State Park, located in Hillsborough County about 4 miles south of Pinecrest, Florida. Plot size was 15 ft × 20 ft (300 sq ft or 0.006887 acre). The cogongrass burned in a wildfire on November 9, 2009, and had regrown to a height of only about 8-12 inches when sprayed. Plots were sprayed on December 14, 2009, with a backpack sprayer using water with a pH of 7.7 and applied at the rate of 40 gallons per acre. There were three replicates of each treatment. Percent cover of cogongrass was visually estimated in April, May and July, 2010.

In general, cogongrass control with glyphosate alone, even at the higher 4 lb a.i./acre rate, was very poor (as indicated by higher cover values) (Table 15). This may be related to the relatively low leaf area (lower uptake dose), leaves still expanding (translocation from rhizomes to leaves during expansion versus translocation from leaves to rhizomes from fully expanded leaves) and slower metabolism in late fall (December 14 application date following November 9 burn). In contrast, control with imazapyr or imazapyr-containing herbicide mixtures was generally good. Arsenal at 1.5 qt/acre (0.75 lb imazapyr/acre) and 4.5 oz MAT 28 (2.25 oz aminocyclopyrachlor) + 1 qt Arsenal (0.5 lb imazapyr) per acre produced the greatest control of cogongrass. As in other experiments, Oust (sulfometuron) enhanced the effect of glyphosate on cogongrass control. Addition of Arsenal (imazapyr) also enhanced glyphosate efficacy. Addition of MAT 28 or Steadfast also enhanced glyphosate activity, but to a lesser extent than Oust or Arsenal. MAT 28 at 9 oz/acre alone gave better cogongrass control than did 3 or 4 lb/acre of glyphosate alone, which contrasts with the results at Chito Branch.

Table 15. Percent Cover of Cogongrass in 2010 as Affected by Glyphosate or Imazapyr with Various Additives Sprayed December 14, 2009.

Treatment (per acre)	4/23	5/28	7/29
Mat 28 9 oz	4.7 (2.7)	14.0 (3.1)	31.7 (4.4)
Mat 28 4.5 oz + Arsenal Powerline 1 qt	2.3 (0.3)	4.0 (1.0)	6.3 (2.3)
Arsenal Powerline 1.5 qt	2.0 (0.6)	2.3 (1.3)	8.0 (2.1)
Arsenal Powerline 1 qt + AquaStar 3 qt	5.0 (1.2)	6.3 (2.3)	15.0 (5.0)
AquaStar 3 qt	40.0 (7.6)	50.0 (7.6)	73.3 (3.3)
Oust 4.5 oz + AquaStar 2.25 qt	4.7 (2.7)	9.7 (5.5)	11.3 (5.2)
Arsenal Powerline 0.75 qt + AquaStar 2.25 qt	9.0 (3.1)	12.3 (3.9)	21.7 (7.3)
Mat 28 4.5 oz + AquaStar 2.25 qt	11.7 (1.7)	24.0 (4.0)	33.3 (6.7)
Steadfast 4.5 oz + AquaStar 2.25 qt	16.7 (4.4)	26.7 (3.3)	53.3 (3.3)
Overdrive 4.5 oz + AquaStar 2.25 qt	26.7 (6.7)	45.0 (2.9)	66.7 (6.7)
Matrix 4.5 oz + AquaStar 2.25 qt	38.3 (6.7)	41.7 (4.4)	68.3 (1.7)
AquaStar 2.25 qt	41.7 (8.3)	57.7 (5.0)	78.3 (1.7)
Untreated check	75	80	95

Data are means of 3 replicates (standard error in parentheses). All treatments with 1% MSO; rates are per acre.
2.25 qt AquaStar = 3 lb glyphosate/acre; 3 qt AquaStar = 4 lb glyphosate/acre.
1.5 qt Arsenal Powerline = 0.75 lb imazapyr; 1 qt Arsenal = 0.50 lb imazapyr; 0.75 qt = 0.375 lb.
MAT 28 = 50% aminocyclopyrachlor by weight; Overdrive = 21.4% diflufenzopyr + 55.0% dicamba by weight; Oust = 75% sulfometuron by weight Matrix = 25% rimsulfuron by weight.
Steadfast = 50% nicosulfuron + 25% rimsulfuron by weight.

Timing of Cogongrass Herbicidal Treatment Following a February Wildfire

A wildfire occurred at the Peace River Park on February 4, 2011. The event provided an opportunity to examine the effectiveness of cogongrass control from herbicide application on cogongrass regrowth through the late winter and spring at various time periods following the February fire. Several 15 ft × 20 ft plots were flagged. AquaStar at 3 qt/acre (4.0 lb glyphosate/acre) plus 1% MSO, or Polaris at 1.5 qt/acre (0.75 lb imazapyr/acre) plus 1% MSO, was applied with a backpack sprayer to cogongrass regrowth on three plots per herbicide treatment on March 2, March 23, April 14 and June 6, 2011. On each date, cogongrass height and cover (line point transect) were determined prior to treatment. Average untreated cogongrass height and percent cover were: 12 in and 56.8% on March 2; 12 in and 72.7% on March 23; 24 in and 85.2% on April 14; and 36 in and 84.1% on June 6. In addition, the same rates of glyphosate and imazapyr were sprayed in strips with an ATV mounted "boomless" sprayer on August 23, 2011. A second wildfire at the site occurred on March 21, 2012.

The longer-term cogongrass control was very poor to non-apparent in all the March and April treatments and in the June glyphosate treatment by the summer of 2012. Some reduction in cogongrass was still apparent in the June 2011 imazapyr treatment in 2012, but the level of control was unacceptable (70% cogongrass cover). In contrast, the August 2011 imazapyr strips treated with the ATV sprayer were still nearly devoid of cogongrass in the summer of 2012. The August 2011 glyphosate-treated strips exhibited better control than on other treatment dates (March to June) in the smaller plots, but control was much less than with imazapyr. By November 2012, all the backpack treated replicate plots, except one plot, had cogongrass cover the same as the untreated check plots—nearly 100% cover. One imazapyr treated plot from the June 2011 date had 50% cover of cogongrass and a heavy infestation of hairy indigo, which may have suppressed the cogongrass in that plot. In November 2012 in the ATV treated strips (sprayed August 2011), cogongrass cover was 100% for the glyphosate treatment, but ranged from 0% to 30% in the imazapyr treatments. These findings agree with our research and experience, and that of others, that control of cogongrass with imazapyr or glyphosate is most effective when the treatments are applied in the late summer and fall and poorest in late winter and spring. Long-term control of cogongrass is better with imazapyr than with glyphosate. In central Florida, we have observed good control when imazapyr treatments were applied from late July through December, with most reliable control in October and November. The period between late July and mid-November appears to give the best control of cogongrass with glyphosate. Fusilade (fluazifop) appears to work best on cogongrass from July through September.

SELECTIVE HERBICIDAL CONTROL OF COGONGRASS

Selective Cogongrass Control with Fusilade (Fluazifop) Herbicide in a Live Oak Planting

The Peace River Park Site was burned October 28, 2004. The site was sprayed with Arsenal (imazapyr) December 3, 2004, and sprayed again with Rodeo (glyphosate) July 7, 2005. Tubeling live oak were planted in rows spaced 8 ft apart (trees about 5 ft apart within each row) on August 12, 2005. The initial herbicide treatment was spotty with many skips, and although the following glyphosate treatment left the site apparently fairly free of weeds above ground at the time of tree planting, there were probably many cogongrass rhizomes still alive underground. Thus, the site had become heavily infested with cogongrass by 2008. On July 30, 2008, cogongrass was treated with 1.0 oz Fusilade DX per gallon + 0.3% Induce non-ionic surfactant (NIS) or 1.0 oz Fusilade DX per gallon + 1.0% methylated seed oil (MSO) with the "wand" ("gun") on an ATV. Each aisle between tree rows was considered a replicate, and there were aisles left as the untreated check. There were eight replicates of the Fusilade treatment with the NIS and six with the MSO.

Percent cogongrass control was visually evaluated one year later on July 30, 2009 (Table 16). Mean percent control for the Fusilade + NIS treatment was 96%, with a range of 94 to 99% (Mean cover 4%). Mean percent control for the Fusilade + MSO treatment was 90%, with a range of 88 to 92% (Mean cover 10%). The check plots had approximately 95% cover of cogongrass. The results suggest that the MSO adjuvant with Fusilade was certainly no better than the NIS adjuvant and perhaps that the NIS was slightly better than the MSO with Fusilade on cogongrass. In earlier studies, we found that Fusilade (fluazifop) was less effective in controlling cogongrass than was glyphosate or imazapyr; however, Fusilade has value in controlling or suppressing cogongrass in stands of trees because it is a grass-specific herbicide and does not injure the trees.

Although repeated treatment with Fusilade will probably be necessary, the competition provided by the trees probably enhanced the effectiveness of Fusilade, while the Fusilade treatment should reduce cogongrass competition and enhance tree growth. The Fusilade treated plots had abundant dog fennel (*Eupatorium capillifolium*), which may also have had an effect on inhibiting cogongrass but could also affect tree growth (see Table 1 and associated text).

Table 16. Cogongrass Control with Fusilade Herbicide in a Live Oak Planting.

	% Control	% Cover
1.0 oz Fusilade DX per gallon + 0.3% NIS	96.3 (0.6)	3.8 (0.6)
1.0 oz Fusilade DX per gallon + 1.0% MSO	90.0 (0.7)	10.0 (0.7)
Untreated Check	0	95

Tubeling live oak planted August 12, 2005.
Sprayed July 22, 2008.
Percent cogongrass control and cover visually evaluated July 30, 2009.
Data are mean values of 8 replicates with NIS and 6 replicates with MSO (standard error in parentheses).

Selective Control of Cogongrass in a Bahiagrass Stand with Imazapyr (Arsenal) Herbicide

The purpose of the experiment was to test the ability of low to moderate rates of Arsenal (imazapyr) herbicide applied in the late fall or early winter to selectively control cogongrass with minimal injury to established stands of bahiagrass. An area of mixed bahiagrass and cogongrass on the north-facing inner slope of a berm (comprised of sand tailings) of a sand-capped clay settling area at the Mosaic Peace River Park (east of Homeland, Florida) was selected for a pre-frost winter application of Arsenal. The area was visually divided into two zones: thick and thin cogongrass density. Areas immediately outside of the intended spray zones were designated as untreated "control" areas for later comparisons with the treated vegetation. Arsenal (2 lb imazapyr/gal) was applied at rates of 0, 12, 16, 24 and 32 fl oz/acre (0.19, 0.25, 0.38, and 0.50 lb imazapyr per acre) on December 4, 2003, to plots measuring 6.3 feet wide by 20 feet long by means of a CO_2 backpack sprayer (R&D Sprayers, model T), using a 4-nozzle boom (nozzle type XR0002; 18 inch spacing) calibrated with a flow rate of 40 gal/acre at 32 PSI pressure. The Arsenal spray solution also contained 0.5 oz surfactant per gallon. The spray boom was held at a height of approximately 18 inches above the foliage. All treatments were replicated three times. On June 11, 2004, line-point intercept data were collected on all plots for percent cover of regrowth. Three fiberglass reel measuring tapes were stretched along the 20 foot axis of each plot. Vegetation point intercepts at each whole foot mark were recorded, resulting in 60 data points per plot.

All the tested rates of Arsenal provided excellent control of cogongrass from December, 2003, through June, 2004 (Table 17). The data show that Arsenal caused some stunting or thinning of the bahiagrass, but the grass looked healthy in June 2004. The slight injury to bahiagrass with the 12 oz/acre rate should be an acceptable trade-off for cogongrass control. The 16 oz/acre rate may also be acceptable when applied in early

December, but injury was probably too great with the 32 oz/acre rate. The plots were not fertilized, and it is quite possible that fertilizer application could speed the recovery of bahiagrass following Arsenal treatment.

The experiment was repeated the following winter on plots adjacent to those used in 2003, except that 12 oz per acre of Plateau (0.19 lb imazapic/acre [2 lb imazapic/gal of Plateau]) was substituted for the 32 oz/acre Arsenal rate. Plots were sprayed January 4, 2005, and line-point transects were analyzed in August, 2005. Results were similar to those of the previous year. Arsenal at 12 oz/acre provided the least injury to bahiagrass while still providing good cogongrass control through August (Table 18). Higher Arsenal rates caused greater injury to bahiagrass while offering no greater control of cogongrass. Arsenal gave better control of cogongrass than Plateau. Plateau at 12 oz/acre applied in early January resulted in no reduction of bahiagrass cover by August. In contrast, Plateau has resulted in greater bahiagrass injury when applied during the active growing season, and seedling bahiagrass was nearly completely killed (Richardson and others 2003, Kluson and others 2000).

Table 17. Percent Cover of Bahiagrass and Cogongrass in June 2004 Following Arsenal Treatment December 4, 2003 (Burned March 2003).

Arsenal Rate	Low Cogongrass Infestation		Moderate Cogongrass Infestation	
(oz/acre)	Cogongrass	Bahiagrass	Cogongrass	Bahiagrass
0	2.8 (1.1)	51.1 (3.1)	13.3 (2.5)	55.6 (5.3)
12	0.0 (0.0)	42.2 (2.4)	0.0 (0.0)	42.8 (9.6)
16	0.0 (0.0)	28.3 (1.9)	0.0 (0.0)	35.0 (6.7)
24	0.0 (0.0)	23.9 (2.4)	0.6 (0.6)	16.1 (2.4)
32	0.0 (0.0)	10.6 (2.0)	0.0 (0.0)	3.9 (1.5)

Data are means of 3 replicates (standard error in parentheses).
12, 16, 24 and 32 oz Arsenal/acre = 0.19, 0.25, 0.38 and 0.50 lb imazapyr/acre.

Table 18. Percent Cover of Cogongrass and Bahiagrass in August 2005 at the Peace River Park (Burned March 2003, Sprayed January 4, 2005).

Rate	Moderate Cogongrass Infestation		Greater Cogongrass Infestation	
(oz/acre)	Cogongrass	Bahiagrass	Cogongrass	Bahiagrass
0	10.8 (5.8)	86.7 (1.7)	36.1 (16.8)	57.8 (13.9)
12 Arsenal	0.0 (0.0)	86.1 (3.4)	2.2 (0.6)	65.6 (3.1)
16 Arsenal	0.0 (0.0)	63.3 (8.3)	1.7 (0.9)	29.4 (11.2)
24 Arsenal	0.0 (0.0)	30.6 (3.6)	1.7 (0.0)	15.6 (3.9)
12 Plateau	2.8 (0.6)	87.2 (3.1)	22.2 (12.8)	57.8 (13.1)

Data are means of 3 replicates (standard error in parentheses).
12, 16 and 24 oz Arsenal/acre = 0.19, 0.25 and 0.38 lb imazapyr/acre.
12 oz Plateau/acre = 0.19 lb imazapic/acre.

Selective Weed Control with Imazapyr (Arsenal) in Mixed Native Plant Communities

We have done several experiments on selective weed control with imazapic (Plateau). Imazapyr is in the same family of chemicals as is imazapic, so we thought that low rates of imazapyr might also provide opportunities for selective weed control. We needed to find out which weeds or desirable (especially native) plants were susceptible and which were tolerant of various rates of imazapyr. Several experiments were conducted at Mosaic Company's Fort Green Mine on overburden soil that had been previously seeded with a variety of native species but subsequently had been invaded by several weed species, including cogongrass. Mosaic's site designation was PC-2, but it is also known as the "16 acre" site because that was the approximate acreage of the area seeded to native species. In one experiment, 12, 16, and 24 oz/acre rates of Arsenal (0.19, 0.25 or 0.38 lb imazapyr per acre) or Plateau (0.19, 0.25 or 0.38 lb imazapic per acre) (with 0.25% nonionic surfactant) were sprayed in October 2004 on plots dominated by cogongrass and *Pityopsis graminifolia*. Percent cover was determined the following July (2005) using line-point transects.

The data (Table 19) show that Arsenal is much more effective in controlling cogongrass than is Plateau and that *Pityopsis* is quite tolerant of both Arsenal and Plateau.

Table 19. Percent Cover at Fort Green "16 Acre" Site in July 2005 Following Spray Treatment in October 2004.

Rate (oz/acre)	Cogongrass	Pityopsis
12 Arsenal	4.6 (0.4)	30.8 (0.8)
16 Arsenal	0.8 (0.8)	34.6 (2.1)
24 Arsenal	0.0 (0.0)	40.0 (1.7)
12 Plateau	16.7 (2.5)	40.0 (15.8)
16 Plateau	26.7 (0.8)	31.3 (2.1)
24 Plateau	22.5 (2.5)	38.3 (5.8)

Data are mean values of 3 replicates (standard error in parentheses).
12, 16 and 24 oz Arsenal/acre = 0.19, 0.25 and 0.38 lb imazapyr/acre.
12, 16 and 24 oz Plateau/acre = 0.19, 0.25 and 0.38 lb imazapic/acre.

Tolerance of Plant Species to Imazapyr

In a more detailed experiment at the same Ft. Green site, two rates of Arsenal (12 and 16 oz/acre + surfactant) were sprayed on plots containing multiple species in November 2005 with the main objective of evaluating plant tolerances or susceptibilities. Plots were treated in areas that differed in degree of wetness or dryness. Permanently marked line-point transects were used to determine cover by plant species just before herbicide treatment in November 2005 and nine months after treatment in August 2006.

Many species had somewhat reduced cover in August following Arsenal treatment in November. Exceptions were *Paspalum notatum*, *Desmodium incanum* and *Helianthus angustifolius*, which were either unaffected or increased slightly in cover (Tables 20 and 21). Although wiregrass cover was reduced somewhat by Arsenal treatment in this experiment, the plants looked healthy, and this study combined with other tests indicate that wiregrass has some tolerance.

Table 20. Percent Cover Before Treatment in November 2005 with 12 or 16 oz/acre Arsenal Compared to 9 Months After Treatment (August 2006) at the Mosaic Fort Green Mine "16 Acre" Site (Drier Plots).

	12 oz/acre		16 oz/acre	
Species	Before	After	Before	After
Andropogon ternarius	3.1 (0.7)	4.2 (0.6)	5.1 (0.3)	2.8 (0.5)
Aristida beyrichiana	21.9 (1.4)	16.6 (0.8)	30.3 (6.5)	18.7 (3.9)
Cyperus spp	0.4 (0.2)	0.4 (0.2)	2.7 (0.6)	0.7 (0.3)
Desmodium incanum	16.4 (13.2)	15.1 (12.7)	17.9 (9.2)	21.4 (10.7)
Elyonuris tripsacoides	3.8 (2.5)	1.7 (1.1)	5.3 (1.2)	1.9 (0.6)
Eremochloa ophiuroides	15.1 (8.2)	3.5 (3.3)	0.0 (0.0)	0.1 (0.1)
Eryngium yuccifolium	1.1 (0.6)	0.4 (0.2)	0.6 (0.4)	0.0 (0.0)
Helianthus angustifolius	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Imperata cylindrica	0.4 (0.4)	0.0 (0.0)	3.3 (2.1)	0.0 (0.0)
Muhlenbergia capillaris	7.1 (4.8)	3.5 (2.9)	4.2 (1.5)	1.1 (0.6)
Paspalum notatum	44.7 (8.6)	50.6 (7.1)	47.4 (3.8)	56.3 (2.9)
Pityopsis graminifolia	32.1 (8.3)	12.8 (6.2)	31.7 (15.0)	10.1 (4.8)
Schizachyrium scoparium	4.4 (2.3)	4.9 (2.5)	3.6 (1.1)	2.6 (1.4)
Solidago stricta	1.8 (1.0)	1.4 (3.8)	4.2 (1.0)	2.5 (0.6)
Sporobolus indicus	5.0 (2.7)	6.0 (3.0)	2.9 (1.8)	3.9 (2.0)

Data are means of 3 replicates (standard error in parentheses).
12 and 16 oz Arsenal/acre = 0.19 and 0.25 lb imazapyr/acre.

Table 21. Percent Cover Before Treatment in November 2005 with 12 or 16 oz/acre Arsenal Compared to 9 Months After Treatment (August 2006) at the Mosaic Fort Green Mine "16 Acre" Site (Wetter Plots).

	12 oz/acre		16 oz/acre	
Species	Before	After	Before	After
Andropogon ternarius	2.4 (1.3)	3.1 (1.0)	4.2 (2.6)	4.2 (2.1)
Aristida beyrichiana	20.3 (4.1)	14.6 (6.0)	11.5 (7.3)	5.4 (3.9)
Cyperus spp	9.6 (5.4)	1.9 (0.8)	18.8 (3.4)	8.5 (2.0)
Desmodium incanum	1.0 (1.0)	2.2 (1.8)	2.4 (0.5)	0.1 (0.1)
Elyonuris tripsacoides	5.2 (2.6)	0.6 (0.4)	13.1 (3.0)	3.8 (1.3)
Eremochloa ophiuroides	4.4 (4.2)	2.4 (1.3)	0.0 (0.0)	0.3 (0.3)
Eryngium yuccifolium	5.0 (1.7)	1.5 (0.6)	8.1 (4.4)	1.4 (0.8)
Helianthus angustifolius	15.0 (2.8)	15.7 (4.6)	20.0 (5.5)	25.4 (3.5)
Imperata cylindrica	1.9 (1.9)	0.1 (0.1)	13.6 (2.5)	1.1 (0.9)
Muhlenbergia capillaris	5.7 (2.6)	0.9 (0.4)	8.6 (3.3)	0.6 (0.4)
Paspalum notatum	27.2 (10.1)	42.5 (16.5)	8.9 (2.0)	11.4 (3.2)
Pityopsis graminifolia	39.5 (7.3)	16.8 (3.7)	22.1 (11.1)	14.3 (6.8)
Schizachyrium scoparium	11.2 (1.9)	3.3 (1.8)	9.0 (4.7)	7.4 (3.2)
Solidago stricta	0.5 (0.3)	1.1 (0.5)	7.1 (2.3)	4.2 (2.1)
Sporobolus indicus	10.1 (4.9)	5.3 (2.6)	0.0 (0.0)	0.0 (0.0)

Data are means of 3 replicates (standard error in parentheses).
12 and 16 oz Arsenal/acre = 0.19 and 0.25 lb imazapyr/acre.

The 12 and 16 oz/acre rates of Arsenal were also sprayed at the Mosaic South Fort Meade Mine "PR-6" Site, which previously had received strips of topsoil removed from another site prior to mining. The site contained various native and non-native plant species at the time of treatment. Spray treatments were applied on August 31, 2005, or on November 31, 2005 (Tables 22 and 23). Permanently marked line-point transects were used to determine cover by plant species just before herbicide treatment and after treatment in August 2006.

At the South Fort Meade Mine, spraying Arsenal in November (Table 23) resulted in much reduced cover of cogongrass in the following August. The 16 oz/acre treatment had a stronger effect than the 12 oz/acre rate. *Galactia elliottii* and *Indigofera hirsuta* increased in cover following treatment. *Paspalum notatum* was only slightly affected by the November treatments, but there appeared to be a slight increase following the 12 oz/acre rate and a slight decrease following the 16 oz/acre rate. With the August spray treatment (Table 22), the 12 oz/acre rate resulted in increased cover one year later for *Aristida beyrichiana*, *Paspalum notatum*, and *Indigofera hirsuta*. At the 16 oz/acre rate, *Galactia elliottii* and *Indigofera hirsuta* increased in cover one year after the August treatment, but *Aristida beyrichiana* and *Paspalum notatum* decreased slightly in cover. *Dichanthelium scabriusculum* was severely injured by Arsenal at all dates and rates and nearly disappeared following treatment. *Eragrostis* appeared to increase slightly following August treatment with Arsenal but appeared to decrease slightly with the November application. *Chamaecrista nictitans* appeared to be injured by Arsenal in November, but the effect in August is not clear. *Cyperus* species are often weedy, but Arsenal (and also Plateau in other trials) provides control. Cogongrass cover was reduced by both rates of Arsenal but more so by the higher rate.

Table 22. Percent Cover Before Treatment (August 31, 2005) with 12 or 16 oz/acre Arsenal Compared to 12 Months After Treatment (August 2006) at the Mosaic South Fort Meade Mine "PR-6" Site.

	12 oz/acre		16 oz/acre	
Species	Before	After	Before	After
Andropogon ternarius	0.8 (0.6)	0.5 (0.5)	1.7 (1.7)	1.6 (1.6)
Aristida beyrichiana	18.3 (9.0)	17.2 (9.2)	16.4 (4.8)	13.6 (5.6)
Chamaecrista nictitans	1.9 (0.3)	0.9 (0.3)	1.7 (0.9)	2.7 (1.1)
Cyperus spp	8.4 (6.0)	0.8 (0.8)	2.2 (1.1)	0.6 (0.3)
Dichanthelium scabriusculum	11.3 (5.7)	0.0 (0.0)	8.4 (3.5)	0.0 (0.0)
Eragrostis spp	4.7 (0.3)	3.0 (0.9)	0.2 (0.2)	1.1 (0.6)
Galactia elliottii	0.0 (0.0)	3.3 (3.3)	0.0 (0.0)	18.4 (6.7)
Imperata cylindrica	28.0 (3.0)	7.2 (1.8)	45.0 (4.7)	4.4 (2.3)
Indigofera hirsuta	0.9 (0.4)	18.4 (2.6)	0.2 (0.2)	17.2 (4.7)
Paspalum notatum	35.3 (5.0)	40.3 (5.3)	35.0 (8.0)	25.5 (8.3)
Pityopsis graminifolia	0.0 (0.0)	0.0 (0.0)	0.2 (0.2)	0.6 (0.4)

Data are means of 3 replicates (standard error in parentheses).
12 and 16 oz Arsenal/acre = 0.19 and 0.25 lb imazapyr/acre.

The data suggest that wiregrass may be more tolerant of Arsenal in August than in November and, as expected, more tolerant of 12 oz/acre than 16 oz/acre. Fortunately, cogongrass seems to be more susceptible to Arsenal at these rates than is wiregrass, so some selective control is possible with broadcast application. Although several native species were injured, their presence following treatment also suggests that they will recover and eventually increase if competition from the non-natives is removed. Unfortunately, the non-native hairy indigo and bahiagrass are quite tolerant of Arsenal at these rates, and other means will be necessary to remove them from native plant communities. Cogongrass, although greatly reduced by modest rates of Arsenal, was not eradicated, and follow-up treatment will likely be needed.

Table 23. Percent Cover Before Treatment (November 31, 2005) with 12 or 16 oz/acre Arsenal Compared to 9 Months After Treatment (August 2006) at the Mosaic South Fort Meade Mine "PR-6" Site.

	12 oz/acre		16 oz/acre	
Species	Before	After	Before	After
Andropogon ternarius	1.1 (1.1)	1.4 (1.2)	0.9 (0.9)	0.0 (0.0)
Aristida beyrichiana	12.0 (2.9)	7.3 (2.2)	16.4 (10.4)	10.6 (6.6)
Chamaecrista nictitans	3.9 (1.4)	0.2 (0.2)	4.7 (1.3)	1.1 (0.6)
Cyperus spp	1.7 (0.6)	0.0 (0.0)	0.6 (0.3)	0.2 (0.2)
Dichanthelium scabriusculum	1.3 (0.3)	0.0 (0.0)	7.5 (1.7)	0.3 (0.2)
Eragrostis spp	3.6 (1.1)	2.0 (0.8)	2.2 (0.9)	0.5 (0.3)
Galactia elliottii	0.0 (0.0)	6.3 (5.2)	0.0 (0.0)	6.4 (3.5)
Imperata cylindrica	45.2 (5.7)	6.4 (3.1)	42.5 (5.5)	1.4 (0.6)
Indigofera hirsuta	4.7 (1.4)	15.9 (3.0)	1.7 (0.7)	15.9 (4.2)
Paspalum notatum	41.9 (9.1)	43.0 (9.2)	39.7 (3.9)	33.8 (3.8)
Pityopsis graminifolia	0.2 (0.2)	0.3 (0.3)	1.3 (1.3)	1.3 (1.3)

Data are means of 3 replicates (standard error in parentheses).
12 and 16 oz Arsenal/acre = 0.19 and 0.25 lb imazapyr/acre.

Selective Control of Cogongrass with Imazapyr in a Wiregrass Community

The purpose of the study was to examine the selective control of cogongrass and tolerance of wiregrass with imazapyr herbicide in the field. The specific aim was to determine an effective rate of imazapyr for good control of cogongrass while achieving acceptable and hopefully minor injury to wiregrass. This experiment included a higher rate of imazapyr than in previous selectivity tests.

The experiment was conducted at Mosaic's Fort Green Mine, area PC-2 (also known as the 16-acre site). Plots, each 10 ft × 20 ft, were selected that contained both wiregrass and cogongrass. Arsenal herbicide (isopropylamine salt of imazapyr 2 lb a.i./gal) was applied at rates of 12, 16 and 24 fl oz product per acre. The nonionic surfactant "Induce" was added to all the treatment solutions (0.5 fl oz/gal or 0.39%). The experiment was laid out as a randomized block design with three replications for each treatment. The treatments were applied with an ATV fitted with a compressed air driven sprayer. The spray boom had 7 flat fan nozzles (LUMARK 02F80) at a distance of 18 inches apart, and height was 1.5 ft above the cogon grass. The effective width of the spray swath was 10 ft. The sprayer was calibrated to deliver 40 gal/acre at 32 psi pressure. Percent cover of the plant species present in individual plots was determined with the line-point transact method on December 7, 2007, and again on August 26, 2008. The treatments were applied on December 17, 2007.

The results are generally similar to previous tests. In August, 8 months after treatment, wiregrass looked healthy in the 12 and 16 oz treatments, but there appeared to be more injury with 24 oz/acre (Table 24). The lower cover of wiregrass with 12 oz/acre than with 16 oz/acre is inconsistent with expectations based on previous tests (Table 24). As expected, cogongrass was controlled to a greater extent with 16 oz/acre than with 12 oz/acre. *Aeschynomene*, *Andropogon*, *Desmodium*, *Indigofera*, and *Pityopsis* persisted or increased after Arsenal treatment, indicating some degree of tolerance to these rates. *Paspalum* cover did not change after treatment and thus also showed some tolerance. Figure 3 shows an example of cogongrass and wiregrass on July 28, 2008, following treatment with 16 oz Arsenal/acre on December 17, 2007. The wiregrass looks healthy while the cogongrass foliage within the plot appears dead, in contrast with the healthy cogongrass that can be seen outside of the sprayed plot.

Table 24. Percent Cover Before Treatment (December 17, 2007) with 12, 16 or 24 oz/acre Arsenal Compared to 8 Months After Treatment (August 2008) at the Mosaic Fort Green Mine.

	12 oz/acre		16 oz/acre		24 oz/acre	
Species	Before	After	Before	After	Before	After
Aeschynomene americana	0.0(0.0)	9.6(5.1)	0.8(0.8)	9.6(6.7)	0.0(0.0)	14.2(10.6)
Andropogon spp	6.7(2.3)	7.9(5.6)	5.0(1.9)	16.3(4.3)	9.2(1.5)	20.0(5.5)
Aristida beyrichiana	51.7(6.9)	27.5(5.0)	58.8(14.4)	50.0(12.3)	64.6(8.4)	32.5(6.9)
Desmodium triflorum	2.9(2.3)	8.3(6.5)	0.4(0.4)	3.8(1.9)	0.8(0.4)	6.3(4.0)
Eremochloa ophiuroides	5.8(5.8)	10.8(10.8)	0.8(0.8)	0.0(0.0)	10.8(5.8)	0.4(0.4)
Imperata cylindrica	42.5(10.6)	18.8(2.9)	38.8(2.5)	6.3(3.3)	35.8(2.3)	3.8(3.2)
Indigofera hirsuta	0.8(0.8)	19.6(9.3)	1.3(1.3)	13.3(11.5)	1.7(1.1)	10.4(2.5)
Paspalum notatum	14.2(9.8)	15.0(11.3)	7.9(5.6)	7.5(6.9)	0.4(0.4)	3.3(0.3)
Pityopsis graminifolia	25.8(14.6)	32.9(18.5)	30.4(5.2)	26.3(7.3)	31.3(9.4)	27.1(13.4)
Leaf Litter	2.5(0.7)	24.2(1.8)	1.7(0.4)	22.9(4.6)	2.1(1.5)	35.0(10.0)

Data are means of 3 replicates (standard error in parentheses).
12, 16 and 24 oz Arsenal/acre = 0.19, 0.25 and 0.38 lb imazapyr/acre.

Figure 3. Cogongrass and Wiregrass on July 28, 2008 Following Treatment with 16 oz Arsenal/acre on December 17, 2007.

Imazapyr for Selective Control of Cogongrass Growing with Maidencane

We have observed that cogongrass is often green in central Florida while maidencane is in its dormant phase in the winter months. Thus, we may be able to control cogongrass with imazapyr without affecting maidencane. Therefore the study was conducted to examine two rates of imazapyr (16 and 24 oz Habitat product/acre [0.25 and 0.375 lb imazapyr/acre]) for selective control of cogongrass.

An area was selected where maidencane was growing adjacent to, and overlapping (or intermixing) with, cogongrass on Mosaic Company's PR-6 site, south of Fort Meade (east of U.S. Highway 17 and west of the Peace River) near the border of Polk and Hardee Counties. Maidencane was almost completely brown and dormant at the time of spraying (February 5, 2008), although some new shoots of maidencane were just emerging from the ground beneath the dead thatch. The plots were 10 ft × 20 ft and replicated three times for each treatment. Habitat herbicide was applied at 0, 16 or 24 fl oz product/acre (imazapyr 0.25 or 0.375 lb a.i./acre). A nonionic surfactant ("Induce" 0.5

oz/gal) was added to all the treatments. The experiment was laid out in a randomized block design. The treatment application was accomplished using an ATV with a 25 gallon motorized spray tank with an agitator for uniform mixture of the chemical. The ATV was fitted with a 10 ft spray boom with 7 flat fan nozzles (LUMARK 02F80) spaced 18 inches apart. The spray boom was mounted on the ATV at a height of 18 inches above the cogongrass. The wind velocity was low and did not affect the spray swath. The sprayer was calibrated to deliver water at 20 gal/acre. The application of the treatments was made on February 5, 2008.

At the time of treatment on February 5, 2008, the maidencane was mostly dormant, although we did find some plants beginning to sprout beneath the dormant thatch. Cogongrass had a mix of green and old, dead standing material. In the photograph taken August 27, 2008 (Figure 4), more than 6 months after treatment, maidencane on the left has survived and regrown well following treatment with Habitat at 16 fl oz/acre (imazapyr 0.25 lb a.i./acre), while the treated cogongrass on the right appeared dead. The untreated cogongrass is in the far right of the photograph.

Figure 4. Maidencane and Cogongrass on August 27, 2008, After Treatment with Habitat at 16 oz/acre on February 5, 2008.

COGONGRASS MANAGEMENT GUIDELINES AND RECOMMENDATIONS

Cogongrass is among the world's worst weeds. It infests thousands of acres in the southeastern United States, especially Florida, Alabama and Mississippi. It is a vigorous, rhizomatous perennial grass that is adapted to a wide range of soil fertility and moisture conditions in tropical and subtropical climates. It spreads by seed and by rhizomes. Tillage, mowing, grazing, biocontrol (insects or disease), fire, soil fertility management, plant competition (shade, etc.), and herbicides are among the management tools that might be used to help control cogongrass. Cogongrass is a vigorous competitor in its area of origin in Southeast Asia, so the likelihood of finding insect or disease organisms for biocontrol seems slim. Some research has been done on the use of fungi as bioherbicides, with some success in causing top kill of cogongrass, but with limited effect on the rhizomes. Unfortunately, the fungi do not seem to spread on their own, which would be a desirable trait for a true biocontrol organism. Thus, the fungi must be produced and sprayed, analogous to chemical herbicides.

Tillage

Repeated tillage can help manage cogongrass by bringing rhizomes to the surface and separating them from the soil to cause death by desiccation, by killing the tops to starve the plants, and by cutting rhizomes into pieces and promoting sprouting of the pieces. Plants are starved when rhizome reserves are depleted through regrowth of tops but sufficient leaf area is not allowed to replenish rhizome reserves via photosynthesis. The cutting of rhizomes into smaller pieces and their increased sprouting may reduce the number of dormant rhizome buds and increase the ratio of leaf area to rhizome and promote a greater dose of herbicide being translocated to the rhizomes. The chisel plow is probably the most cost-effective implement for separating rhizomes from the soil and bringing them to the surface for death by desiccation (most effective in the dry season). The rototiller is the next most effective implement, followed by the disk plow. A moldboard or turning plow tends to bury the rhizomes again.

Rolling or Flattening

Rolling or pressing of cogongrass swards to lay the plants flat upon the ground has been used in developing countries in Africa and Asia to help control cogongrass (see Terry and others 1997, Friday and others 1999, Bourgoing and Boutin 1987). Logs and barrels have been used to roll the cogongrass, and boards or planks have also been used to flatten the grass. The measure is temporary, particularly if the culms are broken in the process, so plants will resprout from rhizomes. However, the flattened swards of cogongrass are much less susceptible to wildfires, or at least the fires are less intense, and they do provide a thick mulch that will continue to control erosion and suppress other weeds. The concept has been tried in central Florida using a tractor drawn roller or using the tractor wheels alone. Because the cogongrass resprouts, herbicide application (glyphosate or imazapyr) has been necessary also. Herbicide has been sprayed immediately after rolling (either in a second separate operation or using a spray attachment behind the roller) or just prior to rolling (with a spray attachment mounted on the tractor before the roller). Spraying before rolling may provide better foliar coverage (both sides of the leaves) than after rolling (one side of the leaves with some portions of the leaves shielded by leaves on top of them). Breaking of the culms by rolling may reduce the amount of herbicide translocated to the rhizomes. The flattened cogongrass may also retard a soil-active herbicide such as imazapyr from reaching the soil.

Mowing, Grazing and Competition

Various factors or treatments may competitively inhibit cogongrass, or conversely, favor it. Some research has indicated that repeated mowing can tip the competitive balance between cogongrass and bahiagrass in favor of bahiagrass. Similarly, the application of lime and fertilizer may also tip the competitive balance in favor of bahiagrass. However, increased fertility may favor cogongrass over less vigorous species such as wiregrass. Grazing, superficially, might seem to be similar to mowing, but cogongrass is not very palatable except for new sprouts immediately following burning or mowing. Unless a cogongrass-infested pasture is intensively managed, livestock grazing could promote an increase in cogongrass as animals selectively choose more palatable plants. One aspect of managing plant competition that does work on controlling cogongrass is the shade provided by a dense tree or shrub canopy. Trees not only compete for light but also for moisture and nutrients. Wax myrtle is known to exude chemicals and competes through the process of allelopathy, in addition to shade effects.

Prescribed Fire

Fire is a force that has molded natural plant communities in Florida and is a tool often recommended for managing vegetation communities. Unfortunately, cogongrass is very tolerant of fire. The large quantity of fuel produced results in very hot fires that often destroy the trees and shrubs that could potentially compete with cogongrass. In other words, fire tends to favor cogongrass. The main value of fire is as a pretreatment to remove the standing dead matter often found in a field of mature cogongrass and to promote the production of green leaf tissue that is more susceptible to effective herbicide uptake. Mowing has been tried as a pre-treatment before applying herbicide to the regrowth; however, our research has shown that herbicidal control was better without mowing, even for a tall, old stand of cogongrass. Our hypothesis is that the large amount of thatch or “trash” following mowing may intercept herbicide and keep it from reaching the soil (important for root uptake with imazapyr) and may shield newer shoots and reduce foliar uptake of glyphosate or imazapyr. The flattened cogongrass following rolling may also inhibit herbicide contact with foliage and the soil. Standing dead cogongrass following herbicide treatment is still a wildfire hazard. Thus, there may be some value in rolling, mowing or tilling the dead cogongrass stand as part of a firebreak.

Chemical Control

Several chemical herbicides have some value in controlling cogongrass, including imazapyr (e.g., Arsenal, Habitat), glyphosate (e.g., Round-up, Rodeo), fluazifop-butyl (Fusilade), and sulfometuron-methyl (e.g., Oust). Imazapyr is the most effective herbicide for cogongrass and has both foliar and soil activity, including soil residual. Imazapyr at higher rates tends to be non-selective, but at lower rates it is selective, meaning some plants have greater tolerance than cogongrass. Glyphosate is the next most effective herbicide available. Glyphosate is non-selective but has no soil residual. Fluazifop-butyl is a grass herbicide that has little to no effect on most broadleaved plants. Fluazifop is not as effective as imazapyr or glyphosate but is useful when trying to control cogongrass in stands of young trees or other broad-leaved plants. The fluazifop tips the competitive balance in favor of the trees and herbaceous broadleaved plants, which in turn then help further suppress the cogongrass. Sulfometuron-methyl has been shown in our research to enhance the effectiveness of glyphosate when tank-mixed, and other researchers have reported sulfometuron enhancement of imazapyr as well.

Where possible in solid stands of cogongrass, we recommend burning in late summer to remove the standing dead matter and promote a flush of fresh green growth. The regrowth should be sprayed in the fall when it reaches a height of about 18 to 30 inches. The effectiveness of imazapyr and glyphosate on cogongrass has been shown to be greater in the fall than at other times of the year. This is hypothesized to be related to greater translocation of the absorbed herbicide to the rhizomes in conjunction with greater translocation of photosynthate to rhizome storage in the fall. We have had greater success when spraying taller cogongrass regrowth (up to 48 inches) than shorter (8-12 inches). We presume this is related to greater herbicide uptake because of greater leaf area and also to greater translocation to rhizomes from fully expanded mature leaves versus young expanding leaves that may initially draw reserves from the rhizomes. We recommend imazapyr rates of 0.75 to 1.0 lb of active ingredient (a.i.) per acre and 4.0 to 5.0 lb glyphosate a.i./acre. This is equivalent to 1.5 to 2.0 quarts of Habitat (or Arsenal) or 4.0 to 5.0 quarts of Round-up Pro (3.0 to 3.7 quarts Rodeo) per acre (or equivalent rates of other brands with equivalent ingredients). We have often observed percent control after one year approaching about 99% with imazapyr and about 75% with glyphosate. The soil residual of imazapyr not only provides more complete and longer control of cogongrass, but also suppresses other weeds longer than with glyphosate treatment. However, even with 99% control, follow-up treatment is needed. It is most certainly needed with 75% control. Because of no soil residual, follow-up treatment using glyphosate is desirable if there is an intention to plant soon after treatment. When imazapyr was applied in the fall, we observed no obvious signs of injury or inhibition when container plants were transplanted in the summer following treatment. We must stress the importance of coming as close to eradication of cogongrass as possible before planting permanent vegetation to help avoid the headaches of reinfestation from the remaining living rhizomes.

We have given some attention to improving herbicide effectiveness. Uptake and translocation are two avenues where effectiveness may be increased. Uptake is affected by several factors that include: the amount of green leaf area; various adjuvants such as surfactants; the concentration or amount of active herbicide reaching the leaves; and root uptake. Translocation to the rhizomes is affected by season of the year, as already mentioned, but also to the rate of kill of the leaves. Rapid kill of the leaves will tend to reduce translocation to the rhizomes, while slower leaf kill should allow greater translocation to the rhizomes. We have seen many recommendations for tank mixing glyphosate and imazapyr. We question the value of the practice. In our studies of lower rates of imazapyr (12 to 24 oz Habitat or Arsenal/acre) we often got cogongrass control equivalent to high rates of glyphosate (3 lb or more per acre). Adding imazapyr to glyphosate almost always improves cogongrass control, but adding glyphosate to imazapyr usually has no positive effect and may be detrimental. The apparent detrimental effect may be related to more rapid leaf kill with glyphosate that could reduce imazapyr translocation to the rhizomes. We feel this warrants further study, but currently think it may be a waste of herbicide in most cases to add glyphosate to even low rates of imazapyr to kill cogongrass. Lower rates of imazapyr (12 to 16 oz Habitat/acre) also selectively injure cogongrass more than several species in the legume family, the aster (or sunflower) family, pines and several grasses such as wiregrass, beardgrasses, lovegrasses, and bahiagrass. The tolerance of these plants to imazapyr is often greatest in the fall when cogongrass is most effectively controlled. For example, pines are more tolerant after their resting buds have set in the fall. As mentioned previously, research also indicates that sulfometuron enhances cogongrass control when tank mixed with glyphosate. We have not carefully examined the effects of sulfometuron alone on cogongrass, but pines have some tolerance.

The effects of urea ammonium nitrate (UAN), ammonium sulfate (AMS), and various other water conditioners, on herbicide uptake and preventing herbicide deactivation (e.g., hard water effects on glyphosate) are more important when optimizing effectiveness of lower rates of herbicide (especially glyphosate). They are less important if consistently higher herbicide rates are used. This also generally applies to use of non-ionic surfactants (NIS) versus methylated seed oils (MSO) or crop oil concentrates (COC). At 0.75 lb or more of imazapyr or 4.0 lb or more of glyphosate per acre, we generally have seen very little or no differences in the effects of the adjuvants, even with our hard water. We have occasionally observed greater effects with MSO than with NIS under suboptimal environmental and plant physiological conditions, but mostly the NIS additive has been sufficient for foliar applied herbicides.

Selective Chemical Control

Selective control (killing the target weed without killing desirable species) is affected by several factors: plant species or genotype, chemical type, rate of application, additives (e.g., surfactants), timing (season or growth stage), and directed application (e.g., ropewick to take advantage of height differences). We have found that at 12 to 16 fl oz per acre of Arsenal or Habitat (0.188 to 0.250 lb imazapyr per acre) several plant species exhibit tolerance while cogongrass is severely injured. The tolerant species include *Andropogon ternarius* (and other *Andropogon* species), *Aristida beyrichiana*, *Eragrostis spp*., *Galactia spp*., *Helianthus angustifolius*, *Liatris spp*., *Pityopsis graminifolia*, *Pinus elliottii*, and longleaf pine (*Pinus palustris)* (some stunting of the desirable native plants may occur but they recover following lower rates of imazapyr). Bahiagrass and bermudagrass (*Cynodon dactylon*) also have some tolerance. As previously mentioned, Fusilade (fluazifop butyl) is useful in controlling cogongrass without injuring young trees (including hardwoods and pines) or other broadleaved plants and seems to be most effective when combined with competition from trees (Fusilade is most effective on cogongrass and other grasses when they are actively growing in the summer). We have had some success in controlling cogongrass by spraying imazapyr (up to 0.38 lb a.i./acre) or glyphosate over the top of dormant maidencane, while cogongrass is still green and physiologically active. Surfactants increase herbicide effectiveness but may reduce selectivity (increase injury to tolerant plants). The Arsenal label recommends that no surfactant be added if the herbicide is sprayed over the top of pines.

Selective rates of 12 to 16 oz Habitat/acre were developed and tested with a calibrated boom sprayer in which the speed of travel and the flow rate were carefully controlled. This can be adapted to a backpack sprayer and "wand" or "gun." If, for example, a person with a backpack sprayer applies 40 gallons per acre, 12 to 16 fl oz of product per acre translates to 0.3-0.4 fl oz (9 to 12 ml) per gal. In practice, an applicator can spray cogongrass plants heavily while trying to minimize overspray on desirable plants. The relatively small amount of overspray should have only a small effect on those desirable plants that have some tolerance to imazapyr. Overspray from a non-selective herbicide, such as glyphosate (or perhaps imazapyr at a high rate), can be more damaging.

Caution must be used when applying herbicides for cogongrass control around trees. As previously stated, fluazifop-butyl is safe to use around trees and can even be sprayed over the top of most young trees with little or no injury. Glyphosate will injure or kill trees if sprayed on the foliage but can be sprayed on cogongrass beneath trees if contact with tree leaves or green stems is avoided. Because of root uptake, imazapyr may cause severe injury to many tree species if sprayed beneath their canopies and perhaps even a little beyond the drip-line. Pines have some tolerance to low rates of imazapyr, so with care it is possible to use imazapyr around pines.

COGONGRASS REFERENCES AND BIBLIOGRAPHY

Akobundu IO, Udensi UE, Chikoye D. 2000. Velvetbean (*Mucuna* spp.) suppresses speargrass (*Imperata cylindrica* (L.) Raeuschel) and increases maize yield. International Journal of Pest Management 46(2): 103-8.

Anoka UA, Akobundu IO, Okonkwo SNC. 1991. Effects of *Gliricidia sepium* (Jacq.) Steud and *Leucaena leucocephala* (Lam.) de Wit on growth and development of *Imperata cylindrica* (L.) Raeuschel. Agroforestry Systems 16(1): 1-12.

Aulakh JS, Enloe SF, Loewenstein NJ, Miller JH. 2010. Herbicide treatments targeting cogongrass eradication [abstract only]. Proc. South. Weed Sci. Soc. 63: 239.

Avav T. 2000. Control of speargrass (*Imperata cylindrica* (L) Raeuschel) with glyphosate and fluazifop-butyl for soybean (*Glycine max* (L) Merr) production in savanna zone of Nigeria. Journal of the Science of Food and Agriculture 80(2): 193-6.

Ayeni AO. 1985. Observations on the vegetative growth patterns of speargrass [*Imperata cylindrica* (L.) Beauv.]. Agr. Ecosyst. Environ. 13(3-4): 301-7.

Ayeni AO, Duke WB. 1985. The influence of rhizome features on subsequent regenerative capacity in speargrass (*Imperata cylindrica* (L.) Beauv.). Agr. Ecosyst. Environ. 13(3-4): 309-17.

Barnett JW, Byrd JD, Mask DB. 2001. Evaluation of 23 herbicides for control of cogongrass (*Imperata cylindrica*) [abstract only]. Proc. South. Weed Sci. Soc. 54: 63.

Barnett JW Jr, Byrd JD Jr, Mask DB. 2000. Efficacy of herbicides on cogongrass (*Imperata cylindrica*) [abstract only]. Proc. South. Weed Sci. Soc. 53: 227.

Barron MC. 2005. Residual herbicide impact on native plant restoration as an integrated approach to cogongrass management [MS thesis]. Gainesville (FL): University of Florida. 108 p.

Barron MC, MacDonald GE, Shilling DG, Fox AM, Comerford NB. 2005. The impact of imazapyr residues on native plant establishment [abstract only]. Proc. South. Weed Sci. Soc. 58: 248.

Barron MC, MacDonald GE, Brecke BJ, Shilling DG. 2003. Integrated approaches to cogongrass [*Imperata cylindrica* (L.) Beauv.] management [abstract only]. Proc. South. Weed Sci. Soc. 56: 158.

Bolfrey-Arku G, Onokpise OU, Coultas CC, Shilling D. 2002. Land preparation and legume cover crops for the biological control of cogongrass. In: Proceedings Soil and Crop Science Society of Florida 61: 4-9.

Bourgoing R, Boutin D. 1987. Method of controlling *Imperata* using light wooden rollers and establishing cover crops (*Pueraria*) in young hybrid coconut plantations in a village environment. Oleagineux 42(1): 19-23.

Brewer JS, Cralle SP. 2003. Phosphorus addition reduces invasion of a longleaf pine savanna (Southeastern USA) by a non-indigenous grass (*Imperata cylindrica*). Plant Ecology 167(2): 237-45.

Bryson CT, Koger CH. 2005. Effect of heat on cogongrass viability [abstract only]. Proc. South. Weed Sci. Soc. 58: 249.

Bryson CT, Carter R. 1993. Cogongrass, *Imperata cylindrica*, in the United States. Weed Technology 7(4): 1005-9.

Burnell KD, Byrd JD Jr, Meintis PD, Peyton BS, Burns BK. 2005. Seedhead management for cogongrass (*Imperata cylindrica*) [abstract only]. In: Proc. South. Weed Sci. Soc. 58: 252.

Burnell KD, Byrd JD Jr, Reddy KR, Meints PD. 2004. Phenological modeling of flower onset in cogongrass [*Imperata cylindrica* (L.) Beauv] [abstract only]. Proc. South. Weed Sci. Soc. 57: 321-2.

Burnell KD, Byrd JD Jr, Meints PD. 2003. Evaluation of plantgrowth regulators for cogongrass [*Imperata cylindrica* (L.) Beauv.] seed development and control [abstract only]. Proc. South. Weed Sci. Soc. 56: 342.

Burnell KD, Byrd JD Jr, Ervin G, Meints PD, Barnett JW Jr, Mask DB. 2003. Mowing and cultural tactics for cogongrass [*Imperata cylindrica* (L.) Beauv.] [abstract only]. Proc. South. Weed Sci. Soc. 56: 353.

Burns BK, Byrd JD, Chesser ZB, Taylor JM, Peyton BS. 2006. Cogongrass management using a Clearfield cropping system [abstract only]. Proc. South. Weed Sci. Soc. 59: 193.

Byrd JD. 2006. Deep-rooted issues: cogongrass ain’t a problem in Texas, so why should I care? [abstract only] Proc. South. Weed Sci. Soc. 59: 250.

Casini P, Vecchio V, Tamantiti I. 1998. Allelopathic interference of itchgrass and cogongrass: germination and early development of rice. Trop. Agr. 75(4): 445-51.

Chan TK, Lim SH, Tan HTW, Lim CP. 1999. Variation of bending capacity along the lamina length of a grass, *Imperata cylindrica* var. *major* (Gramineae). Annals of Botany 84(6): 703-8.

Chesser ZB, Byrd JD, Myers MT, Ivy DN. 2007. Evaluations of additives in herbicide applications for the control of cogongrass (*Imperata cylindrica* (L.) Beauv) with imazapyr [abstract only]. Proc. South. Weed Sci. Soc. 60: 196.

Chesser ZB, Byrd JD, Myers MT, Ivy DN. 2006. Enhancing control of cogongrass (*Imperata cylindrica* (L.) Beauv.) with imazapyr [abstract only]. In: Proc. South. Weed Sci. Soc. 59: 192.

Cheng K-T, Chou C-H. 1997. Ecotypic variation of *Imperata cylindrica* populations in Taiwan: I. Morphological and molecular evidences. Bot. Bull. Acad. Sin. 38(3): 215-23.

Chikoye D. 2003. Characteristics and management of *Imperata cylindrica* (L) Raeuschel in smallholder farms in developing countries. Chapter 2. In: Weed management for developing countries. FAO Plant Production and Protection Paper nr 120 (Add. 1). Rome (Italy): FAO Plant Production and Protection Division. ISBN 92-5-105019-8.

Chikoye D, Ekeleme F, Udensi UE. 2001. Cogongrass suppression by intercropping cover crops in corn/cassava systems. Weed Sci. 49(5): 658-67.

Chikoye D, Manyong VM, Ekeleme F. 2000. Characteristics of speargrass (*Imperata cylindrica*) dominated fields in West Africa: crops, soil properties, farmer perceptions and management strategies. Crop Prot. 19(7): 481-7.

Cooper A. 2007. Invasion continues… Exotic grass marches across Mississippi. Mississippi Landmarks 3(3): 10.

Collins AR. 2005. Implications of plant diversity and soil chemical properties for cogongrass (*Imperata cylindrica*) invasion in Northwest Florida [DPhil dissertation]. Gainesville (FL): University of Florida.

Cummings J, Reid N, Davies I, Grant C. 2005. Adaptive restoration of sand-mined areas for biological conservation. J. Appl. Ecol. 42(1): 160-70.

Derico TR. 1951. Experimental control of cogon (*Imperata cylindrica* (L.) Beauv.), water hyacinth (*Eichornia azurea* Kunth.), *Lantana camara* Linn., and other noxious weeds with 2, 4-D and other herbicides. The Philippine Agriculturist 34(4): 189-201.

Dickens R, Buchanan GA. 1975. Control of cogongrass with herbicides. Weed Sci. 23(3): 194-7.

Dickens R, Moor GM. 1974. Effects of light, temperature, KNO3, and storage on germination of cogongrass. Agron. J. 66(2): 187-8.

Dozier H, Gaffney JF, McDonald SK, Johnson ERRL, Shilling DG. 1998. Cogongrass in the United States: history, ecology, impacts, and management. Weed Tech. 12(4): 737-43.

Duever LC. 2008. Observations from the cogongrass conference: implications for research, management and control. Wildland Weeds 11(2): 5-8.

English R. 1998. The regulation of axillary bud development in the rhizomes of cogongrass (*Imperata cylindrica* (L.) Beauv.) [DPhil dissertation]. Gainesville (FL): University of Florida.

Eussen JHH. 1979. Some competition experiments with alang-alang [*Imperata cylindrica* (L.) Beauv.] in replacement series. Oecologia 40(3): 351-6.

Evans CW, Moorhead DJ, Bargeron CT, Douce GK. 2006. Field identification of cogongrass with comparisons to other commonly found grass species. Tifton (GA): The University of Georgia Bugwood Network. BW-2006-04. Available online at: http://www.cogongrass.org/cogongrassid.pdf

Evans CW, Moorhead DJ, Bargeron CT, Douce GK. 2006. Invasive plant responses to silvicultural practices in the South. Tifton (GA): The University of Georgia Bugwood Network. BW-2006-03. Available online at: http://www.invasive.org/silvicsforinvasives.pdf

Evans CW, Moorhead DJ, Bargeron CT, Douce GK. 2005. Identifying and controlling cogongrass in Georgia. Tifton (GA): The University of Georgia Bugwood Network. BW-2005-04.

Faircloth WH, Patterson MG, Miller JH. 2006. Integrated vegetation management of cogongrass (*Imperata cylindrica*) [abstract only]. In: Proc. South. Weed Sci. Soc. 59: 207.

Faircloth WH, Patterson MG, Teem DH, Miller JH. 2005. Integrated approaches to cogongrass control on highway rights-of-way: a four-year summary [abstract only]. Proc. South. Weed Sci. Soc. 58: 205.

Faircloth WH, Patterson MG, Miller JH, Teem DH. 2005. First-year herbicide release options for cogongrass control in loblolly pine plantations [abstract only]. Proc. South. Weed Sci. Soc. 58: 245.

Faircloth WH, Patterson MG, Teem DH, Miller JH. 2003. Cogongrass (*Imperata cylindrica*): management tactics on rights-of-way [abstract only]. Proc. South. Weed Sci. Soc. 55: 162.

Friday KS, Drilling ME, Garity D. 1999. *Imperata* grassland rehabilitation using agroforestry and assisted natural revegetation. Bogor, Indonesia: International Center for Research in Agroforestry, Southeast Asian Regional Research Programme. 166 p.

Gabel ML. 1982. A biosystematic study of the genus *Imperata* (Gramineae: Andropogoneae) [DPhil dissertation]. Ames (IA): Iowa State University.

Gaffney JF. 1996. Ecophysiological and technological factors influencing the management of cogongrass (*Imperata cylindrica*) [DPhil dissertation]. Gainesville (FL): University of Florida. 114 p.

Gaffney JF, Shilling DG. 1995. Factors influencing the activity of axillary buds in cogongrass (*Imperata cylindrica*) rhizomes. Proc. South. Weed Sci. Soc. 47: 182-3.

Garrity DP, editor. 1997. Special issue: Agroforestry innovations for *Imperata* grassland rehabilitation. Agroforestry Syst. 36(1-3): 1-274.

Garrity DP, Soekardi M, Van Noordwijk M, de la Cruz R, Pathak PS, Gunasena HPM, van So N, Huijun G, Majid NM. 1997. The *Imperata* grasslands of tropical Asia: area, distribution, and typology. Agroforest. Syst. 36(1-3): 3-29.

Ghosal S, Kumar Y, Chakrabarti DK, Lal J, Singh SK. 1986. Parasitism of *Imperata cylindrica* on *Pancratium biflorum* and the concomitant chemical changes in the host species. Phytochemistry 25(5): 1097-1102.

Hartemink AE. 2001. Biomass and nutrient accumulation of *Piper aduncum* and *Imperata cylindrica* fallows in the humid lowlands of Papua New Guinea. Forest Ecol. and Mgmt. 144(1-3): 19-32.

Holly DC., Ervin GN, Jackson CR, Diehl SV, Kirker GT. 2009. Effect of an invasive grass on ambient rates of decomposition and microbial community structure: a search for causality. Biological Invasions 11(8): 1855-68.

Holly DC, Ervin GN. 2006. Characterization and quantitative assessment of interspecific and intraspecific penetration of below-ground vegetation by cogongrass (*Imperata cylindrica* (L.) Beauv.) rhizomes. Weed Biol. and Mgmt. 6(2): 120-3.

Holzmueller EJ, Jose S. 2010. Response of cogongrass to imazapyr herbicides on a reclaimed phosphate-mine site in central Florida, USA. Ecological Restoration 28(3): 300-3.

Holzmueller EJ, Jose S. 2010. Invasion success of cogongrass, an alien C4 perennial grass, in the Southeastern United States: exploration of the ecological basis. Biological Invasions 13(2): 435-42.

Ivy DN, Byrd JD, Peyton BS, Taylor JM, Burnell KD. 2006. Evaluation of herbicides for activity on cogongrass [abstract only]. In: Proc. South. Weed Sci. Soc. 59: 196.

Johnson ERRL, Shilling DG, MacDonald GE, Gaffney JF, Brecke BJ. 2000. Time of year, rate of herbicide application, and revegetation: factors that influence the control of cogongrass (*Imperata cylindrica* [L.] Beauv.) [abstract only]. Proc. South. Weed Sci. Soc. 53: 70.

Johnson ERRL, Gaffney JF, Shilling DG. 1999. The influence of discing on the efficacy of imazapyr for cogongrass (*Imperata cylindrica* (L.) Beauv.) control [abstract only]. Proc. South. Weed Sci. Soc. 52: 165.

Johnson ERRL, Gaffney JF, Shilling DG. 1997. Revegetation as a part of an integrated management approach for the control of cogongrass (*Imperata cylindrica*) [abstract only]. Proc. South. Weed Sci. Soc. 50: 141.

Jose S, Cox J, Miller DL, Shilling DG, Merritt S. 2002. Alien plant invasions: the story of cogongrass in southeastern forests. J. Forest. 100(1): 41-4.

Ketterer EA, MacDonald GE, Ferrell JA, Boote KJ, Sellers BA. 2007. Cogongrass and torpedograss: rhizome manipulation with growth regulator herbicides [abstract only]. Proc. South. Weed Sci. Soc. 60: 201.

Ketterer EA, MacDonald GE, Ferrell JA, Barron MC, Sellers BA. 2006. Studies to enhance herbicide activity in cogongrass (*Imperata cylindrica* L. Beauv) [abstract only]. In: Proc. South. Weed Sci. Soc. 59: 205.

Ketterer EA, MacDonald GE, Ferrell JA, Boote KJ, Sellers BA. 2006. Growth regulators to maximize herbicide uptake in cogongrass (*Imperata cylindrica* L. Beauv) [abstract only]. Proc. Florida Weed Sci. Soc. 29: 2.

King SE, Grace JB. 2000a. The effects of gap size and disturbance type on invasion of wet pine savanna by cogongrass, *Imperata cylindrica* (Poaceae). Amer. J. Bot. 87(9): 1279-86.

King SE, Grace JB. 2000b. The effects of soil flooding on the establishment of cogongrass (*Imperata cylindrica*), a non indigenous invader of the southeastern United States. Wetlands 20(2): 300-6.

Koger CH, Bryson CT. 2003. Effect of cogongrass (*Imperata cylindrica*) residues on bermudagrass (*Cynodon dactylon*) and Italian ryegrass (*Lolium multiflorum*) [abstract only]. In: Proc. South. Weed Sci. Soc. 56: 341.

Kumar P, Sood BR. 1998. Renovation of *Imperata cylindrica* dominant natural grassland through the introduction of improved grass species. Indian J. Agron. 43(1): 183-7.

Kuusipalo J, Adjers G, Jafarsidik Y, Otsamo A, Tuomela K, Vuokko R. 1995. Restoration of natural vegetation in degraded *Imperata cylindrica* grassland: understory development in forest plantations. J. of Veg. Sci. 6(2): 205-10.

Lippincott CL. 2000. Effects of *Imperata cylindrica* (L.) Beauv. (cogongrass) invasion on fire regime in Florida sandhill. Nat. Areas J. 20(2): 140-9.

Loewenstein NJ, Miller JH, editors. 2007. Proceedings of the Regional Cogongrass Conference: a cogongrass management guide; 2007 Nov 7-8; Mobile, AL. Auburn (AL): Alabama Cooperative Extension System, Auburn University. 77 pp.

Lum AF, Chikoye D, Adesiyan SO. 2005. Effect of nicosulfuron dosages and timing on the postemergence control of cogongrass (*Imperata cylindrica*) in corn. Weed Tech. 19(1): 122-7.

Macdicken KG, Hairiah K, Otsamo A, Duguma B, Majid NM. 1997. Shade-based control of *Imperata cylindrica*: tree fallows and cover crops. Agrofor. Syst. 36(1-3): 131-49.

MacDonald GE, Brecke BJ, Gaffney JF, Langeland KA, Ferrell JA, Sellers BA. 2006. Cogongrass (*Imperata cylindrica* (L.) Beauv.) biology, ecology and management in Florida. Gainesville (FL): University of Florida. IFAS Extension Publication nr SS-AGR-52.

MacDonald GE. 2009. Cogongrass (*Imperata cylindrica*)–a comprehensive review of an invasive grass. In: Kohli RK, Jose S, Singh HP, Batish DR, editors. Invasive plants and forest ecosystems. Boca Raton (FL): CRC Press. p 267-94.

MacDonald GE, Ferrell JA, Langeland KA, Sellers BA. 2009. Integrated management of cogongrass (*Imperata cylindrica*) for bahiagrass pastures. Proceedings, Southern Weed Science Society and the Weed Science Society of America 61/49: 349.

MacDonald GE. 2004. Cogongrass (*Imperata cylindrica*)–biology, ecology, and management. Crit. Rev. Plant Sci. 23(5): 367-80.

MacDonald G, Barron M, Shilling D. 2003. Cogongrass (*Imperata cylindrica*) management utilizing integrated re-vegetation techniques. Presented at: Invasive plants in natural and managed systems: linking science and management, 7th International Conference on the Ecology and Management of Alien Plant Invasions; 2003 Nov 3-7; Ft. Lauderdale, FL. Poster Session: Tools for Managing Invasive Plants, Poster nr 105.

MacDonald G, Johnson ERRL, Shilling D, Miller DL, Brecke BJ. 2002. The use of imazapyr and imazapic for cogongrass (*Imperata cylindrica* (L.) Beauv.) control [abstract only]. Proc. South. Weed Sci. Soc. 55: 110.

MacDonald GE, Shilling DG, Meeker J, Charudattan R, Minno M, VanLoan A, DeValerio J, Yandoc C, Johnson ERRL. 2001. Integrated management of non-native invasive plants in Southeastern pine forest ecosystems—cogongrass as a model system. Final report to USDA Forest Service, Forest Health Technologies. Gainesville (FL): University of Florida, Institute of Food and Agricultural Sciences.

Mask DB, Byrd JD Jr, Barnett JW Jr. 2000. Efficacy of postemergence graminicides on cogongrass (*Imperata cylindrica*) [abstract only]. Proc. South. Weed Sci. Soc. 53: 225-6.

Mask DB, Byrd JD Jr, Barnett JW Jr. 2001. Will postemergent graminicides and mowing control cogongrass (*Imperata cylindrica*)? [abstract only] Proc. South. Weed Sci. Soc. 54: 63-4.

McDonald SK, Shilling DG, Bewick TA, Okoli CAN, Smith R. 1995. Sexual reproduction by cogongrass, *Imperata cylindrica* [abstract only]. Proc. South. Weed Sci. Soc. 48: 188.

McDonald SK, Shilling DG, Okoli CAN, Bewick TA, Gordon D, Hall D, Smith R. 1996. Population dynamics of cogongrass [abstract only]. Proc. South. Weed Sci. Soc. 49: 156.

Menz KM, Grist P. 1996. Increasing rubber planting density to shade *Imperata*: a bioeconomic modelling approach. Agrofor. Syst. 34(3): 291-303.

Miller JH. 2000. Refining rates and treatment sequences for cogongrass (*Imperata cylindrica*) control with imazapyr and glyphosate [abstract only]. Proc. South. Weed Sci. Soc. 53: 131-2.

Moosavi-Nia H, Dore J. 1979. Factors affecting glyphosate activity in *Imperata cylindrica* (L.) Beauv. and *Cyperus rotundus* L. II: effect of shade. Weed Res. 19(5): 321-7.

Myers MT, Byrd JD Jr, Peyton BS, Burns BK, Wright RS, Burnell KD. 2006. Should aboveground biomass be removed before herbicide applications for control of cogongrass [abstract only]. In: Proc. South. Weed Sci. Soc. 59: 197.

Myers MT, Byrd JD Jr, Ivy DN, Chesser ZB. 2006. Impact of tillage and tillage frequency on cogongrass (*Imperata cylindrica*) [abstract only]. In: Proc. South. Weed Sci. Soc. 59: 212.

Onokpise OU, Dueberry H, Reid L, Norcini J, Muchovej JJ, Bambo SK. 2007. Comparative studies on the control of cogongrass (*Imperata cylindrica* L.). J. Environ. Mon. & Rest. 3: 323-330.

Otsamo A, Adjers G, Hadi TS, Kuusipalo J, Vuokko R. 1997. Evaluation of reforestation potential of 83 tree species planted on *Imperata cylindrica* dominated grassland. New Forests 14(2): 127-43.

Otsamo A. 2002. Early effects of four fast-growing tree species and their planting density on ground vegetation in *Imperata* grasslands. New Forests 23(1): 1-17.

Otsamo R. 2000a. Early development of three planted indigenous tree species and natural understorey vegetation in artificial gaps in an *Acacia mangium* stand on an *Imperata cylindrica* grassland site in South Kalimantan, Indonesia. New Forests 19(1): 51-68.

Otsamo R. 2000b. Secondary forest regeneration under fast-growing forest plantations on degraded *Imperata cylindrica* grasslands. New Forests 19(1): 69-93.

Otsamo R. 1998. Effect of nurse tree species on early growth of *Anisoptera marginata* Korth. (Dipterocarpaceae) on an *Imperata cylindrica* (L.) Beauv. grassland site in South Kalimantan, Indonesia. For. Ecol. and Mgmt. 105(1-3): 303-11.

Otsamo A, Adjers G, Hadi TS, Kuusipalo J, Tuomela K, Vuokko R. 1995a. Effect of site preparation and initial fertilization on the establishment and growth of four plantation tree species used in reforestation of *Imperata cylindrica* (L.) Beauv. dominated grasslands. For. Ecol. and Mgmt. 73(1-3): 271-7.

Otsamo A, Hadi TS, Adjers G, Kuusipalo J, Vuokko R. 1995b. Performance and yield of 14 eucalypt species on *Imperata cylindrica* (L.) Beauv. grassland 3 years after planting. New Forests 10(3): 257-65.

Patterson DT. 1980. Shading effects on growth and partitioning of plant biomass in cogongrass (*Imperata cylindrica*) from shaded and exposed habitats. Weed Sci. 28(6): 735-40.

Patterson DT, Flint EP, Dickens R. 1980. Effects of temperature, photoperiod, and population source on the growth of cogongrass (*Imperata cylindrica*). Weed Sci. 28(5): 505-9.

Patterson M, Teem D, Faircloth W. 2004. Mapping, control, and revegetation of cogongrass infestations on Alabama right-of-way. Montgomery (AL)?: Alabama Department of Transportation. ALDOT research project nr 930-486. 58 p. Available online at: http://www.cogongrass.org/aldotreport.pdf.

Panggabean G, Soemartono, Mardjuki A. 1981. Some notes on *Salvinia* and *Imperata cylindrica*. In: Venkata Rao BV, editor. Proceedings of the 8th Asian Pacific Weed Science Society Conference; 1981 Nov 22-29; Bangalore, India. p 87-94.

Peet NB, Watkinson AR, Bell DJ, Sharma UR. 1999. The conservation management of *Imperata cylindrica* grassland in Nepal with fire and cutting: an experimental approach. J. Appl. Ecol. 36(3): 374-87.

Peytron BS, Byrd JD, Burnell KD, Burns BK, Myers MT. 2005. Cogongrass (*Imperata cylindrica* (L.) Beauv.) management using sequential applications of imazapyr and glyphosate [abstract only]. Proc. South. Weed Sci. Soc. 58: 246.

Peytron BS, Byrd JD, Burnell KD, Burns BK. 2003. Cogongrass (*Imperata cylindrica* (L.) Beauv.) control utilizing various application techniques and integrated management approaches. Presented at: Invasive plants in natural and managed systems: linking science and management, 7th International Conference on the Ecology and Management of Alien Plant Invasions; 2003 Nov 3-7; Ft. Lauderdale, FL. Poster Session: Tools for Managing Invasive Plants, Poster nr 105.

Ramsey CL, Williams R, Jose S, Zamora D. 2007. Cogongrass: second year results for a Chopper-adjuvant study [abstract only]. Proc. South. Weed Sci. Soc. 60: 198.

Ramsey CL, Jose S, Zamora D, Daneshgar P. 2006. Cogongrass control with Chopper and Glypro Plus when combined with Silwet L-77 and MSO concentrate [abstract only]. In: Proc. South. Weed Sci. Soc. 59: 204.

Ramsey CL, Jose S, Brecke BJ. 2005. Competitive effects of cogongrass on loblolly pine seedlings; second year results [abstract only]. Proc. South. Weed Sci. Soc. 58: 255.

Ramsey CL, Jose S, Miller DL, Cox J, Portier KM, Shilling DG, Merritt S. 2003. Cogongrass (*Imperata cylindrica* (L.) Beauv.) response to herbicides and disking on a cutover site and in a mid-rotation pine plantation in southern USA. For. Ecol. and Mgmt. 179(1-3): 195-207.

Richardson SG. 2008. Selective control of cogongrass and other weeds when restoring native plant communities on phosphate mined lands [abstract only]. Proc. South. Weed Sci. Soc. 61: 208.

Richardson SG. 2008. Selective control of cogongrass (*Imperata cylindrica*) and natalgrass (*Rynchelytrum repens*). In: Florida Exotic Pest Plant Council, 23rd Annual Symposium; 2008 Apr 21-24; Jacksonville, FL. p 20.

Richardson SG. 2008. Selective control of cogongrass and torpedograss. Presented at: 32nd Annual Meeting, The Florida Aquatic Plant Management Society; 2008 Oct 13-16; Daytona Beach, FL.

Rockwood DL, Carter DR, Stricker JA. 2008. Commercial tree crop production for phosphate mined land. Bartow (FL): Florida Institute of Phosphate Research. Publication nr 03-141-225.

Schuler JL, Robison DJ, Quicke HE. 2004. Assessing the use of Chopper herbicide for establishing hardwood plantations on a cutover site. South. J. Appl. Forest. 28(3): 163-70.

Shilling DG, Bewick TA, Gaffney JF, McDonald SK, Chase CA, Johnson ERRL. 1997. Ecology, physiology, and management of cogongrass (*Imperata cylindrica*). Bartow (FL): Florida Institute of Phosphate Research. FIPR Publication nr 03-107-140.

Soerjani M. 1970. Alang-alang, *Imperata cylindrica* (L.) Beauv., pattern of growth as related to its problem of control. Biol. Trop. Bull. 1: 88-96.

Soerjani M, Soemarwoto O. 1969. Some factors affecting germination of alang-alang *Imperata cylindrica* rhizome buds. PANS 15: 376-80.

Sriyani N, Hopen HJ, Balke NE, Tjitrosemito S, Soerianegara I. 1996. Rhizome bud kill of alang-alang (*Imperata cylindrica*) as affected by glyphosate absorption, translocation and exudation. BIOTROP Special Publication nr 58. p 93-105.

Tabor P. 1949. Cogongrass, *Imperata cylindrica* (L.) Beauv., in the southeastern United States. Agron. J. 41(6): 270.

Tamong B, Rockwood DL, Langholtz M, Maehr E, Becker B, Segrest S. 2008. Fast-growing trees for cogongrass (*Imperata cylindrica*) suppression and enhanced colonization of understory plant species on a phosphate-mine clay settling area. Ecol. Eng. 32(4): 329-36.

Tanner GW, Wood JM, Jones SA. 1992. Cogongrass (*Imperata cylindrica*) control with glyphosate. Florida Scientist 55(2): 112-5.

Tanner GW, Werner MR. 1986. Cogongrass in Florida: an encroaching problem. Gainesville (FL): University of Florida. Florida Cooperative Extension Service Fact Sheet nr WRS-5. 4 p.

Terry PJ, Adjers G, Akobundu IO, Anoka AU, Drilling ME, Tjitrosemito S, Utomo M. 1997. Herbicides and mechanical control of *Imperata cylindrica* as a first step in grassland rehabilitation. Agrofor. Syst. 36(1-3): 151-79.

Townson JK, Butler R. 1990. Uptake, translocation and phytotoxicity of imazapyr and glyphosate in *Imperata cylindrica* (L.). Raeuschel: effect of herbicide concentration, position of deposit and two methods of direct contact application. Weed Res. (Oxford) 30(4): 235-43.

Tu M, Rice B. 2002. Weed notes: *Imperata cylindrica* "Red Baron" (Japanese blood grass). [S.l.]: The Nature Conservancy Wildland Invasive Species Team. Available online at: http://www.cogongrass.org/impcyl01.pdf.

Udensi UE, Akobundu IO, Ayeni AO, Chikoye D. 1999. Management of cogongrass (*Imperata cylindrica*) with velvetbean (*Mucuna pruriens* var. *utilis*) and herbicides. Weed Tech. 13(2): 201-8.

Wang J, MacDonald GE, Ferrell JA. 2009. Investigations into mechanisms of cogongrass (*Imperata cylindrica*) competition and rhizome dormancy [abstract only]. Proc. South. Weed Sci. Soc. 62: 172.

Wibowo A, Suharti M, Sagala APS, Hibani W, Van Noordwijk M. 1996. Fire management on *Imperata* grasslands as part of agroforestry development in Indonesia. Agrofor. Syst. 36(1-3): 203-17.

Wilcut JW, Dute RR, Truelove B, Davis DE. 1988. Factors limiting the distribution of cogongrass, *Imperata cylindrica*, and torpedograss, *Panicum repens*. Weed Sci. 36(5): 577-82.

Wilcut JW, Truelove B, Davis DE, Williams JC. 1988b. Temperature factors limiting the spread of cogongrass (*Imperata cylindrica*) and torpedograss (*Panicum repens*). Weed Sci. 36(1): 49-55.

Willard TR, Gaffney JF, Shilling DG. 1997. Influence of herbicide combinations and application technology on cogongrass (*Imperata cylindrica*) control. Weed Tech. 11(1): 76-80.

Willard TR, Shilling DG, Gaffney JF, Currey WL. 1996. Mechanical and chemical control of cogongrass (*Imperata cylindrica*). Weed Tech. 10(4): 722-6.

Willard TR, Shilling DG. 1990. Influence of growth stage and mowing on competition between *Paspalum notatum* and *Imperata cylindrica*. Trop. Grasslands 24(2): 81-6.

Willard TR. 1988. Biology, ecology, and management of cogongrass (*Imperata cylindrica* (L) Beauv.) [DPhil dissertation]. Gainesville (FL): University of Florida.

Wright RS, Byrd JD. 2009. Potential new herbicides to add to Mississippi Department of Transportation's approved production list [abstract only]. Presented at: 2009 Weed Science Society of America Annual Meeting; 2009 Feb 9-13; Orlando, FL. Presentation nr 425.

Yager LY, Byrd J, Jones J, Miller DL. 2006. Effects of native species planted in herbicide-treated cogongrass (*Imperata cylindrica*) [abstract only]. In: Proc. South. Weed Sci. Soc. 59: 206.

Yandoc CB, Charudattan R, Shilling DG. 2004. Suppression of cogongrass (*Imperata cylindrica*) by a bioherbicidal fungus and plant competition. Weed Sci. 52(4): 649-53.

Yandoc C. 2001. Biological control of cogongrass, *Imperata cylindrica* (L.) Beauv. [DPhil dissertation]. Gainesville (FL): University of Florida.

Yandoc CB, Charudattan R, Shilling DG. 1999. Enhancement of efficacy of *Bipolaris sacchari* (E. Butler) Shoem., a bioherbicide agent of cogongrass [*Imperata cylindrica* (L.) Beauv.], with adjuvants [abstract only]. Weed Science Society of America Abstracts 39: 72.

CHAPTER 2: MANAGEMENT OF OTHER GRASSES

Chapter 1 addressed studies on cogongrass management. This chapter includes the results of research and demonstration studies on management of other weedy grasses, including natalgrass (*Melinis repens*, synonym: *Rhynchelytrum repens*), smutgrass (*Sporobolus indicus*), bahiagrass (*Paspalum notatum*), and torpedograss (*Panicum repens*). Bermudagrass (*Cynodon dactylon*) control was not specifically researched, but information was gained incidental to our other studies as we managed research plot areas.

Natalgrass (*Melinis repens*, synonym: *Rhynchelytrum repens*) is a native of Africa and has become a common invader on sand tailings, sandy overburden, disturbed sandy soils, and even on native upland scrub and sandhill habitats. With regard to its competitiveness, in the early 1990s we observed an abundance of natalgrass on areas at the IMC Phosphates (now Mosaic) Noralyn mine reclaimed with a top-dressing of topsoil from sandhill and scrub sites placed on overburden or sand tailings. Competition for moisture from the abundant natalgrass was suspected as an important factor in the poor survival of scrub oak that sprouted from roots carried in the topsoil that was placed over sand tailings, but this was not confirmed. This prompted us to examine the competitive effects of natalgrass and other weeds on the survival and growth of planted native trees and grasses. Subsequent FIPR research, as described in the following pages, has shown that natalgrass does indeed strongly compete with two important native plant species, sand live oak (*Quercus geminata*) and wiregrass (*Aristida beyrichiana*). Larger established scrub oaks should be able to compete well with natalgrass, but weed control efforts may be necessary to enable the young oaks to survive and become established. Although unlikely to be as great a problem as cogongrass, our research on plant competition indicates that natalgrass can indeed interfere severely with the reestablishment of native plants (Richardson and others 2003).

Bahiagrass (*Paspalum notatum*) and bermudagrass (*Cynodon dactylon*) are commonly used by the phosphate industry to provide longer-term ground cover and erosion control on reclaimed lands. Although effective for erosion control, these non-native turf grasses have been reported to inhibit or retard tree establishment and growth (Fisher and Adrian 1981, Whitcomb 1981, Bengtson and others 1973). Richardson and others (1994) observed that bermudagrass and bahiagrass were less detrimental to tree establishment and growth than the native saltbush (*Baccharis halimifolia*) or dog fennel (*Eupatorium capillifolium*), but these non-native grasses appear to be more problematic when establishing herbaceous native plant communities. Torpedograss (*Panicum repens*) and smutgrass (*Sporobolus indicus*) are problem weeds on reclaimed mined lands and other non-mined lands. Torpedograss is a problem in many wetlands and some uplands, while smutgrass is mainly a problem in uplands.

One approach for renovating native plant communities on reclaimed lands that have become infested with exotic weeds includes: (1) herbicides to control major weed infestations applied at appropriate rates and seasons; (2) burning to reinvigorate the native plants and promote flowering and seed production; (3) followed by pre-emergent herbicides applied to the soil shortly after the burn to inhibit weed seed germination (such as natalgrass). The burn, followed by application of a pre-emergent herbicide, is likely to be most effective in the early part of the rainy season when there is sufficient moisture to wash the herbicide into the top inch of soil. Many pre-emergent herbicides have no effect on the established perennial plants. A remaining question is: What rates and timing of application of pre-emergent herbicides will give effective suppression of weed germination after the burn but will result in sufficient dissipation of the herbicides to allow later germination of native seeds after they are shed in the late fall?

This chapter addresses the following topics:

- Herbaceous weed competition with wiregrass, lopsided indiangrass and sand live oak
- Post-emergent and pre-emergent herbicide studies on natalgrass in the greenhouse and field
- Herbicide studies on bahiagrass, smutgrass and torpedograss
- Selective control with imazapic herbicide in mixed species plant communities
- Native plant tolerance to herbicides
- Management guidelines for natalgrass, torpedograss, smutgrass, bahiagrass and bermudagrass

HERBACEOUS WEED COMPETITION STUDIES

Experiments were conducted to document competitive inhibition of two native grasses and a shrub when grown with several herbaceous weeds in the field on a dry sand tailings site. In addition, performance of sandhill and flatwoods ecotypes of wiregrass (*Aristida beyrichiana*) and lopsided indiangrass (*Sorghastrum secundum*) were compared on that well-drained sandy site.

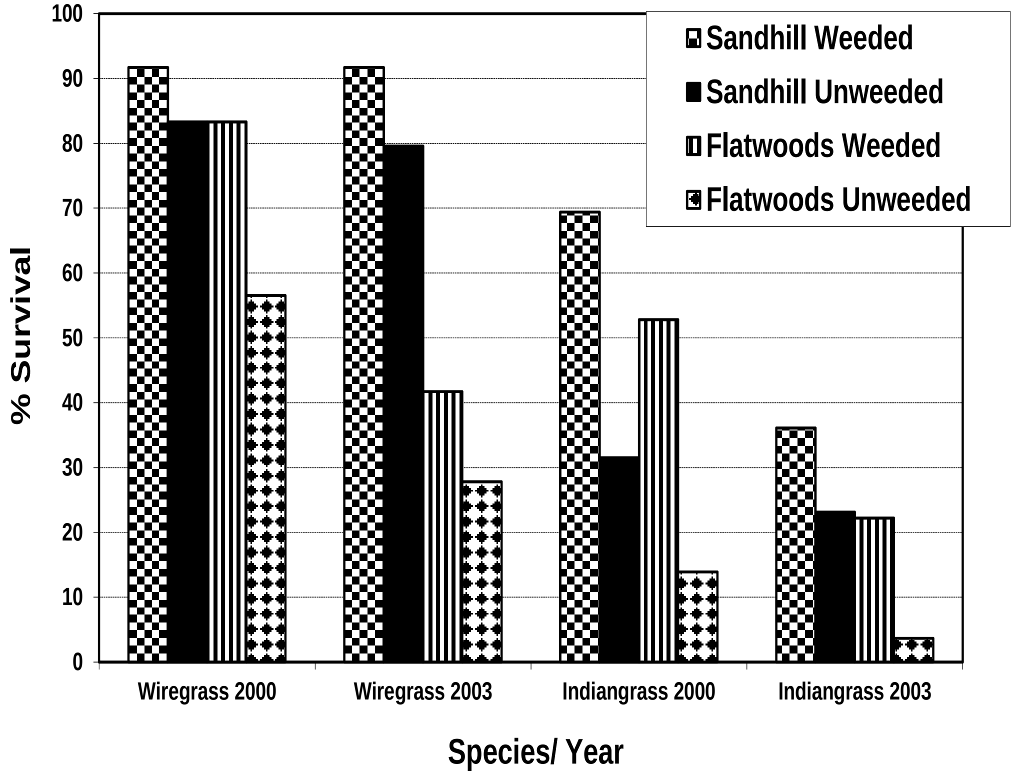
Weed Effects on Native Grasses

In the first experiment, seeds of wiregrass and lopsided indiangrass were planted in conical containers (4 cm maximum diameter, 15 cm high) containing potting mix (2 parts sand tailings: 2 parts peatmoss: 1 part perlite on a volume basis) in the spring of 1999 and grown in the greenhouse. There were four seed sources (collection locations): sandhill wiregrass, flatwoods wiregrass, sandhill lopsided indiangrass, and flatwoods lopsided indiangrass. The small container-grown grasses, referred to as "tubelings," were planted mid-September 1999 on a well-drained sand tailings hill at a former phosphate mine (now the Tenoroc Fish Management Area, northeast of Lakeland, FL, about 5 km south of Interstate 4 and about 3 km east of State Road [SR] 659). There were two weed treatments: (1) weeded—weeds (mainly natalgrass [*Melinis repens*] with some camphorweed [*Heterotheca subaxillaris*]) removed by hoeing and by hand-pulling just prior to planting tubelings and then periodically during the first year; (2) unweeded—weeds were left. Plants were spaced 0.5 m apart, 9 plants per ecotype per replicate and 4 replicate locations. Tubelings were watered approximately weekly through November 1999, unless there was sufficient rain. Percent survival was determined September 2000 and September 2003.

In the second experiment, tubelings of an upland ecotype of wiregrass were obtained from the Florida Division of Forestry in Chiefland, Florida (seed collected near Wekiva Springs, west of Orlando). The tubelings were planted, in the same manner as indicated above, in September 2002 at the Tenoroc Fish Management Area sand tailings site in three areas—dominated by either natalgrass (*Melinis repens*), smutgrass (*Sporobolus indicus*) or camphor weed (*Heterotheca subaxillaris*). There were four replicates of weeded and unweeded treatments per weed type. Weeds were removed by hoeing and by hand-pulling just prior to planting the tubelings and then periodically during the first year. Tubelings were watered approximately weekly through November 2002, unless there was sufficient rain. Percent survival, percent of plants flowering, and basal diameter were determined in October 2003.

At the Tenoroc sand tailings site, weed (primarily natalgrass) removal enhanced survival and growth of wiregrass and lopsided indiangrass planted as tubelings (Figure 5, Table 25). In addition, wiregrass had greater survival than lopsided indiangrass in this droughty, well-drained sandy habitat at Tenoroc, and the sandhill ecotype of either species had better survival than the flatwoods ecotype of the same species. In the second study, basal diameter growth and flowering of upland wiregrass one year after planting of tubelings on sand tailings were greatly increased by removal of natalgrass, smutgrass or camphorweed (Table 26).

The study documented the detrimental effects that established stands of weeds such as natalgrass, smutgrass and camphorweed can have on wiregrass tubeling transplants and also the effects of natalgrass on lopsided indiangrass. The effects would be greater if the wiregrass were germinating from seed in the field (e.g., reproduction from established wiregrass parent plants); however, at a newly disked and seeded site, both the weeds and the wiregrass would become established together, thus initial competition from more widely spaced plants would be less.



Note: Mean values of four replicates.

Figure 5. Percent Survival of Sandhill and Flatwoods Ecotypes of Wiregrass and Lopsided Indiangrass As Affected by Weed Removal ("Weeded" Treatment).

Table 25. Basal Diameter (cm) of Sandhill and Flatwoods Ecotypes of Wiregrass and Lopsided Indiangrass As Affected by Weed (Mainly Natalgrass) Removal.

	2001	2003
Wiregrass		
Sandhill Weeded	13.1 (1.4)	15.6 (1.8)
Sandhill Unweeded	5.2 (0.3)	7.6 (0.7)
Flatwoods Weeded	6.5 (0.9)	5.6 (1.2)
Flatwoods Unweeded	2.2 (0.2)	2.7 (0.8)
Lopsided Indiangrass		
Sandhill Weeded	6.9 (1.3)	8.0 (0.9)
Sandhill Unweeded	5.2 (0.7)	10.2 (1.2)
Flatwoods Weeded	6.4 (5.2)	7.5 (3.5)
Flatwoods Unweeded	2.0 (0.9)	7.9 (2.5)

Tubelings planted September 1999. Watered weekly until October 29, 1999. Weeds removed periodically from "weeded" plots through July 27, 2000. Mean values of 4 replicates (standard error in parenthesis).

Table 26. Weed Effects on Wiregrass (*Aristida beyrichiana*) Tubelings Planted on Sand Tailings in September 2002 and Evaluated in October 2003.

Weed Species	Basal Diameter (cm)	Flowering (%)	Survival (%)
Natalgrass			
Weeded	7.4 (0.3)	53.5 (5.4)	86.0 (2.0)
Unweeded	3.7 (0.1)	0.0 (0.0)	95.2 (2.3)
Smutgrass			
Weeded	6.3 (0.2)	32.8 (3.7)	68.0 (6.7)
Unweeded	3.4 (0.1)	0.0 (0.0)	66.0 (7.4)
Camphorweed			
Weeded	6.9 (0.4)	39.7 (6.7)	89.0 (9.2)
Unweeded	4.7 (0.1)	0.0 (0.0)	94.0 (2.0)

Weeded = weeds removed.
Mean values of 4 replicate plots (standard error in parentheses).

Weed Effects on Sand Live Oak

The Tenoroc Fish Management Area, managed by the Florida Fish and Wildlife Commission (FWC), is a public-owned property northeast of Lakeland in Polk County, Florida. The area was formerly mined for phosphate.

Nearly pure stands of centipedegrass (*Eremochloa ophiuroides*), natalgrass, smutgrass, and bahiagrass were selected for studies of weed competition with sand live oak (*Quercus geminata*) on a sand tailings hill at the Tenoroc Fish Management Area in late August 2002. Plots (3 m × 3 m) were marked with corner flags, and plot treatments were designated as "vegetated (with weeds)" or "vegetation removed (weed-free)"; all treatments were replicated four times for each of the weedy species. Plots denoted as "weed-free" were initially sprayed on August 28-30, 2002, with Roundup Pro (4 lb glyphosate/gal) (100 mL/gal + 15 mL/gal of Activate Plus surfactant) applied to wetness with Solo backpack sprayers. Small "tubeling" (2-inch diameter × 4-inch deep root mass) sand live oak (*Quercus geminata*) were obtained from RSS Field Services and were planted on September 11, 2002, by FIPR staff using PVC corer-style tubeling planters. Trees were spaced 1 meter apart (with 0.5 meter outer borders in the "weed-free" plots). Although it rained at Tenoroc on the planting dates, the period immediately following planting was low in rainfall. Watering of newly planted trees was done approximately 15 times between September 19 and December 6, 2002. Water was delivered from barrels via garden hoses pressurized by submersible bilge pumps powered off the truck battery. "Weed-free" treatments were maintained by hand weeding and hoeing on a monthly or as-needed basis. Cogongrass and passion vine that infested the weed-free plots were treated twice with carefully directed glyphosate applications.

A survival survey was taken on June 19, 2003, and any dead or severely damaged trees were replaced on that same date. Individual replacements were listed in the project logbook. Tree heights and crown diameters (average of north-south and east-west diameters) were measured on March 11, 2004, and January 18, 2005.

Table 27 shows that removal of centipedegrass, natalgrass, smutgrass, and bahiagrass greatly improved the growth of sand live oak. Survival was also improved by grass removal. These results, along with those in Table 25 and Figure 5, illustrate the importance of weed control in the early establishment phase on a dry sand tailings site.

Table 27. Mean Height, Crown Diameter and Percent Survival of Sand Live Oak As Affected by Removal of Centipedegrass, Natalgrass, Smutgrass, and Bahiagrass at the Tenoroc Sandhill After the 2004 Growing Season (Tubelings Planted 2002).

		Height (cm)	Crown Dia. (cm)	Percent Survival
Centipedegrass	With weeds	17.8 (1.7)	3.0 (1.0)	27.8 (7.2)
	Weed-free	35.3 (2.6)	18.0 (2.5)	97.2 (2.8)
Natalgrass	With weeds	22.8 (1.5)	4.3 (0.9)	77.8 (0.0)
	Weed-free	44.4 (2.3)	27.3 (2.3)	86.1 (7.0)
Smutgrass	With weeds	17.0 (1.9)	4.0 (0.7)	52.8 (7.0)
	Weed-free	48.4 (3.4)	25.8 (3.9)	83.3 (7.2)
Bahiagrass	With weeds	23.8 (3.5)	5.0 (1.7)	80.6 (9.5)
	Weed-free	69.9 (0.7)	35.8 (2.5)	91.7 (5.3)

Mean values of 4 replicate plots (standard error in parentheses).

HERBICIDE STUDIES

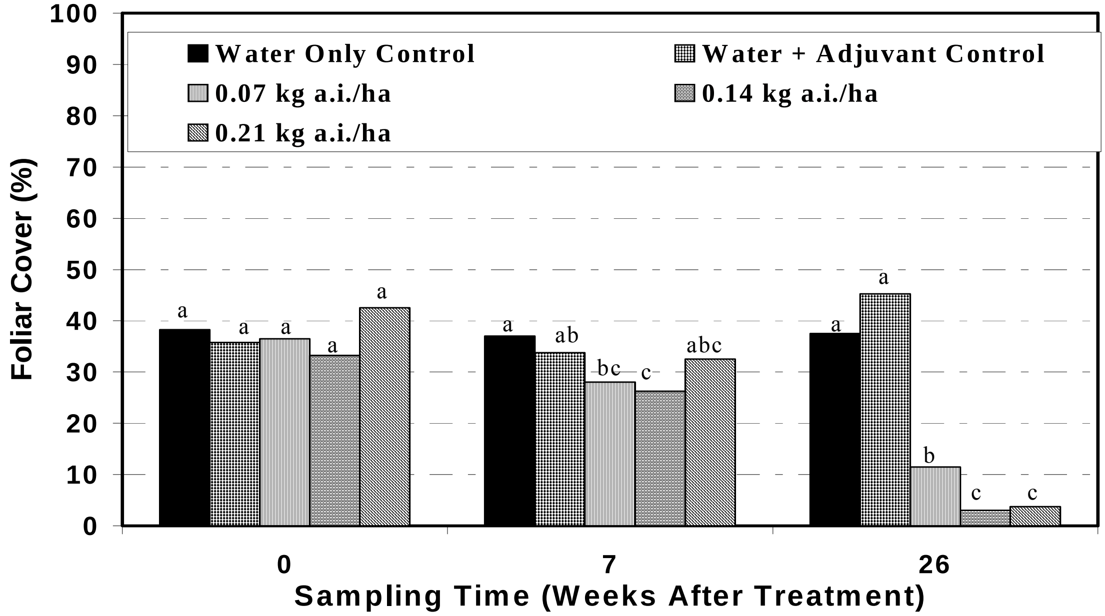
Natalgrass

The previous section on competition studies, plus additional observations by FIPR staff and others, indicated that natalgrass could be a very competitive weed on dry sites. Research was conducted to identify herbicides and appropriate application rates and methods that might be effective in controlling natalgrass, especially for selective control that would minimize injury to desired plants. It was already commonly known that glyphosate could kill natalgrass, but glyphosate is nonselective, and selective control can only be achieved by very careful spot spraying. Field and greenhouse studies were conducted to examine the effectiveness of several herbicides applied to the foliage of natalgrass (post-emergent herbicides) and several herbicides applied to the soil (pre-emergent herbicides that inhibit seed germination). Some of the herbicides had both foliar and soil activity. Post-emergent herbicides tested included: imazapic, imazapyr, imazamox, hexazinone, sulfometuron, metsulfuron, fluazifop, and atrazine. The pre-emergent herbicides included: pendimethalin, norflurazon, diuron, oryzalin, hexazinone, isoxaben, imazapic, imazapyr, oxyfluorfen, sulfometuron, and prodiamine. More information on selective control of natalgrass is contained in a later section dealing with tests of herbicides on multiple species in the field.

Natalgrass Field Experiment

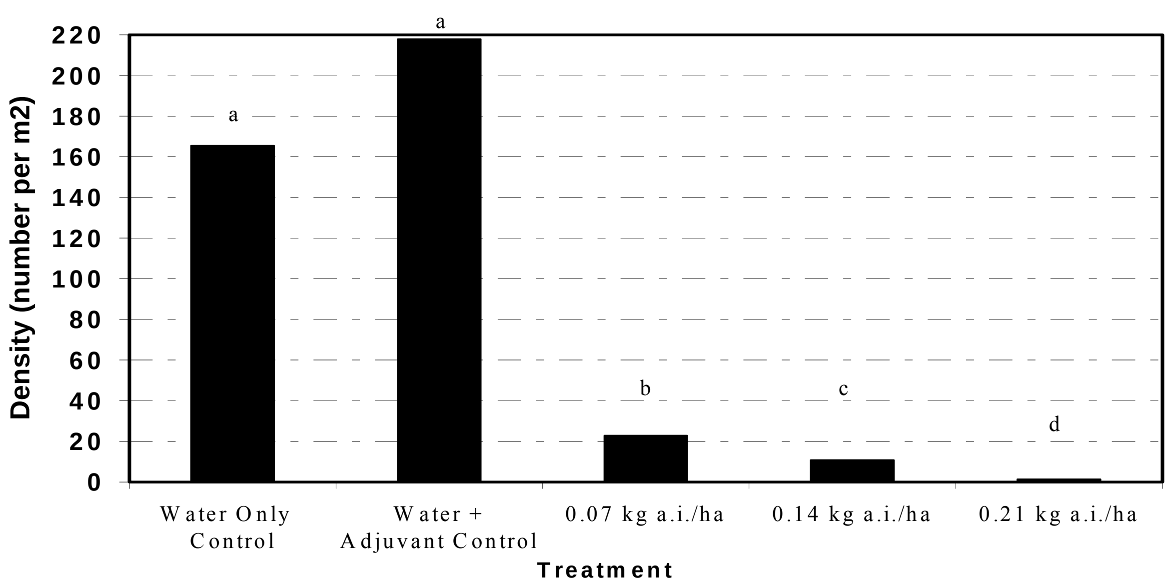
From November 1998 to June 1999 we evaluated the effects of a post-emergence application of imazapic on a naturally established natalgrass-dominated grassland. This study was conducted on a sand tailings site at the Tenoroc Fish Management Area near Lakeland, FL. Natalgrass was treated with imazapic on November 13, 1998, and was monitored for plant vigor and foliar cover at 7 and 26 weeks after treatment (WAT), as well as on the treatment date (0 WAT). We used 3 rates of imazapic at 0.07, 0.14 and 0.21 kg a.i./ha (or 4, 8 and 12 oz/acre of Plateau), as well as 2 controls (water only and water + adjuvant). Each treatment contained a dye marker (Terramark SPI) at a rate of 1.25 ml/L plus 0.39% nonionic surfactant (NIS). There were 4 replications, using plots of 1.9m x 6.1m (6.2 ft × 20 ft) size in a randomized block experimental design, using slope position (apparent effects on drainage and soil moisture) as our blocking factor. We sampled the density of natalgrass seedlings at 26 WAT, using three 0.3 m × 0.3 m quadrats per plot. Cover (%) was estimated visually on a per plot basis for natalgrass.

Imazapic, applied in the field in November 1998, greatly reduced natalgrass cover (Figure 6) and natalgrass seedling density (Figure 7) in May 1999 (26 WAT). There was a significant positive correlation between natalgrass seedling density and cover (r=0.85). Although the imazapic broadcast spraying was intended as a post-emergent foliar treatment, the residual herbicide in the soil also acted as a pre-emergent treatment, as evidenced by the inhibition of new seedlings in May (Figure 7).



Treated November 13 with 4, 8, Or 12 fl oz Plateau/acre (0.0625, 0.125 and 0.1875 lb a.i./acre or 0.07, 0.14 and 0.21 kg a.i./ha). Mean values of 4 replicates.

Figure 6. Imazapic Rate Effects on Natalgrass Cover Over Time (Means at One Sampling Date with the Same Letter Are Not Different at P = 0.05 Level).



Treated November 13 with 4, 8, or 12 fl oz Plateau/acre (0.0625, 0.125 and 0.1875 lb a.i./ acre or 0.07, 0.14 and 0.21 kg a.i./ha). Mean values of 4 replicates.

Figure 7. Imazapic Rate Effects on Density of Natalgrass Seedlings at 26 WAT (Means with the Same Letter Are Not Different at P = 0.05 Level).

Natalgrass Pre-Emergent Herbicide Experiments

Herbicides applied to the soil to inhibit weed seed germination are called pre-emergent herbicides. The November 1998 application of imazapic (Plateau) herbicide inhibited germination of seedlings in the following spring and thus exhibited pre-emergent activity (see Figure 7). Additional tests were conducted in the greenhouse and field to examine the pre-emergent effectiveness of other herbicides.

Greenhouse

Several herbicides were tested in the greenhouse for their pre-emergent (soil-applied seed germination and seedling emergence inhibition) activity on natalgrass in sandy soil and in sand tailings. Natalgrass seeds were planted in flats of sandy soil or sand tailings. There were three replications of each treatment in each experiment (sandy soil and sand tailings experiments). Application of treatment solutions was accomplished using a pressurized air Chamber Track Sprayer. The sprayer was fitted with a Teejet 8003 flat fan spray nozzle delivering 20 gal/acre at 22 psi pressure. The flats were placed in a greenhouse with partial environmental control (thermostat settings: 60 °F [16 °C] for heat and 80 °F [27 °C] for cooling) and ambient photoperiod of 12 to 13 hours of daylight. The following herbicides consistently gave 100% control of natalgrass germination and emergence (compared to the untreated check trays) through the 6 weeks test period: pendimethalin (1.0 lb a.i./acre), norflurazon (1.5 lb a.i./acre), diuron (0.6 lb a.i./acre), oryzalin (1.5 lb a.i./acre), and hexazinone (1.7 lb a.i./acre). Other herbicides provided 6 weeks of pre-emergent control usually in the 90-100% range: isoxaben (0.3 lb a.i./acre), imazapic (0.2 lb a.i./acre), imazapyr (0.3 lb a.i./acre), oxyfluorfen (0.15 lb a.i./acre), sulfometuron (0.1 lb a.i./acre), prodiamine (0.3 lb a.i./acre), and hexazinone (1.0 lb a.i./acre).

Field: Pre-Emergent Herbicides Applied to Soil After a Controlled Burn

The Mosaic Fort Green Mine HC-3/5 (“Xeric”) site, located in Hardee County about 1 mile north of State Highway SR 62 and about 1 mile east of the Hardee County and Manatee County Line, was reclaimed with a cap of topsoil from a xeric scrub site placed on overburden capped sand tailings. The site had become heavily infested with natalgrass and was burned June 16, 2009. On June 23, 2009, Pendulum 3.3E (pendimethalin) was applied at 3 qt/acre, and Velpar L (hexazinone) was applied at 1.5 qt/acre. The treatments were applied with a backpack sprayer, delivering the equivalent of 40 gal water/acre, on three replicate plots (each 20 ft × 15 ft [300 ft sq or 0.006887 acre]) per treatment. On July 9, 2009, Habitat (imazapyr) and Plateau (imazapic) were applied at the rate of 12 fl oz/acre on three replicate plots per treatment.

Table 28 shows the percent cover of natalgrass more than one year after the application of herbicides to the soil at a burned site. All of the herbicides greatly reduced the infestation of natalgrass. Pendulum has virtually no post-emergent effects, so established desirable perennial plants would not be affected by Pendulum. Velpar, Habitat and Plateau also have post-emergent effects through foliar or root uptake, so certain perennial plants might also be injured. However, certain native perennial plants have tolerance to these herbicides, so selective control of natalgrass by pre-emergent application to the soil on a burned site of the herbicides in Table 28 and others tested in the greenhouse (see previous page) is possible and promising.

Table 28. Percent Natalgrass Cover on August 18, 2010, More Than Thirteen Months After Treatment with Pendulum, Velpar, Plateau and Habitat Herbicides in June or July, 2009.

Treatment (rate per acre)	% Cover
Untreated Check	63.3 (3.3)
Pendulum (3 qt)	6.0 (2.6)
Velpar L (1.5 qt)	2.9 (1.2)
Plateau (12 fl oz)	6.7 (2.0)
Habitat (12 fl oz)	6.0 (2.1)

Means of three replicates per treatment (standard error in parentheses). Site was burned June 16, 2009. Treatments of Pendulum and Velpar sprayed 6/23/09, and Plateau and Arsenal sprayed 7/9/09.

Natalgrass Post-Emergent Herbicide Experiments (Greenhouse)

Natalgrass seeds were planted in flats of sand. When natalgrass was 2 to 3 inches in height, seedlings were transplanted into 15 cm × 10 cm plastic pots containing potting medium (Fafard Professional 4 Mix Formula, Conrad Fafard, Inc. Agawam, Mass.). Plants were grown in a greenhouse with partial environmental control (thermostat settings: 60 °F [16 °C] for heat and 80 °F [27 °C] for cooling) and ambient photoperiod of about 13 to 14 hours of daylight. The greenhouse reduced photosynthetically active radiation to a maximum of 1200 $\mu mol/m^2/s$ at midday. The seedlings were established and allowed to grow until the seedlings achieved a height of 9-12 inches (about 2 weeks after transplanting) in two experiments or 15-18 inches (about 3 weeks after transplanting) in two additional experiments. The potting mix provided a low level of nutrients, but all pots were also fertilized with a 20-20-20 N-P-K fertilizer before treatment to promote optimum plant growth. The herbicides used and their rates are shown in Table 29. Application of treatment solutions was accomplished using a pressurized air Chamber Track Sprayer. The sprayer was fitted with a Teejet 8003 flat fan spray nozzle delivering 20 gal/acre at 22 psi pressure. Visual observations of percent control (phytotoxic effect of herbicide) on natalgrass plants compared to the untreated check were recorded weekly. A percent control of 0 meant no herbicide effect, while 100% control meant natalgrass plants were completely brown, as per methodology approved by the Weed Science Society of America (Frans and others 1986). There were three replications of each treatment in each experiment. There were no significant differences between or among experiments, so results of the four experiments were averaged.

Table 29. Effect of Several Post-Emergent Herbicides on Percent Control of Natalgrass (Average of Four Greenhouse Experiments) 6 Weeks After Treatment (WAT).

Herbicides	Rate of Product (oz/acre)	Rates (lb a.i./acre)	% Control 6 WAT
Imazapyr	6	0.094	92
(Arsenal)	9	0.141	95
	12	0.188	96
Imazapic	6	0.094	80
(Plateau)	9	0.141	90
	12	0.188	88
Hexazinone	12	0.188	19
(Velpar L)	24	0.375	100
	36	0.563	100
Sulfometuron*	2*	0.094	80
(Oust)	4*	0.188	89
	6*	0.281	91
Fluazifop	8	0.125	22
(Fusilade)	16	0.250	75
	24	0.375	80
Check			0

*Product rates in fluid ounces, except for Oust, which is a dry granular product and is expressed as ounces dry weight.

Imazamox (Clearcast) herbicide was not available to include in the above greenhouse post-emergent experiment, so when it became available, two tests of the effects on natalgrass of a range of imazamox rates, compared with a range of rates of imazapic (Plateau), were conducted (Table 30). The methods used were the same as in the previous post-emergent herbicide tests.

Table 30. Effect of Imazamox (Clearcast) and Imazapic (Plateau) on Percent Post-Emergent Control of Natalgrass in the Greenhouse (Average of Two Experiments).

No.	Treatments	Rate (fl oz/acre)	Rate (lb a.i./acre)	% Control 6 WAT
1	Clearcast	8	0.063	15
2	Clearcast	12	0.094	81.6
3	Clearcast	16	0.125	100
4	Clearcast	24	0.188	100
5	Clearcast	32	0.250	100
6	Clearcast	48	0.375	100
7	Plateau	6	0.094	88.3
8	Plateau	8	0.125	90
9	Plateau	12	0.188	100
10	Plateau	16	0.250	100
11	Control	0	0	0

Natalgrass Herbicide Screening in the Field

A site on a large sand tailings hill at the Tenoroc Fish Management Area was treated with glyphosate in November 2003 and November 2004 to help eradicate cogongrass. The site was sprayed again with glyphosate on June 20, 2005, in preparation for tree planting that was later cancelled. Following glyphosate spraying, the site became infested with annual weeds, and the portion of the site used for the herbicide screening test was nearly pure natalgrass. The natalgrass was sprayed (CO_2 backpack with handheld boom) just prior to flowering on September 12, 2005. Plot sizes were 6 ft × 20 ft, and there were three replicates of each treatment: Arsenal (12, 16, 24 fl oz/acre), Atrazine 4L (2 qt/acre), Escort DX (0.5, 1.0, 2.0 dry oz/acre), Oust DX (3 and 6 dry oz/acre), Plateau (24 fl oz/acre), Steadfast (2 dry oz/acre), Velpar L (1.5 qt/acre). The plots were observed and photographed periodically, and percent cover of natalgrass was determined with line-point transects on June 17, 2006.

Neither Atrazine nor Escort at the rates applied had any effect on natalgrass. Velpar had the greatest initial effect on natalgrass, while the higher rates of Arsenal, Plateau and Oust also caused major injury to natalgrass (see Figure 8). However, by June 2006 natalgrass cover was unacceptably high in all treatments (data not shown). Velpar appeared to completely kill natalgrass, so reinfestation was likely from seed. Arsenal, Plateau, and Oust did not completely kill the natalgrass in the fall, and some of the reinfestation may have come from resprouting as well as new seedlings. The herbicide spray treatments were made just prior to natalgrass flowering. We suspect that control may have been more effective if the plants had been treated at an earlier stage of growth. In an earlier study, Plateau applied in November provided some pre-emergent control of natalgrass seedlings through the following May (see Figure 7), and Velpar, Habitat (same active ingredient as Arsenal), Plateau and Pendulum provided good control of natalgrass more than a year after treatment of a site burned in June (See Table 28). Perhaps the combination of fire and the subsequent application of pre-emergent herbicides in June (Table 28) reduced the seed bank more than the post-emergent herbicides applied in September on an unburned site (Figure 8). Plant litter and standing foliage were much greater on this unburned site than on the burned site, which may have resulted in greater interception of the herbicides by the plant foliage and litter and less herbicide reaching the soil, thus reducing or eliminating soil residual that could have provided some longer-term pre-emergent control of new seedlings.

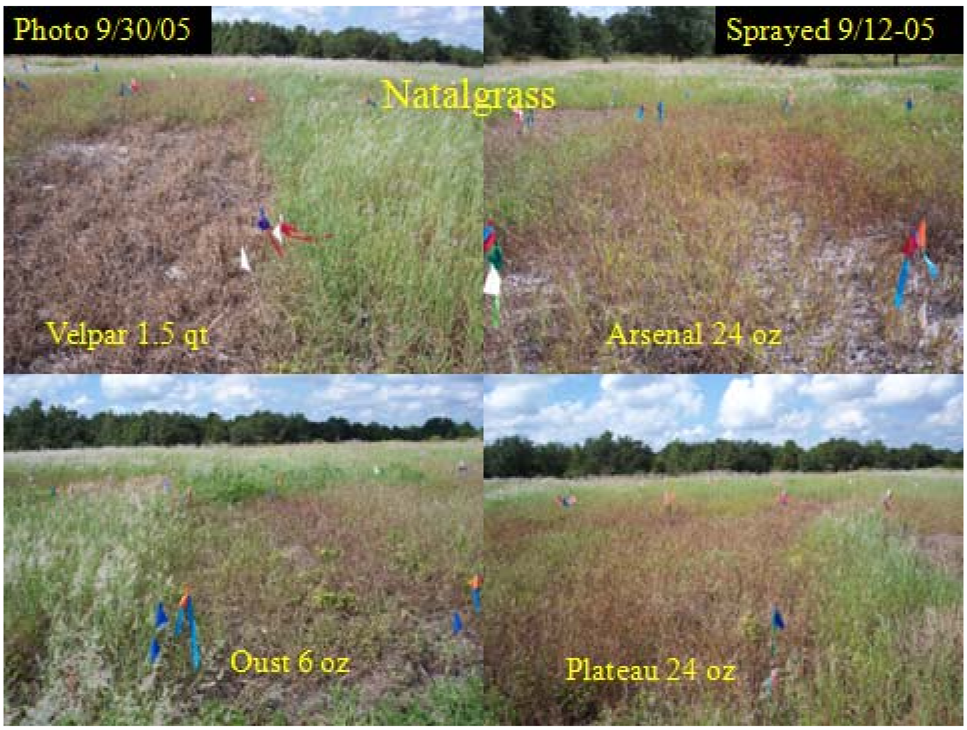


Figure 8. Effect of Four Herbicides on Natalgrass 18 Days After Treatment.

Effects of Post-Emergent Herbicides on Natalgrass Control in the Field

The objective was to find optimum rates of some post-emergent herbicides for the control of natalgrass under field conditions on phosphate mined reclaimed land. The experimental area occupied by natalgrass was located at the "Xeric" reclamation site (HC3/HC5) at the Mosaic Fort Green Mine. Individual treatment plot sizes were 6 ft × 20 ft, and there were three replications for each treatment. Herbicides were each applied at 3 different rates (0.094, 0.141, 0.188 lb a.i./acre for imazapyr, imazapic and imazamox; and 0.188, 0.281, 0.375 lb a.i./acre for fluazifop). A non-ionic surfactant (Induce) was added to each treatment solution at the rate of 15 ml/gal. The experiment was conducted as randomized complete block design. The treatment application was accomplished using a 4-nozzle CO_2 backpack sprayer at 32 PSI pressure and 40 gal/acre carrier volume.

Most natalgrass plants were nearly mature (just prior to flowering) when the treatments were applied on July 1, 2008.

On July 28, 2008, there were differences in effects of the herbicides, but there were no obvious differences among rates of any given herbicide. Imazapyr and imazapic treated plots exhibited the greatest control of natalgrass (plants were mostly brown). Fluazifop had only a slight effect (mostly green), and imazamox was only a little better (intermediate between fluazifop and imazapic). By the end of September, 2008, none of the treatments had acceptable control. Natalgrass had regrown to some extent in all the treatments, but there were slight treatment differences still apparent. In order of greatest to least inhibition of natalgrass, the treatments were: imazapyr > imazapic > imazamox > fluazifop.

Bahiagrass

Bahiagrass and Smutgrass Control

Bahiagrass (*Paspalum notatum*) is a desirable rhizomatous pasture grass, widely planted in Florida, but it is an exotic that is not desired in native plant communities. Smutgrass (*Sporobolus indicus*) is an exotic weedy bunchgrass with low palatability that is not desired in pastures and certainly not in native plant communities. A screening study was conducted to identify herbicides that might be useful in the control of these two species. A site with an established, mixed stand of bahiagrass and smutgrass was selected on former mined land (overburden-capped sand tailings) at the Tenoroc Fish Management Area. Herbicides (with 0.5 oz. nonionic surfactant per gallon of spray solution) were applied on three replicate plots (6 ft × 20 ft) on September 14, 2005, with a CO_2 backpack sprayer with a hand-held boom. The herbicides are listed by brand name in Table 16. The rates of Velpar L (2 lb hexazinone/gal), Arsenal (2 lb imazapyr/gal formulation), Plateau (2 lb imazapic/gal), and Atrazine 4L (4 lb atrazine/gal) are expressed as fluid volumes of the product per acre, while rates of Oust XP (75% sulfometuron), Escort XP (60% metsulfuron) and Steadfast (50% nicosulfuron plus 25% rimsulfuron) are expressed as dry weights of the product per acre. Percent cover on each plot was evaluated with line-point transects in June 2006.

As found in previous research (Mislevy and others 1999), Velpar L at 1.5 qt/acre of product in September was very effective in controlling smutgrass, while bahiagrass was quite tolerant (Table 31). In contrast, Plateau at 24 oz/acre of product gave the greatest control of bahiagrass of the chemicals tested, but did not control smutgrass. Atrazine 4L had no apparent effect on either bahiagrass or smutgrass. Compared to atrazine, both rates of Escort XP and the higher rate of Arsenal provided some suppression of bahiagrass, but Escort XP allowed smutgrass to increase, while Arsenal did not. Oust XP provided less suppression of bahiagrass than did Escort, but did not release smutgrass to the same extent. Steadfast had only a minor effect on bahiagrass or smutgrass. In this test, bahiagrass appeared to have greater tolerance to Arsenal than it did to Plateau, while Arsenal suppressed smutgrass more than did Plateau.

Table 31. Percent Cover of Bahiagrass and Smutgrass in June 2006 Following Herbicide Treatments in September 2005 at Tenoroc.

Rate per acre	Bahiagrass	Smutgrass	Indigo	Litter
Velpar L 1.5 qt	96.7 (0.8)	0.8 (0.8)	4.2 (2.2)	9.2 (3.6)
Plateau 24 oz	11.7 (5.1)	73.3 (8.0)	7.5 (2.5)	32.5 (4.3)
Arsenal 16 oz	68.3 (8.7)	44.2 (11.6)	1.7 (0.8)	6.7 (0.8)
Arsenal 24 oz	32.5 (6.6)	40.0 (6.6)	3.3 (0.8)	36.7 (4.4)
Oust XP 3 oz	55.8 (12.4)	45.8 (13.0)	3.3 (0.8)	5.0 (2.5)
Oust XP 6 oz	46.7 (13.9)	39.2 (15.2)	3.3 (0.8)	23.3 (2.2)
Escort XP 1 oz	34.2 (11.6)	75.8 (6.5)	0.0 (0.0)	1.7 (1.7)
Escort XP 2 oz	33.3 (14.7)	70.0 (13.9)	0.8 (0.8)	6.7 (3.3)
Steadfast 2 oz	62.5 (3.8)	56.7 (2.2)	0.0 (0.0)	0.0 (0.0)
Atrazine 4L 2 qt	79.2 (3.6)	30.8 (8.5)	1.7 (1.7)	4.2 (0.3)
Atrazine 4L 4 qt	70.0 (7.2)	39.2 (8.8)	1.7 (1.7)	6.3 (3.6)

Means of 3 replicates (standard error in parentheses).

Selective Bahiagrass Control

Metsulfuron (Escort) is used for broadleaf weed control in pine forestry and also for broadleaf weed control and bahiagrass control in various warm season turfgrasses (e.g., St. Augustinegrass, bermudagrass). Sethoxydim (Poast) is a grass herbicide that has virtually no effect on most broadleaf plants. These two herbicides were tested in separate experiments for their possible ability to provide selective control of bahiagrass. Imazapic (Plateau) treatment was also included for comparison. The metsulfuron was tested on plots dominated by bahiagrass, wiregrass and hairy indigo. The sethoxydim was tested on plots dominated by bahiagrass, *Pityopsis* and hairy indigo.

Metsulfuron (2 dry oz/acre of Escort product) treatment in late August caused a drastic reduction in hairy indigo (*Indigofera hirsuta*) cover by November (Table 32). It also resulted in a slight reduction of bahiagrass (*Paspalum notatum*) cover and an increase in natalgrass (*Rhynchelytrum repens*) cover. There was virtually no effect on wiregrass (*Aristida beyrichiana*). Imazapic (24 fl oz/acre of Plateau product) caused a drastic reduction in bahiagrass cover but had little or no effect on hairy indigo or wiregrass.

Our general experience with metsulfuron is that it has activity on many broadleaf weeds but little activity on most grasses, except bahiagrass. In earlier research we found that lower rates of Plateau (5-12 oz/acre) could effectively control seedling bahiagrass, but those rates were less effective on well-established bahiagrass. That was the reason for trying the higher rate of Plateau (24 fl oz/acre), which gave good control of bahiagrass, at least for the short term, with minimal effect on wiregrass. The maximum rate allowed by the Plateau label is 12 fl oz product/acre broadcast, but a higher rate (equivalent to 24 oz/acre) is allowed for spot spraying.

Table 32. Percent Cover Before (August 24, 2006) and Three Months After (November 30, 2006) Treatment with 2 dry oz/acre of Escort (Metsulfuron) or 24 fl oz/acre of Plateau (Imazapic) (Treated August 28, 2006) at the Mosaic Ft. Green Mine "16 Acre" Site.

	Escort		Plateau	
Species	Before	After	Before	After
Andropogon ternarius	1.5 (0.5)	1.7 (0.7)	0.4 (0.4)	0.6 (0.6)
Aristida beyrichiana	32.1 (4.6)	30.6 (4.3)	35.6 (5.2)	29.2 (3.9)
Cynodon dactylon	0.4 (0.2)	1.3 (0.8)	0.6 (0.4)	1.3 (5.4)
Desmodium triflorum	0.4 (0.2)	0.0 (0.0)	1.5 (0.7)	1.7 (3.4)
Euthamia tenuifolia	1.3 (1.3)	0.0 (0.0)	0.6 (0.6)	0.8 (0.8)
Indigofera hirsuta	22.3 (5.4)	1.3 (0.7)	20.8 (3.6)	24.8 (5.2)
Paspalum notatum	45.2 (5.9)	26.7 (4.0)	50.4 (8.4)	3.3 (0.9)
Pityopsis graminifolia	1.0 (1.0)	0.0 (0.0)	0.6 (0.6)	1.0 (0.6)
Rhynchelytrum repens	9.0 (2.0)	25.8 (3.1)	7.7 (2.3)	6.0 (1.0)
Sporobolus indicus	5.0 (4.7)	4.2 (3.9)	4.0 (2.4)	1.0 (0.6)
Bare + Litter	8.1 (0.7)	20.8 (3.4)	6.0 (1.2)	39.6 (3.4)

Means of 4 replicates (standard error in parentheses).

The grass herbicide Sethoxydim (Poast) has virtually no effect on most broadleaf plants. This is borne out by the lack of effect on *Indigofera*, *Euthamia*, and *Pityopsis* (Table 33). Unfortunately, at the rate applied there was only a slight effect on bahiagrass. Imazapic was much more effective in controlling bahiagrass than was sethoxydim, at the rates applied in August. *Indigofera*, *Euthamia*, and *Pityopsis* also appeared to have some tolerance to imazapic.

Table 33. Percent Cover Before (August 23, 2006) and Three Months After (November 22, 2006) Treatment with 32 fl oz/acre of Poast (Sethoxydim) or 24 fl oz/acre of Plateau (Imazapic) (Treated August 28, 2006) at the Mosaic Ft. Green Mine "16 Acre" Site.

	Poast		Plateau	
Species	Before	After	Before	After
Aeschynomene americana	1.4 (1.0)	3.3 (1.9)	2.2 (2.2)	2.5 (2.1)
Andropogon spp.	3.6 (0.6)	3.3 (0.5)	2.8 (1.6)	0.8 (0.8)
Cynodon dactylon	0.6 (0.6)	1.7 (1.0)	1.1 (0.6)	0.6 (0.6)
Desmodium triflorum	0.3 (0.3)	6.9 (3.7)	0.6 (0.6)	0.8 (0.8)
Euthamia tenuifolia	5.8 (3.8)	7.5 (3.8)	1.9 (1.2)	2.8 (1.6)
Indigofera hirsuta	15.3 (8.7)	15.3 (8.5)	13.9 (2.3)	11.1 (2.4)
Paspalum notatum	76.4 (7.6)	56.7 (9.3)	76.7 (5.1)	1.9 (0.7)
Pityopsis graminifolia	31.7 (4.2)	42.8 (1.1)	32.2 (1.9)	38.6 (4.7)
Rhynchelytrum repens	0.3 (0.3)	1.7 (1.7)	0.3 (0.3)	0.0 (0.0)
Bare + Litter	3.3 (0.8)	8.9 (4.7)	4.4 (1.7)	45.8 (5.5)

Means of 3 replicates (standard error in parentheses).

Comparison of Imazapyr, Imazapic, Imazamox and Fluazifop Herbicides for the Control of Bahiagrass Growing on Reclaimed Mined Land

Although bahiagrass is a non-native plant, it is grown as a pasture crop and as a turfgrass. When it is growing with the native plant population it provides competition and adversely affects growth of native plants. Therefore, the main objective was to evaluate different herbicides for effective control of bahiagrass. We also compared a nonionic surfactant versus a crop oil additive.

The study was conducted on a bahiagrass stand at the Mosaic Fort Green Mine, PC-2 ("16 acre") site. The experiment was conducted as a randomized complete block design with three replicates per treatment. Each plot was 6 ft × 20 ft. Treatments (Table 34) were applied August 6, 2008, using a CO_2 backpack sprayer with a 4-nozzle boom, at 32 PSI pressure and 40 gal/acre carrier volume. Two different adjuvants were used: Agridex crop oil concentrate at 1.0% by volume in the spray solution or Induce nonionic surfactant at 0.39% by volume (0.5 oz/gal). Observations were made at 6 weeks after treatment (WAT) (9-18-08) and 10 WAT (10-17-08).

Table 34. Treatment Details for Field Comparison of Herbicide Effects on Bahiagrass.

	Herbicide	Active Ingredient	Rate (oz/acre)	lb a.i./acre
1	Imazapyr	2 lb a.i./gal	12 + Induce	0.188
2	Imazapyr	(Arsenal)	16 + Agridex	0.250
3	Imazapyr		16 + Induce	0.250
4	Imazapyr		24 + Induce	0.375
5	Imazamox	1 lb a.i./gal	32 + Induce	0.250
6	Imazamox	(Clearcast)	32 + Agridex	0.250
7	Imazamox		48 + Induce	0.375
8	Imazamox		64 + induce	0.500
9	Imazapic	2 lb a.i./gal	12 + induce	0.188
10	Imazapic	(Plateau)	12 + Agridex	0.188
11	Fluazifop	2 lb a.i./gal (Fusilade DX)	24 + Induce	0.375
12	Control			

At 6 weeks after treatment (WAT) there were no apparent differences among rates of the same herbicide, but we did observe differences among herbicides. Bahiagrass control ranking: imazapyr > imazapic > imazamox > fluazifop. The effect on legumes (hairy indigo, alyceclover, aeschenomene, desmodium) was in the same order. Bahiagrass and legumes appeared completely controlled 10 WAT at the highest imazapyr rate. No differences in the effects of Induce nonionic surfactant or Agridex crop oil concentrate were observed. Visual evaluation of percent control was made on June 12, 2009 (10 months after treatment). By June 2009, there were no apparent effects of fluazifop, imazamox or imazapic on bahiagrass control. Only imazapyr showed any long term (by June 2009) effect on bahiagrass: 55 percent control with 12 oz Arsenal/acre, 75 percent control with 16 oz Arsenal/acre, 93 percent control with 24 oz Arsenal/acre. There was no difference with Induce versus Agridex. An earlier study suggested that bahiagrass may be better controlled by imazapic (Plateau) than by imazapyr (Habitat or Arsenal) at equivalent rates. However, this study indicated that imazapyr may give better control of bahiagrass than does imazapic.

There is more information on bahiagrass control and tolerance to imazapic herbicide in the section on Mixed Species Field Studies. There is also additional information on bahiagrass response to imazapyr herbicide in the Cogongrass Management chapter under the section on Selective Herbicidal Control of Cogongrass.

Mixed Species Field Studies

Selective Control with Imazapic Herbicide: Effects on Native Plants and Weeds

For our imazapic studies, we applied imazapic as Plateau herbicide in the liquid formulation containing 23.6% (2 lb a.i./gal) imazapic. The nonionic surfactant Activate Plus was added to all the imazapic dosages at the rate of 0.25% (v/v). In nearly all experiments (unless stated otherwise), our application method was a CO_2 backpack sprayer (R&D Sprayers, model T), using a 4-nozzle boom sprayer (nozzle type XR0002; 48.3 cm spacing) calibrated using a flow rate of 374 L/ha at 280 kPa pressure. The boom sprayer was held at approximately 0.75 m height (about 45 cm above the top of the target foliage).

Several sites were used to examine the effects of imazapic herbicide on a variety of native species and weeds. Two of the field sites (designated as CF Hardee and CF Plant City) were seeded with native species in early December 1998. Native hay containing seed was harvested and air-dried in November 1998. The hay was broadcast on disked sites with a modified bermudagrass sprigger (furrow openers removed so plant material containing the seed could drop on the ground surface). A toothed cultipacker was installed on the front to create dibbles in the soil, and coulters and rollers were placed on the back to roll the seed material after it was applied. The sites had different soil types: (1) overburden at CF Hardee and (2) sandy flatwoods soil at CF Plant City. Imazapic at 0, 0.04, 0.09, and 0.14 kg a.i./ha (0, 2, 5, and 8 oz/acre of Plateau) was applied at each site at three different times: pre-emergent (just after seeding in December 1998); early post-emergent (late May or early June 1999); or late post-emergent (early October 1999). There were four replicates of each rate and timing treatment. Each individual treatment plot was 3.6 m × 12.2 m, and a swath 1.9 m × 12.2 m was actually sprayed. The pre-emergent treatments were evaluated for percent frequency of each plant species in April 1999. Percent frequency was also determined for all treatments in late August or early October 2000. Percent frequency of the various plant species was determined from thirty 0.6 m × 1.9 m quadrats per plot (120 per treatment). For the post-emergent treatments, herbicide damage on a scale of 0 to 5 (0 = no damage, 5 = complete necrosis) was determined for the various native and non-native species 6 weeks after herbicide application.

The CF Hardee site (overburden) was located in Hardee County northwest of the town of Wauchula at the CF Industries South Pasture Mine. The site was seeded December 2, 1998. Imazapic was applied pre-emergent December 11, 1998; early post-emergent June 10, 1999; and late post-emergent October 12, 1999.

The CF Plant City site (sandy flatwoods soil) was located in Hillsborough County north of Plant City and east of SR [State Road] 39 near the CF Industries chemical plant. The site was seeded December 11-14, 1998. Imazapic was applied pre-emergent December 16, 1998; early post-emergent May 17, 1999; and late post-emergent October 11, 1999. An additional study using the same methods was done to assess slightly higher rates of imazapic (0.14, 0.18, and 0.21 kg a.i./ha [8, 10, and 12 oz/acre of Plateau]) on bahiagrass in May and October 1999 at the Plant City site, and percent frequency was determined in November 2000.

Additional studies were done at a site we called the "16 acre site" (overburden) which was located at the Mosaic Company's (formerly IMC Phosphates) Fort Green Mine in southern Polk County, Florida, just north of the Hardee County line and about 5 km east of SR [State Road] 37. Prairie hay containing a variety of native plant seeds was harvested in November 1994, air dried, and spread on the disked overburden soil with a hay blower in December 1994, followed by rolling with a cultipacker. Half the site was burned July 24, 2000. Imazapic at 0, 0.04, 0.09, 0.14, and 0.21 kg a.i./ha (0, 2, 5, 8, and 12 oz/acre of Plateau) was applied August 16 and 17, 2000. There were 5 replicates per herbicide treatment in the burned and also in the unburned portions of the site. The plots were each 2.4 m × 12.2 m (actual sprayed area was 1.9 m × 12.2 m). Percent frequency was determined from twenty 0.61 m × 1.8 m quadrats per plot (100 per treatment in the burned and 100 in the unburned portions of the site)—frequency data not shown. Herbicide damage on a scale of 0 to 5 (0 = no damage, 5 = complete necrosis) was determined for the various native and non-native species 6 weeks after herbicide application (data presented are averages of the ratings for five replicates).

Pre-Emergence Imazapic Herbicide Effects

Imazapic applied just after seeding in early December 1998 greatly inhibited the germination and emergence of most species, both native and weedy, based on percent frequency evaluations in April 1999. One exception was the emergence of *Andropogon* species, which was not affected by imazapic (Table 35).

Percent frequency was also evaluated at the end of August 2000 (Table 36). By that time the frequency of the *Andropogon* species in the untreated control at the Plant City site was severely reduced, compared to April 1999, while the frequency with the imazapic pre-emergent treatments increased with time. This might be related to greater competition from other species, which had greater frequency in the control than in the treated plots. At the Hardee site in August 2000, *Digitaria ciliaris* had reestablished itself such that percent frequency was similar regardless of pre-emergent treatment in December 1998. Interestingly however, the frequency of *Digitaria* in the untreated control was reduced in August 2000 compared to April 1999, suggesting greater competition from the increasing perennials. Most of the other species in Table 3 still showed the effects of the pre-emergent treatment, although percent frequencies in many cases were increasing. *Liatris* decreased in frequency at the Plant City site in contrast to increases at the Hardee site. This is most likely related to greater competition from *Eupatorium capillifolium* and *Paspalum notatum* at the Plant City site.

Post-Emergence Imazapic Herbicide Effects

Herbicide damage ratings (0-5, with 0 indicating no damage and 5 being totally necrotic) at the Plant City and Hardee sites six weeks after herbicide application indicated that several native species were quite tolerant of imazapic at rates up to 0.14 kg a.i./ha (8 oz/acre of Plateau) when applied in late May or early June (Table 37). *Andropogon spp.*, *Aristida beyrichiana*, *Eragrostis spp.*, and *Liatris spp.* exhibited little or no damage, while *Digitaria ciliaris*, and *Cyperus spp.* were damaged quite severely. *Sorghastrum secundum*, *Eupatorium capillifolium* and *Paspalum notatum* sustained moderate damage. The results with later post-emergent (early October, Table 38) treatments were very similar to the earlier post-emergent treatments (late May or early June, Table 37).

Table 35. Percent Frequency of Several Plant Species Evaluated in April 1999 Following Pre-Emergent Application of Imazapic (Plateau) Herbicide in December 1998.

	Plateau Rate (oz/acre)			
Species	0	2	5	8
Plant City				
Andropogon spp.	17	25	20	18
Aristida beyrichiana	31	8	7	2
Eragrostis spp.	23	13	3	2
Liatris spp.	16	13	4	6
Sorghastrum secundum	11	9	2	1
Cyperus spp.	92	14	3	3
Eupatorium capillifolium	23	3	1	0
Paspalum notatum	48	19	2	3
Hardee				
Aristida beyrichiana	68	1	0	0
Eragrostis spp.	7	2	0	0
Liatris spp.	59	3	0	0
Sorghastrum secundum	31	5	0	0
Digitaria ciliaris	100	65	13	1

Table 36. Percent Frequency of Several Plant Species Evaluated in August 2000 Following Pre-Emergent Application of Imazapic (Plateau) Herbicide in December 1998.

	Plateau Rate (oz/acre)			
Species	0	2	5	8
Plant City				
Andropogon spp.	1	33	23	38
Aristida beyrichiana	29	24	18	13
Eragrostis spp.	50	32	38	29
Liatris spp.	2	2	0	0
Sorghastrum secundum	14	33	10	21
Cyperus spp.	37	21	14	10
Eupatorium capillifolium	68	22	31	32
Paspalum notatum	63	43	7	5
Hardee				
Digitaria ciliaris	60	71	63	58
Aristida beyrichiana	81	3	0	3
Liatris spp.	69	28	27	6
Sorghastrum secundum	68	48	15	12

Table 37. Effects of Early Post-Emergent (Late May 1999) Application of Imazapic (Plateau) on Herbicide Damage Rating 6 WAT.

	Plateau Rate (oz/acre)			
Species	0	2	5	8
Plant City				
Andropogon spp.	0	0	0	0
Aristida beyrichiana	0	0	0	0
Eragrostis spp.	0	0	0.6 (0.2)	0.8 (0.3)
Liatris spp.	0	0	0.3 (0.2)	0.8 (0.4)
Sorghastrum secundum	0	0.3 (0.3)	1.3 (0.5)	1.3 (1.3)
Eupatorium capillifolium	0	0.9 (0.1)	1.2 (0.1)	2.1 (0.3)
Cyperus spp.	0	2.9 (0.3)	4.1 (0.2)	4.3 (0.2)
Paspalum notatum	0	1.7 (0.4)	2.4 (0.3)	2.7 (0.2)
Hardee				
Aristida beyrichiana	0	0	0.1 (0.1)	0.2 (0.1)
Liatris spp.	0	0	0.3 (0.2)	0.2 (0.2)
Sorghastrum secundum	0	0.5 (0.4)	1.3 (0.5)	2.2 (0.6)
Digitaria ciliaris	0	3.0 (0.4)	5.0 (0.0)	5.0 (0.0)

Herbicide Damage Rating (0 indicates no damage, 5 indicates total necrosis) 6 WAT.

Table 38. Effects of Late Post-Emergent (Early October 1999) Application of Imazapic (Plateau) on Herbicide Damage Rating 6 WAT.

Species	Plateau Rate (oz/acre) 0	2	5	8
Plant City				
Andropogon spp.	0	0.1(0.1)	0.7(0.7)	0
Aristida beyrichiana	0	0.2(0.2)	0.2(0.2)	0
Eragrostis spp.	0	0.3(0.1)	0.5(0.2)	0.9(0.2)
Liatris spp.	0	0	0.2(0.2)	0
Sorghastrum secundum	0	1.5(0.5)	2.3(0.7)	2.8(0.6)
Eupatorium capillifolium	0	1.3(0.3)	2.3(0.5)	3.0(0.0)
Cyperus spp.	0	3.9(0.6)	3.2(1.0)	5.0
Paspalum notatum	0	2.3(0.4)	3.7(0.2)	3.5(0.5)
Hardee				
Aristida beyrichiana	0	0	0	0
Liatris spp.	0	0	0	0.1(0.1)
Sorghastrum secundum	0	1.3(0.3)	2.3(0.3)	3.6(0.3)
Digitaria ciliaris	0	2.2(0.1)	3.1(0.1)	4.6(0.3)

Mean of 4 replicates (standard error in parentheses).

Bahiagrass control with 0.14 to 0.21 kg a.i./ha of imazapic (8 to 12 oz/acre of Plateau) was evaluated in additional experiments at the Plant City site (Table 39). The herbicide was applied in late May and early October 1999, and percent frequency was determined in November 2000. All the rates gave similar control (as indicated by reduced percent frequency compared to the untreated check), and there was no difference between the earlier and the later application dates.

Table 39. Bahiagrass Control with Imazapic (Plateau) Herbicide: Percent Frequency November 2000 After Application in May or October 1999.

Plateau Rate (oz/acre)	Post-Emergent Application Early (May 1999)	Late (Oct. 1999)
0	36	28
8	8	9
10	8	6
12	10	7

Tables 40 and 41 show the effects of imazapic (Plateau) herbicide on four perennial grasses at two sites one year or more after treatment and 21 to 22 months after seeding.

Table 40. Percent Frequency at the Hardee Site on August 30, 2000.

Species	Plateau Rate (oz/acre) 0	2	5	8
Preemergent (12/98)				
Aristida beyrichiana	81	3	0	3
Eragrostis spp.	62	52	39	38
Sorghastrum secundum	68	48	15	12
Paspalum notatum	10	2	0	2
Early Postemergent (5/99)				
Aristida beyrichiana	87	86	73	87
Eragrostis spp.	63	71	59	72
Sorghastrum secundum	89	71	53	43
Paspalum notatum	8	0	0	0
Late Postemergent (10/99)				
Aristida beyrichiana	84	95	84	89
Eragrostis spp.	61	73	69	71
Sorghastrum secundum	71	73	61	55
Paspalum notatum	5	2	3	0

Table 41. Percent Frequency at the Plant City Site in October 2000.

Species	Plateau Rate (oz/acre) 0	2	5	8
Preemergent (12/98)				
Aristida beyrichiana	29	24	18	13
Eragrostis spp.	50	32	38	29
Sorghastrum secundum	14	33	10	21
Paspalum notatum	63	43	7	5
Early Postemergent (5/99)				
Aristida beyrichiana	14	15	18	15
Eragrostis spp.	53	57	40	46
Sorghastrum secundum	13	8	4	2
Paspalum notatum	41	43	29	5
Late Postemergent (10/99)				
Aristida beyrichiana	14	15	20	11
Eragrostis spp.	47	58	29	34
Sorghastrum secundum	28	11	5	0
Paspalum notatum	62	28	16	10

At the Mosaic Fort Green 16 Acre Site, imazapic applied in August at rates up to 0.21 kg a.i./ha (12 oz/acre Plateau) caused little or no damage to *Andropogon spp.*, *Aristida beyrichiana*, *Eragrostis spp.*, *Liatris spp.*, *Chaemaechrista nictitans*, *Pityopsis* *graminifolia*, *Schizachyrium scoparium var. stoloniferum* and *Solidago stricta*, based on herbicide damage ratings six weeks after treatment (Tables 42 and 43). *Cyperus spp.*, *Fimbristylis dichotoma*, *Paspalum notatum*, *Rhynchelytrum repens*, *Setaria geniculata*, and *Axonopus affinis* had more severe damage, while *Crotolaria rotundifolia* and *Euthamia tenuifolia* had moderate damage.

Table 42. Effects of Mid-August Application of Imazapic (Plateau) on Herbicide Damage Rating of Plants in the *Unburned* Portion of the Fort Green Mine "16 Acre" Site 6 WAT.

	Plateau Rate (oz/acre)				
Species	0	2	5	8	12
Andropogon spp.	0	0	0	0	0
Eragrostis spp.	0	0	0	0	0
Chaemaechrista nictitans	0	0	0	0	0
Liatris spp.	0	0	0	0	0
Schizachyrium scoparium	0	0	0	0	0
Solidago stricta	0	0	0.2	0	0
Aristida beyrichiana	0	0	0.1	0.3	0.4
Pityopsis graminifolia	0	0.3	0.7	0.8	0.9
Euthamia tenuifolia	0	0.8	0.6	0.7	1.3
Crotolaria rotundifolia	0	1.0	1.3	1.0	1.4
Axonopus affinis	0	0	0.5	3.0	3.0
Setaria geniculata	0	0.7	1.3	2.0	3.0
Fimbristylis dichotoma	0	1.5	2.5	4.0	4.5
Paspalum notatum	0	2.5	2.9	3.1	3.8
Rhynchelytrum repens	0	2.5	3.2	4.6	4.8
Cyperus spp.	0	3.5	4.5	4.8	4.6

Herbicide Damage Rating (0 indicates no damage, 5 indicates total necrosis).
Mean values of 5 replicates.

Table 43. Effects of Mid-August Application of Imazapic (Plateau) on Herbicide Damage Rating of Plants in the *Burned* Portion of the Fort Green Mine "16 Acre" Site 6 WAT.

	Plateau Rate (oz/acre)				
Species	0	2	5	8	12
Andropogon spp.	0	0	0	0	0
Chaemaechrista nictitans	0	0	0	0	0
Eragrostis spp.	0	0	0	0	0
Schizachyrium scoparium	0	0	0	0	0
Liatris spp.	0	0	0	0	0.1
Solidago stricta	0	0	0	0.6	0.7
Pityopsis graminifolia	0	0.2	0.9	0.8	0.9
Aristida beyrichiana	0	0.3	0.7	0.8	0.8
Crotolaria rotundifolia	0	1.0	--	--	1.7
Euthamia tenuifolia	0	0.3	1.0	1.5	2.1
Fimbristylis dichotoma	0	0.3	2.0	--	2.0
Axonopus affinis	0	0	1.3	1.5	3.0
Setaria geniculata	0	0.0	2.0	4.0	--
Rhynchelytrum repens	0	1.0	--	5.0	--
Paspalum notatum	0	1.3	3.5	4.2	4.6
Cyperus spp.	0	3.4	4.5	4.8	4.8

Herbicide Damage Rating (0 indicates no damage, 5 indicates total necrosis).
Mean values of 5 replicates.

Discussion

Pre-emergent application of imazapic at seeding time should be considered cautiously. The establishment of all but a few desirable native plants was inhibited by pre-emergent imazapic. However, an application of imazapic that is post-emergent for the established native plants but pre-emergent for weeds such as crabgrass or natalgrass (late winter or early spring prior to the second growing season) may be successful in providing selective weed control.

Several weed species, including natalgrass, seedling bahiagrass, crabgrass, and nutsedges (*Cyperus spp.*) were controlled with about 0.14 kg a.i./ha of imazapic (8 oz/acre of Plateau) applied either pre- or post-emergent. Cogongrass (*Imperata cylindrica*), bermudagrass (*Cynodon dactylon*) and hairy indigo (*Indigofera hirsuta*) were not controlled effectively by imazapic. Many legumes (Fabaceae family) and members of the sunflower family (Asteraceae) appear to be quite tolerant of imazapic.

Yellow indiangrass (*Sorghastrum nutans*) has been described in manufacturers' literature (Anonymous 1997a, 1997b) as tolerant to imazapic, but our research has shown that lopsided indiangrass (*Sorghastrum secundum*) is not, or at least is much less tolerant. Imazapic is not recommended for use where lopsided indiangrass is an important component of the plant community. If contemplated at all, only the lower rates should be considered with lopsided indiangrass. In earlier research (Kluson and others 2000), we observed that a younger stand of lopsided indiangrass seeded in May 1999 and treated in August 1999 was more tolerant than an older stand that had been seeded in January 1997 and treated in August 1999. It has been observed that stands of lopsided indiangrass in seed production fields may decline after two or three years, especially if irrigated, probably due to pathogens (Pfaff and Maura 2000). The lesser tolerance of the older stand in our study (Kluson and others 2000) may have been related to a similar reduction in vigor. The observations of Pfaff and Maura (2000), and others, indicate lopsided indiangrass is a short-lived perennial that depends on reseeding to maintain a stand.

Fortunately, several native grasses, including wiregrass, creeping bluestem (*Schizachyrium scoparium var. stoloniferum*), and various species of *Andropogon* and *Eragrostis* are tolerant of 0.14 to 0.21 kg a.i./ha of imazapic (8 to 12 oz/acre Plateau) applied post-emergent during the growing season. Many legumes (Fabaceae family) and members of the sunflower family (Asteraceae) appear to be quite tolerant of imazapic.

Native Species Herbicide Tolerance

Wiregrass and Lopsided Indiangrass Tolerance to Imazapic Herbicide

For our imazapic studies, we applied imazapic as Plateau herbicide in the liquid formulation containing 23.6% imazapic. The adjuvant Activate Plus was added to all the imazapic dosages at the rate of 0.25% (v/v). In all experiments, our application method was a CO_2 backpack sprayer (R&D Sprayers, model T), using a 4-nozzle boom sprayer (nozzle type XR0002; 48.3 cm spacing) calibrated using a flow rate of 374 L/ha at 280 kPa pressure. Our boom sprayer was set at approximately 1 m height. For the herbicide applications, the time of day was between 7:45-10:00 AM in the field experiments and 2-4 PM in the greenhouse experiments. The weather conditions of the field experiments ranged from clear to partly cloudy skies, 8 or less kph wind speed, 85-92% relative humidity, and 21-27 ^{o}C air temperature.

Parameters from the experiments were statistically analyzed by the MSTAT (Nissen 1993) package. Treatment effects were analyzed with parametric (ANOVA) statistics. Tests for violations of assumptions of analysis of variance (ANOVA) were performed by the STATISTICA (STATSOFT 1995) package. Data as percentages were calculated with the arcsine transformation to meet the assumptions of ANOVA. Means separations with ANOVA were done with Duncan’s Multiple Range Test. Orthogonal comparisons of the means (excluding the adjuvant control) were calculated for response trends (e.g., linear, quadratic and cubic) to the herbicide rates.

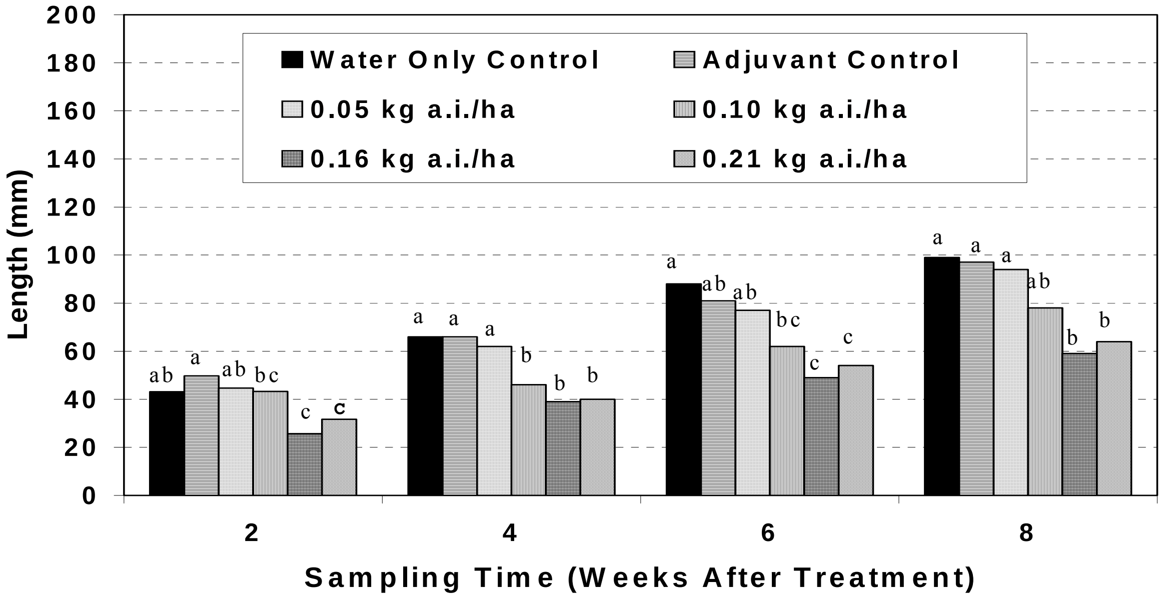
Greenhouse Experiments

Our greenhouse studies of wiregrass and lopsided indiangrass were completed at the reclamation research facilities of FIPR in Bartow, FL. From February to April 1999, we evaluated the effects of imazapic as a post-emergence application (February 5, 1999) on foliar regrowth of 18-month-old plants of wiregrass and lopsided indiangrass in the greenhouse. These plants had been propagated in tubeling trays (5.7 × 15.2 cm cell size), using a potting mix of peat:sand tailings:perlite in a ratio of 2:2:1. Fertilization of all plants was done 7 weeks before the experiment, and 2.5, 5.0, and 6.5 weeks after treatment (WAT) at the rate of 25 ml/cell of Miracle Gro (15-30-15) solution (12 g/11.4 L). Our experimental units for each separate species consisted of 8 plants in 28 × 25 cm tubeling trays. The plants were arranged in alternating cells to minimize any shading from neighboring plants. Just prior to the imazapic application, the foliage of these plants was clipped to a height of 12.5 cm above the soil surface in order to standardize growth responses after the treatments. The foliage regrowth was measured as the longest leaf length per plant at 2, 4, 6 and 8 WAT. Growing conditions in the greenhouse included temperature maintained between 16 and 32 ^{o}C, daily overhead irrigation of approximately 2 cm, and the natural photoperiod of 11 to 12.5 hours.

We applied 4 rates of imazapic at 0.05, 0.10, 0.16, and 0.21 kg a.i./ha (or 3, 6, 9 and 12 oz/ac of Plateau), as well as 2 controls (water only and water + adjuvant). There were 6 replications in separate experiments for each species. The spraying procedure consisted of placing the tubeling trays outside on the ground in order to use the CO_2 backpack sprayer. After spraying, the experimental units for each separate species were arranged on the greenhouse benches in a randomized complete block (RCB) design, using position under the overhead irrigation as the blocking factor.

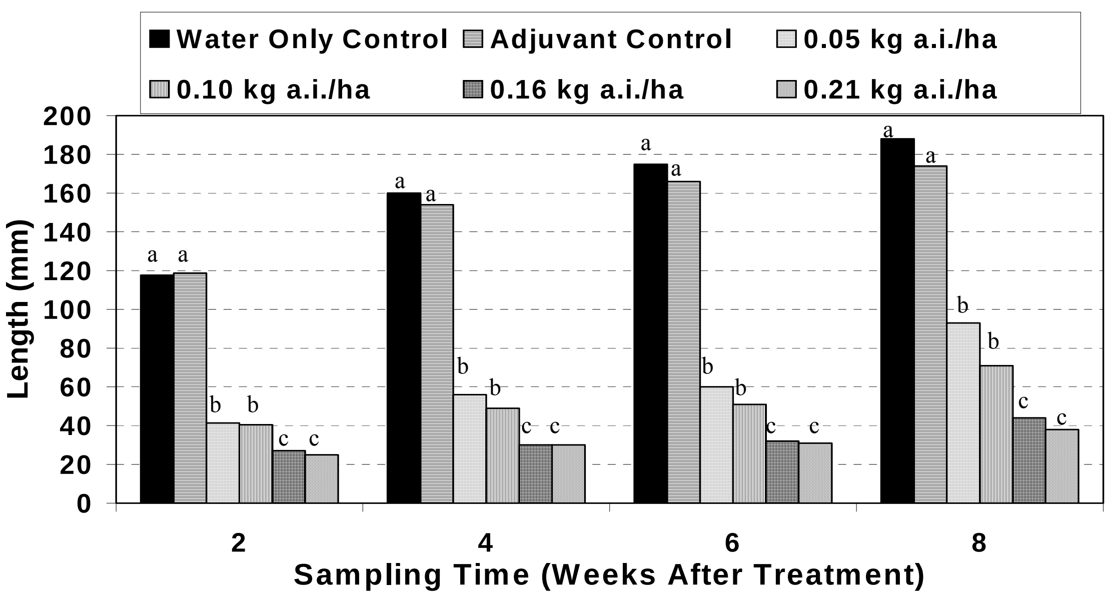
In the greenhouse, all the wiregrass and lopsided indiangrass plants survived all imazapic rates. Foliar regrowth of the control plants of lopsided indiangrass was much greater than that of wiregrass, but wiregrass was more tolerant of imazapic and more resilient in recovering from negative effects (Figures 9 and 10). For example, wiregrass growth at 4, 6 and 8 WAT compared to the water control was significantly reduced at rates of 0.10 kg a.i./ha and above, and at 2 WAT only by the two highest dosages (Figure 5). On the other hand, lopsided indiangrass foliar regrowth was strongly inhibited at all imazapic rates and on all sampling dates (Figure 10).

Both wiregrass and lopsided indiangrass demonstrated significant response trends of less growth with increasing imazapic rates at every sampling period. There was no effect of the adjuvant control on either native species (Figures 9 and 10).



Means at one sampling with the same letter are not different at the P = 0.05 level. Imazapic rates are equivalent to 3, 6, 9, and 12 oz Plateau/acre. Mean values of 6 replicates.

Figure 9. Imazapic Rate Effects on Foliar Growth of Wiregrass Over Time in Greenhouse Experiment.



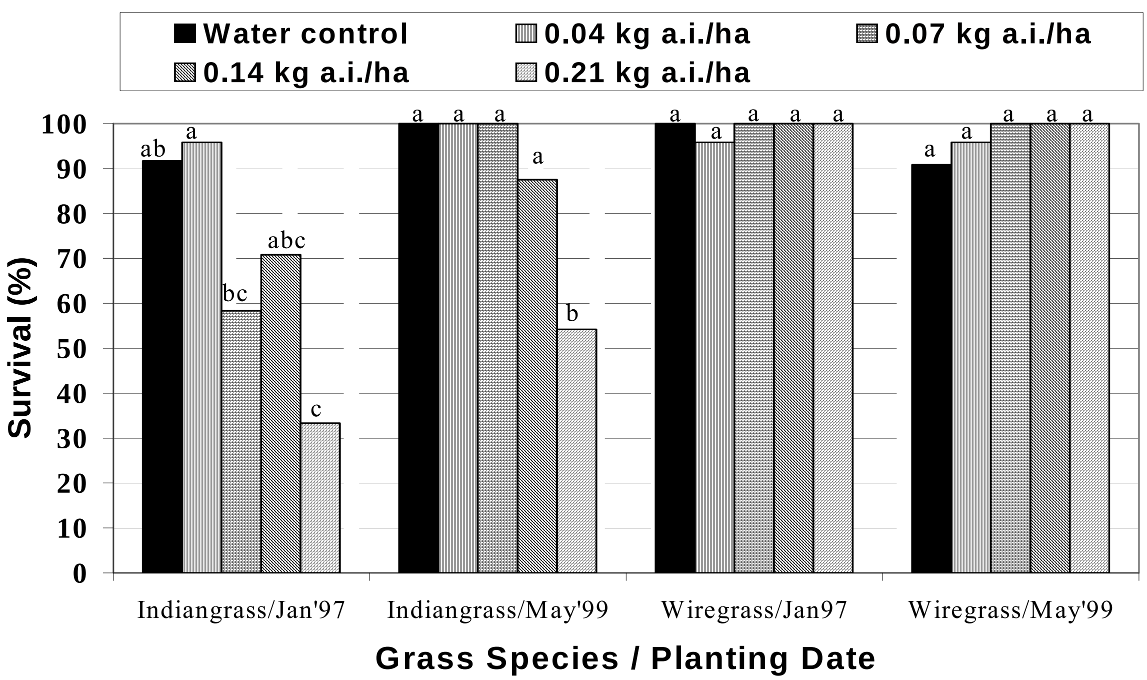
Means at one sampling with the same letter are not different at the P = 0.05 level. Imazapic rates are equivalent to 3, 6, 9, and 12 oz Plateau/acre). Mean values of 6 replicates.

Figure 10. Imazapic Rate Effects on Foliar Growth of Lopsided Indiangrass Over Time in Greenhouse Experiment).

Field Experiments

This study was conducted at the Hookers Prairie mine (overburden-capped sand tailings) of Cargill, Inc. (now the Mosaic Company), in Polk County, FL. We evaluated the effects of a post-emergence application of imazapic (August 13, 1999) on 2 ages of wiregrass and lopsided indiangrass plantings, i.e., 31 months (planted January 1997) and 3 months (planted May 1999). Plants were from plots established as seeding trials of native grasses by USDA Natural Resource Conservation Service, Brooksville, FL. Plantings of January 1997 were monocultures of each grass while plantings of May 1999 were mixtures of the 2 grasses. We used 4 rates of imazapic at 0.04, 0.07, 0.14 and 0.21 kg a.i./ha (or 2, 4, 8 and 12 oz/ac of Plateau), as well as a water-only control. There were 4 replications, using plots of 0.9 × 2.4 m size in a randomized complete block (RCB) design, using depth of overburden cap as our blocking factor. At 13 WAT six plants per plot (which were tagged at application) were individually monitored for survival and plant vigor. Plant vigor was defined as the percentage of green foliage present (not chlorotic or necrotic) and was estimated visually on a per plant basis. None of the plants was fertilized or watered during the course of the experiments.

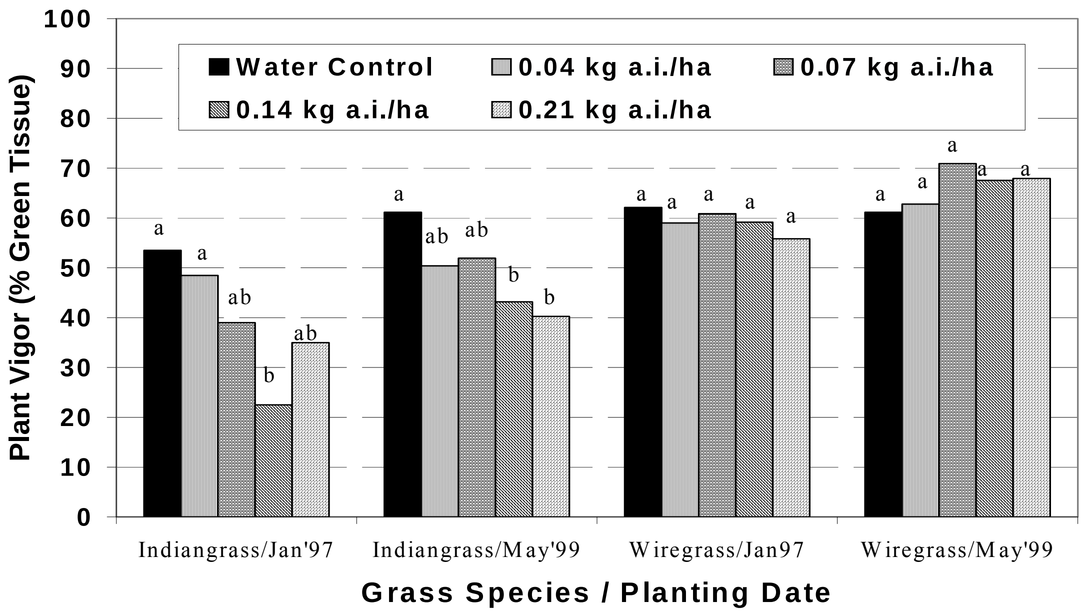
In the field, percent survival of wiregrass was not affected by imazapic, whereas indiangrass percent survival was (Figure 7). Survival of lopsided indiangrass from both planting dates was significantly reduced at the 0.21 kg a.i./ ha rate, and the older lopsided indiangrass (31-month) appeared to be more susceptible, with only 34% survival from the August 1999 application compared to younger plants (3-month) with 55% survival.



Means of one species/date with the same letter are not different at 0.05 level. Imazapic rates are equivalent to 3, 6, 9, and 12 oz Plateau/acre). Mean values of 4 replicates.

Figure 11. Imazapic Dosage Effects on Survival at 13 WAT of Lopsided Indiangrass and Wiregrass from Different Planting Dates in Field Experiment.

Similarly, imazapic had no effect on the plant vigor of wiregrass, but indiangrass did tend to decrease in percent green tissue with greater imazapic rates (Figure 12). Older indiangrass plants showed greater vigor damage than younger plants, and vigor response trends were significant only for lopsided indiangrass. For example, there were significant linear and quadratic trends for 31-month-old plants and a significant linear trend for 3-month-old plants for decreased vigor with increased imazapic rates. Older lopsided indiangrass also had a significant positive correlation between survival and plant vigor (r = 0.46).



Means of one species/date with the same letter are not different at P = 0.05 level). Imazapic rates are equivalent to 3, 6, 9, and 12 oz Plateau/acre).

Figure 12. Imazapic Dosage Effects at 13 WAT on Plant Vigor of Surviving Lopsided Indiangrass and Wiregrass from Different Planting Dates In Field Experiment.

Field Study of Lopsided Indiangrass Tolerance to Imazapic

In earlier research (Kluson and others 2000), we had found that lopsided indiangrass (*Sorghastrum secundum*) was somewhat sensitive to imazapic. An additional trial was conducted in 2003, using low rates of imazapic (0, 0.05, and 0.11 kg a.i./ha [0, 3 and 6 oz/acre Plateau]) to further evaluate lopsided indiangrass sensitivity. Stands of lopsided indiangrass established by direct seeding in June 1999 at the Cargill (now Mosaic) Hooker's Prairie mine, 1 km south of Polk CR [County Road] 630 and about 5 km west of the city of Fort Meade (sand tailings fill with overburden cap). Lopsided indiangrass plots (four replicate plots per treatment) were sprayed in May 2003, and 10 plants per plot were randomly selected and evaluated for change in leaf height, mortality and flowering in July and October. Even the 0.05 kg a.i./ha (3 oz/acre Plateau) rate caused leaf dieback, severely inhibited flowering, and increased mortality slightly (Table 44).

Table 44. Effects of Imazapic (Plateau) Herbicide Applied in May 2003 on Lopsided Indiangrass in July and October 2003.

		Plateau Rate (oz/acre)		
		0	3	6
Height (cm)				
Before	May	57.0 (1.1)	57.5 (1.4)	58.8 (1.2)
After	July	64.2 (1.2)	45.1 (1.2)	39.4 (2.1)
Ratio After/Before		1.13	0.78	0.67
Mortality (%)	July	0.0 (0.0)	5.0 (5.0)	15.0 (9.6)
	Oct.	2.5 (2.5)	12.5 (7.5)	35.0 (19.4)
Flowering (%)	Oct.	65.0 (2.9)	10.0 (5.8)	0.0 (0.0)

Mean values of four replicates (standard error in parentheses).

Herbicide Tolerance of Three Native Grasses: Greenhouse Study

The objective was to examine the tolerance of maidencane (*Panicum hemitomon*), blue maidencane (*Amphicarpum muhlenbergianum*) and splitbeard bluestem (*Andropogon ternarius*) to imazapyr, imazapic and imazamox.

Andropogon ternarius (split-beard bluestem) seeds (previously obtained from the NRCS Plant Materials Center in Brooksville) were collected from FIPR property and planted into tubeling trays (each cone or cell was 2 inches in diameter × 4.5 inches deep) on 12/21/07. Seedlings were fertilized (¼ tsp Osmocote Plus 8-9 month formula [15-9-12 plus micronutrients] per cone) on 7/24/07. *Panicum hemitomon* (citrus maidencane) rhizomes were collected from the DEP Homeland site and were planted into tubeling trays 7/3-5/07. Transplants were fertilized (¼ tsp Osmocote per cone) after they were established. *Amphicarpum muhlenbergianum* (blue maidencane) rhizomes were collected from a FIPR planting at the Tenoroc Fish Management Area and planted into tubeling trays 7/3-5/07 and fertilized (¼ tsp each cone) on 7/24/07. The *Andropogon, Panicum* and *Amphicarpum* plants were moved to gallon-sized pots on May 12, 2008, and fertilized on May 20 with ¼ tsp Osmocote per pot.

The experiment was planned to evaluate the phytotoxic effects of three herbicides (imazapyr, imazapic and imazamox) applied at three rates as described in Table 45. The product formulations for imazapyr and imazapic contained 2 lb active ingredient per gallon, while the imazamox formulation contained only 1 lb active ingredient per gallon. On June 2, 2008, pots were placed outside on a paved area, and the treatments were applied with a CO_2 backpack sprayer with a 4-nozzle boom. The sprayer was calibrated to deliver 40 gal/acre at 32 psi pressure. Following treatment, the pots were placed back in the greenhouse and overhead irrigation was resumed 18 hours after treatment. There were three replications of each treatment and the experiment was set up in a randomized block design.

Observations were made, photographs were taken, and heights of green foliage were measured periodically. On August 14, 2008, *Panicum hemitomon* and *Amphicarpum muhlenbergianum* were clipped to a height of 9 inches (23 cm) above the soil, and 0.25 tsp of Osmocote slow release fertilizer was added to each pot. Height of regrowth was then measured periodically.

Table 45. Herbicide Treatments Applied to Three Native Grasses in the Greenhouse.

	Herbicide	Active Ingredient (a.i.)	Rate (oz/acre)	Product (lb a.i./acre)
1	Arsenal	Imazapyr	4	0.0625
2		Imazapyr	8	0.1250
3		Imazapyr	12	0.1875
4	Plateau	Imazapic	4	0.0625
5		Imazapic	8	0.1250
6		Imazapic	12	0.1875
7	Clearcast	Imazamox	8	0.0625
8		Imazamox	16	0.1250
9		Imazamox	24	0.1875
10		Control	0	

Results—5 Weeks After Treatment (WAT) (July 5, 2008). There was slight stunting of *Andropogon* with imazapyr and a very slightly greater effect with the higher rate, based on comparative visual evaluation of plant size (height, diameter and density of foliage) of treated versus untreated control plants. There were no obvious effects with imazapic or imazamox. *Panicum* exhibited some stunting (about half the size of the controls) and some discoloration with imazapyr, and the effects were slightly greater at higher rates. There was some stunting with imazapic but no obvious differences with rates. There was very slightly stunting at the highest rate of imazamox. *Amphicarpum* showed some discoloration with imazapyr but no obvious effects with imazapic or imazamox.

11 WAT (August 14, 2008). *Andropogon* exhibited no differences from the control for any treatment. *Panicum* treated with imazapyr was ½ the size of the control with the lowest rate down to ⅓ the size of the control with the highest rate. Imazapic-treated *Panicum* was ⅞ the size of the control at the lowest rate and down to ¾ the size of the control with the highest rate. With imazamox only the highest rate caused a reduction in size (¾ the size of the control). *Amphicarpum* was ¾ the size of the control with the low rate of imazapyr down to ½ the size of the control with the highest rate. The imazapic and imazamox treatments were no different from the controls. (Note: *Panicum* and *Amphicarpum* clipped to a height of 23 cm following data collection on August 14. *Andropogon* not clipped.)

14 WAT (September 4, 2008). The *Andropogon* controls had obvious flower stalks but not the imazapyr treated plants (flower stalks no taller than foliage with imazapyr). Otherwise all looked healthy. With imazapic all plants had flower stalks similar to the controls and were similarly healthy. Imazamox treated plants had slightly shorter flower stalks than the control but otherwise appeared healthy. *Panicum* regrowth with imazapyr was less than the control (⅞ at the low rate and down to ¾ the size of the control at the highest rate). There were no obvious differences in regrowth compared to the controls for imazapic or imazamox treated plants. *Amphicarpum* regrowth was inhibited by all rates of imazapyr so that none of the treated plants had regrowth above the 23 cm height of clipping (clipped August 14). Regrowth in imazapic and imazamox treated plants was similar to the control.

17.5 WAT (September 29, 2008). *Panicum* regrowth was similar to the control for the lower rates of imazapyr, but there was a very slight reduction in regrowth with the highest rate. Regrowth of *Panicum* was similar to the control for all rates of imazapic or imazamox. There was some regrowth of *Amphicarpum* above the clipped height with imazapyr treatment but it was less than the control. *Amphicarpum* regrowth was similar to the control for all rates of imazapic or imazamox.

October 21, 2008. *Panicum* appeared to have recovered completely from any effects of the herbicides. *Amphicarpum* had mostly recovered but there was still less regrowth in the imazapyr treated plants than in the control. Neither *Panicum hemitomon* nor *Amphicarpum muhlenbergianum* flowered during the course of the experiment.

Andropogon ternarius, under greenhouse growth conditions in the summer and fall, was quite tolerant of imazapyr, imazapic and imazamox at rates from 0.0625 to 0.1875 lb a.i./acre. Initially, there was a very slight stunting with imazapyr, but *Andropogon* foliage soon grew out of it. There was still some inhibition of flowering with imazapyr at 14 WAT. There were no obvious effects on growth or flowering from imazapic or imazamox.

Panicum hemitomon was more tolerant of imazamox than imazapic and more tolerant of imazapic than imazapyr at the same rates of active ingredient. There was slight stunting at the highest rate of imazamox. There was some stunting with all rates of imazapic and slightly more stunting at higher rates. Stunting was more severe with imazapyr. Plants were clipped to a height of 23 cm at 11 WAT. At 14 WAT, regrowth was less than the controls with imazapyr but equal to the controls with imazapic and imazamox.

Amphicarpum muhlenbergianum was very tolerant of imazamox and imazapic but quite sensitive to imazapyr. Imazapyr inhibition of *Amphicarpum* was especially evident in the severe stunting of regrowth following clipping.

Height of the tallest green leaf tissue was quite variable, and there were only slight visual differences among rates of any chemical. Therefore, heights were averaged over rates in the tables below (Tables 46 and 47) to illustrate differences in herbicide responses.

Table 46. Height (cm) of Tallest Green Leaf Tissue 11 WAT.

	Panicum	*Amphicarpum*	*Andropogon*
Imazapyr	51	66	83
Imazapic	60	79	66
Imazamox	62	81	76
Control	70	88	70

Table 47. Foliage Height (cm) After Clipping to 23 cm 11 WAT.

	Panicum		*Amphicarpum*	
	14 WAT	17 WAT	14 WAT	17 WAT
Imazapyr	46	65	23	56
Imazapic	60	71	59	76
Imazamox	61	73	60	86
Control	60	70	66	78

Asulam and Velpar Effects on Natalgrass, Blue Maidencane, Maidencane, and Splitbeard Bluestem: Greenhouse Study

Natalgrass, maidencane, blue maidencane, and splitbeard bluestem were sprayed 12/19/08 with a 4-nozzle boom CO_2 sprayer. There were three 6-inch pots of each plant species per treatment (32 oz Velpar L per acre, 80 or 120 oz Asulam per acre).

Splitbeard bluestem was very tolerant of Velpar L at 32 oz/acre and Asulam at 80 or 120 oz/acre. There were no obvious signs of injury. Natalgrass was killed by Velpar and severely injured by Asulam, but the Asulam-treated natalgrass eventually began to resprout at the nodes. Asulam injured maidencane and blue maidencane; taller stems present when sprayed eventually died back, but new shoots began to grow back from the rhizomes. Velpar severely injured maidencane and blue maidencane.

Velpar appears very promising for selective control of natalgrass in a stand of splitbeard bluestem. Asulam might provide some selective control of natalgrass in a stand of splitbeard bluestem, but natalgrass would likely be suppressed rather than killed. Because of severe injury to maidencane and blue maidencane, the rates of Velpar or

Asulam used in this study probably should not be used on these species when actively growing.

Velpar Rate Effects on Maidencane, Blue Maidencane and Natalgrass: Greenhouse Study

In the previous experiment, only one rate of Velpar L was tested (32 oz/acre). Further information was needed on the effects of other rates. Treatments were applied 2/24/09 with CO_2 backpack sprayer with 4-nozzle boom (40 gal/acre at 32 psi) to three plants in 6 inch diameter pots per treatment. Treatments: Check, 12 fl oz/acre, 16 oz/acre, 24 oz/acre, 48 oz/acre of Velpar L (hexazinone).

All rates of Velpar L injured natalgrass, maidencane and blue maidencane at 4 WAT. Blue maidencane appeared to be more tolerant than maidencane, and natalgrass appeared to be more sensitive to Velpar than maidencane or blue maidencane. Natalgrass was completely dead at 24 oz/acre, and there was only a small amount of green leaf tissue on one of the three plants treated with 16 oz/acre. It may be possible to achieve selective control of natalgrass in blue maidencane with Velpar L at about 16 oz/acre, but there would likely be some injury to the blue maidencane.

Torpedograss Control

Torpedograss (*Panicum repens*) is a major exotic weed problem in wetlands in Florida (Hanlon and others 2000), but it also can be found in uplands. A site on a sand tailings pile that was dominated by torpedograss was located at the Tenoroc Fish Management Area, northeast of Lakeland, Florida. Plateau (23.6% imazapic) and Habitat (28.7% imazapyr) herbicides (with 0.5 oz. nonionic surfactant per gallon of spray solution) were applied at rates of 16, 32 and 48 oz of product per acre on three replicate plots (6 ft × 20 ft) per treatment on October 28, 2004, with a CO_2 backpack sprayer with a hand-held boom. Percent cover on each plot was evaluated with line-point transects on July 21, 2005.

Habitat appears to be more effective in controlling or suppressing torpedograss than is Plateau (Table 48). The control of torpedograss with imazapyr on this dry upland site was rather poor compared to our previous experience (see photograph in Figure 5) and that of others (Hanlon and others 2000) in more moist conditions. However, the suppression of torpedograss by imazapyr resulted in increases in natalgrass and camphorweed (*Heterotheca*). Smutgrass cover was slightly greater with Plateau than with Habitat, suggesting greater tolerance to Plateau than Habitat. Because of dry conditions, October 28 probably was not the ideal time for herbicidal control of torpedograss on this upland, well-drained, sandy site. An earlier treatment date in the rainy season, such as in September, may be more effective. In addition, a higher rate of Habitat, such as 64 oz of product (1.0 lb imazapyr) per acre may be necessary for control. Perhaps a methylated seed oil adjuvant, as recommended on the herbicide label for non-optimum dry conditions, might have improved the control of torpedograss in this upland situation.

Table 48. Percent Cover of Torpedograss and Other Species on July 21, 2005, on an Upland Sand Tailings Site at Tenoroc After Treatment with Plateau and Habitat on October 28, 2004.

Rate (oz/acre)		Torpedograss	Heterotheca	Natalgrass	Smutgrass	Litter-Bare
Plateau	16	75.7 (4.8)	3.6 (1.9)	0	9.4 (4.9)	8.8 (1.5)
	32	87.7 (2.2)	1.4 (0.7)	0	5.1 (2.0)	5.7 (1.1)
	48	87.4 (1.8)	0	0	2.3 (1.2)	8.4 (1.6)
Habitat	16	57.0 (1.7)	8.8 (3.2)	11.4 (3.6)	0.6 (0.6)	14.5 (2.2)
	32	43.5 (5.4)	13.5 (1.2)	12.6 (1.9)	0	30.4 (3.3)
	48	31.9 (1.2)	10.1(4.0)	10.9 (1.7)	0	46.6 (3.9)

Mean values of 3 replicates (standard error in parentheses).

Figure 13 shows the effectiveness of approximately 64 oz Habitat (imazapyr, similar to Arsenal) per acre applied with an ATV boom sprayer on torpedograss at a wetland site on overburden on FDEP's Homeland property. The greater effectiveness on torpedograss, compared to the Tenoroc upland, could be partly attributed to the higher rate of imazapyr but also to the moister, more optimal conditions for torpedograss metabolic activity. The perimeter of the site in Figure 13 was planted with maidencane in the summer of 2005, and Figure 14 shows the site in August 2009.

Figure 13. Torpedograss Control in a Wetland on Reclaimed Mined Land on May 24, 2005, Following Treatment with 2 qt/acre of Habitat (1.0 lb/acre of Imazapyr) in October 2004.

Figure 14. View of Site in August 2009 Where Torpedograss Was Treated with Imazapyr in the Fall of 2004 and Planted with Maidencane in the Summer of 2005.

Another wetland at the FDEP Homeland property, which was completely infested with torpedograss (east of the wetland in Figure 13), was treated with imazapyr in October 2008 (see Figure 15 before treatment). Figure 16 shows the same site in September 2009 and also shows some of the maidencane that had been planted around the perimeter in August 2009. The same site with established and spreading maidencane is shown in September 2010 (Figure 17).

Figure 15. Torpedograss October 2, 2008 Just Prior to Treatment with Imazapyr.

Figure 16. Torpedograss September 25, 2009, Following Treatment with Habitat (Imazapyr) Herbicide in October 2008 and Planting of Maidencane in August 2009.

Figure 17. Maidencane September 17, 2010, Following Treatment of Torpedograss in October 2008 and Planting of Maidencane in Summer 2009.

Fusilade and Clearcast Effects on Torpedograss

A site west of other torpedograss sites on the FDEP Homeland property (dubbed "cypress garden" by FDEP staff) was treated with Fusilade (fluazifop) April 20, 2011, when there was no standing water in the sprayed area. Figure 18 shows the site before treatment, and Figures 19 and 20 show the site after treatment. Torpedograss was suppressed and broadleaved plants were unharmed and released from competition. On separate plots, Fusilade was applied in August, and photographs of untreated and Fusilade-treated plots are shown one month after treatment in Figure 21.

Figure 22 shows a torpedograss and cattail plot on June 17, 2011, one year after treatment with 2% Clearcast on June 10, 2010.

Figure 18. Torpedograss Before Treatment on April 20, 2011.

Figure 19. Torpedograss on June 1, 2011, Six Weeks After Treatment with Fusilade at 1.0 fl oz/gal (with 0.3% NIS) on April 20, 2011.

Figure 20. Torpedograss Site on April 11, 2012, Nearly One Year After Treatment with Fusilade.

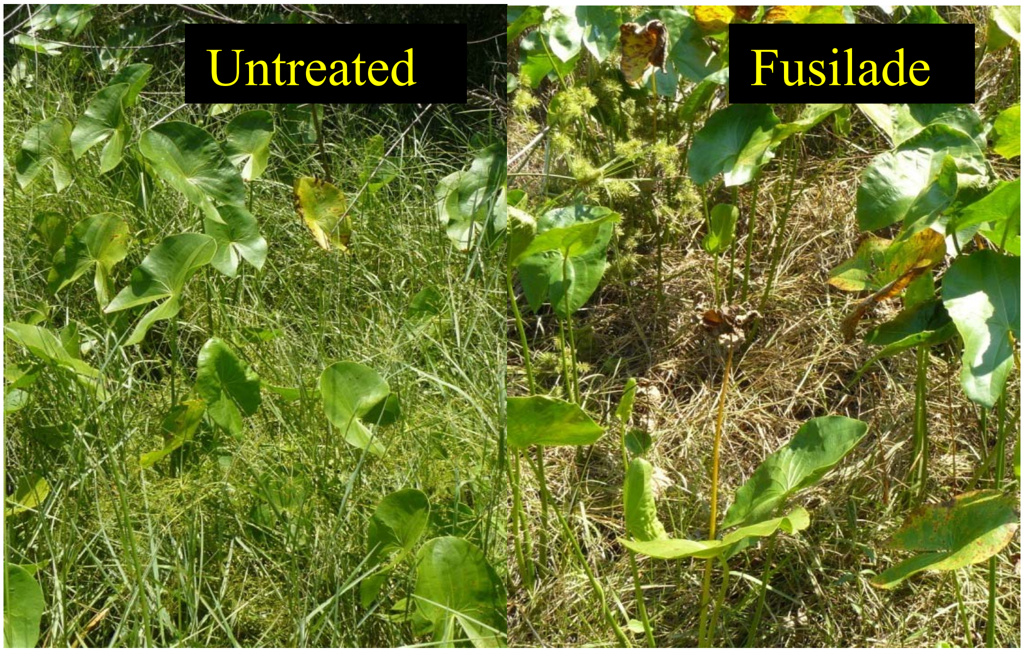


Figure 21. Torpedograss Untreated and Treated with Fusilade (Photograph Taken in Mid-September, One Month After Treatment in Mid-August).

Figure 22. Torpedograss and Cattail Plot on June 17, 2011, After Treatment with 2% Clearcast (Imazamox) on June 10, 2010 (Untreated Cattail to the Left of White PVC Poles).

Torpedograss has been treated at the FDEP Homeland site with imazapyr (Habitat), glyphosate (Rodeo), fluazifop (Fusilade) and imazamox (Clearcast). Imazapyr provides the best control. Fluazifop caused little to no injury of plants other than torpedograss, and the competition from the other plants is an important factor in controlling torpedograss after herbicide application. Imazamox provided good control of torpedograss and also cattail, but injured some other herbaceous species. Red maple, bald cypress, wax myrtle and saltbush have some tolerance to imazamox (also other members of the sunflower and legume plant families have some tolerance). Habitat, Rodeo and Clearcast are labeled for wetland and aquatic use. CAUTION: Current Fusilade labels do not allow application to standing water in wetlands. Application to fringe areas around wetlands without standing water may be possible, but clarification from the Florida Department of Agriculture and Consumer Services, the USEPA and the manufacturer is needed. If Fusilade was authorized for torpedograss in wetlands, the combination of the herbicide plus competition from broadleaved marsh plants would likely provide good control of torpedograss. Test plantings indicate that maidencane may be a good competitor to retard or prevent reinfestation of torpedograss, in addition to vigorous broadleaved plants. The propensity of maidencane to go dormant in the winter may also allow a window of opportunity to selectively control torpedograss, which tends to remain active at slightly lower temperatures than maidencane.

Imazamox and Glyphosate Effects on Torpedograss in a Forested Wetland

A site at the CF Industries' R-14 wetland that was heavily infested with torpedograss but also contained many trees (mostly red maple) was selected for study.

Our herbicide of choice would have been fluazifop (Fusilade) because this grass herbicide was quite effective on torpedograss in preliminary tests and was very safe to use around trees and broadleaved plants. However, fluazifop is not labeled for wetland use, especially where there is standing water. Imazapyr (Habitat) could have been used, but there likely would have been great injury to the trees. Therefore, we tested imazamox (2% solution of Clearcast plus 0.3% NIS) because it has been shown to be fairly safe around red maple, and because certain composite and legume species have shown some tolerance to other herbicides in this chemical family (e.g., *Bidens laevis*, a composite, was common on the study area). We also tested a directed application (aimed to miss trees) of glyphosate (2% solution of AquaStar plus 0.3% NIS) for comparison.

The Clearcast was sprayed with a backpack sprayer to thoroughly wet the torpedograss on September 15, 2011, and the AquaStar was sprayed in the same manner on November 3, 2011. The plots were evaluated and photographed on November 22, 2011, and also observed the following spring and summer. Both herbicides caused a significant browning of the torpedograss, although the glyphosate caused more complete browning. Neither treatment caused injury to the 6-8 ft tall trees. Unfortunately, the torpedograss had grown back in all plots by late spring 2012.

MANAGEMENT GUIDELINES

Natalgrass

Natalgrass behaves much like an annual plant. It grows rapidly from seed and is a prolific seed producer. However, in central and southern Florida it may also behave like a short-lived perennial. A hard frost may kill the plants, but with a slightly milder winter, the plants may resprout from roots and stem nodes. It can also spread vegetatively by producing roots and new shoots at stem nodes.

The key to controlling natalgrass is to prevent seed production and to inhibit seed germination. Natalgrass can be killed by higher rates of glyphosate (e.g., 3-4 qt Round-up), imazapyr (1-2 qt Habitat or Arsenal/acre) and hexazinone (e.g., 1 qt Velpar L/acre). Fluazifop is not very effective on natalgrass even at the higher labeled rates, except on very young seedlings. Diquat is a contact herbicide that can kill natalgrass, but it is more effective on younger plants at the higher labeled rates and with greater carrier water volumes (e.g., 40 gal/acre or more) to provide complete foliar coverage. Many of the pre-emergent herbicides commonly used in agriculture, such as pendimethalin (Pendulum) and oryzalin (Surflan), effectively inhibit seed germination. Imazapyr and imazapic at lower rates (e.g., 12 fl oz Habitat or Plateau per acre) can control seedlings or young plants and also inhibit seed germination of natalgrass. Hexazinone also has pre-emergent activity on natalgrass seed germination.

A renovation technique used effectively on a natalgrass-infested xeric scrub reclamation site involved burning the site in June and applying pre-emergent herbicides to the bare ground to inhibit germination of natalgrass seeds in the soil. Natalgrass germination was effectively controlled by pendimethalin, but there was no effect on the resprouting perennial species. Hexazinone, imazapyr and imazapic also gave good pre-emergent control of natalgrass following the burn. These three herbicides also have post-emergent activity, but because of virtually no herbaceous leaf area after a burn, the uptake would be via roots. Fortunately, many native species in the legume and composite families, plus wiregrass and beardgrasses (*Andropogon* spp.) have some tolerance to imazapyr and imazapic at lower rates. Wiregrass, beardgrasses and pines have some tolerance to hexazinone.

Natalgrass is a problem particularly in xeric habitats where one expects to have some bare ground. It may be a temporary problem on newly seeded/planted mesic sites where the later establishing herbaceous vegetation is more competitive.

Torpedograss

Imazapyr (Habitat) is the most effective herbicide for controlling torpedograss. Glyphosate is less effective than imazapyr but has no soil residual. Imazamox (Clearcast), in our preliminary tests, provided some control of torpedograss at the highest rates listed on the label. Imazamox is tolerated by several wetland tree species, but we observed some injury to some broadleaved wetland herbaceous species. Fluazifop (Fusilade) is a grass herbicide that has little or no activity on non-grasses, including most trees and broadleaved herbaceous species. Our preliminary tests indicate fluazifop has good potential to kill or suppress torpedograss and encourage growth of broadleaved wetland plants that may further compete with the weakened torpedograss. CAUTION: Current Fusilade labels do not allow application to standing water in wetlands (apparently because of concerns about fluazifop effects on fish and other aquatic organisms). Application to torpedograss in fringe areas around wetlands without standing water or perhaps to seasonally dry wetlands might be possible, but clarification from the Florida Department of Agriculture and Consumer Services, the USEPA and the manufacturer is needed. Test plantings indicate that maidencane may be a good competitor to retard or prevent reinfestation of torpedograss. The propensity of maidencane to go dormant in the winter may also allow a window of opportunity to selectively control torpedograss, which tends to remain active at slightly lower temperatures than maidencane.

Smutgrass

Smutgrass can be controlled with high rates of imazapyr and glyphosate. It can be selectively controlled by applying 1.0-1.5 qt Velpar L (hexazinone) per acre during the rainy season. Wiregrass, pines, beardgrasses (*Andropogon* spp.) and bahiagrass are tolerant of hexazinone at these rates.

Bahiagrass

Seed germination is inhibited and seedlings and young plants can be selectively killed by imazapic (Plateau) or imazapyr (Habitat) at rates near 12 oz of product (Plateau or Habitat) per acre. More mature bahiagrass requires higher rates of imazapyr (32 to 48 oz/acre of Habitat) or glyphosate (3-4 qt Roundup Pro per acre) for control. Bahiagrass is most susceptible to imazapyr or imazapic in the spring or early summer before it flowers and is most tolerant in late fall or winter. Bahiagrass is more tolerant of imazapyr (12 fl oz Habitat/acre) than is cogongrass, which allows selective control of cogongrass in a bahiagrass stand. Bahiagrass is tolerant of hexazinone at rates of 1.0-1.5 quart Velpar L per acre, which allows selective control of smutgrass in a bahiagrass stand.

Bermudagrass

Bermudagrass is best controlled before other vegetation is planted. Tillage alone does not effectively control bermudagrass but may serve to spread rhizomes and stolons. It can be killed with higher rates of imazapyr or glyphosate, and imazapyr is more effective than glyphosate. As we learned with cogongrass, imazapyr alone does a better job than when glyphosate is applied in tank-mix with imazapyr (Boyd and Rogers 1999). Bermudagrass has some tolerance to imazapyr, imazapic and hexazinone. Fluazifop can be used to selectively control it without harming broadleaved plants. Triclopyr, a broadleaf and brush killer, causes some injury and suppresses bermudagrass at rates of 0.75 to 1.0 lb a.i./acre (McCullough 2011).

REFERENCES AND BIBLIOGRAPHY—OTHER GRASSES

Bahiagrass

Akanda RU, Mullahey JJ, Dowler CC, Shilling DG. 1997. Influence of postemergence herbicides on tropical soda apple (*Solanum viarum*) and bahiagrass (*Paspalum notatum*). Weed Technology 11(4): 656-61.

Baker R. 1996. Differential susceptibility of five bahiagrass cultivars to metsulfuron methyl [DPhil dissertation]. Gainesville (FL): University of Florida.

Black CC, Rodgers EG. 1960. Response of pensacola bahiagrass to herbicides. Weeds, 8(1): 71-7.

Brecke BJ, Unruh JB. 2002. Weed management in warm-season turfgrass with CGA 362622 [abstract only]. Proc. South. Weed Sci. Soc. 55: 52.

Bunnell BT, Baker RD, McCarty LB, Hall DW, Colvin DL. 2003. Differential response of five bahiagrass (*Paspalum notatum*) cultivars to metsulfuron. Weed Technology 17(3): 550-3.

Eichhorn MM. 1995. Control of pensacola bahiagrass and southern crabgrass in bermudagrass hay meadows. Louisiana Agriculture 38(3): 23.

Fisher RF, Adrian F. 1981. Bahiagrass impairs slash pine seedling growth. Tree Planters' Notes 32(2): 19-21.

Goatley JM. Jr, Maddox VL, Watkins RM. 1996. Growth regulation of bahiagrass (*Paspalum notatum* Fluegge) with imazaquin and AC 263,222. HortScience 31(3): 396-9.
Gonzalez FE, Atkins RL, Brown GC. 1984. Sulfometuron methyl, rate and timing studies on bermudagrass and bahiagrass roadside turf. Proc. South. Weed. Sci. Soc. 37: 272-4.

Hanna WW, Swann CW, Schroeder J, Utley PR. 1989. Sulfometuron for eliminating bahiagrass (*Paspalum notatum*) from centipedegrass (*Eremochloa ophiuroides*) and bermudagrass (*Cynodon dactylon*). Weed Technology 3(3): 509-12.

Johnson BJ. 1990. Response of bahiagrass (*Paspalum notatum*) to plant growth regulators. Weed Technology 4(4): 895-9.

Kluson RA, Richardson SG, Shibles DB, Corley DB. 2000. Response of two native and two non-native grasses to imazapic herbicide on phosphate mined lands in Florida. In: Daniels WL, Richardson SG, editors. Proceedings, Seventeenth Annual Meeting of the American Society for Surface Mining and Reclamation: A New Era of Land Reclamation; 2000 Jun 11-15; Tampa, FL. p 49-57.

Mislevy P, Burton GW, Busey P. 1991. Bahiagrass response to grazing frequency. Soil and Crop Sci. Soc. Fla. Proc. 50: 58-64.

Richardson SG, Bissett N, Knott C, Himel K. 2003. Weed control and upland native plant establishment on phosphate mined lands in Florida. In: In: Cannizzaro PJ, editor. Proceedings of the 30th Annual Conference on Ecosystems Restoration and Creation; 2003 Oct; Plant City, FL. Tampa (FL): Hillsborough Community College. p 126-38.

Sellers BA, Ferrell JA. 2009. Managing bahiagrass in bermudagrass and stargrass pastures. Gainesville (FL): University of Florida. IFAS Extension Publication nr SS-AGR-257.

Uridel KW. 1994. Restoration of native herbs in abandoned *paspalum notatum* (bahiagrass) pastures [MA thesis]. Gainesville (FL): University of Florida.

Walker GB. 1999. Developments in the restoration of upland pasture lands in Florida [MS thesis]. Orlando (FL): University of Central Florida.

Weaver DN. 1988. Bahiagrass control in bermudagrass pastures [abstract only]. Proc. South. Weed Sci. Soc. 41: 114.

Weinbrecht JS, McCarty LB. 1993. Differential response of bahiagrass (*Paspalum notatum*) cultivars to postemergence herbicides [abstract only]. Proc. South. Weed Sci. Soc. 46: 109.

Bermudagrass

Boyd JW, Rodgers BN. 1999. Bermudagrass control with Arsenal. Little Rock (AR): Cooperative Extension Service, Pest Management Section. AAES Research Series nr 475.

Boyd JW. 1991. Common bermudagrass eradication in pastures [abstract only]. Proc. South. Weed Sci. Soc. 44: 189.

Boyd JW, Rodgers BN. 2001. Bermudagrass control with imazapyr [abstract only]. Proc. South. Weed Sci. Soc. 54: 65.

Boyd J. 2000. Killing off bermudagrass with one less spraying. Golf Course Mgmt. 5: 68-71.

Cudney DW, Bell CE. 2007. Bermudagrass. Davis (CA): University of California, Agriculture and Natural Resources. Pest Notes Publication nr 7453. Available online at: http://ucanr.org/sites/ipm/pdf/pestnotes/pnbermudagrass.pdf

Dangerfield CW, Merck HL, Bullock FD. 1990. Projected economic returns: pine release from bermudagrass. Proc. South. Weed Sci. Soc. 43: 282-6.

Ferrell JA, Murphy TR, Bridges DC. 2005. Postemergence control of hybrid bermudagrass (*Cynodon transvaalensis* Burtt-Davy x *Cynodon dactylon*). Weed Technology 19(3): 636-9.

Griffin KA, Dickens R, West MS. 1994. Imazapyr for common bermudagrass control in sod fields. Crop Sci. 34(1): 202-7.

Johnson BJ. 1988. Glyphosate and SC-0224 for bermudagrass (*Cynodon*) cultivar control. Weed Technol. 2(1): 20-3.

Main CL, Robinson DK, Mueller TC. 2002. Bermudagrass control prior to tall fescue establishment with clethodim and glyphosate [abstract only]. Proc. South. Weed Sci. Soc. 55: 64.

McCullough P. 2011. Bermudagrass control in southern lawns. Athens (GA): University of Georgia. Cooperative Extension Bulletin nr 1393.

Rhodes GN, Thompson MA. 2009. Efficacy and phytotoxicity of nicosulfuron applied in combination with other herbicides in forage bermudagrass [abstract only]. Proc. South. Weed Sci. Soc. 62: 423.

Sellers BA, Ferrell JA. 2009. Managing bahiagrass in bermudagrass and stargrass pastures. Gainesville (FL): University of Florida. IFAS Extension Publication nr SS-AGR-257.

Whitcomb CE. 1981. Response of woody landscape plants to bermudagrass competition and fertility. J. Arboriculture 7(7): 191-4.

Limpograss

Sellers BA, Ferrell JA, Haller WT, Mislevy P, Adjei MB. 2007. Phytotoxicity of selected herbicides on limpograss (*Hemarthria altissima*). J. Aquat. Plant Mgmt. 45: 54-7.

Natalgrass

David AS, Menges ES. 2011. Microhabitat preference constrains invasive spread of non-native natal grass (*Melinis repens*). Biol. Invasions 13(10): 2309-22.

Kluson RA, Richardson SG, Shibles DB, Corley DB. 2000. Responses of two native and two non-native grasses to imazapic herbicide on phosphate mined lands in Florida. In: Daniels WL, Richardson SG, editors. Proceedings, Seventeenth Annual Meeting of the American Society for Surface Mining and Reclamation: A New Era of Land Reclamation; 2000 Jun 11-15; Tampa, FL. p. 49-57.

Possley J, Woodmansee SW, Maschinski J. 2008. Patterns of plant composition in fragments of globally imperiled pine rockland forest: effects of soil type, recent fire frequency, and fragment size. Nat. Areas J. 28(4): 379-94.

Possley J, Maschinski J. 2006. Competitive effects of the invasive grass *Rhynchelytrum repens* (willd.) [C.E. Hubb.] on pine rockland vegetation. Nat. Areas J. 26(4): 391-5.

Pratt C, Lottermoser BG. 2007. Trace metal uptake by the grass *Melinis repens* from roadside soils and sediments, tropical Australia. Environ. Geol. 52(8): 1651-62.

Richardson SG, Bissett N, Knott C, Himel K. 2003. Weed control and upland native plant establishment on phosphate mined lands in Florida. In: Cannizzaro PJ, editor. Proceedings of the 30th Annual Conference on Ecosystems Restoration and Creation; 2003 Oct; Plant City, FL. Tampa (FL): Hillsborough Community College. p 126-38.

Richardson SG. 2008. Selective control of cogongrass (*Imperata cylindrica*) and natalgrass (*Rynchelytrum repens*). In: Florida Exotic Pest Plant Council, 23rd Annual Symposium; 2008 Apr 21-24; Jacksonville, FL. p 20.

Stampe ED, Daehler CC. 2003. Mycorrhizal species identity affects plant community structure and invasion: a microcosm study. Oikos 100(2): 362-72.

Stevens JM, Fehmi JS. 2009. Competitive effect of two nonnative grasses on a native grass in southern Arizona. Invas. Plant Sci. and Mgmt. 2(4): 379-85.

Stokes CA, MacDonald GE, Adams CR. 2009. Factors affecting natalgrass (*Melinis repens*) seed germination [abstract only]. Proc. South. Weed Sci. Soc. 62: 177.

Stokes CA, MacDonald GE, Adams CR, Langeland KA. 2010. Management strategies for natalgrass (*Melinis repens*) in Florida [abstract only]. In: Proc. South. Weed Sci. Soc. 63: 219.

Smutgrass

Betts J, Officer D. 2001. Control of giant parramatta grass. Agnote [New South Wales, Australia] nr DPI/354. ISSN 1034-6848. 11 p.

Brecke BJ. 1981. Smutgrass (*Sporobolus poiretii*) control in bahiagrass (*Paspalum notatum*) pastures. Weed Sci. 29(5): 553-5.

Ferrell JA, Mullahey JJ, Dusky JA, Roka FM. 2006. Competition of giant smutgrass (*Sporobolus indicus*) in a bahiagrass pasture. Weed Sci. 54(1): 100-5.

Ferrell JA, Mullahey JJ. 2006. Effect of mowing and hexazinone application on giant smutgrass (*Sporobolus indicus* var. *pyramidalis*) control. Weed Tech. 20(1): 90-4.

Mislevy P, Martin FG, Hall DW. 2002. West Indian dropseed/giant smutgrass control in bahiagrass pastures. Weed Tech. 16(4): 707-11.

Mislevy P, Shilling DG, Martin FG, Hatch SL. 1999. Smutgrass (*Sporobolus indicus*) control in bahiagrass (*Paspalum notatum*) pastures. Weed Tech. 13(3): 571-5.

Mislevy P, Currey WL. 1980. Smutgrass (*Sporobolus poiretii*) control in south Florida. Weed Sci. 28(3): 316-20.

Mislevy P, Currey WL, Brecke BJ. 1980. Herbicide and cultural practices in smutgrass (*Sporobolus poiretii*) control. Weed Sci. 28(5): 585-8.

Mullahey JJ. 2000. Evaluating grazing management systems to control giant smutgrass (*Sporobolus indicus* var. *pyramidalis*) [abstract only]. Proc. South. Weed Sci. Soc 53: 59-60.

Sellers B, Ferrell JA, Mullahey JJ. 2009. Smutgrass control in perennial grass pastures. Gainesville (FL): University of Florida, Institute of Food and Agricultural Sciences, Florida Cooperative Extension Service. Publication nr SS-AGR-18. 4 p.

Torpedograss

Akamine H, Hossain MA, Ishimine Y, Kuramochi H. 2007. Bud sprouting of Torpedograss (*Panicum repens* L.) as influenced by the rhizome moisture content. Weed Biol. and Mgmt. 7(3): 188-91.

Bodle M, Hanlon C. 2001. Damn the torpedograss! Wildland Weeds 4(4): 6-12.

Brecke BJ, Unruh JB, Dusky JA. 2001. Torpedograss (*Panicum repens*) control with quinclorac in bermudagrass (*Cynodon dactylon x C. transvaalensis*) turf. Weed Tech. 15(4): 732-6.

Busey P. 2003. Reduction of torpedograss (*Panicum repens*) canopy and rhizomes by quinclorac split applications. Weed Tech. 17(1): 190-4.

Chandrasena JPNR. 1990. Torpedograss (*Panicum repens* L.) control with lower rates of glyphosate. Trop. Pest. Man. 36(4): 336-42.

Gettys LA, Sutton DL. 2004. Comparison of torpedograss and pickerelweed susceptibility to glyphosate. J. Aquat. Plant Mgmt. 42: 1-4.

Hanlon CG, Langeland K. 2000. Comparison of experimental strategies to control torpedo grass. J. Aquat. Plant Mgmt. 38: 40-7.

Hossain MA, Ishimine Y, Akamine H, Kuramochi H. 2004. Effect of nitrogen fertilizer application on growth, biomass production and N-uptake of torpedograss (*Panicum repens* L.). Weed Biol. and Mgmt. 4(2): 86-94.

Hossain MA, Ishimine Y, Kuramochi H, Akamine H. 2002. Interval between sequential applications of asulam for regrowth control of torpedograss (*Panicum repens L.*). Weed Biol. and Mgmt. 2(2): 92-7.

Hossain MA, Ishimine Y, Kuramochi H, Akamine H. 2002. Effect of standing water and shoot removal plus standing water regimes on growth, regrowth and biomass production of torpedograss (*Panicum repens L.*). Weed Biol. and Mgmt. 2(3): 153-8.

Hossain MA, Akamine H, Nakamura I, Ishimine Y, Kuramochi H. 2001. Influence of temperature levels and planting time on the sprouting of rhizome-bud and biomass production of torpedograss (*Panicum repens L.*) in Okinawa island, southern Japan. Weed Biol. and Mgmt. 1(3): 164-9.

Hossain MA, Kuramochi H, Ishimine Y, Akamine H. 2001. Application timing of asulam for torpedograss (*Panicum repens L.*) control in sugarcane in Okinawa Island. Weed Biol. and Mgmt. 1(2): 108-14.

Hossain MA, Ishimine Y, Kuramochi H, Akamine H, Murayama S, Konnai M. 1997. Efficacy of post-emergence herbicides on torpedograss (*Panicum repens L.*). J. Weed Sci. Tech. 42(3): 197-205.

Ketterer EA, MacDonald GE, Ferrell JA, Boote KJ, Sellers BA. 2007. Cogongrass and torpedograss: rhizome manipulation with growth regulator herbicides [abstract only]. Proc. South. Weed Sci. Soc. 60: 201.

Langeland K, Smith B, Hanlon C. 1998. Torpedograss—forage gone wild. Wildland Weeds 1(3): 4-6.

Matson C, Schulte JA. 2006. Combining herbicide application regimens with revegetation using maidencane cuttings to control torpedograss infestations in wetlands at The Nature Conservancy's Disney Wilderness Preserve over three growing seasons. Presented at: "Little Crop of Horrors," Florida Exotic Pest Plant Council 21st Annual Symposium; 2006 Apr 24-26; Gainesville, FL.

Richardson SG. 2008. Selective control of cogongrass and torpedograss. Presented at: Florida Aquatic Plant Management Society Symposium; 2008 Oct 15-16; Daytona Beach, FL.

Shabana YM, Stiles CM, Charudattan R, Abou Tabl AH. 2010. Evaluation of bioherbicidal control of tropical signalgrass, crabgrass, smutgrass, and torpedograss. Weed Tech. 24(2): 165-72.

Shilling DG, Haller WT. 1989. Interactive effects of diluent pH and calcium content on glyphosate activity on *Panicum repens* L. (torpedograss). Weed Res. 29(6): 441-8.

Shilling DG, Haller WT, Willard TR, Mossler MA. 1990. Influence of surfactants and additives on phytotoxicity of glyphosate to torpedograss. J. Aquat. Plant Mgmt. 28: 23-7.

Smith BE, Shilling DG, Haller WT, MacDonald GE. 1993. Factors influencing the efficacy of glyphosate on torpedograss (*Panicum repens* L.). J. Aquat. Plant Mgmt. 31: 199-202.

Smith B, Langeland K, Hanlon C. 1998. Comparison of various glyphosate application schedules to control torpedograss. Aquatics 20(1): 4-9.

Smith BE, Langeland KA, Hanlon CG. 1999. Influence of foliar exposure, adjuvants, and rain-free period on the efficacy of glyphosate for torpedograss control. J. Aquat. Plant Mgmt. 37: 13-6.

Stephenson DO, Brecke BJ, Unruh JB. 2006. Control of torpedograss (*Panicum repens*) with trifloxysulfuron-sodium in bermudagrass (*Cynodon dactylon* X *Cynodon transvaalensis*) turf. Weed Tech. 20(2): 351-5.

Sutton DL. 1996. Growth of torpedograss from rhizomes planted under flooded conditions. J. Aquat. Plant Mgmt. 34: 50-3.

Taverner J, Beasley JS, Strahan RE, Griffin JL, Borst SM. 2011. Selective postemergence herbicide control of torpedograss in centipedegrass. Weed Tech. 25(2): 212-6.

Toth LA. 2007. Establishment of submerged aquatic vegetation in Everglades stormwater treatment areas: value of early control of torpedograss (*Panicum repens*). J. Aquat. Plant Mgmt. 45: 17-20.

Walker W, Je GW, Walker RH. 2004. Quinclorac: soil behavior and foliar vs. root absorption by torpedograss (*Panicum repens*). Weed Tech. 18(3): 626-33.

Wilcut JW, Dute RR, Truelove B, Davis DE. 1988. Factors limiting the distribution of cogongrass, *Imperata cylindrica,* and torpedograss, *Panicum repens*. Weed Sci. 36(5): 577-82.

Willard TR, Shilling DG, Haller WT, Langeland KA. 1998. Physico-chemical factors influencing the control of torpedograss with glyphosate. J. Aquatic Plant Mgmt. 36: 11-5.

Native Plants and Herbicides

Aldrich JH, Roddenberry JL, Norcini JG. 1998. Tolerance of four container-grown native wildflower species to selected herbicides. In: Proc. Florida State Hort. Soc. 111: 25-9.

Beran DD, Gaussoin RE, Masters RA. 1999. Native wildflower establishment with imidazolinone herbicides. HortScience 34(2): 283-6.

Bissett NJ. 2006. Restoration of dry prairie by direct seeding: methods and techniques. In: Noss RF, editor. Land of fire and water: the Florida dry prairie ecosystem. Proceedings of the Florida Dry Prairie Conference; 2004 Oct 5-7; Sebring, FL. p 231-7.

Butler TJ. 2003. Effect of timing application of Plateau on 10 newly seeded grasses [abstract only]. Proc. South. Weed Sci. Soc. 56: 76.

Dixon FL, Clay DV, Willoughby I. 2005. The tolerance of young trees to applications of clopyralid alone and in mixture with foliar-acting herbicides. Forestry 78(4): 353-64.

Dwyer N, Glass S, McCollom J, Marois K. 2010. Groundcover restoration implementation guidebook: restoring native groundcover for FWC restoration practitioners. Tallahassee (FL): Florida Fish and Wildlife Conservation Commission. 64 p. Available online at:
http://www.floridainvasives.org/Central/GCRGuidebook.pdf

Ezell AW, Yeiser JL, Nelson LR. 2007. Survival of planted oak seedlings is improved by herbaceous weed control. Weed Tech. 21(1): 175-8.

Ezell AW. 2007. Pre and post emergent applications of Oust XP, Sinbar, and Telar for herbaceous weed control in first-year oak plantations [abstract only]. Proc. South. Weed Sci. Soc. 60: 163.

Ezell AW, Nelson L. 2001. Weed control and crop tolerance after pre-emergent and post-emergent applications of sulfometuron in oak (*Quercus* spp.) plantations. Weed Tech. 15(3): 585-9.

Ezell AW. 2000. Comparison of sulfometuron methyl formulations for use in nuttail and cherrybark oak plantations [abstract only]. Proc. South. Weed Sci. Soc. 53: 108.

Ezell AW, Quicke HF. 2000. Competition control for sweetgum plantations using imidazoline products in pre- and post-emergent applications. Proc. South. Weed Sci. Soc. 53: 103-6.

Ezell AW. 2000. Two-year results for crop tolerance testing of pre- and post-emergent applications of Goal 2XL over five hardwood species. Proc. South. Weed Sci. Soc. 53: 109-10.

Freeman JA, Jose S. 2009. The role of herbicide in savanna restoration: effect of shrub reduction treatments on the understory and overstory of a longleaf pine flatwoods. Forest Ecology and Management 257(3): 978-86.

Guynn DC, Guynn ST, Wigley TB, Miller DA. 2004. Herbicides and forest biodiversity—what do we know and where do we go from here? Wildlife Society Bulletin 32(4): 1085-92.

Hay-Smith L, Tanner GW. 1994. Restoring longleaf pine sandhill communities with an herbicide. Gainesville (FL): University of Florida, Florida Cooperative Extension Service. Fact Sheet nr WRS-10.

Hay-Smith L, Tanner GW. 1994. Responses of wildlife food plants to a forest herbicide. Gainesville (FL): University of Florida, Florida Cooperative Extension Service. Fact Sheet nr WRS-9.

Hinton JD, Yelverton FH. 2002. Herbicide tolerance of selected native grass species in North Carolina. Proc. South. Weed Sci. Soc. 55(1): 67.

Jacobs JS, Winslow SR, Pokorny ML. 2007. The effect of five pre-emergence herbicides on emergence and establishment of four native wildflowers. Native Plants Journal 8(3): 224-31.

Jones JDJ, Chamberlain MJ. 2004. Efficacy of herbicides and fire to improve vegetative condition for northern bobwhites in mature pine forests. Wildlife Society Bulletin 32(4): 1077-84.

Jose S, Ranasinghe S, Ramsey CL. 2010. Longleaf pine (*Pinus palustris* P. Mill.) restoration using herbicides: overstory and understory vegetation responses on a coastal plain flatwoods in Florida, U.S.A. Restoration Ecology 18(2): 244-51.

Kaeser MJ, Kirkman LK. 2010. The effects of pre- and post-emergent herbicides on non-target native plant species of the longleaf pine ecosystem. J. Torrey Bot. Soc. 137(4): 420-30.

Kluson RA, Richardson SG, Shibles DB, Corley DB. 2000. Response of two native and two non-native grasses to imazapic herbicide on phosphate mined lands in Florida. In: Daniels WL, Richardson SG, editors. Proceedings, Seventeenth Annual Meeting of the American Society for Surface Mining and Reclamation: A New Era of Land Reclamation; 2000 Jun 11-15; Tampa, FL. p 49-57.

Litt AR, Herring BJ, Provencher L. 2001. Herbicide effects on ground-layer vegetation in southern pinelands, USA: a review. Nat. Areas J. 21(2): 177-88.

Norcini JG, Aldrich JH. 2009. Establishment of native wildflower plantings by seed. Rev. ed. Gainesville (FL): University of Florida IFAS Extension. Publication nr ENH968. 11 p.

Norcini JG, Aldrich JH, Martin FG. 2003. Tolerance of native wildflowers seedlings to imazapic. Journal of Environmental Horticulture 21(2): 68-72.

Pfaff S, Maura C. 2002. Development of seed sources and establishment methods for native upland restoration. Bartow (FL): Florida Institute of Phosphate Research. FIPR Publication nr 03-120-189.

Richardson SG, Bissett N, Knott C, Himel K. 2003. Weed control and upland native plant establishment on phosphate mined lands in Florida. In: Cannizzaro PJ, editor.

Proceedings of the 30th Annual Conference on Ecosystems Restoration and Creation; 2003 Oct; Plant City, FL. Tampa (FL): Hillsborough Community College. p 126-38.

Salon PR, van der Grinten M. 1997. Eastern gamagrass response to Accent (nicosulfuron), Basis (rimsulfuron), and Plateau (imazapic) herbicides in comparison to a few common corn herbicides. ID# 2569. Corning (NY): USDA-NRCS Big Flats Plant Materials Center. 7p. Available online at:
http://www.plant-materials.nrcs.usda.gov/pubs/nypmcargamherb.pdf

Sellers BA, Ferrell J. 2009. Utility of sulfosulfuron for grass forage establishment in Florida [abstract only]. Proc. South. Weed Sci. Soc. 62: 421.

Shilling DG, Bewick TA, Gaffney JF, McDonald SK, Chase CA, Johnson ERRL. 1997. Ecology, physiology, and management of cogongrass (*Imperata cylindrica*). Bartow (FL): Florida Institute of Phosphate Research. FIPR Publication nr 03-107-140.

Welch JR, Miller KV, Palmer WE, Harrington TB. 2004. Response of understory vegetation important to the northern bobwhite following imazapyr and mechanical treatments. Wildl. Soc. Bull. 32(4): 1071-6.

Willoughby I, Jinks RL, Stokes V. 2006. The tolerance of newly emerged broadleaved tree seedlings to the herbicides clopyralid, cycloxydim and metazachlor. Forestry 79(5): 559-608.

Woeste KE, Seifert JR, Selig MF. 2005. Evaluation of four herbicides and tillage for weed control on third year growth of tree seedlings. Weed Sci. 53(3): 331-6.

Yager LY, Byrd J, Jones J, Miller DL. 2006. Effects of native species planted in herbicide-treated cogongrass (*Imperata cylindrica*) [abstract only]. In: Proc. South. Weed Sci. Soc. 59: 206.

Yeiser JL. 2003. Establishing hardwood plantations with Chopper, Accord and Oust combinations. Proc. South. Weed Sci. Soc. 56: 133-9.