PROCEEDINGS
OF
THE SECOND EASTERN NATIVE GRASS SYMPOSIUM

HELD IN
BALTIMORE, MARYLAND
NOVEMBER 17-19, 1999

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HOSTED BY
USDA NATURAL RESOURCES CONSERVATION SERVICE
USDA NRCS PLANT MATERIALS PROGRAM
USDA AGRICULTURAL RESEARCH SERVICE
NATIONAL ASSOCIATION OF CONSERVATION DISTRICTS

PUBLISHED BY
AGRICULTURAL RESEARCH SERVICE
NATURAL RESOURCES CONSERVATION SERVICE
Beltsville, Maryland
May 2000

Preface

The Second Eastern Native Grass Symposium was held in Baltimore, MD during November, 1999. The Symposium provided 70 presentations, comprised of invited and volunteer oral presentations and poster papers. Presented here are the written papers or abstracts of the papers presented.

Native grass use is expanding as rapidly as the seed and plant supplies of eastern sources will allow. The recent demand for materials is being driven by both a desire to utilize native plants to meet resource conservation objectives, and additional discovery of valuable functions which native grasses bring to discreet habitats and the environment in general. Native grasses bring a host of valuable traits to the conservation effort. Relatively unknown, under-appreciated, under-researched, and therefore under-used, native grasses will play a powerful role in environmental improvement as use technology is developed and institutionalized.

It was the goal of the co-chairs and the program committee to organize the Symposium to be as all encompassing of native grass interests as 2½ days would permit. The decision to publish the technical Proceedings was a response to the view of participants that the presented technology will be indeed very valuable to their diverse activities. We also feel that it will be valuable to extend the information to those who could not attend the Symposium.

The Symposium received tangible support from the Natural Resources Conservation Service and the Agricultural Research Service, both of USDA. Ernst Conservation Seeds, Inc. also generously supported the Symposium. The National Association of Conservation Districts, Conference Services was extremely helpful in planning and providing registration support at the conference.

This Proceedings documents a baseline of knowledge, and an overview of action regarding native grass use as we begin a new century. The use of native grasses and grasslands will increase in scale and sophistication. It was our pleasure to assemble this record from the Symposium and we would like to thank the authors for their support.

Jerry C. Ritchie, ARS
John Dickerson, NRCS
Gwen C. Meyer, NRCS

For additional information on Eastern Native Grasses, or for an electronic copy of this publication, please visit our web sire at: "http://www.nhq.nrcs.usda.gov/BCS/PMC/eng/eng.html"

This publication should be cited as:
Ritchie, J.C., J.A. Dickerson, and C.A. Ritchie (eds.). 2000. Proc. Second Eastern Native Grass Symposium: Baltimore, MD November 17-19, 1999. Published by USDA-Agricultural Research Service, and USDA-Natural Resources Conservation Service, Beltsville, MD. 370 p.

Published as Agricultural Research Service, Hydrology Lab, Occasional Paper #2000-1

DEDICATION

Dr. Ronald S. Schnabel

The Symposium Proceedings are
dedicated in the memory of
Dr. Ronald S. Schnabel,
who was a Soil Scientist for the
USDA-Agricultural Research Service,
Pasture Systems and Watershed
Management and Research Lab,
University Park, Pennsylvania.
Ronald R. Schnabel's areas of expertise
included adsorption-desorption kinetics,
N transformation processes and
field measurement methodology.
His research interests included impacts of
riparian ecosystems on quality of agricultural
drainage, and effect of near-stream
management on nutrient
export from the watershed.

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Agricultural Research Service Activities Pertinent to the Eastern Native Grass Symposium

Dr. Floyd P. Horn[1]
Administrator, ARS

Introduction

The USDA Agricultural Research Service (ARS) conducts native grass research within its new National Program for Rangeland, Pastures, and Forages, one of 23 such national programs within ARS (Table 1).

The mission of this program is to develop and transfer economically sustainable technologies and integrated management strategies for the nation's rangeland, pasture, and forage resources. To conserve and enhance these diverse natural resource bases, these technologies and strategies must be based on fundamental knowledge of ecological processes and agronomic practices.

This research is conducted by 127 scientists at 47 ARS locations around the United States. ARS is uniquely situated to provide national leadership in research to understand and manage our nation's rangeland, pasture, and forage resources. The 47 locations represent the major climatic regions and biomes (Figure 1). Their geographic distribution, their inherent land resources, their ties to major land grant institutions, and their long history of scientific investigation make them invaluable.

Planning the National Research Program

ARS uses a customer-focused workshop and a subsequent participatory research planning meeting to identify the vision, mission, research components, and specific problem areas for this national program to address.

The workshop for rangelands, pastures, and forage was held in Kansas City, Missouri, in September 1999. More than 80 customers, partners, and stakeholders--representing producers, industry, environmental groups, non-government organizations, universities, state agricultural experiment stations, federal stewardship agencies, the USDA Natural Resource Conservation Service (NRCS), and other government agencies--interacted with more than 70 ARS scientists, administrators, and staff to identify key issues. The high priority research components identified at that workshop reflect the needs of this diverse clientele, and the specific research problem areas focus on some of the most important research needs. The six components are: (1) ecosystems and their management, (2) plant resources, (3) grazing and the environment, (4) forage management, (5) integrated pest management, and (6) integrated farming and ranching systems.

Some specific research identified at the workshop that are related to native grasses, included (i) improving characteristics that limit native plant growth and development; (ii) improving native forages for livestock production; (iii) developing DNA fingerprinting techniques to characterize important native plants; and (iv) identifying ecological processes important for sustainable use of native grasslands.

After the workshop, writing teams--composed of ARS scientists and the ARS National Program Team--wrote an action plan. It was reviewed by all ARS scientists whose programs could make significant contributions. The plan will be available for public review and comment soon at http://www.nps.ars.usda.gov/ programs/nrsas/ 205/ACTionplan/.

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[1] Administrator, USDA Agricultural Research Service, Washington, D.C.

More specific research project plans will then be developed at all participating research locations. These 5-year plans will be subjected to a thorough peer review process involving evaluation primarily by scientists outside of ARS. These projects will be revised accordingly and then implemented. The same cycle will be repeated every 5 years. In this way, ARS can continually use focused input from beneficiaries and critical evaluation by eminent scientists.

Beneficiaries of the National Research Program

ARS research benefits ranchers who use both harvested and grazed forages. It benefits the action agencies that serve these ranchers, such as NRCS and the Cooperative Extension Service. Others include federal land stewardship agencies responsible for the nearly 1 billion acres of publicly owned lands across the Nation such as the Bureau of Land Management, the Forest Service, the National Parks Service, the Fish and Wildlife Service, the Bureau of Indian Affairs, and the U.S. Geological Survey. It also benefits state land management agencies responsible for state owned grazinglands, resource managers, policymakers, and both rural and urban community organizations with rangeland resources. The public at large benefits through improved resource conditions associated with our Nation's grazinglands and their inherent watershed and wildlife habitat values.

A large part of the rangeland, pasture, and forage programs benefits small farms. There are major efforts on grazingland management and improvement, forages, and decision support systems for small farms at several locations including the Dale Bumpers Small Farm Research Center in Booneville, Arkansas and the Appalachian Farming Systems Research Center near Beaver, West Virginia. These two locations are researching economic and sustainable forage and livestock production systems for small family farms in hill lands.

At Beaver, West Virginia, ARS scientists are working with Virginia Tech and West Virginia University to develop complete grass-based beef production systems for small farms using native pastures in the Appalachian hill lands. At University Park, Pennsylvania, ARS ecologists and agronomists are working with producers throughout the northeast to evaluate the roles of plant species diversity to increase the sustainability of grazinglands in the northeast. Ecologists, soil scientists, and animal scientists in Watkinsville, Georgia, are researching how sustainable grazing systems affect soil biochemical properties, nutrient distribution in pasture soils, and soil microbial diversity.

Currently, the ARS national program staff is assessing each of its approximately 1,200 research projects--including those involving native grasses--for their relevance to small farm needs. The results will be available this year.

Other Examples of ARS Research Related to Eastern Native Grasses

As stated in the introduction, ARS maintains a large national program of research related to native grasses for use in hay, pasture, and natural systems. A few other examples follow:

ARS scientists in Lincoln, Nebraska, are developing improved cultivars of switchgrass, big bluestem, Indiangrass, Canada wildrye and other native grasses. Their research has shown that a 1% unit increase in forage digestibility can increase stocker weight by 3.2%. Most of these improved native grasses are adapted to the eastern U.S. The Lincoln scientists are also at the forefront of developing switchgrass for use as a bioenergy crop to produce ethanol from biomass or for combustion in power plants to produce electricity.

ARS scientists also work closely with many of the Plant Materials Centers maintained by NRCS in evaluating new sources of native plants. 'Pete', a commercial eastern gamagrass cultivar, came from the Plant Material Center at Manhattan, Kansas, working closely with ARS scientists at Woodward, Oklahoma.

Scientists in Raleigh, North Carolina, have developed techniques for establishing and using eastern gamagrass for grazing, hay, and silage. Scientists in Columbia, Missouri, are evaluating alternative cropping systems using eastern gamagrass to increase water infiltration and water use efficiency.

At Woodward, Oklahoma, ARS scientists are working to select, characterize, and map genes controlling apomixis in eastern gamagrass and to develop ways to transfer the eastern gamagrass genes to corn and other grasses. Many of the current cultivars of eastern gamagrass have their origins from the research at Woodward.

ARS scientists in Beltsville, Maryland, are evaluating native grasses for use in producing high quality forage, improving acid, compact horizons of marginal soils, and creating buffer strips around cropland and along streams to reduce soil loss and movement of sediment and nutrient into stream channels.

A team of ARS scientists working with NRCS has shown that native grasses can be used in narrow grass rows to reduce soil loss from agricultural fields. The NRCS working with ARS scientists have developed a " Conservation Practice Standard on Vegetative Barriers" for use by NRCS on farms.

ARS scientists in Temple, Texas, have developed methods for improving warm season grasses focussing on seedling establishment, nutrient quality, forage production and biomass for energy production.

Summary

Native grasslands in the U.S. are a unique resource and pose unique challenges for management, use, and conservation. ARS directs research to develop and transfer methods and strategies to maintain the strong rangeland, pasture, and forage research effort required to meet these challenges and to provide more efficient ways to manage these lands and ensure that they continue to play a role in sustainable plant and animal agricultural systems.

Table 1. List of the Agriculture Research Service National Programs. More details on these programs can be found at http://www.nps.ars.usda.gov/programs/table.cfm

Animal Production, Product Value and Safety	**Natural Resources and Sustainable Agricultural Systems**	**Crop Production, Product Value and Safety**
101 - Animal Genomes, Germplasm, Reproduction & Development	201 - Water Quality and Management	301 - Plant, Microbial, and Insect Genetic Resources, Genomics and Genetic Improvement
102 - Animal Production Systems	202 - Soil Resource Management	302 - Plant Biological and Molecular Processes
103 - Animal Health	203 - Air Quality	303 - Plant Diseases
104 - Arthropod Pests of Animals and Humans	204 - Global Change	304 - Crop Protection and Quarantine
105 - Animal Well-Being & Stress Control Systems	205 - Rangeland, Pasture and Forages	305 - Crop Production
106 - Aquaculture	206 - Manure and Byproduct Utilization	306 - New Uses, Quality, and Marketability of Plant and Animal Products
107 - Human Nutrition	207 - Integrated Farming Systems	307 - Bioenergy and Energy Alternatives
108 - Food Safety (animal & plant products)		308 - Methyl Bromide Alternatives

Figure 1. Agricultural Research Service
Rangeland, Pasture, and Forage Research Locations

Native Grass Technology: A Brief History, Its Spin-offs and Refinements and Where It May Be Headed in the East

Billy M. Teels[1]
Director, USDA, NRCS, Wetland Science Institute

Of all the plants, the grasses are the most important to man. All our breadstuffs (corn, wheat, oats, rye, and barley), rice, and sugarcane are grasses. Our lawns of Kentucky bluegrass and fescue are grasses, as well as the majority of our pasture and range plants. Grasses have been so successful in the struggle for existence that they have a wider range than any other plant family. They occupy nearly all parts of the earth and far exceed any other in the total number of individuals (Chase 1948).

Native grasses have long been appreciated and utilized on this continent. Native Americans understood the relationship of grass and buffalo and helped maintain the open prairie with fire. It is originally thought that about 700 million acres in the United States were covered with grass (Wooten and Barnes 1948). The grasslands of the tall-grass prairies also formed the largest single block of highly productive soils in North America. As a result, nearly 250 million acres of that grassland have been plowed up and planted in crops or pasture. Although most of the tall-grass prairie has been converted, much of the mixed- and short-grass prairie still remains.

Since the turn of the century much has been done, especially in the prairies, to understand how native grasses grow and respond to management. Research and observations over the past century have formed a significant body of knowledge that contribute to a successful, modern native grass industry and an ever growing native grass technology that supports it. J.E. Weaver at the University of Nebraska conducted some of the first work on native grasses. Weaver demonstrated that native prairie flora was much more drought-resistant than the agronomic flora which has largely supplanted it. He found that the diversity of grass species that formed the native prairie practiced "team work" underground by distributing their root-systems to cover multiple depths to utilize and conserve moisture, whereas the roots of agronomic plant species were confined to a single level without such interaction.

Early range conservationists recognized that native grasses also produced highly nutritious and palatable forage, particularly the dominant species associated with climax grass communities. Not only were those grasses valuable for livestock, but, because they evolved as part of the prairie ecosystem, they were also extremely well adapted and could be easily maintained with proper grazing. Early range conservationists also recognized that continuous removal of foliage by grazing could lead to declining range condition resulting in a reduction in both the production and quality of forage. Accordingly, they devised an ecologically based classification system that rated the condition of rangeland based on the degree that a plant community deviated from the preferred climax stage. Reference conditions, known as range sites, were then developed for each soil association that supported a different climax community. The species composition and productive capacity for each range site were then characterized from clipping data to provide a benchmark, or measure, against which the condition of any plant community could be compared. This system allowed early range conservationists to assist landowners with the management of native grasses--to reduce grazing pressure when range condition was at a low or declining state or to prescribe livestock stocking rates that were in keeping with the capacity of the land.

It followed that if native grasses could be managed under such a scenario, then they could also be established under the same concept. Knowledge of the species composition for each range site allowed the development of seeding mixtures that were designed specifically for the site. This technique enabled the planting of a diverse and natural plant community that matched the

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site's capability with species known to thrive there under natural conditions, which in turn helped ensure a successful establishment.

However, merely knowing the plant species that are best suited to a particular site by no means guarantees success. Many obstacles had to be overcome before the first native grass plantings could become reality. For example, most climax plant communities are composed of an array of species, meaning that plantings would necessarily have to include a mixture of seeds from different species. Although the plantings could concentrate on the dominants of the climax communities, there were still many problems to overcome such as; how to harvest the seeds of species that grew at different heights, how to collect seeds from species that fruited at different times of the year, and how deal with the many differences in species' growth habitats and biology. That challenge must have seemed overwhelming to the early plant material specialists who were confronted with the problem. But all those problems were addressed. Seeds were collected and planted in single species blocks so that their progeny could be uniformly harvested and then put in a mix with other species that were treated similarly. Seed cleaners were developed to reduce the hairs, plumes, and bristles that are so common to native grasses. Certified seed testing programs to address seed purity were developed, so that landowners would know how many pounds of pure live seed they were actually getting with their purchases. The USDA, SCS Plant Materials Program developed and released varieties of many native grass species and encouraged their commercial production for the large-scale plantings which were to follow.

The seed production and agriculture industries also contributed significantly to the early technology. For example, conventional grain drills were incapable of passing the small, light seeds that are characteristic of native grass species; so planters were developed specifically for native grasses that were capable of distributing and planting seed at the appropriate spacing and depth. Native grasses are also characteristically slow growers and often succumb to the competition of weeds, so many agronomic practices were developed for weed control to provide opportunity for native grass stands to grow and mature with reduced competition. These and other technological developments helped give the practice of native grass planting a sound footing upon which many landowners relied to plant thousands if not millions acres of worn out fields and abandoned cropland to healthy stands of native grass. The conservation programs that followed the dust bowl, the Soil Bank Program, the Great Plains Conservation Program, and others provided added incentives to the practice through both technical and financial assistance.

In addition to the early technological advances, other developments have followed and still continue to occur. For example, Jacobson in 1981 introduced the concept of sculpturing plantings to hydrologic gradients, which made the practice of establishing native grasses valuable not only for restoring rangeland but for restoring wetlands as well. The recognition that the seed of certain grass species could not be moved beyond a certain distance from their original point of collection was important in the Plant Materials Program developing cultivars that were much more locally adapted. Improvements have been made in all aspects of seed cleaning, testing, storage, and harvesting occurred, as well as advances in planting and weed control. Now, chemicals can accomplish in a few hours what once required a half-year of culture and applied agronomy. Additionally, the recognition of benefits of native grasses, especially the warm-season species, has now become widespread. Warm-season native grasses are currently promoted in nearly every State and Federal conservation program, not only for the diverse natural cover that they provide but also for their benefits to multiple species of wildlife. Accordingly, the demand for native grass seed has grown exponentially and has expanded well beyond the prairie where the industry had its beginnings.

Because the use of native grasses is relatively new to some regions, advocates may not be aware of all the associated technology. Without such knowledge, mistakes can be made in planting or management that will severely compromise the benefits that native grasses can provide. For example, seeds from the Midwest may be purchased and transported over vast distances without knowing their geographic limits. Plantings may occur on sites where little is known about the species that would grow there naturally. Tried and proven techniques for planting or weed control may be ignored. Attention to these details is important if native grasses are to be successfully grown.

The fact that you are holding this symposium demonstrates that you care about the science and technology associated with native grasses as well the grasses themselves. This symposium offers a forum for the exchange of ideas and information that will be valuable in spreading that technology. The recognition that a significant body of knowledge already exists will be important in that cause. Although the East will certainly have technological needs that are uniquely its own, we do not need to reinvent the wheel with every problem. Much has been learned that could be successfully applied if only there was an awareness of the technology.

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Native Grasses and Grasslands in the Presettlement Landscape of Eastern North America

Cecil Frost[1]

Before European settlement, the landscape of eastern North America supported a rich diversity of grasslands and woodlands with a well-developed herb layer in nearly every physiographic province and latitude. Today's remnants likely represent only 1-3% of the original extent and variety. Prairies and pyrophytic woodlands with sparse tree cover were exploited for grazing and farming immediately upon settlement. Wetter areas, although grazed, persisted until after exploitation of uplands was complete. Some were drained in the Colonial era but most persisted until passage of legislation in the late 1800s facilitated wetland drainage, which then escalated throughout the 20th century. In plant communities having a dominant herb layer, grasses were favored in the drier, sunnier locations while forbs dominated in moister, shadier locations. Original habitats where grasses were dominant seem to have been those with the following conditions: drier soils, wet saline marsh soils, xeric sites like ridges and dry south slopes, sites with soil conditions stressful to plant growth, such as serpentine barrens and places where soils feather out onto rock outcrops and ledges. Even where woody succession was retarded by thin soils, phytotoxic soils, excessively xeric, or excessively wet conditions, fire seems to have been required for maintenance of all eastern grasslands, with exception only of brackish and salt marshes. Most species diversity, including most rare species, is found in the herb layer. Exclusion of fire from natural communities has led to development of multistoried woody vegetation and consequent depauperization of the herb layer in all but a few mesic, non-pyrophytic types like cove hardwood and northern beech-maple forests. Loss of the species-rich grass-forb layer throughout eastern North America is an ecological catastrophe still largely unrecognized.

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[1] North Carolina Plant Conservation Program, Raleigh, North Carolina

Seed Production: How Much of What, by Whom?

W. R. (Bill) Poole[1]

The mandated use of native species for some applications, program criteria that encourage their use in others and increasing public interest in native species plantings are all helping fuel the demand for native seed. Meeting that demand presents both opportunities and challenges for the native seed industry. Opportunities and challenges that can be summarized in three questions: How much? What species? By whom? Regardless of how you answer those questions – and maybe we'll start with the last one first – successful native plantings start with quality seed. While seed quality is a prerequisite, your choice of seed source is very likely to be determined by your planting objectives.

If your objective is to restore a piece of native prairie you're likely to be looking for as wide a range of species as you can possibly get. At least in the part of the country I'm most familiar with, those plantings are usually on relatively small areas, often in an urban setting and intended to serve both public education and conservation functions. In those situations, locally collected wild harvest seed is usually seen as being the most suitable source of plant material. That same source may be your only option if there's a mandated requirement to use local-source seed as, for example, is sometimes the case when disturbed sites have to be revegetated in areas like national parks.

If, on the other hand, your objective is to reclaim a gravel pit in Vermont you may well choose to use a mix of native species cultivars that have variety characteristics suited to the very limited range of site conditions you're dealing with. A cultivar, or mix of cultivars, might also be the preferred choice if your objective is to establish a native species planting for a specific use like summer grazing in central New York. In planting situations where you're facing very uniform site conditions or a specific use objective, the higher level of "predictability" inherent in cultivars may make them your most suitable plant material choice.

In short, I believe the answer to the question "Seed production by whom?" is "Everyone". As the demand for native species plant material grows, and as planting objectives become more diverse, we'll continue to need increasing amounts of both wild harvest and cultivar seed. As has been recognized by seed certifying agencies in both Canada and the US, there is also a need for native seed classes that have characteristics somewhere between "wild harvest" and "cultivar".

Much of the impetus for the consideration of those changes in Canada was initiated by Ducks Unlimited. So you won't think I'm immodest when I say that, I should perhaps tell you a little bit about Ducks Unlimited Canada's use of native species plant material and how our interest in the seed production industry developed. That background also leads us into the question "Seed production of what species?" - - at least from our agency's point of view.

Although precise statistics aren't available, I don't think there's any doubt that Ducks Unlimited has been the largest single user of native species plant material in Canada over the past twelve or fifteen years. Our primary objective in making those plantings has been to provide habitat for waterfowl and other wildlife species. I won't say much more than that about wildlife considerations and I'll limit most of my remarks to our experience in the Canadian prairie provinces.

Because we were planting fairly large acreages and because there was virtually no native seed production in Canada at the time, we really had only one source of seed at the outset; a relatively limited number of adapted cultivars that had been developed in the US Northern Great Plains. Almost all of those first plantings were simple mixes of only three or four species of straight cool-season or straight warm-season grasses.

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When we began delivering programs under the North American Waterfowl Management Plan in 1989, our habitat emphasis shifted much more toward the provision of nesting cover plantings on previously cultivated uplands associated with wetlands. Suddenly we were faced with the challenge of planting 10,000 acres or more per year on very diverse – and often somewhat unproductive – sites.

It very quickly became evident that there were two major shortcomings in our program. Firstly, the range of species we had available was too limited to formulate mixtures for the wide array of range sites we were encountering. In addition, our planting techniques needed to be revised to allow us to better place those mixtures on the range sites to which they were adapted. Unless those shortcomings were addressed, we couldn't fully realize the biodiversity benefits we felt native species plantings should give us.

To deal with the shortage of sufficient numbers of adapted species, we initiated what has become known as an ecovar™ development program in cooperation with a number of Canadian federal agriculture research stations, two universities and the NRCS in 1991. Since that time, 19 grass, 9 forbs and 3 shrub species have been entered in the program. A listing of the species in the program at this time appears at the end of this paper.

An ecovar™, or ecological variety, may share some characteristics with both what is now known as Source Identified and Selected plant material in the US. The species is subjected to minimal selection pressure, with reasonably dependable seed production being the primary selection criterion. As a result, it retains more genetic diversity than would be the case if it were taken to cultivar status.

To take advantage of the wider choice now available in plant material, we have also adopted what we call "sculptured seeding" with a number of mixes going on different range sites in the same field to produce a better adapted, more sustainable planting.

Going back to the question "Seed production of what species?", I believe the initiation of alternative native species certification systems in Canada and the US, coupled with the development and adoption of new planting techniques, will make it increasingly possible for more people to successfully make more diverse, more ecologically-appropriate plantings. As that happens, the need for commercially available supplies of a greater range of species will continue to grow at an accelerated rate. The seed for some of those species will likely continue to come from native harvest, probably with associated seed increase activity in some cases, some from traditional cultivar development and production and some from new approaches like Source Identified and ecovar™ production.

The final question, "How much?", can only be answered by individual seed producers, based on the best market analysis information they can get. Native seed prices have historically been subject to periodic fluctuations and that's unlikely to change in the future. In spite of those periodic ups and downs, my personal bet is that the native seed business will be a good place to be for some time to come.

ECOVAR™ PROGRAM SPECIES
October 1999

Species	Area of Origin
Grasses	
Awned wheatgrass (A)	southern Alberta & Saskatchewan
Awned wheatgrass (B)	northern Alberta & Saskatchewan
Big bluestem	Manitoba & SE Saskatchewan
Blue grama	Manitoba
Fringed brome	parkland Alberta, Saskatchewan & Manitoba
Green needlegrass (A)	Alberta
Green needlegrass (B)	Manitoba
Indian ricegrass	Alberta
June grass (A)	northern Alberta & Saskatchewan
June grass (B)	Manitoba
Little bluestem (A)	Alberta
Little bluestem (B)	Manitoba
Needle and thread	Prairie Canada
Nodding brome	parkland Alberta, Saskatchewan & Manitoba
Northern wheatgrass	Prairie Canada
Plains rough fescue (A)	Alberta
Plains rough fescue (B)	Saskatchewan
Porcupine grass	Prairie Canada
Prairie cordgrass	Manitoba, North Dakota & SE Saskatchewan
Prairie sandreed	North Dakota & Montana
Richardson's brome	parkland Alberta, Saskatchewan & Manitoba
Sideoats grama	North Dakota
Western wheatgrass	Prairie Canada, Montana & North Dakota
Whitetop	Manitoba & North Dakota
Forbs	
American hedysarum	Alberta & Saskatchewan
Canada goldenrod	northern Alberta & Saskatchewan
Canada milkvetch	Prairie Canada
Cream colored vetch	Prairie Canada
Maximilian sunflower	Manitoba
Purple prairie clover	Prairie Canada
White prairie clover	Manitoba
Wild peavine	Prairie Canada
Yarrow	northern Alberta & Saskatchewan
Shrubs	
Western snowberry	Prairie Canada
Woods rose	Prairie Canada
Winterfat (half shrub)	southern Saskatchewan

Native Grass Establishment: Pitfalls and Potentials

Michael Panciera[1]

Switchgrass [*Panicum virgatum* L.], Indiangrass [*Sorghastrum nutans* (L.) Nash], and big bluestem [*Andropogon gerardii* Vitman] are native grasses that are widely adapted in the U.S. They were once dominant species as part of the tall grass prairie ecosystem, but two agricultural techniques, tillage and heavy grazing, led to the decline of these grasses. Their broad climatic adaptation and tolerances to many edaphic and biotic factors have been documented (Duke 1978). These characteristics have helped to rekindle interest in these native grasses for wildlife habitat, increasing species diversity, soil and water conservation, landscaping, biofuels, and forage production. Despite the many advantages of these grasses, difficult establishment has limited their use. The purposes of this paper are to review what is known about establishment, identify some gaps in knowledge, and offer some challenges for the future.

As a general rule, plants are considered established when they become a stable component of the plant community. The definition is simple, but the different end uses of these grasses make it difficult to develop a single set of recommendations for establishment. In an agricultural context, establishment is often synonymous with dominance. The desired population or density of grass differs if the purpose of a planting is wildlife habitat. Density must be high enough to provide shelter, but sparse enough to allow animals to effectively navigate through the stand and search for food within it. Clearly the criteria for establishment would differ in these two cases, but planting rates, companion species, and other management variables would likely vary as well.

The wide adaptation and former prevalence of these grasses lead to the assumption that they should be easy to establish. While some grasses are ubiquitous in their native ranges, such is not the case for switchgrass, big bluestem, and Indiangrass. The difficulty in establishment is reflected in the relative lack of agreement for establishment recommendations among several states (Table 1). The establishment guidelines for these six states are consistent on several important points. They each indicate that these grasses can be planted with conventional or notill methods, but weed control must be good and no nitrogen should be applied. In addition, establishment will normally take two years. The recommendations differ on two key points: the potential for dormant seeds and ideal planting date. The differences with respect to dormancy and planting date are difficult to reconcile based on current knowledge of these grasses. There are some differences in recommendations from state to state for corn or alfalfa establishment, but the differences can be explained based on environmental differences and the known responses of corn or alfalfa to environmental factors. More information is needed to develop a similar level of understanding for the native warm season grasses.

Switchgrass, Indiangrass, and big bluestem have not been subjected to selection pressure for as long as most introduced grasses. Some traits that are important for survival in the wild interfere with the speed or uniformity of establishment under cultivated conditions (Leopold 1996). These traits are regarded as impediments to establishment and they may function at various stages of development and different processes may be involved (Table 2). Three approaches are possible to deal with an impediment: remove it (breed them out of the species); overcome it (e.g. seed treatment for dormancy); or adjust for it (modify management to mimic nature).

Seed dormancy

Seed dormancy is a fundamental problem in establishment because this one factor can completely negate the best fertility, moisture, and weed control conditions. Seed dormancy is a condition where either anatomical or physiological characteristics prevent germination (Wareing 1982). Leopold (1996) identified several roles for seed dormancy including: synchronization of germination and seedling development with good growing conditions; spreading out the time (year, season) for germination; link germination to ephemeral opportunities; and aiding in the dispersal of seeds through animals. These functions of dormancy would be valuable in stands

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that were being managed for wildlife habitat or conservation. While removal of this impediment through plant breeding may be an advantage for cultivated crops, it may not be the best solution for all end uses.

Table 1. Summary of selected recommendations for warm season grass establishment from six states.

State	2 years for establishment	No N applied	Till/ Notill	Weed control	Seed dormancy	Planting Date	
						Early	Late
NE	X	X	X	X		X	
MO	X	X	X	X	X	X	
OH	X	X	X	X		X	
KY	X	X	X	X			X
PA	X	X	X	X	X	X	
VA		X	X	X	X		X

Adapted from: Anderson 1989; Bartholomew et al. 1995; Hall 1994, 1999; Henning 1993; Rasnake et al. 1998; Wolf and Fiske 1996.

Table 2. Potential solutions for characteristics that impede the establishment of crops.

Process	Impediment	Solution
Imbibition	hard seeds, dry soil	scarification, water
Germination	slow germ, dormancy	genetic selection 'change' temperature seed size seed treatment modify storage conditions
Seedling Development	slow growth insufficient: water, nutrients, light	genetics selection 'change' temperature weather, weed control fertility

Dormancy is not as clearly understood as some other plant traits because dormancy develops as a particular species evolves within an ecosystem. As a result it is difficult to generalize about dormancy (Chapman 1996; Leopold 1996). For some grass species it is known that temperature conditions during seedfill, oxygen conditions around the germinating seed, and the location of seed production can promote the development of dormancy (Chapman 1996). Many factors have been studied in an effort to define ways to release or reduce dormancy. Light during germination, chilling imbibed seeds, seed age, seed storage conditions, and acid, mechanical scarification, bleach, hydrogen peroxide, and gibberellic acid treatments have all been linked to dormancy release (Chapman 1996; Emal and Conard 1973; Geng and Barnett 1969; Haynes et al. 1997; Jensen and Boe 1991; Panciera 1982; Panciera et al. 1987; Sautter 1962; Shaidaee et al. 1969; Tischler et al. 1994; Zarnstoff et al. 1994). One thing is certain, the development and expression of dormancy cannot be generalized for grass species.

Official procedures for all three grasses discussed here specify that for fresh or dormant seeds a two week prechill must be used (AOSA 1998). The prechill treatment consists of holding moist seeds at a temperature of 4°C for 14 days. The official procedures do not require that the percentage dormancy be reported. Germination percentage routinely includes dormant seeds that have been stimulated to germinate by the prechill treatment. The impact of this method of reporting is that two seedlots with different dormancy may have the same germination percentage listed on the seed tag. These grasses are planted on a pure live seed (PLS) basis, but PLS may not accurately define a dormant seedlot. Planting rates based on kg ha^{-1} of germinable seed would be more useful. For a dormant seedlot, a single rate of PLS would result in different germinable seeding rates depending on soil temperatures following planting.

For example, four acres of Cave-in-rock switchgrass were planted on the Berea College farms in late May 1999. Small plots of Blackwell, Carthage, Shawnee, and Shelter were also planted. Foxtail and other warm season weeds developed rapidly and switchgrass seedlings were not numerous. A planting rate of 8 kg PLS ha^{-1} was used, which should have been adequate for a good stand. The stand densities in the pasture and the small plots were disappointing. Subsequent germination tests indicated that all seedlots except Carthage exhibited a statistically significant amount of dormancy (Figure 1). Soil temperatures did not fall below 15°C after planting, so temperatures were not sufficiently low to break dormancy. The combination of high soil temperatures and high seedlot dormancy resulted in a germinable planting rate of about 1 kg ha^{-1}. Many of the dormant seeds may germinate in the spring of 2000, which will contribute to a 2-year establishment period.

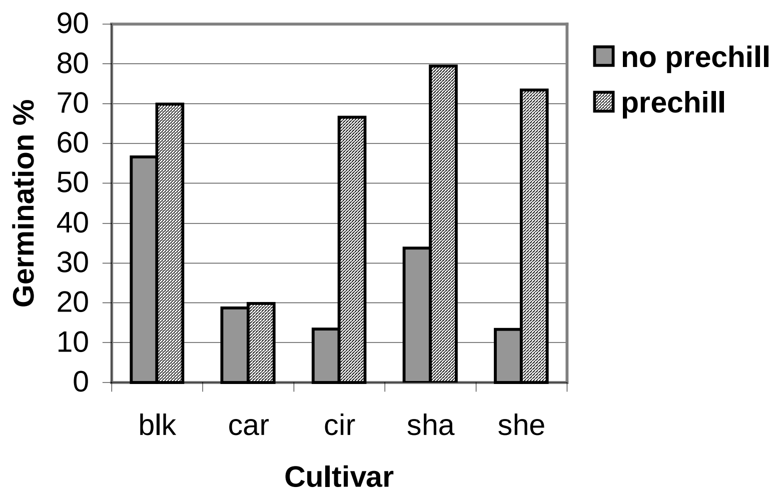

Figure 1. Effect of prechill treatment on the germination of Blackwell (blk), Carthage (car), Cave-in-rock (cir), Shawnee (sha), and Shelter (she) switchgrass (Panciera, unpublished data).

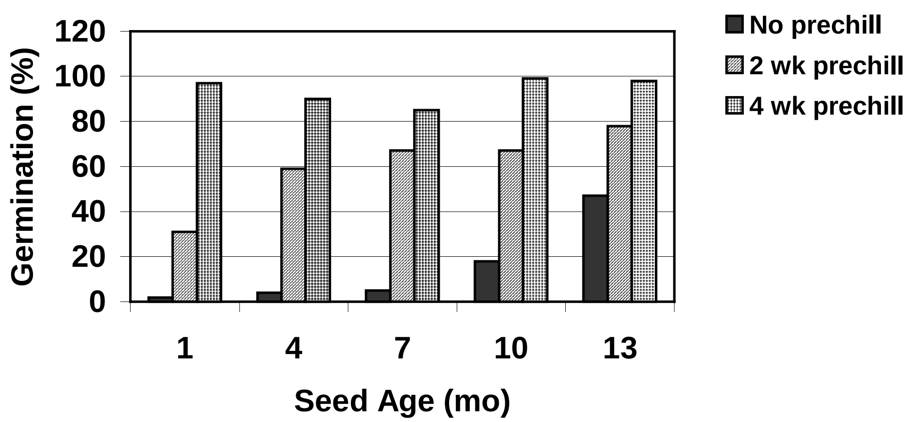

Figure 2. Effect of seed age and duration of prechill on Indiangrass seed germination (adapted from Emal and Conard 1973).

Methods of breaking dormancy have been studied for many years. Some authors have reported that a combination of time and storage conditions can be used to overcome the dormancy problem (Emal, and Conard 1973; Shaidaee et al. 1969; Zarnstoff et al. 1994). Emal and Conard (1973) reported that prechilling had less effect on germination as seeds aged (Figure 2). In addition,

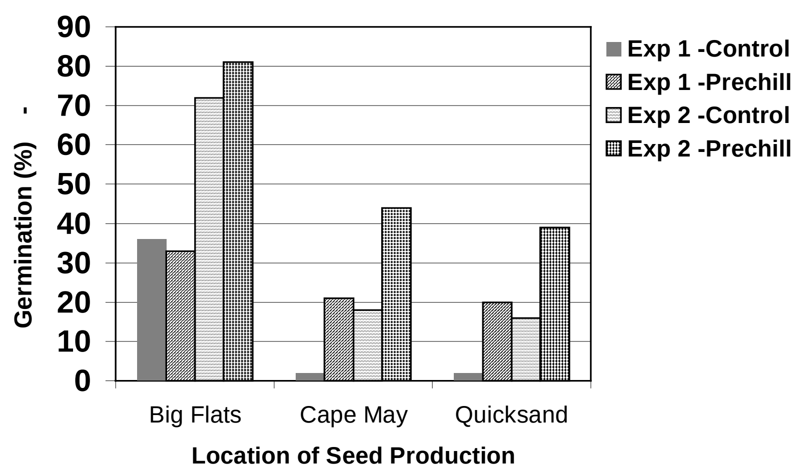

Figure 3. Influence of prechill and seedlot on the germination of one- and two-year old KY 1625 switchgrass seeds (all pairs are significantly different except Exp 1 Big Flats; 1-year old (Exp 1) and 2-year old (Exp 2) seeds not statistically compared; adapted from Panciera 1982).

the more seeds aged, the less prechill time was required to break the remaining dormancy. Zarnstoff et al. (1994) found that after 90 days of aging at 23°C, short-term dormancy was effectively eliminated.

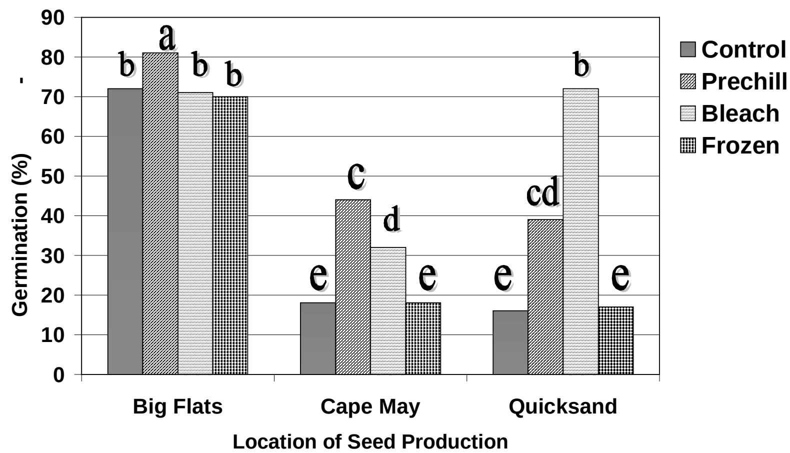

Figure 4. Effect of prechill, bleach, and freezing treatments on germination of three seedlots of KY 1625 switchgrass (adapted from Panciera et al. 1987).

In studies conducted at Penn State by Panciera (1982), average germination increased as seeds aged (1 to 2 yr), but seeds continued to respond to prechill treatments (Figure 3). Seeds were stored at low temperatures (4°C) which may explain the maintenance of dormancy over an extended period of storage. In addition to prechill treatments, the following methods have also proven effective for overcoming dormancy in switchgrass and Indiangrass: bleach, acid, hydrogen peroxide, and mechanical scarification (Emal and Conard 1973; Geng and Barnett 1969; Haynes et al. 1997; Panciera 1982; Panciera et al. 1987; Tischler et al. 1994). However, it is not clear that all of these treatments act upon the same impediment to germination. Panciera et al. (1987) found that prechill and bleach treatments both increased germination of dormant switchgrass seedlots, but the seedlots responded differently to these two treatments (Figure 4). Germination for the Cape May seedlot was greatest for the prechill treatment, while the bleach treatment produced the highest germination for the Quicksand seedlot. Haynes et al. (1997) reported that prechill, scarification, and bleach all increased switchgrass germination and emergence. Furthermore, the effects of these three treatments were additive for percent emergence suggesting that different mechanisms were involved (Figure 5). Under cool conditions, prechill did not improve emergence, but it did under warm conditions.

Management

Other management inputs that are also important for establishment of these warm season grasses include planting date, weed control, and nitrogen fertilization. Planting date responses may involve both dormancy and weed pressure. The lasting effect of planting date on yield provides an incentive for selecting the best date (Table 3), but conflicting data make the planting date selection less than clear.

Seedlings invariably develop more rapidly at higher temperatures, thus one would expect that later planting dates would result in better establishment for nondormant seedlots. Recommendations for Kentucky and Virginia both cite rapid seedling development as a reason to plant later (Rasnake et al. 1998; Wolf and Fiske 1996), Pennsylvania recommendations advocate early planting, in part, to break dormancy (Hall 1994; 1999).

Weed competition for light, water, and nutrients is an important variable in establishment of these grasses. Since seedling development is slow, weed competition can further slow plant development. Weed pressure varies by location, season, and year, so planting date may have an influence on weed pressure. Early planting is cited as a way to reduce weed competition in Pennsylvania (Hall 1999), while late planting is preferred (for the same reason) in Virginia (Wolf and Fiske 1996).

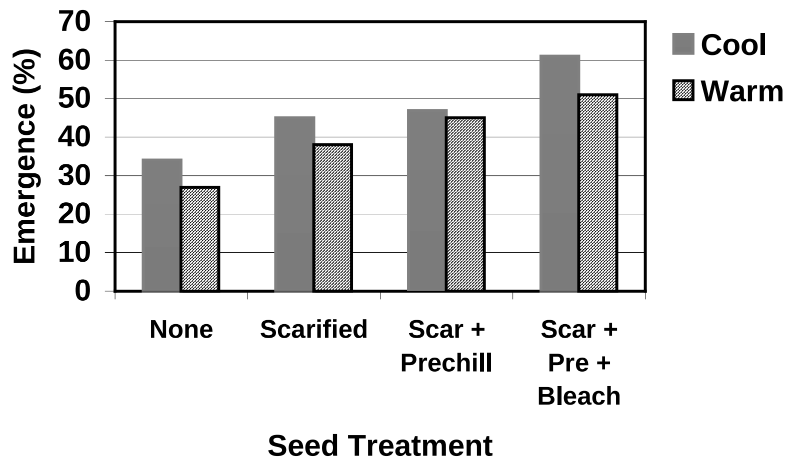

Figure 5. Effects of temperature and seed treatments on emergence of switchgrass (adapted from Haynes et al. 1997).

Table 3. Influence of planting date on yield of two switchgrass cultivars.

Year/Cultivar	Planting Date[1]			
	1	2	3	4
Seeding year	Kg ha^{-1}			
Blackwell	810 b[2]	1279 a	605 b	24 c
KY 1625	404 a	100 b	65 b	1 c
Year after seeding				
Blackwell	3694 b	5690 a	3827b	379 c
KY 1625	2185 a	771 b	824 b	27 c

[1]Dates: 1 Early May, 2 Late May, 3 Early June, 4 Late June
[2]Means within a row followed by the same letter are not significantly different at the 5% level according to Duncan's New Multiple Range Test.
Adapted from Panciera and Jung 1984.

Extension Service recommendations presented earlier (Table 1) are in agreement about nitrogen fertilization. The slow seedling growth of these grasses together with an apparently poor capacity to respond to N indicate that the addition of this element will favor weeds more than the seeded grasses. The effect may be more pronounced for some cultivars.

Other factors

The tolerance of seedlings to clipping could be an important avenue for crop improvement. Because weed control options for these grasses are limited, the ability to recommend mowing as a weed control technique could improve seeding year management. Preliminary trials in Pennsylvania indicate that some cultivar differences exist for tolerance to clipping (Dr. G.A. Jung, personal communication 1999). Further study concerning the variability and heritability of this trait is warranted.

Application of carbofuran (2,3-Dihydro-2,2-dimethyl-7- benzofuranylmethy carbamate) has been associated with rapid establishment in some cases. While the mechanism has not been conclusively defined, researchers at Virginia Tech have proposed that carbofuran controls flea beetle (See Parrish et al. in these Proceedings). Carbofuran is not labeled for use on native warm season grasses, but an understanding of the mechanisms involved will aid in the improvement of establishment techniques.

Success on a large scale

Different groups have had excellent success with establishment of warm season grasses. Mr. Jose Taracido with California University of Pennsylvania and Partners for Fish and Wildlife Habitat received national recognition for his work using native warm season grasses to improve wildlife habitat in the 11,000 ha Pike Run watershed in southwestern Pennsylvania (USFWS 1999). He has considerable practical experience with these grasses because he is either a consultant or primarily responsible for approximately 400 ha of new seedings per year. The following points summarize some recent conversations with Jose Taracido (Mr. J. Taracido, personal communication 1999).

Figure 6. An excellent stand of Blackwell switchgrass three months after planting.

- Establishment can be rapid (Figure 6) – up to 1.5 m tall in the seeding year. Conditions must be perfect for this to occur, but it is possible.
- Success rate is about 95% - The key is how long it will take. Most stands will be in good condition within two years if producers are willing to apply management recommendations. Stands still develop without good management, but 3-5 years will be required.
- The combination of slow seedling growth and dormancy contribute to the two-year time frame for establishment. Stand density often improves after the first winter, likely due to germination of dormant seeds. While the majority of seedings are made between April 1 and June 1, planting has been successful even into late autumn. Earlier plantings are preferred in Pennsylvania, but the later seedings were also successful if herbicides were used to control competition.
- One of the most beneficial practices is mowing to control weeds. Mowing in the spring of the year following establishment is an effective method to enhance stand development.
- Be patient.

Criticisms

Several problems exist that make establishment more difficult or, at least, less consistent. First, too many burdens (time, money, and information) have been placed on the producer. Second, germination test procedures should indicate the percent dormancy. Obtaining a second germination test on a seedlot would cost an additional $20 which would only add a few cents per pound to seed cost. Third, few cultivars have been developed specifically for improved establishment (Alderson and Sharp 1994). And, fourth, successes have not been carefully analyzed to explain rapid establishment.

Most forage and conservation crops that are widely used do not put this amount of burden on the producer:

- Buy expensive seeds.
- Buy seeds a year early.
- Do your own germination test.
- Early or late planting may be best
- Prechill your seeds before planting.
- Within two years, more often than not you will have a good stand.

Most of these recommendations work, but they rely too heavily on the producer. The dormancy status should be available so producers understand the options (e.g. plant early vs. prechill treatment). This information is essential because, in most cases, these grasses are being planted on a small portion of the farm. Livestock producers have limited time and resources available for long term projects. They simply cannot afford to divert labor and finances away from the backbone of their feed production system, be it corn silage, cool season pasture, or hay crops. Despite the need for midsummer pasture, producers will work at it slowly, a few acres at a time. They could be more aggressive if the results were more certain. The easier it is for the producer to “do it right”, the higher the probability for success. Consistent results are in everyone’s best interest because more hectares of these grasses will be planted, so producers will have more summer pasture, seed dealers will do more business, wildlife habitat will improve, etc.

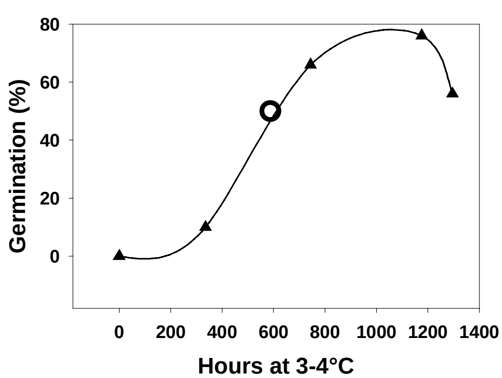

Figure 7. Influence of constant (▲) vs. alternating (O) exposure to prechill temperatures on switchgrass germination (adapted from Sautter 1962).

Challenges

Consistent results will demand: better cultivars with more aggressive seedlings; better information including percent dormancy of each seedlot and a systematic explanation of successes; elimination or circumvention of impediments to establishment; and uniform recommendations. Several areas of research may provide information that will improve the consistency of recommendations.

Emal and Conard (1973) found that longer prechill periods were needed to break dormancy in fresh Indiangrass seeds (Figure 2). Sautter (1962) used different prechill treatments on switchgrass seeds (Figure 7). These treatments included constant prechill for 14 to 54 d and prechill only at night for 49 d. The germination data were plotted against hours of exposure to prechilling temperatures in Figure 7 (assumes a 12 h night cycle). The night only treatment falls right on the line suggesting that chilling requirements (analogous to growing degree-days) or a chilling threshold could be defined for dormancy release.

Work by Hsu et al. (1984) suggests that some dormancy is released at temperatures above 4°C (Table 4). Optimal temperatures appear to change depending on the prechill treatments. When seeds were exposed to prechilling conditions, optimum temperatures were 20-30°C, but without the prechill they were lower, in the 15-20°C range. The data are from two separate experiments, thus not directly comparable, but further study is warranted because such information could lead to a better definition of optimum planting dates.

No review of this type can provide all of the answers. Impediments to establishment such as seed dormancy must be identified and addressed in a manner that is consistent with the intended use for the crop. New ways to improve establishment must be sought through plant breeding and management with the objective of making consistent results ever easier to achieve.

Table 4. Selected data from two experiments illustrating the influence of temperature on germination. (Adapted from Hsu et al. 1985.)

	Temperature °C		
	15	20	30
PreChilled	*% germination*		
Big Bluestem	37b	47a	34b
Indiangrass	78b	80ab	83ab
Switchgrass (Blackwell)	19c	28b	36a
Switchgrass (Cave-in-rock)	10d	18c	79a
PreChilled	*% germination*		
Big Bluestem	38a	32bc	15d
Indiangrass	74a	54b	27d
Switchgrass (Blackwell)	20a	6c	11b
Switchgrass (Cave-in-rock)	11bc	15ab	9cd

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Native Grass Management

Dan Carroll and Floyd Knowlton[1]

Abstract

The Oak Orchard and Tonawanda Wildlife Management Areas are located in the Western New York Lake Plains region approximately half way between Rochester and Buffalo. These areas are managed to provide emergent marsh and grassland habitat for a variety of wildlife including endangered, threatened and special concern species. The grassland objective is to develop and maintain approximately 500 acres of dense nesting cover of which 50 percent is native warm season grass and 50 percent is introduced cool season grass. The warm season grass is primarily switchgrass established on the higher, more droughty soils (Elnora sand). This poor-soil grass will provide excellent nesting cover for wildlife without annual additions of lime and fertilizer. Switchgrass is maintained on these areas by controlled burns and mowing. In recent years over 100 acres of switchgrass seed production has been harvested from the Management Areas to provide for additional plantings throughout the New York State Wildlife Management Area system. Cool season grasses are established on the lower, wetter soils by planting or through natural invasion onto tilled, compacted seedbeds. The cool season grasses are managed for later-nesting birds. Suitable nesting cover is created by mid to late spring grass growth. All of the cool season grasses are maintained by an annual August mowing. Other management activities associated with grasslands include hedgerow removal and shoreline clearing. The removal of these woody plants increases the size of grasslands, controls invasive woody plants, reduces predation, and increases the utilization by and nesting success of the grassland species of wildlife.

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Non-native Genotypes and Outbreeding Depression in Plants: Theoretical and Empirical Issues

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The increasing use of locally non-native seed stock of many species in agricultural and wildlife management programs have raised several issues regarding the ecological/genetic effects that such programs may have upon natural populations of these same species. There is therefore a need to investigate the ecological implications of using so-called non-native genotypes (NNG's) for outplanting in areas where there is a high probability that introgression (via pollen and seed) will occur between outplanted and native populations of these species. The supposed deleterious effects of such introgression are called outbreeding depression (OBD) (sensu Shields 1982, Templeton 1986). The major goal of this paper is to examine, through reviewing the scientific literature, the theoretical mechanisms of OBD and the empirical studies of plants concluding evidence of OBD. Other goals are to identify OBD in the contexts of fields of biological inquiry; to identify sources of information, and to promote discussion among biologists regarding the evolutionary and ecological implications of outplanting NNG's.

Outbreeding depression (OBD) is defined as the reduction in fitness (of the progeny) accompanying the crossing of genetically dissimilar individuals. Some of the potential affects of using NNG's are: 1) loss of genetic diversity by swamping of native genotypes, 2) reduction of population sizes through the introduction of deleterious or lethal alleles, 3) loss of evolutionary potentials through genetic homogenization, 4) unforeseen changes in plant-animal interactions, and 5) loss of research potential utilizing native populations. This paper will not so much argue whether or not the above actually occur but will take issue with the broad application of such ideas because they are based on premises that may be too general and simplistic for such a complex biological phenomenon.

Reports of OBD in plants has created much concern among conservation biologists whom often explicate the phenomena using terms such as genetic assimilation, genetic pollution, or genetic swamping, but often these terms are used vaguely and with few or exceptional examples ignoring more common issues (Lynch 1996, Millar and Libby 1989). Without the specific contexts for using these terms, such as offered by Ellenstrand (1992), this has, in the author's opinion, tended to create much confusion. Additionally, the literature regarding both inbreeding and OBD has been consistently plagued by semantic problems arising from different paradigms and conceptions of what outbreeding and inbreeding mean, and how they are defined (Shields 1993). Thus, it is imperative that in this discussion a clear context be formed for what follows.

Firstly, most of the literature regarding OBD that promotes the use of extreme caution in population augmentation or outplanting programs focuses squarely on rare and/or narrowly endemic species (Falk and Holsinger 1991, Ellenstrand 1992, Ellenstrand and Elam 1993, Falk et al. 1996, Avise 1994, Lynch 1996). The discussion here will not focus on rare species *per se* but rather on the basic biological mechanisms underlying OBD. Secondly, it should be understood that there are many levels of genetic dissimilarity. There exists a continuum of levels of genetic dissimilarity from matings between congeners (interspecific hybrids) to matings between local populations at various distances. This paper takes a different approach to the study of OBD by ignoring arguments as to whether or not OBD actually occurs in nature or can be deleterious since at some level of genetic dissimilarity outbreeding produces OBD (e.g., sterile hybrids).

This paper reflects the opinion that OBD can be expressed within the context of evolutionary biology as a continuum from mild reductions in fitness to F_1 inviability; thus OBD may be seen as a consequence of natural selection capable of producing divergent lineages if selection is

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sufficiently strong. Additionally, other factors as diverse as historical phylogeography, taxonomic concepts and mating system evolution, either working in concert with selection or alone may have a profound influence on the expression, severity and persistence of OBD in plants. Identifying the contexts of history, taxonomy, and genetics and the mechanisms of OBD will form the bulk of this review.

Firstly, I will discuss OBD in a historical context. This discussion will examine how past history, both natural and anthropogenic, may affect plant distribution and genetic structuring across a taxons range which would in large part determine the propensity for OBD. Throughout this paper propensities rather than outcomes or probabilities are discussed because evolutionary outcomes may often have very long time-frames and while we may discover trends we cannot be sure that these trends may not be altered by future events (see Mills and Beatty 1994 for discussion).

Secondly, I will discuss OBD in an evolutionary-taxonomic context. While at first this may seem peripheral it is extremely important that clear taxonomic concepts be applied since even our conceptualization of species as entities is temporal. Schierup and Christiansen (1996) conceptualize OBD as the "population counterpart to mechanisms separating species or subspecies". This all too rare, but very clear statement indicates that populations may diverge, speciate and that these species may have distinct subdivisions and so on. However, the difficulty arises where these boundaries become difficult to distinguish (such as in many intraspecific taxa). It is very important that taxonomic categories be clearly defined (through consulting the taxonomic literature) to prevent conflating taxonomic categories with evidence for pervasive OBD in plants.

Thirdly, I will discuss OBD within an ecological-genetic context. This will include the examination of life history components of plant species but particularly the breeding system and how this may affect the propensity for OBD in plants. An analysis of empirical studies published within the last two decades will be presented in this section.

Although discussed primarily in the final section of this paper there is a need to introduce three important questions that have been largely ignored but are singularly important for conservation biologists and land managers evaluating a taxon for outplanting:

1) Is OBD predictable for taxa that have a certain suite of characteristics?
2) Is the resulting OBD likely to be severe?
3) Is the resulting OBD likely to persist?

Mechanisms of Outbreeding Depression

The genetic mechanisms underlying the expression of OBD in plants have received some theoretical work but very little empirical confirmation. Outbreeding depression in plants is poorly studied and perhaps only became of interest to evolutionary biologists after Price and Waser (1979) reported the finding of an optimal outcrossing distance in the plant *Delphinium nuttalianum Pritz. (Delphinium nelsonii Greene* of cited studies herein). This is significant because in order for there to be an optimal outcrossing distance there must be selective pressures attempting to produce an equilibrium between inbreeding (which has the advantage of conferring a maternal advantage if the parental plants are well adapted) and outbreeding which has the advantage of conferring heterosis or new, potentially better adapted genes to their offspring (see Shields 1982). An optimal outcrossing distance also indicates that there is an optimal genetic relatedness between mates and since in plants genetic similarity is usually a function of distance between individuals or populations this raised (I believe) the spectra that perhaps increasing the genetic variation of a population is not necessarily always desirable.

While the specific genetic causes of OBD are not well understood there are two types of theoretical mechanisms that are reported in the literature. The first mechanism thought to be responsible for the perceived OBD is that resulting from local adaptation of the genome to the environment. This is the ecological or extrinsic mechanism (Price and Waser 1979, Shields 1982, Fischer and Matthies 1997, Waser and Price 1993, Ellenstrand and Elam 1993) and is the more intuitive of the two theories. Under this mechanism populations are over evolutionary time expected to become adapted to their local environmental conditions through a combination of restricted gene flow between sites, local selection and genetic drift. Evidence for local adaptation in plants is strong and adaptive divergence has been documented on very small scales (reviews by Linhart and Grant 1996, Waser 1993). If selection favors the increasing coadaptation of the genome to the environment then the importation of NNG's is expected to breakup the coadapted gene complexes (via recombination) responsible for local adaptation (Lynch 1996). The evidence is not necessarily straightforward as the expression of heterosis or hybrid vigor is common in the F_1 generation (Shields 1982, Thornhill 1993) and there is some disagreement about the relative severity of OBD in plant populations (see Templeton 1986 and Lynch 1996). Lynch (1996) suggests that the negative consequences of outbreeding may take several generations for full expression, as heterotic effects begin to breakdown with subsequent backcrossing in later generations, but it appears that this assumption was made with certain conditions in mind (e.g. weak selection, fast generation time, etc.). One obvious confounding factor is the time scale over which this may occur. For example the severity of OBD should vary widely among different life forms (e.g., annuals versus long-lived perennials) as the time to produce a new cohort would vary greatly. Additionally, there is a problem of the scale of gene flow via pollen. One would have to assume that the rearrangement of the genome via interpopulational gene flow and selection is a fairly frequent occurrence in nature; at least in continuous populations. What is at issue here is, a potentially large-scale, human mediated gene flow that may alter the time frames considerably.

The second mechanism hypothesizes that local gene pools can be coadapted intrinsically (Templeton 1986, Lynch 1991, 1996) that is, even if the external environment is uniform the internal genetic environment is expected to develop coadapted complexes of genes by epistatic interactions (Campbell and Waser 1987, Mitton 1993). Empirical studies regarding this mechanism are few but are fairly robust (Schneller 1996, Parker 1992, Svensson 1990) as are the theoretical genetic models (Campbell and Waser 1987, Lynch 1991, Schierup and Christiansen 1996). Under this mechanism NNG's would break up the favorable gene complexes (via recombination) that have formed (perhaps solely due to chance) and tend to become inherited together in the local gene pool.

Given that plants are sedentary and that gene flow by pollen and seed tend to be fairly localized (Levin and Kerster 1974, see also Ellenstrand 1992) we should expect that any disruption of the historical patterns of gene flow among populations has the potential to breakup the kinds of coadaptation that may form among populations. However, it is far from clear that the *in situ* fitness of individuals within a given population is necessarily optimal or even likely to be optimal, since an optimal genotype may only be optimal for a given environment at a given time, i.e., it is temporal. It is always possible that in some cases further outbreeding or inbreeding may be beneficial, by moving the population to a higher "adaptive peak". Thus broadly invoking local adaptation as a cause of OBD has no particular theoretical rigor because it assumes the optimality of current conditions that is within the perspective of the observer not the species lineage.

The Historical Context of Outbreeding Depression

If we conceptualize OBD as resulting from genetic divergence of populations then both historical patterns of geographic distribution as well historical and recent patterns of gene flow need to be evaluated. For example, the present range of a species may not reflect its past distribution (Harper 1977); a once widespread species may have experienced a severe decline in range or are of relatively recent origin and never occupied a large range (see Karron 1991). Additionally, historical land use and human mediated changes in plant communities may create phylogeographic patterns over the landscape (Motzkin et al. 1996). Discovering these historical details will probably not be easy thing to do, but some amount of study of historical phylogeography would lend one measure of confidence in predicting the occurrence of OBD.

Given that plants are non-motile, they become subject to both temporal and spatial selective pressures. While there has been considerable study of local population dynamics there has been until relatively recently, little study of how past events have shaped the distribution of both plant species and their genetic variation. Recent progress (Mahy et al. 1999, Utelli et al. 1999) has been facilitated by advancements in molecular technologies for interpreting phylogeographic patterns of population-genetic structure (see also Hedrick 1999).

Why would past events that occurred hundreds or even thousands of years ago be important in understanding OBD? Primarily, this has to do with the partitioning of genetic variation of a taxon within and among populations. The genetic substructuring of species and populations across the range of the taxon is influenced not only by the breeding system (Hamrick and Godt 1996a) but also by patterns of gene flow and intensity of selection (Linhart and Grant 1996). All of these would be modified directly, or indirectly, by past range contractions and expansions.

For example, during the Pleistocene, at the height of the Wisconsin glaciation what we know as the Delmarva Peninsula would have been a vast grassland mixed with conifers such as red spruce [*Picea rubens* Sarg.] (Scott 1989). During this period of time much of our present flora would have been pushed into glacial refugia in the southern United States. Recent studies show that such range contractions have had dramatic and long-lasting effects on the genetic structure of plant populations (see review by Thompson 1999). In red pine [*Pinus resinosa* Aiton] and eastern hemlock [*Tsuga canadensis* (L.) Carriere], no and little genetic variation (respectively) at isozyme loci has been found despite wide current distributions in the northeastern United States. This result was surprising, especially for conifers which are typically highly variable (Hamrick and Godt 1989, Hamrick and Godt 1996b, p. 292). The situation in red spruce is attributed to Pleistocene glaciation which reduced the species to a small area and the subsequent inbreeding eliminated variation (Millar and Libby 1991, ch. 10). The notable absence (4800 ybp) of eastern hemlock from the flora for a period of about 1000 years indicates that the species passed through a severe bottleneck eliminating (perhaps by disease) most genetic variation (Hamrick and Godt 1996b, p. 282). During the range contractions of the Pleistocene it is likely that the genetic composition of many species changed dramatically (see Hewitt 1996) and some evidence suggests that the most diverse populations of northeastern species may be found in those remnant populations that now exist as isolates in patchy habitats. Such is the case for swamp pink [*Helonias bullata* L] where the most genetically diverse populations are located in peripheral populations in the Southern Appalachians now widely disjunct from the main northeastern range (Godt et al. 1995, Hamrick and Godt 1996b Pp. 293-294). This finding is intuitively satisfying given that we would expect some sampling error to occur as the species recolonized the northeast following glacial retreat and indicates that genetic drift has played a major role in the genetic structure of this species. Restorationists should be mindful of this study for other northeastern herbaceous species as it indicates relatively short periods of population isolation. Additionally, in cases of man-created habitat fragmentation the genetic differences that may arise between populations may be seen as artificial and perhaps not desirable.

One of the most interesting climatic events in some respects was the pronounced warming period called the Xerothermic (ca. 3200 ybp) during which some components of midwestern floras expanded their ranges eastward. This would have likely included several warm season grasses typical of prairies such as little bluestem [*Schizachyrium scoparium* (Michx.) Nash], big bluestem [*Andropogon gerardii* Vitman] and Indiangrass [*Sorghastrum nutans* (L.) Nash] which are currently widely outplanted. Remnant prairies may be found at many sites in Maryland where edaphic conditions have slowed successional rates. Species typical of western floras may be found in these environments supporting the hypothesis that these species colonized during the prolonged drought. Whether the movement of these species took place as a wave of advancement or as founder populations following long-distance dispersal events is unknown; but it is likely that this expansion founded many populations of these plants that we see at the present.

The distinction between a wave of advancement and long-distance founder events is an important one. If the species expanded its range as a wave then there are reasons to believe that genetic divergence would be minimal since in relatively recent time there could have been considerable gene flow between currently isolated populations. If the species expanded its range due primarily to long-distance founding of populations then there would be reason to believe that a combination of genetic drift and small population size from few or single founders would create conditions conducive for divergence. Nichols and Hewitt (1994) found that in modeling the two types of range expansion that "if long distance dispersal is sufficiently frequent, the populations do not spread as a wave of advancement but instead found intermingled isolates." In a study of metapopulation dynamics of the weedy plant *Silene alba* (Mill.) E. H. L. Krause, McCauley et al. (1995) reported little mixing of individuals in founding of new populations even with the presence of a diverse source population from which to draw alleles. These results are consistent with estimates of rapid plant migration and recolonization from glacial refugia (Merrell 1981, p. 412, Cain et al. 1998). Clearly, the occurrence and severity of OBD in plants may be strongly conditioned by past events.

If historical factors are capable of producing divergent lineages then the historical context of OBD demands that the taxa likely to have developed isolating mechanisms be identified. These isolating mechanisms as traditionally defined by the Biological Species Concept (Mayr 1970) can be important in predicting the severity of OBD. Some measure of predicting the severity of OBD may be found within classical morphological taxonomy.

The Evolutionary-Taxonomic Context of Outbreeding Depression

Classic morphological taxonomy has been subject to criticism under the Biological Species Concept (see Mayr 1994). Often taxonomy is criticized as being wholly typological; which refers to the inherent equivocality in defining the type and setting limits, i.e., what amount of divergence from the type is enough to categorize species, subspecies, variety etc. The confusion created by applying (or lack of applying) different species concepts is apparent in two studies of OBD in plants. In an often-cited empirical study of OBD in plant populations, Parker (1992) performed artificial crosses between two populations of a widespread, predominately selfing, annual plant, the hog peanut [*Amphicarpaea bracteata* (L.) Fernald]. The populations were found to consist of fixed sets of alternative alleles at 12 loci and were so identified as "biotypes". Crosses between the two populations expressed severe OBD in the form of significantly reduced seed biomass and other fitness characters. Since the two populations existed in the same general environment it was concluded that the OBD mechanism could not be attributed to gene-environment coadaptation but to internal or intrinsic coadaptation between favorably interacting gene complexes.

The point here is that what has been cited as clear evidence of OBD in widespread plant species could also be considered to be an entirely predictable reduction of fitness resulting from crossing two different taxa. The two "biotypes" correspond to two segregate taxa (varieties) described by Gleason and Cronquist (1991) and Fernald (1950). Evidently the formation of rare hybrids was taken as evidence against taxonomic delimitation as a consequence of a strict application of the Biological Species Concept, requiring complete reproductive isolation. In this study historical factors were discounted but it is apparent that taxonomic concepts can be used to predict the occurrence if not the severity of OBD. In a similar situation, Walters et al. (1995) in determining genetically appropriate local stock of the widespread wiregrass [*Aristida stricta* Michx.] indicate throughout their paper a deep concern over the potential for OBD in populations of wiregrass due to inappropriate stock use in restoration projects. Emphasizing different electrophoretic profiles between populations the authors concluded that collections of wiregrass should include separately maintained accessions from local populations. This potential for OBD was confirmed by Peet (1993) in a taxonomic study of the *Aristida stricta* complex who determined that the grasses traditionally assigned to this species included two morphologically and ecologically distinct species.

In the examples above the taxa were difficult to distinguish morphologically and only careful study and the use of genetic tools such as enzyme electrophoresis uncovered the underlying differences. Clearly, taxonomic evidence can be used to at least assign a probability for the occurrence of OBD. The occurrence of intraspecific taxa within a species indicates that evolutionary forces, especially selection, have ordered phenotypic and genotypic traits along environmental or ecological gradients. Interpreting phenotypic patterns is the job of taxonomists and the various floras are the sources for valuable information. For example, the common and widespread grass little bluestem [*Schizachyrium scoparium* (Michx.) Nash] exhibits a wide range of phenotypes associated with particular regions of the United States and/or distinct habitats (Fernald 1950). If environmental heterogeneity promotes genetic heterogeneity then this should be taken as a clear indication that widespread species with high amounts of intraspecific variation indicate different evolutionary trajectories of these taxa and care should be taken in choosing appropriate stock for outplanting.

Employing taxonomic evidence should substantially facilitate our assessment of OBD in a given situation. This premise is well founded as differential phenotypes could well indicate different selection regimes and the possibility of genetic divergence (Linhart and Grant 1996). Clearly applying taxonomic concepts will also provide a context for OBD and eliminate confusion that may occur through conflating taxonomic concepts with evidence for pervasive OBD in plants. Taxonomists would be quick to add that the weakness of morphological taxonomy is also its strength, the recognition of phenotypic patterns in nature.

The Ecological-Genetic Context of Outbreeding Depression

Plant populations may often be genetically and phenotypically variable over geographic space (for historical perspective see Briggs and Walters 1969; Epperson 1990). In fact genetic subdivision in plant populations may occur over distances of a few meters and genetic divergence as measured by neutral loci is typical among populations of many species. Spatial genetic structure is primarily determined by distances of gene flow and migration between populations. Additionally, life history components of species may have a profound effect on genetic structuring of populations (Loveless et al. 1998). Indeed, conservation biologists have long recognized that certain characteristics of rare species increase the probability of extinction via the loss of genetic diversity through inbreeding effects. These same characteristics have the potential to influence the evolution of mating systems. For example, selection may favor the evolution of selfing in rare species due to characteristics such as small population size, poor or unpredictable pollinator service, and isolation from other populations due to restriction to patchy habitats (Karron 1991). Additionally, as discussed previously, historical factors that may contribute to isolation may influence the amount of genetic subdivision and divergence.

What are the consequences of such dramatic subdivision? Does the finding of genetic differences between populations reflect local adaptation to a site via strong local selection, random genetic drift, or some combination of the above? Additionally, how do we reconcile the finding of optimal outcrossing distances of a few meters with substantial evidence for at least F_1 heterosis in crosses between distant populations? While a full exposition on life-history characteristics is beyond the scope of this paper the literature strongly suggests that the breeding system of plant species is a useful character in predicting distances of gene flow and determining the degree of genetic subdivision, and so it would appear that the breeding system of a plant would be similarly useful for predicting OBD. Implicit in this discussion is that in species where genetic population subdivision is substantial that this subdivision is created and maintained by selection i.e., they are not a series of random events but highly repeatable observations for certain breeding systems. If these assumptions are correct then local adaptation by either the ecological or genetic mechanism is conditioned by the breeding system.

The manner in which genetic variation is distributed among populations of a species is closely tied to gene flow (Levin and Kerster 1974, Loveless and Hamrick 1984). Hamrick and Godt (1989, 1996a) examine the correlation between and number of life-history traits and genetic variation. One of the strongest correlations occurs between plant mating system and the distribution of genetic variation among and within populations, with selfing species showing a significantly greater degree of genetic variation among populations rather than within populations. Outcrossing species show a typical pattern of more of the genetic variation distributed within populations rather than among populations. If a selfing mating system leads to greater genetic subdivision between populations due to low rates of gene flow, then it logically follows that these species have at least the opportunity for greater divergence given some degree of local selection or drift. Since OBD is defined as a loss of fitness occurring as a consequence of matings between genetically dissimilar individuals then we should find a correlation between a selfing mating system and the expression of severe OBD. Of course any degree of population divergence within a species would depend heavily on the strength and direction of selection, as well as historical factors such as past genetic bottlenecks and the period of time over which isolation has occurred. Thus, it is expected that the correlation between mating system and OBD will not always be a strong one.

If the expression of OBD is correlated with the mating system of a plant then the data from experimental crosses over distance and breeding systems should indicate trends. For this purpose 36 studies (40 taxa) that indicated variation in fitness with crossing distance or between selfed and outcrossed flowers were reviewed.

Table 1. Associations between mating system and outbreeding depression.

Reference	Species	Breeding System
Fischer and Matthies 1997	*Gentianella germanica* (Willd.) Borner ex E. F. Warb	Selfing
Parker 1992	*Amphicarpaea bracteata* (L.) Fernald	Selfing
Schneller 1996	Asplenium ruta-muraria L.	Selfing
Waser and Price 1979, 1994	*Delphinium nelsonii* Greene	Outcrossing self-compatible
Svensson 1990	*Scleranthus annuus* L.	Selfing
Raimundez and Ramirez 1998	*Hypoxis decumbens* L.	Selfing
Waser and Price 1989	*Ipomopsis aggregata* (Pursh) V. E. Grant	Outcrossing self-compatible
Sobrevilla 1988	*Espeletia schultzii* Wedd.	Outcrossing self-compatible
Levin 1984	*Phlox drummondii* Hook.	Outcrossing self-incompatible
Schemske and Pautler 1984	*Costus allenii* Maas	Outcrossing self-compatible
McCall et al. 1991	*Impatiens capensis* Meerb.	Mixed
Schmitt and Gamble 1990	*Impatiens capensis* Meerb.	Selfing*

Twelve studies (11 taxa) concluded evidence of OBD at long crossing distances (Table 1). Of these 12 studies five species were described as being highly selfing or autogamous, two species were outcrossing but self compatible, 3 species were outcrossing and self-incompatible and one specie had a mixed mating system with both cleistogamous and chasmogamous flowers. While the trend of a selfing breeding mechanism was confirmed, the three studies observing OBD for outcrossing and self-incompatible species was unexpected. Waser and Price (1989) concluded that OBD in *Ipomopsis aggregata* was expressed over lifetime fitness with intermediate (optimal) outcrossing distances having the greatest fitness. Waser (1993) reports that for this species

(*Ipomopsis aggregata*) there was a 12% detriment in seed maturation relative to the intermediate cross and a 32 % detriment in lifetime F_1 fitness of the offspring in the field. The presence of strong self-incompatibility in this species coupled with an apparent small genetic neighborhood size is counterintuitive. Large neighborhood sizes were found in the self-incompatible *Asclepias exaltata L.* (Broyles and Wyatt 1991). In another strongly self incompatible species [*Aster furcatus E.S. Burgess]* it became necessary to augment local populations to regain normal seed set (Les et al. 1991). It is possible that other life history traits aside from breeding system were responsible for this finding such as animal (hummingbird) pollination or monocarpy.

Sobrevila (1988) described OBD in *Espeletia schultzii* at crossing distances greater than 500 meters. OBD was expressed as an increase in seed abortion (% filled achenes), a 23% detriment relative to the intermediate cross (in Waser 1993) but the authors concluded that there was a strong environmental effect. Populations of *E. schultzii* presented different phenotypes at different elevations and it was concluded that populations may be undergoing some divergence and so one must also apply the evolutionary-taxonomic context to this species.

Levin (1984) reported OBD in the annual, *Phlox drummondii* as expressed by seed abortion, but only in half the crosses at 200 meters; the other half showed evidence of heterosis. The review by Waser (1993) does not indicate OBD for this study and instead indicates that the longest crosses performed best. All of the species reported by Waser where the longest crosses performed best are outcrossing and self-incompatible (Waser 1993, Table 9.4), as would be expected.

The evidence for OBD in those species described as outcrossing but self-compatible is weak or extremely variable. Only *Delphinium nelsonii* (Waser and Price 1994) exhibited strong OBD as expressed over the lifetime of the individual. OBD in *Costus allenii* (Schemske and Pautler 1984) was expressed as consistent reductions in seed number per fruit and percent germination, however two other fitness components showed increases (seed weight and total dry weight). The only species with a mixed mating system (*Impatiens capensis*) expressed an optimal outcrossing distance (and thus OBD) in one trait (seedling height at one month) but the authors (McCall et al. 1991) concluded that the optimum resulted from a negative correlation between interparent distance and seed weight and that emergence and survival were not correlated with crossing distance. Other studies with *Impatiens capensis* (Schmitt and Gamble 1990) found evidence for OBD only with seed derived from cleistogamous (selfing flowers). Extreme variation among maternal parents in experimental crosses is frequent (Parker et al. 1995) making the interpretation of the data difficult. Additionally, maternal effects appear to break down over time (Wolfe 1993) and perhaps the severity of OBD due to local adaptation would be ameliorated over generations.

Studies describing inbreeding depression were abundant and include all but two of the studies (Parker 1992, Schneller 1996) in Table 1; a selfing annual and a homosporous inbreeding fern respectively. Thirty-three studies covering 39 taxa described significant inbreeding depression for self or short crosses as compared to outcrossed or long crosses. Tabulating the breeding systems for these 39 taxa produced trends consistent with lower inbreeding depression for species with a selfing breeding system and high inbreeding depression for species with an outcrossing breeding system (Table 2). Only four of the 39 species were described as selfing (Fischer and Matthies 1997, Svensson 1990, Parker et al. 1995, Carr and Dudash 1996) whereas nineteen were outcrossing but self compatible (Waser and Price 1994, Dudash 1990, Van Treuren et al. 1994, Helenurm and Schaal 1996, Lyons 1996, Holtsford 1995, Trame et al. 1995, Oostermeijer et al. 1995, Schemske and Pautler 1984, Carr and Dudash 1996, Husband and Gurney 1998, Delesalle and Muenchow 1992, Johnston 1992, Montalvo 1992, Wolfe 1993, Galen et al. 1985, Coles and Fowler 1976), 12 were outcrossing and self incompatible (Broyles and Wyatt 1991, Lyons 1996, Waser and Price 1989, Newport 1989, Sobrevila 1988, Levin 1984, Young and Brown 1998, Harder et al. 1995, Redmond et al. 1989, Koptur 1984) and three were considered to have a mixed breeding system (Schoen 1983, McCall et al. 1991, Schmitt and Gamble 1990, Ayre et al. 1994).

Table 2. Frequency of different breeding systems among studies finding inbreeding depression.

Breeding System	**Frequency (N-39 taxa)**
Selfing	0.103
Outcrossing self-compatible	0.487
Outcrossing self-incompatible	0.307
Mixed	0.103

The general trends of these studies support the hypothesis that in situations where gene flow is localized and subsequently natural inbreeding in the population is occurring that the propensity of the population to exhibit OBD is increased. Local adaptation may be particularly strong for highly selfing species for several reasons. Firstly, the whole genome may be tightly linked as a consequence of increasing relatedness among members of the local population. Secondly, selfing species should experience a slower decay of linkage disequilibrium (Hamrick et al. 1991) than outcrossing species given that recombination within a genome that is extremely homozygous produces little change. Thirdly and related to the above, genetic variation is typically low within populations of selfing species but may be highly variable among populations. The latter has two explanations. Either it is the case that populations are formed from few founders that by chance have generally equal fitness or populations are formed from many individuals drawn from a source pool and strong selection sorts the progeny into a few fit genotypes. In either case the indication is that in highly self-fertilizing species local adaptation to the environment is highly plausible (Pannell and Charlesworth 1999).

Are there reasons to believe that selection is capable of producing such breeding system plasticity? If selection for self compatibility or selfing among plant species is favored where there are reduced opportunities for outcrossing then there should be situations where the mating system shows some plasticity in responding to selection. Such data is present in four studies. In *Leavenworthia crassa* Rollins (Lyons 1996) different populations show dramatic differences in outcrossing rates. Furthermore, these differences in outcrossing rates are associated with phenotypic divergence. The highly outcrossing populations of *L. crassa* have strongly scented flowers and extrorse anthers whereas the selfing populations have smaller, lightly scented flowers and introrse anthers. Charlesworth and Zang (1998) conclude that selfing in *L. crassa* may be of recent evolutionary origin. In *Clarkia tembloriensis Vasek* (Holtsford and Ellenstrand 1990, Holtsford 1996) outcrossing rates varied between populations and these were highly correlated with anther-stigma separation and the degree of protrandry. Additionally, the selfing populations occupied marginal habitats where there were more severe environmental conditions leading to drastic population fluctuations. Ayre et al. (1994) report high levels of selfing in the rare Australian shrub *Grevillea barklyana* F. Muell. ex Benth. that were unexpected given that most of the taxa in the family Proteaceae are highly outcrossing and that experimental crosses indicated a preference for outcross pollen. A fourth population of *G. barklyana* was found to be highly outcrossing indicating that the breeding system may vary widely and may be less than optimal.

For highly outcrossing species, high migration rates and longer distances of pollen movement may be inferred from high genetic diversity at both the population and species levels, especially for wind-pollinated species (Hamrick et al. 1991, Table 5.1, 5.2, Godt and Hamrick 1998). Therefore, there is less probability that populations will exhibit OBD due to local adaptation except in situations where there is strong selection due to extreme environmental conditions (e.g., heavy metal tolerance).

The data are sufficient to support the hypothesis that OBD in plants can be predicted with some reasonable assumptions if appropriate attention is given to understand the generalities of the mating system. But if OBD occurs more regularly under some mating systems, is it likely to be severe and most importantly is it likely to persist, increasing the probability of detriment to the population.

While OBD may be severe as in the case of seed abortion or F_1 inviability these are generally not of great concern as OBD will be expressed early and lethally and so there will not be OBD in the populational sense. What is of concern is the carryover of numerous mildly deleterious alleles (genetic load) that are capable of being passed to further generations and expressed over an undetermined time possibly via a dominance-recessive mechanism as has been postulated for inbreeding depression (Charlesworth and Charlesworth 1987). The finding that inbreeding depression may persist even in populations of highly selfing species (Karron 1991) is worrisome because it indicates that these mildly deleterious alleles are maintained even under strong inbreeding. Other authors hypothesize that inbreeding populations may purge such "genetic load" once a certain level of inbreeding is reached (Lacy 1992, but see Hedrick 1994). Purging the genetic load seems likely for those species which have reached a stable strategy of complete self-fertilization but it appears unlikely to be generally true for all selfing species given the plasticity of the breeding system under local selective conditions. The point here is that most species, perhaps with the exception of highly inbreeding species are likely to carry a significant genetic load. There is abundant evidence that the genetic load of a population is often expressed under unnatural inbreeding and as such inbreeding depression has been a major focus of conservation genetics (Lacy 1992). If we assume that NNG's are likely to (1) add to the genetic load of a population by carrying additional deleterious alleles and (2) increase OBD by disrupting coadapted gene complexes rather than be expressed as heterosis then the major concern over OBD should be on those taxa that are predominately naturally inbreeding.

With respect to local adaptation but there are important differences between selfing and outcrossing species. For selfing species there are two considerations. Firstly, the genome of a selfing species is likely to be highly homozygous and any highly deleterious mutations will be expressed at some time (Hedrick 1994) under intensive inbreeding. Therefore, the importation of NNG's are likely to be expressed as severe OBD in the F_1 generation and in the case of annuals there is a remote possibility that population size could be drastically reduced if pollen flow from established NNG's is large enough to produce a predominantly unadapted cohort. Secondly, because the loci may be so tightly linked there is little chance of disrupting coadapted gene complexes and thus mildly deleterious alleles may be hidden from selection due to limited recombination (Wolfe 1993). The importation of NNG's are likely to produce substantial reorganization of the genome and subsequently gene-environment coadaptations are likely to be disrupted.

For outcrossing species the heterogeneity of the genome is likely to contain a high genetic load which often is expressed as severe inbreeding depression under forced selfing. Any number of deleterious alleles are likely to accompany NNG's arriving via pollen in natural populations. This may increase OBD temporarily in a population. Temporal OBD rather than persistent OBD is expected because it is difficult to see how strongly deleterious alleles could be maintained in any population. Further, strong linkage among loci in outcrossing species would only be maintained under strong selection, something not likely for populations that are generally highly variable and often geographically widespread. This is evident in studies of grasses (Balfourier et al. 1994, Godt and Hamrick 1998, Warren et al. 1998). The likelihood of persistent OBD due to increased genetic load under outcrossing would appear to be small since in most situations deleterious alleles will be exposed to selection after recombination via progeny with low fitness and additionally the progeny must compete in the population with established (and presumably well adapted) plants.

Conclusions

No discussion of OBD would be complete without addressing the concept of optimal outcrossing distances. This concept is important to consider here because optimal outcrossing theory suggests that a combination of inbreeding and OBD interact to produce an optimal degree of outcrossing in populations and this may lead to overly emphasizing the potential for OBD. I have several objections to broadly applying this concept. Firstly, optimal outcrossing distances imply that these distances are stable and permanently associated with reductions in fitness for long outcrosses. The concepts of fitness and selection are best expressed as propensities for certain evolutionary outcomes (see Mills and Beatty 1994 for discussion) which are not entirely stable or even predictable. Optimal outcrossing as a populational concept can only be represented statistically, as optimal outcrossing is the property of individuals not populations. Secondly, the distance for an optimal outcross depends entirely upon where the individual is with respect to other individuals in the population. Fitness differences can be averaged over individuals and thus we create the statistical illusion that the population has an optimal outcrossing distance while in reality there is great variation in pollination distances achieved by individuals. Additionally such a optimization theory becomes extremely complicated with fluctuating population densities as is common among populations of annuals and to some extent perennials.

Waddington (1983) proposes that optimal outcrossing distances may never be achieved by plants and presents two models of OBD for explanation. Under the "isolation by distance" model, OBD increases with distance from a source plant because of reduced relatedness caused by limited gene flow. If selection for longer distance of pollen flow is possible then the zone of inbreeding depression increases as a consequence. Additionally, as the genetic neighborhood size increases the effects of inbreeding become less pronounced and so selection should relax, shifting the "optimum". It is difficult to see how a plant may manage to maintain an optimal pollen flow particularly for those species that may need to influence a variety of pollinators or where pollen flow is passive (wind-pollinated species).

Under the "heterogeneous environment" model, OBD occurs as a consequence of different selective pressures in different habitat patches (local adaptation to a patch); thus the optimum is fixed at the boundary of the patch beyond which is the zone of OBD. The optimum depends entirely upon the position in the patch; those near the edge require a shorter distance than those near the center. It seems likely that a plant's pollen flow is subject to selection at fairly gross levels, that is, under balancing selection for selfing and outcrossing through changes in plant density and characters associated with flower physiology/physiognomy. The plasticity of such morphological traits (e.g., protrandry) seems testament to such a possibility. A shifting response to factors such as pollinator availability, plant density and environmental changes does not require invoking optimality, just a phenotypic response.

Many arguments regarding the *a priori* severity of OBD are presented in what I call null-selection arguments. That is, no role is allowed for selection to reassort the genetic structure upon outcrossing with NNG pollen. This is especially irritating in light of the evidence of the role of selection. Additionally, any number of sub-optimal crosses occur frequently, especially in continuous populations, and these are expressed in varying degrees of fitness loss in individuals, which are subject to selection. I am not arguing that choices of seed sources can be indiscriminate without deleterious effects; I am arguing however, that the potential for OBD in native populations be evaluated in light of the evidence and put in context of the evolutionary biology.

There is, however, a well founded concern that the widespread use of NNG's among native populations may drastically reduce the efficacy of studies of gene flow and divergence utilizing *a priori* native populations but this issue cannot be resolved here. Additionally, there is a concern that the use of NNG's may result in unintentional disruption of plant-animal interactions, but this seems plausible only in cases of close plant-animal coevolution or in cases whereby there would be substantial alteration of phenotypic characteristics, much of which could be avoided by applying clear taxonomic concepts in choosing sources of genetic stock and choosing stock from sites that have comparable environments (in the broad sense) such as light cues, similar growing seasons etc.

The conclusions of this review are that OBD can be predicted for species with some combination of the following characteristics: annual habit, small population sizes, occur in patchily distributed habitats, have locally high intraspecific variability (e.g., many segregate taxa), a mainly inbreeding mating system and/or have very localized patterns of gene flow and dispersal. These general characteristics are summed in Table 3.

Table 3. Associations between biological traits and the potential for outbreeding depression.

Trait	**Low potential for OBD**	**High potential for OBD**
Geographic range	Widespread	Narrow/endemic/rare
Breeding system	Outcrossing	Selfing
Lifeform	Long-lived perennials	Annuals
Pollen and seed dispersal	Pollen and seed dispersal	Short distances (gravity)
Pollination syndrome	Wind	Animals
Intraspecific variations	Few	Many

The severity of OBD is less predictable and depends a great deal upon other factors such as taxonomic concepts, historical components of geographical distribution, and the time periods of genetic isolation. Severe OBD is predictable for species that exist as small populations in patchy habitats or those that are naturally highly inbreeding due to the increased likelihood that local adaptation is strongly promoted by natural selection. The persistence of OBD in populations is also not very predictable as it depends primarily on the strength and direction of selection in the local environment; however, when considering the above characteristics there is a strong inference that OBD as a consequence of increased genetic load is unlikely to persist among populations of some long-lived perennials. Long-lived perennials may ameliorate OBD through longer generation times and lengthy periods for producing a new reproductive cohort. Thus even weak selection may have a significant period to reassort population genetic structure. For annuals there may be strong selection against unadapted genotypes when the unfit progeny are fully exposed to selection in each generation. However, in annuals some amount of OBD may persist under weak selection perhaps facilitated by rapid population turnover as well as chance sampling events among numerous progeny.

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Native Grasslands and Their Wildlife Value in Southern Ontario Landscapes

Owen Steele[1]

It is widely believed that the original landscape of Ontario was a vast unbroken forest, however research conducted by the Natural Heritage Information Centre of the Provincial government's Ministry of Natural Resources has concluded that there existed a very diverse mosaic of tall grass vegetation. This ranged from open grassland to savannahs and even more closed woodlands in areas not so frequently burned. Currently less than 3% of the estimated grassland extent remains today. Wetland losses closely mimic that of grasslands as European settlers modified the landscape to benefit their needs.

Ducks Unlimited Canada's (DUC) mission is to address these impacts through the conservation of wetland ecosystems and associated upland habitats to promote a healthy, sustainable environment for people and wildlife. Upland areas adjacent to wetlands are critical to wetland dependent wildlife, especially the interface between the two habitats. Waterfowl research indicates that as many as 80% of upland nesting waterfowl nests are found within 300 m of the wetland. Thus, land use practices surrounding wetlands have a significant impact (both positively and negatively) on habitat productivity.

In order to answer questions regarding upland habitat issues, DUC 's research branch, the Institute of Wetland and Waterfowl Research, is presently completing a waterfowl study of various Southern Ontario landscapes. In each year since 1997, 60 Mallard [*Anas platyrhynchos*] hens were implanted with radio telemetry devices to track and monitor their habitat preferences and reproductive success. In the two years the study was conducted in the agriculturally influenced portion of Southern Ontario, upland grassland habitat (both tame forage and idled grassland) proved most attractive to the nesting birds. Nest success was variable based on a number of interrelated parameters including timing of hay cut, predator species and abundance, along with grassland habitat considerations such as quality, quantity, and juxtaposition.

In an initial attempt to improve wildlife habitat adjacent to wetlands, DUC planted tame grasses and legumes. The resultant grassland was found to require regular and expensive management that frequently compromised the habitat's wildlife value. These limitations, combined with a Southern Ontario average annual snowfall that exceeds 250 cm and promotes stand compaction, motivated DUC to search for better alternatives. Following the lead of DUC in western Canada who have been utilizing prairie grasses and forbs for more than 15 years, we began investigating the merits of native plant species that were historically present in Ontario.

With the assistance of many partners, including the USDA NRCS, we tested dozens of warm and cool season native grass species in plots to determine their suitability for a nesting cover program. The evaluation progressed from establishment issues to investigations of stand resiliency and habitat quality, leading us to our current array of warm and cool season species:

Warm Season Grasses	Cool Season Grasses
- big bluestem	- bluejoint
- little bluestem	- slender wheat grass
- switchgrass	- northern wheat grass
- sideoats grama	- Canada wildrye
- Indian grass	

Because our large-scale plantings are usually next to wetlands, we commonly encounter variability in site conditions. The sculptured seeding technique is an ecological approach to

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revegetation based on matching site capability with appropriate plant species to create a diverse plant community capable of maximizing wildlife benefits.

Monitoring and Adaptive Resource Management (ARM) is a very important components of our program. Habitat quality is contingent on having sufficient species diversity to provide both vertical and horizontal structure as well as field heterogeneity and patchiness.

In addition to numerous studies in the 1980's that focused on pheasants in New York State, Kerr in 1987 recorded 16 species of birds nesting in switchgrass stands at Tonowanda including – Northern Harrier, 3 species of Sparrows (song, swamp, and savannah), Mallard, Blue Winged Teal and Woodcock. DUC informal studies conducted by volunteer birders combined with other observations in Ontario have inventoried similar avian species compositions with the common addition of Meadow Lark and Sedge Wren.

In southwestern Manitoba, the Prairie Habitat Joint Venture (PHJV) assessment study has documented the effect of upland habitat programs on prairie songbirds. Mixed grassland plantings of various ages ranked highest in relative abundance of grassland nesting songbirds, many of which have shown significant population declines in the past several decades. According to Hartley's PHJV work in 1994 on passerine abundance and productivity indices, significantly fewer passerines were found to utilize agricultural lands when compared to remnant and planted grasslands.

Native grasslands play host to a diverse array of other wildlife species that benefit from this important habitat for reasons other than nesting. More research will be required to quantify other species benefits and this will undoubtedly provide additional support for grassland programs. In addition, understanding the indirect role native grasslands play in conserving wildlife habitats and benefiting society in general, through such activities as the improvement of water quality and minimization of soil erosion from water runoff and wind, will greatly enhance the status of native plants for restoring the overall health of our ecosystems.

Improving Water Quality Using Native Grasses

Ronald R. Schnabel [1]

Abstract

Numerous water quality challenges confront the people of the eastern United States. Thousands of miles of streams and thousands of acres of lakes and estuaries do not fully meet the water quality standards of their designated uses. The Clean Water Act requires states to devise and implement plans to bring these waterbodies into compliance. The States within the Chesapeake basin have agreed, by 2000, to reduce the mass of pollutants entering the Bay to 40% below 1985 levels and then cap them at that level regardless of population or industrial growth. At the same time, the U.S. Department of Agriculture has started a program (National Conservation Buffer Initiative) to establish 2 million miles (3 million km) of conservation buffers by 2002. Each of these efforts to improve water quality will require choices of vegetation. Native grasses should be strongly considered during planning and implementing water quality improvement projects.

Native grass buffers limit the transport of nonpoint source pollutants within and from fields. Vegetative barriers of switchgrass [*Panicum virgatum* L.] and eastern gamagrass [*Tripsacum dactyloides* (L.) L.] commonly trap up to 50% of coarse sediment and significant amounts of plant nutrients within the field. Grassy riparian buffers, either alone or as part of a forested buffer system, trap or transform sediments and plant nutrients before they enter streams. Native grasses might also be used in contour filter strips that can retain 50-70% of nutrients, pathogens and sediment.

Incorporating perennial, native warm-season grasses into farming systems and seeding them in critical areas further reduces erosion and loss of plant nutrients. Native warm-season grasses produce large amounts of biomass suitable for forage or as biofuel feedstock with less fertilizer than other vegetation. Their incorporation into farming systems can reduce inputs to the farm and the potential for their loss. Native grasses have a place in efforts to improve water quality, both in limiting the source of pollutants and intercepting pollutants before they enter a waterbody.

Introduction

How we define "water quality" depends on how the water is used and on our proximity to it. For example, to residents of an upland watershed drained by a high-value, cold-water fishery, stream temperature, channel and biological community characteristics as well as plant nutrient concentrations are all important components of water quality. In contrast to the multiple local concerns, the export of pollutants to a lake or estuary is the principle regional water quality issue for residents of upland watersheds. Likewise, while the quality of estuaries and lakes has many facets, the delivery of pollutants is the leading regional concern and will be the focus of the remainder of this paper.

Water Quality Challenges

Two major water quality challenges currently face the residents of the eastern United States and they will continue into the next century. In 1987, the Commonwealths of Pennsylvania and Virginia, the State of Maryland, the Environmental Protection Agency (USEPA) and the Chesapeake Bay Commission, signed the Chesapeake Bay Agreement establishing a goal of improving water quality in the Bay to support living resources. A commitment to reduce nutrient pollution by 40% by 2000 was key to achieving that goal. In 1992, the Executive Council recommitted itself to reducing nutrient levels by 2000 and then capping nutrient loads regardless

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of continued population, industrial or agricultural growth. The Executive Council reaffirmed that commitment in 1997.

The Clean Water Act requires that the States implement plans to bring the quality of their water bodies up to levels established for their designated uses. Section 303(d) of the Act mandates that States determine the total load of each pollutant that an impaired water body can accept on a daily basis and still meet water quality standards for its designated use. The States must further apportion current loads among the various sources, develop and then implement plans to reduce total loads below maximum permissible levels.

How are we doing?

Phosphorus (P) and nitrogen (N) are the major plant nutrients of concern in the Chesapeake Bay. The Susquehanna, Potomac and James River watersheds are the largest in the Bay drainage and contribute the greatest quantities of water, P, and N (Figure 1). Monitoring data showed an overall decline in P entering the Bay from 1987-1992, with substantial reductions from the Susquehanna and Potomac watersheds (USGS 1995). These reductions in P delivery to the Bay were largely attributable to improvements at point sources, for example at sewage treatment plants. More recent data, while not yet clear, may show a reversal in the P trend as increases in nonpoint source P losses offset previous reductions in point source P. Nitrogen delivery to the Bay continued to rise, although at a lower rate than earlier in the decade. Improvements in sewage treatment technology and changes in detergent formulation that caused a major reduction in point source P did not, and were not, expected to cause similar reductions in point source N. Later data show that both N and P levels declined between 1985 and 1997 when adjusted for year-to-year differences in flow (Chesapeake Bay Program 1999). Computer simulations indicate that basin-wide acceptance of best management practices (BMP), to control nonpoint N sources, and the adoption of biological nutrient reduction (BNR) at wastewater treatment plants, will reduce N delivery to the Bay below the 40% reduction goals sometime after 2000 (Chesapeake Bay Program 1999). The full extent of N reductions achievable from widespread use of BMPs are not yet measurable at the Bay, because most of the N exported to the Bay enters streams as discharging ground water. Ground water residence times in parts of the Basin are long, perhaps decades. Thus, some of the water currently entering the Bay has an N load that reflects management prior to the adoption of BMPs, and the total improvement will not be measurable for some time. Even if reductions in N delivery continue to work their way through the ground water system, we must recognize that to meet the year 2000 goals and certainly to cap loads at that level, greater efforts must be made to reduce both N and P entering the Bay. The largest sources of both N and P to the Bay are still nonpoint sources of agricultural origin (Table 1), and we must expect that the agricultural sector will be asked to do more.

Throughout the eastern US the states must evaluate their waters, sort them into 4 categories relative to their intended uses, and report the results to the USEPA. In 1992, only 56% of assessed stream miles across the country fully supported their designated uses. Siltation and plant nutrients were the two most common reasons for lack of compliance, with 45% of the assessed streams having too much sediment and 37% having excessive levels of nutrients. Twenty-one thousand waterbodies were listed as not fully supporting their designated uses in the 1998 reports to the USEPA (USEPA 1999). They accounted for 300,000 miles (482,700 km) of stream or shoreline and 5 million acres (2 million hectares) of lake or estuary. Approximately 220 million Americans live within 10 miles (16 km) of an impaired waterbody. The most common causes of impairment were still excessive levels of sediment, plant nutrients, and pathogens. These high levels of noncompliance are the sum of the categories fully supporting but threatened, partially supporting, and not supporting. While much progress has been made in educating the public and in improving water quality over the last decade, the levels of noncompliance show that much remains to be done.

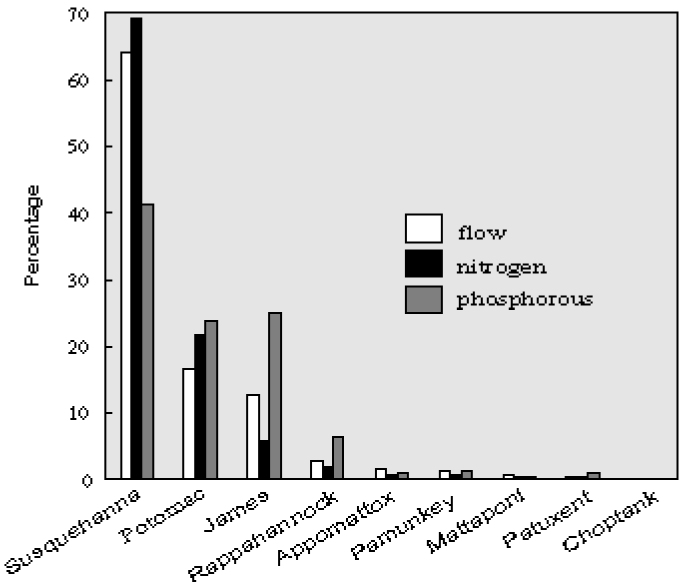

Figure 1. Percentage of water, nitrogen and phosphorus exported to the Chesapeake Bay from the major tributaries.

Table 1. Nutrient export to the Chesapeake Bay (Chesapeake Bay Program 1998).

Source	***Area***	***N***	***P***
	%		
Non-point	100	76	74
Forest	58	17	5
Agriculture	33	44	58
Urban	8	10	10
Point	-	24	26

Pollution Control Options

Whether we focus on the Chesapeake Bay or take a broader view, we find many water quality problems caused by nonpoint source pollutants. There are essentially two ways to control nonpoint source pollution. It can be controlled at the source by management that reduces erosion and closely matches the timing and concentration of plant nutrient availability with crop requirements, or it can be intercepted before it enters an impaired waterbody. Whenever possible, it is preferable to control pollution at the source by improved nutrient management and reduced tillage. However, given inefficient nutrient use by crops, vagaries of the weather, and current high to excessive levels of plant nutrients in many soils, transport control is a necessary component of water quality improvement strategies. Many of the options available to land managers require them to select appropriate vegetation. Native warm-season grasses can be used effectively to reduce the potential for NPS pollutant loss (source control), and to contain pollutants within the field or watershed (transport control).

Source Control

The goal of source control is to reduce the potential for pollution by reducing the addition of nutrients to the field, by applying them in a less mobile form, and by keeping the soil in place.

Eastern native grasses can be used a number of ways to reduce the source of pollutants. Eastern native grasses are perennial with deep, dense root systems. Thus erosion and the transport of sediment associated pollutants will be diminished, especially compared to cropped soils. These deeply rooted perennial grasses also enhance infiltration that reduces runoff and the potential loss of dissolved pollutants (i.e., phosphorus) that are only slightly soluble in the soil.

Many native warm-season grasses are well adapted to droughty, acidic, and infertile soils, and they require much less N and P to produce more biomass than similarly located cool-season grasses (Table 2). These grasses could be used in the planting of critical areas, such as those that are especially erosive or are locations most likely to lose applied nutrients.

Table 2. Biomass yields for selected native warm-season grasses and adapted cool-season grasses. Sharp and Gates (1986).

Grass	w/o fertilizer	75 kg N ha^{-1}
	Mg ha^{-1}	Mg ha^{-1}
Native Grasses		
Niagara big bluestem [*Andropogon gerardii* Vitman]	4.4	6.8
Blackwell switchgrass [*Panicum virgatum* L.]	4.2	7.9
NJ50 switchgrass [*Panicum virgatum* L.]	10.7	11.2
NY591 Indiangrass [*Sorghastrum nutans* (L.) Nash]	5.2	6.2
Adapted grasses		
KY31 tall fescue [*Festuca arundinacea* Schreb.]	0.8	3.8
Reed canarygrass [*Phalaris arundinacea* L.]	1.6	3.9
Pennlate orchardgrass [*Dactylis glomerata* L.]	1.3	3.1

Beef cattle and sheep grazing native grasses as part of their diet gain as much as or more than animals grazing cool-season grasses (Jung 1986; Reid et al. 1988a; Reid et al. 1988b). By incorporating native grass pastures farmers could maintain or increase the productivity of their farms while reducing the need for nitrogen and phosphorus additions. Since native grasses utilize nutrients as efficiently as cool-season grasses (Staley et al. 1991), reduced additions should translate directly into reduced losses from the watershed.

Using native grasses as energy crops has been studied extensively (e.g., Hohenstein and Wright 1994; Sanderson et al. 1996; McLaughlin and Walsh 1998; Walsh 1998), and the net energy produced with these grasses ranks near the top of all biofuels. Current markets for energy crops are small. However, markets will continue to increase as energy conversion technology improves, making the economics of biofuels more competitive with fossil fuels, and in response to environmental concerns over atmospheric concentrations of carbon dioxide. Conversion of cropland to native grasses to supply the emerging biofuels market has the potential to decrease the amounts of plant nutrients that are transported to surface and ground water.

Transport Control

The National Conservation Buffer Initiative is one program in which native grasses can be used to diminish the adverse impacts of agriculture on water quality by controlling the transport of pollutants to streams. The initiative, administered by the Natural Resources Conservation Service (NRCS), has the goal of establishing 2 million miles (3 million km) of conservation buffers by 2002. Conservation buffers are small areas or strips of land in permanent vegetation designed primarily to intercept pollutants. Conservation buffers include vegetative barriers, contour grass strips, riparian buffers, and grassed waterways. Each of these practices controls pollutant transport by slowing water runoff, trapping sediment, and enhancing infiltration within the buffer. Conservation buffers have been shown to remove 50% or more of nutrients and pesticides, 60%

or more of certain pesticides, and 75% or more of sediments. Combined with appropriate upland treatments, buffers should allow farmers greater economic and environmental sustainability. This and other conservation efforts occur at a time when governmental directives strongly encourage using native plants in revegetation programs.

While each of these conservation measures has been practiced in the U.S. and around the world for many years and their effectiveness is well documented, most of the information has been gathered for adapted, non-native species. Vegetative barriers, grass hedges, are an exception for which over a decade of research exists using grasses native to the eastern U.S.

Vegetative Barriers

Vegetative barriers are parallel strips of stiff, erect, dense grass planted close to the contour and across concentrated flow areas. They are usually about 3 feet (1 m) wide with hundreds of stems per square foot. Soil berms that develop during the use of vegetative barriers, in contrast to those that build up around other buffers, do not hinder buffer performance and do not need to be smoothed out during maintenance operations.

The coarse, stiff grasses of vegetative barriers can withstand high water flows and pond runoff. As the water ponds above the barrier, concentrated flows are slowed and spread, reducing the erosive energy of the runoff. Sediments settling out of the ponded water fill areas of concentrated flow and generally reduce the slope between hedges. The erosive energy of runoff is further reduced by enhanced infiltration within and ahead of the barrier before it enters the next crop strip or associated conservation buffer.

Vegetative barriers are reported to remove from 40 to 60% of sediment and sediment-associated chemicals from runoff (Meyer 1995; Meyer et al. 1995; Dabney et al. 1995). Numerous factors affect the pollutant trapping efficiency of vegetative barriers. Land slope affects trapping efficiency and, therefore, vegetative barriers are not recommended on slopes greater than 10% (NRCS 1997b). The distribution of particles or aggregate sizes entrained in runoff is the predominant soil characteristic affecting hedge effectiveness. While over 90% of aggregates larger than 125 microns settle in pools formed by hedges, only 20% of aggregates or particles smaller than 32 microns are trapped (Dabney et al. 1995). Consequently, vegetative barriers are not very effective where a large fraction of eroded material is silt or clay sized. The physical strength and resilience of the hedges also affect trapping efficiency. The strength to resist the force of concentrated flow and create a large pool in front of the hedge, and the ability to flex instead of break when the force becomes too great, is a prime consideration when choosing grasses for hedge plantings. Switchgrass [*Panicum virgatum* L.] and eastern gamagrass [*Tripsacum dactyloides* (L) L.] are two grasses native to the eastern U.S. that possess these characteristics and are commonly used in vegetative barriers (Dunn and Dabney 1996).

Filter strips

Filter strips and grass waterways are some of the older, most tested conservation practices. In contrast to vegetative barriers, they are wider, less dense strips of grass designed to allow runoff to move through them and trap pollutants within them. They remove 70-90% of sediment and associated contaminants, infiltrate 20-60% of runoff and dissolved contaminants, and transform entrapped contaminants. While most of what we know about the effectiveness of filter strips and their management we learned from strips planted to naturalized, non-native grasses, native warm-season grasses are being included in filter strip studies. Mersie et al. (1999) reported that switchgrass filter strips retained the herbicide atrazine and metolachlor by enhancing infiltration. If appropriately managed, filter strips of native eastern grasses may be as effective as non-native grasses, but that has yet to be demonstrated.

Buffers designed to slow runoff and keep sediment in the field are most effective in controlling sediment-associated contaminants. By enhancing infiltration, they also control dissolved contaminants such as phosphorus that are only slightly soluble in the soil. Since most nitrogen enters streams as nitrate, and nitrate is soluble in the soil, these practices have little positive affect on nitrogen delivery to streams. In fact, practices that enhance infiltration might increase nitrogen delivery to the stream by transporting more nitrate through the soil into ground water.

Riparian buffers

Riparian buffers are the last place on the watershed where sediment associated contaminants can be removed from runoff before it enters the stream or lake. Since most ground water discharges to streams in the riparian zone, they are also the only buffers that can remove nitrate from discharging ground water. The NRCS (NRCS 1997a) recommends a 3 zone forested riparian buffer system (Figure 2). The buffer system is designed to remove most of the P and N in the managed wooded strip (zone 2). The grass strip (zone 3) is designed to spread concentrated flow and control erosion.

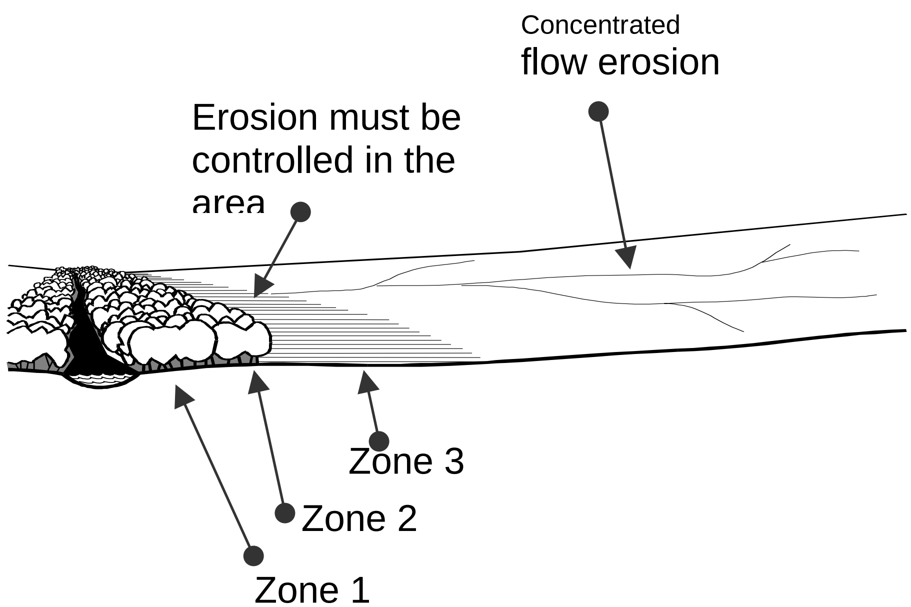

Figure 2. Schematic of the riparian buffer system recommended by the NRCS (NRCS 1997a).

In contrast to forested riparian buffer systems, many streams have an entirely grassy riparian buffer. Nutrient removal by riparian buffers with different vegetation has rarely been compared; however, where wooded and herbaceous buffers have been compared they were similarly effective (Haycock and Pinay 1993; Osborne and Kovacic 1993). Denitrification, an important process in eliminating N from discharging ground water, is generally higher in grassed riparian buffers than in wooded buffers (Groffman et al. 1991; Haycock and Pinay 1993; Schnabel et al. 1997). Both forested riparian buffer systems and herbaceous riparian buffers can remove 50-90% of sediment, N, and P**.**

Sediment and P removal in riparian buffers depends on the same factors as for in-field buffers: buffer width and slope, and elimination of concentrated flow. Nitrogen removal in riparian buffers depends largely on subsurface hydrology. Where the subsurface flow system is shallow and most ground water discharges through an extensive shallow layer in the riparian buffer, substantial reductions in nitrate concentrations have been measured, regardless of vegetation. Where flow systems are deeper and much discharging ground water spends little time in biologically active parts of the riparian zone, N transformation causes small or no reductions in nitrate concentration. In a study in central Pennsylvania (Schnabel, 2000), nitrate concentrations in shallow ground water under a cornfield were >10 mg l^{-1}. Shallow ground water discharging into the stream had a nitrate concentration of ~0.5 mg l^{-1}. This site was located on a floodplain, had a 30 foot (9 m) grass riparian buffer and a flow restrictive layer at a depth of 10 feet (3 m). Much of the change in nitrate concentration occurred in the cornfield, upgradient of the buffer, because conditions created by a shallow, fluctuating water table supported rapid denitrification. Denitrification rates in the grass buffer were greater than in a wooded section of buffer along this stream (Schnabel et al. 1996). Despite the low streamside ground water nitrate concentration, nitrate concentrations in the stream were from 3 to 5 mg l^{-1}, indicating that the conditions found at this floodplain site are not common in the watershed. Additionally, nitrate concentrations were virtually unchanged through the riparian buffer at two other locations in Pennsylvania with deeper subsurface flow systems (Schnabel, unpublished data).

None of these evaluations of grass riparian buffers used native grasses. Consequently, projections of how riparian buffers of native grasses will function are made from a small base of information. One study evaluated denitrification rates under wooded riparian buffers, buffers in adapted cool-season grasses, and native, warm-season grass (switchgrass) buffers (Schnabel and Genito 1999). We found no difference in average denitrification rates under the different types of vegetation at sites in Maryland and Virginia. These data suggest that native grass buffers may be as effective as wooded or adapted grass riparian buffers in removing nitrate from discharging ground water. It should be said that both the highest and lowest rates of denitrification were measured under the switchgrass buffers. The difference may be a varietal difference where switchgrass with a higher protein content and lower C/N ratio will support higher rates of denitrification and accumulate more N in biomass.

Watershed-Scale Considerations

From the discussion above we see that native grasses could be used in a variety of ways to either reduce the source of contamination or to intercept contaminants before they enter streams. How they might best be used depends on some watershed characteristics.

Most of the N exported from watersheds enters the stream in discharging ground water during the dormant season. Nitrogen leaches to ground water across the entire watershed and the mass of N leached can be predicted from land use. Since vegetative barriers, filter strips, and grassed waterways are designed to control erosion and surface runoff they have little positive impact on N loss from the watershed. As stated above, since they enhance infiltration, these conservation buffers could actually increase N leaching to ground water and its subsequent export from the watershed. Riparian buffers can remove N from discharging ground water if hydrologic conditions outlined above are met, conditions that are more common to parts of the Atlantic Coastal Plain and some glaciated watersheds. Overall, changing land use from nutrient intensive agriculture is the most reliable way to use native grasses to control N loss.

In contrast to N, most P is lost in surface runoff. In watersheds where rainfall rates rarely exceed the soil's intake rate, runoff occurs from small predictable areas on the watershed close to a stream. In these watersheds, more common to the Ridge and Valley physiographic province, P loss is most directly controlled by managing runoff-producing zones as critical areas and planting crops that control erosion and require little P, perhaps native grasses. Where soil intake rates are commonly less than rainfall rates, runoff and erosion occur over the entire landscape and any of the conservation buffers as well as source control could be used to reduce P export from the watershed

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Landscape and Design Issues with Natives

Neil Diboll[1]

The utilization of native prairie plants in home landscapes and commercial settings has grown steadily over the past two decades. One of the primary reasons for this increase is due to changes in people's perceptions of native plants. Formerly regarded as "weeds", many native plants have now attained acceptances in our gardens and landscapes, as people have come to know them. Benefits include long-term maintenance cost savings, reduced fertilizer and pesticide usage, elimination of irrigation, and creation of wildlife habitat while restoring a portion of our natural heritage.

People tend to view native plantings as "weedy" due to the apparent chaos of a prairie meadow. As in nature, plants in the landscape associate themselves together in a mixed, diverse plant community. The lack of a formal garden design requires a re-orientation of esthetic perceptions in order to appreciate the meadow. The hand of the human species does not prevail in the structure of a meadow garden. It is indeed a "Joint Venture with Nature" wherein natural ecosystem models are used as the guideline for the landscape.

Plant selection is another important factor in the growing acceptance of utilizing native prairie plants in the landscape. Most homeowners prefer relatively short plants around their dwelling spaces. Since many of the flowers and grasses of the prairie are tall (5 to 12 feet), they are not acceptable in a home garden setting. By planting shorter species (less than four feet tall), people feel more comfortable in meadow landscapes. To address this concern, seed mixes have been selected that are composed of flowers and grasses that grow only a few feet tall. These short mixes are more popular than tall prairie mixes for home landscapes and commercial plantings.

Prior to widespread acceptance of prairie-style landscapes in the Upper Midwest, numerous battles, in court and in city hall, were waged between the "Weed Ordinance Enforcement" proponents and the "Natural Landscape" proponents. The overwhelming result of these conflicts has been the acceptance of natural landscapes, provided they are properly planned, installed, and maintained. The realization that native landscapes require little or no fertilizer, pesticides, or irrigation, while attracting a tremendous diversity of birds and butterflies, has made them an increasingly popular choice for a variety of landscape applications.

A significant obstacle preventing the more widespread adoption of native prairie landscapes is the requirement of thorough weed control prior to planting. Due to the relatively slow rate of maturation of these native perennials, perennial weeds must be eliminated completely, prior to seeding. This can be a long process, sometimes requiring a full year or longer. After seeding, annual and biennial weeds often dominate in the first two growing seasons. The entire process of prairie establishment typically requires three to four years to achieve a mature, blooming meadow.

Although a prairie meadow is composed of long-lived perennial flowers and grasses that return year after year, it is by no means an "instant gratification" landscape. Many people think twice before embarking on such a long landscape journey. Landscaping with native plant meadow is for those who wish to invest in the long-term ecological health of their land. It is not for people who want to see pretty flowers two months after they till up the ground and scatter the seed.

A common concern is that dense stands of prairie grasses and flowers might promote wildlife habitat for certain "less desirable" animal species, such as insects, mice, and snakes. Native grasslands do indeed create habitat for a variety of animal life. These in turn are fed on by the owls, hawks, foxes, and other predators. A balance of nature is maintained, and many forms of

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life are provided homes by the prairie meadow gardener. For those who do not wish to attract a variety of wildlife to their property, a prairie meadow may not be a good choice.

Finally, prairie management is not for the faint of heart. The preferred method of managing established prairie meadows is the use of controlled burning to discourage woody plants and invasive exotic plants. Some people embrace the fire management program with enthusiasm, while other shrink in trepidation and fear. With proper planning and foresight, firebreaks can be designed into the landscape so that they are in place in advance of initiating a controlled burn. By following proper safety precautions, fire is a cost-effective landscape management tool that almost anyone can learn how to use safely. In the event that burning is not an option, mowing can be substituted as a reasonably effective second choice.

Thus, the main obstacles to more widespread use of native grasslands in the landscape include:

- Perception of chaotic, "weedy" appearance.
- Some native prairie plants get too tall.
- Takes too long to establish.
- Might attract unwanted wildlife.
- Fear of managing with controlled burning.

These concerns are addressed by:

- Designing prairie seed mixes with attractive flowers and grasses that fit into the surrounding landscapes.
- Using shorter plants, less than four feet tall.
- Educating people on the long-term benefits of native meadow plantings, including reduced chemical use, no irrigation, pest-resistance, lower maintenance, and significant long-term cost savings.
- Focusing on the beneficial wildlife attracted to meadows, and the value of restoring the ecosystem as a whole.
- Providing educational information on prairie management using controlled burning, and using mowing management as an alternative to fire.

As more people plant native plant prairies, these habitats are becoming increasingly accepted as an alternative to high maintenance, intensively managed landscapes that rely on herbicides, pesticides, and irrigation. The natural beauty of prairie landscapes has won many converts. The added benefit of the birds, butterflies, and other wildlife that visit native meadows is a strong motivator for many people to establish a prairie. Restoring the land to a healthy, functioning ecosystem that is in harmony with nature is another big reason prairies. With the long-term time and cost savings that are realized from reduced maintenance of native meadows, there are more reasons to plant a prairie.

Reference:

Diboll, N. 1986. Mowing as an alternative to Spring burning for control of cool season exotic grasses in prairie grass plantings, pp. 204-209. In: Proceedings of the Ninth North American Prairie Conference, Tri-College University Center for Environmental Studies, Moorhead, Minnesota.

Ecosystem Restoration May Prairie State Natural Area

Brian Bowen[1]

Abstract

Ecosystem restoration begins by recognizing function and identifying the ecosystem properties that drive the process. These properties are the biotic and abiotic factors necessary for ecosystem function to occur. Completing basic research and identifying reference natural areas is a first step in identifying restoration goals. These goals identify restoration conservation targets (communities, rare species, etc.) so that objectives can be developed to prioritize actions or tasks. These objectives should be measurable through monitoring and have the flexibility to enable adaptive management actions. A site assessment of biotic factors identifies these restoration targets including the plant community types, rare species, and any critical keystone species for the site. An abiotic assessment identifies essential influences including disturbance regimes, substrate, hydrologic features, and topography that support the biotic elements. These assessments provide the information to determine the richness or intactness of the ecosystem, threats, and restoration feasibility.

This approach is presently underway at May Prairie Designated State Natural Area in Coffee County, Tennessee. It is a part of the larger landscape scale barrens restoration initiative for the Southeastern Highland Rim of the Interior Low Plateau Physiographic Province. The May Prairie restoration effort has identified the oak barren community types of the oak barren grassland ecosystem and its 25 rare species as restoration conservation targets. The goal is to restore the associated community types for this ecosystem and protect its rare species. A remnant intact ecosystem on site is the reference area. Research has identified fire as an essential influence on ecosystem function. Site assessment has determined that hydrologic function has been disrupted, successional red maple forest and converted pastureland has displaced wet to mesic tall grass barrens, and understory growth in the shrub layer has altered the oak barrens community structure. The restoration objectives are to restore hydrologic function by a series corrective tasks including the removal of red maple, control of fescue in the pasture to release native vegetation, and reduction of the shrub layer in the oak barrens community. Monitoring is ongoing and management actions are adaptive. Fire has been reintroduced into the ecosystem. Restoration is long term in scope and will contribute to the barren restoration effort for this region.

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Native Warm-Season Perennial Grasses: The Unrealized Potential as a Forage Crop

Richard W. Taylor[1]

During discussions with the symposium organizers, it became clear that the species of most interest were the native warm-season grasses (NWSG). The species of particular interest were switchgrass [*Panicum virgatum* L.], big bluestem [*Andropogon gerardii* Vitman], little bluestem [*Schizachyrium scoparium* (Michx.) Nash], Indiangrass [*Sorghastrum nutans* (L.) Nash], and eastern gamagrass [*Tripsacum dactyloides* (L.) L.]. A look at the distribution of each of these species, shows that at the time of European settlement of America NWSG covered much of the Eastern United States and would have been available to the European settlers. Another species native to the United States was reed canarygrass [*Phalaris arundinacea* L.]. It is a cool-season grass (CSG) and is quite productive and could have been competitive against introduced CSG. However, the distribution of the grass did not include coastal Virginia, Maryland, New Jersey, New York, Connecticut, and Massachusetts (Stubbbendieck et al. 1997). Its distribution plus other problems discussed below precluded it from consideration by the early colonists and helped contribute to the eventual dominance of the introduced CSG.

Although we think of big bluestem, little bluestem, Indiangrass, eastern gamagrass, and switchgrass as natives of North America, the centers of origin for the tribes they represent (Andropogoneae and Paniceae) were the warmer parts of the eastern hemisphere, possibly in the East African-Madagascar region (Hartley 1959a,b). The Andropogoneae developed in tropical climates with a high midsummer rainfall or monsoonal climate pattern while the Paniceae developed in the equatorial zone with high summer temperatures. The distribution of the Paniceae in the United States shows a close relationship to winter temperature and especially to annual rainfall. Species and genera of Andropogoneae spread more recently to the Western Hemisphere than the Paniceae and have not yet attained their full development. Especially along the eastern edge of the continent where the warm waters from the Gulf Stream have a significant influence, the unique climates have led to the development of NWSG that use the growing season characteristics of the Eastern United States to full advantage.

Although the genera of the tribe, Andropogoneae, are relatively new to North America, individual species evolved here with adaptations suited to this climate. With species from the tribe, Paniceae, these adapted species were the established grasses when the first European colonist arrived in the New World.

The most notable characteristics of the most productive NWSG were late spring initiation of regrowth, rapid early- and mid-summer growth, mid-summer flowering, tall growth habit, and bulky seed unreliable for germination the year following harvest. The primary native, productive CSG, reed canarygrass, was not present in the coastal areas of Virginia or Massachusetts in colonial times (Stubbendieck et al. 1997), and until recent cultivar improvements through plant breeding, this grass contained high alkaloid levels that caused palatability and animal performance problems.

The reaction of European colonists to the native grasses can possibly be characterized as follows: already used to having grasses grow during milder interludes of winter and initiating rapid growth in early spring, the colonists may have perceived the growth habit of NWSG as undesirable. Other traits, unsuited to their farming and grazing practices, became obstacles to the incorporation of native grasses into farming operations. The difficulties European settlers experienced in establishing these native grasses after forests were cleared provided additional impetus towards their tendency to introduced CSG.

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The tall growth habit of the native grasses also may have been perceived as detrimental. The colonists' style of grazing which might be described as continuous mob grazing at a set and relatively low stocking rate was very unsuited to the growth characteristics of the NWSG and would not have eliminated problems caused by excessive plant height. As relations with the native Indian tribes deteriorated into sporadic warfare, there arose an increased need to keep nearby pastures and hay fields closely cropped in the summer months during danger periods.

The amount of labor required to harvest enough hay to last the winter had three impacts. First, the single hay harvest available from NWSG may have discouraged its use. Second, the length of time required to harvest hay in colonial times meant that hay quality of the NWSG could have fallen below the level the animals needed to maintain themselves over the winter. Hay from NWSG certainly would not have compared favorably with hay from introduced CSG that colonists were used to feeding. Third, not only did the lower hay quality necessitate the accumulation of more hay than expected but the delayed spring initiation of growth also increased the need for hay plus additional labor and materials to increase storage capacity.

The final obstacle involves the grazing techniques used by the colonist and still in play today. Animals were generally grazed in a commons area on a continuous basis. Techniques such as continuous mob grazing and constant stocking rate that resulted in variable grazing intensity were ill suited to NWSG long-term survival.

Native Warm-Season Grass Usage Survey

In preparation for this symposium, a survey was conducted via email involving Natural Resources Conservation Service (NRCS) personnel (nationwide) and Extension and research forage agronomists located in states east of the Mississippi River. The first part of the survey requested information on the number of acres of NWSG planted in their county, region, or state and what was the intended use of the plantings. Since some plantings could be put to multiple use the percentages for usage can add up to more than 100 percent. The second part asked participants to rank a number of factors in order of importance from 1 (being most important) to 5 (being least important). Some respondents ranked the factors from first to last. If the number exceeded 5, the author arbitrarily grouped the responses to reflect a ranking from 1 to 5.

Acreage of NWSG

Table 1a lists the acreage estimates received for 25 states in the upper mid-West, northeast, mid-Atlantic, and southern regions of the country (considered as the eastern region with the remaining states as the western region). In some cases, state estimates were supplied by survey respondents and in other cases the acreage is reported for a specified number of counties in the state. If multiple state estimates were received, the estimates are presented as a range and the mean of the answers is also reported. It will be noted that in come cases, for example Maryland and Virginia, a few counties reported more acres than reported for the entire state. All acreage estimates should be read with some degree of skepticism.

Table 1b contains the acreage estimates from the remaining states that responded to the survey (labeled as the western region). A state estimate was only reported for Nebraska. For Iowa, thirteen counties reported both acres and usage but a 26 county region in the northwest reported usage but not acreage.

Results are reported by region. The eastern U.S. consists of the following states: ME, NH, VT, MA, CT, NY, PA, OH, MI, WI, WV, NJ, DE, MD, VA, TN, KY, GA, NC, SC, FL, AL, MO, AK, and MS. Table 1a presents acreage data from the eastern region and Table 1b from the western region that consists of all remaining states.

For the eastern 25 states (using the mean of answers or sum of county acreage if that was larger), respondents reported 59,000 acres of switchgrass, 40,000 of big bluestem, 22,000 of Indiangrass, 6,900 of eastern gamagrass, 42,000 of little bluestem, 258,000 of mixtures of the above species, and about 91,000 acres of other native grasses (Table 1a). Surveys also were received from NRCS personnel western states although in fewer numbers. Acreage reported for the western states is reported in Table 1b along with notes on the number of counties responding in a particular state. Mixtures of switchgrass, big bluestem, and Indiangrass and native prairie were much more common for this region compared to the eastern states.

Impediments to Adoption of NWSG

Survey respondents were asked to rank in order of importance the following factors that might impede adoption of NWSG. The factors ranked were grower perception of lower forage quality for NWSG versus cool-season grasses, intake limitations with NWSG due to higher fiber content, expense and availability of seed, establishment unreliability, grazing management concerns and problems, and hay management concerns and problems. Under establishment reliability, grazing management, and hay management, respondents ranked a number of other factors related to the main problem.

Ratings for the factors involved in adoption of NWSG (Tables 2 to 6) are presented for both regions although the discussion below concentrates on the results from the eastern region. There were only minor changes in the rankings of the factors between the East and the West.

Establishment Difficulty: The most important factor inhibiting adoption of the NWSG was establishment reliability (Table 2). After establishment reliability, seed expense/availability was next in importance. These two factors switched in ranking between the East and West regions with seed expense/availability most important in the West. The remaining factors in order of importance from most to least were knowledge of grazing management techniques, quality perceptions for NWSG, knowledge of hay management techniques, and intake limitations. These four factors were ranked in the same order of importance in both regions.

Survey participants were asked to rank a number of factors that could limit establishment reliability of the NWSG. Their concern was greatest for the long establishment phase when little to no harvestable forage is produced (Table 3). Establishment usually requires a year but when weed control problems occur, successful establishment can take almost two years from the time of seeding, if establishment occurs at all. This long establishment phase is economically a burden on producers and according to survey respondents is the main concern producers have for planting NWSG.

Within establishment reliability, the next most important factor after long establishment phase was the category, all other factors cited by respondents (Table 3). Concerns listed under the other category included seed dormancy problems, lack of registered herbicides, poor understanding of grazing needs, lack of familiarity with NWSG, lack of knowledge of proper planting procedures, poor knowledge base, inadequate support from Cooperative Extension, low availability of specialized planters, landowner knowledge, tradition, and lack of ability to burn for maintenance.

Table 1a. Native warm-season grass acreage reported in Eastern United States from November 1999 survey.

State	Species	Acreage (estimates are for the state unless otherwise noted)	
		Range	Mean of answers
Northeast or New England (VT, NH, ME, NY)	Switchgrass	100-3,500	2,200
	Big bluestem	0-4,000	2,333
	Indiangrass	100-1,000	533
	Eastern gamagrass	0-500	263
	Little bluestem	100-10,000	4,700
	Mixtures of above	-	-
	Other natives	88,000	-
Vermont (State report did not list acres; acreage is from 2 reporting counties)	Switchgrass	1	1
	Big bluestem	50	50
	Indiangrass	0	0
	Eastern gamagrass	0	0
	Little bluestem	-	-
	Mixtures of above	-	-
	Other natives	-	-
Connecticut	Switchgrass	35	35
	Big bluestem	100	100
	Indiangrass	100	100
	Eastern gamagrass	1	1
	Little bluestem	50	50
	Mixtures of above	-	-
	Other natives	-	-
Massachusetts	Switchgrass	1,000	1,000
	Big bluestem	100	100
	Indiangrass	25	25
	Eastern gamagrass	0	0
	Little bluestem	5,000	5,000
	Mixtures of above	-	-
	Other natives	-	-
New Jersey (No state estimate, reported acres are sum of two counties reporting)	Switchgrass	300	300
	Big bluestem	-	-
	Indiangrass	-	-
	Eastern gamagrass	-	-
	Little bluestem	-	-
	Mixtures of above	-	-
	Other natives	-	-
Pennsylvania	Switchgrass	10,000-40,000	25,000
	Big bluestem	500-40,000	20,250
	Indiangrass	0-10,000	5,000
	Eastern gamagrass	0-5,000	2,500
	Little bluestem	0-50,000	25,000
	Mixtures of above	200	200
	Other natives	-	-
Delaware (No state estimate, reported acres are sum of 2 counties reporting)	Switchgrass	125	125
	Big bluestem	275	275
	Indiangrass	275	275
	Eastern gamagrass	125	125
	Little bluestem	75	75
	Mixtures of above	2,375	2,375
	Other natives	-	-

Table 1a. Native warm-season grass acreage reported in Eastern United States from November 1999 survey (Continued).

State	Species	Acreage (estimates are for the state unless otherwise noted)	
		Range	Mean of answers
Maryland (Sum of 6 individual counties in parenthesis)	Switchgrass	8-67 (85)	38
	Big bluestem	5-41 (41)	23
	Indiangrass	0-48 (43)	24
	Eastern gamagrass	10-48 (58)	29
	Little bluestem	13 (13)	13
	Mixtures of above	4562	4562
	Other natives	-	-
Virginia (Sum of 13 individual counties in parenthesis)	Switchgrass	8,100 (1,776)	8,100
	Big bluestem	450 (625)	450
	Indiangrass	450 (405)	450
	Eastern gamagrass	550 (77)	550
	Little bluestem	450	450
	Mixtures of above	-	-
	Other natives	-	-
West Virginia (Sum of 7 individual counties in parenthesis)	Switchgrass	100 (145)	-
	Big bluestem	in mixtures (0)	-
	Indiangrass	5,000 (native) (0)	-
	Eastern gamagrass	50 (planted) (0)	100 (native)
	Little bluestem	-	-
	Mixtures of above	-	-
	Other natives	-	-
Ohio (No state estimate, reported acres are sum of 4 counties reporting)	Switchgrass	1,415	-
	Big bluestem	1,025	-
	Indiangrass	850	-
	Eastern gamagrass	10	-
	Little bluestem	-	-
	Mixtures of above	-	-
	Other natives	-	-
Wisconsin (Sum of 10 individual counties in parenthesis)	Switchgrass	- (6,725)	-
	Big bluestem	- (4,400)	-
	Indiangrass	- (4,400)	-
	Eastern gamagrass	-	-
	Little bluestem	-	-
	Mixtures of above	60,000 (13,607)	-
	Other natives	(7)	-
Michigan (No state estimate, reported acres are sum of 9 counties reporting)	Switchgrass	5,150	-
	Big bluestem	330	-
	Indiangrass	85	-
	Eastern gamagrass	10	-
	Little bluestem	350	-
	Mixtures of above	250	-
	Other natives	-	-
Tennessee (State estimate)	Switchgrass	1,100	-
	Big bluestem	<150	-
	Indiangrass	<150	-
	Eastern gamagrass	<150	-
	Little bluestem	-	-
	Mixtures of above	13,650	-
	Other natives	-	-

Table 1a. Native warm-season grass acreage reported in Eastern United States from November 1999 survey.

State	Species	Acreage (estimates are for the state unless otherwise noted)	
		Range	Mean of answers
Kentucky (No state estimate, reported acres are sum of 8 counties reporting)	Switchgrass	393	-
	Big bluestem	29	-
	Indiangrass	238	-
	Eastern gamagrass	292	-
	Little bluestem	-	-
	Mixtures of above	-	-
	Other natives	-	-
North Carolina (Sum of 5 individual counties in parenthesis)	Switchgrass	200-1,500 (95)	850
	Big bluestem	15-30	42.5
	Indiangrass	0-2	1
	Eastern gamagrass	0-1,200 (2)	600
	Little bluestem	-	-
	Mixtures of above	-	-
	Other natives	-	-
South Carolina (State estimate)	Switchgrass	250	-
	Big bluestem	0	-
	Indiangrass	0	-
	Eastern gamagrass	200	-
	Little bluestem	-	-
	Mixtures of above	400	-
	Other natives	-	-
Georgia [Estimate for southeast GA (250,000 acres) is in parenthesis]	Switchgrass	300 (2,000)	-
	Big bluestem	50 (50)	-
	Indiangrass	20 (1,000)	-
	Eastern gamagrass	100 (200)	-
	Little bluestem	5,000	-
	Mixtures of above	-	-
	Other natives	-	-
Florida (No state estimate, reported acres are sum of 1 county reporting)	Switchgrass	0	-
	Big bluestem	7,000	-
	Indiangrass	1,000	-
	Eastern gamagrass	0	-
	Little bluestem	0	-
	Mixtures of above	0	-
	Other natives	-	-
Alabama (State estimate)	Switchgrass	300	-
	Big bluestem	-	-
	Indiangrass	-	-
	Eastern gamagrass	-	-
	Little bluestem	-	-
	Mixtures of above	-	-
	Other natives	-	-
Mississippi (No state estimate, reported acres are sum of 1 county reporting)	Switchgrass	250	-
	Big bluestem	0	-
	Indiangrass	175	-
	Eastern gamagrass	0	-
	Little bluestem	200	-
	Mixtures of above	-	-
	Other natives	-	-

Table 1a. Native warm-season grass acreage reported in the eastern United States from November 1999 survey (Continued).

State	Species	Acreage	
		Range	Mean of answers
Missouri (Sum of 8 individual counties in parenthesis)	Switchgrass	- (3,430)	-
	Big bluestem	- (3,180)	-
	Indiangrass	- (2,945)	-
	Eastern gamagrass	- (1,801)	-
	Little bluestem	- (1,000)	-
	Mixtures of above	176,287 (8,860)	-
	Other natives	- (1,000)	-
Arkansas (Sum of 2 individual counties in parenthesis)	Switchgrass	<1 (150)	-
	Big bluestem	<1	-
	Indiangrass	<1	-
	Eastern gamagrass	<1	-
	Little bluestem	-	-
	Mixtures of above	-	-
	Other natives	- (2,150)	-

The next most important category under factors affecting NWSG establishment reliability was weed control (Table 3). Many NRCS respondents felt that NRCS should take a more active role in herbicide registration and perhaps act as a third party registrant, if possible. Reliability of establishment was next most important indicating concern for the success of seedings. Related to this, seed viability was ranked next and has been reported to be responsible for some failures. Before planting, growers should always conduct a quick germination test and be certain to plant at recommended rates using pure live seed (PLS) per acre. The final category, cultivar (variety) selection, was rated at 4.29 indicating that growers are not concerned about what cultivar they plant.

After establishment reliability, the next impediment to adoption of NWSG was seed expense and availability (Table 2). Frequent droughts and adverse weather conditions where seed is produced have meant that seed supplies and prices fluctuate radically from year to year. Apparently, this variability in supply and prices has raised serious concerns for many farmers and discouraged them from planting NWSG.

Managing NWSG in Grazing Systems: The third critical concern was for grazing management with a rating of 2.41. Two factors plus the 'other' category within this were most important to respondents (Table 4). These were the lack of knowledge about species requirements by producers and the fact that NWSG sometimes do not fit into the management style of producers.

In the all other factors cited by respondents' category, comments included the short grazing season versus the acreage commitment. Many producers do not consider NWSG reliable but to use them they would have to take some CSG acreage out of production and in return only get at best a 3-month grazing period. Additional comments included: establishment cost, lack of need for hay from NWSG in wet seasons, a higher skill level required to manage NWSG, length of establishment, lack of promotion, the fact that introduced CSG out yield NWSG in some locations, difficulty in learning a different grazing system, tradition (against their use), and the requirement of radical change in grazing management if using NWSG.

Table 1b. Native warm-season grass acreage reported in the western United States from November 1999 survey.

State	Species	Acreage	
		Range	Mean of answers
Illinois (No state estimate, 8 counties reporting)	Switchgrass	100-525	1,050
	Big bluestem	40-140	280
	Indiangrass	75-175	350
	Eastern gamagrass	50-425	850
	Little bluestem	--	--
	Mixtures and natives	390-16,340	32,680
Iowa (No state estimate, 13 counties reporting)	Switchgrass	250-19,000	44,900
	Big bluestem	40-10,000	24,090
	Indiangrass	20-5,000	9,235
	Eastern gamagrass	0-50	205
	Little bluestem	0-2,000	4,510
	Mixtures and natives	0-2,000	4,303
Nebraska (State estimate)	Switchgrass	--	14,000
	Big bluestem	--	400
	Indiangrass	--	100
	Eastern gamagrass	--	400
	Little bluestem	--	--
	Mixtures and natives	--	26,750,000
Nebraska (5 counties reporting)	Switchgrass	--	111,100
	Big bluestem	--	25,800
	Indiangrass	--	22,330
	Eastern gamagrass	--	365
	Little bluestem	--	13,400
	Mixtures and natives	--	176,700
Kansas	Switchgrass	--	11,900,00
	Big bluestem	--	11,900,000
	Indiangrass	--	6,000,000
	Eastern gamagrass	--	1,000,000
	Little bluestem	--	--
	Mixtures and natives	--	--
Oklahoma (No state estimate, 13 counties reporting)	Switchgrass	1,000-300,000	444,359
	Big bluestem	0-300,000	457,425
	Indiangrass	0-300,000	471,491
	Eastern gamagrass	0-28,131	29,631
	Little bluestem	0-400,000	602,527
	Mixtures and natives	50,000-130,000	528,385
Texas (No state estimate, only 3 counties reporting)	Switchgrass	50-500	949
	Bib bluestem	0-150	155
	Indiangrass	0-20,000	21,200
	Eastern gamagrass	15-150	215
	Little bluestem	0-100,000	100,00
	Mixtures and natives	0-200,000	200,005
South Dakota (No state estimate, 7 counties reporting)	Switchgrass	0-8,000	15,750
	Big bluestem	0-1,200	2,050
	Indiangrass	0-400	800
	Eastern gamagrass	--	--
	Little bluestem	--	--
	Mixtures and natives	1-1,232,500	1,430,500

Table 1b. Native warm-season grass acreage reported in the western United States from November 1999 survey (Continued).

		Acreage	
State	Species	Range	Mean of answers
Louisiana (No state estimate, 1 county reporting)	Switchgrass	--	40
	Big bluestem	--	--
	Indiangrass	--	--
	Eastern gamagrass	--	--
	Little bluestem	--	--
	Mixtures and natives	--	--
North Dakota (No state estimate, 1 county reporting)	Switchgrass	--	6,000
	Big bluestem	--	200
	Indiangrass	--	20
	Eastern gamagrass	--	--
	Little bluestem	--	--
	Mixtures and natives	--	50
Montana (No state estimate, 1 county reporting)	Switchgrass	--	--
	Big bluestem	--	1,500
	Indiangrass	--	--
	Eastern gamagrass	--	--
	Little bluestem	--	200,000
	Mixtures and natives	--	795,000
Washington (No state estimate, 1 county reporting)	Switchgrass	--	--
	Big bluestem	--	--
	Indiangrass	--	--
	Eastern gamagrass	--	--
	Little bluestem	--	--
	Mixtures and natives	150,000-200,000	175,000
Idaho (State est.)	Switchgrass	-	150
	Big bluestem	--	--
	Indiangrass	--	--
	Eastern gamagrass	--	--
	Little bluestem	--	--
	Mixtures and natives	--	10,000
Other western states[1]	Switchgrass	--	--
	Big bluestem	--	--
	Indiangrass	--	--
	Eastern gamagrass	--	--
	Little bluestem	--	--
	Mixtures and natives	--	--

[1] Reliable data were not available for Minnesota and California; no acreage was reported in Arizona, Wyoming, Oregon, Colorado, and Utah; All remaining states did not respond to the survey.

Table 2. Rankings from 1 (most important) to 5 (least important) of factors limiting the adoption of native warm-season grasses (NWSG) in the Eastern vs. Western U.S.

Factor	Rating	
	Eastern U.S.	Western U.S.
Establishment reliability	1.63	2.11
Seed expense and/or availability	2.16	1.92
Knowledge of grazing management techniques	2.49	2.57
Perception of lower forage quality of NWSG vs. cool-season grasses	2.88	3.11
Knowledge of hay management techniques	3.41	3.67
Intake limitations	4.15	3.86

Table 3. Rankings from 1 (most important) to 5 (least important) of factors limiting the establishment reliability of native warm-season grasses (NWSG) in the Eastern vs. Western U.S.

Factor affecting establishment reliability of NWSG	Rating	
	Eastern U.S.	Western U.S.
Long establishment phase	1.91	1.82
All other factors cited by respondents	2.08	1.88
Weed control	2.32	2.43
Reliability	2.62	3.05
Seed viability	2.93	3.43
Cultivar (variety) selection	4.29	4.07

Table 4. Rankings from (most important) to 5 (least important) of factors affecting grazing management of native warm-season grasses (NWSG) in the Eastern vs. Western U.S.

Factors affecting grazing management of NWSG	Rating	
	Eastern U.S.	Western U.S.
All other factors cited by respondents	1.30	1.33
Lack of knowledge of species requirements	2.12	1.93
Does not fit manager's grazing style	2.14	2.31
Weed control	2.92	3.13
Palatability concerns	3.09	2.88
Concerns over the use of controlled burns	3.13	3.59
Expected gain per acre	3.29	3.00
Expected gain per animal unit	3.30	2.85
Cultivar (variety) selection	3.85	4.27
Toxicity concerns (photosensitivity in sheep during years of drought and heat stress with switchgrass)	4.38	4.47

Other factors that were moderately important were weed control (lack of), palatability concerns, problems of understanding and using controlled burns to manage the grasses, expected livestock gain per acre, and expected weight gain per animal unit (Table 4). Least important in managing NWSG for grazing were cultivar selection and concerns over toxicity (see section below).

Managing NWSG for Hay: Hay management was a concern but was not as much of an impediment to adoption of NWSG as was grazing management (Table 2). Within hay management, the all other factors cited by respondents' category again ranked first in importance (Table 5). Comments this category involved forage quality and market value, yield—quality versus quantity, obtaining only one good cutting, lack of promotion, lack of knowledge of nutrient content of NWSG, and lack of specific information on hay management for NWSG.

Table 5. Rankings from 1 (most important) to 5 (least important) of factors affecting hay management of native warm-season grasses (NWSG) in the Eastern vs. Western U.S.

Factors affecting hay management of NWSG	Rating	
	Eastern U.S.	Western U.S.
All other factors cited by respondents	1.60	1.00
Long establishment phase	1.67	1.82
Reliability of establishment	2.53	2.97
Weed control	2.57	2.97
Seed viability	3.18	3.97
Cultivar (variety) selection	3.90	3.63

The long establishment phase when no hay is produced was a major concern for growers. Weed control and reliability of establishment were also important factors inhibiting the adoption of NWSG for hay. Seed viability was another issue since it has a significant impact along with the long establishment phase on the economics of planting NWSG for hay.

Factors to Promote NWSG: Survey respondents were asked to rank a number of factors that could promote more use of NWSG in the Eastern U.S. The most important factor was the production of forage during the summer months when heat and moisture stress can severely limit the productivity of the CSG (Table 6). Next in importance was the improved drought tolerance of the NWSG as compared to the introduced CSG. Reed canarygrass has shown some tolerance to drought conditions. Recent breeding improvements in reducing alkaloid content and improving palatability have increased the appeal of this grass to forage producers.

Two other factors important in promoting NWSG are potential wildlife benefits both in regard to forage potential and nesting cover and the potential to produce high tonnage and excellent weight gains when grazed properly or cut for hay at the correct growth stage (Table 6). Concentrating hay production in the summer months when it is easier to cure the hay was also considered important. Lower nitrogen requirements can decrease production costs after successful establishment and promote the use of these crops where nutrient management concerns are high. The lowest rated category was the use of NWSG and switchgrass in particular as a biomass or biofuel crop. Although important in a few states, for most other states biomass/biofuel was rated lowest in importance.

Table 6. Rankings from 1 (most important) to 5 (least important) of factors that will promote more use of native warm-season grasses (NWSG) in the Eastern United States.

Factors promoting more use of NWSG	Rating	
	Eastern U.S.	Western U.S.
Forage production during the summer months	1.70	2.00
Better drought tolerance or water use efficiency by NWSG	2.21	2.24
Potential tonnage and improved weight gain when used best	2.63	2.36
Wildlife benefits	2.63	2.74
Hay production concentrated in summer months when it can be more easily cured	2.98	3.22
Lower fertilizer requirements compared to cool-season grasses	3.13	2.73
Biomass/Biofuel potential	4.14	3.82
All other factors cited by respondents	1.15	1.67

Table 7. Native warm-season grasses (NWSG) use in the Eastern United States according to 1999 survey either by state estimate or by averaging acreage reports from individual counties responding to the survey.

	Percentage of Land Area by Usage Category												
State(s)	Grazed land	Hay land	% Cut for cow /calf	% Cut for beef	% Cut for sheep	% Cut for goat	% Cut for other[*]	Wildlife habitat[**]	Wildlife feed	Land Conservation /Protection	CREP/ CRP/ WHIP	Erosion control	Biofuel/ Biomass
Northeast/New England (VT, NH, ME, and NY)	0	20	100	--	--	--	--	30	--	50	--	--	--
Vermont	1	1	100	--	--	--	--	50	24	24	--	--	--
Connecticut	0	0	--	--	--	--	--	75[***]	25	50	--	--	--
Massachusetts	0	0	--	--	--	--	--	50	--	50	--	--	--
New Jersey	0	0	--	--	--	--	--	50	--	50	--	--	--
Pennsylvania (State est.)	17.3	15.2	72.4	27.6	--	--	--	32.9	13.3	22.7	--	--	--
Pennsylvania (County)	5.0	5.6	100	--	--	--	--	89.4	62.5	--	--	--	--
Delaware	1	0	80	20	--	--	--	95	85	15	--	--	--
Maryland (State est.[Ψ])	0.5	1.5	20	80	--	--	--	98	--	--	99.5	--	--
Maryland (County avg.)	2	34.5	25.2	67.2	--	3.1	4.5	61.2	--	--	18.5	--	--
Virginia	21	9	80	20	--	--	--	40	--	30	--	--	--
West Virginia	45	5	90	5	3	2	--	50	--	--	--	--	--
Ohio	0	46	2[ΨΨ]	0.2	--	--	--	96	1.4	7.3	--	--	--
Wisconsin (State est.)	1	2	99	--	--	--	--	20	--	76	100	--	1
Wisconsin (County avg.)	0.24	0.48	99	--	--	--	1	74	64.4	29.3	--	--	--
Michigan	0	0.7	--	100	--	--	--	90.6	6.3	11.3	--	--	--
Tennessee	4	1	--	--	--	--	--	95	--	--	--	--	--
Kentucky	3.8	4.2	--	100	--	--	--	91.7	40.7	76.9	72.5	0	0
North Carolina	12.3	31.7	38	62	--	--	--	52.6	2.4	1	--	--	--
South Carolina	45	30	100	--	--	--	--	20	--	5	--	--	--
Georgia (State estimate)	0	100	--	--	--	--	--	--	--	10	--	--	0.5
Georgia (Southeast GA)	10	10	90	--	--	--	--	80	--	--	--	--	--
Florida	0	95	95	5	--	--	--	5	--	--	--	--	--
Alabama	0	0	--	--	--	--	--	0	0	0	--	--	100
Mississippi	0	0	--	--	--	--	--	--	--	100	--	--	--
Missouri	20.5	17.5	75.6	13.1	--	--	0.6	30	--	50.5	100	--	0.5
Arkansas (State est.)	15	15	50	50	--	--	--	70	--	--	--	--	--
Arkansas (County est.)	100	100[Ω]	80	20	--	--	--	--	--	--	--	--	--

- Other grazing animals were horses and dairy cows. [**] Wildlife mentioned were white tailed deer, turkey, bob white quail, grouse, pheasant, upland song birds, ducks, geese, and rabbits. [***] Totals add up to more than 100 percent since multiple uses were reported. [Ψ] Ninety-eight percent of grazed and hayed NWSG area was not specified according to species use. [ΨΨ] Est. = estimate. [Ω] Spring/summer harvest cut for hay and fall growth grazed so both 100 percent.

Table 8. Native warm-season grasses (NWSG) in the Western United States uses according to 1999 survey either by state estimate or by averaging acreage reports from individual counties responding to the survey.

State(s)	Percentage of Land Area by Usage Category												
	Grazed land	Hay land	% Cut for cow/calf	% Cut for beef	% Cut for sheep	% Cut for goats	% Cut for other[*]	Wildlife habitat (WLH)[**]	Wildlife feed	Land Conservation/ Protection	CREP/ CRP/ WHIP	Erosion control	Biofuel/ Biomass
Illinois (8 County est.[Ψ])	0.85	0	100	--	--	--	--	93.2	2.6	95.1[***]	2.8	--	--
Illinois (26NW County est.)	15	5	45	25	--	--	--	80	--	In WLH	In WLH	--	--
Iowa (12 County est.)	3.3	16	87.7	10.85	1.45	--	--	59.7	1.4	49.1	8.6	[ΨΨΨ]	--
Nebraska (State est.)	90	10	70	12	1	--	4	3	--	5	--	--	10
Nebraska (5 County est.)	58.7	33.5	68.4	24.4	1.3	--	0.4	2.7	48.6	25.7	--	0.09	0.39
Kansas (State est.)	85	15	50	50	--	--	--	--	--	--	--	--	--
Kansas (1 County est.)	90	10	74	18.5	7	0.2	0.2	0.1	--	2.8	--	--	--
Oklahoma (13 County est.)	77.3	20.6	57.7	18.0	2.0	1.54	0.65	15.5	5.4	7.1	--	--	1.4
Texas	99.99	.001	76.3	17.1	3.6	2.3	0.63	99.97	34.2	34.2	--	--	34.2
South Dakota (7 County est.)	90.6	6.7	80.8	4.6	8.7	.006	4.3	0.9	2.6	3.9	--	0.02	--
Louisiana (1 County)	--	--	--	--	--	--	--	--	--	100	--	--	--
North Dakota (1 County)	80	20	50	50	--	--	--	80	--	100	--	--	--
Montana (1 County est.)	98	2	75	20	5	--	--	100	100	--	--	--	--
Idaho (State est.)	75	5	50	40	10	--	--	100	--	20	--	--	--
Washington (State est.)	50	10	80	15	--	--	--	25	--	38		--	--
Colorado (1 County est.)	--	--	--	--	--	--	--	--	--	100	--	--	--
California (2 County est.)	--	--	--	--	--	--	--	30	--	30[ΨΨ]	--	--	--

[*] Other foragers included horses, bison, and dairy cows. [**] Wildlife reported to benefit from NWSG include white tailed deer, mule deer, turkey, Rio Grande turkey, bob white quail, sharp tailed grouse, ringneck pheasant, ducks, geese, waterfowl, whooping cranes, sandhill cranes, jackrabbit, antelope, elk, and upland game birds. [***] Totals add up to more than 100 percent since multiple uses were reported. [Ψ] Est. = estimate. [ΨΨ] Natural land restoration was an additional 40 percent. [ΨΨΨ] Iowa counties also reported seed production on 0.3 percent of acres.

The category (all other factors cited by respondents) contained several interesting ideas for promoting NWSG. Additional accessible test and evaluation plots, more information on seeding and establishment, lower seed costs, improved establishment techniques, EPA-approved herbicides to assist in establishment, and demonstrations of summer grazing would help promote the crop. Promotion of these crops by NRCS and Cooperative Extension through the Conservation Reserve Program (CRP) requirements, erosion control programs, and other government programs can be effective in increasing the use of NWSG. Improved communication with producers to increase their knowledge of the value of these crops in grower production systems can increase the use of NWSG.

NWSG Uses

Wildlife habitat and/or feed and land protection/conservation purposes were the primary use of the majority of acres in NWSG according to the survey (Table 7). Probably only one-third of the acres in NWSG is used primarily for hay and grazing. Overall, in the eastern states, while usage varied widely from state to state, most of the acreage is used for hay or grazing. Cow-calf and beef operations constituted the majority of forage users.

However for the western states, usage again varied widely from state to state (Table 8) although grazing accounted for 75 to almost 100 percent of the NWSG usage. Within the acres grazed or hayed, the vast majority was for cow-calf operations, a smaller percentage (usually about 25 percent) for beef, and much of the remaining 1 to 10 percent for sheep. Many states used NWSG as a dual-purpose cover for wildlife habitat and land conservation and protection. Nebraska and Texas reported the largest acreage percentage for biomass-biofuel use.

Literature Review

Establishment

Cultivar selection is an important aspect of establishment. However, cultivar suitability varies widely from location to location and environment to environment. To choose an appropriate cultivar, contact local seed dealers, Cooperative Extension, University research facility, or other company or agency that will have information pertinent to local conditions. Wolf and Fiske (1995) reported that if switchgrass is to be grazed the preferable cultivar was Indian.

Establishment of perennial grasses can be divided into two separate phases. The first phase involves seed imbibition of water, enzyme activation, seed germination, and seedling emergence. The second phase is the development of the adventitious root system (Newman and Moser 1988). In general, establishment failures most often are caused by inadequate soil moisture, weed competition, low seedling vigor, or poor germination. Research has shown that within a species, larger, heavier seeds have a higher germination rate (Kneebone 1972; Kneebone and Cremer 1955; Rogler 1954; and Tossell 1960) and these seedlings have more rapid growth after emergence (Kneebone and Cremer 1955; Tossell 1960; Trupp and Carlson 1967) than those from lighter seed. This has been shown to be true for switchgrass (Aiken and Springer 1995; Green and Bransby 1995).

Smart and Moser (1999) found that seed size differences in switchgrass appeared to produce only slight differences in morphological development of shoot and root systems, leaf area, shoot weight, and adventitious root weight from seedling emergence through six weeks of growth. Adventitious roots formed more quickly on seedlings from heavier than lighter seed, but the advantage to seedling establishment was minimal even under moisture stress. After seedlings had formed two or more adventitious roots, seed size no longer affected establishment and growth. Smart and Moser (1999) concluded that seed size in switchgrass appears to have a minimal long-term effect on growth and development of seedlings. However, formation of adventitious roots is critical to seedling survival (Hyder et al. 1971; Newman and Moser 1988; Ries and Svejcar 1991) and depends primarily on the presence of adequate soil moisture in the surface layer (Newman and Moser 1988; Wilson and Briske 1979).

Roundy et al. (1993) found that for the three warm-season grasses (WSG) studied including side-oats grama [*Bouteloua curtipendula* (Michx.) Torr.] seminal root elongation rates ranged from 0.229 to 0.343 inches d^{-1} (5.8 to 8.7 mm d^{-1}). If the typical drying front in the soil during the period of establishment moves faster than seminal (adventitious) root growth, frequent rainfall will be needed to permit adventitious root development and establishment of warm-season grasses. Of the species Roundy et al. (1993) studied, all three grasses elongated their subcoleoptile internodes to place the coleoptilar node and site of adventitious root initiation near the soil surface regardless of seeding depth.

Problems with switchgrass establishment from seed seem to be related to inherent seed dormancy from seeds harvested in fall and seeded the following spring (Blake 1935; Robocker et al. 1953). Although storing seed for a year or two to overcome dormancy problems (Byers 1973; Robocker et al. 1953; Shaidaee et al. 1969) seems to be the obvious answer, economics and frequent seed shortages prevent the implementation of this solution. Zarnstorff et al. (1994) found that wet pre-chill treatment significantly increased germination percentage. They also found some increase from treatment with ethylene and gibberellin although the increases were small. They concluded that post-harvest storage of seeds at 73° F (23° C) from January to April (90 days) should ensure adequate germination at time of seeding.

Beckman et al. (1993) evaluated seed priming as an option for improving establishment in big bluestem and switchgrass. Seed priming is an osmotic conditioning process in which seed is hydrated to a level that pre-germination metabolic activity is initiated but emergence of the radicle does not occur (Bradford 1986). A form of this is called solid matrix priming (SMP). SMP is a process in which seed is mixed with a particulate solid matrix material and provided aeration and only enough water to allow osmoconditioning, but not germination (Eastin 1990). Beckman et al. (1993) found that in field studies, SMP-treated seed produced the highest seedling emergence for switchgrass under moist planting conditions and had the potential to improve stands when seed was planted without drying. However, final seedling emergence from dry untreated seed was greater than that for SMP-treated seed under dry soil conditions which occur more frequently than wet soil conditions during traditional switchgrass planting times.

Seeding Rate and Placement

Masters (1997) found that for big bluestem frequency of success during planting increased as seeding rates increased from 10.2 to 20.4 to 40.9 pure live seed (PLS) ft^{-2} (110 to 220 to 440 PLS m^{-2}). Within this range, Anderson (1989) recommended a seeding rate of at least 31 PLS ft^{-2} (8.3 lb. PLS A^{-1}) [330 PLS m^{-2} (9.3 kg PLS ha^{-1})] to establish big bluestem in monoculture stands. Wolf and Fiske (1995) recommend in Virginia and North Carolina a seeding rate for switchgrass of 10 lb. PLS A^{-1} (11.2 kg PLS ha^{-1}) for conventional plantings and 8 lb. PLS A^{-1} (8.96 kg PLS ha^{-1}) for no-till plantings. They noted differences in cultivars for seeds per pound with Indian switchgrass having usually 250,000 seed lb^{-1} (551,250 seed kg^{-1}) versus Alamo with 454,000 seed lb^{-1} (1,001,070 seed kg^{-1}). Wolf and Fiske (1995) recommend a "Ragdoll" test for germination that can easily be done by producers. Seed tests often indicate very high germination since the test is done under ideal conditions that include stratification. For later plantings, stratification will not occur in the field and the "Ragdoll" test will provide a better estimate of PLS.

Seed placement in rows with a grain drill that has a small seed or fluffy seed attachment (for seed like big bluestem, Indiangrass, and little bluestem) is ideal. When seeding in a conventional seedbed be sure it is weed-free and that the soil is especially firm at planting. Cultipacking after drill planting to obtain good soil-seed contact is desirable. No-till plantings should not be made when the soil surface is too wet or else the seed will be planted too deep. Place seed ¼ to ½ inch deep. After emergence observe the planting for signs of insect damage. If grassy weeds become a problem, their competition can be minimized by clipping above the height of the leaves of the NWSG seedlings.

Planting Date

Smart and Moser (1997) suggested using earlier planting as a means of avoiding planting failures from dry soil conditions and annual grass and broadleaf weed competition. This could result in better adventitious root formation important for seedling survival. Another benefit suggested is a reduction in seed dormancy that results from exposing seed to cool moist conditions in the seedbed. However, seedlings resulting from early spring seeding in the northeast and mid-Atlantic regions may be impacted by late-season frosts.

Smart and Moser (1997) found that seedlings from March planting dates were more advanced morphologically in both root and shoot development, had accumulated 2 to 12 times more leaf area, 2 to 10 times more shoot mass, and 2 to 33 times more adventitious root mass than seedlings from April or May planting dates.

Wolf and Fiske (1995) report that switchgrass germinates very slowly when soil temperature is below 60°F (16°C); but, if maintained at 85°F (30°C) for three days, many seeds will germinate. Therefore, they suggest a planting time similar to that for millet [*Pennisetum* spp.] and sorghum-sudangrass [*Sorghum drummondii (Nees ex Steud.) Millsp. & Chase]*. For conventional seedings, they suggest planting between June 1 to 15 since soil moisture may become limited when planting later than June 15. For no-till, they suggest planting between June 15 and July 15 since soil moisture is usually less of a concern; earlier planting is possible in situations where weeds are not a problem. Later planting limits weed competition helps weed control. Seedlings should develop tillers before the fall to ensure winter survival.

Weed Control

Developing productive stands of NWSG is difficult when compared to CSG in part because NWSG are slow to establish dense ground cover (Panciera and Jung 1984; Warnes et al. 1971; Robocker et al. 1953). This characteristic makes the NWSG vulnerable to weed competition in the seedling year. Herbicides once available for use during establishment are no longer registered for use on these grasses.

There is a wide tolerance for the herbicide atrazine among WSG (Martin et al. 1982), and switchgrass and big bluestem were two of the most tolerant species. Bahler et al. (1984) reported that atrazine reduced stands of switchgrass and Caucasian bluestem [*Bothriochloa caucasica* (Trin.) C. E. Hubbard] in a loamy sand (Udic Haplustoll) more than in a silty clay loam (Typic Argiudoll). McKenna et al. (1991) found that atrazine at 2 lb. a.i. A^{-1} (2.2 kg a.i. ha^{-1}) appeared to injure switchgrass more than Caucasian bluestem. They found that dry matter yields in the second year confirmed their impression. They concluded that atrazine at 1 lb. a.i. A^{-1} (1.1 kg a.i. ha^{-1}) was considered the best recommendation for the establishment of the two species. Martin et al. (1982) found that preemergence applications of atrazine caused less stand reduction in switchgrass and big bluestem than in Indiangrass and side-oats grama. Increasing the rate of atrazine decreased seedling height and seedling number (Bahler et al. 1984; Martin et al. 1982; Bovey and Hussey 1991). McKenna et al. (1991) also found that the insecticide, carbofuran, at 1 lb. a.i. A^{-1} (1.1 kg a.i. ha^{-1}) placed in the row with the seed at planting enabled seedlings to develop faster, elongate more rapidly, and produce heavier and more seedlings than without carbofuran.

Weed competition in young stands of NWSG can inhibit grass seedling vigor and establishment. Warm-season grass yields can be as low as 1,116lb A^{-1} (1,250 kg ha^{-1}) or even undetectable during the establishment year without any form of weed control (Martin et al. 1982; Masters et al. 1990). Atrazine can significantly increase establishment year yields for switchgrass [7,519 lb. A^{-1} (8,420 kg ha^{-1})] and big bluestem [3,840 lb. A^{-1} (4,300 kg ha^{-1})] (Martin et al. 1982).

Masters (1997) found that metolachlor (Dual) and/or atrazine could be applied preemergence the year of planting to improve yield of big bluestem seeded as low as 10.2 PLS ft^{-2} (110 PLS m^{-2}). Metolachlor provided better control of warm-season annual grasses than atrazine including large crabgrass [*Digitaria sanguinalis* (L.) Scop.], fall panicum [*Panicum dichotomiflorum* Michx.], green and yellow foxtails [*Setaria* spp.], and barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.]. Masters (1995) found that metolachlor was a suitable replacement for atrazine to improve establishment of big bluestem and sand bluestem cultivars although yield and stand frequency were maximized when metolachlor and atrazine were applied in combination. Weed control provided by metolachlor and atrazine could reduce both the cost of big bluestem establishment through lower seeding rates and the risk of seeding failures. The use of metolachlor and atrazine has potential to be cost effective by ensuring increased seeding success and lower seeding rate necessary for big bluestem establishment

However, weed control is now more difficult to attain, because switchgrass and big bluestem pastures for forage production have been removed from the atrazine label. This can substantially increase producers cost since greater weed competition can result in little biomass production for grazing or hay during the establishment year and this means the land must be left idle for a year or more. Hintz et al. (1998) evaluated the establishment of switchgrass and big bluestem in corn [*Zea mays* L.] using atrazine. They found that the use of corn as a companion crop could provide potential for high biomass production during NWSG establishment by allowing the use of atrazine for weed control. They found that both switchgrass and big bluestem successfully established in corn and that long-season corn hybrids and higher density corn populations increased corn silage or grain yield without reducing NWSG stands. They concluded that switchgrass and big bluestem grown in corn with atrazine reduced land production losses during the establishment year, yet allowed adequate establishment of these grasses for future forage production.

As noted in a survey of NRCS personnel and forage agronomists, weed control is essential for NWSG establishment. More effort must be made to obtain registration of herbicides to control annual grass and broadleaf weeds during the establishment year. Work along the lines of Hintz et al. (1998) offers options to producers but all workers involved in promotion of NWSG need to explore ways to obtain registration of herbicides for these grasses or other options to permit the legal use of herbicides during establishment.

Yield Potential of NWSG

Yield estimates for NWSG vary widely depending on the management regime; fertilization practices; age of stand; climate factors such as temperature, rainfall, and accumulated solar radiation; cultivar; height of cut; and a host of other factors. Papers to review on this topic include Belesky and Fedders (1995), Berg (1971), Faix and Kaiser (1982), Faix et al. (1977), George et al. (1990), Henry et al. (1976), Jung et al. (1985), Reid et al. (1988a), and Stout et al. (1986).

Fertility for NWSG

NWSG in the Midwest have yielded well on phosphorus (P) deficient soils (Daniel and Harper 1934; Murphy 1933) and were shown to respond to P fertilizer with increased yields and higher forage P concentrations (Fraps and Fudge 1945; McMurphy et al. 1975; Murphy 1933; Taliaferro et al. 1975). Morris et al. (1982) found that CSG absorbed markedly more P than the WSG at low and high P fertilization rates although the trend did not hold every year. For both types of grasses, the P uptake response was about 80 to 100 percent higher on the P fertilized soil each year of their study. P uptake varied significantly among WSG cultivars. Morris et al. (1982) reported that weed competition was a factor affecting grasses at high not low P levels. The WSG studied produced high yields on both the low and high P soils. They suggested that the NWSG have tolerance and adaptation to lower levels of available P resulting in little yield increase with P fertilization.

Nitrogen (N) fertilization plays an important management role for boosting forage production on NWSG swards (Perry and Baltensperger 1979; Hall et al. 1982). Environment also plays an important role in the response of NWSG to N fertilization since it affects the release and transformation of N components in the soil and the efficiency of NWSG in using N (Craswell and Godwin 1984). Rainfall amount, rainfall distribution pattern, temperature, and solar intensity all impact the interdependent soil—microorganism—plant system. Stout and Jung (1995) reported that the less fertile the soil the greater the increase in switchgrass yields and with increasing rates of N the greater the accumulation of N in the tissues. Nitrogen fertilization increases the crude protein concentration in NWSG (Chapman and Kretschmer 1964; Cuomo and Anderson 1996; Dee and Box 1967; Madakadze et al. 1999; Minson 1973; Rehm 1984, Rehm et al. 1977). Cuomo and Anderson (1996) found that 65 percent of the additional crude protein (CP) associated with N fertilization was rumen degradable protein (RDP). They found that RDP was greater in switchgrass and Indiangrass than in big bluestem.

Perry and Baltensperger (1979) found that N fertilization increased leaf CP percentages and leaf yields of big bluestem, Indiangrass, and switchgrass especially for later harvests. Leaf material of all grasses comprised approximately 85 percent of the total forage yield at most N levels. Rapid declines occurred in leaf CP and *in vitro* digestible dry matter (IVDDM) throughout the growing season, indicating that leaf maturation was responsible for declining forage quality rather than stem growth in these NWSG. However, McMurphy et al. (1975) found that severe lodging of big bluestem at 160 lb. A^{-1} (180 kg N ha^{-1}) limited its yield potential. Fertilizer N recovery for NWSG was most efficient (52 to 66 percent) at 80 lb N A^{-1} (90 kg N ha^{-1}) plus 35.7 lb P A^{-1} (40 kg P ha^{-1}) [82 lb. P_2O_5 A^{-1} (91.8 kg P_2O_5 ha^{-1})] (McMurphy et al. 1975).

Jung et al. (1990) also studied the response of NWSG yield, plant morphology, and forage N composition in a long-term study. The percentage showing a yield response to applied N of grasses from six genera of WSG grown in Pennsylvania increased each year although the mean yield response to N varied greatly among cultivars. The sheath-stem component of dry matter yield was 6 percent (60 g kg^{-1}) higher when N was applied than when no N was applied. Jung et al. (1988) found that N fertilization increased the production of stems and leaf sheaths more than leaf laminae.

Balasko and Smith (1971) found that total nonstructural carbohydrate percentages in switchgrass herbage, stubble, and rhizomes at anthesis were not affected greatly by temperatures or N rate. Nitrogen fertilization generally increased nutrient element concentrations.

Brown (1985) reported that dry matter produced per unit of N absorbed was twice as high in C_4 grasses as in other species (C_3 and C_3 /C_4). He concluded that at very low soil N levels, C_4 species are likely to produce more growth and be more competitive than C_3 species. NWSG (C_4) use soil nutrients more efficiently and have lower macronutrient requirements than CSG (C_3) (Kroth and Mattas 1982; Morris et al. 1982; Wuenscher and Gerloff 1971).

For switchgrass, Friedrich et al. (1977) found that dry matter yield of all herbage fractions increased significantly with each increment of N [0, 200, and 400 lb N A^{-1} (0, 224, and 448 kg N ha^{-1}) as ammonium nitrate in split applications]. At the highest rate of N, fertilizing with sulfur (S) increased N concentration in the leaves, decreased N concentration in the stems, and increased the total herbage uptake of N. When S was applied, switchgrass responded to increased N fertilization by increasing S uptake. Critical N:S ratios for switchgrass appeared to be greater than 10:1 for herbage, greater than 12:1 for leaf blades, and greater than 8:1 for stems.

Staley et al. (1991) found that on acidic soils of varying water holding capacity (WHC) first cut switchgrass yields were two- to three-fold greater than for tall fescue (mid-June cut) on all sites receiving N. Second cuttings were similar between species but much reduced. Nitrogen concentration generally increased with N rate but not with WHC. Percentage of total N uptake derived from fertilizer N ranged from 23 to 47 percent for tall fescue and 14 to 39 percent for switchgrass. Switchgrass took up 25 to 33 percent of the fertilizer N applied to the two deeper soil sites. At one shallow soil site at the 80 lb N A^{-1} (90 kg N ha^{-1}) level, switchgrass took up 31 percent compared to tall fescue at 19 percent. They concluded that despite relatively low uptake rates by both species, switchgrass used fertilizer N more efficiently (yield and uptake) and, therefore, recommended usage in the Appalachian Region of the Eastern United States where N rates are low.

Stout and Jung (1995) found in a 3-year 4-site study on switchgrass that soil N, N fertilization, and temperature controlled biomass accumulation rates. Total N uptake rates ranged from 1.33 to 2.35 lb A^{-1} d^{-1} (1.49 to 2.63 kg ha^{-1} d^{-1}) and were controlled by soil N levels and N fertilization. Fertilizer N uptake averaged about 40 percent and was lowest where yearly soil N mineralization exceeded 2,000 ppm (2.0 g kg^{-1}).

Soil fertility is more critical for NWSG at planting time. Growers are often tempted to emulate the fertilization requirements for introduced CSG by applying 25 to 50 lb A^{-1} (28 to 56 kg N ha^{-1}) at planting. Nitrogen should not be applied at or shortly after planting since under low soil N levels the NWSG often out-compete weeds for water and nutrients (Capel 1977). Judicious applications of N may be made to assist growth once establishment is successful if forage is needed later during the establishment year and weeds are not a serious concern. The application should be kept below 50 lb N A^{-1} (56 kg N ha^{-1}). Weed growth is minimized when N application is delayed until right after the first cutting where hay production includes two cuttings per year (Rehm et al. 1976).

Eastern gamagrass requires different management practices than other NWSG (Aiken and Springer 1998). It tolerates more frequent harvesting and requires higher rates of N and more frequent applications of N. Brejda et al. (1997) found that variations in precipitation amounts influenced harvest yields of eastern gamagrass regrowth cuttings. They also noted that the grass's response to N rate varied between years. Peterson et al. (1999) found that eastern gamagrass was highly responsive to N rates up to 150 lb N A^{-1} yr^{-1} (168 kg N ha^{-1} yr^{-1}) and that N fertilization increased CP concentrations as well as acid detergent fiber and neutral detergent fiber concentrations.

For all NWSG prior to planting, soil pH should be adjusted to the upper 5's or higher and phosphorus and potassium soil test levels should be brought to the medium soil test level. For calcium, magnesium, sulfur, and the micronutrients, follow soil test guidelines for other grass forage crops.

Brejda et al. (1998) found that switchgrass seedlings inoculated with rhizosphere microflora produced up to 15-fold greater shoot and root yields and recovered up to 6-fold more N and 36-fold more P than seedlings inoculated with rhizosphere bacteria only. Rhizosphere populations that stimulated the greatest N uptake differed from populations that resulted in the greatest P uptake. These effects were thought to be mainly due to arbuscular mycorrhizal fungi. Future developments in this field may allow manipulation of NWSG nutrient uptake and performance on poor sites.

Interseeding Legumes for Yield and Quality

Mixed stands of NWSG, CSG, and legumes can be maintained under grazing and hay management systems although grazing management and species selection must be oriented to favor NWSG persistence. Jung et al. (1985) found that the mean yield distribution of switchgrass and bluestem pastures was approximately 15 percent in May, 55 percent in July to August, and 30 percent in October. Fertilization of NWSG with 40 to 80 lb N A^{-1} (45 or 90 kg N ha^{-1}) increased crude protein concentration by 10 to 26 percent, respectively, versus unfertilized grass. Jung et al. (1985) also found that legumes, especially red clover [*Trifolium pratense* L.], can establish good stands in NWSG and that legumes can be maintained under grazing or hay production, with a substantial shift in seasonal yield distribution that can be very beneficial to beef producers.

A number of researchers have looked at various legumes for interseeding into NWSG. Legumes grown in combination with grasses can provide symbiotic N to the associated grass (Farnham and George 1993; Mallarino et al. 1990; Evers 1985). Gettle et al. (1996b) concluded that yields of legume-renovated switchgrass were generally greater than for mid to high levels of N fertilization during the second year following frost seedings of a number of legumes. With legume frost seedings, Gettle et al. (1996b) suggests that producers limit the acreage seeded to only part of the existing switchgrass pasture so that the remaining acreage can be fertilized with N to maintain high forage supply and pasture productivity. Frost seeded legumes, which involves broadcasting legume seed in late winter or early spring when daily freezing and thawing cycles work small legume seeds into the soil, can replace from 60 to 120 lbs. N A^{-1} (67.2 to 14.4 kg N ha^{-1}) and will involve the least cost for establishment.

Gettle et al. (1996a) found that frost-seeded legumes did not seriously reduce switchgrass stem density, although red clover, birdsfoot trefoil [*Lotus corniculatus* L.], and their mixture were more competitive than other legumes tested. With proper attention to the recommended steps for frost seeding, legumes can be successfully introduced into established Indian switchgrass and will persist for several years with favorable weather. Similar results were obtained by Blanchet et al. (1995) for no-till interseeding of legumes into established switchgrass swards.

A number of researchers have found that cool-season legumes can substitute for N fertilization after the seeding year (McGinnies and Townsend 1983; Jung et al. 1985; Posler et al. 1993; George et al. 1995; Gettle et al. 1996a,b). To maintain warm-season grass productivity, legume competition should be minimized by adequate defoliation by early June.

Grazing NWSG

Perennial NWSG have been found to be some of the most productive grasses available for production of summer grazing in many areas of the Eastern U. S. They often grow well on acidic soil and are efficient in the use of water and plant nutrients (Stout et al. 1986; Staley et al. 1991). However, they are C_4 grasses and have high levels of structural fiber and low concentrations of N and certain essential elements especially at or near maturity (Reid et al. 1988 a,b). Certainly in relation to the non-native, CSG, estimates of digestibility, both *in vitro* and *in vivo*, have been relatively low. However, grazing studies, in contrast, have shown good animal performance (Burns et al. 1984; Anderson et al. 1988). Vona et al. (1984) and Reid et al. (1988b) reported higher levels of intake by cattle than would have been predicted from fiber concentrations and digestibility values.

A number of factors affect animal performance on these grasses and include but are not limited to the management system employed, the stage of growth at which grazing is initiated, leaf to stem ratio, stocking rate and grazing selectivity, and fertilization of the grasses.
Wolf and Fiske (1995) report that each acre should provide about 200 animal unit days (AUD) of grazing per year (switchgrass). To maximize yields, rotational grazing is required. Intensive grazing, a form of rotational grazing, is best to use with the NWSG since it will allow better control over the height of stubble remaining after the grazing period and stubble height is critical to maintaining NWSG stands. Work in Pennsylvania indicated that by grazing early and at high densities 12 AU A^{-1} (30 AU ha^{-1}) animal gains can approach 3 lb. day^{-1} (1.36 kg day^{-1}). Similar gains have been reported in North Carolina (personal communication). Stubble height should be at 6 to 10 inches (15.24 to 25.4 cm) after the animals are removed. Wolf and Fiske (1995) report using a 35 day rest period between grazing cycles.

For forage purposes, switchgrass, big bluestem, little bluestem, and Indiangrass have mainly been used to support growing or lactating beef cattle. The growth habit, seasonal forage distribution, and nutritive composition of these grasses are best suited to this use. A limited number of studies have examined these grasses for use with sheep but those have found that sheep digest switchgrass hays less efficiently than do cattle (Vona et al. 1984; Reid et al. 1988b). Puoli et al. (1992) cited unpublished work by Corsi and Puoli (M. Corsi and J. R. Puoli 1990, unpublished data) that showed that switchgrass rotationally grazed at initial heights of 40 or 55 cm and defoliated quickly using a high seasonal ewe carrying capacity resulted in reasonable rates of gain.

NWSG Quality Aspects

Digestibility of Cell Fiber Components

NWSG are different in leaf anatomy, photosynthetic pathway, photorespiration, and ^{13}C to ^{12}C ratios than the C_3 CSG. These differences, and especially the fundamental leaf structure difference, result in very marked differences in composition and nutritional quality between the tropical and temperate forage grasses (Moore and Mott 1973; Minson 1981; Norton 1982). These differences are responsible at least in part for reduced rates of fiber degradation by bacteria and fungi in the rumen (Akin 1982, 1986; Wilson 1985) and lower digestibility by cattle and sheep (Minson and McLeod 1970; Minson 1981). In contrast to this, the NWSG in pasture systems in the northern United States frequently support good rates of gain in grazing cattle making conclusions based solely on laboratory analyses much less reliable for the NWSG than for the introduced CSG.

A major disadvantage of NWSG is their rapid decline in digestibility during mid- to late- summer as the plant matures. Digestion of forage results from a complex interaction between rumen microorganisms, the rumen environment, previous diet, and forage cell wall structure (Akin 1982). Differences in anatomical structure, chemical composition, and site and type of lignification in grass cells have been related to the rate and extent of cell wall degradation in the rumen (Akin and Robinson 1982). Differences in the amounts of easily digested tissues can affect the rate of grass leaf blade digestibility (Akin and Burdick 1975) that is compounded by the grazing selectivity of the animal. It is thought that this decline in digestibility with maturity is in part due to decreased susceptibility of the cell wall polysaccharides to microbial degradation in the rumen. The poor degradation of these structural polysaccharides may result from either the close spatial arrangement of cells in leaves (Hanna et al. 1973) or the composition and structural organization of the cell wall polymers (Fan et al. 1980). Research targeted at evaluating these hypotheses include work by Faix and Kaiser (1980), Grabber and Jung (1991 a,b), Grabber et al. (1991), Grabber et al. (1992), Magai et al. (1994), and Piwonka et al. (1991).

Digestibility of Other Cell Components

Besides differences in fiber components, a number of other nutritional factors may impact the differences between predicted performance based on chemical tests and actual performance in live animals. The major factor in this is CP concentration that is reported to be lower for NWSG especially as they mature. After reviewing the literature, Minson (1981) found that 22 percent of tropical grass values for CP concentration were less than 6 percent, compared with only 6 percent of values with temperate forages. He considered that CP levels of less than 6 to 8 percent in forage would result in depressed intake by the animal. Crude protein concentration in NWSG has been found to decline as the grasses mature. It was lower in regrowth material than in first growth, and it differed significantly between plant components (leaves and stems) (Anderson and Matches 1983; Griffin and Jung 1983; Koshi et al. 1982; Newell and Moline 1978; Reid et al. 1988a; Taylor and Allinson 1981).

Studies have shown that performance of livestock grazing NWSG is generally greater than would be expected given their relatively low protein and high fiber concentrations of these grasses (Abrams et al. 1983; Reid et al. 1988b). Mullahey et al. (1992) compared the ruminal escape protein from switchgrass and smooth bromegrass [*Bromus inermis* Leyss.]. Ruminal microbial degradation of digestible protein in excess of microbial needs results in N loss as ammonia. Escape protein is dietary protein that is not degraded ruminally but is available for absorption in the small intestine. This can increase N use efficiency by the animal if adequate N remains available for microbial growth in the rumen. Mullahey et al. (1992) found that whole-plant escape protein concentration in switchgrass was 42 percent greater than for smooth bromegrass, averaged across all growth stages. Escape protein concentration declined with maturity in both species. Escape protein percentage was similar for smooth bromegrass leaves and stems while switchgrass stems were generally higher than leaves.

Another factor that influences performance is the clear differences in the concentrations of certain minerals between tropical and temperate forages (Fleming 1973; Reid et al. 1979; Norton 1982). Phosphorus concentrations in unharvested switchgrass grown in Texas decreased from 0.23 percent in June to 0.12 percent in November (Koshi et al. 1982). Taylor (unpublished data) found declines in P concentrations with maturity for switchgrass, Indiangrass, and Caucasian bluestem in field studies in Louisiana in the early 1980s. Balasko and Smith (1971) noted decreased concentrations of N, Ca, P, and K in switchgrass as temperature was increased in a growth chamber study. Temperature did not affect the concentrations of Mg, Na, Al, Fe, Sr, Cu, or Zn but N fertilization increased concentrations for all but Na, Al, B, and Cu. Friedrich et al. (1977) reported low S concentrations in switchgrass with an unfavorable N:S ratio although S fertilization did boost leaf and stem S concentrations.

Animal Studies

As mentioned above, laboratory measurements do not accurately predict animal performance. Griffin et al., (1980) found that the IVDDM laboratory technique underestimated *in vivo* digestible dry matter (DDM) by as much as 17 percentage points in studies with switchgrass and big bluestem in Pennsylvania. Their studies indicated the importance of animal evaluation in supporting laboratory forage quality analyses. Still, their findings did indicate that these forages when harvested at early head emergence or later appeared most suitable for animals with lower nutrient requirements such as beef cows rather than high performing dairy animals. Vona et al. (1984) also found that IVDDM underestimated DDM by 10 percent (100 g kg^{-1}) at jointing and 21 percent (210 g kg^{-1}) at heading stage. Vona et al. (1984) concluded that their trials indicated that when NWSG are harvested at an early stage of growth they provide cattle with a high intake of digestible energy. They also found that the poorer utilization of the grasses by sheep than by cattle offers less potential for use of these forages in lamb production systems.

The ideal, season-long pasture system must supply high yields of quality forage throughout the grazing period. An approach to achieving this type system is to use a series of grasses that differ in their growth habits and periods of maximum production and combine that with intensive, rotational grazing to maximize quality and use of the available forage. Studies have shown the value of various components of this strategy. Conard and Clanton (1963) reported highest animal gains per hectare and highest average daily animal gains when CSG were grazed heavily in spring and fall, and WSG were used in summer. Krueger et al. (1974) found the use of WSG pasture in July and August increased beef gains by 83 percent and that a combination of separate pastures of cool- and warm-season species provided the highest carrying capacity and beef production per acre.

Many feeding trials and grazing trials have been conducted on NWSG. Results vary from study to study but, when managed in a way to maximize animal gains, trials generally show good performance on NWSG. Readers should refer to the following papers for more detailed information (Anderson and Matches 1983; Burns et al. 1984; Griffin and Jung 1983; Griffin et al. 1980; Kneebone et al. 1961; Krueger and Curtis 1979; Martin and Hibberd 1990; Newell 1968; Olsen et al. 1999; Prigge et al. 1990; Reid et al. 1988a,b; Stokes et al. 1988; Vona et al. 1984; Wolf and Fiske 1995).

Toxicology in NWSG

Forage toxicology came into prominence with producers following the discovery of the presence of an endophyte fungus in tall fescue [*Festuca arundinacea* Schreb.] that caused 'summer slump', festucosis, or fescue toxicosis in grazers consuming endophyte infected tall fescue during the summer months. Although little information is available on animal health problems when grazing NWSG, it is an area that should not be overlooked. The potential of these native grasses is great but the management challenges are also great. If producers are forearmed with knowledge, it is unlikely that a rare combination of events will create an impenetrable barrier to eventual acceptance of these grasses.

It has been noted in other *Panicum* species that secondary or hepatogenous photosensitization sometimes occurs in herbivores grazing these grasses. In this type of photosensitization, a photodynamic compound, phylloerythrin, is produced from chlorophyll by microbial action in the digestive tract. Excretion of the compound is decreased by hepatic (liver) injury, caused by a toxicant in the plant, and photosensitization occurs when hepatic damage becomes generalized (Jubb et al. 1985). Smith and O'Hara (1978) reported that photosensitization occurred in grazers on pastures containing *P. miliaceum* L., *P. dichotomiflorum* Michx., *P. laevifolium* Hack, and *P. capillare* L. In 1992, Puoli et al. first reported photosensitization in lambs grazing switchgrass. Of a total of 104 lambs grazed on switchgrass during an abnormally hot, dry summer, 17 showed photosensitization and eight died. The symptoms were similar to those reported for 'geeldikkop' in sheep (Button et al. 1987). Puoli et al. (1992) reported that mature ewes were not affected and no signs of photosensitization were noted in suckling lambs grazing switchgrass during a year under more normal temperature and rainfall conditions. The problem has not been reported in cattle. However, producers should monitor young animals of all breeds when grazing switchgrass or any other *Panicum* species especially during periods of high temperatures and inadequate rainfall.

Crop Models for Perennial NWSG

A number of models are available to simulate grassland production or predict the stage of development of the perennial NWSG. A full discussion of these models is not within the scope of this paper. For further information readers should refer to the following papers (Beaty et al. 1978; Welles and Norman 1991; Sanderson 1992; Stout 1994; Sanderson and Wolf 1995; Kiniry et al. 1996; Mitchell et al. 1997; Redfearn et al. 1997; Mitchell et al. 1998; Madakadze et al. 1998a,b; Sanderson and Moore 1999;).

Biomass and Biofuel Usage of Native Grasses

Although not directly related to the forage use of the NWSG, research on the biomass potential and chemical composition of switchgrass as a source of biofuel does have relevancy for forage and livestock producers. Research already published and scheduled for publication at this symposium has shown that switchgrass in particular has potential as a biomass crop in North America and Eastern Canada (Parrish et al. 1997; Parrish et al. 1999; Madakadze et al. 1999). The research not only evaluates the yield potential of switchgrass under several cutting regimes but also reports the chemical composition of switchgrass and the potential removal of nutrients from soil by the crop.

Madakadze et al. (1999) found that end-of-season switchgrass yields ranged from 9,466 lb A^{-1} (10.6 Mg ha^{-1}) to 10,895 lb A^{-1} (12.2 Mg ha^{-1}) for three cultivars grown in Canada. Parrish et al. (2000) (reported at this symposium) found a 20 to 30 percent increase in biomass yields with two cuts versus a single cut. They also found that standing biomass declines by about 10 percent between August and late October and concluded that switchgrass translocates significant amounts of biomass and N below ground at the end of the growing season. Parrish et al. (1999) reported that in 1998 the mean switchgrass yield across eight locations for a two-cut system with N fertilization was from 15,538 lb A^{-1} (17.4 Mg ha^{-1}) versus 12,859 lb A^{-1} (14.4 Mg ha^{-1}) for a one-cut system. Parrish et al. (1997) reported that lowland cultivars yielded 38 percent more than the upland cultivars studied when cut once and 12 percent more when cut twice in a season. Average yields from 1994 to 1996 over eight locations and three years for a single-cut system ranged from 8,841 to 10,895 lb A^{-1} (9.9 to 12.2 Mg ha^{-1}) and cut twice from 11,520 to 12,949 lb A^{-1} (12.9 to 14.5 Mg ha^{-1}).

Development of a biofuel industry with switchgrass as one crop component will offer livestock managers a reason to expand acreage of switchgrass which could be used as an emergency forage crop when heat or rainfall problems limit the availability of cool-season grass forage. Most likely, economics will determine how and when the crop will be used wholly or partially as a forage resource. In addition, the expanded acreage of switchgrass will serve as needed wildlife habitat and feed/forage reserve.

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A Grass Manual for North America

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Abstract

Grasses are the world's most important plants. They occur in almost every terrestrial ecosystem, often as the dominant component, provide over 70% of the calories consumed by humans, and are a conspicuous element in the modified landscapes associated with our homes, recreation areas, and work places.

Despite their importance, there is no good identification manual for North America's grasses. Until recently, the most frequently used reference was Hitchcock's *Manual of Grasses for the United States*, but it covers only the contiguous 48 states, employs a long since discredited taxonomic treatment, provides rather superficial descriptions for many species, does not include illustrations for all the included species, has only state-level distribution maps and, of course, omits all species described, or discovered for the first time in North America, since 1951.

In 1988, the USDA Agriculture Research Service, in conjunction with the Utah Agricultural Experiment Station and Utah State University, agreed to sponsor development of a new grass identification manual. This new *Manual* would treat all grasses that have been found growing in North America north of Mexico, reflect current taxonomic thought, have comparable descriptions and illustrations for all the included species, provide more detailed distribution maps, and include a more comprehensive nomenclatural treatment. In fall, 1999, the management committee of the *Flora North America (FNA)* project decided, with our agreement, to recommend to *FNA's* publisher that the *Manual* be accepted as the grass treatment for that project.

Over 70 taxonomists have helped prepare treatments for the *Manual* and many more have provided distributional data. None of these individuals received any compensation from the project's funds. Not surprisingly, some, but not all, treatments were a long time coming. Nevertheless, we now have most of the components for completing the *Manual* in hand. There are two keys to genera, one natural and one artificial. These are currently being tested. Treatments for all genera have been received and are in various stages of editing. About 300 pages of nomenclatural information are almost ready for publication as a separate volume; the information will be placed on a compact disk for inclusion in the *Manual* itself. We have developed a major distributional database, including both locality and county-level data that will be used in generating maps for contributors unable to obtain the data needed. Lastly, Linda Vorobik has begun preparing the illustrations needed; a task that had to be delayed until the treatments had been received.

The new *Manual* currently includes 237 genera and 1,393 species. About 896 species are considered native and 331 of the remainder are established introductions. The remaining 166 species include those known only as ornamentals, those known only from one location or from historical collections, and a few that are known in North America only as species used in cereal and forage grass breeding programs.

The major obstacle to completing the *Manual* in the next three years is lack of funding. Funds are needed to pay both Capels and Vorobik. In addition, we need assistance in developing the geographic database; including making the maps available over the Web, and in completing some of the mundane tasks that drain time from both Barkworth and Capels. It is hard to believe that we shall not find the funding, given the importance of grasses in so many ecosystems.

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Cades Cove Meadow and Wetland Restoration

Jenny Beeler[1]

Cades Cove is a 2,500-acre limestone based valley in the western portion of the Great Smoky Mountains National Park. This is a very unique area that supports many diverse natural communities. The National Park Service has designated Cades Cove as a cultural management zone. The Park Service also determined that the area should reflect the historical time period of 1850-1920. The cabins and churches throughout the cove accurately reflect this time period; however, the landscape around these structures does not relate to the historical time period.

History of Past Management Practices in Cades Cove

Over the years a number of management practices have drastically changed the landscape of the cove. A 1936 aerial photograph of Cades Cove illustrates a patchwork appearance of small fields, ranging in size from 8-12 acres. These small fields eventually were consolidated into much larger fields for aesthetics or grazing/hay lease permittee convenience. Today the large fescue fields of 60 acres or more do not reflect the historical time period of 1850-1920.

The haying and grazing practices are also very different today. The hay is harvested mechanically twice a year. This can be detrimental to the wildlife, especially small fawns and ground nesting birds. Until recently, 800 acres of the cove was leased to an individual who had 500 cattle on the land. In the 1970's there were up to 1,500 cattle in the cove. In comparison, during the historical time period each farmer had only 10-20 cows that they grazed on the mountain balds in the summer. The valley floor was more valuable for cropland than for grazing cattle.

The final management practice that altered the landscape of the cove was the result of a joint program of the National Park Service (NPS) and the Soil Conservation Service (SCS). This program was implemented in the 1950's and 1960's in order to increase the amount of farmland available for modern agriculture, control flooding, and increase farm productivity. Wetlands were drained, streams were channelized, and tall fescue was planted in the fields.

Wetland Restoration

Today the park managers realize the importance of having a functioning wetland system that filters and treats runoff before slowly releasing it into the streams. The NPS and SCS project resulted in 25,000 feet of channelized streams, created ditches, and drained wetlands in Cades Cove.

In 1995 a wetland restoration project was initiated with research of the past history of the wetland areas in the cove. Information from the park archives and local SCS offices was collected and reviewed. Next, each potential site in the cove was visited and documented. The sites were prioritized according to how much they had been altered in the past and the feasibility of restoration within the project guidelines. Two sites were chosen for restoration. Vegetation monitoring was conducted at each site before the restoration in order to document over time the changes in the vegetation due to the restoration of the hydrology to the areas.

The first site was located in a very unique area of the cove. In the 1940's a meandering marshy drainage system was found in this area. A 1965 farm plan of the area details the construction of two straight V-ditches. Today the ditches are about 5m wide and 1m deep. During the vegetation monitoring some very unique plants were found in and near the ditches. Because of this unique vegetation the restoration techniques had to be carefully considered. It was decided that the best option was to create four soil plugs (dams) throughout the area. Unique plants were

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salvaged from the plug locations before soil was deposited into the ditches. The soil used to create the plugs was first inspected for the presence of exotic species. The finished plugs were revegetated with the rescued plant material and native grasses. Over the first winter a heavy rain event washed gullies in each of the plugs. The next spring a log structure was built into the existing plugs to eliminate the erosion problems. Today the plugs are holding well and beginning to push the water into the surrounding fields. A variety of amphibians are using the newly restored areas to lay their eggs.

The second site was a ditch 700m long that had originally been dug with a backhoe in 1964. The soil had been piled on either side of the ditch creating a soil berm. Since there were no significant plants found in or near this ditch, the type of restoration techniques used was not as important in this situation. A bulldozer was used to push the soil berm into the ditch to fill it and then reshape the natural lay of the land. This was done in the upper 450m of the ditch. In the lower portion of the ditch the soil berm had been eroded away over the years. Since there was not enough soil to fill the ditch, three soil plugs were installed in the lower portion. The next year some hay and log check dams were placed in the upper portion of the ditch in order to slow the water coming through the area and eliminate some erosion problems. This site is progressing very well and the water has been forced out of the created ditch and is beginning to naturally meander through the field. In the lower portion the plugs are forcing water into the surrounding fields and the amphibians are using these pools to lay their eggs.

Both of these projects have worked very well and we hope that over time the hydrology of these areas will be restored.

Meadow Restoration

The second part of the 1995 restoration project was the meadow restoration. As mentioned before, in the 1950's and 1960's meadow fescue [*Festuca pratensis Huds.]* was brought into the park. At that time fescue was thought to be the best forage grass for grazing and hay production. It was widely planted throughout the cove. Today fescue is the predominant grass in the cove. Fields dominated by fescue can be detrimental to small mammals and livestock. A fungus that is often associated with fescue can cause a decrease in small mammal populations by up to 50%. Fescue also provides very little nutrition or cover for small mammals, ground-nesting birds, and insects. In addition, fescue is a mat forming grass through which animals can not travel or find cover from predators. In contrast, the native grasses grow in clumps, which allows space for animals to travel, provides excellent nesting habitat, and provides protection from predators. A fescue field is not very diverse and is very uniform looking. In comparison, native grassland areas are more diverse in appearance and in species composition.

Our goal in this project was to restore native warm season grasses (NWSG's) to the fescue fields and experiment with different management techniques. Three one-acre sites were delineated in the cove. Two of the sites were in regularly mown hay fields, while the third site was in an abandoned field. The hay fields were obviously dominated by fescue. In the abandoned field fescue was present but the native grasses were beginning to reestablish. Of the eight plots established at each site, four were randomly chosen as treatment plots and the other four as control plots. Vegetation monitoring was completed at each site, in order to document the changes that might occur in the native vs. exotic species numbers and in the numbers of the rare species.

In the fall of 1995 the restoration began with a herbicide application of 0.125% glyphosate. This was done on a warm day after the second frost when the fescue was actively growing and the native grasses were dormant. In the spring of 1996 the two hay field sites were planted with a mixture of Indian grass [*Sorghastrum nutans (L.) Nash]*, purpletop [*Tridens flavus (L.) Hitchc.]*, hairy clover [*Lespedeza hirta* (L.) Hornem.], and grass-leaved golden aster [*Pityopsis graminifolia* (Michx.) Nutt.]. This seed mix was planted with a Great Plains No-Till Seed Drill. The vegetation monitoring was completed a second time. It was obvious that some control of the fescue was achieved the first year after the herbicide application.

Another method we wanted to test in the establishment of NWSG's was prescribed burning. In the spring of 1997 the treatment plots were burned. Unfortunately, there was not enough plant material to adequately carry the fire in the plots. In the summer the vegetation monitoring was completed for the third and last time. The data the third time showed a slight increase in the number of fescue plants. The species that had been planted did not show up in the plots until 1999. Indian grass can now be found in each of the treatment plots at one of the sites.

Future Projects

In the future we hope to continue restoring NWSG's to the fescue fields in Cades Cove. In order to protect the genetic integrity of our native species of grasses, only seeds collected from plants within the cove will be used for the meadow restoration. These seeds collected from cove grasses will be planted in seed increase fields of individual species that can be harvested mechanically in the future. Eventually these seeds will be collected and used in a mixture to restore other areas of the cove.

Summary

By implementing these management changes in the grasslands and wetlands of Cades Cove the natural resources will be greatly enriched. The restored meadows and wetlands will create more habitats for native plant species that previously were found only in limited areas of the cove. The increased number of native plants will also support more species of invertebrates, small mammals, birds, and amphibians. These restored areas also present an excellent opportunity to educate the public about the benefits of a functioning natural community.

Sweetgrass Propagation Project

David Burgdorf, Philip Koch and Tony Bush[1]

Abstract

Sweetgrass [*Hierochloe odorata* (L.) P. Beauv.] is a plant of great cultural significance among many of the North American Indian tribes. Its diverse tribal uses range from medicinal to cosmetic. Sweetgrass because of its sweet, vanilla-like fragrance is most commonly braided and burned for ceremonial purposes, or woven into handicrafts. The widespread decline of tribal sweetgrass stands in the Great Lakes region coupled with the resurgence of American Indian cultural preservation has created the need and opportunity for the NRCS Rose Lake Plant Materials Program to assist tribes in the region with rejuvenating these stands.

As sweetgrass is somewhat difficult to grow from seed due to slow development and infertility problems, plant division is generally the most successful means of reproduction. Sweetgrass spreads vigorously by often-deep creeping rhizomes. In the spring these rhizomes produce inconspicuous fruiting stems with sparse, short leaves. Dividing a plant is accomplished by separating the individual propagules (containing some root material and an identifiable shoot) that have developed from the rhizomes of a spreading plant. Each propagule can then be placed in a container for further separation or future planting. Newly separated plants do best if placed in the shade for 2-3 weeks while their roots establish then transplanted at 1-foot spacings into areas of partial to full sun.

The original sweetgrass assemblage grown at the Rose Lake facility was collected in Michigan from historic harvest sites of the Sault Ste. Marie Tribe of Chippewa Indians. The 18 plants collected in January of 1995 soon developed into 300 plants. With assistance from the tribal youth the 300 plants were separated into 3000 and planted back in the Sault Ste. Marie tribal stands by July 1996. To date more than 15 American Indian tribal stands across a 5-state area have been repopulated with sweetgrass propagated from the original collection.

[1] USDA-NRCS Rose Lake Plant Materials Center, 7472 Stoll Road, East Lansing, MI 48823

Forage Potential of Switchgrass and Eastern Gamagrass in the Eastern Piedmont

J.C. Burns and D. S. Fisher[1]

The early presence of switchgrass [*Panicum virgatum* L.] and eastern gamagrass [*Tripsacum dactyloides* (L.) L.] in the Southeast is evidenced by the spotty occurrence of remnant stands across this region. Lowland-type switchgrass can be found on undisturbed sites such as on old-road or railroad right of ways, while its relatives [*Panicum amarum* var. amarulum (Hitchc. and Chase), P.G. Palmer, and *P. amarum Elliott*] can be found growing in back of the fore dunes in the maritime environment of the Atlantic Coast. Remnants of eastern gamagrass stands can be found in more moist environments, such as undisturbed wetlands and along streambeds and roadside ditches. Although these forage grasses are generally thought of as being native only to the tall grass prairie, both have occurred as part of the mixed woodland and grassland vegetation of the Southeastern USA.

Native grasses in the Piedmont may provide improved wildlife habitat and pasture of higher nutritive value than those presently grown. Bermudagrasses and bahiagrass, two introduced species, are the most common perennial grasses grown throughout the region, and both possess only moderate quality and provide poor wildlife habitat.

Evaluation as pasture

Steer performance and pasture productivity

A summary of several experiments shows the potential quality of switchgrass (SG) and gamagrass (GG) when continuously grazed. After the first week in June and into September, steer average daily gains (ADG) were 1.47 lbs for SG and 1.34 lbs for GG. This compared with 0.97 lbs for Tifton-44 bermudagrass. When considering the total grazing season, which begins in mid-April for SG and GG, steer ADGs were about 2 lbs for both forages. This compared with about 1.6 lbs during the same period for the widely used tall fescue-bermudagrass system.

In a three-year study in which both gain per animal and gain per acre were determined, the trade-off between forage of high quality and high productivity is demonstrated (Table 1). In the spring ADG for tall fescue (TF), SG, and Carostan flaccidgrass [*Pennisetum flaccidum Griseb.*, an introduced subtropical, perennial forage] averaged over 2 lbs. Both SG and flaccidgrass (FG) had greater ADG than TF, and this difference is of biological importance. Stocking rate, on the other hand, was greater for TF, averaging 6.1 steers per acre in the spring compared with 3.6 for SG and 4.7 for FG.

In the summer, steers grazing Coastal bermudagrass had ADG of 0.93 lbs, which was less than ADG of about 2 lbs from SG and FG. During this portion of the grazing season BG carried about 10 head per acre compared with 3 to 4 steers per acre for SG and FG. Although BG was inferior in quality to both SG and FG, it carried about three times as many steers.

The season data (Table 1) show that the productivity of the TF - BG system is not as great as when the two components appear separately. This is because when TF is being grazed the BG component is not productive, and when BG is grazed the TF component is not productive. When the land areas for TF and BG are summed for the season, the stocking rate advantage is lost when compared to SG and FG, but the productivity in terms of total digestible nutrients (TDN) per acre is retained. Steers grazing SG and FG were retained on the same land area throughout the growing season.

[1] USDA-ARS, Raleigh, NC and Watkinsville, GA; and North Carolina State University, Raleigh, NC 27695

Table 1. Quality and productivity of the recommended tall fescue (TF) – bermudagrass (BG) system compared with Kanlow switchgrass and Carostan flaccidgrass. [1]

	Spring		Summer		Season		
Forage	ADG	SR	ADG	SR	ADG	SR	TDN
	(lbs)	(hd/ac)	(lbs)	(hd/ac)	(lbs)	(hd/ac)	(ton/ac)
Tall Fescue	2.05	6.1	---	---	---	---	---
Bermudagrass	---	---	0.93	10.2	---	---	---
TF – BG	---	---	---	---	1.28	3.9	2.4
Switchgrass	2.38	3.6	2.03	3.2	2.12	3.3	1.7
Flaccidgrass	2.98	3.6	1.99	3.7	1.99	3.9	1.9

[1]See Burns et al. 1984, *Agron J.* 76:795-800.

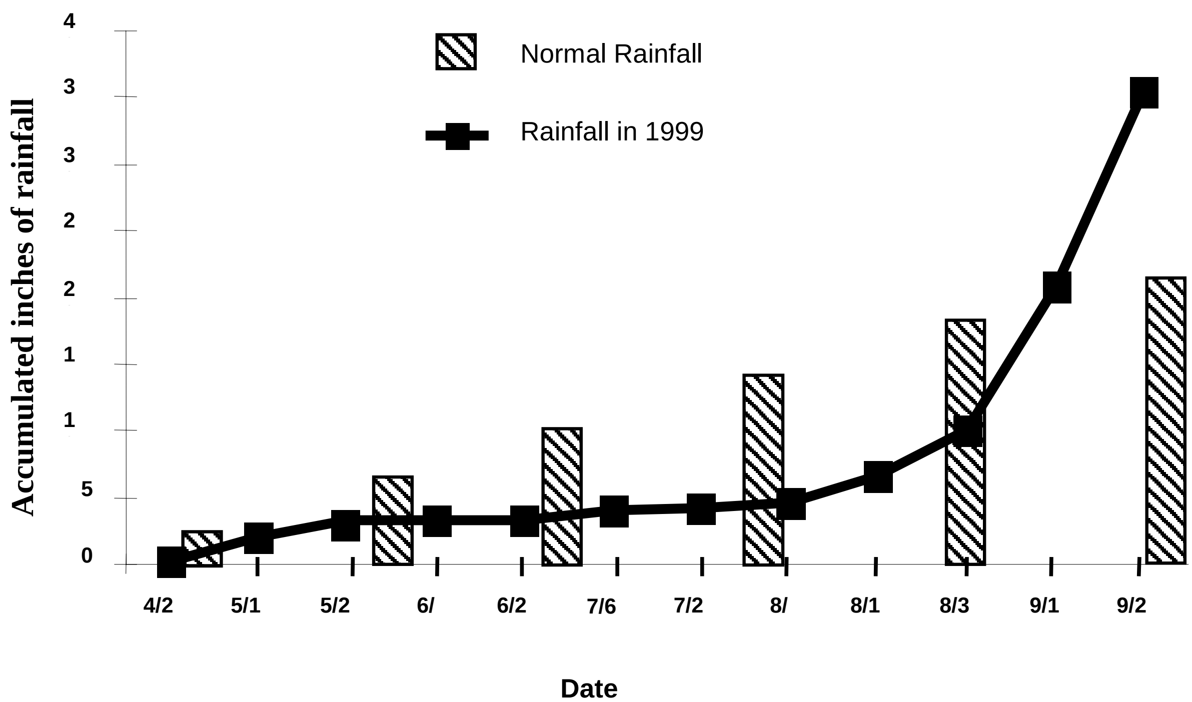

Figure 1. Accumulated rainfall (inches) that occurred by each weigh day from April through September in 1999 compared with accumulated monthly normal (30-yr average) rainfall for the region (NOAA, National Climatic Data Center, Raleigh-Durham Airport).

Pasture performance under stress

Frequent two to three week droughts occur in the Piedmont during the growing season. Because of these repeated periods of moisture and temperature stresses, it is advantageous to have pasture species that are well adapted to such adversity. The 1999 growing season provided such an assessment of several introduced and native species being evaluated for grazing in the region. Accumulated rain during the 1999 pasture season was about 10 inches below normal from May 11 through mid-August (Figure 1).

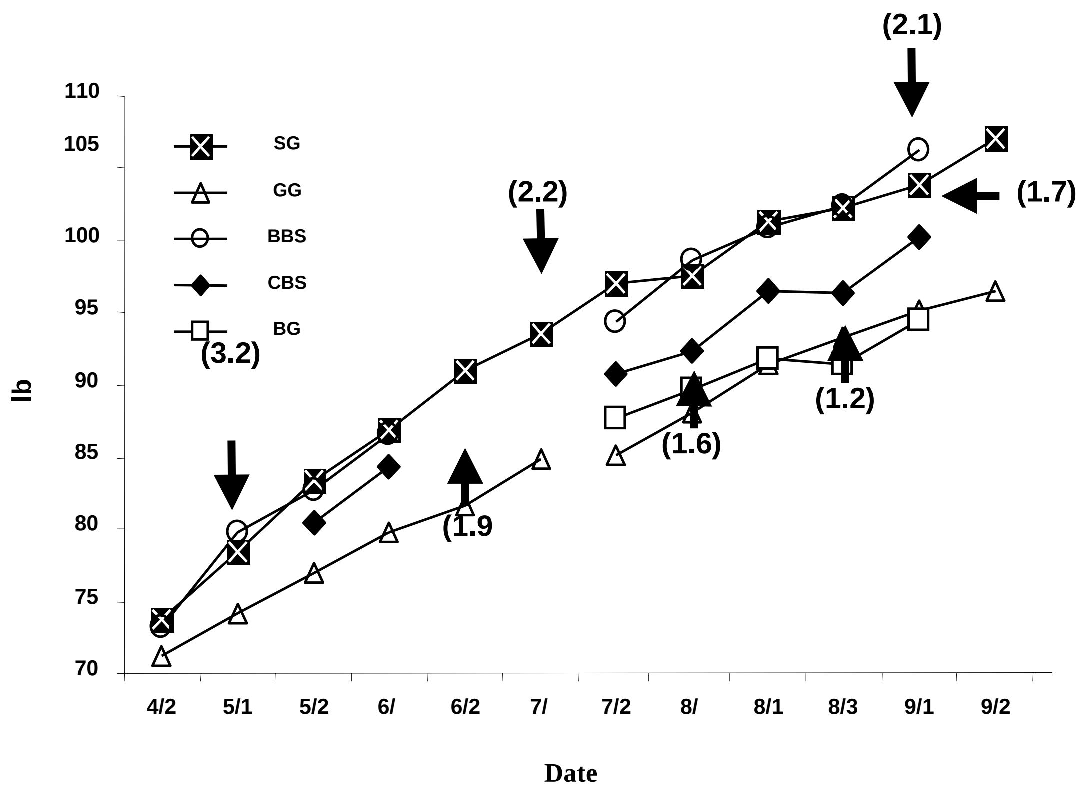

Figure 2. Accumulated steer weights during the growing season while grazing five experimental forages. Discontinuity in accumulated weights within a forage treatment occurred when all animals were removed from the treatment. Numbers in parentheses are steer average daily gain for each forage. When animals were removed from a treatment, an average daily gain was calculated for each grazing segment that exceeded four weeks. All values are the mean of two pasture replicates.

A trial was initiated April 27 with steers grazing pastures of Alamo switchgrass, Iuka gamagrass, and Roundtree big bluestem [*Andropogon gerardii* Vitman]. With the onset of moisture stress, stocking rates were reduced to maintain an excess of herbage mass so as not to limit daily dry matter intake. Caucasian bluestem [*Bothriochloa caucasica* (Trin.) C.E. Hubb.] (CBS) pasture was stocked May 25, but grazing was terminated June 8 as it was for big bluestem (BBS).

Grazing on GG continued until July 6 while SG pastures remained stocked through September 28 (Figure 2). Bermudagrass pastures were stocked for three intermittent one-week periods with continuous grazing delayed until July 20. On July 20, BG was stocked and BBS, CBS, and GG were all restocked, with grazing continuing to September 14 for BBS, CBS, and BG. Both SG and GG were grazed through September 28. The accumulated steer weights (approaching 1100 lbs) and associated daily gains (>2.0 lbs) noted in Figure 2 clearly show that Alamo SG performed best under the climatic and edaphic stresses of this season. Iuka GG provided the next best source of pasture, but steer daily gains were inferior to SG. The other forages did not perform well under these stresses. Adaptation to such stresses warrants special consideration when selecting forage species for grazing systems. Information about canopy structure, nutritive value of the canopy, and the animals' diet are needed to understand why steers perform better when grazing SG, GG, and FG compared with BG. Summaries of previous research findings that address this question are presented below.

Canopy structure and nutritive value

When herbage mass (dry matter in lbs per acre) in pastures of TF, BG, SG, FG, and GG was from 1,500 to 2,000 lbs per acre, the digestibility estimated by in vitro dry matter disappearance (IVDMD) of the harvested canopy averaged 68, 57, 63, 64, and 59%, respectively. Both BG and GG appeared to be lower in nutritive value than the others. The lower IVDMD for BG is consistent with the lower ADG noted in Table 1, but is inconsistent with the ADG obtained for GG (other studies).

Separation of the canopy from several studies into leaf, stem (including sheath), and dead tissue shows that TF is 78% leaves (June sampling), with GG next at 59% leaves, and BG, FG, and SG lower (Table 2). Switchgrass had the highest proportion of stems (54%), followed by BG, with FG and GG intermediate, and TF lowest. Except for FG, dead tissue was generally similar, making up 15 to 19% of the dry matter. The proportions of leaf, stem, and dead tissue for FG were nearly equal.

The IVDMD of the forage components (Table 2) shows that leaf tissue is generally higher in digestibility than stem tissue, and both leaf and stem tissue are higher in digestibility than dead tissue. Exceptions are the digestibility of stem for TF, which is mainly pseudo-stem at a June harvest, and of GG, which shows little difference in digestibility (IVDMD) between it and the leaf tissues.

Table 2. Proportion and in vitro dry matter disappearance (IVDMD) of pasture samples from several studies when separated into leaf, stem, and dead tissue.

	Proportion			IVDMD		
Forage	Leaf	Stem	Dead	Leaf	Stem	Dead
			%			
Tall Fescue	78	7	15	72	75	42
Bermudagrass	27	47	16	64	59	36
Switchgrass	29	54	19	69	63	52
Flaccidgrass	33	32	35	71	66	55
Gamagrass	59	25	16	64	63	29

These data indicate that the forage grasses evaluated in Table 2 have different canopy attributes that could differentially alter animal grazing behavior and subsequent daily responses.

Animal diet characteristics

Allowing animals with an esophageal cannula to graze each of the pasture canopies and collecting the resulting masticate provides information on how the animal interacts with the morphology of the pasture canopy offered. Examination of the digestibility of the masticated extrusa, compared with the digestibility of the harvested canopy (Table 3), reveals that steers selected a diet from the canopy that was 7 to 10 percentage units more digestible. The variation in neutral detergent fiber (NDF) concentrations generally reflects the variation in digestibility (IVDMD), but the correlation is negative. An exception was GG, which had high fiber and relatively high digestibility.

Table 3. In vitro dry matter disappearance (IVDMD) of pasture canopies and the associated IVDMD and neutral detergent fiber (NDF) of the steers' diet from several studies.

Forage	Pasture IVDMD	Diet IVDMD	Diet NDF
	%		
Tall Fescue	68	76	43
Bermudagrass	57	64	54
Switchgrass	63	72	54
Flaccidgrass	64	72	49
Gamagrass	59	69	60

Ruminants must reduce ingested forage to about 1 mm before it can escape from the reticulo-rumen. To check for differences among forages for particle size reduction, the masticated extrusa was freeze dried and passed through a series of sieves to give large ($\geq$2.8 mm), medium ($\leq$2.8 and $\geq$0.5 mm), and small (<0.5 mm) particles. The proportion of the dry matter composed of each particle size was determined and then each particle class was analyzed for digestibility (IVDMD). This provided an assessment of how the different forages fractionated upon initial ingestion and an estimate of digestibility for each particle size class. The largest proportion of the large particle class occurred for TF and the lowest for BG. The others (SF, FG, and GG) were intermediate (Table 4). Associated with the low proportion of large particles for BG was its highest proportion of medium particles and intermediate portion of small particles. Gamagrass, on the other hand, had the lowest proportion of medium particles and the highest proportion of small particles.

Table 4. Proportion and in vitro dry matter disappearance (IVDMD) of large, medium, and small particles in the steers' diet from several studies.

Forage	Proportion			IVDMD		
	Large	Medium	Small	Large	Medium	Small
	%					
Tall Fescue	30	61	9	77	76	70
Bermudagrass	8	72	20	54	66	64
Switchgrass	20	65	15	74	73	68
Flaccidgrass	21	69	10	72	72	68
Gamagrass	16	55	29	80	77	69

It is clear from the IVDMD data (Table 4) that the digestibility of the diet consumed by the steers grazing BG pasture was inferior to the other species for all three particle sizes examined. This provides insight as to why steer ADG (Table 1) was consistently less for BG compared with SG and FG in one study and GG in another study. Further, the IVDMD for the large and medium particle sizes for GG were extremely high relative to the NDF concentrations reported for the total diet (Table 3). Even though GG had a high proportion of small particles, the IVDMD was as high as noted for SG and FG (Table 4). These data provide evidence why SG and GG generally gave high and similar ADG even though they differ considerably in morphology.

Evaluation as hay

Both SG and GG may be successfully harvested and stored as hay. Kanlow and Alamo SG have been evaluated and both require prolonged periods of drying (4 to 6 days), which complicates haying in the humid Piedmont. Gamagrass dries much quicker than SG because of its high proportion of leaves and less developed stems. Drying can be greatly aided through teddering following mowing and conditioning. This process removes the conditioned forage from the windrow and scatters it over the cut stubble.

Hay harvested with an effort to equalize NDF (cell wall) concentrations provided insight as to why steers gained more when grazing on native grasses compared with bermudagrass (Table 1). The subtropical forage harvested had an NDF range of 71 to 75% (Table 5). Tall fescue, although lower in NDF than the others, was high in NDF for a temperate forage and was probably at the maximum as the plants were fully headed. Bermudagrass was consumed by steers in highest amounts (2.7% of body weight) compared with TF, SG, and FG, which were in the same study (Table 5). Gamagrass, although evaluated in a separate study with wether sheep, showed dry matter intake similar to the intake (body weight basis) of SG and FG by steers.

Table 5. Quality among native grass hays with similar NDF concentrations.

	Hay	DM	Digestibility[1]			
Forage	NDF	Intake	DM	NDF	CELL	HEMI
	(%)	(% BW)	%			
Tall Fescue[2]	62	2.3	62	62	65	68
Bermudagrass[2]	74	2.7	50	49	52	54
Switchgrass[2]	75	2.1	61	65	68	72
Flaccidgrass[2]	71	2.3	64	68	69	76
Gamagrass[3]	71	2.4	64	66	68	73

[1] DM = dry matter, NDF = neutral detergent fiber, CELL = cellulose, and HEMI = hemicellulose
[2] Evaluated with steers (see Burns et al.,1985, *Agron J* 77:933-936).
[3] Evaluated with wether sheep (see Burns et al. 1996, *Post Harvest Biol. and Tech* 7:261-269).

The apparent digestibilities for dry matter and NDF (cell walls) and constituent fiber fractions, along with the dry matter intake, show that BG is not as digestible as the other subtropical grasses but is consumed in larger amounts. This infers a higher passage rate of fiber that is not very digestible to increase dry matter intake and has been observed previously in herbivores.

Evaluation as silage

The high humidity and the occurrence of frequent thunderstorms across the Piedmont make field curing of hays, especially of switchgrass, difficult with a high risk of rain damage. Direct harvesting and preserving as silage would remove the risk of rain damage.

Silage characteristics and quality of switchgrass

Kanlow switchgrass has been evaluated for fermentability as well as quality when harvested at several growth stages and ensiled directly or after field wilting. Direct cut forage averaged about 25% dry matter compared with 34 to 37% dry matter when wilted (Table 6). The resulting pH was not as low as desired for a stable silage (pH about 4.0), but it was generally free of mold once the surface 10 to 12 inches were removed and stable enough for feeding.

Lactic acid generally predominates in good silage and butyric acid should be low. Acetic and lactic acid concentrations were low and consistent with the observed high pH. Butyric acid was present and concentrations may be higher than desired in the direct cut, vegetative, and late boot treatments. Although all forages fermented, the fermentation process did not proceed sufficiently to ensure

Table 6. Ensiling characteristics of direct cut and wilted switchgrass silage for three growth stages.

	Stages					
	Vegetative		Late Boot		Headed	
Item	Direct Cut	Wilted	Direct Cut	Wilted	Direct Cut	Wilted
Dry Matter (%)	25.5	35.2	25.2	37.1	24.3	34.0
pH	4.8	4.8	5.1	4.9	4.9	4.6
Acids (%):						
Acetic	2.1	0.9	2.0	0.9	1.9	1.0
Propionic	0.2	0.3	0.2	0.1	0.1	<0.1
Lactic	2.8	2.5	1.3	1.7	2.6	2.8
Butyric	1.1	0.4	1.2	0.4	0.2	<0.1

[1] See Burns et al. 1993, *Post Harvest Biol and Tech* 3:349-359.

a stable silage. This is attributed to a lack of readily fermentable carbohydrates in the forage. Additional care in packing needs to be taken with SG and other native grasses to exclude the maximum amount of air possible at the time of ensiling to aid in the development and the maintenance of an anaerobic environment.

Evaluation of silage dry matter intake by steers, compared with the same forage field cured as hay, showed no difference within either the late-boot or the headed growth stages. Dry matter intake (percent body weight) averaged 1.5% for the late boot stage and 1.4% for the headed stage. Intakes of about 2.5% of body weight are generally desired. Crude protein concentrations were < 7% at both growth stages and could be, in part, responsible for suppressed dry matter intake.

Table 7. Ensiling characteristics of direct cut Iuka and Pete gamagrass.

			Late Summer			
	Spring		August		September	
Item	Iuka	Pete	Iuka	Pete	Iuka	Pete
Dry Matter (%)	18.3	18.5	29.4	24.8	30.8	26.8
pH	4.3	4.2	4.4	6.0	4.3	4.3
Acids (%):						
Acetic	2.4	2.0	0.7	0.1	1.3	1.1
Propionic	0.1	0.1	<0.1	<0.1	<0.1	<0.1
Lactic	5.6	6.2	2.6	0.4	4.3	3.8
Butyric	1.3	1.3	<0.1	<0.1	0.1	<0.1

Ensiling characteristics of gamagrass

Fermentation characteristics of Iuka and Pete gamagrass when cut and ensiled directly have been evaluated for both spring and late summer harvests. Dry matter concentrations were similar in the spring for Iuka and Pete, averaging 18.4% (Table 7) while concentrations were higher in the late summer, averaging 30.1% for Iuka and 25.8% for Pete. The pH was about 4.3 and generally lower than noted for SG (Table 6). An exception is noted at the August harvest for

Pete. This forage showed little fermentation as noted by the low acid concentrations and apparent aerobic decomposition when the silo was opened.
In general, lactic acid dominated and butyric acid was present in the spring harvest but generally lacking in the late summer harvests. No animal evaluation data of these silages is available at this time.

Summary

Both switchgrass and gamagrass have potential roles in animal production enterprises in the Piedmont. Both grasses have the following attributes:

1) They can be grown throughout the Piedmont and Coastal Plains.

2) They can be managed as pasture or harvested and stored as hay or silage.

3) Their pasture canopy morphology provides easy access for selective consumption of green leaves by grazing animals.

4) Their NDF concentrations are indicative of moderate to low nutritive value, but animal performance is relatively high because their cell walls are highly digestible.

5) They will support seasonal steer daily gains from pasture of about 2 lbs per day, but the carrying capacity may be less than introduced subtropical pasture species such as bermudagrass.

Revegetating Slag Refuse Areas with Native Warm Season Grasses

Tony Bush[1]

This study was designed to determine how topsoil and fertilizer supplements affect the establishment of native warm season grasses on a northwestern Indiana slag refuse site. A mix of five locally collected species of warm season grasses that included big bluestem [*Andropogon gerardii* Vitman], little bluestem [*Schizachyrium scoparium* (Michx.) Nash], Indiangrass [*Sorghastrum nutans* (L.) Nash], prairie sandreed [*Calamovilfa longifolia* (Hook.) Scribn.], and switchgrass [*Panicum virgatum* L.] was seeded to plots with and without topsoil additions. Split plots were either treated with a starter fertilizer or left unfertilized. Data was collected on percent foliar cover, seeded species counts, non-seeded species counts, and the relative effectiveness of the warm season grasses for improving wildlife and aesthetic value to the site. The percent foliar cover, warm season grass counts, warm season grasses as a percent of the total plant population and effectiveness were significantly higher ($P<0.05$) in treatments receiving additional topsoil. Based on comparisons between individual seeded warm season grasses little bluestem had the highest plant counts relative to its proportion in the mix and exceeded expectation ($P=0.10$) across all seeded treatments. Although non-seeded species counts and total plant counts were generally higher in treatments without topsoil supplements, the differences were not significant ($P=0.05$). Likewise, no significant differences ($P>0.05$) were found between fertilized and non-fertilized split plots for the features measured.

Introduction

The City of Hammond, Indiana, has had a long association with the steel industry. Slag is the discarded material resulting from the production of metals from ore, in this case, steel from iron ore. Past slag disposal practices have resulted in numerous poorly vegetated sites where the slag refuse was stockpiled. Historically, many of these sites had uniquely diverse plant communities and were in areas historically used as resting sites by migratory birds.

In response to the situations created by slag disposal, the City of Hammond Parks Department in partnership with the United States Department of Agriculture – Natural Resources Conservation Service (NRCS) filed for and received a Great Lakes National Program Office (GLNPO) grant through the Environmental Protection Agency (EPA) to study site specific methodologies by which slag refuse areas could be revegetated with native plants. The hope of this study was to identify methodologies that would create a favorable environment for continued native plant succession, improve wildlife habitat and improve the aesthetic value of the site.

Methods and Materials

The study was located in the City of Hammond within an area known as Strawberry Island at the southern end of Lake Michigan. The site was flat with dense, slag-permeated surface and sparse weedy vegetation. An analysis of the slag content indicated there were no inherent elemental properties that would inhibit plant growth.

This study was developed as a split-plot design with 4 replications. The selection of treatments (Table 1) was based on practicality and previous experience in other critical area situations. Non-sterilized loamy topsoil was used in treatments receiving supplemental soil. Framework warm season grass species were chosen for the seed mix from available local genotypes collected by the Friends of Gibson Woods. Each was cleaned and tested for purity and viability to determine pure live seed (PLS) content. Information on the species mix is provided in Table 2.

Table 1. Treatment summary.

[1] USDA-NRCS, Rose Lake Plant Materials Center, East Lansing, MI 48823

Treatments	Soil Component	Seed Component
1(control)	no top soil added	not seeded
2	no top soil added	seeded with warm season grass mix
3	4 inches of topsoil placed over slag	seeded with warm season grass mix
4	4 inch topsoil cap incorporated into top 4 inches of slag	seeded with warm season grass mix

Table 2. Warm season grass seed mix used in seeded plots.

Species	seeds/lb.	lbs. PLS/acre	PLS/plot	PLS/sq. ft.	% of mix
Big bluestem	165,000	1.77	5841	6.7	9.5
Little bluestem	240,000	0.61	2928	3.4	4.8
Indiangrass	175,000	0.99	3465	4.0	5.7
Prairie sandreed	274,000	0.82	4494	5.2	7.4
Switchgrass	389,000	5.73	44579	51.2	72.6
Total		9.92	61307	70.5	100.0

Table 3. Summary of 1998 groundcover composition and warm season grass effectiveness on 4 land treatments.

Treatments	Foliar Cover (%)	(average count / square foot)			Warm Season Grasses (% of total)	Warm Season Grass Effectiveness (Highest = 1, Lowest = 9)
		Warm Season Grasses	Non-Seeded Species	Total Plants		
	**	*	ns	ns	*	*
Control (no seed, no soil)	37.0	0.6	17.5	18.1	3.5	9.0
Seeded	38.1	0.9	21.8	22.8	4.0	7.1
Seeded with soil cap	68.4	4.0	13.5	17.5	22.9	1.6
Seeded with soil incorp.	68.1	3.4	15.4	18.9	18.2	2.6

* highly significant (1% level)
** significant (5% level)
ns not significant at the 5% level

The site was disked to remove existing vegetation and treatment plots were established in early summer 1996. Each plot measured 8.7 x 100 ft and was divided at the 50 ft mark into fertilized and not fertilized subplots. Seeded plots were hand broadcast with the mix at a PLS rate of approximately 10 lbs/acre and raked to provide better seed to soil contact. After seeding 12-12-12 fertilizer was broadcast on the appropriate subplots at a rate of 1000 lbs/acre. The study area was mowed several times during the first year and sprayed once with 2,4-D in October for weed control.

In October 1997 a line transect approach was used to obtain preliminary data on the site. Information was collected on plant type or species, and plant vigor at each of 50 points, spaced 1 foot apart, within each of the subplots. A total of 1600 points were sampled (50 points x 2 subplots x 4 treatments x 4 replications). A report on the 1997 findings was issued in early 1998. Results of consequence will also be discussed in this report.

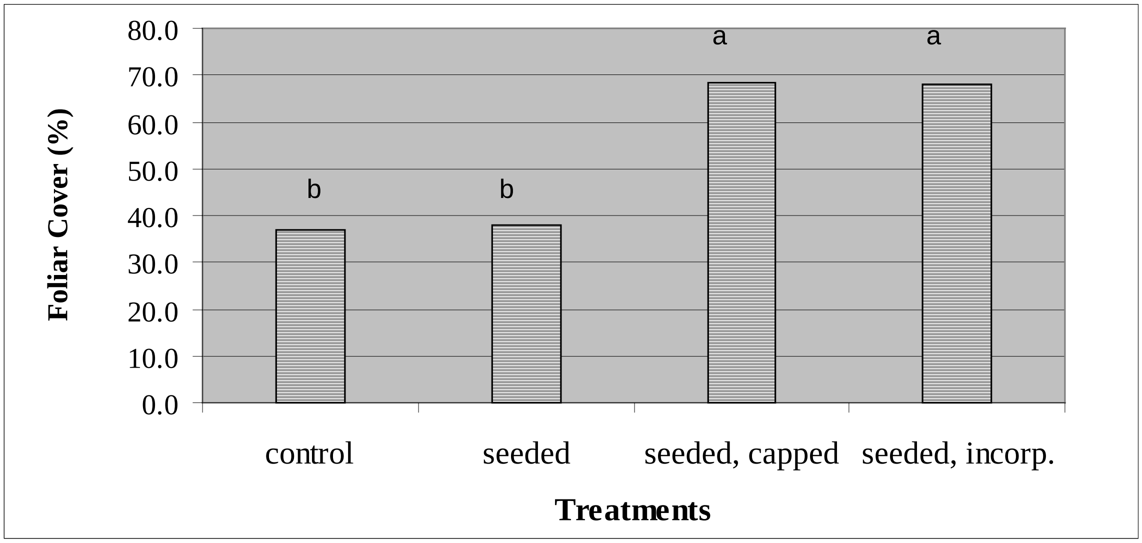

Figure 1. Average percent of ground covered by aerial portion of plants over 4 types of land treatments in 1998: bars with no common letters are significantly different by Duncan's multiple range test at the 5% level.

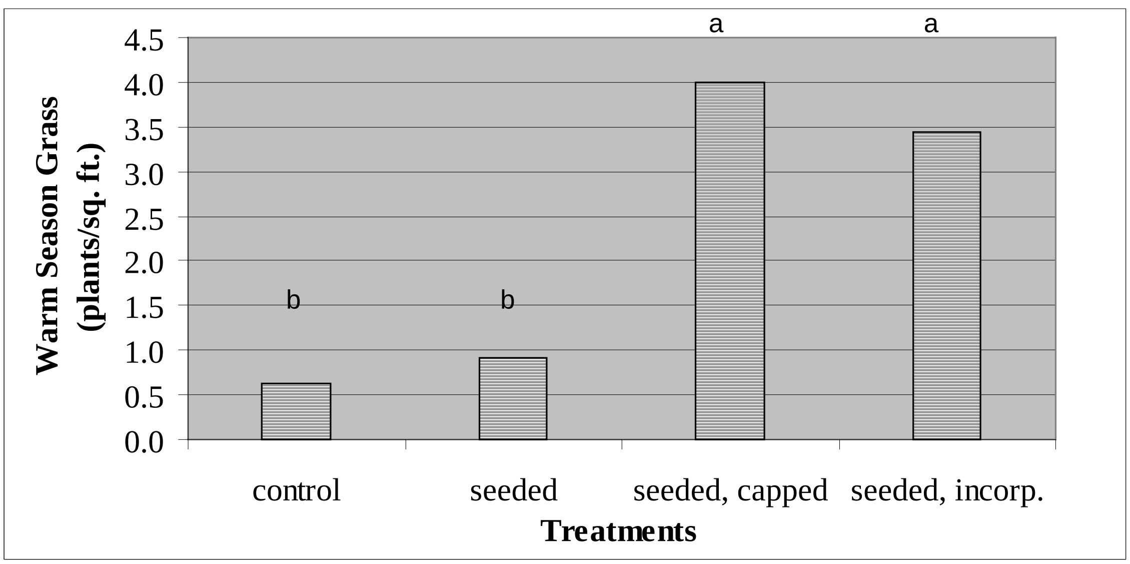

Figure 2. Average warm season grass plants per square foot over 4 types of land treatment in 1998: bars with no common letters are significantly different by Duncan's multiple range test at the 5% level.

In October 1998 a second collection of data was completed on the study. However, instead of a line transect, measurements were taken from 4 randomly located square foot sections in each of the subplots. Data was recorded on % foliar cover, number and type of planted species and the number of non-planted species for each of the sections. A visual observation was also taken for each subplot on the effectiveness of the planted species in providing improved wildlife habitat and aesthetic value to the land.

Results and Discussion

Changing the method of collecting data from a line transect (one-dimensional view) in 1997 to an area transect (two-dimensional view) in 1998 caused some difficulty in comparing the data. Although some correlations can be drawn, this report will center on the information gathered in 1998 (Table 3). Considering the nature of the seeded species and the objectives of this study it is believed that the second year data is a more reliable picture of the site conditions and the potential for revegetating these slag sites.

Statistics for the categories that reached a level of significance (5% or greater) showed the sharp distinction between the treatments where soil was added and those where soil was not added. In treatments with additional soil the percent of foliar cover nearly doubled but the percent of warm season grasses and their average counts per square foot were 4 to 7 times greater (Figures 1-3). Mean separation in each of these cases revealed a significant difference between those treatments receiving supplemental soil and those that had not.

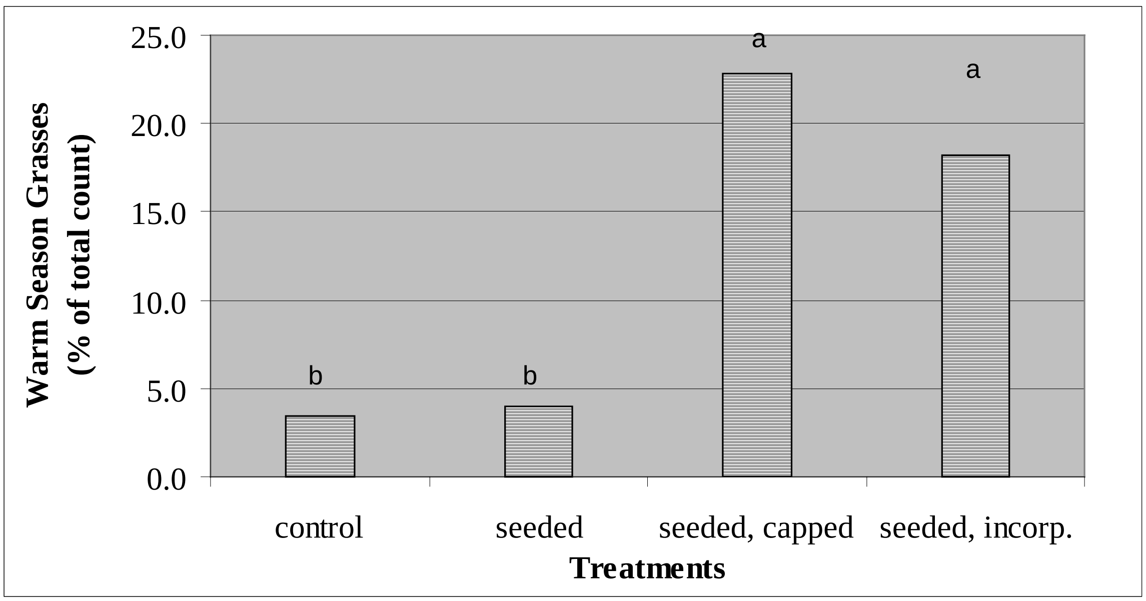

Figure 3. Average percent of warm season grasses in total plant count over 4 types of land treatment in 1998: bars with no common letters are significantly different by Duncan's multiple range test at the 5% level.

The 1997 data (Table 4) is consistent with the 1998 data. As in 1998 the percent vegetative cover (comparable to foliar cover), and warm season grass counts and percents of total vegetation were substantially higher (P=0.01) in treatments with the soil additions.

Also of importance are the categories that were not significantly different in 1998, non-seeded species and total plant counts. Adding topsoil to the slag substantially increased the number of seeded warm season grasses but it did not statistically affect the non-planted or total vegetation counts (Figure 4).

Visually the vigor of all plants in the plots with topsoil additions was more pronounced, however, it was particularly noticeable in the warm season grasses. Each subplot was rated for effectiveness of the warm season grasses in improving wildlife habitat and adding aesthetic value to the site (Figure 5). This was essentially a measure of plant numbers and health. The soil treated plots, consistently and dramatically, had higher ratings than those that had no soil additions.

Statistics and observations show that where topsoil was supplemented seeded species progress in number and health much better than the non-seeded species. This likely accounts for the increase in foliar cover.

Warm season grass data include a breakdown by species. However, it is important to consider the actual counts in relation to their individual proportions in the seed mix. Multiplying the total warm season count in a treatment by the proportion of a species in the mix (Table 2) gives the expected count for that species in a particular treatment. The values for actual and expected counts for each species in a total sample area of 32 square feet are provided in Table 5.

Table 4. 1997 vegetative cover and warm season grass data.

Treatments	Vegetative Cover (%)[1]	Warm Season Grasses (Count)[2]		Warm Season Grasses (% of total vegetation) [1]	
Control (no seed, no soil)	63.0 b	0	b	0	b
Seeded	61.5 b	8	b	3.3	b
Seeded with soil cap	86.7 a	108	a	31.1	a
Seeded with soil incorp.	92.2 a	69	a	18.7	a

Treatments with no common letters are significantly different by Duncan's multiple range test at the 1% level

[1] average of 4 replication

[2] out of 400 observations

A Chi-square analysis was completed to determine if the actual counts were statistically the same as the expected counts. Big bluestem fell significantly (5% level) short of expected counts in the soil-incorporated treatment; prairie sandreed had significantly (highly at 1% level) fewer plants than expected in both supplemental soil treatments. Little bluestem was the only species that significantly (highly at 1% level) exceeded expected counts, and that was accomplished in all 3 seeded treatments.

Furthermore, as shown by the extrapolated warm season grass counts per 100 seeds planted (Figure 6), most species performed better in one or both of the treatments where soil was added. Again, little bluestem had a comparatively higher percentage than any other species in each of the seeded treatments. The existence of these species in the control (unseeded) plots suggests possible self-reseeding and spread by rhizomes which would influence the actual counts. However, the counts are indicative of the relative success of the species under each of these conditions.

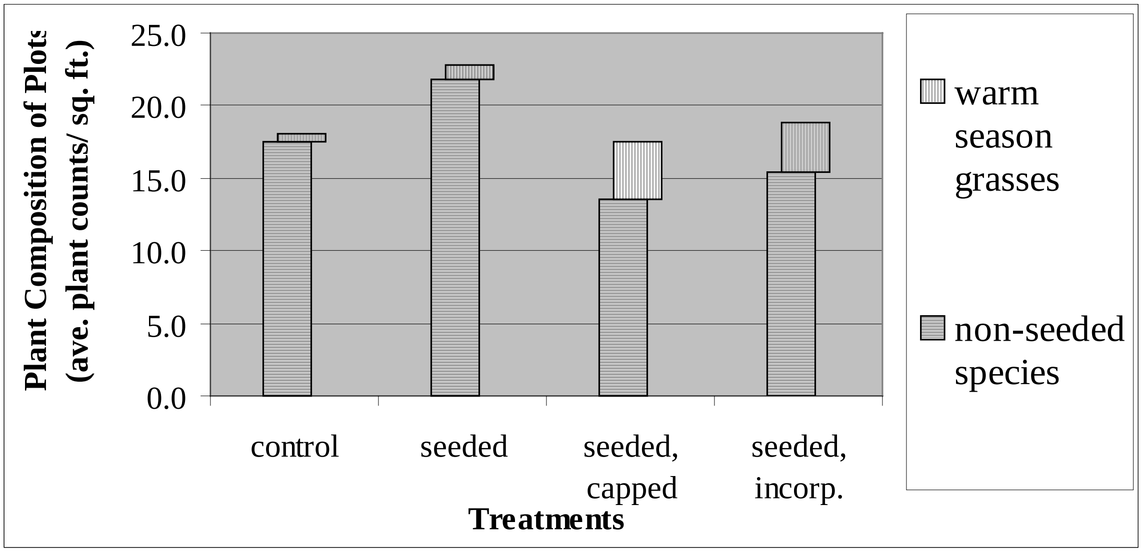

Figure 4. Plant composition of plots on the 4 land treatments in 1998.

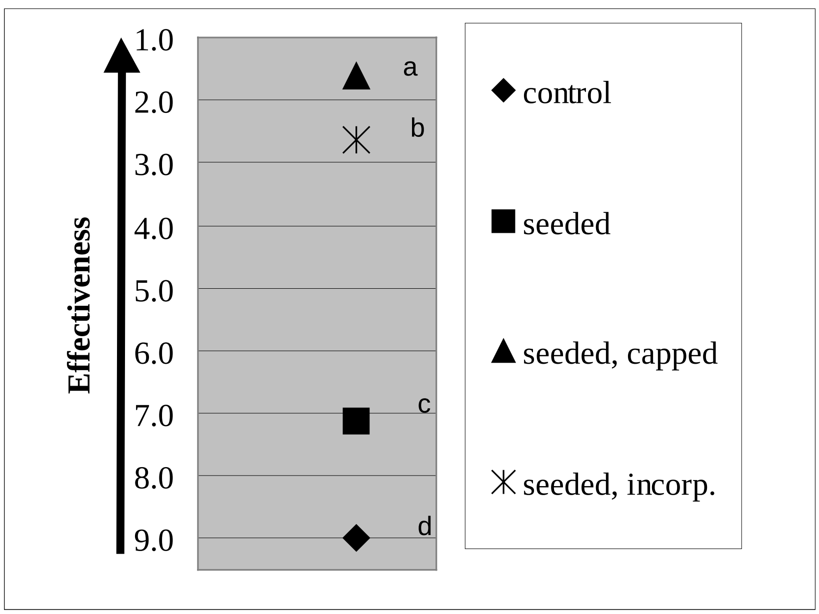

Figure 5. Comparative effectiveness of the warm season grasses in improving wildlife habitat and aesthetic value to the site on the 4 land treatments in 1998: treatments with no common letters are significantly different by Duncan's multiple range test at the 5% level.

Table 5. Total warm season grass count, and actual and expected warm season grass counts by species on the 3 seeded treatments in 1998.

Treatment	32 square foot total sample area										
	Total WSG Count	Big Bluestem		Little Bluestem		Switchgrass		Indiangrass		Prairie Sandreed	
		Actual Count	Expt. Count	Actual Count	Expt. Count	Actual Count	Expt. Count	Actual Count	Expt. Count	Actual Count	Expt. Count
Seeded	29	4	2.8	*6	1.4	18	21.1	0	1.7	1	2.1
Seeded, cap	128	14	12.2	*18	6.1	89	92.9	7	7.3	*0	9.5
Seeded, incorp	110	** 3	10.5	*21	5.3	82	79.9	4	6.3	*0	8.1

* highly significant (1% level)
** significant (5% level)
all others are not significantly different

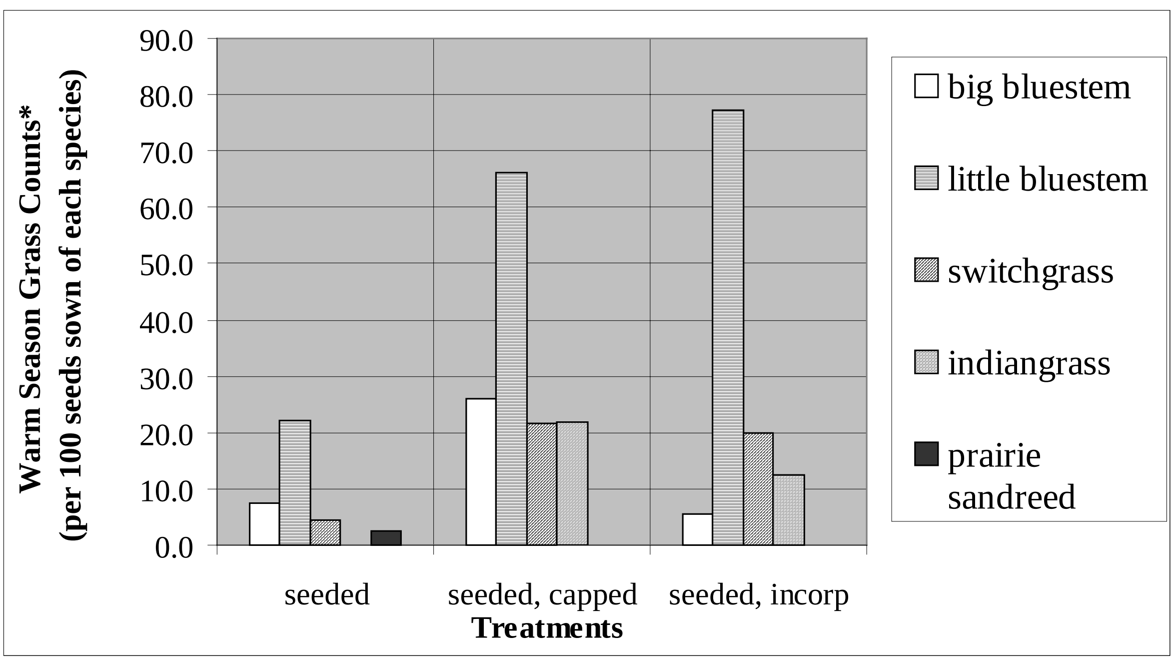

Figure 6. 1998 warm season grass counts per 100 seeds planted in the 3 seeded treatments, (*) extrapolations based on sample data.

Table 6. Summary of 1998 groundcover composition and warm season grass effectiveness on subplots.

Subplots	Foliar Cover (%)	(average count / square foot) Warm Season Grasses	Non-Seeded Species	Total Plants	Warm Season Grasses (% of total)	Warm Season Grass Effectiveness (Highest = 1, Lowest = 9)
	ns	ns	ns	ns	ns	ns
no fertilizer	50.6	2.3	17.8	20.2	11.6	5.1
fertilizer	55.2	2.2	16.3	18.5	11.7	5.1

ns not significantly different at 5% level

Table 7. Summary of 1998 ground cover composition and warm season grass effectiveness on treatment and subplot interaction.

Treatments/ Subplots	Foliar Cover (%)	(average count / square foot) Warm Season Grasses	Non-Seeded Species	Total Plants	Warm Season Grasses (% of total)	Warm Season Grass Effectiveness (Highest = 1, Lowest = 9)
	ns	ns	ns	ns	ns	ns
no seed, no soil no fertilizer	34.7	0.9	18.9	19.9	4.7	9.0
no seed, no soil fertilizer	39.4	0.3	16.0	16.3	1.9	9.0
seeded, no soil no fertilizer	39.1	0.8	23.6	24.3	3.1	7.3
seeded, no soil fertilizer	37.2	1.1	20.1	21.2	5.0	7.0
seeded, soil cap no fertilizer	61.6	3.9	15.5	19.4	20.3	1.8
seeded, soil cap fertilizer	75.3	4.1	11.5	15.6	26.1	1.5
seeded, soil incorp no fertilizer	67.2	3.7	13.3	17.0	21.7	2.5
seeded, soil incorp fertilizer	69.1	3.2	17.6	20.8	15.4	2.8

ns not significantly different at 5% level

There were no significant differences between the fertilized and non-fertilized subplots across all categories (Table 6). Likewise, the interaction between treatments and subplot factors was not significantly different in any category (Table 7). This indicates most, or all, of the differences are a result of the treatment effect and not the subplot (fertilizer) effect or an interaction between the two treatments.

Conclusions

The foremost conclusion of this study is that the warm season grass mix performed far better, both in number and vigor, on the soil amended areas. Although the non-seeded species, mostly weeds, were somewhat improved in vigor on these same areas, their numbers were not. This suggests a strong competitive edge to the native grass mix where soil was added. The extensive root systems, typical of warm season grasses, probably figured greatly into these results but it is beyond the scope of this study to assess the possible soil-climate-plant interactions.

A rule of thumb is that a warm season grass planting will most likely be successful if it has two strong plants per square foot in the second year after planting (Dickerson, et. al. 1997). Although the overall bulk of the grasses was generally less than what would be found on a deep soil site, both of the treatments receiving supplemental soil doubled or nearly doubled the plant count. The two treatments not receiving soil additions reached less than half that goal (Table 3, Figure 2). Enhanced wildlife benefits and aesthetic value to the land are, of course, commensurate with this improved development. This study identifies approaches using additions of topsoil that enhance the establishment of native warm season grasses on Indiana slag refuse sites.

Fertilizer additions to the subplots did not affect the growth of the grass species used in this study. Varying the application rate or blend would most likely produce different results. However, a successful stand of warm season grasses was produced within a respectable period of time without fertilizer additions.

As to the individual species, little bluestem was the only one to statistically exceed expected counts, substantially outperforming all the others. At the other extreme, prairie sandreed fell severely short of expectations. The other species for the most part met expected counts. This suggests some species may not be appropriate for use under these growing conditions while others seem to flourish. However, keep in mind that plants are successional and develop at different rates, and the makeup of any community may change over time.

Finally, the warm season grasses are long-lived but are also relatively slow in above ground development compared to other common species. Good pre-planting weed control and proper management, particularly in the first two years after planting, will considerably improve the chances for a successful planting.

Acknowledgement

Under the terms of Agreement No. 68-52KY-6-649 with the City of Hammond, NRCS, through the Rose Lake Plant Materials Center, designed and evaluated the methodologies used in this study.

This project was completed through the cooperation of the City of Hammond, Parks Dept.; USDA-NRCS, Rose Lake PMC and Lake County Field Office; GLNPO, EPA; The Nature Conservancy; Friends of Gibson Woods; Allen Landscape Construction; and the Lake County Soil and Water Conservation District.

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Applied Native Grass Restoration Projects in Western North Carolina

Jon Calabria[1]

Changing land use patterns and their resultant modification of the landscape have steadily degraded the Southern Appalachians. Although several decades of restoration have begun to reverse past degradation, these environmentally focused efforts have seldom addressed the public's need for aesthetic appreciation, recreation amenities, and environmental education. In contrast, several projects in Western North Carolina illustrate efforts to address both the need for ecological restoration and the public's need for rejuvenation and recreation in natural settings.

Brevard College Wetland Garden

Brevard College has completed two projects: 1) a wet detention basin that improves water quality and 2) a streambank stabilization program. These stabilization and restoration efforts will improve water quality and increase biodiversity by reconnecting the stream channel with the flood plain. Streamside greenways and pocket parks along the campus stream will provide park users opportunities to interpret these unique stormwater mitigation features and stream stabilization techniques.

Headwaters

Headwaters Club emulates a rustic Scottish golf course embraced by indigenous grasses and forbs. Although the last minute addition of mostly exotic wildflowers and annual rye for additional erosion control significantly altered the restoration program, users will be exposed to an ecologically beneficial landscape that outweighs traditional treatments of these areas.

Meadow Ridge

Meadow Ridge is a development that surrounds reserved open space. Homesites surround an open space that consists of a meadow that encloses a fescue clearing used for recreation. The long-term restoration effort focuses on recreating a grassy bald community. The restoration consisted of clearing the failing fir and spruce tree plantation and establishing a pioneer crop of indigenous ryes and other grasses, including several forbs to increase interest and appeal.

These efforts to combine restoration with environmental education and aesthetics are of critical importance to the ecological restoration movement. Restorations that invite interaction have tremendous opportunity to influence public opinion and allow practitioners to address the most seriously degraded environments**.**

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Estimating Digestibility in Eastern Gamagrass

Joel L. Douglas[1], Scott D. Edwards[1] and David J. Lang[2]

Equations to predict total digestible nutrients (TDN) were developed for a variety of introduced perennial forage grasses and legumes, and annual small grain forages (Undersander et al. 1993). Livestock producers and forage specialists use TDN equations to estimate the feed value of different forages and determine nutrient supplement needs. Quality estimates for crude protein (CP), acid detergent fiber (ADF) and neutral detergent fiber (NDF) are used in various equations to predict TDN. Age of forage at harvest is among several factors influencing quality estimates that will ultimately effect TDN. Because many TDN equations give emphasis to introduced forages, they have limited use for predicting TDN of native forage grasses such as eastern gamagrass [*Tripsacum dactyloides* (L.) L.].

The USDA-Natural Resources Conservation Service (NRCS) Jamie L. Whitten Plant Materials Center (PMC), Coffeeville, Mississippi has selected an accession of eastern gamagrass (9062680) for future release as a potential forage crop in the southeastern U.S. Information is needed on the effect of clipping frequency on quality estimates and true digestibility of 9062680. Therefore, the objectives of this study were to determine the effect of clipping frequency (CF) on forage quality estimates for ADF, NDF, CP and lignin (L), and determine if these estimates could be regressed on *in vitro* dry matter digestibility (IVDMD) to estimate digestibility of the grass.

Methods

The 118 samples used in this study were collected from replicated plots clipped on a 30 and 45 day CF in 1996-1998 at the USDA-NRCS Jamie L. Whitten PMC near Coffeeville, MS. For specific details on experimental design, clipping management, and fertilization, refer to paper by Edwards et al. (2000) published in this Proceedings.

In 1996, 30 day harvests were made 14 June, 15 July and 12 August and the 45 day harvests were made 28 June and 12 August. In 1997, 30 day harvests were made 14 May, 19 June, 18 July and 18 August and the 45 day harvest were made 19 May, 30 June, and 11 August. In 1998, 30-day harvests were made 22 May, 18 June, 24 July and 3 September and 45 day harvests were made 22 May, 30 June, and 25 August.

Harvested material was weighed green in the field and random samples collected for dry matter (DM) yield, %N, ADF, NDF, L, and IVDMD. Samples were dried at 55°C for 16 hours (Undersander et al. 1993). Percent N was determined from Kjeldahl N digest using flow injection analysis on a Lachat Quick Chem Automated Ion Analyzer (Lachat Instruments, Milwaukee, WI). Crude protein was estimated by multiplying %N by 6.25. Acid detergent fiber, NDF, L, IVDMD were determined by the procedures of Goering and Van Soest (1970) with IVDMD utilizing a Daisy[II] Incubator and an ANKOM[200/220] Fiber Analyzer (Cherney et al. 1997). Data was subjected to analysis of variance and step wise regression procedure for general linear models in SAS (v 6.12, (1996) SAS Institute Inc., Cary, NC). Duncan's multiple range test (DMRT) at the 5% level of probability separated significant differences between means.

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Results
Yield

There was a marked decrease in DM yield in 1998 for the 30 day CF (Table 1). The grass was slow to recover from winter dormancy in 1998 and weed competition became a problem as the stand declined during the year. Brakie (1998) reported that a 30-day CF weakened stands of Texas ecotypes of eastern gamagrass in eastern Texas. This frequent defoliation coupled with morphological development and physiological processes of the plant may have contributed to a reduction in organic reserves in the above ground shoots that limited regrowth and thus, lowered DM yield in 1998 (Dewald and Sims 1981). Above average growing season rainfall totals in 1996 and 1997, particularly in June, may have contributed to DM yield similarities between CF (Table 2). Remarkably, DM yield of 9062680 harvested in 1998 with a 45 day CF was comparable to yields observed in 1996 and 1997 and produced 333% more DM yield than the 30 day CF despite lower than average rainfall in 1998. A visual investigation of the plants in the 30-day CF plots found them to be less vigorous and slower to recover following defoliation than plants clipped in the 45-day CF plots in 1998. Dry matter yields reported for 9062680 are comparable to those reported for PMK-24 eastern gamagrass in south central Missouri and southern Illinois (Brejda 1997; Faix et al. 1980).

Quality

The 30-day CF typically produced lower fiber, higher protein and IVDMD than the 45 day CF in 1996-1998 (Table 3). In 1996 and 1998 the 30 day CF significantly increased IVDMD by 3% units and 6% units, respectively, compared to the 45 day clipping frequency. The IVDMD values for 9062680 for both clipping frequencies are higher than those reported for ‘Coastal’ bermudagrass [*Cynodon dactylon* (L.) Pers.] harvested at four weeks (Ball et al. 1991). The 30-day CF significantly decreased ADF by 6% units in 1996. In comparing the 3-year average, the 30-day CF produced a significantly lower ADF and a significantly higher protein and IVDMD than the 45-day CF but the magnitude of these differences were small. Brejda et al. (1994) and Horner et al. (1985) reported similar ADF, protein, and lignin but lower NDF for eastern gamagrass in their studies. The average IVDMD for 9062680 was 18% units higher than those reported for PMK-24 eastern gamagrass (Brejda 1994; Faix et al. 1985). However, Burns et al. (1992) reported ingestive masticates of ‘Pete’ eastern gamagrass ranged from 64 to 80% IVDMD. True digestibility of eastern gamagrass may be higher than indicated by conventional Van Soest estimates. Horner et al. (1985) reported that eastern gamagrass was nearly equal to alfalfa [*Medicago sativa* L.] as a source of hay for lactating dairy cows.

Table 1. Season total DM yield of 9062680 eastern gamagrass as influenced by CF in 1996-1998 and 3-year average, Coffeeville, MS.

	Year			
Frequency	1996	1997	1998	3 yr. avg.
	-----lbs/acre-----			
30	12 494 a*	13 123 a	3707 a	9775 a
45	10 361 a	14 652 a	12 329 b	12 447 b

* Means in columns within year and 3 year average followed by the same letters are not significantly different at P≤0.05 according to DMRT.

Estimating digestibility

Undersander et al. (1993) identified numerous digestibility equations for different regions of the U.S. utilizing ADF, CP, and NDF to predict TDN of various perennial and annual grasses, legumes, and other crops. In this study, regression analysis produced similar equations for the 30 and 45 day CF when ADF, NDF, CP and L estimates were regressed on IVDMD (data not shown). Therefore, data were pooled for final statistical analyses.

Table 2. Rainfall received during the growing season for 1996 – 1998 and 20 year average, Coffeeville, MS.

	Rainfall			
Month	1996	1997	1998	20 yr. Avg.
	---------------------------inches---------------------------			
March	5.20	7.83	6.57	5.75
April	5.94	3.15	5.59	5.47
May	3.90	7.17	4.53	5.75
June	11.77	12.32	1.97	4.84
July	4.80	4.09	4.09	4.33
August	3.50	3.15	3.62	3.27
September	7.52	5.59	0.28	4.17
Total	42.64	43.31	26.65	33.58

Regression analysis gave different equations each year (Table 4). Although the regression equations for 1996-1998 were highly significant, their correlation was weak. The equation produced in 1996 with NDF, CP and L gave the highest correlation. Bidlack et al. (1999) found that IVDMD was highly correlated with L and CP in the genotypes of eastern gamagrass in their study. When combined over years, no combination of quality estimates produced a consistent equation. However, ADF and CP remained in the over all equation but was a weak primary influence. Many state and university forage testing laboratories in the southeastern U.S. use ADF and CP for predicting TDN of cool and warm season grasses and legumes, grass-legume combinations, and other forages (http://www.uark.edu/depts/agronomy/facpage/west/tdn). The overall equation has relevance for estimating digestibility of 9062680. Additional laboratory analysis may be necessary before an equation can be verified. In addition, *in vivo* digestibility studies need to be conducted.

Table 3. Quality estimates of 9062680 eastern gamagrass as influenced by CF in 1996-1998 and 3-year average, Coffeeville, MS.

	Quality estimates				
Frequency	ADF[1]	NDF[2]	CP[3]	L[4]	IVDMD[5]
1996	-------------------------------------%-----------------------------------				
30	38 a*	79 a	10 a	8 a	79 a
45	44 b	78 b	8 b	11 a	76 b
1997					
30	40 a	80 a	10 a	8 a	74 a
45	42 a	81 a	10 a	11 a	74 a
1998					
30	42 a	78 a	11 a	8 a	77 a
45	41 a	77 b	10 a	12 b	71 b
3 yr. Avg.					
30	40 a	79 a	10 a	8 a	77 a
45	42 b	79 a	9 b	11 a	74 a

1 - acid detergent fiber; 2 - neutral detergent fiber; 3 - crude protein; 4 - lignin; 5 - *in vitro* dry matter digestibility.
* Means in columns within year and 3 year average followed by the same case letters are not significantly different at $P \leq 0.05$ according to DMRT.

Conclusions

A 45-day CF appears to be suited for sustainable yields and favorable quality for 9062680 eastern gamagrass. There was no combination of quality estimates that produced a consistent equation for estimating digestibility of the grass. However, CP and ADF remained in the overall equation but were a weak influence. The overall equation has relevance for estimating digestibility of 9062680 but additional laboratory analysis will be conducted before a final equation is verified.

Table 4. Regression equations, R^2 and P values for IVDMD (Y) vs. quality estimates (ADF[1], NDF[2], CP[3] and L[4]) of 9062680 eastern gamagrass for 1996-1998 and combined over years.

Year	Regression equation	R^2	P value
1996	Y = 85.6 - 0.33 * NDF + 1.63 * CP + 0.24 * L	0.63	0.0001
1997	Y = 67.7 - 0.27 * ADF + 0.22 * NDF	0.16	0.0242
1998	Y = 77.3 - 0.43 * L	0.19	0.0112
Combined over yrs.	Y = 77.9 - 0.21 * ADF + 0.56 * CP	0.13	0.0004

1 - acid detergent fiber; 2- neutral detergent fiber; 3 - crude protein; 4 - lignin.

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A Comparison of Seed Cleaning Techniques for Improving Quality of Eastern Gamagrass Seed

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Eastern gamagrass [*Tripsacum dactyloides* (L.) L.] is a native warm-season perennial bunchgrass with potential for livestock forage and cropland erosion control in the Southeast (Ball et al. 1991; Dewald et al. 1996). Attempts to establish stands from seed have given inconsistent results. The seed of eastern gamagrass is protected between a rachis internode and an outer glume association known as a cupulate fruitcase (Galinat 1956). The cupulate fruitcase has been shown to inhibit germination in some genotypes of eastern gamagrass, but germination can be enhanced with cold-moist stratification for 60 days followed by exposure to temperatures of at least 30° C (Anderson 1990). Indeterminate seed maturity is another factor that indirectly affects seed quality. A typical combine-run harvest consists of complete seed units (cupulate fruitcase with filled seed), incomplete seed units (cupulate fruitcase with unfilled seed) and other non-viable inert matter. Inability to adequately separate filled seeds from unfilled seeds may lead to poor establishment (Ahring and Franks 1968).

Air screen cleaners (ASC) are commonly used for cleaning eastern gamagrass seed. They remove most of the inert matter and a portion of immature seed units, but are not capable of separating complete seed units from incomplete ones. Similarities in size and shape, and the inability of the system's air flow mechanism to separate complete units from incomplete units complicates cleaning operations, thus both types are included in the final product. A South Dakota Seed Blower has been shown to improve separation of complete seed units from incomplete seed units of eastern gamagrass and increase germination potential 73 to 95% (Ahring and Franks,1968). However, the South Dakota Seed Blower was designed for processing limited seed quantities and does not have the capacity to accommodate large seed lots.

An air fractionating aspirator (AFA) is a seed cleaner that utilizes terminal velocity to separate light materials from heavy materials and partitions them into fractions. Gravity separator (GS) uses specific gravity created by forced air and oscillating movement to separate seed components according to density. Both of these cleaning techniques have potential to improve seed quality of eastern gamagrass.

There is no published literature on the use of an AFA or GS to improve seed quality of eastern gamagrass once the seed has been partially cleaned with an air screen cleaner. Therefore, the objective of this study was to compare percent fill and percent germination of fractions separated by an AFA and GS, and contrast these results to those for a single fraction from an ASC.

Methods

Three lots were chosen for the experiment. Lots A, B, and C were harvested with a John Deere 4400 conventional combine in September 1992, 1993, and 1995, respectively, from a stand of eastern gamagrass at the USDA-Natural Resources Conservation Service, Jamie L. Whitten Plant Materials Center (PMC) near Coffeeville, Mississippi. Seed units and other components of the harvest were spread evenly on a concrete floor and allowed to air dry in a ventilated warehouse for approximately one week. An ASC (Clipper M2B, A. T. Ferrell and Co., Saginaw, MI), equipped with an upper and lower screen, was used for cleaning. Seed units were stored in

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Accepted for publication in Journal of Seed Science and Technology

cloth bags and placed in a storage vault maintained at 13° C and 45% relative humidity. In January 1997, a 4.5 kg random sub-sample was collected from each lot.

A 200 gram random sub-sub-sample was obtained from each 4.5 kg sub-sample and separated into four fractions with an AFA (Carter-Day Model No. CF 21, Minneapolis, MN). Each fraction was weighed to determine its percentage relative to the sample size.

A GS (Oliver MFG, Rocky Ford, CO) was used to separate a 3.5 kg sub sample of lot C into two fractions. Weight or percentage of the two fractions was not determined due to the excessive loss of seed units that fell from the GS to the floor during the cleaning operation.

Percent filled seed was determined by hand dissecting three replicates of 10 randomly selected seed units to determine the presence or absence of a seed. A single fraction from each lot separated by an ASC served as a control. Four replications of 25 seed units were randomly selected from each fraction and control, and planted in 17.5 cm x 13.3 cm x 5.9 cm containers filled with a commercial potting medium. Containers were placed in a cooler maintained at 5° C with no humidity control on 15 April 1997 for cold-moist stratification. Containers were watered regularly to keep potting medium moistened.

Containers were removed from the cooler and placed in a greenhouse on 27 May 1997. Germination counts were made 7, 14, and 21 days after placement in the greenhouse. Total germination was determined by summing germination counts at the end of 21 days.

Filled seed and germination percentages by fraction and lot were subjected to an analysis of variance procedure in MSTAT-C (Michigan State Univ. 1988) and significant means were determined by least significant difference (LSD) at $P<0.05$ (Gomez and Gomez 1984).

Results

There was variability between lots in the percentage of seed units contained in each fraction from the AFA (Table 1). Fractions one and two, which contained the heaviest seed units, accounted for 37, 28 and 40% of the seed in lots A, B, and C, respectively. Light seed units and inert matter, contained in fractions three and four, accounted for 60% or more of the lots. Differences in percentage of seed units in each fraction indicate that an AFA has the capability to make discreet separations between seed components not obtainable with an ASC.

Table 1. Percent seed units accounted for in each lot by fraction as determined by AFA.

	Lot		
Fraction	A	B	C
	----------------	%	----------------
1	20	11	20
2	17	17	20
3	35	35	30
4	28	37	30

Seed fill of fractions by lot and cleaning technique was defined by determining the presence or absence of a seed. Fractions one and two of lot A, B and C separated by the AFA, and fraction one of lot C separated by the GS, had significantly increased seed fill compared to the other fractions and control (Table 2). This indicates that the heaviest seed units associated with these fractions contained a filled seed determined to be of good quality based on size and visual appearance. Fraction three from the AFA was determined to have a higher percent fill than fraction four and the control. Compared to the control, fractions one and two in lot A, B, and C from the AFA were found to increase germination potential 44, 67 and 61%, respectively. Fraction one from the GS increased germination potential 67% when compared to the control.

Ahring and Franks (1968) reported that a South Dakota Seed Blower increased germination potential 73 to 95%.

Percent germination for each fraction by lot and cleaning technique is presented in Table 3. Percent germination of fractions one and two of lot A and B separated by the AFA was found to be significantly higher than fractions three and four. Germination percentages of fractions one and two of lot A were also significantly higher than the control. Germination of fraction one from the GS was significantly higher than fraction two and the control. Typically the first fractions had the highest germination percentages because they had a higher seed fill and thus a greater germination potential. Although fraction three from the AFA contained a reasonably high percentage of filled seed this germination potential was not reflected in the actual germination percentages.

Table 2. Percent seed fill by lot and fraction for two cleaning techniques.

	AFA			GS
	Lot			
Fraction	A	B	C	C
	%			
1	93	90	87	90
2	90	90	80	30
3	57	73	43	--
4	10	20	20	--
Control	47	23	23	23
LSD (0.05)	22	12	25	30

Low germination percentages for fractions with high germination potential could be explained by seed dormancy that was not overcome by stratification (Anderson 1990) or by lesser quality of seed than was visually estimated. Possibly a higher germination rate could have been obtained if the test had been extended beyond 21 days.

Table 3. Percent germination by lot and fraction for two cleaning techniques.

	AFA			GS
	Lot			
Fraction	A	B	C	C
	%			
1	43	21	24	48
2	35	29	25	15
3	15	15	18	--
4	3	3	3	--
Control	22	22	16	22
LSD (0.05)	12	12	10	13

Conclusions

Results show that seed quality of lots used in this study was improved with these seed cleaning techniques. Fractions one and two from the AFA and fraction one from the GS contained the highest seed quality. Fraction four and most likely fraction three from AFA can be discarded during the cleaning operation because they may contribute few germinable seed. However, examination of several seed units for seed fill will determine whether the third fraction is discarded or retained.

Potential implications of such cleaning techniques include improving uniformity of stands, pricing of lots based on seed quality and selecting for seedling vigor. Seed companies upgrading seed cleaning equipment to improve quality of eastern gamagrass seed may want to consider an AFA as opposed to a GS due to reduced equipment costs. Based on preliminary results from this test, the GS may have the potential to better separate complete seed units from incomplete seed units but additional testing will be needed to verify this observation.

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Clipping Effect on Yield and Quality of Eastern Gamagrass, Switchgrass, and Bermudagrass

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In the southeastern United States, forage producers have relied on the introduced species bermudagrass [*Cynodon dactylon* (L.) Pers.] as a major component in their forage programs (Ball et. al 1991). Numerous cultivars have been released through plant breeding and selection to increase forage production and quality (USDA 1994). Bermudagrass should be harvested every 4 to 5 weeks to maintain optimum quality. The stage of maturity at harvest influences the palatability, crude protein content, and especially the digestible energy level. Forage quality deteriorates rapidly with advancing maturity even though yield will continue to increase (Ball et. al 1991).

Eastern gamagrass [*Tripsacum dactyloides* (L.) L.] and switchgrass [*Panicum virgatum* L.], both perennial warm-season grasses native to the southeastern United States, have potential as forage crops. Eastern gamagrass is adapted from Massachusetts to Michigan, Iowa and Nebraska, south to Florida and Texas. Switchgrass has an even larger distribution from Maine to North Dakota and Wyoming, south to Florida, Arizona and Mexico (Hitchcock 1951).

The increased demand for native forage species for summer grazing (Burns et al. 1992), hay production (Hall et al. 1982) and silage (Brejda et al. 1994) have resulted in many advances in seed production, seed quality and stand establishment techniques. However, limited information is available on production potential of native grasses under management conditions used for introduced species (i.e., frequent clipping). The objective of this study was to evaluate clipping effects on yield and quality of eastern gamagrass, switchgrass, and bermudagrass.

Methods

The study was conducted over a 3-year period from 1996 to 1998 at the USDA-NRCS-Jamie L. Whitten Plant Materials Center near Coffeeville, MS, on an Oaklimeter silt loam (Coarse-silty, mixed, thermic Fluvaquentic Dystrochrepts). Plots were established from transplants and sprigs and allowed to grow for 2 years before clipping treatments were introduced in May 1996.

During the establishment phase, 60 lbs N, 26 lbs P, and 36 lbs K were applied. All species were burned each spring prior to green-up. Thirty days after green-up all plots received 60 lbs N, 39 lbs P, and 48 lbs K. After initial harvest, 180 lb N and 120 lb K were applied in split applications. Study design was a split plot in a randomized complete block with 5 replications. Plots were split by 30 days and 45 days clipping frequency into 10 by 20-ft plots.

Bermudagrass and switchgrass were harvested from a 3-ft by 20-ft strip in each plot at a 4 inch cutting height using a sickle bar mower. Five eastern gamagrass plants were harvested from each plot to a 4-inch cutting height with a hand held sickle bar trimmer. Harvested material was weighed green in the field before a subsample was collected from each plot. Dry matter content was determined by drying sample in a forced air oven at 55°C for 16 hours. In 1996, 30 day plots were harvested 14 June, 15 July and 12 August; 45 day plots were harvested 28 June and 12 August. In 1997, 30 day plots were harvested 14 May, 19 June, 18 July and 18 August; 45 day plots 19 May, 30 June, and 11 August. In 1998, 30 day plots were harvested 22 May, 18 June, 24 July and 3 September; 45 day plots 22 May, 30 June, and 25 August. Precipitation was recorded on-site at the PMC for each year of the study (Table 1).

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Table 1. Growing season precipitation totals for 1996 – 1998 and 20 year average, Coffeeville, Mississippi.

	Precipitation			
Month	1996	1997	1998	20 yr avg.
	---------------------------inches-----------------------------------			
March	5.20	7.83	6.57	5.75
April	5.94	3.15	5.59	5.47
May	3.90	7.17	4.53	5.75
June	11.77	12.32	1.97	4.84
July	4.80	4.09	4.09	4.33
August	3.50	3.15	3.62	3.27
September	7.52	5.59	0.28	4.17
Total	42.64	43.31	26.65	33.58

Harvested material was weighed green in the field and random samples collected for dry matter (DM) yield, %N, ADF, NDF. Samples were dried at 55°C for 16 hours. Percent N was determined from Kjeldahl N digest using flow injection analysis on a Lachat Quick Chem Automated Ion Analyzer (Lachat Instruments, Milwaukee, WI). Acid detergent fiber and NDF were analyzed with an ANKOM$^{200/220}$ Fiber Analyzer (Cherney et al. 1997). Data was subjected to analysis of variance in SAS (v 6.12, (1996) SAS Institute Inc., Cary, NC). Duncan's multiple range test (DMRT) at the 5% level of probability separated significant differences between means.

Table 2. Influence of clipping frequency on season total dry matter yield of 3 warm season grasses, 1996-1998, Coffeeville, Mississippi.

	Year			
Frequency	1996	1997	1998	**Mean**
----------------------------------Bermudagrass-------------------------------				
	-------------------------------lbs/ acre-------------------------------			
30 day	11561	10221	10542	10775
45 day	11092	7905	10860	9952
LSD (0.05)	**NS***	1602	NS	693
--------------------------------------Eastern gamagrass---------------------------				
30 day	12494	13123	3707	9775
45 day	10361	14652	12329	12447
LSD (0.05)	NS	**NS**	2235	2517
----------------------------------Switchgrass----------------------------				
30 day	5681	5675	8594	6650
45 day	3130	7914	12300	7781
LSD (0.05)	989	1915	1297	933

* Not significant

Results

There was a significant year x frequency x species interaction, therefore each frequency was analyzed separately. Bermudagrass produced relatively consistent yields each year for both clipping frequencies with no differences in 1996 and 1998 (Table 2). These bermudagrass yields agree with Fisher and Caldwell (1958) but are higher than 4 year average yield for 'Tifton 44' reported by Hearn (1999).

Eastern gamagrass responded early to a 30 day frequency but decreased 71% to 3707 lb/acre in 1998 (Table 3). In 1998, eastern gamagrass clipped on 30 day was slow to recover from winter dormancy and excessive weed competition became a problem as the stand declined under the frequent clipping regime. Brakie (1998) reported that a 30 day clipping frequency weakened plants of southern ecotypes of eastern gamagrass in eastern Texas. Kinsinger and Hopkins (1961) found that frequent defoliation in big bluestem [*Andropogon gerardii* Vitman] and western wheatgrass [*Pascopyrum smithii* (Rydb.) A. Love] depleted root reserves. These food reserves are important for growth and regrowth following dormancy, defoliation, and other stressful conditions (Sosebee and Wiebe 1971).

Brejda (1997) reported significant variation in eastern gamagrass forage yield between years because of wide variation in growing season precipitation amounts. In this study, it appears that clipping frequency had more of an effect on yield for eastern gamagrass than precipitation. During this study precipitation received during the growing season was more than 21% above the 20 year average in 1996 and 23% above average in 1997. In 1998, growing season precipitation was 21% below the 20 year average. During 1998, with limited precipitation, there was no significant difference in yield for 45 day plots as compared to 1996 and 1997. Eastern gamagrass yields reported in this study for 45 day clipping frequency are consistent with yields reported by Brejda (1997) but are lower than those reported by Brakie (1998).

Table 3. Season total dry matter yield comparison of 3 warm season grasses clipped on 30 and 45 day frequency, 1996 – 1998, Coffeeville, Mississippi.

Year	Bermudagrass	Eastern gamagrass	Switchgrass	LSD (0.05)
-------30 day Clipping Frequency-------				
	------lbs / acre------			
1996	11561	12494	5682	1983
1997	10221	13123	5675	2560
1998	10541	3707	8597	1214
LSD (0.05)	1065	3088	1136	
-------45 day Clipping Frequency-------				
	------lbs / acre------			
1996	11092	10361	3130	1377
1997	7905	14652	7914	3654
1998	10860	12329	12300	NS
LSD (0.05)	1381	NS*	1573	

* Not significant

Bermudagrass and eastern gamagrass produced significantly higher yields than switchgrass in 1996 and 1997 when clipped on 30 days. In 1998, there was a significant increase in switchgrass yield. This is somewhat misleading because over half of the season total yield for 1998 30 day clipping frequency was produced in the third cutting (data not shown). Switchgrass clipped on 30 day began to show signs of decline similar to the eastern gamagrass with increased weed competition following winter dormancy which severely limited yield in the first and second cutting. Beaty and Powell (1975) reported that switchgrass yield and stand decreased under frequent defoliation resulting in an increase in weed growth.

Switchgrass yields increased significantly each year under 45 day clipping frequency. There was a 9170 lbs/acre increase from 1996 to 1998. In 1998, there was no significant difference between species clipped on 45 day. Switchgrass yields reported in this study are 3 times larger than those reported by Beaty and Powell (1975).

There were significant differences in crude protein, ADF and NDF for species clipped on a 30 day frequency (Table 4). Percent crude protein content ranged from 6 to 11% in bermudagrass, 8 to 12% in eastern gamagrass and 7 to 13% in switchgrass. Crude protein contents for eastern gamagrass are in agreement with Brakie (1998). Protein content increased with each cutting in all three years peaking in the third or fourth cutting except in 1998. The highest crude protein content was in the 1998 second cutting during an extremely low precipitation period. Kamstra (1973) and Perry and Baltensperger (1979) reported that higher crude protein levels in switchgrass during drought years are associated with a higher leaf to stem ratio.

Table 4. Quality estimates by cutting and species for 30 day clipping frequency in 1996 – 1998, Coffeeville, Mississippi.

Species	% Protein				% ADF				% NDF			
	------Cutting--------				-----Cutting---------				-----------Cutting------			
	1	2	3	4	1	2	3	4	1	2	3	4
	1996											
Bermudagrass	8	9	8	10	38	33	37	36	72	71	72	71
Eastern gamagrass	10	10	10	12	41	38	39	37	67	69	67	67
Switchgrass	10	9	7	9	34	34	38	36	71	69	69	66
	1997											
Bermudagrass	6	12	10	11	33	34	35	33	72	70	70	70
Eastern gamagrass	10	8	12	12	37	38	38	38	69	70	68	67
Switchgrass	10	8	12	12	34	33	35	35	67	70	66	65
	1998											
Bermudagrass	9	11	9	8	38	35	38	40	74	71	71	70
Eastern gamagrass	9	12	10	N/A*	36	36	38	N/A	67	66	68	N/A
Switchgrass	8	13	10	N/A	37	34	38	N/A	68	65	67	N/A

LSD (0.05) for differences in species and cutting for Protein = 1.5
LSD (0.05) for differences in species and cutting for ADF = 2.0
LSD (0.05) for differences in species and cutting for NDF = 2.0

* N/A = Eastern gamagrass and Switchgrass were only clipped three times in 1998.

Percent ADF ranged from 33 to 40% in bermudagrass which was significantly lower than eastern gamagrass (36 to 41%) in all cuttings in 1996 and 1997. In 1998, there was no significant difference in %ADF. Eastern gamagrass and switchgrass had significantly lower %NDF per cutting as compared to bermudagrass for all years on a 30 day clipping frequency.

In 1997, bermudagrass was only clipped twice on a 45 day clipping frequency. Bermudagrass did not respond well to a late 45 day harvest in 1996. Bermudagrass clipped on 45 day produced lower % crude protein than both eastern gamagrass and switchgrass (Table 5). Protein levels remained more consistent across cuttings for eastern gamagrass and switchgrass unlike the 30 day frequency ranging from 6 to 11% and 6 to 10% respectively.

There was no significant difference in %ADF across cuttings or species in 1998 on a 45 day cutting frequency. Percent NDF also remained constant from first to last cutting each year with no significant difference within species.

Table 5. Quality estimates by cutting and species for 45 day clipping frequency in 1996 – 1998, Coffeeville, Mississippi.

Species	% Protein			% ADF			% NDF		
	------Cutting------			------Cutting------			-----Cutting-------		
	1	2	3	1	2	3	1	2	3
	--------------------------------1996----------------------------------								
Bermudagrass	8	6	7	37	38	38	72	74	72
Eastern gamagrass	10	6	9	37	41	40	71	70	70
Switchgrass	10	6	7	33	40	38	71	71	68
	--------------------------------1997----------------------------------								
Bermudagrass	5	6	N/A*	35	38	N/A	74	74	N/A
Eastern gamagrass	11	10	10	38	40	39	69	72	68
Switchgrass	10	8	8	34	36	39	67	71	70
	--------------------------------1998----------------------------------								
Bermudagrass	9	9	7	37	38	39	75	73	71
Eastern gamagrass	10	10	10	37	38	38	68	68	70
Switchgrass	8	10	7	36	37	38	68	68	65

LSD (0.05) for differences in species and cutting for Protein = 1.5
LSD (0.05) for differences in species and cutting for ADF = 2.5
LSD (0.05) for differences in species and cutting for NDF = 4.0

* N/A = Bermudagrass was only clipped twice in 1997.

Conclusions

A 45 day clipping frequency typically represents two to three harvests per growing season in the lower southern states, but is greatly influenced by moisture and length of growing season. Eastern gamagrass clipped on 45 day had a 3 year average dry matter yield of 12 447 lb/acre with no significant variation between years. Bermudagrass clipped on 30 day had one more clipping per year but only had a 3 year average dry matter yield of 10 775. Clipping on a 30 day frequency reduced stands allowing weeds to invade both eastern gamagrass and switchgrass. A 45 day clipping frequency appears to be more suited for eastern gamagrass, as indicated by the sustained yield across years.

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New and Upcoming Native Grass Releases from the Eastern US Plant Materials Centers

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Introduction

In recent years there has been an increased emphasis in using native plants for planting projects ranging from ecosystem restoration to USDA conservation programs to home landscaping. In the eastern US many of these native species are often available in limited quantities or only as vegetative propagules, which makes large planting projects expensive or difficult. The eight eastern US Plant Materials Centers (PMC) of the USDA-NRCS Plant Materials Program are currently developing nearly 50 new native grass releases for the eastern US. These new releases have their origin in the eastern US, and will serve important roles in conservation programs and restoration activities in the region.

Meeting the Challenge

Current needs for native plants in restoration or conservation projects often calls for local-source ecotypes. Depending on the user's concept of "native" and the type of planting being conducted, "local-source" plant materials can be defined as material found from several miles to several *hundred* miles from the location of the planting site. For small projects, it is often possible to find very local materials either through collection or small-scale production. For larger projects covering hundreds or thousands of acres, plant materials are usually purchased from commercial nurseries. Native grasses in the East are often expensive, in limited quantities as seed, or impossible to find, thus making it necessary to develop and release new plants for the eastern US. Plant Materials Centers seek to find a middle ground when developing new native grass releases. Releases must have the potential to be viable in the commercial market in order to meet the needs of conservation activities supported by USDA. To accomplish this, PMCs carefully assemble and select plants to meet identified needs and assess the viability of the proposed release for commercial production.

The Development of New Releases

There are four types of plant releases defined by the Association of Official Seed Certifying Agencies (AOSCA). The traditional type of release that most people are familiar with is the cultivar. *Cultivars* are the most developed release material. The material is usually genetically uniform, and the performance and adaptation of the cultivar has been well documented. *Tested* and *Selected* types have had some genetic selection and the materials may have undergone varying degrees of testing on planting sites. The material usually has greater genetic diversity than the cultivar, but the performance and adaptation of tested and selected classes of releases may not be fully investigated. *Source-identified* types are typically "straight from the field" and may have the most genetic diversity within the collection. There is usually no information developed on the performance and adaptation of source-identified releases beyond what can be inferred from the collection site.

When ecological restoration or enhancement is the goal of a planting project, locally collected, source-identified plant materials are usually preferred because they are assumed to have a wide variety of genetic material which is adapted to the area around the planting site. For most conservation work, and in particular the stabilization of "highly stressed" critical areas, using source-identified class plant materials may be risky due to the lack of performance information on the material. With critical area stabilization work, such as that done on streambanks and

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shorelines, it is necessary to stabilize the site so that excessive erosion does not occur. In this case, cultivars which are specifically adapted to such sites are often the best suited. Similar situations may occur in other conservation activities. In the case of plant materials used for forage, cultivars specifically selected for improved nutrition and regrowth may outperform local unselected materials. “Middle ground” type projects include those for buffers and wildlife plantings. Usually it is desirable to know that the plant materials are going to achieve the desired results, i.e. produce food for wildlife or provide a vegetative buffer between developed land and a wetland, but it is often not necessary or desirable to have highly selected materials or to know the entire range of performance and adaptation. In this case, selected and tested class releases are often best suited. The bottom line is that the person or office planning the planting needs to decide what the objective is and which plant materials are best suited to meet that objective.

One of the major challenges in using native grasses is finding local ecotypes, which are native to the eastern, US. Many of the warm-season grass cultivars now used in the East are from mid-western sources. Finding local ecotype materials for conservation activities can be especially challenging. There are very few species of cool-season native grasses available from commercial sources. PMCs in the east are currently making collections of both cool-season and warm-season native grass species. Materials that are currently being selected or developed are often collected from areas over 100-300 miles in diameter, and the intended area of use is usually similar in size to the original collection area. In this way we are able to release a plant that should have enough market potential to be a viable product to commercial growers, but yet retain the native germplasm of the intended area of use. Depending on the class of release, the plant materials have undergone different levels of selection and testing appropriate to the intended use of the material.

Plant Materials Currently Being Evaluated for Release

There are currently about 50 new assemblies for potential release under evaluation (Table 1). These assemblies range in development from source-identified to cultivar type releases. Anticipated dates of release and availability on the commercial market range from 2000 to 2006. Table 1 briefly describes these species under evaluation and details anticipated uses and area of adaptation for these species. For more information on particular materials, please contact the PMC listed under the “Releasing PMC” column in Table 1. A listing of contact information for these PMCs is located in Table 2.

Table 1. Listing of native grasses under evaluation.

Scientific Name/ Common Name	Projected Year of Release	Collection Location	Releasing PMC	Type of Release	Known or Potential Uses	Area of Adaptation or Use
Warm-season Grass Species						
Amphicarpum muhlenbergianum (Schult.) Hitchc. / blue maidencane	2001-2002	Florida	FLPMC	Selected	forage, wetland restoration, improve water quality	Florida
Andropogon gerardii Vitman / big bluestem	2002-2003	Great Lakes states	MIPMC	Cultivar	Rotational grazing systems	Great Lakes region
Andropogon gerardii Vitman / big bluestem	2001-2002	lower MI peninsula	MIPMC	Source-identified	Cons. Reserve Program, other conservation uses	lower MI peninsula
Andropogon gerardii Vitman / big bluestem	2002-2003	Mid-Atlantic US	NJPMC	Selected	general conservation use	Mid-Atlantic
Andropogon glomeratus(Walter) Britton et al. var. *glaucopsis/* chalky bluestem	2002-2003	Florida	FLPMC	Selected	forage, wetland restoration, improve water quality	Florida
Calamovilfa longifolia (Hook.) Scribn. / prairie sandreed	2002-2003	Great Lakes coastal areas	MIPMC	Tested	dune stabilization	Great Lakes coastal areas
Coelorachis (Manisuris) cylindrica/ Carolina jointtail grass	2002-2003	Southern Mid-Atlantic coastline	NJPMC	Selected	general conservation use	southern Mid-Atlantic coastline
Panicum anceps Michx. / Beaked panicum	2002-2003	Mid-Atlantic Coastal Plain	NJPMC	selected	tolerant to hot dry site, high pH, and high heavy metals	Mid-Atlantic states
Panicum virgatum L./ 'Carthage' switchgrass	2000	Carthage, NC	NJPMC	cultivar	wildlife habitat, buffers, pastures, and as a component of native plant mixes	Mid-Atlantic US
Panicum virgatum L./ Switchgrass	2002	Brooklyn, NY	NJPMC	tested	dune/coastal stabilization, critical area stabilization	Mid-Atlantic coast line
Panicum virgatum L./ Switchgrass	2001-2002	lower MI peninsula	MIPMC	source-identified	Conservation Reserve Program, other conservation uses	lower MI peninsula

Scientific Name/ Common Name	**Projected Year of Release**	**Collection Location**	**Releasing PMC**	**Type of Release**	**Known or Potential Uses**	**Area of Adaptation or Use**
Panicum virgatum L./ Switchgrass	2002	northern Mid-Atlantic Piedmont	MDPMC	selected	General conservation use	northern Mid-Atlantic Piedmont
Panicum virgatum L./ Switchgrass	2003-2004	Mid-Atlantic US	NJPMC	selected/ tested	Saline-tolerant; for riparian area stabilization in saline-water areas	Mid-Atlantic coastal areas
Schizachyrium scoparium (Michx.) Nash / Little bluestem	2001-2002	lower MI peninsula	MIPMC	source-identified	Conservation Reserve Program, other conservation uses	lower MI peninsula
Schizachyrium scoparium (Michx.) Nash / Little bluestem	2002	Mid-Atlantic US	NJPMC	selected	General conservation use	Mid-Atlantic US
Schizachyrium scoparium var. *littoralis (Nash) Gandhi & Smeins /* Coastal little bluestem	2002	coastal Mid-Atlantic	NJPMC	selected	General conservation use	Mid-Atlantic Coastal sites
Sorghastrum secundum (Elliott) Nash / Lopsided Indiangrass	2002-2003	Florida	FLPMC	selected	wildlife habitat, rangeland improvement, native plant community restoration	Florida
Sorghastrum nutans (L.) Nash / Indiangrass	2000	composite NJ, DE, MD, VA	MDPMC	selected	general conservation use, wildlife habitat	northern Mid-Atlantic states
Sorghastrum nutans (L.) Nash / Indiangrass	2000-2001	GA, AL	GAPMC	cultivar	forage, grazing	Southeast US
Sorghastrum nutans (L.) Nash / Indiangrass	2001-2002	lower MI peninsula	MIPMC	source-identified	Conservation Reserve Program, other conservation uses	lower MI peninsula
Sorghastrum nutans (L.) Nash / Indiangrass	2003-2004	composite VA, NC	NJPMC	selected/ tested	general conservation use, grazing	southern Mid-Atlantic states
Sorghastrum nutans (L.) Nash / Indiangrass	2003-2004	composite NY, PA, MD	NYPMC	tested/ cultivar	wildlife habitat, general conservation use	lower Northeast states
Spartina pectinata Link/ Prairie cordgrass	2004	coastal Mid-Atlantic	NJPMC	tested	stabilization, improve water quality	Mid-Atlantic Coastal Plain

Scientific Name/ Common Name	Projected Year of Release	Collection Location	Releasing PMC	Type of Release	Known or Potential Uses	Area of Adaptation or Use
Spartina pectinata Link/ prairie cordgrass	2002-2003	Long Island, NY	NYPMC	selected	freshwater shoreline stabilization, critical area CRP, wet sites, riparian areas	lower Northeast States
Spartina pectinata Link/ prairie cordgrass	2002-2003	NH, MA	NYPMC	selected	freshwater shoreline stabilization, critical area CRP, wet sites, riparian areas	New England US
Tripsacum dactyloides (L.) L./ eastern gamagrass	2002-2003	Montgomery Co., TN	MSPMC, GAPMC	cultivar	Tetraploid; for forage, general conservation use	Southeast US
Tripsacum dactyloides (L.) L / eastern gamagrass	2001-2002	Florida	FLPMC	cultivar	forage, wildlife, general conservation	Florida and SE US
Tripsacum dactyloides (L.) L / eastern gamagrass	2001-2002	Florida	FLPMC	selected	Foliage has bluish color; xeriscaping, buffers	Florida
Tripsacum dactyloides (L.) L / eastern gamagrass	2001-2002	Beltsville, MD	NYPMC	tested/ cultivar	Tetraploid; higher forage production than 'Pete'	Mid-Atlantic and Northeast US
Uniola paniculata L. / sea oats	2000	Mid-Atlantic coastline	NJPMC	tested	dune stabilization, plant diversity, general conservation use	Mid-Atlantic US
Cool-season grass species						
Bromus pubescens Muhl. ex Willd. / Canada brome	2002-2004	Great Lakes region	MIPMC	selected	general conservation use, pasture	Great Lakes region
Bromus pubescens Muhl. ex Willd. / Canada brome	2002-2004	Mid-Atlantic Piedmont region	MDPMC	selected	general conservation use, pasture	Mid-Atlantic Piedmont region
Calamagrostis canadensis (Michx.) P. Beauv. / Canada bluejoint	2002-2004	Great Lakes region	MIPMC		general conservation use	Great Lakes region
Calamagrostis canadensis (Michx.) P. Beauv. / Canada bluejoint	2002-2004	upper Mid-Atlantic	NJPMC	selected	general conservation use	upper Mid-Atlantic

Scientific Name/ Common Name	Projected Year of Release	Collection Location	Releasing PMC	Type of Release	Known or Potential Uses	Area of Adaptation or Use
Calamagrostis canadensis (Michx.) P. Beauv. / Canada bluejoint	2002-2004	Northeast	NYPMC	selected/ tested	general conservation use	Northeast
Cinna arundinacea L. / stout woodreed	2002-2004	Mid-Atlantic Piedmont region	MDPMC	selected	general conservation use	Mid-Atlantic Piedmont region
Cinna arundinacea L. / stout woodreed	2002-2004	Northeast	NYPMC	selected	general conservation use	Northeast
Danthonia spicata (L.) P. Beauv. ex Roem. & Schult. / poverty oatgrass	2002-2004	Great Lakes region	MIPMC	selected	general conservation use	Great Lakes region
Danthonia spicata (L.) P. Beauv. ex Roem. & Schult. / poverty oatgrass	2002-2004	Northeast	NYPMC	selected	general conservation use	Northeast
Deschampsia flexuosa (L.) Trin. / crinkled hairgrass	2002-2004	Mid-Atlantic	NJPMC	selected	general conservation use	Mid-Atlantic
Elymus canadensis L. / Canada wildrye	2003-2004	Northeast	NYPMC	selected	general conservation use	Northeast
*Elymus canadensis L. /*Canada wildrye	2003-2004	Great Lakes region	MIPMC	selected	general conservation use	Great Lakes region
Elymus villosus Muhl. ex Willd. / hairy wildrye	2003-2004	Mid-Atlantic Piedmont region	MDPMC	selected	general conservation use	Mid-Atlantic Piedmont region
Elymus virginicus L. / Virginia wildrye	2001	Mid-Atlantic Piedmont region	MDPMC	selected	general conservation use	Mid-Atlantic Piedmont region
Elymus virginicus L. / Virginia wildrye	2002-2003	coastal NJ, VA, NC	NJPMC	selected	stabilization of backdune areas in the Mid-Atlantic	Mid-Atlantic US coastal areas
Elymus virginicus L. / Virginia wildrye	2001-2003	Great Lakes region	MIPMC	selected	general conservation use	Great Lakes region
*Hordeum pusillum Nutt. /*little barley	2002-2003	Mid-Atlantic Piedmont region, NC	MDPMC		winter annual cover crop	Mid-Atlantic states

Scientific Name/ Common Name	Projected Year of Release	Collection Location	Releasing PMC	Type of Release	Known or Potential Uses	Area of Adaptation or Use
Hystrix patula Moench/ bottlebrush grass	2001-2002	Mid-Atlantic Piedmont region	MDPMC	selected	general conservation use	Mid-Atlantic Piedmont region
Hystrix patula Moench/ bottlebrush grass	2002-2003	Great Lakes region	MIPMC	selected	general conservation use	Great Lakes region
Koeleria macrantha (Ledeb.) Schult.) / Junegrass	2002-2004	Great Lakes region	MIPMC	selected	general conservation use	Great Lakes region

Table 2. Contact Information for eastern PMCs

Florida
Clarence Maura, Jr.; PMC Manager
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Maryland
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USDA-NRCS National Plant Materials Center, Bldg. 509, BARC-East, E. Beaver Dam Rd., Beltsville, MD 20705
phone: 301-504-8175; fax: 301-504-8741; e-mail: jenglert@md.usda.gov

Michigan
Tony Bush; Acting Manager/Agronomist
USDA-NRCS Rose Lake Plant Materials Center, 7472 Stoll Rd., East Lansing, MI 48823-9420
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Mississippi
Joel L. Douglas; PMC Manager
USDA-NRCS Jamie L. Whitten Plant Materials Center, 2533 County Road 65, Coffeeville, MS 38922-2652
phone: 601-675-2588; fax: 601-675-2369; e-mail: jdouglas@ms.nrcs.usda.gov

New Jersey
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USDA-NRCS Cape May Plant Materials Center, 1536 Route 9 North, Cape May Court House, NJ 08210
phone: 609-465-5901; fax: 609-465-9284; e-mail: wskaradek@nj.nrcs.usda.gov

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West Virginia
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Is Growing Native Seeds for Me?
The Who, What, When, Where and Why

Calvin L. Ernst[1]

Summary

1. Are you one **who** has the resources and desire to be a native grass producer?

2. Do you know **what** should be grown?

3. **When** do you start growing native grasses and **when** will there be a return for growing seed?

4. **Where** are the best locations to grow native seeds and does that '**where**' limit the available species that can be grown?

5. **Why** should one be willing to grow native species?

Calvin Ernst, with his wife Marcia and three children, own and operate a seed production and marketing business known as Ernst Conservation Seeds.

The northwestern Pennsylvania farm consists of 1,600 acres of seed production for conservation and restoration use. About 30 full time employees are engaged in all aspects of growing and marketing conservation seed.

Our seed is marketed for environmental restoration of wetlands, roadsides, surface mining, wildlife habitat and landfills.

Our principal market is in the eastern United States and Canada through direct sales and through a network of seed distributors.

[1] General Partner, Ernst Conservation Seeds, Meadville, Pennsylvania

Extending the Grazing Season in Southeast Pennsylvania

Cheryl A. Fairbairn, G.A. Jung, and L.D. Hoffman[1]

Pasture is the cornerstone of a successful beef cattle operation. Green grass supplies most of the essential nutrients needed by a cow for all stages of her reproductive cycle. Desired goals of pasture production are:

1. To produce higher yields of palatable and nutritious forage.
2. To extend the grazing season from as early in the spring to as late in the Fall as possible.
3. To provide a fairly uniform supply of feed throughout the entire season.

No one plant species embodies all the desirable characteristics necessary to meet the above goals. None will grow year round or during extremely cold or dry weather. Each species has a period of peak growth which must be conserved for periods of little growth. Cattlemen must utilize various grass species and a combination of permanent, rotational and temporary pastures.

Warm season grass species such as switchgrass and big bluestem fit well into the scheme of weather patterns and pasture situations in southeastern Pennsylvania. The majority of pastures in southeastern Pennsylvania are comprised of cool season grasses such as orchardgrass, smooth bromegrass, timothy, and Kentucky bluegrass, which make 60 to 70 percent of their yearly production (growth) prior to June 15. Heavy grazing of these pastures along with high temperature and low moisture common to southeastern Pennsylvania usually results in very little grass for grazing during July and August.

Warm season grasses such as big bluestem, Indiangrass, and switchgrass make nearly 85% percent of their production after June 1. As temperatures reach 80°F and water stress increases, cool season grass growth slows and at 95°F cool season grasses grow very little. As cool season grass production slows, warm season grass production begins and continues through the summer.

In a cow/calf operation, weaning weights are often lowered due to the lack of green forages in July and August. At the same time cows often lose weight and milk production begins to tail off. Producers are often forced to feed expensive hay at this time to keep weight loss at a minimum or they graze their pastures to the ground resulting in little or no re-growth during the cool fall months. If they didn't feed hay in the summer, they are forced to begin feeding hay in early September.

Because of the extreme heat and low moisture found in southeastern Pennsylvania during the summer months, it was decided to try two warm season grass demonstration plots in Chester County. In May of 1983, with the cooperation of the USDA ARS Pasture Research Lab, Pennsylvania State Agronomy Department, the Natural Resource Conservation Service and the Pennsylvania State Extension Service, two fields totaling 12 acres were seeded to switchgrass. Both fields were no-tilled using a John Deere Power Drill and a Tye drill. Both were planted in corn stubble. No fertilizer or lime was applied at this time. An interesting aspect of these native grasses is that they can grow in acid soils and require less fertilizer than do cool season grasses. They also grow well in very droughty soils as well as very wet soils.

A major drawback of the warm season grasses is their slow establishment. They are slow to germinate and cannot withstand much competition from weeds. A herbicide program was utilized to keep broadleaf weed competition to a minimum. Cattle were kept off the field the entire growing season to insure adequate development of the root system. At the end of the droughty summer, the newly planted grasses were 12 inches tall. After the first hard frost, the producers had the option of mowing or grazing the grasses.

[1] Pennsylvania State University and USDA-ARS, University Park, PA.

In May of 1984 a grant was obtained from Allied Chemical Company to study the effect of nitrogen fertilization on four varieties of switchgrass (Table 1). Each switchgrass variety received zero nitrogen treatment or 50 lbs. of nitrogen using urea or 50 lbs. of nitrogen using ammonium sulfate. Weekly growth measurements were taken along with yield and quality samples. On the 8-acre Flagg field, the first cutting of hay was taken on July 8 and 9. In order to insure proper regrowth, an 8-inch stubble was left since the growing point of the warm season grasses was 4 feet. Some varieties stood as tall as 5 feet. Excellent regrowth occurred and the second cutting was made on September 15. Yield production for each variety and treatment are listed in Table 1.

Table 1. Total Summer Production - Flagg Farm (Tons Acre^{-1})

Variety	Ammonium Sulfate	Urea	Zero N
Blackwell	5.32	4.05	3.65
Indian	6.93	6.17	4.78
NJ 50	4.78	4.41	3.52
Pathfinder	3.83	5.00	3.11

At the Cairns Farm, the 4-acres were split into 3 equal sections with portable electric fence. Each section allowed access to all varieties and fertilizer treatments. Cows grazed cool season grasses from May until the first part of July. On July 8 the cows and calves were weighed and turned into the switchgrass test field. Seven cow/calf units and three yearling heifers were turned into one section at a time for a period of ten days. As the grasses were grazed down to an approximate 12-inch stubble the cattle were moved. At the end of thirty days the cattle were moved and weighed again. As at the Flagg Farm, height, yield and quality samples were taken. Cattle were turned in when the grasses were on the average four feet tall. After thirty days on the warm season grasses, the cattle were moved back onto rested cool season grasses and thirty days later, they were turned back onto the first section of warm season grasses. The cattle grazed these grasses from September 1 until September 27 and then they were again turned back onto the cool season grasses. After the first hard frost in November, they were again turned onto the switchgrass to graze it to the ground. The producer then moved them onto corn stubble and began to feed hay around the end of November.

During that first grazing period, cow's gained an average of 2.12 lbs per day with a stocking density of 7.52 animal units (AU) per acre. Quite different from the usual cow/calf operation where stocking density can range from 1 AU per acre to as low as 0.2 AU per acre depending on the management of the cool season grass pastures. Usually, cows nursing calves and grazing worn-out cool season grass pastures in July and August will lose weight and drop in their milk production. Weaning weights are a direct result of the milking ability of the dam. Increased milk production will result in increased weaning weights, and there is no better promoter of milk production in cows than fresh green grass. Yield production for each variety and treatment is listed in Table 2.

Table 2. Total Summer Production-Cairns Farm (Tons Acre^{-1}**)**

Variety	Ammonium Sulfate	Urea	Zero N
Blackwell	3.20	3.03	1.62
Indian	4.23	3.25	2.35
NJ 50	3.20	3.20	1.85
Pathfinder	3.38	2.84	1.85

Warm season grasses reduce production costs. It takes one-half as much water to produce a ton of native warm season grass forage as it takes to produce a ton of cool season grass forage. Native warm season grasses utilize nitrogen more efficiently and produce 2 to 3 times more forage than cool season grasses when no commercial nitrogen is applied. They also produce palatable and nutritious forages during the hot, dry-summer months when the cool season grasses are relatively non-productive. With proper care they can have a stand life of 10-20 years. The Flagg Farm, now under new ownership, still has warm season grasses existing on that site.

In summary, warm season grasses provide these benefits to the producer:

1. Extend the grazing season through the hot summer months.
2. Require little fertilization which cuts down production costs.
3. Are a great safeguard against drought.
4. Can turn less productive ground into very useable pasture.
5. Allow the producer to increase his stocking rate.

Problems of warm season grasses that limit the use to producer:

1. Slow to establish. It is very difficult for producers in southeast Pennsylvania to set ground aside for an entire year just to get the crop established.
2. Management is a must with these grasses especially during the establishment year. Invading cool season grasses have to be controlled. The mindset of overgrazing has to be changed. Rotational grazing is a must for these grasses to be used properly.
3. Producers must have adequate cool season pasture acreage in order to give the warm seasons the rest they require.

In summary, warm season grasses do have a place in cow/calf production systems in southeast Pennsylvania. We have seen some increases in the use of warm season grasses in larger cow/calf operations. However, the major stumbling block continues to be the establishment problem. With continued research in this area, this problem may be overcome and an even greater increase of warm season grass acreage may be seen in this part of the country in the future.

Albany Pine Bush Native Plant Restoration Project: Attractive Alternatives Help Protect a Rare Ecosystem

Neil A. Gifford[1]

Abstract

The Albany Pine Bush is the best remaining example of an inland pitch pine - scrub oak barrens and home to a variety of rare plants and animals (including the federally endangered Karner blue butterfly), hundreds of common, but no less worthy species, many people, businesses and jobs. The Albany Pine Bush Native Plant Restoration and Landscaping Project is a cooperative public and private effort making locally derived native Pine Bush plants commercially available for ecosystem restoration and landscaping. Landscaping with locally-derived native species enhances the buffer between developed and adjacent protected Preserve lands, softening development's impacts on this globally rare ecosystem and reducing the abundance of potentially invasive pest plants. Native grasses, wildflowers, trees, and shrubs provide a wide variety of attractive landscape choices and are accustomed to local conditions (water, soil, and insect pests), costing less in the long-term than many non-native alternatives. Whether landscaping roadsides, residential or commercial sites, using native plants makes good economic and ecological sense. Working together, goals of biodiversity conservation and sustainable and compatible economic development can be balanced.

[1] Preserve Ecologist, The Nature Conservancy, Albany Pine Bush Preserve, 108 Wade Road, Latham, NY 12110, Phone (518) 785-1800 ext. 214

Transfer of Technology on Native Grasses

Robert Glennon[1]

Abstract

The key to successful native grass establishment and management on a large scale is a well-trained cadre of professionals in the field to better educate, inform, and assist landowners. Current establishment and management technology must be incorporated into all USDA standards and specifications, Extension Service bulletins, and Game and Fish agency publications that address the land uses or practices that may use the species. All commercial sources of all species and cultivars must be updated at least annually and forwarded to field personnel. Specialists must remain current on seed costs; incorporate those costs into USDA cost share rates and Extension Service budgets, and share the information with field personnel. Practical skills such as seed rate calculation, drill calibration, seeding depth adjustment, and species identification and deferred grazing must be taught to field personnel. Successful use of the technology will involve technology transfer not only to NRCS and Extension Service employees, but employees of conservation districts, state wildlife and fish agencies, and natural heritage agencies and organizations. Further transfer to the landowners who will be actually establishing and managing stands must be accomplished not only with printed information, but also with workshops, field days, tours, pasture walks, and videos.

[1] Ecologist, USDA, Natural Resources Conservation Service, Little Rock, Arkansas

NRCS National Practice Standard for Vegetative Barriers

Robert Glennon[1]

Abstract

Over the past 12 years, a group of researchers and conservation practitioners have been developing technology on vegetative barriers (grass hedges) and comparing notes on how they perform over a wide range of conditions. The technology is at a stage where a national practice standard has been prepared and is posted for comment this summer. The standard includes the usual institutional requirements for a standard: definition, purpose, condition where the practice applies, criteria, planning considerations, operation and maintenance, and specifications and plans. The standard is broad enough to allow the use of any herbaceous or woody plant that will slow runoff and cause sediment to be deposited. The standard encourages the use of native grasses and stiff-stemmed cultivars of those grasses. It presents criteria for establishment from seed and vegetative material. Criteria for an adequate stand in terms of stems per square foot are based on the diameter of the stem. It includes special criteria for barriers on uniform slopes, barriers in concentrated flow areas, barriers as field borders, and barriers used to increase the efficiency of other conservation practices.

[1] Ecologist, USDA, Natural Resources Conservation Service, Little Rock, Arkansas

Wildflower Seed Production at the Jamie L. Whitten Plant Materials Center

Janet M. Grabowski[1]

The demand is increasing for incorporating wildflowers into appropriate plantings on both public and private lands. Wildflowers provide seasonal beauty and visual interest to the landscape. Some may also have edible seed or act as cover to benefit various types of wildlife. Appropriate selection and use of wildflowers can also express a sense of regional identity; for example bluebonnets [*Lupinus subcarnosus* Hook.] are synonymous with spring in Texas. Use of native species is highly recommended because they are generally not prone to encroaching into areas in which they were not planted and will therefore present little weed potential. Wildflowers can be ideal companion plants for native or introduced grasses on many planting sites (e.g. prairie restorations, roadsides, and critical areas). Healthy wildflower plantings usually require minimal care to maintain a satisfactory level of attractiveness, which makes them ideal for use in low maintenance areas. Many state highway departments are promoting the use of wildflowers, not only for beautification, but also from a practical standpoint in response to increasing costs associated with mowing and restrictions on herbicide applications.

Although wildflower seed can be purchased from commercial producers, the species of interest may not always be available in sufficient quantities to meet demands. Also, available seed may not be adapted to specific conditions on the planting site. Seed purchased from a producer in a different geographic region, will generally not be as well adapted as seed from a more local source due to ecotypic differences in plant populations. Growers are not required to inform customers of the original source of their seed, so even local producers may not be offering seed of local ecotypes. Often seed companies will subject their plant populations to a selection or breeding process to improve appearance or production characteristics (increase flower size, plant size, seed set, etc.). This improvement process could decrease the chance for survival on poor planting sites by reducing genetic diversity and potentially increasing susceptibility to insect, disease, and environmental stresses. For these reasons, many state highway departments and other customers are increasingly requesting local ecotypes of seed for their plantings. However, the potential market for seed of specific ecotypes may not be large or lucrative enough to encourage growers to initiate production. United States Department of Agriculture, Natural Resources Conservation Service, Plant Materials Centers (PMCs) explore various ways to use vegetation to solve conservation problems. As a part of this mission, PMCs have achieved a high level of expertise in producing seed of many different types of plants. The Jamie L. Whitten PMC in Coffeeville, Mississippi currently has a memorandum of understanding with the Mississippi Soil and Water Conservation Commission to produce wildflower seed under the auspices of the Native Wildflower Conservation Program. This program addresses an identified need in Mississippi for locally adapted wildflower seed to be made available to local conservation districts for use in district projects or for them to supply to landowners or to various government or regional entities.

Methods

Wildflower species being produced for this program are listed in Table 1. Ease-of-production and yield characteristics were major criteria used in selecting species for production. All species are considered to be native to all or portions of the state of Mississippi, with the exception of plains coreopsis, whose native range extends to areas just west of the state. All seed was originally collected from sites in Mississippi. The first six species listed are in large-scale production (0.4 to 5 ha) at the PMC. The following two and the final species are adapted to specialized site conditions and are therefore being produced in smaller quantities. Purple coneflower populations are currently being increased for future large-scale production.

[1] United States Department of Agriculture, Natural Resources Conservation Service, Jamie L. Whitten Plant Materials Center, Coffeeville, MS 38922-2652.

Table 1. Wildflower species being produced at the Jamie L. Whitten PMC.

Common Name	Scientific Name
Black-eyed Susan	*Rudbeckia hirta* L.
Clasping coneflower	*Dracopis amplexicaulis* (Vahl) Cass.
Plains coreopsis	*Coreopsis tinctoria* Nutt.
Partridge pea	*Chamaecrista fasciculata* (Michx.) Greene
Bur marigold	*Bidens aristosa* (Michx.) Britton
Lyre-leaf sage	*Salvia lyrata* L.
Swamp rose-mallow	*Hibiscus moscheutos subsp. lasiocarpos* (Cav.) O.J. Blanchard
Cardinal flower	*Lobelia cardinalis* L.
Purple coneflower	*Echinacea purpurea* (L.) Moench
Meadow beauty	*Rhexia mariana* L.

Although most of these wildflower species have a fairly high tolerance to adverse growing conditions, they produce the greatest amount of seed when planted on appropriate sites. Planting species on fields with the correct soil moisture regime (Table 2) is the greatest key to success. This is why swamp rose-mallow is planted in aquatic plant production ponds and black-eyed Susan is planted on dry, hilly fields. Most of the PMC fields utilized for production of wildflower seed are poorly suited for research purposes. All species except cardinal flower are grown in fields with full sun exposure. Cardinal flower is grown in a somewhat shaded field, mainly to increase available soil moisture levels. Capability to irrigate production fields is not readily available at the PMC. Earlier attempts to grow cardinal flower in aquatic ponds (similar to swamp rose-mallow) were unsuccessful due to intense weed pressure.

Table 2. Site information requirements for species produced.

Species	Soil Moisture
Black-eyed Susan	Normal/Dry
Clasping coneflower	Normal/Moist
Plains coreopsis	Normal/Moist
Partridge pea	Normal/Dry
Bur marigold	Moist
Lyre-leaf sage	Normal/Dry
Swamp rose-mallow	Wet/Moist
Cardinal flower	Moist/Wet
Purple coneflower	Normal/Dry
Meadow beauty	Moist

Appropriate planting dates for each species are listed in Table 3. The majority of these species are planted in late summer to early fall. A typical germination pattern is for seed to germinate in the fall and for plants to overwinter in a rosette stage. If environmental conditions are not favorable for seed to germinate in the fall it will retain viability and germinate the following spring; however, flowering will be delayed that first year. Bur marigold is an exception; although sown in the fall, it will not germinate until spring because its seed requires a stratification (cold-moist) period.

Field establishment methods follow a similar pattern for all species, with the exceptions noted below. The first step is spraying the planting site with a herbicide to control weeds several weeks before the scheduled planting time. Usually glyphosate (Roundup Ultra®) is used at a rate of 1.12 to 2.24 kg ai ha^{-1}, (ai – active ingredient) with the higher rate used on areas with problem perennial weeds. The field is then burned to eliminate plant residue and disked to prepare a clean seedbed and incorporate ash deposits. PMC personnel have noticed that germination appeared to be delayed in fields where the ash residue was not incorporated. The soil is then packed with a cultipacker because a fluffy seedbed will result in the seed being buried too deeply for optimum emergence. Seed is then either broadcast or drilled in rows onto planting site (Table

3). Broadcast planting is used mainly because wildflower fields will not be cultivated to control weeds; however, broadcasting also allows for higher plant populations and greater seed production per unit area. Cultivation will be discussed further under the topic of weed control. The field is then cultipacked again after planting to ensure good seed-to-soil contact. A full plant stand is generally produced in the first growing year; however, some species such as lyre-leaf sage and occasionally black-eyed Susan require additional growing seasons for populations to build up to an acceptable stand. To encourage stand development, fields are treated with appropriate herbicides to control weeds, seed is not harvested, and the field is mowed after seed set to scatter any seed produced. Many fields have remained in continuous production for close to a decade and are still producing large quantities of seed. Fields of some species such as black-eyed Susan are renovated or moved to new locations every few years, generally because of weed encroachment.

Table 3. Planting information on species produced.

Species	Planting Date	Method
Black-eyed-Susan	August – September	Broadcast
Clasping coneflower	August – September	Broadcast
Plains coreopsis	August – September	Broadcast
Partridge pea	March – April	Drill
Bur marigold	August - September*	Broadcast
Lyre-leaf sage	August – September	Broadcast
Swamp rose-mallow	April – May	Broadcast
Cardinal flower	August – September	Broadcast**
Purple coneflower	August – September	Broadcast
Meadow beauty	August - September*	Broadcast**

* Will not germinate until the following spring.
** Small seed size makes direct sowing difficult.

Smaller increase fields have also been established using greenhouse-grown transplants. Seed is sown in the greenhouse in the summer or late winter depending on whether the field will be planted in the fall or spring. Seedlings are grown in plastic bedding plant containers and planted in the field using a mechanical vegetable transplanter or occasionally by hand using a dibble bar. Field preparation methods are basically the same as for seed establishment, with the exception of cultipacking.

These wildflower species are well adapted to local soil conditions and therefore require fairly low amounts of fertility for optimum seed production. Fertilizer is normally applied in the spring. Rates used are 224 kg ha^{-1} 13-13-13 on normal soils or 112 kg ammonium nitrate on moist soils. Clasping coneflower requires slightly higher N rates for proper growth and is fertilized at a rate of 168 to 224 kg ha^{-1} ammonium nitrate. Soil tests are taken periodically and the fields are limed if the soil pH falls into the low range.

Mowing is the primary weed control method used at the PMC. Appropriately timed mowing (Table 4) can control the growth of undesirable vegetation and improve growth of wildflower species, but will not maintain the fields in a weed-free state. Several species flower late in the year and must not be mowed during critical growth stages in the summer, which allows many weed species to grow unfettered. This reality has required an adjustment of expectations on the part of PMC staff and others regarding attainable field appearance.

Although many commercial producers use cultivation to control weeds in wildflower fields, past experience at the PMC has shown poor results from this practice. Many of the plants died or showed signs of severe stress following cultivation. It appeared that the main causes of this were soil deposition on or around the root crown and root disturbance. Silt loam soils at the PMC have a tendency to form clods, which can then be deposited in the plant row by the cultivator. Species such as black-eyed Susan and purple coneflower are highly susceptible to crown rot following such deposition, although several other species can also be affected. Most of these species grow naturally in waste sites that are not subject to soil disturbance; therefore, the plants are not adapted to root disturbance such as occurs during cultivation. Partridge pea is an invader species on disturbed sites (Grelen and Hughes 1984), which explains why it can be drilled and cultivated early in the growing season before the plant canopy gets too dense.

Table 4. Recommended mowing schedules for wildflower species.

Species	Mowing Schedule
Black-eyed Susan Plains coreopsis Clasping coneflower	Early April (if needed), mid-July, early September, after frost
Lyre-leaf sage	Late May and every 6 weeks until frost
Partridge pea Bur marigold	Late May, after frost
Meadow beauty Purple coneflower Cardinal flower	April, early to mid-October, after frost
Swamp rose-mallow	February to March

Herbicides may also be used to control weeds; however, few herbicides are labeled specifically for wildflower production. Wildflower seed is not considered to be a food crop and use of most herbicides would not present an undue risk to humans or the environment; therefore, additional herbicides have been used on species where plant tolerance has been proven. Glyphosate was mentioned previously for use in field establishment. It is regularly applied to clasping coneflower and plains coreopsis fields after harvest to control weeds before germination occurs in the fall. Both of these are annual species that die back after harvest. The fields are then disked and cultipacked similar to newly established ones. This herbicide is also sometimes used to renovate black-eyed Susan fields that have become weedy; however, it will kill perenniating plants and the field must then be treated as a newly established one. It can also be used on swamp rose-mallow in the early spring before shoot emergence. Sethoxydim (Poast Plus®) has been used on all species at a rate of 0.28 kg ai ha^{-1} for postemergence control of grasses. Imazameth (Plateau®) is a new herbicide developed for pre and postemergence weed control in native grasses and wildflowers. It is labeled for use on black-eyed Susan, plains coreopsis, purple coneflower, and partridge pea. It has been used at the PMC preemergence on fields of clasping coneflower and plains coreopsis and postemergence on black-eyed Susan and partridge pea (with some burning) at a rate of 0.105 kg ai ha^{-1}. Plot tests showed excellent weed control and no damage on black-eyed Susan when applied post-emergence at a slightly higher rate of 0.14 kg ai ha^{-1}. Legumes such as partridge pea are sensitive to rates of imazameth above 0.07 kg ai ha^{-1} and to applications at very young growth stages. DCPA (Dacthal®) can be safely used preemergence on most of these species; however, its wettable powder formulation and limited spectrum of weed control make it less desirable for regular use. Short residual preemergence herbicides often provide less than desired weed control for many of these species because they normally germinate in the fall, whereas the majority of problem weeds germinate in the spring or summer. DCPA (8.96 kg ai ha^{-1}) has been used at the PMC mainly for weed control on fields that were mechanically transplanted in the spring. Dicamba (Banvel®) or 2,4-D can be used post-harvest on clasping coneflower and plains coreopsis fields, in addition to glyphosate, to control problem broadleaf weeds. Recommended rates are 0.56 to 1.12 kg ai ha^{-1} (dicamba) and 0.71 to 0.95 kg acid equivalent (ae) ha^{-1} (2,4-D). Metolachlor (Dual®) is used for preemergence weed control on partridge pea at a rate of 2.24 kg ai ha^{-1}. Tolerance testing at the PMC demonstrated that several of the other wildflower species are sensitive to this herbicide. Another formulation (Pennant®) has been recommended for plains coreopsis (Skroch et al. 1982); however, little tolerance to Dual was demonstrated in PMC tolerance testing. Another herbicide used on partridge pea is bentazon (Basagran®), largely for postemergence control of yellow nutsedge

[*Cyperus esculentus* L.], at a rate of 1.12 kg ai ha^{-1}. Plot tests at the PMC have shown that black-eyed Susan and clasping coneflower may be somewhat tolerant to this herbicide.

All species are indeterminate in their flowering and seed ripening habits and seed of some species is prone to shattering; therefore, harvest must be timed correctly to obtain the highest possible yields. Approximate harvest dates are listed in Table 5; however, they can vary by several weeks from one year to another. Most production fields are harvested using a standard commercial combine; however, some small production fields may be harvested by hand. Practice was required to learn how to successfully combine this seed. The air speed must be severely reduced to prevent seed from blowing out the back of the combine. In the past, this necessitated the placement of a piece of cardboard over the air intake; however, purchase of a new combine with a slow speed fan kit simplified this operation. Experience has also determined the appropriate concave settings to adequately thresh the seed of each species. Species such as plains coreopsis still have a great deal of green plant matter when harvested, which can wrap around and potentially stall the combine header. The new combine has a reversible header that makes this problem somewhat easier to manage. Augers for commercial combines are designed for moving larger-sized seed of typical agronomic crops. Much of this smaller wildflower seed tends to pack together in the grain hopper, which makes it difficult to remove using the auger. There is no adequate technique that can be used to overcome this problem. Hand-harvested seed is fed though portable threshers to release the seed and then treated in a similar manner as combined seed. After harvesting, seed is spread on the floor of a ventilated building and allowed to dry before cleaning. Fans are used to provide air movement and the seed is turned as needed to prevent heating. Seed is cleaned with an air-screen cleaner. Experience has also determined the correct screen combinations and cleaner settings for each species. Usually several stages of cleaning are required, each using different screens or settings, to adequately clean this seed. The limited weed control options discussed previously generally result in seed of a large number of plant species being present in the combined seed as well as much inert matter. It is not possible to remove all of these contaminants with available cleaner screens. Also, small seed size severely limits the amount of air separation that can be used. Differences in size, shape, or other characteristics make seed of some species easier to clean more completely than others. Once seed has been cleaned it is bagged and stored in a cooler maintained at approximately 13°C and 45% relative humidity, until requested by conservation districts.

Table 5. Approximate harvest dates for wildflower species.

Species	Harvest Date
Black-eyed Susan	Mid-July
Clasping coneflower	Late June to early July
Plains coreopsis	Mid- to late July
Partridge pea	Early October
Bur marigold	Late October to early November
Lyre-leaf sage	Early to mid-May
Swamp rose-mallow	Mid-September
Cardinal flower	Early October
Purple coneflower	Early to mid-September
Meadow beauty	Late September to early October

Conclusions

Production of native wildflower seed is an activity that allows the PMC to make use of acknowledged seed production experience to benefit conservation districts and ultimately individuals within the state of Mississippi. The PMC currently plans to develop a publication on harvesting and seed cleaning techniques for these and other conservation plants in order to encourage others to begin production of these species.

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Treatments to Overcome Dormancy of Eastern Gamagrass Seed

Janet M. Grabowski and Joel L. Douglas[1]

Eastern gamagrass [*Tripsacum dactyloides* (L.) L.] is a warm season perennial grass, native to the eastern and central portions of the United States and the West Indies (Hitchcock 1951). It has been recognized as a highly palatable forage species (Polk and Adcock 1964; Rechenthin 1951); however, its utilization in forage systems has largely been hampered by seed production and establishment problems (Ahring and Frank 1968; Anderson 1990).

The seed unit of eastern gamagrass consists of a caryopsis surrounded by a hard, indurate, cupulate fruit case (Anderson 1985). Many years ago, researchers such as Crocker (1916) recognized that hard seed or fruit coats could prevent germination by restricting the absorption of water or oxygen, or by physically restricting growth of the embryo. Seed coverings of many species will also contain chemical inhibitors that prevent germination from occurring (Hartmann and Kester 1975). Anderson (1985) found that germination inhibitors were not present in the fruit coverings of eastern gamagrass and that these coverings did not restrict germination by preventing the passage of respired carbon dioxide out of the fruit. Since the coverings do not act as a barrier to movement of carbon dioxide, they likely would not impose any restrictions on the absorption of oxygen. Removal of the cupule promoted germination (Anderson 1990) but, unfortunately, there is no effective way for seed producers to accomplish this for larger seed lots without causing a significant amount of damage to the seed. Anderson (1985) suggested that the cupule mainly affected germination by imposing limits on the environmental conditions under which germination could occur. The restrictive effect of the cupule can be overcome by a period of cold, moist stratification (Ahring and Frank 1968; Anderson 1985). Anderson (1990) found that there were genetic differences between populations that affected their response to stratification. Ahring and Frank (1968) tested various stratification intervals ranging from one to nine weeks and obtained best germination for the two seed lots tested with 6 weeks of stratification at 5 to 10°C.

This stratification requirement presents several agronomic problems for potential growers. First of all, the seed producer must be capable of providing the stratification treatment. Current recommendations are to hydrate the seed by soaking overnight in a 0.5 percent solution of Thiram 42S fungicide to control seed pathogens, and stratifying for 6 to 12 weeks at 1 to 4°C (Row 1998). If stratified seed is subsequently exposed to environmental conditions that are not conducive to germination, then the seed may enter secondary dormancy (Hartmann and Kester 1975; Simpson 1990) and will not germinate until the following year. This problem is most severe when adequate soil moisture is not available after planting, and in many cases, would require irrigation to ensure establishment (Row 1998). Also, many growers are not accustomed to handling and planting stratified seed. It should be refrigerated before planting and protected from high temperatures during the planting operation. For these reasons, an alternative seed treatment that could simplify the production and planting operation would be desirable.

Hot water treatments have been used to modify hard seed coats and promote germination (Hartmann and Kester 1975). Keith (1981) successfully treated a hard-seeded cotton [*Gossypium hirsutum* L.] breeding line by soaking the seed in a hot water bath for 60 seconds at 85°C. Seed is usually planted immediately following hot water treatment, but certain types of seed have been allowed to dry and were then stored without greatly affecting germination percentages (Hartmann and Kester 1975). If eastern gamagrass seed responded to hot water treatment, it might be less likely to encounter the potential secondary dormancy problems associated with stratification and would therefore become more attractive to potential growers.

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Various types of chemical stimulants have been shown to promote germination (Hartmann and Kester 1975). If an appropriate stimulant or combination of stimulants could be found for use on eastern gamagrass seed, planting operations could be simplified and establishment rates improved. Soaking seed in a potassium nitrate (KNO_3) solution is one method commonly used to improve germination of freshly harvested seed (Hartmann and Kester 1975). Ahring and Frank (1968) found that soaking eastern gamagrass seed in sodium hypochlorite or KNO_3 solutions had no effect on germination. Soaking in a solution of ethylene chlorohydrin slightly increased germination, but the effect was not significant and germination percentages were much lower than stratified seed. Row (1998) found that soaking in KNO_3 or Thiram did not improve germination over soaking seed in water alone. Exogenous applications of gibberellins and cytokinins have also been shown to stimulate germination of various types of seed (Hartmann and Kester 1975). It has been reported that eastern gamagrass seed is deficient in gibberellins and cytokinins. Treating seed with gibberellic acid (GA) improved early, but not total germination of eastern gamagrass seed (Anderson,1985).

Methods

The efficacy of hot water soaking was tested on seed from two accessions of eastern gamagrass, 9058543, which was originally collected in Pushmataha County, Oklahoma, and 9062708, from Williamsburg County, South Carolina. Seed were hand collected from plants growing at the Jamie L. Whitten Plant Materials Center (PMC) in Coffeeville, Mississippi during the months of July and August 1997. Seed harvested from eastern gamagrass often contains a fairly high and often variable percentage of unfilled seed, either without a caryopsis or with a shriveled, non-viable caryopsis (Ahring and Frank 1968; Douglas et al. 1997). To determine seed fill, 30 seed of each lot were opened and examined for the presence of a healthy caryopsis. It was found that 9058543 contained an average of 87 percent filled seed and 9062708 averaged 80 percent filled seed. Seed fill was fairly high because the seed was collected by hand, not combine harvested.

To determine appropriate hot water temperatures for testing, a non-replicated preliminary study was conducted using a seed lot from a previous experiment that contained a mixture of accessions cleaned to 90 percent fill. Temperatures used were 70, 80, 90, and 100°C and soaking duration ranged from 60 to 240 seconds in increments of 30 seconds using the methods outlined below. Seed from both the 90 and 100°C treatments exhibited zero percent germination. Because of this result, the 100°C temperature was dropped from further testing and 90°C was retained as the upper testing limit. Treatment intervals for final testing were not altered from those used in the preliminary test.

Seed treatments used in this study were the hot water treatments outlined above, plus stratification, and an untreated control. Twenty-five seed were used for each treatment. Samples were hot water treated by placing the seed in a basket constructed of hardware cloth (6 mm square openings) lined with aluminum window screen; an attached wire handle facilitated placement in and removal from the water bath. A cover was made from similar window screen to prevent seed from floating out of the basket during treatment. The basket containing the seed was submerged in a one liter beaker containing distilled water placed on a multiple setting hot plate previously calibrated to provide the appropriate temperatures. Care was taken to ensure that temperatures did not vary by more than 2°C from the target temperature during the treatment period. After hot water treatment, seed samples were placed in a greenhouse and allowed to dry before planting. A quantity of seed was prepared for stratification by soaking overnight in tap water. It was then enclosed in a self-closing plastic bag with a minimal amount of free water, and put in a cooler maintained at 42°F with no humidity control.

The experiment was conducted twice. For the first treatment run, seed of both accessions were stratified on 24 February 1998. Seed of 9058543 was hot water treated on 25 March 1998 and all seed treatments for that accession were planted the following day. Accession 9062708 was hot water treated on 26 March 1998 and all treatments were also planted the following day. For the second run, seed was stratified on 24 April 1998; 9062708 was hot water treated on 26 May

1998, and 9058543 was hot water treated on 27 May 1998 with all treatments planted the day after hot water treatment as before. Germination containers used were 17.8 cm x 13.3 cm x 5.9 cm plastic bedding plant liners and seeds were planted 0.6 to 1.3 cm deep in a commercial potting medium. The test was arranged as a randomized complete block with three replications in a split plot design with accessions as the main plot and seed treatments as the split plot. Germination containers were placed in a germinator maintained at 20/30°C night/day regime, with an eight-hour day period when the internal lights were on. There are no Association of Official Seed Analysts recommendations for eastern gamagrass germination testing; however, this temperature regime was recommended by seed laboratory personnel experienced in testing this species (J. Franklin, personal communication). All containers were irrigated thoroughly following planting and watered throughout the testing period as necessary. Germination counts were made every seven days over a five week period and a total germination percentage was determined for each treatment. This data was subjected to an analysis of variance (ANOVA) using MSTAT-C (Michigan State Univ. 1988) and appropriate mean separations were performed at the five percent level of probability ($P<0.05$) using a least significant difference test.

A non-replicated field trial using seed of both accessions was planted on 28 May 1998 at the PMC on an Oaklimiter silt loam soil. Seed treatments used were stratification (seed placed in stratification on 24 April 1998), untreated seed, and the highest ranking of the hot water treatments from the first run of the germinator experiment. Hot water treatments used were 70°C for 60, 90, 120, 150,180, 210, 240 sec, and 80°C for 60 sec. Seed sample size was 25 seed as in the germinator test. Hot water treated seed was dried in the greenhouse for one to two days before planting. Seed samples were planted by forming a shallow row with a hoe, hand sowing the seed, and covering to a depth of about 2.5 cm. Germination counts were made every three or four days until 9 July 1998.

Accession 9062680 (collected in Montgomery County, Tennessee) has been selected by PMC personnel as a superior accession. Seed of this accession was not available in early 1998 when the original testing was performed, so it could not be included in those trials. Seed was collected in July and August of 1998 and was subsequently tested in the germinator to determine its response to hot water treatment. For this study, seed quality was improved by separating out the heavier seed using a South Dakota Seed Blower (Seedburo Equipment Co., Chicago, Ill.); fill was determined to be 87 percent using similar methods to those of the previous test. Limited seed quantities were available which restricted the number of seed treatments that could be tested. Treatments used were stratification, control, and hot water soaking at 70°C for 240 sec, which ranked as the top hot water treatment for both accessions tested previously. This study was arranged as a randomized complete block with three replications. The seed was stratified on 8 August 1998, and was hot water treated in the morning of 10 November 1998 and all treatments were planted later that day. Methods used were the same as those for the previous germinator trials, except that germination counts were made for six weeks rather than five, because germination rates were slightly slower in this test. Data was subjected to ANOVA using MSTAT-C (Michigan State Univ. 1988) and mean separation was performed using Tukey's honestly significant difference test (HSD) at $P<0.05$.

All three accessions were tested for the effect of soaking in KNO_3 or GA solutions on germination rate and percentage of hot water treated and stratified seed. Stratification treatments consisted of soaking seed in a 0.2% KNO_3 solution, 1000 mg L^{-1} GA solution, or distilled water for 24 hours before commencement of the cold period. ProGibb, a commercial formulation of gibberellic acid was used as the GA source. After soaking, seeds were rinsed with distilled water before being placed in the cooler on 9 March 1999. Seed samples were hot water treated at 70°C for 240 sec and then soaked in the same treatments as used for stratification. Seeds were then rinsed with distilled water and kept moist until planting in the field or germinator. An untreated control was also included. Seed samples for the field test were hot water treated on 3 May 1999 and all treatments planted the following day. Stratified seed was placed in an insulated container to limit heat exposure while being transported to and before planting in the field. Seed for the germinator test were hot water treated on 5 May 1999 and planted 6 May 1999. Sample sizes used were 25 seed for the field test and ten seed for the germinator test. The tests were arranged as a two factor randomized complete block with six replications for the field test and four for the germinator test. The field test was planted at the PMC on an Oaklimiter silt loam soil using similar methods to those for the preliminary field test above. After planting, the study area was treated with 1.68 kg ha^{-1} of atrazine for weed control. Seed samples for the germinator test were planted using the methods outlined for the initial hot water tests. Germination counts were made weekly for 42 days, when the germinator study was terminated; counting seedlings in the field test became difficult after this time period due to weed growth, but the study was left in place in order to do a final survival count in the fall. Data from these tests were subjected to an analysis of variance (ANOVA) using MSTAT-C (Michigan State Univ. 1988) and appropriate mean separations were performed at the five percent level of probability (P<0.05) using a least significant difference test.

Results

Hot Water Treatment: The germination percentages for each accession and each trial run were first analyzed separately to determine trends in responses to the treatments. The accessions responded in a similar manner to the seed treatments in each run of the experiment, so the data for each accession was averaged across the two runs. This data is presented in Tables 1 and 2. Germination rates were fairly low as is typical of eastern gamagrass. It appears that all 90°C treatments and the 80°C treatments soaked for 150 sec or longer may have been lethal or otherwise prevented from germinating. The true cause for this lack of germination was not determined, because it was apparent that such treatments would be unacceptable which made further examination irrelevant.

Table 1. Total germination percentages of eastern gamagrass accession 9058543 exposed to various seed treatments averaged over two trial runs.

Seed Treatment	Soaking Time	Water Temperature (°C)		
	(Sec)	70	80	90
		----------------------%----------------------		
Hot Water Soak	60	11	19	0
	90	7	6	0
	120	13	1	0
	150	9	0	0
	180	12	0	0
	210	17	0	0
	240	22	0	0
Untreated		11		
Stratified		57		

Table 2. Total germination percentages of eastern gamagrass accession 9062708 exposed to various seed treatments averaged over two trial runs.

Seed Treatment	Soaking Time	Water Temperature (°C)		
	(Sec)	70	80	90
		----------------------%----------------------		
Hot Water Soak	60	27	21	0
	90	29	5	0
	120	28	1	0
	150	25	0	0
	180	28	0	0
	210	30	0	0
	240	30	0	0
Untreated		24		
Stratified		42		

Those treatments that yielded zero germination were dropped from the final ANOVA. The resulting data analysis showed that there was a significant interaction effect between accession and seed treatment (Figure 1). There are several factors that could have contributed to this interaction. First, germination percentages for all seed treatments, except the stratification treatment and the 80°C treatments, were much higher for 9062708. Secondly, germination of stratified 9058543 was much greater than that of any of the other treatments for this accession, but for 9062708, several of the hot water treatments had germination percentages similar in magnitude to those of the stratification treatment. In fact, the germination percentage of 9058543 stratified seed was significantly higher than that of same treatment for the other accession. Anderson (1990) noted variability in stratification response between genotypes of eastern gamagrass from different locations. From these results, it seems likely that of the two accessions, 9062708 is not as dependent on stratification for optimum germination. Also, the two accessions did not respond in a similar manner to the hot water treatments. When each accession is looked at separately, the 70°C 240 sec treatment provided the best germination of any of the hot water treatments. However, the 80°C 60 sec treatment would be ranked as the second best hot water treatment for 9058543, whereas this treatment would have ranked as the eighth best hot water treatment for 9062708, below even the control treatment. Germination percentages of the 80°C 90 and 120 sec treatments were very low, which indicates that there may have been damage to the seed.

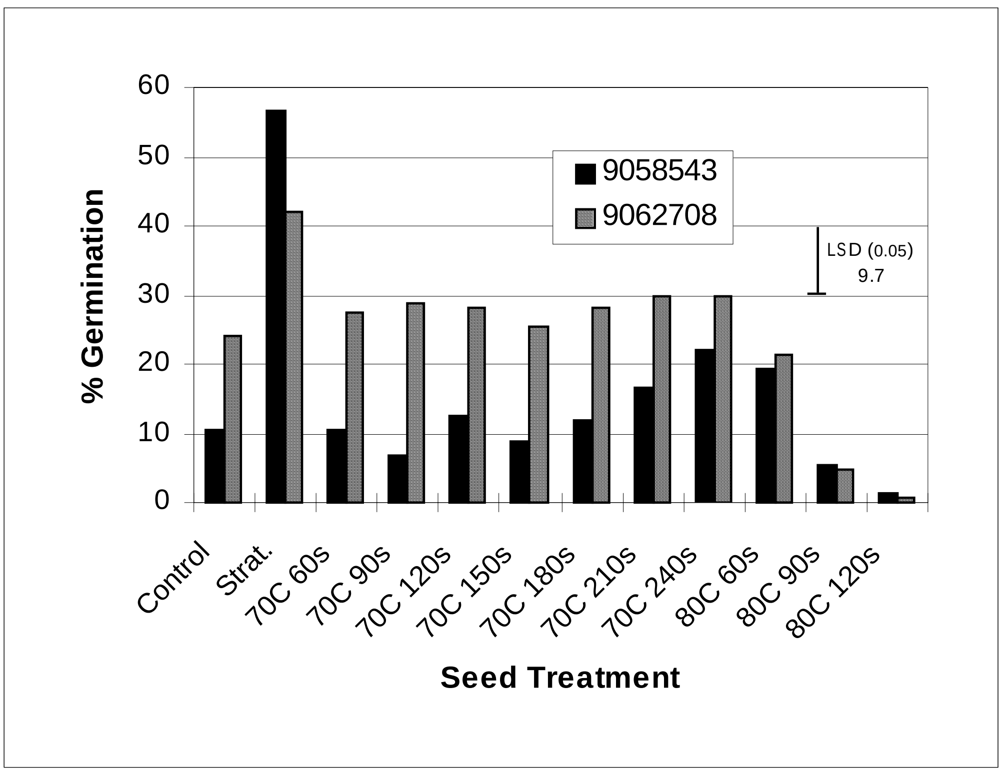

Figure 1. Interaction effect of selected seed treatments on total germination percentages of eastern gamagrass seed

Figure 2 illustrates differences in germination rate for selected treatments by graphing the germination percentage mean over both accessions at each evaluation interval. Stratified seed germinated much more quickly than the other treatments. Anderson (1985) found that stratified seed exposed to appropriate temperatures germinated very rapidly, with several treatments showing relatively high germination percentages within five days. In this experiment, none of the treatments germinated by the first count at seven days. Anderson used filter paper as the germination medium and could have detected germination much more quickly than in this study where seed were planted in a potting medium. Also, Anderson was working with populations of eastern gamagrass that originated from southern Illinois, which is father north than the collection site of the accessions used in this test. He notes that eastern gamagrass has naturally occurring races with various ploidy levels. Although Anderson did not specify the ploidy level of the seed used, most northerly accessions tend to be diploid whereas the southern accessions used in this study were tetraploid (C. Dewald, personal communication). Tetraploid seed has been shown to have a larger, heavier fruit case than diploid seed (Douglas 1999) and this larger fruit case probably imposes more restrictions on the embryo, which may have slowed the germination rate for these accessions. The germination rate of the hot water treated seed was somewhat similar to that of the control, although final germination percentages were higher than those of the control. This response has profound agronomic implications. Even if final germination percentage of the hot water treated seed were equal to that of stratified seed, the fact that it germinates more slowly subjects the seedling to increased competition from other plant species, which could prevent establishment.

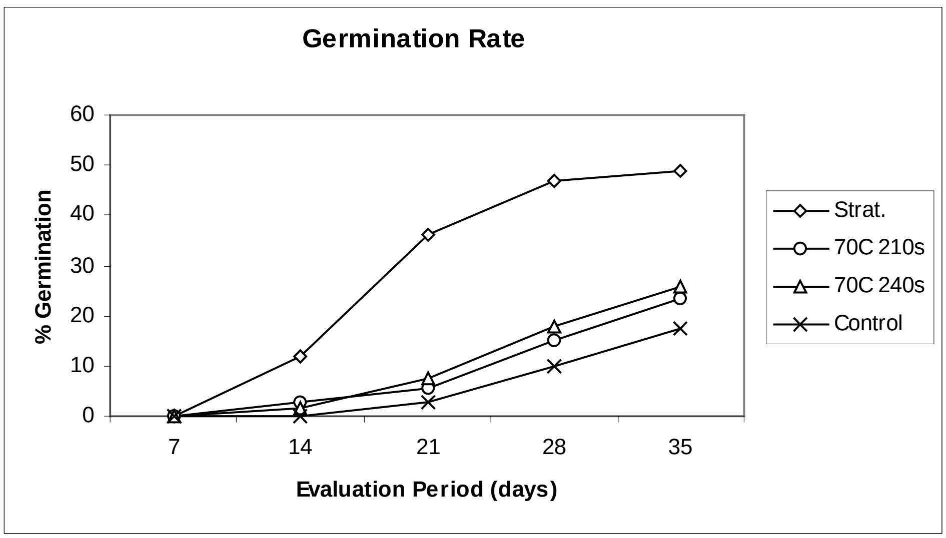

Figure 2. Mean germination percentages of stratified (Strat.), two selected hot water treatments, and untreated seed (Control).

Data for the preliminary field planting is presented in Table 3. No herbicides were used, so locating the seedlings for germination counts was somewhat difficult and this probably affected the counts made on several evaluation dates. The data presented is the maximum count recorded for each treatment, and may not be the true total germination percentage. Field response of the hot water treated seed was disappointing; however, weather conditions during the treatment period were unusually hot and dry. There was almost no germination recorded for any of the hot water treated seed of accession 9062708, the same accession that showed a more favorable response in the germinator. Those hot water treatments with the highest germination percentages for 9058543 in the field were not those that performed best for this accession in the germinator. Keith (1981) found a similar disparity in the hard-seeded cotton line between those hot water treatments with the best germination percentages in the laboratory as opposed to those that germinated best in the field. Final recommendations for treating this cotton seed line were based on those treatments that performed best in the field. Due to the unusual environmental conditions experienced during this study, such conclusions would not be appropriate in this case. It is interesting to note the high germination percentages recorded for stratified seed. Several researchers have documented that secondary dormancy can be induced in stratified eastern gamagrass seed by drought (Row 1998); however, germination percentages for these accessions were higher in the hot dry conditions in the field than they were for the more ideal conditions in the germinator. This could possibly be an instance of the seed responding favorably to high temperatures. Anderson (1985) noted that stratified seed germinated much better at a higher temperature (32°C) than at a lower temperature (25°C). Possibly 20°C/30°C is not the appropriate temperature regime to produce optimum germination percentages of eastern gamagrass seed and seed testing methods should be altered.

Table 3. Total germination percentages for a preliminary field test of two eastern gamagrass accessions exposed to various seed treatment regimes.

Seed Treatment	Germination	
	9058543	9062708
	--------------------------%--------------------------	
Untreated	0	0
Stratified	68	84
70°C 60 sec	0	0
70°C 90 sec	4	0
70°C 120 sec	16	0
70°C 150 sec	0	0
70°C 180 sec	24	4
70°C 210 sec	0	0
70°C 240 sec	0	0
80°C 60 sec	0	0

Table 4 shows the response of accession 9062680 to the three seed treatments used. This accession showed a somewhat favorable response to the 70°C 240 sec hot water treatment, but seed germination for this treatment was still significantly lower than that of the stratified seed. From this data, it appears that the response of this accession to the hot water treatment is probably similar to that shown for 9058543.

Table 4. Germination of eastern gamagrass accession 9062680 exposed to three seed treatment regimes.

Seed Treatment	Germination
	----------%----------
Untreated	4b*
Stratified	23a
70°C 240 sec	15ab

Treatment means followed by different letters are significantly different by Tukey's HSD at $P<0.05$.

Chemical Seed Stimulants: Germination percentages for both locations of testing are presented in Table 5. There was an interaction effect between accession and seed treatment in both tests, because accessions responded differently to the various seed treatments. Germination of hot water treated seed was much higher in the germinator than in the field, which concurs with results from preliminary field testing (Table 3). Non-conducive environmental conditions were cited as a possible cause for the lack of germination in the preliminary test, but conditions were highly favorable during the germination period in this study (data not presented). It appears that hot water soaking does not provide sufficient seed coat modification to permit field establishment of eastern gamagrass seed. Germination of stratified 9062680 seed was lower than the other two accessions and the difference was significant for both accessions in the field test and one accession in the germinator test. Soaking in KNO_3 or GA slightly improved germination of hot water treated seed in the germinator; however, neither of these chemicals consistently improved germination of stratified seed. Row (1998) reported that a 24-hour exposure to KNO_3 reduced germination of some seed lots, but no such reduction was noted in this study. Response to KNO_3 appeared to be greater in the field than in the germinator test.

Table 5. The effect of chemical stimulants on germination of stratified and hot water treated seed of three eastern gamagrass accessions.

Accession	Seed Treatment	Germination	
		Germinator	Field
		---------------------%	---------------------
9058543	Stratified	63	49
	GA + Stratified	60	57
	KNO_3 + Stratified	58	62
	Hot Water	8	2
	Hot Water + GA	23	3
	Hot Water + KNO_3	13	4
	Untreated	3	1
9062708	Stratified	70	49
	GA + Stratified	58	45
	KNO_3 + Stratified	43	49
	Hot Water	20	2
	Hot Water + GA	23	0
	Hot Water + KNO_3	13	1
	Untreated	5	2
9062680	Stratified	51	38
	GA + Stratified	27	47
	KNO_3 + Stratified	21	36
	Hot Water	8	3
	Hot Water + GA	21	5
	Hot Water + KNO_3	21	1
	Untreated	8	1
LSD (0.05)		19	10

Figure 3 illustrates germination rates for the three stratification treatments and the control in the germinator test. Germination rate data from the field test is not presented because interference from weeds prevented accurate counts during later evaluation dates. Early germination was improved by GA exposure; however, the difference was not significant in the germinator. In the field, early germination was significantly greater for two of the three accessions. This finding is in agreement with Anderson (1985), who reported that GA increased early but not total germination percentages of seed with intact fruit cases. The GA treatment caused abnormal elongation and chlorosis of the seedlings, which made the shoots highly susceptible to being broken by wind or physical contact. Although Anderson (1985) also used a 1000 mg L^{-1} concentration of GA, abnormal growth was not reported in that study. Anderson (1985) did not specify the length of the GA treatment period or what formulation of GA was used. In this study, GA was added to the pre-stratification soak, which would appear to be a commercially acceptable treatment method. Reduced concentrations may be required to effectively treat seed with the GA formulation and treatment duration used in this study. KNO_3 had no effect on germination rate.

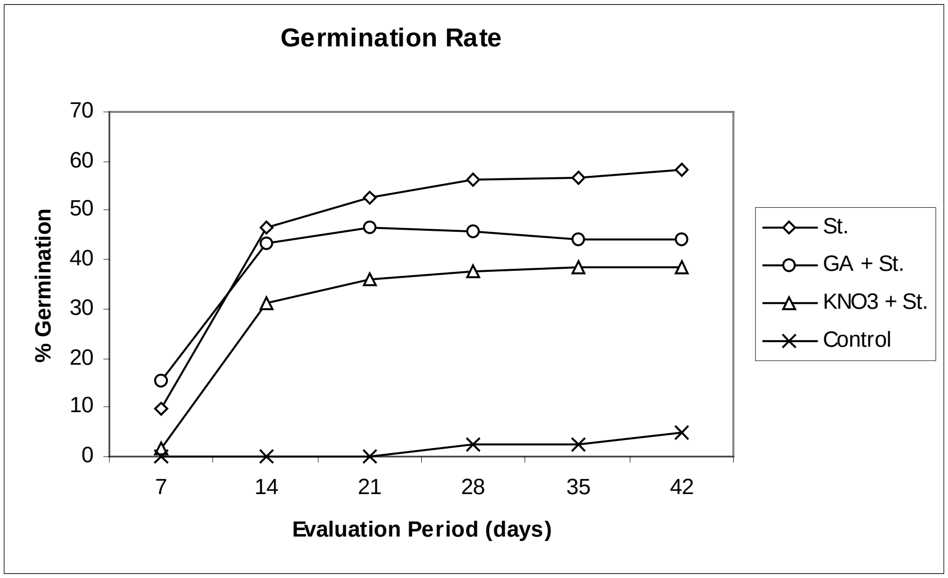

Figure 3. Mean germination percentages of stratified (St.) seed with or without pretreatment with chemical stimulants (GA or KNO_3) and untreated seed (Control) in the germinator.

Conclusions

Although eastern gamagrass seed responded to hot water soaking in the germinator, the effect on field-sown seed was minimal. Hot water treatments were not able to overcome the fruit coat imposed dormancy as effectively as cold stratification. Germination rate of hot water treated seed was much slower than that of stratified seed, which could affect its establishment potential. Treating seed with GA increased early emergence of stratified seed; however, appropriate rates and treatment methods need to be determined before commercial use could be recommended. Treatment with KNO_3 did not appear to adversely affect germination. Various combinations of these two chemicals will be tested in the future, along with other stimulants such as cytokinins. Seed of different eastern gamagrass genotypes appeared to respond differently to all seed treatments tested.

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Selecting Native Plants Using VegSpec: A Web-based System

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Abstract

VegSpec is a decision support system designed to assist in the selection of appropriate plant species for site-specific conservation problems. VegSpec contains a library of approximately 2500 species and cultivars. Each species and cultivar is characterized by 92 attributes. Users characterize a site by selecting a soil map unit and the nearest climate station from choice lists, which cover the entire United States. Users also characterize the site's current conditions and the objectives of the planting. VegSpec uses these specifications as filters to select appropriate plants from the plant library. The filters are encoded as a series of expert rules. These rules select species and cultivars based on the 92 attributes. A planting design module provides information about propagule types, optimum-planting dates, species compatibility in mixed plantings, and establishment methods. The planting design module also provides spreadsheets, which users can use to calculate the required seed and vegetative propagule amounts for both single and multiple species plantings.

Vegspec Demonstration

We present an example of VegSpec use. The site is in Montgomery County, Maryland on a Hyattstown soil with a steep, severely eroding, and east-facing slope. The landowner wants to control water erosion on this land and prefers to use native herbaceous plants.

From Netscape 4.06/Internet Explorer 4.0 or higher version, enter the PLANTS Project homepage address **http://plants.usda.gov** ***followed by a carriage return on the web address line.***

In the box entitled **Plant tools** ***click on*** **VegSpec**.

On the thin green bar in the upper half of the screen, ***click on*** **Start VegSpec.**

Please read the disclaimer page. The VegSpec running mode will be selected as **Site Specific** as the default. Do not change this. Once you have finished reading the disclaimer, ***click*** **OK**.

This is the beginning of the program. You are on the **Site Description** section. The Site Description icon on the top of the page will bring you back to this page from other locations in the program. You will begin to fill out all sections on this page.

1) Under **State** ***select*** **Maryland**. That is all that is required here. The others (Site, User and Project Names) are optional and will show on the report.

2) Soils

   3) The soil surveys for Maryland are already selected, so on the 2nd line **Soil Survey Area ID** ***click on the arrow*** to pull down the menu. **Highlight and click on the Montgomery County, Maryland:31.** Wait for the screen to refresh.
   4) **For the Soil Map Unit,** ***click on the arrow, highlight and click on the*** **Hyattstown**

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channery silt loam, 25 to 45 percent slope, very …: 109E. Wait for the screen to refresh.

5) For the **Soil Component, Hyattstown 90%** is the default because it is the greatest component in this map unit. If you select another component, then wait for the screen to refresh after you select it before you continue.
6) You may view Soil Attributes and the MLRA for the site by selecting the blue hypertext **soil attributes suboption**. For this demo, we will not change any features. If you have gone here, then select **Cancel** to return. If you made changes, click on the **Site Description icon**.

7) Climate

8) For the Climate Station, ***click on the arrow, highlight and click on*** **MD7705:ROCKVILLE 1 NE**. Wait for the screen to refresh.
9) You may look at the hypertext **climate attribute suboption** if you wanted to change any values. For this demo, don't change anything. If you entered this section, then select **Cancel**. If you changed values and want to save them, then click on **Site Description icon** to return to the Site Description page.

10) Landscape

11) Under **Generally, what aspect does the site face?** ***Click the radio button to the left of*** **East**.
12) For this demo, we will leave the remaining three selections in the default state.

This completes the Site Description section.

At the top of the page, ***click on the*** **Objectives** icon.

13) To choose a **Practice**, ***click the radical button to the left of*** **Critical Area Planting.** Wait for the screen to refresh.

14) Under **Purpose**, you will select 1 purpose. ***Click the box for*** **Water Erosion Control**, Then ***click on*** **Accept Purpose(s)**. Wait for the screen to refresh.

15) Under **Sub-Purpose**, do not select a Sub-Purpose.

16) Optional Plant Characteristics

17) Under **Plant Type** ***click the box to the left of*** **Grass**.
18) For this demo, leave **Commercial Availability** in the default mode.
19) Under **Plant Origin** ***click the box to the left of*** **Native to U.S.**

This completes the Objectives section.

At the top of the page, ***click on the*** **Select Plants** icon. It may take up to a minute to provide the new screen. The program is processing and selecting potential plants for the site.

20) There should be a number below the column labeled **Potential Plants**. It should come up with 39 plants. These are the native grasses that are suitable for water erosion control on Hayttstown soil in Montgomery County, Maryland.

21) Now you will highlight the species on the Potential Plants column that you and the landowner choose for this site. To highlight them, ***hold down the ctrl-key*** and ***click on the selected plants.*** For this example, ***highlight***: (1) field paspalum:n.a.:PALA10; (2) purple lovegrass:n.a.:ERSP; and (3) purpletop tridens:n.a.:TRFL2.

22) ***Click on the*** **Right-facing Arrow icon** to place these species on the User Selected Plants list**.**

This completes the Select Plants section.

At the top of the page, ***click on the*** **Planting Design** icon**.** It may take up to 5 minutes to load. You will eventually get a table with tabs at the top.

23) On the **Plant Material Tab**, ***click the arrow next to seed for*** **field paspalum.** Note that seed is the only option for this species. This is also true for the other two selected species.

24) ***Click on the*** **Seeding Calculation** Tab.

25) Click the box labeled Acres to Seed.
    26) Type **15** in the box.
27) Click the box to the right of Seeding Method.
    28) Type **12.0** if it is not already in the box.
29) Click the Mix % cell for field paspalum.
    30) Type **40** in the box.
    31) Hit the Tab-key
    32) The Actual Seeding Rate, Actual Seeds ft^2, & Total Needs will be filled in automatically.
33) In the Mix % cell for purple lovegrass.
    34) Type **30** in the box
    35) Hit the Tab-key
36) In the Mix % cell for purpletop tridens.
    (1) Type **30** in the box
    (2) Hit the Tab-key
37) Scroll down and ***click the*** **Evaluate** box**.**
38) In the **Plant Attribute Warring** box you will see one **Evaluation Result**. ***Click the*** **Show Attribute** box for this Evaluation Result. The **Plant Attribute** Table displays the **Active Growth Period** for each species. If you wish, you can return to the Select Plants Page and select species with more similar Active Growth Periods. For this demo, we will <u>not</u> return to the Select Plants Page. ***Click on*** **OK** then ***click on*** **Submit**.

39) ***Click on the*** **Site Specification** Tab**.**

40) You can enter various plans and dates for cultural treatments or you can leave this tab blank.

41) ***Click on the*** **Planting Specification** Tab.

42) You may click on the boxes under **Additional Planting Specifications** to specify seed or propagule treatments, change the method of seeding and change planting dates.

You have now completed VegSpec. You may now look at the Reports that are produced. ***Click on*** **Reports** at the top of the page. The VegSpec reports present: 1) the soil and climate information, which corresponds to the project site; 2) the planting objectives; 3) a list of both potential and selected plant species and cultivars; 4) the seeding and vegetative propagule rate calculations; 5) the site specific cultural treatments and information about each treatment; 6) the planting specifications and information about planting methods. After viewing the combination report, you can print it using the print function of your browser. This completes VegSpec.

VEGSPEC Development

Currently, VegSpec development is directed by an interagency steering committee, with members from USGS, NRCS and the U.S. Army Corps of Engineers. Plans for future VegSpec development include:

43) PRISM (Parameter-evaluation Regressions on Independent Slopes Model) was developed at Oregon State University, and is a hybrid statistical-geographical approach to mapping climate. Our plan is to incorporate PRISM Climate Mapping Project data into VegSpec. This will enable VegSpec to interpolate climates for regions that are far from climate stations. This is critical for the mountainous regions of the western U.S.
44) Add plants to the VegSpec library, which are appropriate for Hawaii/Pacific Islands, Alaska and the US Protectorates.
45) Add practices and plants, which will enable VegSpec users to select plants for wetland restoration, riparian area restoration, fire rehabilitation, mined-land reclamation, phytoremediation, wildlife habit and forage enhancement, reclamation of roadways, landscaping, and conservation buffers.
46) Add an invasive species module. This module will enable VegSpec to recommend native plants for competitiveness with invasive species, provide information on invasive species control, and provide site-specific warnings of possible invasive species.
47) Incorporate GIS capability into VegSpec. This would enable VegSpec users to zoom in on an aerial image of a site by clicking on a series of maps and orthophoto quadrangles. VegSpec would automatically select the soil and climate station for the re-vegetation project from information, which is linked to the aerial image.
48) Assign plant native origin by state, county and region.
49) Link plant species to a list of vendors.

The VegSpec World Wide Web address is http://plants.usda.gov, in the Plant Tools box click VegSpec

DNA Marker Variation Within and Among Populations of Native and Commercial Little Bluestem

David R. Huff[1], Antonio J. Palazzo[2], Martin van der Grinten[3], and Thomas Lent[4]

Abstract

Little bluestem [*Schizachyrium scoparium* (Michx.) Nash var. *scoparium*] is a native, warm-season, perennial bunchgrass that ranges throughout much of the central plains grasslands and the eastern temperate forests. As a native species, little bluestem is increasingly being used for restoration projects to enhance the biodiversity of locally disturbed sites. However, a question of concern arises: "Are commercial seed sources, originating from the central plains region, genetically appropriate to replace northeast native populations in restoration projects?" In this study, 60 random amplified polymorphic DNA (RAPD) markers were used to provide estimates of the comparative genetic variation within and among 30 populations of little bluestem. The 30 populations included: 13 northeast natives, 9 south-central Canadian natives, five commercial cultivar sources, two central plains land races, and one vegetative source used for restoration. Genetic distances, calculated among all individuals, were analyzed using the analysis of molecular variance (AMOVA) technique. Even though most genetic variation resided within populations, four distinct groupings of the 30 populations were apparent, namely: 1) 11 of the 13 northeastern natives 2) the plains-type (including all mid-west commercial cultivar sources, land races, and Canadian populations), 3) the Ohio population, and 4) a class of very different material containing the western PA population and the Cape May Plant Material Center vegetative selection. These results suggest that northeast native populations are genetically distinct from populations of the remaining groups and thus, the procurement of seed stock for northeast restoration projects becomes more difficult. In addition, genetic distance and geographic distance were observed to be correlated among northeast populations. However, the high amount of genetic variability observed within populations of little bluestem should aid in the construction of genetically broad-based materials useful for restoration efforts, in the event that local sources are no longer available.

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Extraction and Germination Ecology of Twelve Native Grasses from Western North Carolina

Robert P. Karrfalt[1]

The National Forests in North Carolina working in cooperation with the National Park Service, the Blue Ridge Parkway, collected 31 seedlots of native grasses representing 12 native grass species (Tables 1). The National Tree Seed Laboratory agreed to extract, clean, and test the seed lots. Germination conditions were not established for some of the species, and the possibility existed that because they were collected from high elevation, that established prescriptions might not be appropriate.

Methods

The lots were hand collected in the fall of 1998. After an initial drying period they were transported to the National Tree Seed Laboratory for cleaning and testing. Extraction was with the Westrop Brush Machine. Some lots were hand screened to remove a few stems. All lots were then aspirated in a custom built aspirator with fine air speed control and a 12 inches wide vibratory feeder. This aspirator gave relatively high volume output of clean seed even on small seeded species.

Cleaned seed lots were tested for moisture content using from 0.010 to 0.060 grams of seeds, depending on the species. The ISTA oven method (ISTA 1999) was used except for the smaller weight used to conserve seeds. Grinding is required also in the ISTA rules for grasses, but this was not practical with the small weight tested. Therefore, whole seeds were used.

Radiographs were made of all seed lots to determine that they all had high percentage of seeds. Germination tests were made under five temperature combinations: constant 15, 20, and 25^o C, alternating 15-25^{o}C, and 20-30^{o}C. When the number of seeds was limited, two treatments of a constant 20 and 15-25 temperature were used. The cool temperature was for sixteen hours and the warm treatment for eight hours except for 15-25^{o}C which on the weekends was kept at a constant 15^o C. Light was supplied for either 8 or 16 hours. When darkness was used the seeds were placed inside a light proof envelope. Dark treatments were exposed to the normal light in the germinator during germination counts. Light was at 100+ foot-candles from cool white fluorescent lamps. Prechill was for 21 days. Half of the seeds of each lot were prechilled while half were not. Four ten-seed replications were planted for each treatment combination. Each replication was randomly assigned a position in the germinator. Blue blotters, the germination media, were placed in plastic petri dishes in sandwich bags to prevent moisture loss and avoid the need to add water to the dishes after planting. Prechill was accomplished by planting the seeds and placing the bagged dish in the cold room. Figure 1. shows the treatment combinations. Germination counts were made at weekly intervals beginning at 7 days and ending at 28 days. Tests were planted beginning in June of 1999, and completed in August 1999.

Results

Although this experiment was designed for response surface analysis to identify the optimal conditions for seed germination, the analysis could not be completed in time for publication of this Proceedings. Therefore, general observations are given based on inspection of the data and means (table 1.). Light appeared to be beneficial in all species to some degree. The effect was greater for some species than for others. In a few cases the 16-hour period appears to be poorer than the 8 hours, but this is probably more the effect of the germination temperature used with the 16 hours of light rather than the photoperiod. Germination without light was common in many of the lots. On the average, however, thew percentage of seed germination in the light was

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observed to be higher than in the dark. Prechill gave positive results with six species: *Andropogon gerardii* Vitman, *Danthonia spicata* (L.) P. Beauv. ex Roem. & Schult., *Panicum virgatum* L, *Schizachyrium scoparium* (Michx.) Nash, *Sorghastrum nutans* (L.) Nash, and *Tridens flavus* (L.) Hitchc. Some of the lots of *Deschampsia flexisoa* (L.) Trin. and *Elymus virginicus* L. may have shown a response to prechill. Therefore, these eight species will be treated with prechill in future tests to make a firm determination of their dormancy. In some cases germination in the dark appeared to be facilitated by prechill. This effect was seen in *Sorghastrum nutans, Festuca rubra* L. and *Elymus virginicus*.

Conclusions

Four of these species are listed in the Rules of Testing Seeds (AOSA 1998). These species are *Andropogon gerardii, Panicum virgatum, Schizachyrium scoparium,* and *Sorghastrum nutans*. Since the seed lots reported on here are from high elevations in the southern Appalachian Mountains, they might have different germination conditions from the Great Plains seed sources which are the likely source of seeds on which the rules were based. It would appear from this data that any differences are not large, if they exist at all. More study will be needed to identify the optimum conditions for seed germination as this data only provides an initial screening. However, an observed optimum test prescription is listed in table 2 for each species tested. This optimum was based on trends in the data and what combination gave the highest germination. As the samples were small, table 2 should only be viewed as a starting point. Further tests with larger seed samples hopefully will be done to delineate what the exact germination conditions should be. Light will be used on all future tests. Prechill will be used were it clearly or possibly had an effect as listed in table 1. Future tests will use the optimums listed in table 2 as starting points on the response surface

Figure 1. Matrix of germination treatment combinations. Treatments that were used are marked with a "X." Treatments used when the number of seeds was limited are marked with a "S".

Temperature	15	20	25	15-25	20-30
No prechill					
16 hours light	X	X S	X		
8 hours light	X	X S		X S	X
Dark	X	X S	X	X S	X
Chill 21 days					
16 hours light	X	X S	X		
8 hours light	X	X S		X S	X
Dark	X	X S	X	X S	X

Table 1. Observed seed lot means showing the effect of prechill and light.

Species		Prechill		Hours of light		
	Lot #	None	21 days	0	8	16
Andropogon gerardii Vitman	1	2	6	3	4	6
Bromus pubescens Muhl. ex Willd.	1	61	60	38	78	55
	2	39	37	30	46	43
	3	58	58	39	68	79
	4	40	42	33	45	49
	5	34	33	4	53	55
Danthonia spicata (L.) P. Beauv. ex Roem. & Schult.	1	30	56	17	66	58
Deschampsia flexuosa (L.) Trin.	1	37	44	27	53	50
	2	64	63	61	69	62
	3	35	33	31	38	36
	4	54	49	51	58	46
Elymus hystrix L.	1	69	58	45	94	40
	2	51	36	35	60	38
Elymus virginicus L.	1	42	42	12	68	51
	2	67	76	58	84	83
	3	14	28	9	33	21
	4	25	27	19	35	23
	5	53	43	41	59	40
Festuca rubra L.	1	67	63	73	53	74
	2	5	6	5	6	5
Panicum virgatum L.	1	0	2	0	4	0
Saccharum alopecuroideum (L.) Nutt.	1	8	9	4	15	8
	2	28	30	19	45	27
	3	23	17	15	24	25
	4	16	12	5	25	17
Schizachyrium scoparium (Michx.) Nash	1	1	5	1	5	5
Sorghastrum nutans (L.) Nash	1	10	20	12	20	16
Tridens flavus (L.) Hitchc.	1	6	22	2	35	7
	2	0	19	1	23	7
	3	0	18	0	22	0
	4	1	28	6	28	9
	5	0	26	3	26	14

Table 2. Estimated optimal germination conditions. (These should not be taken as proven best.)

Species	Prechill days	Light Hrs	Temperature	Highest Observed Germination
Andropogon gerardii Vitman	21	8	20	15
Bromus pubescens Muhl. ex Willd.	0	8	20,20-30, 15-25	93
Danthonia spicata (L.) P. Beauv. ex Roem. & Schult.	21	8	15-25	100
Deschampsia flexuosa (L.) Trin.	21	8	20-30	85
Elymus hystrix L.	0	8	15-25	78
Elymus virginicus L.	21	8	15-25	90
Festuca rubra L.	0	8	20	83
Panicum virgatum L.	21	8	20-30	15
Saccharum alopecuroideum (L.) Nutt.	21	8	15-25	63
Schizachyrium scoparium (Michx.) Nash	21	8	15-25	10
Sorghastrum nutans (L.) Nash	21	8	15-25	40
Tridens flavus (L.) Hitchc.	21	8	15-25	98

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ISTA. 1999. International Rules for Seed Testing Rules 1999. Seed Science and Technology 27(Supplement)

Simulating Biomass/Forage Production of Eastern Gamagrass, Switchgrass, and Other Warm Season Grasses

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A robust model capable of realistically simulating range productivity would be valuable for a variety of applications. It could be used to compare soil erosion rates for row cropping systems with different perennial forages. Such a model could help answer water quality questions downstream from such production systems. The model could be used to look at effects of changes in CO_2 levels and changes in temperature and rainfall on range productivity. With adequate parameters for different grass species, the model could be used to compare productivity of communities composed of native grass species with productivity of improved pastures. Finally, such a model could be used to simulate changes in soil erosion and range productivity in response to overgrazing or invasion by woody species.

The ALMANAC model (Kiniry et al. 1992b) holds promise for such applications. The model was used to simulate Alamo switchgrass productivity at several locations in Texas (Kiniry et al. 1996). The model simulates plant growth using leaf area index (LAI) and radiation use efficiency (RUE). The model can simulate several plant species competing for light, water, and nutrients. The soil inputs can be easily derived from the NRCS Soils 5 Data Base. Required inputs, daily maximum and minimum temperatures, solar irradiance, and rainfall are readily available from many sites.

With these potential applications in mind, the objective of this study was to demonstrate the capability of the ALMANAC model to dynamically simulate range productivity in five regions of Texas, with multiple soils in each region. Fifty year simulations were compared to published range productivity values for the soils in each region. Texas, with its diverse rainfall and temperature zones, varies widely in range productivity. The state's differences in rainfall, air temperature, relative humidity, and soils offer excellent environmental conditions for testing simulation models.

Methods

General Model Description

The ALMANAC model simulates water balance, nutrient balance, and interception of solar radiation. This model includes subroutines and functions from the EPIC model (Williams et al. 1984; Williams et al. 1989) with added details for plant growth. The model has a daily time step. It simulates plant growth reasonably well and is implemented easily.

Light Interception

ALMANAC simulates light interception by the leaf canopy with Beer's law (Monsi and Saeki 1953) and the LAI. The greater the value of the extinction coefficient k, the more light will be intercepted at a given LAI.

The fraction of incoming solar radiation intercepted by the leaf canopy is

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$$\text{Fraction} = 1.0 - \exp(-k * \text{LAI}) \quad (1)$$

We derived k values for several grass species in field plots at Temple (Kiniry et al. 1999).

Leaf Area Development

Accurate prediction of light interception depends on realistic description of leaf area. Values for LAI development were from measurements on plots at Temple (Kiniry et al. 1999). ALMANAC simulates decreases in LAI due to plant density. Plant stand was estimated for the two most common grass species for each soil at each site.

Simulation of light interception also requires accurate description of leaf area production and decline. The model estimates leaf area production up to the point of maximum leaf area for the growing season using Eq(2). The model generates a curve that is forced through the origin and through two points, asymptotically approaching y=1.0. The s-curve function takes the form:

$$F = X / (X + \exp(Y1 - Y2 * X)) \quad (2)$$

where F is the factor for relative LAI, X is the fraction of heat units from planting to maturity, and Y1 and Y2 are the s-curve coefficients generated by ALMANAC. For each day, the fraction of total heat units that have accumulated is determined, denoted as SYP. The sum of heat units is zero at planting in the establishment year and at tiller emergence in subsequent years, and is maximum at maturity. The s-curve describes how LAI can increase, under nonstress conditions, as a function of SYP.

Loss of leaf area late in the season is described with the LAI decline factor (RLAD). This occurs after an input fraction (XDLAI) of heat units for the season has accumulated. Three equations describe how leaf area (SLAI) declines late in the season:

$$XX = \log_{10}[(1.001 - SYP)/(1.0 - XDLAI)] \quad (3)$$
$$RTO = RLAD * XX \quad (4)$$

where RTO is constrained to be greater than or equal to -10.0, and

$$SLAI_t = \text{Minimum of } (SLAI_{t-1} \text{ and } SLAIO * 10^{RTO}) \quad (5)$$

where t is the current day, t-1 is the previous day, and SLAIO is the SLAI on the day before leaf area begins to decrease.

Biomass Production and Partitioning

Biomass growth is simulated with a RUE approach (Kiniry et al. 1989). Values for RUE have been derived for wheat [*Triticum aestivum* L.], rice [*Oryza sativa* L.], maize [*Zea mays* L.], and sorghum [*Sorghum bicolor* (L.) Moench] (Kiniry et al. 1989), for potato [*Solanum tuberosum* L.] (Manrique et al. 1991), and for sunflower [*Helianthus annuus* L.] (Kiniry et al. 1992a). For grasses, we used values derived at Temple (Kiniry et al. 1999).

The decline in RUE in later growth stages is described with an identical function to the one for the decrease in LAI but with different input values.

The maximum rooting depth defines the potential depth in the absence of a root-restricting soil layer. Soil cores from the plots at Temple in 1994 indicated that some grass roots extended to 2.2 m.

Model Evaluation

Data Sets

We tested ALMANAC on a total of 20 soils, from a diverse set of regions in Texas (Tables 1 and 2). Appropriate soil parameters were used and the weather data was the measured daily maximum and minimum air temperatures, and rain from the nearest weather station. Distances between weather stations and yield plots are especially important for rain data.

Population densities and grass species used were based on the reported species composition for each soil in the soil surveys.

Soils at the sites differed in their capacity to store water (Table 2). Soils with the highest plant available water (PAW) in the profile at field capacity were the Houston Black, Nuff, Topsey, and Pullman. Potter, Doss, Tivoli, Brewster, Delnorte and Santo Tomas had the lowest PAW at field capacity.

Table 1. Texas data sets used in range simulations.

Region	Counties	Lat./Long. N, W degrees/min	Weather Station	MLRA[H]	Mean Annual Rain[I] mm
East Texas	Kaufman	32.36/96.18	Wills Point	86A, 87A	1050
Central Texas	Coryell Bell	31.06/97.20	Temple	85, 86A	794
High Plains	Moore Potter	35.14/101.49	Amarillo	78A	444
West Texas	Jeff Davis	31.26/101.30	Pecos	42	221
	Reeves	30.19/104.01	Marfa	42	329
	Reeves	31.00/103.40	Balmorhea	42	294
Coastal Region	Chambers	29.46/94.41	Anahuac	150B	1189

[H]Major land resource areas
[I]Average for the sixty simulated years

The model was evaluated by addressing the following questions:

1. Could the model simulate the mean expected productivity for a soil at a site using 50 years of weather data?

2. For each soil at each site, how well did simulated yields for high rainfall and low rainfall years compare to reported productivity values for favorable and unfavorable years?

Results and Discussion

ALMANAC realistically simulated differences among soils in range productivity (Table 3). Mean simulated yields were within 0.3 t ha^{-1} of mean reported yields for all soils except Reakor, Balmorhea and Harris. The model also reasonably simulated yields on “good” and “poor” rainfall years.

ALMANAC shows promise as a tool for decision making with grasses in diverse environments on a diverse range of soils. The data sets developed here can be used as starting points to derive data sets for sites with similar soils and weather, providing users with examples of realistic values for soil and plant parameters.

Models and data sets described herein are available to users at no charge. Users wanting these models and data should send three 1.44 MB diskettes to the senior author.

Table 2. Range Data Sets in Texas. PAW is the plant available water; the difference between the drained upper limit and the lower limit for the profile. Runoff curve numbers are based on soil hydrologic groups.

Region	Soil Type	Soil Depth m	PAW cm	Runoff Curve Number
East Texas	Crockett	2.03	22	80
Central Texas	Houston Black clay	1.89	26	80
Central Texas	Topsey	2.03	29	80
Central Texas	Brackett	0.86	12	80
Central Texas	Doss	0.46	7	80
Central Texas	Nuff	2.03	32	80
High Plains	Potter	0.23	2	80
High Plains	Pullman	2.03	26	80
High Plains	Tivoli	1.52	8	39
High Plains	Amarillo	1.00	12	80
High Plains	Mobeetie	1.52	14	61
High Plains	Spur	1.50	22	80
High Plains	Sweetwater	1.52	16	80
West Texas	Santo Tomas	1.91	8	61
West Texas	Delnorte	1.52	4	80
West Texas	Brewster	0.20	1	61
West Texas	Reakor	1.50	25	61
West Texas	Balmorhea	1.52	22	74
Gulf Coast	Lake Charles	2.03	23	80
Gulf Coast	Anahuac	1.52	21	80

Table 3. Annual range productivity with good, average, or poor rainfall conditions.

Range Site	Soil		Yields t ha^{-1}		
			Good	Average	Poor
Central Texas Blackland	Houston black	NRCS	7.0	6.0	3.5
		Simulated	6.9	5.9	4.5
Clay loam	Topsey	NRCS	6.5	5.0	3.0
		Simulated	5.7	4.9	4.2
Adobe	Brackett	NRCS	4.0	3.2	1.8
		Simulated	3.7	3.2	2.7
Shallow	Doss	NRCS	4.0	3.0	1.8
		Simulated	3.1	2.7	2.4
Stony clay loam	Nuff	NRCS	5.5	4.5	2.5
		Simulated	5.5	4.4	3.1
High Plains Very shallow	Potter	NRCS	0.8	0.7	0.4
		Simulated	0.8	0.5	0.3
Deep hardland	Pullman	NRCS	21	1.5	0.9
		Simulated	2.0	1.5	1.0
Sand hills	Tivoli	NRCS	2.2	1.6	1.4
		Simulated	2.0	1.6	1.2
Sandy loam	Amarillo	NRCS	2.3	1.6	1.2
		Simulated	2.0	1.5	1.0
Mixed slopes	Mobeetie	NRCS	2.7	2.0	1.4
		Simulated	2.6	2.0	1.5
Loamy bottomland	Spur	NRCS	3.9	2.6	1.8
		Simulated	3.6	2.5	1.7
Wet bottomland	Sweetwater	NRCS	5.6	4.3	3.0
		Simulated	6.4	4.0	1.9
East Texas Claypan prairie	Crockett	NRCS	6.0	5.0	3.0
		Simulated	5.9	5.1	4.3
West Texas Igneous hill and mountain	Santo Tomas	NRCS	1.3	1.1	0.9
		Simulated	1.3	1.1	0.9
Gravely desert Grassland	Delnorte	NRCS	0.8	0.5	0.3
		Simulated	1.0	0.5	0.1
Mixed prairie	Brewster	NRCS	1.4	1.1	0.8
		Simulated	1.7	1.0	0.4
Desert grassland	Reakor	NRCS	1.0	0.8	0.6
		Simulated	1.1	0.4	0.1
Desert grassland	Balmorhea	NRCS	2.2	1.8	1.2
		Simulated	1.5	0.6	0.1
Gulf Coast Blackland	Lake Charles	NRCS	9.0	7.5	6.0
		Simulated	9.0	7.5	5.9
Firm brackish marsh	Anahuac	NRCS	11.0	8.3	5.5
		Simulated	10.8	8.7	6.5

[1]t ha^{-1} multiplied by 1.009 equals thousands of pounds acre^{-1}

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Leaf Area Production, Biomass Production, and Biomass Partitioning for Eastern Gamagrass, Alamo Switchgrass, and Two Other C_4 Grasses

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Grassland modeling requires knowledge of rate-limiting processes to accurately simulate biomass growth. Increased understanding of factors controlling grass biomass production will help define productivity of different grassland communities. Thus, limitations due to stress or due to canopy architecture and leaf area can be better understood. As part of a project to model grasslands (Kiniry et al. 1996; Kiniry 1998, Kiniry et al. 1999), we measured several aspects of growth of Alamo switchgrass [*Panicum virgatum* L.], eastern gamagrass [*Tripsacum dactyloides* (L.) L.], and two other common warm-season grasses (sideoats grama [*Bouteloua curtipendula* (Mich.) Torrey] and big bluestem [*Andropogon gerardii* Vitman]). Traits including leaf area index (LAI), above-ground biomass, and light interception were measured several times during the three growing seasons on a deep, Houston Black clay soil near Temple, TX. We also measured root mass and soil carbon with soil cores at the end of two growing seasons. These measurements were all designed to quantify leaf area production and biomass growth to assist in computer simulation of these grasses in diverse environments.

Differences in partitioning to roots and shoots could cause erroneous conclusions when comparing productivity among species if only the aboveground biomass is measured. Ideally, productivity should be analyzed in terms of shoots, roots, and soil carbon.

The objective of this field study was to quantify leaf area and biomass growth of four C_4 grasses: sideoats grama, big bluestem, eastern gamagrass, and switchgrass. The LAI and light extinction coefficients were determined for these species to quantify how efficiently the grasses intercept light. Root:shoot ratios were measured to assess how these contributed to differences in growth among species. These results should help modelers focus their efforts on predicting biomass production at sites dominated by C_4 grasses.

Methods

Studies were carried out on four C_4 grass species at the Grassland, Soil and Water Research Laboratory near Temple, TX, on Houston Black clay (fine, montmorillonitic, thermic Udic Pellustert). Grasses included two separate plots of Alamo switchgrass, Haskell sideoats grama, and Kaw big bluestem, and Experimental Line 1209 of eastern gamagrass (from Woodward, OK). Four plots of each species, each plot 5 m by 75 m, were established in 1993. Adequate N was applied to prevent nutrient stress. Grasses were burned in Feb. each year.

The fraction of light intercepted was measured on seven dates in 1995, six dates in 1996, and six dates in 1997. Five PAR readings were taken above the canopy, followed by ten below and then five more above.

Aboveground biomass was harvested on several dates each year, from three 1 m^2 areas for switchgrass and eastern gamagrass and from three 0.25 m x 0.25 m areas per plot for big bluestem and sideoats grama. There were seven biomass harvest dates in 1995, six dates in 1996, and five dates in 1997. All samples were dried in a forced-air oven. Leaf and stem area was determined on the samples harvested destructively.

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We sampled belowground biomass by taking six 0.041 m diameter cores per plot, three on grass plants and three between grass plants, on 13 July 1995 and 30 July 1996. Cores were taken for the entire soil depth. We washed each 0.25 m increment of each core, collected plant material on a window screen with squares 0.23 mm x 0.23 mm, dried the roots at 65[1] C for 48 h, and determined dry mass.

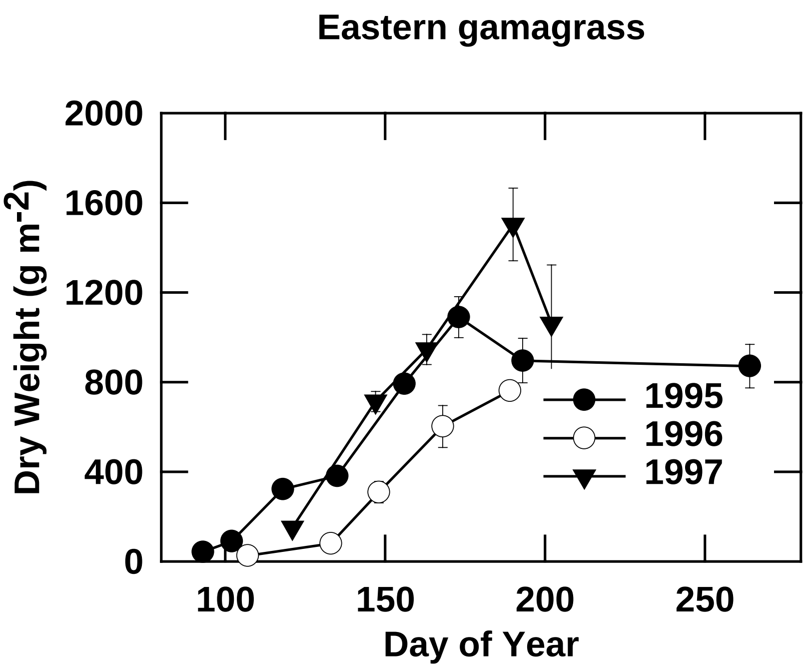

Figure 1. Above-ground biomass per unit area of two areas of eastern gamagrass

Soil organic carbon was determined with cores of the same diameter, taken to 1 m depth on 30 Aug. 1995 and for the entire soil profile on 20 July 1996. There were six cores 0.5 m apart on a transect. We also sampled cores on an adjacent cultivated field (in both years) and from a nearby native prairie (1996 only) for comparison. All six samples from a depth were combined and ground. Depth increments were 0.10 m in 1995 and 0.25 m in 1996. The roots were removed by screening. A subsample was then analyzed for organic matter with the modified Walkley-Black method (Walkley 1947).

Results

In 1995, plots received adequate rainfall to avoid drought stress during the growing season. However, rainfall after July 1995 was insufficient to refill the soil profile. This resulted in drought stress during the 1996 growing season, as evidenced by leaf rolling, especially for eastern gamagrass and switchgrass. This caused a shorter period of active growth in 1996. Rainfall was greatest in 1997 and plants did not suffer from drought stress.

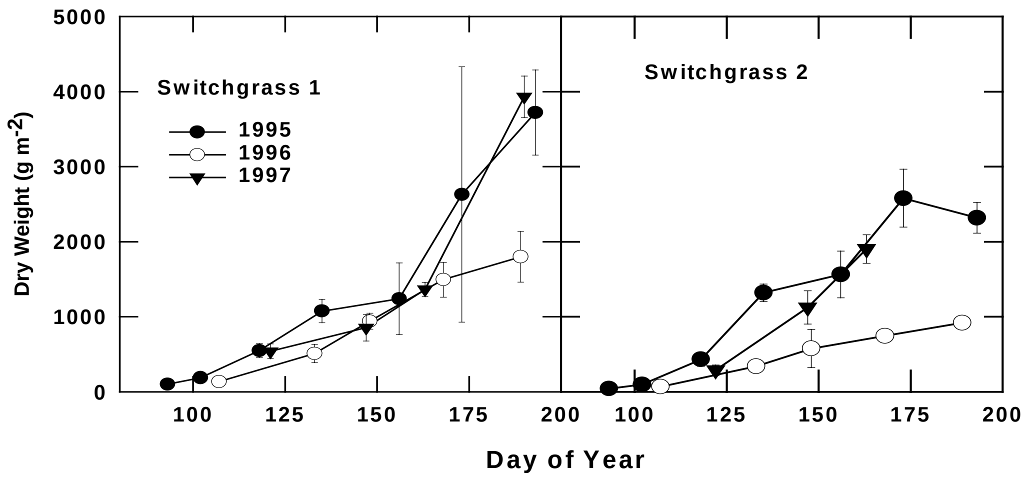

Figure 2. Above-ground biomass per unit ground area of two areas of switchgrass

Switchgrass had more biomass than the other species throughout the growing seasons (Fig. 2). Sideoats grama (not shown) had the least biomass and eastern gamagrass (Fig. 1) and big bluestem (not shown) was intermediate. Final biomass of switchgrass in 1995 and 1997 was greater than biomass of Alamo switchgrass measured previously at several Texas locations (Sanderson et al. 1996). These other locations in Texas received 67 or 134 kg N ha^{-1}, less than the 200 kg N ha^{-1} in the present study. The maximums in 1995 for Switchgrass 2 and Switchgrass 1 yields in the present study were 2318 and 3720 g m^{-2}. In 1997 these maximums were 1903 and 3929 g m^{-2}. Similar values for Alamo switchgrass were reported in Auburn, AL with 2439 g m^{-2} for an Aug. 1990 harvest and 3696 g m^{-2} for the total 1990 production (Sladden et al. 1991).

Leaf area index (LAI) values were usually greatest in 1995 and 1997 (Fig. 3 & 4). In these two years, maximum LAI values were 17.7 and 15.7 for Switchgrass 1, 12.9 and 11.1 for Switchgrass 2, and 1.7 and 1.6 for sideoats grama. In these two years, eastern gamagrass had maximums of 4.3 and 4.8 and big bluestem had 7.7 and 7.6. The big bluestem maximums were similar to values of 5.8 to 8.0 for "pawnee" big bluestem in two years in Nebraska (Mitchell et al. 1998). The switchgrass maximums were greater than those in the Nebraska study for "trailblazer" switchgrass, with maximums of 4.9 and 7.7 in two years.

In the drier year, 1996, maximum LAI values were noticeably lower for switchgrass and big bluestem. Maximums were 8.1 and 3.4 for switchgrass, 2.4 for big bluestem, 1.5 for sideoats grama, and 4.2 for eastern gamagrass.

Light extinction coefficients

Pooling data across years, within each species indicates that the light extinction coefficient (k) was not significantly related to LAI for sideoats grama, switchgrass, or eastern gamagrass (Fig. 5 and 6). Thus, one k value was sufficient for each of these grasses. The means for switchgrass and eastern gamagrass were similar, 0.33 and 0.31. The mean for sideoats grama was much greater, 1.05.

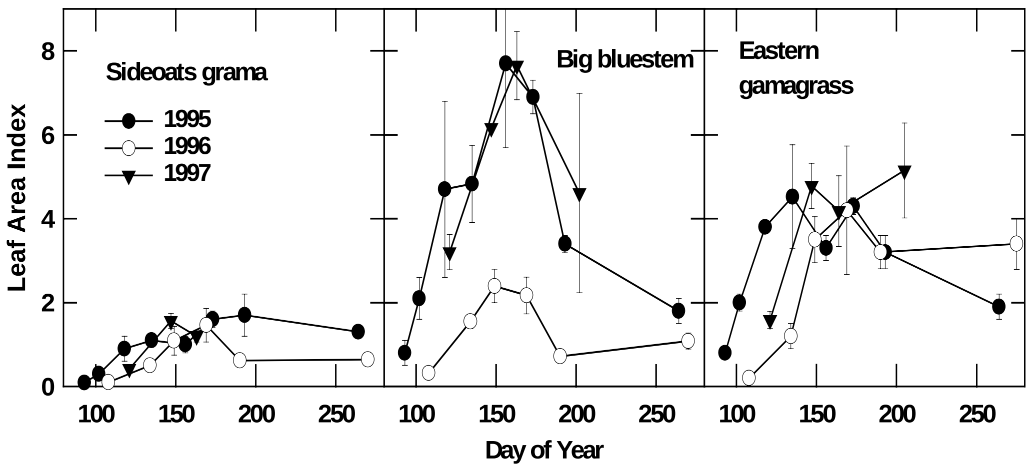

Figure 3. Leaf area index of two areas of switchgrass

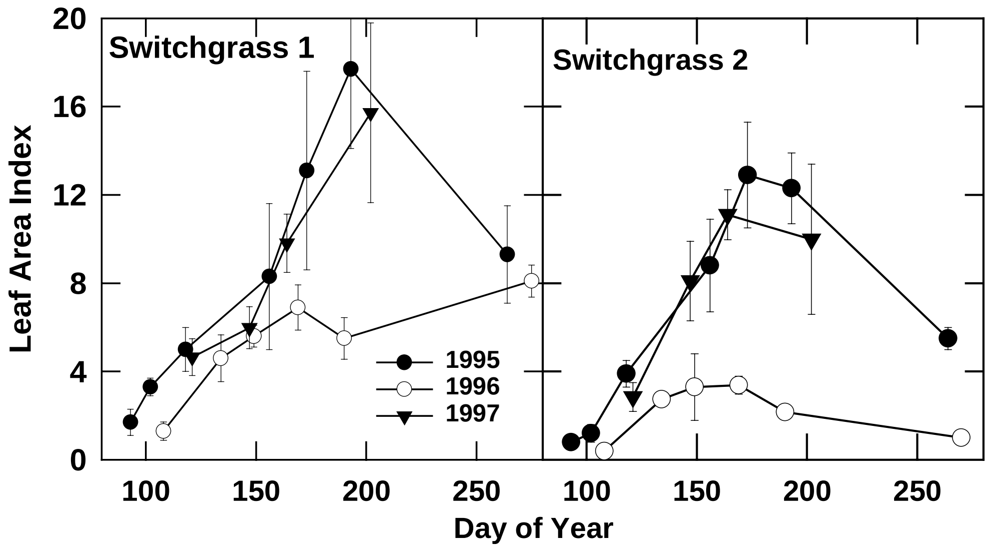

Figure 4. Leaf area index of three species of grasses.

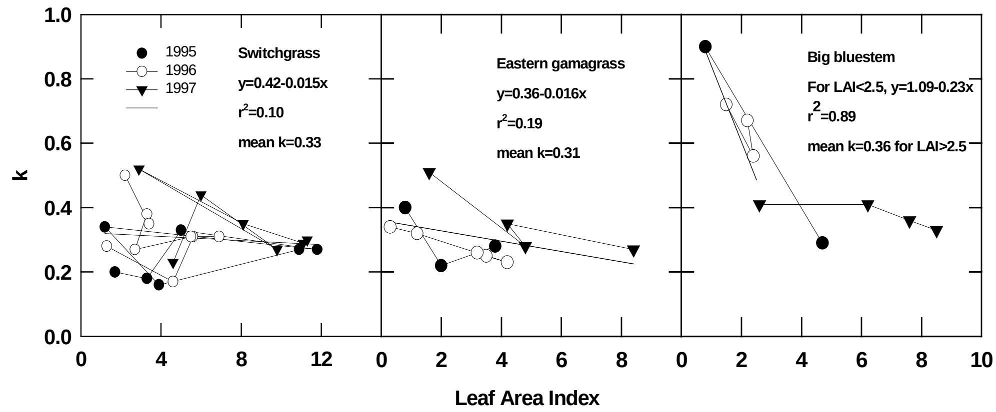

Figure 5. Light extinction coefficient (k) for Beer's law for the three species over three years.

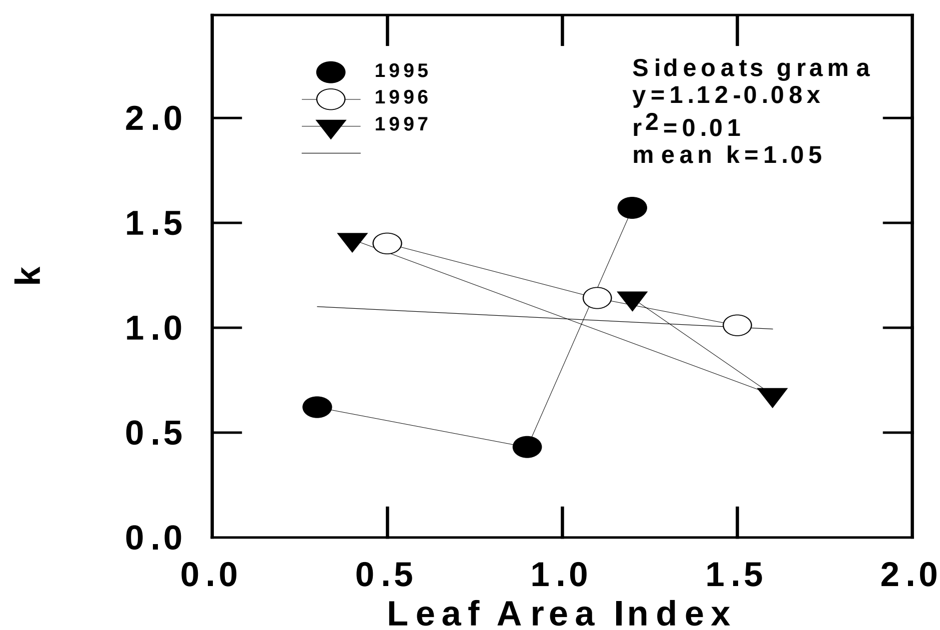

Figure 6. Light extinction coefficient (k) for Beer's law for sideoats grama over three years.

Big bluestem was the only grass which showed a trend of decreasing k with increasing LAI, similar to that reported for napier grass [*Pennisetum purpureum* Schumach.] (Kubota et al. 1994). However, napier grass k decreased from 1.1 to 0.4 as LAI increased from 2.8 to 15.3. Big bluestem k decreased only for LAI values less than 2.5. Above 2.5, mean k was 0.36, similar to switchgrass and eastern gamagrass. The values of k for three of the grasses in the present study were similar to the 0.3 value reported for grasses by Monteith (1965).

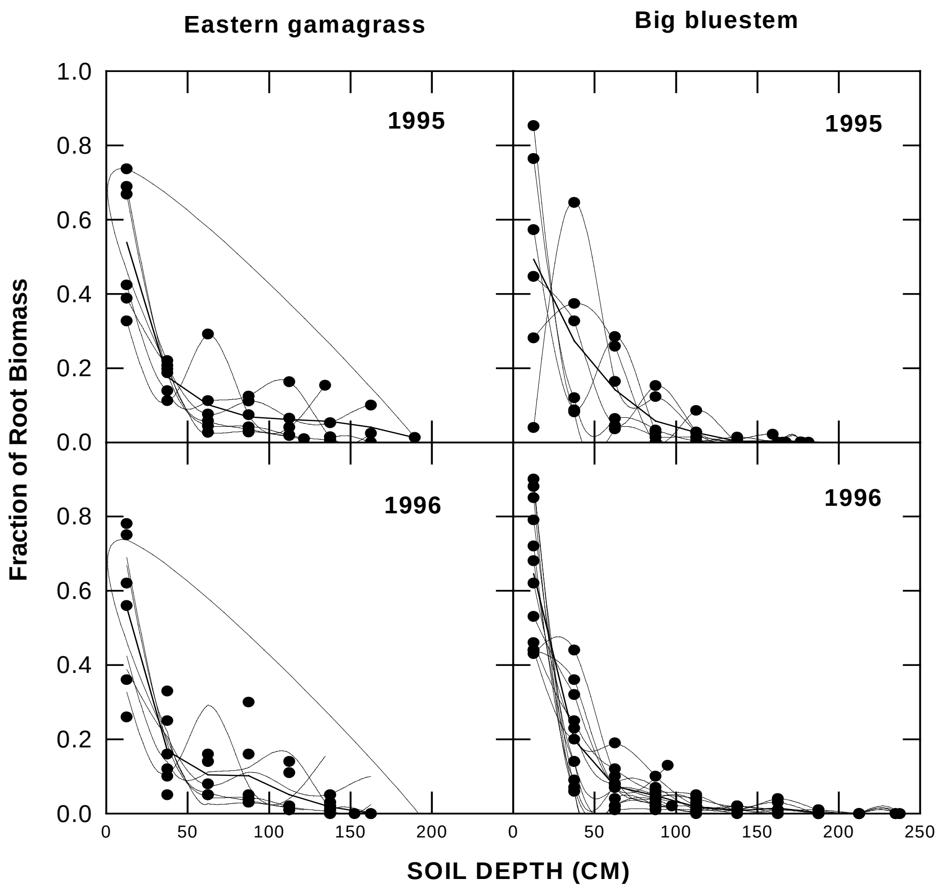

Figure 7. Root mass distribution at different soil depths for eastern gamagrass and big bluestem. Samples were taken at the end of 1996 and 1997 growing seasons. Line connects the mean values for each depth.

Root biomass was measured to compare whole-plant productivity among species. Root biomass of these species had similar patterns of distribution, with sideoats grama being the shallowest rooting (Fig. 7 and 8). In 1995 and 1996, sideoats grama had 61 to 68 percent of its total root biomass in the top 0.25 m of soil and 84 to 85 percent in the top 0.5 m. By comparison, the other species had 45 to 54 percent in the top 0.25 m in 1995 and 34 to 65 percent at that depth in 1996. For the top 0.50 m the other species had 67 to 77 percent in 1995 and 50 to 84 percent in 1996.

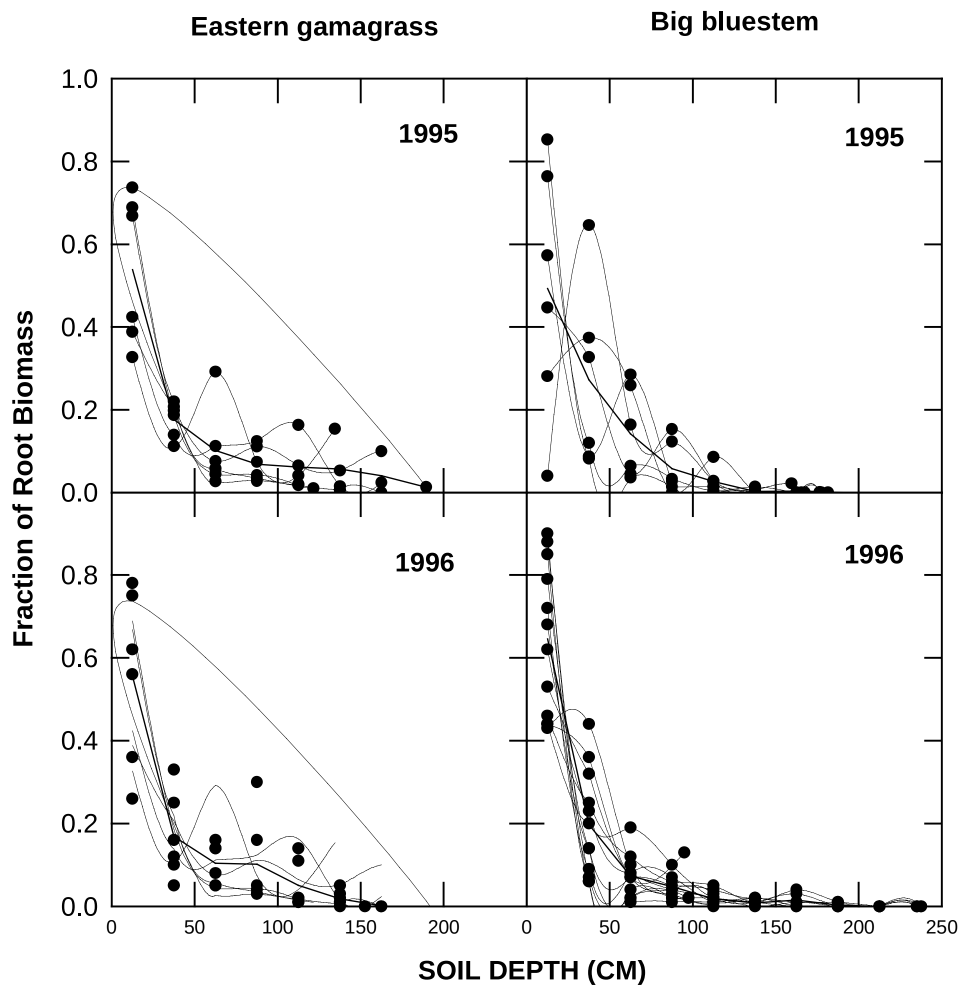

Figure 8. Root mass distribution at different soil depths for sideoats grama and big bluestem. Samples were taken at the end of 1996 and 1997 growing seasons. Line connects the mean values for each depth.

The fraction of total plant biomass in the roots was similar between switchgrass and sideoats grama (Table 1). In 1995, the root:total biomass ratio of sideoats grama was intermediate between that for Switchgrass 1 and Switchgrass 2. Eastern gamagrass and big bluestem had ratios greater than 0.50 in this year. Root values were generally greater in the drier, 1996 season than in 1995. The root:total mass ratios were sometimes doubled relative to the ratio in 1995. Mean root mass increased in all cases except for Switchgrass 1.

Table 1. Ratio of root biomass divided by total biomass for the end of the growing seasons in two years. Values in parentheses are the g of dry root biomass per m^2 ground area.

	1995 (3rd Season)	1996 (4th Season)
Sideoats grama	0.35 (390)	0.60 (635)
Switchgrass 1	0.37 (2142)	0.73 (1384)
Switchgrass 2	0.30 (978)	0.60 (1853)
E. gamagrass	0.62 (1473)	0.81 (2290)
Big bluestem	0.53 (1134)	0.83 (1654)

Soil carbon is a possible site where carbon losses could differ among grass species. However, carbon was not lost to the soil as organic carbon to a greater extent for sideoats grama than for switchgrass (Table 2). The mean for sideoats was intermediate to the two switchgrass plots in 1995 and lower than the two switchgrass plots in 1996. In 1995, all grass plots means were greater than the mean for an adjacent area that had been in continuous cultivation with row crops. The nearby native prairie had the highest organic carbon.

Table 2. Soil organic carbon concentration (by weight). Values are for four cores per replication, with 13 to 14 July sampling in 1995 and 15 July sampling in 1996. Soil cores were taken to 1.0 m in 1995 and to 1.5 m in 1996. No SE is shown when only one replication was sampled. Switchgrass 1 and Switchgrass 2 are different plots of switchgrass.

	Mean +\- SE Percent	Mean/Sideoats mean
1995		
Sideoats grama	1.10	1.00
Switchgrass 1	1.15	1.04
Switchgrass 2	1.03	0.94
E. gamagrass	1.04	0.95
Big bluestem	0.95	0.86
Cultivated field	0.83	0.76
1996		
Sideoats grama	0.72 +\- 0.04	1.00
Switchgrass 1	1.15	1.60
Switchgrass 2	0.79 +\- 0.06	1.10
E. gamagrass	0.73	1.01
Big bluestem	0.79 +\- 0.05	1.10
Cultivated field	0.90	1.25
Native prairie	1.22	1.69

Conclusions

With the exception of switchgrass, the biomass and LAI values of the grasses we studied were similar to values reported in the literature for other grasses. Differences among species in biomass production were not related to partitioning between roots and shoots, or soil organic carbon.

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Comparative Germination of 1998 and 1999 Lots of Germtec II™ Treated Eastern Gamagrass Seed after 28 Days in the Greenhouse and Laboratory

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Abstract

Preliminary greenhouse studies conducted in 1998 indicated that Germtec II™ primed seed of eastern gamagrass [*Tripsacum dactyloides* (L.) L.] kept at 4°C showed a decline in germination within 2 months after receiving the seed. The experiment was repeated during 1999 in greenhouses using both 1998 and 1999 seed lots. Three trays of 100 seeds each from both lots were planted at each location every 4 weeks from March 17 to September 2, 1999. Three germination tests were also conducted on identical dates in April, July, and September in a germinator at a day/night temperature of 30/20°C (8 h photoperiod), using 8 replicates of 50 seeds each. Results indicated that overall there was no significant difference in initial percentage germination in the greenhouse between the two seed lots, but that over time, there were significant differences. Both groups showed a similar pattern, with high initial percentage germination and then a gradual decline. The average 28 d percentage germination values in the greenhouses for the two seed lots on April 14, May 12, June 9, July 7, August 5, September 2 and September 30, 1999 were 65%, 38%, 44%, 31%, 34%, 37%, and 37%, respectively. The comparable 28 day percentage germination values in laboratory tests on May 12, July 7, and September 30 were 67%, 66% (plus 7% dormant), and 64% (plus 7% dormant), respectively, for the 1998 seed lot and 76%, 72% (plus 11% dormant), and 67% (plus 11% dormant), respectively for the 1999 seed lot. Tetrazolium chloride tests indicated that the 1998 seed lot had a significantly greater percentage of dead seed than the 1999 seed lot. The decline in germination of Germtec II™ treated seed in both seed lots in 1999 is consistent with the pattern observed in 1998 and suggests that: (1) the stimulatory effects of this treatment are relatively short-lasting; and (2) secondary dormancy may be induced during late spring, and this dormancy may be broken during subsequent cold storage. The 5-10% variation in percentage germination of this species at any one date is consistent with previous observations made by NRCS researchers in Kansas over a 25-year period.

Introduction

Eastern gamagrass [*Tripsacum dactyloides* (L.) L.] is a native, warm-season, perennial bunch grass, 2-3 meters tall, that is found in natural grassland prairies of the central, eastern, and northeastern United States along swales, stream banks, and other lowland sites (Fick 1993; Dickerson et al. 1997; Row 1998a). It grows from the East Coast to Western Kansas and from the southern U.S. to upper New York (Beitelspacher 1998). The desirable attributes of this species have been widely described (Anderson 1990; Beitelspacher 1998; Magoffin 1843; Fine et al. 1990; Foy 1997; Foy et al.1999; Rechenthin 1951; Tian et al. 1997).

Eastern gamagrass is used for livestock forage (Aiken 1997; Aiken and Springer 1998; Brejda et al. 1997; Coblentz et al. 1998; Horner et al.1985; Wright et al. 1983), wildlife food and cover

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(Dickerson et al. 1997), erosion control (Dabney et al. 1999; Dewald et al.1996; Kemper et al. 1992; Ritchie et al.1997), wetland and upland planting, and native plant community restoration. It also has the potential for use in carbon sequestration (Kemper et al. 1997) and for biomass production for fuel. Early reports indicate that it was the mainstay of the American bison but became nearly extinct through overgrazing (Beitelspacher 1998; Polk and Adcock 1964; Rechenthin 1951). It flourishes in acid, Al-toxic soils that are severely restricting to most crop plants (Foy 1997; Foy et al.1999). Because of aerenchyma cells in their roots, eastern gamagrass plants penetrate waterlogged soils early in the spring, and this provides a source of needed moisture during much of the summer (Clark et al. 1998; Kemper et al. 1997).

Two obstacles to widespread adoption of eastern gamagrass as a forage plant are erratic germination and severe weed competition that often result in poor stand establishment (Row 1998a). Problems in metering the seed are also sometimes experienced. Like many warm season grasses, eastern gamagrass has severe seed dormancy problems which must be overcome to get a successful stand established (Row 1998a; Knapp 2000; Tian et al. 1997).

The basis of this dormancy is not completely understood but appears to involve both morphological and physiological barriers (Toole et al. 1956). Various techniques have been used to break seed dormancy in eastern gamagrass (Ahring and Frank 1968; Anderson 1985, 1990; Kindiger 1994; Knapp 2000; Row 1998a; Tian et al. 1997) and other warm season grasses (Knapp 2000; Simpson 1990; Tian et al. 1997; Tischler et al. 1994). One of the main methods employed is the use of moist pre-chill treatment for 6 to 8 to 10 weeks prior to planting (Dewald 1993; Gamagrass Seed Co. 1999). While excellent results have been obtained using this procedure, the difficulty is that the seeds must be planted shortly after being received since they will start to sprout. Recently, a proprietary priming process referred to as Germtec II™ has been developed by Gamagrass Seed Company. The advantage of this treatment is that the seeds do not require refrigeration since they are stable at room temperature.

Preliminary greenhouse studies conducted in 1998 indicated that Germtec II™ primed seed of eastern gamagrass stored at 4°C showed a decline in germination within 2 months after the seed was received. The objective of the present study was to compare the germination responses of 1998 and 1999 seed lots of eastern gamagrass given a proprietary seed priming treatment (Germtec II™) after 28 days under greenhouse and germinator conditions.

Materials and Methods

Plant material. Seed consisted of 1998 and 1999 lots of eastern gamagrass seed given a proprietary priming treatment (Germtec II™) by Gamagrass Seed Co. The 1998 seed lot was harvested in 1997 and was shipped in February 1998; the 1999 seed lot was harvested in 1998 and was shipped in March 1999. Both seed lots were stored in a cold room (4°C and 40% RH) at the Natural Resources Conservation Service (NRCS) Plant Materials Center in Beltsville, MD. The total percentage germination plus dormant seed for these lots labeled by the dealer was 93 and 85%, respectively (including the dormant fraction).

Location and dates of study. Experiments were conducted in three locations at the Beltsville Agricultural Research Center (BARC) - two greenhouses, Agricultural Research Service (ARS) and NRCS; and an Agricultural Marketing Service (AMS) laboratory germinator. Lots of 100 seeds were weighed just before planting. Tests were run on concurrent dates at each location even though the number of tests varied somewhat between locations. To determine time-course differences in germination responses in the greenhouse, seeds were planted at seven dates beginning on March 17, 1999 (DATE 1), and thereafter on April 14 (DATE 2), May 12 (DATE 3), June 9 (DATE 4), July 8 (DATE 5), August 5 (DATE 6), and September 2 (DATE 7). Germinator studies were begun on three dates (April 14, July 8, and September 2).

Experimental design. There were three replicates of 100 seeds for each seed lot in the greenhouse studies and eight replicates of 50 seeds for the germinator studies. For the greenhouse studies, plastic trays were filled with a peat-vermiculite mix (Jiffy Mix, Jiffy Products of America, West Chicago, IL) and seeds were planted in five rows of 20 seeds each using a specially made dibble to ensure that all seeds were planted at a uniform depth of 3.2 cm. For the germinator studies, seeds were placed on top of two layers of 15 x 23 cm (6 x 9 inch) moistened blue blotter paper in covered plastic boxes.

Environmental conditions. To standardize germination conditions in the greenhouse, trays were placed on thermostatically controlled propagating mats (Pro-Grow Supply Corp., Brookfield, WI) maintained at 30^{o}C with a GC-1 Gro-Control Thermostat. Dial thermometers were calibrated and inserted into each tray to monitor soil temperatures and to provide a basis for adjusting the thermostatic controls. Air temperature in the greenhouse was maintained at a minimum of 27^{o}C. A 16 hr photoperiod was maintained by means of supplemental incandescent lamps to provide a 16 hr daylength. Environmental conditions in the germinator consisted of an alternating 30/20^{o}C day/night temperature and an 8 hr photoperiod provided by cool white fluorescent lamps. Although testing guidelines call for addition of 0.2% $KN0_3$ (Chirco and Turner 1986), distilled water was used because of the Germtec II™ treatment. Relative humidity in the germinator was maintained at ca.100%.

Data collected. Germination counts were made at weekly intervals in the greenhouses and germinator. Emergence of the seedlings through the peat-lite mix was used as the basis for germination counts in the greenhouses. Although eastern gamagrass is not included in the Rules for Testing Seeds of the Association of Official Seed Analysts (AOSA), seedling evaluation in the germinator followed the same general criteria used for grasses, viz., development of a primary root and a leaf extending more than half the length of the coleoptile. Abnormal seedlings, such as those with no root development or leaf extending half or less the length of the coleoptile, were not included in the percentage germination.

Tetrazolium chloride assay. To determine whether or not reductions in seed germination were caused by dormancy or a decline in viability, tetrazolium chloride (TZ) tests were run after 28 days. This assay was carried out using a 0.1% solution of 2,3,5-triphenyl tetrazolium chloride prepared in a sodium phosphate buffer solution (Grabe 1970; Moore 1985). In the presence of living cells, the colorless TZ solution becomes reduced to a reddish, water insoluble compound. Imbibed, ungerminated seeds are bisected longitudinally through the embryonic axis. The cut surfaces of each half are placed face-down on filter paper that is saturated with a 0.1% solution of TZ in a covered container. This is placed in an oven at 35^{o}C for approximately 2 hours or until staining is complete. Evaluation of the seeds is done after staining.

Seeds are considered to be viable if essential structures of the embryonic axis are stained and appear otherwise sound. In eastern gamagrass, as in other grasses, the endosperm does not stain. Ungerminated seeds that are determined to be viable by the TZ test are considered dormant. TZ testing was done on seeds remaining ungerminated at the end of the germination test for DATE 5 (July 1999) and DATE 7 (September 1999). TZ testing was also done on freshly imbibed seeds at the beginning of DATE 5. Two replicates of 100 seeds each were allowed to imbibe overnight on germination paper moistened with water.

Statistical analysis and graphs. Statistical analysis of the data collected in the ARS and NRCS greenhouses and in the AMS laboratory were carried out using PROC MIXED (SAS Institute). Graphs of germination results were drawn using non-parametric *loess* (local regression) plots using Axum (Mathsoft Inc.) statistical graphics software. The fit parameter λ was 1, i.e., locally linear, and the panel size parameter α was 0.50.

Results

ARS and NRCS Greenhouses. The percentage germination on day 28 was analyzed as a 3-factor general linear mixed model using PROC MIXED with DATE, 1-7, and YEAR, 1998 and 1999, as the fixed factors and location (LOC) the random factor. The assumptions of the general mixed model were tested. To correct the variance heterogeneity, treatments were grouped into similar variance groups for the analysis.

The analysis of variance results showed the YEAR × DATE interaction to be significant (F=2.31, p=0.0511) and the main effect DATE highly significant (F=21.56, p≤0.0001) while YEAR was not significant (F=1.96, p=0.1675).

Means were compared using pair-wise contrasts (Table 1). Overall, there was no significant difference in average percentage germination in the greenhouses between the two seed lots (42% for 1998 and 40% for 1999); only at DATE 4 (July 7) was there a significant difference between the two years. The most striking differences in percentage germination were between DATE 1 (April 14) and DATE 2 (May 12); this was true for both 1998 and 1999 seed lots. Significant differences were also observed between DATE 3 (June 9) and DATE 4 (July 7) for the 1999 seed lot.

The comparative germination responses of the two seed lots in the greenhouses showed a similar pattern (Fig. 1), with high initial percentage germination and then a gradual smooth decline.

Table 1. Means and means comparisons for the greenhouse study

	DATE							YEAR
YEAR	1	2	3	4	5	6	7	Avg.
1998	59.33a[1]x[2]	40.83a y	45.00a xy	36.33a y	34.67a y	37.50a y	40.33a y	42.00
1999	70.83a x	34.83a yz	43.50a y	26.17b z	33.67a yz	36.50a yz	33.33a yz	39.83
DATE Avg	65.08	37.83	44.25	31.25	34.17	37.00	36.83	

[1] Column (Year within Date) means with different a,b letters are different at p ≤ 0.007 significance level. (Experiment-wise error 0.05)

[2] Row (Date within Year) means with different x,y,z letters are different at p ≤ 0.002 significance level. (Experiment-wise error 0.05)

AMS Laboratory. The number of seeds germinated by day 28 was analyzed as a two-factor general linear model using PROC MIXED with DATE and YEAR as the factors. The assumptions of the general linear model were met. Analysis of variance results showed that both main effects were statistically, significant YEAR (F=9.27, p=0.0040) and DATE (F=3.31, p=0.0462), while the YEAR×DATE interaction was not significant (F=0.40, p=0.6737).

The means were compared using pair-wise contrasts where the p-value was adjusted for the number of comparisons so that the overall p-value was 0.05. Table 2 shows that overall, the 1999 seed lot had significantly higher average percentage germination than the 1998 seed lot. There were also significant differences in average percentage germination between DATE 2 and DATE 7.

Table 2. Means and means comparisons for the AMS germinator study

	DATE			
YEAR	2	5	7	YEAR AVG
1998	67.25	65.75	63.50	65.50b[1]
1999	75.50	71.50	67.00	71.08a
DATE Avg	71.00x[2]	68.62xy	65.25y	

[1] YEAR means with different letters are different at p=0.040 significance level.
[2] DATE means with different letters are different at p≤0.017 significance level, (overall p=0.05).

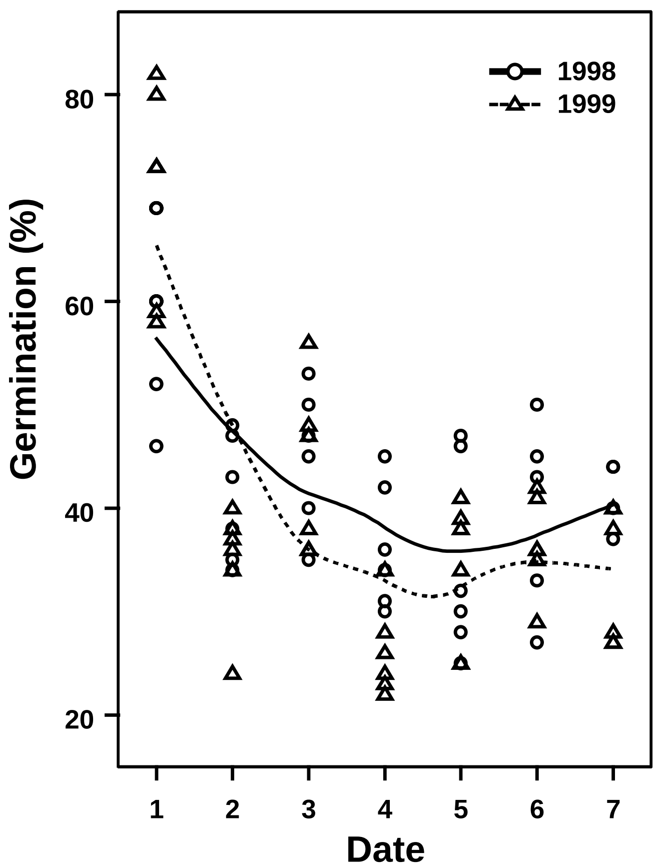

Figure 1. *Loess* (local regression) curves and germination values for 1998 and 1999 lots of eastern gamagrass in the greenhouse after 28 days at seven planting dates: March 17 (Date 1) to September 2, 1999 (Date 7). Data for ARS and NRCS greenhouses combined.

Investigation into the trend of seed germination over storage time showed that there were differences in the shapes of the curves (Fig. 2, Table 3). The 1998 seed lot showed a flat line indicating no difference in germination at the 3 dates, while the 1999 seed lot (Fig. 2, Table 3) and combined 1998 and 1999 seed lots (Table 3) showed decreasing straight lines which indicated that germination decreased over time.

Table 3. Trend analysis – p-values for AMS germinator responses

YEAR	Linear	Quadratic
98	0.2537	0.7878
99	0.0210 (-)	0.6157
98 & 99	0.0159 (-)	0.5858

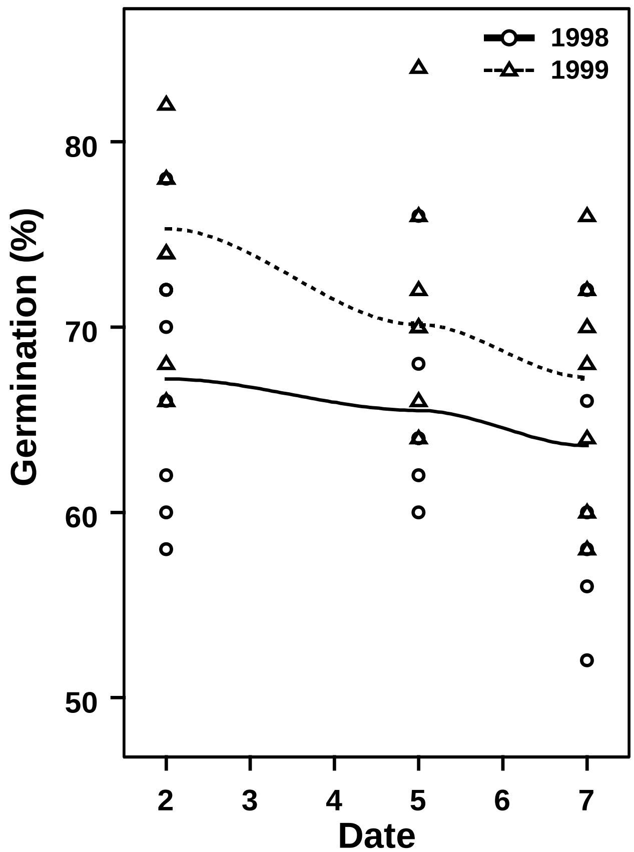

Figure 2. *Loess* (local regression) curves and germination values for 1998 and 1999 lots of eastern gamagrass in the germinator after 28 days. Seed planted at three dates: April 14 (DATE 2); July 8 (DATE 5); and September 2, 1999 (DATE 7).

The germinated and ungerminated (dormant + dead) seeds by day 28 were analyzed as two-factor general linear models using PROC MIXED with DATE and YEAR as the factors. The assumptions of the general linear model were met. The analysis of variance results indicate that only YEAR was statistically significant for the germinated (F=4.16, p=0.0509) and ungerminated (F=5.96, p=0.0212) seed.

Table 4 shows that the 1998 seed lot had a significantly greater percentage of ungerminated seed than the 1999 seed lot.

Table 4. Means and means comparisons for AMS germinator study

	Germinated			Ungerminated		
YEAR	5	7	YEAR AVG	5	7	YEAR AVG
1998	65.75	63.50	64.62b[1]	32.25	36.00	34.12a[2]
1999	71.50	67.00	69.25a	27.00	31.25	29.12b
DATE AVG	68.62	65.25		29.62	33.62	

[1] Year means with different letters are different at p=0.05 significance level.
[2] Year means with different letters are different at p=0.05 significance level.

Since there were just two dates, only a linear trend could be tested over storage time. The results showed flat lines indicating that there were no differences for the seed lots (storage years) at the two dates (Table 5).

Table 5. Trend analysis – p-values for AMS germinator study

YEAR	Germinated	Ungerminated
98	0.4887	0.2059
99	0.1715	0.1533
98 & 99	0.1478	0.0608

The number of dormant or dead seeds at day 28 was analyzed as a three-factor general linear model using PROC MIXED with DATE, YEAR, and CONDITION (dead or dormant) as the factors. To correct variance heterogeneity, the variance grouping technique was used. The analysis of variance results showed statistical significance only for the effects YEAR (F=4.38, p=0.0422), COND (F=130.15, p≤0.0001) and YEAR X COND interaction (F=31.94, p≤0.0001).

The means (Table 6) were compared using pair-wise contrasts where the p-value was adjusted for the number of comparisons so that the overall p-value is 0.05. The 1998 seed lot had a significantly lower percentage of dormant seed and a higher percentage of dead seed than the 1999 seed lot.

Table 6. Means (%) and means comparisons of 1998 and 1999 Seeds that were dormant or dead in AMS germinator study

	Condition		
YEAR	DORMANT	DEAD	YEAR AVG.
1998	6.87b[1] y[2]	27.25a x	17.06
1999	11.12a y	18.00b x	14.56
	9.00	22.62	

[1] Column (Condition within Year) means with different a,b letters are different at p ≤ 0.0050 significance level.
[2] Row (Year within Condition) means with different x,y letters are different at p ≤ 0.0050 significance level.

A TZ test conducted in an AMS laboratory germinator at the end of 28 days indicated that the mean percentage of dead seeds was higher at Test 7 than at Test 5 for both 1998 and 1999 but that (Table 7).

Table 7. Means (%) of dead and dormant seeds in Tests 5 and 7 in AMS germinator study

		Condition			
		DORMANT		DEAD	
	DATE	5	7	5	7
YEAR	1998	7.00	6.75	25.25	29.25
	1999	11.00	11.25	16.00	20.00

Discussion

The present studies provide the first evidence for time-course differences in germination responses of Germtec II™ treated eastern gamagrass seeds over a six-month period. The gradual decline in percentage germination of both 1998 and 1999 seed lots of Germtec II™ treated seed observed at 28 days in both ARS and NRCS greenhouses from 59% and 71%, respectively, on April 14, 1999 to 41% and 35%, respectively, on May 12, 1999 is consistent with what we observed the previous year and suggests that the stimulatory effects of this seed-priming treatment are relatively short lasting. However, the fact that the 1998 seed lot showed a resumption in germinability, as evidenced by the high initial germination count in April 1999 after dropping to 35-40% the previous summer, suggests that either the effects of the initial seed priming treatment might not have been lost entirely or that a secondary dormancy induced during late spring was broken during subsequent cold storage. This may involve some combination of morphological and physiological changes, whose nature remains to be determined.

The variation in percentage germination of eastern gamagrass in our greenhouses from April to September 1999 during the current study is consistent with findings for eastern gamagrass reported by Row (1998b) and his associates over a twenty-five year period in a seed storage study conducted in Kansas at the NRCS/Plant Material Center (Fig. 3). Their data show that the germination percentage of a single seed lot of eastern gamagrass kept in dry storage in Kansas under controlled conditions and tested at 14 or 21 days varied from 24 to 58%. While some of this variation is undoubtedly due to differences in environmental conditions from year to year, Row (personal communication) has suggested that much of the variation could be accounted for by the presence or absence of a caryopsis and the fact that a random population of seed is generally taken from the container.

Two factors that might explain the large difference in percentage of seed germination between the germinator and the greenhouses are differences in temperature and relative humidity. The germinator had an alternating day-night temperature as required (AOSA 1999) for nearly all cultivated grasses. On the other hand, in the greenhouse the soil temperature remained relatively constant since the propagating mat was kept on continuously. In addition, the atmosphere in the germinator was saturated.

Based on TZ tests, loss in viability was primarily responsible for the decline in germination percentage with time. The fact that the 1998 seed lot had a higher percentage of dead seed by late summer (DATES 5 and 7) than did the 1999 seed lot may be attributed to the increased age of the seed. Results of the total percentage germination plus dormant seed (83%) obtained at Date 5 for the 1999 lot seed compared favorably to the percentage of viability on the seed label (85%). At DATE 7 the 78% observed is within the allowable tolerance of the Federal Seed Act Regulation (2000).

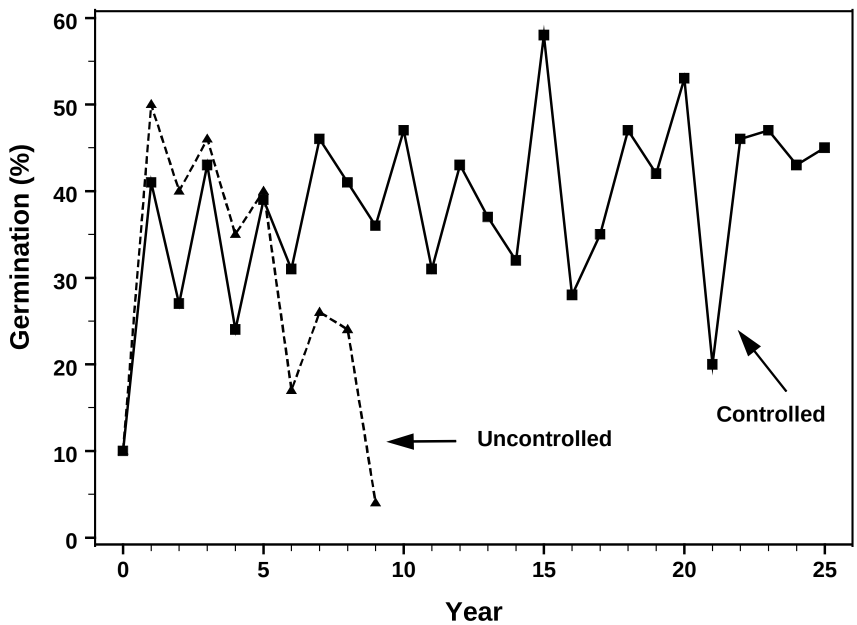

Figure 3. Twenty-five year germination record of a single lot of eastern gamagrass kept in dry storage at the NRCS Plant Materials Center, Manhattan, Kansas under controlled and uncontrolled conditions. Germination tests run after 14 or 21 days. Data from John Row (1998b).

However, the term *hard seed* on the label provided by the supplier, while suitable for describing certain leguminous seeds, is not really appropriate for characterizing dormancy of eastern gamagrass seed. Based on our results, we recommend that the seed label reflect both the total percent germination as well as the total percent dormant seed. By providing such information on the seed label, seed companies can provide the grower with valuable information in making decisions as to adjustments that may be necessary in planting density.

At present, there is no standard AOSA seed testing procedure to determine germination of eastern gamagrass (Dewald 1993), and Federal Seed Act Regulations do not presently apply. Because of seed dormancy characteristics of currently available germplasm and variations in seed testing protocols, laboratory tests may be misleading (Dewald 1993). Dewald (personal communication) has indicated that he sent seed samples of identical lots of eastern gamagrass for testing to several seed testing laboratories and obtained wide differences in germination results.

Seed dormancy in eastern gamagrass and in many other warm season grasses has been attributed to various morphological and physiological factors. These include structures surrounding the embryo, the physiological state of the embryo itself or a combination of these factors (Anderson 1985, 1990; Coukos 1944; Crocker 1916; Knapp 2000; Simpson 1990). The seed of eastern gamagrass is encased in a tough "capsule" referred to as a cupulate fruitcase (Galinat 1956) or cupule (Row 1998a, Knapp, personal communication). There is increasing evidence that the cupule may provide a significant morphological barrier to germination in eastern gamagrass since its removal (including lemma and palea) and scarification of the caryopsis have been found to be effective in overcoming dormancy (Knapp, personal communication). Anderson (1985) showed that germination could be increased from 5% in the control (with intact cupule) to 40% by removing the cupule but failed to explain the basis for the residual dormancy.

Our results indicate that the germination behavior of eastern gamagrass is highly complex and may involve interplay of many different factors, some of which may still need to be described.

There is no consistent duration used for the pre-chill period or for the germination test. It would be helpful if standardized germination procedures were published for this species. This would greatly facilitate making intercomparisons of data.

Based on reports in the literature (Dewald 1993), we conclude that Germtec II™ treatment would be equivalent to that provided by pre-chilling. At BARC, Germtec II™ treated seed received in March 1999 was planted (with irrigation) in May 1999 at an increased density to compensate for the reduction in germination percentage observed in the greenhouse. This resulted in good stand establishment (unpublished data). Based on our results, we would expect that a 1-2 month delay in planting might result in a lower percentage of seedlings established. Yet, this number would still greatly exceed the numbers of seedlings likely to emerge using untreated seeds. Reports from cooperators in several Maryland counties support this contention. We welcome feedback from other investigators who have used seeds given this priming treatment.

Acknowledgments

Grateful acknowledgments are extended to John Englert for his encouragement and support of this study; John Row for sharing unpublished data from his Masters thesis at Kansas State University and in providing unpublished data for the illustration used in Figure 3; Chet Dewald for his insightful thoughts on dormancy and for sharing his storehouse of knowledge on the culture of eastern gamagrass; Allen Knapp for providing drafts of two manuscripts on dormancy in eastern gamagrass and other warm season grasses and for helpful discussions in trying to interpret the results; Louis Rose for his careful monitoring of environmental conditions in the greenhouse; Roman Mirecki and Randy Rowland, for their helpful suggestions in solving various computer problems; David Bitzel and Leigh Wiltison for their expert assistance in conducting the tetrazolium chloride assays; and Debbie Stevens and Dean Stevens, Gamagrass Seed Co., for providing unpublished data on germination tests conducted. Partial funding provided by USDA Competitive Research Grant awarded to Donald Krizek, Principal Investigator.

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Cool Season Natives Common To Southeastern Riparian Areas

Alison Krohn[1]

The basis of this paper is observation rather than scientific trial and evaluation. As a member of the Southeast Regional Engineering Team for USDA Natural Resources Conservation Service (NRCS), I worked with engineers and conservationists in several southern states on streambank stabilization projects. Wherever feasible soil bioengineering techniques were used and native plants were recommended for the vegetative component of these practices. The desire of the engineering team was to use plants native to the watershed for stabilization, preferably from the same stream. Existing stable riparian areas were explored especially those proximate to the site. An inventory of trees, shrubs and groundcover species was recorded for each site. This paper will focus on the cool season native grasses that were most common, tolerant of the widest range of conditions, or exhibited desirable aesthetic qualities.

The need for aesthetically pleasing plants was identified by conservationists working in urban areas where native ecosystems are at greatest risk. Aesthetics is an important issue for landowners who prefer a "clean" stream bank and routinely mow to the edge of the bank. Areas that are mowed cannot regenerate woody plants and many native grasses and forbs will not survive. Management plays a critical role in the stability and condition of riparian areas. If we can identify and plant aesthetically pleasing species then perhaps the mowing can be pushed back a safe distance from the water's edge for both landowners and riparian systems.

Observations

Cool season native grasses are common groundcover components of riparian systems in the southeastern states. The groundcover component on stream banks and floodplains provides surface scour resistance. This groundcover component also increases the friction coefficient thereby decreasing the erosion potential of floodwaters. Typically 50% of the groundcover will be composed of grasses, the remainder being forbs. Some of the most common species observed at sites in South Carolina, Tennessee and Kentucky were Virginia wildrye [*Elymus virginicus* L.], switchcane or rivercane [*Arundinaria gigantea* (Walter) Muhl.], and river oats [*Chasmanthium latifolium* (Michx.) H.O. Yates]. Virginia wildrye appeared to be the most tolerant of disturbance and a wide range of solar exposure from full sun to full shade. It was observed on over half of the sites visited in the three states. Switchcane was present on 48% of the sites and is also tolerant of sun and shade. It is not available commercially and is established by transplanting. River oats was observed only 5% of the time but it has great aesthetic appeal. Limited seed sources are available commercially and several nurseries including Burpee Seed Company offer this grass in potted form. The chart below shows the number of sites where these grasses were found between 1998-99. Forty-five sites were visited in total.

In vegetative stabilization projects or soil bioengineering the role of grasses is critical to the initial stability of the site. Until the trees have survived three years, they provide little protection. In fact we have had almost as much success with natural succession as with seedlings. Since grasses provide the initial protection on a stabilization project it is important to use reliable species. Additional concerns include the risk of introducing invasive species, such as overly aggressive grasses that will out-compete woody vegetation, or fail as the tree canopy matures. The value of cool season natives such as Virginia wildrye is they tolerate both sun and shade. As the canopy matures this grass will thin out, yet persist. The same is true of switchcane. It may be more aggressive than wildrye, but is much more difficult to establish and does not seem to expand aggressively for several years after transplanting.

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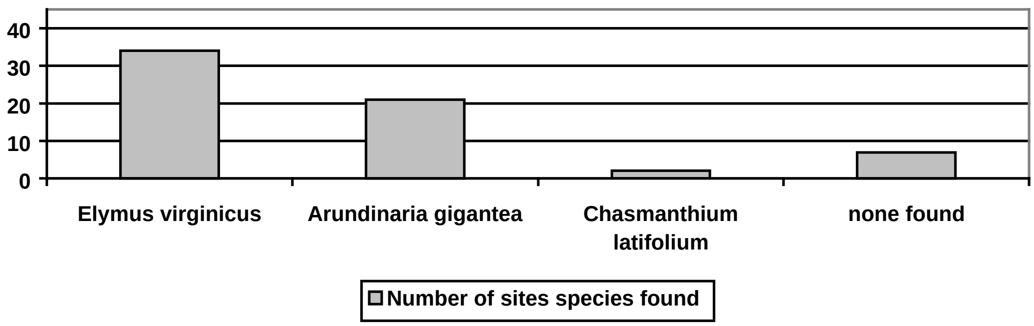

Virginia wildrye planted on a stream bank in South Carolina

Switchcane growing on a stream in South Carolina

Experiences

Having established the value of native plants that are adapted to local conditions and local flora and utilized by local fauna, we attempted to use them in the projects described below.

Claredon Estates, Anderson, SC

Local NRCS conservationists were asked by a group of residents living in the Claredon Estates subdivision to address erosion problems in a stream that ran along one side of the development. The sites were difficult to deal with because they were literally in people's back yards and had limited access. The typical riprap solution was neither practical nor cost effective. Aesthetics was a concern for the residents. Like many streams in the piedmont, this one was entrenched and showed some evidence of downcutting in the upper reaches, but the majority of its length was lined with mature trees: the resident's backyard landscapes. Under the emergency watershed program a series of riprap grade control structures were installed and coconut fiber rolls were used for toe protection where needed. The remainder of the project was the installation of vegetation. Switchcane was transplanted along with local rushes [*Juncus effusus* L.]. Where the banks were disturbed, Virginia wildrye was seeded at a rate of 20 lbs per acre. This took place in February. The following July the sites were inspected and the wildrye had germinated and showed vigorous growth. Not all of the switchcane had survived but it outperformed the other local material. The cool season natives performed well in heavy shade, which had been a major challenge of this project.

Portland Channel

Under a project authorized during the 1960's, NRCS in Tennessee had built a floodway for a town on the Kentucky border. An extension was built in 1997 and the site was required by state regulations to be seeded with native species. A mixture of switchgrass and Virginia wildrye was used.

12 lbs switchgrass
20 lbs Virginia wildrye
½ bushel rye grain
2 tons lime
30 lbs 0-20-20
1.5 tons straw mulch

The channel was seeded in August and the grasses performed better than expected. In the second growing season both species had formed seed heads and exhibited good cover except on some south facing slopes that were extremely dry.

Poor coverage on upper slope

Successful seeding at Portland

This combination of switchgrass and wildrye has been recommended for use on several stream stabilization sites throughout Tennessee. Our desire was to develop a mix that could be seeded at any time of year. Using both warm and cool season species means at least one will be seeded at an inopportune time but there is always the chance of later germination if the seed has not been washed away by floodwaters. The Tennessee Wildlife Resources Agency (TWRA) has donated seed to be used on sites throughout the state, especially those not funded under any other programs. The success of native grasses seeded without inspection or local guidance has been poor to date for reasons discussed below.

Challenges

Conservation concerns that fall outside of funded programs are difficult to control and assess. Typically, NRCS personnel will make recommendations or develop plans for the landowner to implement. How these recommendations are implemented depends on the landowner's resources, including time, access to materials and recommendations from other sources. What usually happens is the cheapest seed from the local Co-op is planted. Warm season native seeds are more common than they were ten years ago, but cool season natives are still a specialty item. Many landowners have never heard of Virginia wildrye even though it may be underfoot. They will prefer to use fescue, which they know how to seed. Familiarity supercedes recommendations when the landowner is financing and installing a project. The TWRA program has overcome some of the resistance but lack of experience in the field has hampered success with warm season grasses such as the switchgrass. Natives do not require the same fertilization as introduced species, and have narrower seeding dates, although Virginia wildrye seems to be very similar to fescue in its range. Cost and availability are additional hurdles in the wider use of cool season natives. Switchcane must be transplanted since it is not available commercially, and to my knowledge, it does not propagate by seed.

Opportunities

There is a need for cool season native grasses in restoration and stabilization projects. The species described above take flooding very well, are adapted to sun and shade, and will not create a threat to local ecosystems. If we wish to protect our streams and riparian systems we need to address the landscape industry and aesthetic expectations of the public. The image of a stream coursing through a mowed landscape must change to one of swaying seed heads and trees of diverse size and age. Both Virginia wildrye and river oats have interesting seed heads that could be enhanced through selection and breeding. Switchgrass has made inroads into the landscape industry as an ornamental and the same is possible with the other native grasses.

Plant Conservation Alliance

Olivia Kwong[1]

Defining the Problem

As of the end of September 1999, the Fish and Wildlife Service's (FWS) federal list of threatened and endangered plants and animals contained 716 plants and 481 animals, a ratio of 3 to 2. The problem becomes clear when you look at a sample federal agency's threatened and endangered species expenditures. Year after year, of the millions in total funding spent on endangered species, most is spent on animal species and a mere fraction on plant species which make up over 60% of the list.

The major land managing federal government agencies own roughly 29% of the United States, 651 million acres. To put this information in perspective for you, the comparably sized country can be found for each agency's landholdings: Department of Defense (DOD) and Austria; National Park Service (NPS) and Norway; FWS and Japan; USDA Forest Service and Turkey; Bureau of Land Management (BLM) and Egypt. Each year these agencies deal with a variety of issues such as restoration, wildfires, and invasive exotic species. The BLM alone lost 2.5 million acres to wildfires in the Great Basin area during the summer of 1999. However, personnel numbers from 1999 show that in NPS, FWS, U.S. Geological Survey USGS), and BLM (BLM data approximated from 1997) the ratio of botanists or plant specialists (20-45) to the total number of biologists (3,444 to 390) ranges from less than 1% to 11%.

Creating and Providing Solutions

In 1994, 80 participants representing 34 agencies and organizations met during a workshop in Phoenix, Arizona to discuss the problems plaguing native plant conservation on federal and private lands. The meeting resulted in the writing of a Native Plant Conservation Strategy and the creation of the Native Plant Conservation Alliance, now known as the Plant Conservation Alliance (PCA).

PCA is a consortium of ten federal government Member agencies and over 150 non-federal Cooperators representing various disciplines within the conservation field. Currently, there are ten federal agencies officially participating in the PCA as the Federal Committee. The agencies which have signed the Memorandum of Understanding are the BLM, DOD, Federal Highway Administration, NP, Office of Surface Mining Reclamation and Enforcement, USDA Agricultural Research Service, USDA Forest Service, USDA Natural Resources Conservation Service, FWS, and USGS. The non-federal Cooperators include a range of professional societies, trade associations, research organizations, universities, state agencies, museums, growers, non-profit organizations, gardens and arboreta, native plant societies, garden clubs, and Native American tribal councils. These partners share PCA's mission: "To protect native plants by ensuring that native plant populations and their communities are maintained, enhanced, and restored."

PCA Members and Cooperators work collectively to solve the problems of native plant extinction and native habitat restoration, ensuring the preservation of our ecosystem. Strategically, the PCA aims to help establish common priorities and direction in plant conservation activities among cooperators; support collaborative efforts, including training programs; coordinate public education and outreach efforts; and develop networking tools for communication and coordination. The PCA provides the organization and structure to implement the overall mission through those specific goals.

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When used as a tool in restoration, natives should be seen as a solution to many of the problems facing agencies on their lands. In order for this to happen federal plant conservation resources must be pooled at the national level to provide a focused, strategic approach to plant conservation at the local level on public and private lands, eliminating duplication of effort and increasing the effectiveness of these programs.

Recognizing the diverse participation and methods needed for their work, PCA invites federal, non-profit, state, industry and other interested parties to participate in technical working groups covering the following areas: Alien Plant, Data & Information Sharing, Medicinal Plant, Pollinator, Public Outreach, and Restoration Working Groups.

Each year, PCA awards thousands of dollars for on-the-ground conservation and restoration projects through a matching funds grant program administered by the National Fish and Wildlife Foundation. Since PCA's inception in 1994, grants have been awarded for more than 100 projects totaling over $2,000,000 in federal funds and matching non-federal contributions. However, native plant conservation does not consist of funding alone; PCA, as a public-private partnership, also serves as a forum for the exchange of ideas, expertise and information between organizations engaged in habitat restoration and preservation. These exchanges take place in various forms of public outreach, including e-mail lists, postal mailings, a website, a bi-monthly newsletter, and meetings.

The PCA website contains:

- Alien Plant Working Group section with a comprehensive list of troublesome invasive plants of natural areas, separate lists for aquatics, herbs, vines, shrubs, and trees, fact sheets produced in a consistent format with a nation-wide perspective, and links to exotic pest plant councils, national parks, other web sites, persons, and organizations working on the issue.
- Restoration Working Group section (in development)
- Medicinal Plant Working Group section (in development)
- Information on the NFWF Grant Program
- Celebrating Wildflowers Coloring Book and the On-Line Events Directory for North America
- PCA Cooperator list with links to member pages
- Planting Foundations newsletter and announcements for native plant conferences and symposia
- On-line copies of the current meeting agenda, national strategy, Wild Wealth brochure, and other useful information

Please see our website for more information about the Plant Conservation Alliance at http://www.nps.gov/plants/

Army Training Lands - The Native Perspective

David G. Lorenz[1]

The U.S. Army's twelve million acres of training lands are some of the most unique and diverse land areas in the nation. These lands often contain pristine vegetation including rare and threatened plants, and are in many cases some of the last remaining undisturbed habitats for vegetative and wildlife species. On the other hand, the active portions of these lands are some of the most intensively used in the nation and therefore are subject to severe soil erosion and the loss of native vegetation and wildlife habitat.

Native plants thrive on the live fire ranges and buffer areas of training lands because there is relatively little disturbance on these areas. However, on the heavily used areas of active training the opposite occurs. Continuous or intermittent wheeled, track or foot traffic on roads and trails combined with rigorous training on open ground, bivouac and convergence areas tend to eliminate most of or all of the existing vegetation. The recent closing of some training units has concentrated activities on the remaining units, intensifying training, and further stressing remaining vegetation.

Native plants, particularly grasses, have a vital role in stabilizing, maintaining and reclaiming Army training lands. The difficulty arises in determining the situations in which natives can be re-established for permanent vegetative cover on active training lands and be able to tolerate the amount of scheduled training for the area.

I am a Natural Resources Conservation Service (NRCS) liaison to the US Army Environmental Center (AEC) headquartered at Aberdeen Proving Ground, MD. The Army Environmental Center's primary mission is to help installations keep their training lands open and available for training. This is an all-encompassing role including cleanup of chemical spills, designing oil and water separation devices for recycling, cleanup of contaminated ground water, cleanup of UXO (unexploded ordnance), and stabilizing the soil on training lands. Soil stabilization is the key to ensuring that compliance actions do not shut down training activities. This mission is getting harder to do as the recent closing of a number of training areas has concentrated the same amount of training on existing areas. There are three NRCS liaisons located at the Center, along with liaisons from the Forest Service, Fish and Wildlife Service, Geological Survey, Bureau of Land Management and the Advisory Council on Historic Places. Army Civilian Biologists, Chemists, Engineers and contractors hold most of the USAEC positions. It all makes for an interesting and diverse work group not always agreeing on the same solutions.

My role at the AEC is to assist in reclaiming training grounds either lost or threatened to be lost to training because of soil erosion or soil and water contamination and to prevent this from happening on the remaining training sites. I have been to problem areas on 15 installations in an effort to help them control soil erosion and re-vegetate training lands. Some of these areas have had sparse or no vegetation growing on them for many years. Many of these sites have no topsoil; some are or have been contaminated with metals, fuel spills or chemical spills.

The Army mission is to "train soldiers" under as many diverse landscapes as possible. This is where the NATIVE PERSPECTIVE on Army training lands comes into focus. In its effort to re-vegetate these lands, the Army will use whatever vegetation that can do the job. Natives are selected when available, then whatever else that will meet the mission. The problem is that there

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are not many natives, especially cool season grasses, that are adapted to solve the unique vegetative needs presented by the Army.

Some of the situations that the Army is up against include:

1) 70 ton tanks tear up a lot of ground that in many cases does not get a chance to recover because of the continuous training, poor soil conditions or lack of reseeding efforts and /or proper species to reseed with.
2) Small arms firing ranges are in constant use and because of the safety regulations (steep berms-short mowed grass) tend to be bare and to erode. Not only is the loss of soil important but so is the wash of metals and other contaminants that may go with it.
3) Roads, trails and footpaths are continuous sources of soil erosion.
4) Many training areas can never be rested long enough to recover, haven't healed and are now critical area sites in dire need of reclamation.
5) Invasive, many times exotic, plants are often more situated to this hostile environment and tend to become established in place of natives and continue to spread as the training intensifies or is prolonged on these areas.

The following two projects involve developing new and unique methods of reclamation and maintenance procedures to control erosion and establish vegetation on damaged training lands.

Project Berm Stabilization - Fort Jackson SC:

The objective of the study is to diminish the effects of bullet pockets and the resulting soil erosion on small arms firing ranges. Bullet pockets are a necessary evil on small arms firing ranges. The resulting erosion caused by the bullet pockets is a continuos problem. Attempts to contain the pockets have led to the construction of bullet traps made from shock absorbing concrete (SACON). There is a complete absence of vegetation on the berm even though the area was seeded during March, which is a good time of year for seeding in South Carolina. Failure to promptly re-seed, re-seed correctly and failure to maintain new seedings are just a few of the reasons there is sparse vegetation on most berms on small arms training ranges. Change of mindset and scheduled maintenance will help in the battle to maintain vegetation on berms and training floors. However, it will take native plant selection and breeding to produce "natives" that can survive the abuse of small arms training ranges.

Project Vegetative Wear Tolerance Study - Fort Leonard Wood, MO.

The objective of the study is to determine what species of vegetation is the most tolerant to five common wear situations on Fort Leonard Wood. The three-year study was established during the spring and summer of 1998. The NRCS Elsberry, MO, Plant Materials Center is conducting the study.

The study is in progress. The following are the results of the study through October 1999.
Site #1. Barracks Lawn
Species being evaluated:

Rebel Jr. tall fescue	Meyer zoysia grass
Leprechaun tall fescue	Marage bermudagrass
Finelawn tall fescue	Chieftain tall fescue
Tufcote bermudagrass	Jaguar tall fescue
Mo-Buff buffalograss	Adobe tall fescue
Divine perennial rye	KY-31 tall fescue

Observation 10/99: Tufcote looks best. Doubtful if Zoysia can take traffic. Buffalograss is slow in getting started, but may be a good survivor.

Site #2. TA-244 Upland vehicle traffic site
Species being evaluated:

Rumsey Indiangrass	Lespedeza Daurica Schimadea
VA-70 Shrub lespedeza	KY-31 tall fescue
Indian switchgrass	Cimarron little bluestem

Observation 10/99: Ky-31 tall fescue and the Cimarron little bluestem look the best.
Site #3 Disturbed Bottomland

Species being evaluated:

Leprechaun tall fescue	Rumsey Indiangrass
Rebel Jr. tall fescue	Lespedeza Daurica Schimadea
Chieftain tall fescue	Loreed Reed Canarygrass
Ky-31 tall fescue	Sodar Streambank Wheatgrass
Indian switchgrass	Bottlebrush Squirrel tail

Observation 10/99: This site has been abandon due to a tremendous influx of weeds.
Site #4 Bivouac Area

Species being evaluated:

Shademaster II red fescue	Chieftain tall fescue
Flyer red fescue	Finelawn 5GL tall fescue
Covar sheep fescue	Finelawn petite tall fescue
SR-3100 hard fescue	Divine perennial rye
Unique KY bluegrass	

Observation 10/99: No traffic has been employed on the site. SR-3100 Hard Fescue looks the best followed by Flyer red fescue and Unique KY bluegrass. Plant in the spring to avoid a smothering effect from leaf drop. Virginia wildrye was not selected for evaluation because it grows too tall for this type of training.

Site #5 Active Small Arms Range
Species being evaluated:

Bottlebrush squirrel tail	Lespedeza daurica schimadea
Guymon bermudagrass	Top gun buffalograss
TifBlair centipedegrass	

Observation 10/99: This is an extremely tough site. Top gun buffalograss is the choice so far. TifBlair centipedegrass looked excellent the establishment year but deteriorated during the second growing season.

RECOMMENDED ACTIONS

6) Rest and rotate training lands as much as possible
7) Plant native species when available to reclaim training lands
8) Follow a maintenance plan to establish and maintain training areas

CONCLUSION

There are not many native species especially cool season grasses, which can compete with introduced cool season species, for use on Army training lands.

Remembering the Army mission "To Train Solders" it is a must to keep Army training lands open for training. The Army will use whatever species are available do the job, selecting natives first when available and applicable, then whatever will meet the mission. The problem is, there are not enough native species available, and in some cases no native species available, to adequately support the mission.

I believe that through proper selection and breeding, native species can become competitive with introduced species on tough sites, not only on Army training lands, but anywhere America needs them. This is a challenge to our grass breeders and others who work with native grasses to concentrate more work in this area, as our soldiers and our lands depend on it.

Developing Integrated Weed Management Strategies to Restore Great Plains Grasslands

Robert A. Masters, Daniel D. Beran, Fernando Rivas-Pantoja, and Roch E. Gaussoin[1]

The productivity of Great Plains grasslands has been substantially reduced by past management that enabled the establishment of invasive exotic weeds and displacement of native species. Many grasslands are comprised of degraded plant communities with reduced native species diversity and are producing at less than 50% of their potential. According to the 1992 National Resources Inventory conducted by the USDA-Natural Resources Conservation Service, there are over 70 million acres of degraded grassland in the Northern Great Plains in serious need of weed management, site stabilization, and reclamation.

The focus of grassland management should be to improve degraded grassland communities in a manner that makes them less vulnerable to invasion by exotic weeds and to spread of undesirable native species. In many instances grasslands have deteriorated to the point that desirable species are either not present or in such low abundance that grassland recovery will be unacceptably slow without direct intervention. A generalized model describes grassland degradation and improvement processes (Figure 1). Site-specific management systems comprised of multiple, complementary technologies or tools applied in appropriate sequences are developed. Such management systems can improve grassland quality and to optimize improvement of degraded grassland need to decrease negative impacts of undesirable exotic and native species.

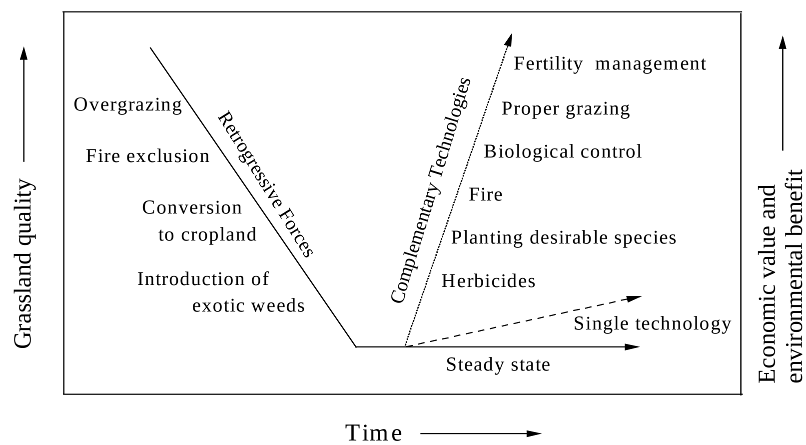

Figure 1. Proposed improvement model for Great Plains grasslands. Degradation leads to steady state conditions of low productivity. Reliance on a single technology results in slow grassland recovery rate. Implementation of integrated weed management strategies accelerates development of high quality grasslands.

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The herbicides, Plateau© and Roundup©, have been determined to be important components of integrated weed management strategies being developed to improve Great Plains grasslands. In Nebraska, these herbicides have been used to (1) improve establishment of native warm-season grasses and legumes (Beran et al. 1999a, 1999b, Rivas-Pantoja et al. 1997); (2) revegetated leafy spurge [*Euphorbia esula* L.]-infested grasslands with desirable perennial forages (Masters et al. 1996, Masters and Nissen 1998), and (3) control leafy spurge (Masters et al. 1998).

Leafy spurge is a serious threat to the productivity and biological diversity of Great Plains grasslands. Leafy spurge was introduced from Eurasia into the northern Great Plains and Prairie Provinces of Canada in the late 1800s. Leafy spurge is estimated to infest more than 2.5 million acres in North America (Dunn 1979). This invasive weed reduces grassland quality by interfering with desirable native species, reducing livestock carrying capacity, and lowering wildlife habitat quality (Belcher and Wilson 1989). The aggressive nature of leafy spurge is related to its ability to reproduce from seed and adventitious shoot buds on the roots and the lack of natural enemies in North America. Seed dispersal mechanisms, high seed yields and viability, and rapid seedling growth and development enable new infestations to quickly establish. Past management practices have often caused undesirable shifts in species composition and hastened leafy spurge establishment and expansion.

Biological and chemical control methods have been the focus of leafy spurge management programs. Biological control agents used against leafy spurge include goats, sheep, and insects. Insects including the spurge hawkmoth, flea beetles, longhorn beetle, and gall midge have been approved for leafy spurge biological control programs in North America. It is too early to fully assess the impact of insect biocontrol agents since most have been released within the past seven years.

Leafy spurge control with herbicides is variable. Effective long-term control of small infestations of leafy spurge is possible with Tordon© applied at 1 gallon per acre. The high cost of this treatment limits its use to small infestations. Application of 2,4-D (2 lbs active ingredient (ai) per acre) or 2,4-D (1 lb ai per acre) combined with Tordon (0.5 lb ai per acre) provides short-term control of leafy spurge and reduces seed production. These herbicides selectively control broadleaf plants including desirable native legumes and forbs. Plateau is a herbicide that has recently been shown to provide effective control of leafy spurge, while not controlling desirable legumes growing in leafy spurge stands.

Historically, rangeland weed management research has emphasized development of chemical and biological control tactics. There is growing recognition that rangeland weed research should shift from the search for a single control technology to development of integrated strategies comprised of multiple technologies used in sequences and combinations that optimize weed control and rangeland improvement (Scifres 1987). A goal of rangeland weed management should be to improve degraded rangeland communities so they are less susceptible to invasion by weeds (Masters et al. 1996; Masters and Nissen 1998; Sheley et al. 1996). Invasive weeds appear to be symptomatic of underlying management problems that must be corrected before sustained progress can be made toward weed control and improving rangeland productivity. One of the concerns about simply focusing on controlling a weed in a plant community with chemical or biological control measures is that where the weed is removed other undesirable species will likely move into the niche vacated by the weed unless there are desirable species available to occupy that open niche. Often rangelands have deteriorated to the point that desirable species are either not present or in such low abundance that plant community recovery may not occur without revegetation with desirable species.

A study was undertaken to evaluate a strategy to improve leafy spurge-infested grassland sites near Mason City and Tilden, Nebraska. This grassland improvement strategy consisted of the combined application of herbicides, fire, and planting mixtures of native grasses and legumes. Plateau (0.13 or 0.19 lbs ai per acre, which is equivalent to 8 or 12 oz per acre of the 2 lb per gallon formulation of Plateau) and Roundup (1.5 lbs ai per acre, which is equivalent to 48 oz per acre of Roundup Ultra formulation) were applied in October 1995. These two herbicides were selected because they are very complementary in their activity. Roundup controls cool-season grasses that are actively growing at the time of application, but provides no residual weed control. Plateau provides residual control of leafy spurge and annual weeds. Plateau is also tolerated by a number of warm-season grasses and legumes. In April 1996, the sites were burned to remove dead plant residue and the grass and legume mixtures were planted into the herbicide-suppressed sod without tillage. Leafy spurge density and yield of the vegetation including the planted grasses and legumes were measured in August 1997.

Treatment with Plateau applied with Roundup and planting the mixture of desirable forage grasses and legumes decreased leafy spurge abundance and dramatically increased forage yield on the leafy spurge-infested research sites. Leafy spurge density and yield were reduced by 60% at Mason City and 95% at Tilden where the Plateau and Roundup treatment was applied compared to where no herbicide was applied. Application of the combined herbicides increased forage yield of the planted grasses from 0 to 3,700 lbs per acre at Mason City and 560 to 2,800 lbs per acre at Tilden. Moreover, total vegetation yield (yield of planted species and other remnant vegetation) increased from 2,200 to 5,700 lbs per acre at Mason City and 1,300 to 3,400 lbs per acre at Tilden where the Plateau and Roundup were applied together.

The strategy developed in this study, which involved the sequential application of Plateau with Roundup, fire, and planting native grasses and legumes, was successfully used to reclaim the productive potential of leafy spurge-infested rangeland at sites in the central Great Plains. The established mixture of native species has the potential to more fully utilize resources on the leafy spurge-infested grassland and preempt resource use by leafy spurge and other undesirable species. By maximizing resource capture, the more diverse reestablished grassland community should be more resistant to invasion by less desirable species. Tilman et al. (1996) determined that plant productivity and nitrogen use were greater in more diverse plant species mixtures than less diverse mixtures. This supports the concept that differences in resource use by multiple plant species allows more diverse plant communities to more fully use resources and improve overall productivity (McNaughton 1993). More diverse grassland communities should also be more resilient and better able to sustain stable ecosystem processes over a range of disturbances, e.g., grazing, fire, periodic droughts, etc., and return to a desirable state once disturbances moderate.

Our goal is to provide rangeland managers with strategies that go beyond the control of undesirable vegetation and lead to restoration of degraded rangeland communities by reintroducing desirable native plant mixtures. Once established, it is essential to use management systems that shift the competitive advantage to desirable species and away from invasive species. The strategy developed in this study restores native prairie flora on degraded rangeland sites, improves carrying capacity and native plant diversity, and decreases leafy spurge dominance. Ultimately, management systems developed must be reliable, efficient, and cost-effective, which is possible if multiple tools are used in appropriate combinations.

Note: Plateau is currently registered for use on roadsides and right-of-ways and not on rangeland and pastures. The research from which these findings were obtained was supported in part by the USDA-Agricultural Research Service, U.S. Environmental Protection Agency, Nebraska Department of Agriculture, American Cyanamid, Monsanto, and the Arthur Sampson Pasture Management Endowment Fund from the University of Nebraska Foundation.

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Piedmont Prairie Restoration in the Charlotte, NC Area

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Abstract

The Piedmont Prairie near Charlotte, NC was possibly first reported by the Spanish explorer Hernando de Soto in 1540 and again in 1670 by a 26-year-old German traveler named John Lederer. Both of these men reported open “savannas” or large open areas covered by wildflowers, grasses and few trees. The existence of these prairies is somewhat unexpected given the Piedmont’s usual abundant rainfall that would normally support forests of large trees. However, there is mounting evidence that these prairies may have been created by the burning and agricultural practices of the local Native Americans communities. Piedmont Prairies are smaller than those found in the Midwestern U.S., mostly due to the numerous creeks and streams found in the Piedmont that act as firebreaks. Today, agriculture and urbanization, along with European land management practices have reduced these large open areas to small remnant isolates. Many of the prairie plants thought to have occurred in these prairies still persist along roadsides, in utility rights-of-way, and along field edges. In an effort to restore the Piedmont Prairie, several locations around Charlotte, NC, have been targeted for restoration projects. Restoration involves clearing trees and shrubs, planting or enhancing prairie plant populations, and then managing the land by periodic prescribed burning. Examples of these prairie sites include the Shuffletown Prairie, the Mineral Springs Nature Conservancy prairie, the Anne Springs Close Greenway Prairie sites, the Suther Prairie, the Latta Plantation Prairie, and the McDowell Park Prairie sites. These sites all vary according to size, plant communities and moisture regime. The restoration of these sites has all occurred because of the cooperation of landowners, private consultants, municipality departments, the university community, and State and Federal agencies. Several of these sites will be examined as case studies showing restoration techniques and rationale behind the efforts.

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Developing and Evaluating Switchgrass as a Bioenergy Crop

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Summary

The utilization of energy crops produced on American farms as a source of renewable fuels is a concept with great relevance to current ecological and economic issues at both national and global scales. Development of a significant national capacity to utilize perennial forage crops, such as switchgrass [*Panicum virgatum* L.] as biofuels could benefit our agricultural economy by providing an important new source of income for farmers. In addition, energy production from perennial cropping systems, which are compatible with conventional farming practices, would help reduce degradation of agricultural soils, lower national dependence on foreign oil supplies, and reduce emissions of greenhouse gases and toxic pollutants to the atmosphere (McLaughlin et al. 1999).

Over the past 7 years research designed to evaluate and improve switchgrass as a bioenergy crop has been conducted by a team of government and university researchers in the southeastern and central United States. This effort is part of the Department of Energy sponsored Bioenergy Feedstock Development Program at Oak Ridge National Laboratory and has been focused in the areas of yield improvement through management and breeding, physiological and genetic characterization, and applications of biotechnology for regeneration and breeding research. Switchgrass, a native warm season prairie grass, was chosen as the model species because of its perennial growth habit, high yield potential, compatibility with conventional farming practices, and high value in improving soil conservation and quality. Variety trials centered in Virginia, Alabama, and Texas have identified three excellent high-yielding switchgrass varieties. The varieties include Alamo, in the deep South, Kanlow at intermediate latitudes, and Indian for the upper Midwest. Yields of fully established stands of best adapted varieties have averaged approximately 16 Mg ha^{-1} in research plots across 18 testing sites, and minimum costs of \$1.78-\$2.03 $MBtu^{-1}$ have been estimated for farm-scale production in the Southeast.

Management research has been directed at documenting nitrogen, row spacing, and cutting regimes to maximize sustained yields. These studies indicate that one or two-harvests per season are best for maintaining high yields over time and that the optimum cutting frequency depends on both latitude and switchgrass ecotype. In Texas where late season droughts are frequent, highest yields are provided by the lowland ecotype Alamo utilizing a 1-cut system, whereas in the Southeast and mid-Atlantic regions, highest yields of upland varieties, such as Indian have been attained with a 2 cut-per-year system. By contrast lowland varieties such as Kanlow and Alamo do well with either single or 2-cut systems in this region. This offers the farmer an opportunity for flexible harvesting regimes within and between years that should help optimize use of equipment.

The timing of harvesting is critical to optimizing and maintaining high yields. In Alabama delaying the initial cut until July, resulted in an approximate doubling of average yield of a 2-cut system with Alamo switchgrass over 5 years. Late season cuts, after October, typically result in up to 20% yield loss associated with retranslocation of carbohydrates and mineral nutrients, notably nitrogen, back into the root system. An additional factor favoring the single cut system is the reduction of up to 60% in usage of nitrogen associated with harvesting mature vs. the more

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succulent tissues that are included in the 2 cut regime. Lower ash content, particularly potassium, associated with late season harvest also results in improved suitability of this material for combustion in power generation systems (Sanderson and Wolf 1995 and McLaughlin et al. 1996).

Significant gains in soil carbon have been documented for a wide range of sites under switchgrass and associated gains in soil quality and erosion control are anticipated in connection with long term production of this species (McLaughlin et al. 1994). Recent studies of the dynamics of soil carbon indicate that switchgrass contributes both labile (3-5 yr. turnover) and relatively stable (26-40 yr. turnover) forms of carbon to soil carbon pools. Total carbon gains in degraded agricultural soils have been estimated at 12 % over a 10-year period (Garten et al. 1999)

To date switchgrass has been bred primarily to enhance its nutritional value as a forage crop for livestock (Vogel et al. 1989). Thus, it has been managed primarily as a hay crop for which high leaf to stem ratio and high nutrient content are important. These targets are quite different from the criteria for biofuels crops for which high cellulose and low ash content are important for high energy conversion and low contamination of combustion systems, respectively. Breeding research has focused on developing and characterizing an extensive germplasm collection, characterizing breeding behavior traits, and both narrow and broader base selection for yield improvement for both marginal and better quality soils (Taliaferro et al. 1999). Breeding gains of $\geq$5% per breeding cycle (3-4 yr.) have been indicated with improving techniques for narrow base genetic selection and associated heterotic gains. Tissue culture techniques have now been developed (Denchev and Conger 1994) to permit rapid clonal propagation of select switchgrass lines and to offer opportunities for application of advanced biotechnological tools such as gene transfer (Denchev and Conger 1996).

Energy budgets indicate that significant gains in net energy return and carbon emissions reduction can be achieved by utilizing switchgrass as a biofuel (McLaughlin and Walsh 1998). These gains are associated with the low energy demands of growing and harvesting perennial grasses, high nutrient and water use efficiency, and the fact that the whole aboveground plant can be converted to energy products. In addition the increased storage of carbon belowground provides a second avenue for reducing net carbon emissions to accompany reductions in direct $C0_2$ emissions associated with supplanting fossil fuels with renewable energy derived from atmospheric carbon.

The bioenergy industry is still in its infancy in terms of its impacts on national energy use. However, the potential of biofuels to contribute to a national energy strategy is substantial. The benefits to the nation of providing cleaner burning fuels that improve both regional and global air quality while improving soil and water quality should be obvious. A multiagency task force is currently conducting analyses with an agricultural sector model (POLYSYS) to estimate the capacity of switchgrass at current production levels and costs to penetrate conventional agricultural markets (Walsh et al.1998). The most recent analyses with this approach project that, at a price of $30 per ton for switchgrass, improved economic returns would be realized on approximately 17 million acres of agricultural land compared to current returns from conventional crops grown on these lands. At a price of $40 per ton for switchgrass economic gains are projected on 42 million acres. With the improvements in the farm economy, which can be expected with the production of energy on American farms and associated increased income for American farmers, bioenergy crops offer a "win-win" option for the planners of Americas future energy strategy. Bioenergy crops can be expected to become increasingly competitive in the future as the diversity of products possible from reformulation of biochemical constituents is developed through processes such as gasification and bioreactor technology. There are promising signs that the utility industry has recognized the value of cleaner burning renewable fuels, which reduce environmental and political liabilities associated with relying totally on fossil fuels. Attainment of the potential for significantly greater participation of biofuels in national energy supply curves will require continued research on producing and improving energy crops more economically, continued improvement of the bioconversion technology to increase the diversity and value of end products, and a commitment of policy makers to improvement of environmental quality, which is measured in both long and short- term time frames.

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Native Warm-Season Grass Establishment as Affected by Weed Control in the Maryland Coastal Plain

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Abstract

There are numerous warm-season grass (WSG) species native to the Mid-Atlantic Coastal Plain of Maryland. However, few regional species are commercially available and little research has focused on their successful direct seeding establishment. Reliable establishment research procedures for native WSG species will promote their use in ecological restoration, soil conservation, and summer pastures of the region. Because weed control is often critical to WSG establishment, our objective was to evaluate the effect of four weed control practices on establishment of beaked panicum [*Panicum anceps* Michx.], purpletop [*Tridens flavus (*L.) Hitchc.], and Indiangrass [*Sorghastrum nutans (*L.) Nash] collected in the Mid-Atlantic Coastal Plain. Treatments used for 2-yr establishment study at two sites were 1) infrequent mowing regime (once per season), 2) frequent mowing regime, 3) frequent mowing in the first year with a broadleaf herbicide mixture (2,4-D, MCPP, and Dicamba) applied in the second year, 4) frequent mowing in the first year with an imidazolinone herbicide applied in the second year, and 5) a control. Stand density (m^2) was recorded in September of the seeding year and monthly from June through September during the second growing season at both research sites. Indiangrass averaged a minimum stand density of 11 or more plants m^{-2} with all weed control practices including the control. Results indicate that all weed control treatments produced significantly higher stand densities as well as higher tiller numbers than the control. Therefore, even minimal weed control, such as one mowing per season, significantly reduced weed competition improving WSG stand establishment in the Mid-Atlantic Coastal Plain over two growing seasons for the species tested.

Introduction

Warm-season native grasses often are slow to establish the year they are seeded because of factors such as seed dormancy, lack of soil moisture (Hyder et al. 1971), and delayed development of an adventitious root system (Whalley et al. 1966; Newman and Moser 1988). In determining the success of native WSG plantings, a major determining factor is control of weed competition prior to and following seeding. Inadequate weed suppression causes more WSG seeding failures than any other single factor, and failure to address a weed problem will result in failure or a substandard grass stand (Duebbert et al. 1981; Mathis et al. 1971). Weed control is critical during establishment of warm-season grasses since weeds shade the developing grass seedlings and contribute to decreasing permanent root development (Wilson 1984).

After planting WSG seed, weed control practices are generally needed to provide reduction of weed competition. Most perennial native WSG species are susceptible to weed competition in the seedling stage, because of low seedling vigor and slower growth in comparison to annual weed species. Furthermore, when annuals are given an initial advantage, they quickly dominate the planting. Hsu and Nelson's (1986) 2-year study showed that the annual weed, crabgrass [*Digitaria sanguinalis* L. Scop.], developed more tillers, more leaves per plant, more leaf area, and accumulated more dry matter than did perennial warm-season grasses. This suggests that crabgrass competes strongly with perennial native WSG species during seedling development in

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the field. They further stated that young weeds removed after emergence reduced grass seedling performance compared to preventing weed emergence.

A cultural weed control practice proposed by Launchbaugh and Owensby (1978) in the Midwest is grazing first-year grass plantings where the seedlings and weeds serve as a resource for livestock. However in sub-humid and humid environments, grazing treatments over a two-year period resulted in inadequate stands (fewer than 11 plants m^{-2}) of the WSG big bluestem [*Andropogon gerardii* Vitman] (Lawrence et al. 1995). Lawrence et al. concluded that grazing was not a suitable alternative to chemical suppression for weed control where high weed populations exist.

Mechanical weed control by mowing can accomplish several things such as nutrient recycling of standing vegetation, grass tiller recruitment, providing mulch for bare areas, and reduction of annual weed competition for light. Clipping should be completed after sufficient weed growth, so that the most active growth buds of weeds are removed. Additionally, pasturing or clipping new grass seedings is helpful but both should end 4-6 weeks before a killing frost (Vough et al. 1995). If the WSG tiller is vegetative when cut, the undamaged intercalary meristem at the base of the plant continues to differentiate blade tissue. Weed can be controlled in a first year tall-grass prairie native grass planting by mowing when weeds reach a height of 31-46 cm to prevent them from forming seed (Ohlenbusch 1997). Flail mowers, sickle bar mowers, and rotary mulching mowers have all been successful at uniformly distributing clippings. If proper mowing equipment is not available, an option is to bale clippings. Another type of mechanical weed control used in the seed production industry is interrow cultivation (Smith and Smith 1997) which can take place when rows of native grass are visible. This type of cultivation should not be closer than one inch to the planted row so grass seedlings are not disturbed.

Herbicides labeled for pre- and post-emergence use in native grass seedings are limited and their use is often dependent on growth stage of the grass plant. The non-selective herbicide glyphosate [N-(phosphonomethyl)glycine], can be used anytime prior to seedling emergence to control perennial grasses and broadleaf weeds. The broad-spectrum herbicide atrazine [6-chloro-*N*-ethyl-*N*-(1-methylethyl)-1,3,5-triazine-2,4diamine] has also been applied pre-emergence to native grass seed germination (Vassey et al. 1985). For post-emergence broadleaf weed control 2,4-D [2,4-dichlorophenoxy)acetic acid], dicamba [3,6-dichloro-2-methoxybenzoic acid] and MCPP [2,2(2-methyl-4-chlorophenoxy) propionic acid] are commonly used and are labeled for use only after native WSG seedlings reach the three to five leaf stage. The practice of post-emergence wicking or wiping with a nonselective herbicide requires that the weeds are taller than the desirable grass crop to be effective (Smith and Smith 1997).

Imazapic (Plateau) [($\pm$)-2-[4,5-dihydro-4-methyl-4- (1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-methyl-3-pyridinecarboxylic acid] is a broad-spectrum herbicide released in 1997 for weed control and growth suppression in non-crop areas (American Cyanamid 1997). Imazapic can be used in many native grass and wildflower plantings and is labeled for pre- or post-emergence control of broadleaf weeds and some perennial and annual grasses. Application rates vary depending on application timing, soil type, preferred native species, and weed species to control. It is readily absorbed through leaves, stems, and roots and is rapidly translocated through the plant with accumulation in meristematic regions (American Cyanamid 1996).

Establishment of native grasses and selected forbs using varying rates of three imidazolinone herbicides show improved establishment of native grasses, especially with pre-emergence treatment as opposed to post-emergence treatment (Masters et al. 1996). It was concluded that imidazolinone herbicides could be important components of integrated weed management strategies to reverse deterioration of grasslands, improve grassland productivity, and decrease exotic weeds. However, a major disadvantage for post-emergence application is that often there is limited time when herbicides are effective due to the growth stage restrictions of weeds to be controlled.

Advantages of planting native warm season grasses in the Mid-Atlantic Coastal Plain are that they grow well in acid soils, are more efficient in the use of water, N and P, maintain growth at higher temperatures than cool-season grasses, and provide soil conservation and restoration benefits (Stout et al. 1986, 1988; Jung et al. 1988, 1990; Brejda et al. 1995; Moser and Vogel 1995). While WSG establishment data exist for more mesic sites, establishment of seeded native WSG species under different weed control practices is lacking in the humid region of the Mid-Atlantic Coastal Plain. The research objective was to determine if significant differences in establishment of three native WSG species exist with four weed control treatments in the Coastal Plain of Maryland.

Methods

Site Characteristics

The study was duplicated at two University of Maryland research facilities. The Turfgrass Research and Education Facility in Silver Spring, MD is located in the northern coastal plain (Soil Conservation Service 1981) and Plant Hardiness zone 6b. Soil is a Rumford loamy sand (coarse-loamy, siliceous, subactive, thermic Typic Hapludults) with a pH of 6.1 and 1.5% organic matter. Soil texture is 89% sand, 6% silt, and 5% clay for the Turfgrass farm. Initial soil P, K, and Mg levels were 177, 74 and 209 kg ha^{-1}, respectively. Nitrate (NO_3) levels were 21 kg ha^{-1}. Precipitation at the Turfgrass farm from May to September 1996 was 850 mm (301 mm above the average) and 350 mm (199 mm less than average) for the same period during 1997.

The second study site was the University of Maryland Wye Research Center in Wye Island, MD located in the Mid-Atlantic Coastal Plain (Soil Conservation Service 1981) and Plant Hardiness Zone 7a. Soil is a Mattapex silt loam (fine-silty, mixed, mesic Aquic Hapludults) with a pH of 6.5 and 3.5% organic matter. Soil texture is 38% sand, 50% silt, and 12% clay. Initial P, K and Mg levels were 319, 504 and 300 kg ha^{-1}, respectively and nitrate levels measured at 55 kg ha^{-1}. Precipitation at the Wye farm in 1996 from May to September was 600 mm, and for the same period during 1997 was 480 mm. Prior to this study, *Festuca arundinacea* Schreb. (tall fescue) was maintained at both research sites.

Species Selection and Planting

The perennial WSG species chosen were common to the coastal plain region, had direct seeding capabilities, wildlife value, known restoration benefits, and good seed availability. Seed of the WSG species were hand collected from local native Maryland coastal plain populations during the fall of 1995. Seed of each species was collected from more than 30 plants with no preference for any traits such as height, larger seed heads, etc. After collection, species symbols (USDA NRCS 1997) and accession numbers were assigned for identification and tracking. Seed viability using the tetrazolium (TZ) method (USDA 1961) and purity were evaluated by the Maryland Department of Agriculture Seed Testing Lab (Table 1). The three native species were beaked panicum and purpletop, both collected in Prince George's County, MD and Indiangrass collected in Queen Anne's County, MD. To aid in planting, collected seed was cleaned by various methods of hand rubbing and passing through sieves. Beaked panicum was moistened and cold stratified at 4^0 C for three weeks prior to planting to break dormancy (Mathew 1942). The three species were individually weighed and 100 seed weights were determined from averages of three separate measurements (Table 1).

Based on the normal rainfall of the region and the planned broadcast seeding technique, a seeding rate of 431 pure live seed (PLS) m^{-2} (40 PLS seed $ft.^{-2}$) was selected (Wark et al. 1995; Nelson and Shepherd 1940). In addition to filed plantings, all species were individually seeded in cell packs in the greenhouse. This enabled observation of the emerging and developing grass seedlings to aid in field identification. The study was initiated in 1996 by spraying existing tall fescue vegetation with 6.72 kg ha^{-1} glyphosate on 12 April at the Wye farm (17 d before seeding) and 15 April at the Turfgrass farm (10 d before seeding). One week after spraying, both sites were moldboard plowed, disked, and packed twice by a solid wheel packer to achieve a firm seedbed (Thornburg 1982). Plots measured 2 x 2 m with three replicates of the four weed treatments and the control at each site.

Table 1. Warm-season native grass symbols, classification, seed purity, viability, and weights.

Genus	Common Name	Symbol	Wetland Classification	TZ† %	Purity %	PLS‡	100 Seed Wg (g)
Panicum anceps Michx.	beaked panicum	PAAN	FAC	25	98	25%	0.079
Sorghastrum nutans (L.) Nash	Indiangrass	SONU2	UPL	100	37	37%	0.141
Tridens flavus (L.) Hitchc.	purpletop	TRFL2	FACU	100	99	99%	0.073

†TZ = tetrazolium test that visibly stains viable seeds
‡PLS = Purity of seed lot multiplied by germination divided by 100

The grasses were individually broadcast seeded using a spring planting date (Hsu and Nelson 1986; Panciera and Jung 1984; Vassey et al. 1985) into a clean-tilled seedbed on 25 April 1996 at the Turfgrass farm on 29 April 1996 and at the Wye farm. For ease of spreading seed, WSG seed was mixed with small amounts of a white granular cacined clay oil absorbent (Associates Absorbents Association, High Point, NC). Grass seed was broadcast planted by shaking evenly over each plot from a jar with 6-mm holes in the lid. After seeding, each plot was raked lightly to obtain a shallow soil cover over the seed, and hand rolled twice with a metal, water-filled 189-L drum to obtain good seed-to-soil contact. No supplemental irrigation was applied at any time during the study and no herbicides were applied in 1996 growing season.

Weed Control Treatments

The four weed control treatments were 1) mowing once per season to 10 cm ht, 2) frequent mowing to 10 cm ht without herbicide, when weeds reached 31-46 cm, 3) frequent mowing in the first year plus a prepackaged broadleaf herbicide mixture of 2,4-D, dicamba, and MCPP (Dernoden et al. 1994) applied in the second year, and 4) frequent mowing in the first year plus imazapic herbicide applied in the second year. The herbicide treatments applied during the second growing season replaced mowing at both research sites. The broadleaf herbicide mixture applied in the second year was labeled for post-emergence broadleaf weed control in native WSG. Imazapic was labeled for non-cropland pre-emergence weed control during the establishment of native warm season grasses. Imazapic controls weedy perennial and annual grasses in addition to broadleaf weeds. Herbicides were not used until the second year because the broadleaf herbicide mixture was labeled for WSG seedlings at the 3-5 leaf stage or beyond. It is common to wait until fall of the seeding year or the second growing season for WSG seedlings to reach the stage where a broadleaf herbicide can be used. Imazapic labeled for establishment of WSG was not available until 1997 so was not used until the second year as a post-emergence.

Weed control treatments that included mowing utilized a self-propelled rotary mower. Mowed weed control treatment plots were cut to an approximate height of 10 cm above the soil surface during both growing seasons. The frequent mowing treatment was completed whenever weed cover reached a height of 31-46 cm to reduce competition with the WSG and before most weeds produced seeds. The infrequent mowing treatment was applied once per year at mid-season. No clippings were removed during two growing seasons.

The 1997 second year herbicide treatments were each applied post-emergence at both research study sites. The broadleaf 2,4-D, dicamba and MCPP herbicide mix was applied at a rate of 1.8 kg ha^{-1} on 2 May 1997 at the Wye farm and on 8 May 1997 at the Turfgrass farm. The imazapic herbicide treatment was applied on 2 May 1997 at a rate of 0.113 kg ai ha^{-1} at both research sites according to label recommendations. All herbicide treatments were applied with a Walkover (Allen Power Equipment Ltd., Didcot, England) push sprayer with a 3.8-L tank. The control was untreated during two growing seasons at both research sites. Throughout the 1996 and 1997 seasons, a 2.54-cm-wide line of glyphosate was sprayed approximately every month on the outside border of each 4 m^2 plot in order to keep clear delineation between research plots

Stand density data were collected the seeding year on 26 Sept 1996 and on four dates in 1997 at each research site. Stand density data were collected randomly in each plot by counting individual germinated seedlings in a sample m^2 PVC square. In the second growing season of 1997, individual plant density and tiller density (total number of stems per plant) data m^2 were collected and recorded at four measurement dates at approximately 30-day intervals from June through September. Percent weed cover per treatment was estimated during 1997 and weed species were recorded.

Experimental Design

Stand densities from the two research sites were analyzed separately for the second growing season as a randomized split-block design. Whole plots consisted of three WSG species with subplots of four weed control treatments and a control, with three replications. Stand density data for 1997 were analyzed ($p<0.05$) using the mixed model analysis of variance (ANOVA) procedure in SAS version 6.12 (1996) to partition experimental variance. Repeated-measures analysis (ANOVA) was used for covariance between multiple samples on the same experimental unit throughout the 1997 growing season. Orthogonal contrasts were an independent analysis between weed control treatments at both research sites. Means for September 1996 stand density measurements show plant development differences after one growing season. However, these data are not part of the final analysis since all treatments were not applied until the second growing season in 1997.

Results and Discussion
1996 Stand Densities

At 144 d after seeding at the Turfgrass farm, beaked panicum had not germinated, Indiangrass had a mean stand density of 17.2 plants m^{-2}, and purpletop a mean stand density of 0.32 plants m^{-2}. Mean stand densities at the Wye farm at 154 d were 0.65 plants m^{-2} for beaked panicum, 13.9 plants m^{-2} for Indiangrass, and 2.15 plants m^{-2} for purpletop. No herbicides were applied until the second growing season (1997). At the Wye site only one treatment with beaked panicum had any germination, and only two treatments with purpletop had any germination (Table 2).

Stand Density at the Turfgrass Farm-1997

Stand densities were significant for the main effects of date and species. Indiangrass was the only species to produce 11 or more plants m^{-2} by the July 1997 date as a measure of successful establishment (Dickerson and Wark 1997) (Table 3). The highest mean tiller number was for the frequent mow the first year with imazapic herbicide in the second year treatment, with an average of 118.4 tillers m^{-2}. The next highest mean tiller number was for the infrequent mowing treatment with 99.0 tillers m^{-2}, followed by the frequent mowing treatment, then the frequent mow the first year with 2,4-D, dicamba, and MCPP herbicide in the second year treatment with means of 86.9 and 88.2 tillers m^{-2}, respectively. Lastly the control had a mean tiller number of 33.1 m^{-2}. Percent weed cover at the Turfgrass farm in 1997 was the highest for the control (Table 4) and was lowest for the frequently mowed treatment in the first year with imazapic herbicide in the second year.

Table 2. Stand density means for Turfgrass farm and Wye farm on 26 September 1996 N=3.

Treatment	Species	Turfgrass Farm	Wye Farm
		Plants m^{-2}	
Control			
	beaked panicum	0.0	0.0
	Indiangrass	15.3	25.1
	purpletop	0.0	0.0
Frequent mow both years			
	beaked panicum	0.0	0.0
	Indiangrass	16.1	7.2
	purpletop	0.0	0.0
Frequent mow the first year + 2,4-D, dicamba, MCPP the second year			
	beaked panicum	0.0	0.0
	Indiangrass	14.3	10.8
	purpletop	0.0	3.58
Frequent mow the first year + imazapic the second year			
	beaked panicum	0.0	3.58
	Indiangrass	20.7	18.0
	purpletop	1.80	3.58
Infrequent mow both years			
	beaked panicum	0.0	0.0
	Indiangrass	18.0	10.8
	purpletop	0.0	0.0

Table 3. Plant densities for all species in 1997 by treatments N=36.

Treatment	Turfgrass Farm	Wye Farm
	Plants m^{-2} ± SE	
Control	8.37 ± 2.88	6.58 ± 1.42
Frequent mow both years	17.90 ± 2.88*	12.30 ± 1.79*
Frequent mow the first year + 2,4-D, dicamba, MCPP the second year	15.00 ± 2.88*	16.11 ± 1.79*
Frequent mow the first year + imazapic the second year	18.50 ± 2.88*	11.90 ± 1.62*
Infrequent mow both years	20.10 ± 2.88*	8.37 ± 1.79*

* significant at 0.05 probability level

Table 4. Weed cover for 1997 treatments N=36.

	Turfgrass Farm	Wye Farm
Treatment	weed cover % ± SE	
Control	75 ± 2.56	90 ± 1.17
Frequent mow both years	58 ± 2.66	88 ± 0.87
Frequent mow the first year + 2,4-D, dicamba, MCPP the second year	58 ± 4.48	91 ± 1.11
Frequent mow the first year + imazapic the second year	17 ± 1.05	79 ± 1.01
Infrequent mow both years	62 ± 3.35	73 ± 3.33

Stand Density at the Wye Farm-1997

Tests of fixed effects resulted in a significant interaction between plant densities and measurement dates and between plant densities and weed control treatments. The beaked panicum had significant treatment results of 12.6 ± 2.92 plants m^{-2} with frequent mowing the first year, 2,4-D, dicamba, and MCPP herbicide the second year and with infrequent mowing both years that had a stand density of 7.18 ± 3.06 plants m^{-2} (Table 5). During the 1997 growing season at the Wye farm, the Indiangrass yielded 11 or more plants m^{-2} with all weed control treatments including the control, and all treatments were significant (Table 5). The highest stand density for Indiangrass at the Wye farm was from the frequent mowing in the first year with imazapic herbicide in the second year treatment producing 24.2 ± 2.34 plants m^{-2}. All weed control treatments produced significantly different plant densities for purpletop during the 1997 growing season (Table 5). The weed control treatment of frequent mowing in the first year with 2,4-D, dicamba, and MCPP mix herbicide in the second year had the highest stand density means for purpletop with 16.1 ± 4.08 plants m^{-2}.

Orthogonal contrasts for all treatment results at the Wye farm in 1997 indicated that stand densities for the control were significantly lower than all weed control treatments (Table 3). In addition, stand density for the infrequent mowing treatment was significantly lower than the other three weed control treatments. Species tiller number m^{-2} means were highest for the frequent mow in the first year with 2,4-D, dicamba, and MCPP herbicide mix the second year treatment with an average of 82.2 tillers m^{-2} followed by the frequent mow in the first year with imazapic herbicide the second year treatment with 65.4 tillers m^{-2}. The frequent mow for both year treatment and the control produced mean tiller numbers of 36.2 and 33.1 m^{-2}, respectively. The infrequent mowing treatment had the lowest mean tiller number with 27.2 m^{-2}. From observation at each date, the highest weed cover percentages during 1997 were for the control and the frequent mowing in the first year with 2,4-D, dicamba, and MCPP herbicide mix in the second year treatment (Table 4), with the lowest weed cover percentage for the infrequently mowed weed control treatment.

Conclusions

Results of weed control treatments varied depending on the WSG species. During the second growing season after direct seeding, the control always had lower stand densities than any of the four weed treatments at both Mid-Atlantic Coastal Plain research sites. When observing the significant interaction between species stand densities and treatments at the Wye farm in 1997 (Table 5), both beaked panicum and purpletop stand densities were highest with the treatment of frequent mowing the first year followed by 2,4-D, dicamba, and MCPP herbicide mix applied the second year following direct seeding. Indiangrass stand density was highest with the treatment of frequent mowing the first year followed by imazapic herbicide applied the second year following direct seeding. At the Turfgrass farm there were no significant differences between any weed control treatments (Table 5). Imazapic is not labeled for use in switchgrass during seedling establishment (American Cyanamid 1997), and potentially adversely affected the beaked panicum establishment with the June 1997 application at each site.

Table 5. Species x treatment interaction for Wye farm in 1997 N=2.

Treatment	Species	Wye Farm	
		Plants $m^{-2} \pm$ SE	
Control	beaked panicum	0.0	0.0
	Indiangrass	17.9 ± 2.75*	24.3 ± 6.01
	purpletop	1.2 ± 1.10	0.0
Frequent mow both years	beaked panicum	3.6 ± 2.03	5.4 ± 1.61
	Indiangrass	20.7 ± 2.79*	37.8 ± 1.62
	purpletop	12.6 ± 3.45*	10.9 ± 2.23
Frequent mow the first year + 2,4-D, dicamba, MCPP the second year	beaked panicum	12.6 ± 2.92*	3.6 ± 1.52
	Indiangrass	19.7 ± 2.23*	35.1 ± 4.23
	Purpletop	16.1 ± 4.08*	6.3 ± 2.08
Frequent mow the first year + imazapic the second year	beaked panicum	0.0	1.7 ± 1.21
	Indiangrass	24.2 ± 2.34*	47.6 ± 8.87
	purpletop	11.6 ± 2.80*	6.3 ± 2.01
Infrequent mow both years	beaked panicum	7.2 ± 3.06*	3.6 ± 1.52
	Indiangrass	11.6 ± 2.46*	42.3 ± 6.34
	purpletop	6.3 ± 2.08*	13.5 ± 5.00

*significant at 0.05 probability level

The three perennial native WSG species tested germinated and established with all weed control treatments producing significantly greater stand densities than the controls at each study site. Therefore, even minimal weed control provided reduced competition to improve WSG stand establishment in the Mid-Atlantic Coastal Plain over two growing seasons when compared to the control. Neither beaked panicum nor purpletop established significant stand densities in the control in the second growing season at either research site. In contrast the Indiangrass established significant stand densities in the control (more than 11 plants m^{-2}) at both research sites during 1997, showing that this WSG species can establish to minimum success levels with no weed control in this region.

Mean tiller numbers were also significantly higher during the second growing season with all treatments tested in contrast to the control. Therefore, there are options in the Mid-Atlantic Coastal Plain of Maryland when choosing native WSG weed control measures depending on the planting site, severity of weed competition, native WSG species selection and available resources. Additional weed control research would be beneficial to test imazapic as a pre-emergence herbicide treatment for collected WSG species, as imazapic was not commercially available prior to the planting dates for this research study.

Acknowledgments

Research support provided by Dr. Billy Teels, Director of NRCS Wetland Science Institute in Laurel, MD through Cooperative Agreement NRCS 68-3B-19-5-267 with the NRCS Maryland State Office.

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The Use of Native Warm Season Grasses for Critical Area Stabilization

Christopher F. Miller[1] and John A. Dickerson[2]

Native warm season grasses are indigenous to the Northeastern United States but now are found growing naturally only in isolated pockets throughout the region. When Europeans arrived on the continent, there were some impressive grasslands contained within the eastern forest, primarily in burned areas and in "barrens" or rocky outcrops. Now, the most extensive remnants are found along the coastal strip/barrier islands, railroad/utility rights-of-way and in natural areas along major river systems. The most common warm season grasses found include: switchgrass [*Panicum virgatum* L.], coastal panicgrass [*Panicum amarum* Elliott], big bluestem [*Andropogon gerardii* Vitman], little bluestem [*Schizachyrium scoparium* (Michx.) Nash], Indiangrass [*Sorghastrum nutans* (L.) Nash], deertongue [*Dichanthelium clandestinum* (L.) Gould], purpletop [*Tridens flavus* (L.) Hitchc.], eastern gamagrass [*Tripsacum dactyloides* (L.) L.], sideoats grama [Bouteloua curtipendula (Michx.) Torr.], and the cordgrasses [Spartina *spp*.].

These native warm season grasses provide extremely valuable habitat for ground-nesting birds and many mammals. They are very deep rooted, making for long lasting, stress tolerant, low maintenance plants. The root biomass of native warm season grasses far exceeds that of the introduced cool season grasses. This characteristic provides increased organic matter in soils and more rapid infiltration rates. The bunch-type habit of these grasses provides space for the inclusion of native forbs and legumes to further improve habitat quality. Although these attributes of the native grasses are well documented, there has been a reluctance to utilize them in the Northeast, particularly for the purpose of erosion control.

The Northeast has a long history of utilizing introduced cool season turf and forage grasses for erosion control. Introduced cool season grasses such as perennial ryegrass [*Lolium perenne* L.], Kentucky bluegrass [*Poa pratensis* L.], tall fescue [*Festuca arundinacea* Schreb.], and orchardgrass [*Dactylis glomerata* L.], are readily available, relatively inexpensive and have good seedling vigor which is useful for quick stabilization. In addition, the cool season grasses may be seeded almost year-round, except during the typical midsummer dry period. Conversely, the native warm season grasses are not as readily available, are more expensive, and have relatively low seedling vigor compared to cool-season grasses, which results in a longer establishment period.

There are other reasons for reluctance to using warm season grasses. A warm season grass seedling partitions initial energy into root development so seedlings are vulnerable to competition and frost heave until the end of the second growing season. The primary seeding window is limited to the early spring, but late fall/early winter seedings are a possible option on droughty soils with little weed competition. There is no late summer/early fall seeding window as with cool season grasses. Many of the warm season grasses produce chaffy seeds with long awns, which do not efficiently flow through a conventional grass seeder. As a result, specialized seed drills, which handle this type of seed, are needed, but have not been commonly available in the Northeast. However, recent purchases of native grass seed drills by Soil Conservation Districts, grass-roots environmental and wildlife organizations, and the U.S. Fish and Wildlife Service have greatly improved the availability of native grass drills in the Northeast region.

In general, warm season grasses have more exacting requirements for establishment than do cool season grasses. However, the benefits of utilizing the native grasses far outweigh the potential difficulties encountered. This article intends to minimize the concerns with establishing native warm season grasses for erosion control by presenting recommendations which have proven to be successful in the Northeast for the last eighteen years.

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Site Selection

Suitable planting sites for warm season grasses have the following attributes:

1. Soil drainage class of moderately well drained or better, with no history of frost heave. Frost heave is less of a threat in states with longer and/or warmer summers than we have in New York, Vermont, New Hampshire, Maine, Massachusetts, and southeastern Canada. Even within the frost heave area, sandy or gravely soils rarely have this problem.

2. Good control of perennial cool season grasses and forbs. Weed competition is typically much lower on critical area stabilization sites such as mined areas, sanitary landfill caps, and other disturbed areas due to poor soil conditions.

3. At least a 100-day frost-free season, and 1600 growing degree days (corn formula).

4. Full sun with south, west and east exposures at elevations below 2000 feet in plant hardiness zone 3 or warmer. A northern exposure limits elevations to below 1500 ft. and to slopes of less than 20 degrees in plant hardiness zone 4 or warmer. Add 500 feet to elevation limits for each warmer hardiness zone.

5. Soil pH of 5.5 or higher with moderate or low N, P, K.

Site Preparation

The area to be planted should be firm and free of weeds, large rocks, stumps and other debris over 2" in diameter.

Weed competition is typically not a problem on critical area planting sites due to the sterile, droughty soil conditions which often exist in disturbed areas. However, perennial cool season grasses pose the biggest threat to warm season grass establishment and must be addressed the year prior to planting if they are present. Contact herbicides such as Roundup, Poast, Fusilade, Gramoxone, 2,4-D, and Banvel combined with tillage, are effective ways to eliminate perennial weeds. All herbicides must be used according to the label requirements.

Planting Procedure

Switchgrass, coastal panicgrass, and deertongue can be planted with conventional grass or grain seeding equipment because the seed will meter through the feed mechanisms. The bluestems, Indiangrass, and sideoats grama have chaffy seed which requires either broadcasting or a native grass drill with "picker wheel" feed mechanisms and hopper agitation. Eastern gamagrass can be planted with a corn planter if a forage stand is desired.

Drills should be set to plant 0.25 to 0.5 inch deep. Depth bands help with this, otherwise careful adjustment of the drill pressure is required. Eastern gamagrass does best at depths of 1 to 1.5 inches.

In the Northeast, availability of native grass drills has been minimal. In addition, some sites do not lend themselves to drilling because of slope steepness or coarse soil texture. So where the chaffy grasses are part of the seed mix, broadcasting onto a prepared seedbed is sometimes a necessity. Under these conditions, a second pass over the site with a cultipacker (with tines raised) or a bulldozer (tracking) must be used to incorporate the seed into the soil. Hydroseeding without tracking or cultipacking is unacceptable. Mixing chaffy seed with dry vermiculite or oat seed will sometimes allow for flow through fertilizer spreaders, but this takes some experience with particular machines to make it work.

Apply mulch if needed. Acceptable amounts of mulch (0.5-1.0 ton ac^{-1}) can vary based upon the planting method to be used, but heavy mulching (2 ton ac^{-1}.) rates are unacceptable because this will hinder soil warming and light penetration to the developing seedlings.

Planting Dates

The ideal planting dates for seeding warm season grasses range from April 15 in the Mid-Atlantic States to May 15 in northern New England. This roughly approximates corn planting season. Late plantings increase the risk of frost heave on moderately well drained soils, because the seedlings will not be as large as they would have been with a longer growing season. Late plantings also increase the risk of hitting a dry period, and further delaying germination. However, delaying planting to the end of corn planting season is justified if final weed control is required. Where weed control has been very effective the year prior to planting, and/or droughty soils are present, an early planting (one to three weeks prior to corn planting) is possible.

If a cover crop is needed over the winter, plant oats in late August or early September. The oats will winterkill, thus not requiring herbicide kill in the spring, unless there are other grasses or weeds germinating at that time.

Seeding Rates

Warm season grass seed is sold, and planted, based upon pure live seed pounds (PLS lb.). This means that the gross weight of seed is increased to compensate for the inert material and dead seed in the given seed lot. Buying mixtures of seed is not recommended, rather buy the seed needed and make the mix just prior to planting. This allows for better quality control, and for greater flexibility in using planting equipment. For instance, a seed like switchgrass which "flow" can be planted out of a small seed box on a conventional drill. Smooth, flowable seeds tend to settle out of a mix with the chaffy seeds as the drill bounces across the field.

Typical Grass Seeding Rates
(Use high range if broadcast or hydroseeding)

Core Mix:

Switchgrass or Coastal panicgrass; 2-5 PLS lbs ac^{-1}
Big bluestem; 3-7 PLS lbs ac^{-1}
Little bluestem; 4-6 PLS lbs ac^{-1}
Indiangrass; 3-7 PLS lbs ac^{-1}
Sideoats grama; 1-2 PLS lbs ac^{-1}
Deertongue; 5-8 PLS lbs ac^{-1}

For sites where less than 15% fines is present (sands, loamy sands, course stands)

Add 1 PLS lbs ac^{-1} of sand lovegrass or 2 PLS lbs ac^{-1} of sand bluegrass

Optional additions to core seed mix if quick cover is needed for erosion control

Nurse grasses for quick cover:
Oats [*Avena sativa* L.] – 30 lbs ac^{-1} or
Annual ryegrass [*Lolium multiflorum* Lam.] -10 lbs ac^{-1}

Plus: companion grasses for initial and short-term cover
Redtop [*Agrostis gigantea* Roth] -1 lbs ac^{-1} or
Canada wildrye [*Elymus canadensis* L.] – 5 lbs ac^{-1} or
Fine fescue [Festuca *spp*.] - 15 lbs ac^{-1}

Fine fescues include: hard fescue [*Festuca brevipila* R. Tracy], Chewing's fescue [*Festuca rubra var. commutata* Gaudin], and sheep fescue [*Festuca ovina* L.]

Choose these companion (cool season) grasses based on availability, price and seeding objectives. Redtop is acid tolerant and will withstand short periods of drought. Persistence is much longer on wetter, poorly drained sites, however these sites are poor candidates for warm season grasses. Canada wildrye has fair drought tolerance, but good salt tolerance. The fine fescues will persist for many years under droughty, acid, and sterile soil conditions.

Adding the following legumes improves soil conditioning and habitat quality: select one or two)

Partridge pea [*Chamaecrista fasciculata* (Michx.) Greene]	4
Round-headed bush clover [*Lespedeza capitata* Michx.]	2
Wild indigo [*Baptisia tinctoria* (L.) R. Br.]	2

Recommended warm season grass cultivars for the northeast

GRASS SPECIES	CULTIVAR(S)
Big bluestem	Niagara, Kaw
Coastal panicgrass	Atlantic
Deertongue	Tioga
Indiangrass	Rumsey, Osage, NE-54
Little bluestem	Aldous, Camper, Blaze
Sand bluestem [*Andropogon hallii* Hack.]	Goldstrike
Sand lovegrass [*Eragrostis trichodes (Nutt.)* A.W. Wood]	Bend, Nebraska 27
Sideoats grama	El Reno, Trailway
Switchgrass	Blackwell (critical sites) Cave-in-Rock (forage-north) Carthage (forage-south) Shelter (wildlife)

Managing the Establishing Stand

Warm season grasses are slower to germinate than cool season grasses, often taking 14-21 days before the seedlings can be seen. To determine what is coming up gently pass your hand just over the soil surface and "feel" the emerging leaves, then dig up some seedlings to find and identify the seed coats.

Unfortunately, weeds do not have low seedling vigor. The best treatment, when weeds begin to shade the grass seedlings, is to clip the weeds just above the grass leaves with a sickle-bar mower. Cut off as little grass leaf surface as possible although a leaf tip here and there is no problem. Two to three clippings are almost always needed during the first growing season, sometimes more. A rotary mower can be used as long as it can be elevated high enough, but it tends to leave clippings in wads and windrows rather than thinly and evenly deposited over the field.

Dry weather after the seedlings are 3-4 inches tall is not a problem and, in fact, will help the warm season grass by putting the brakes on the cool season grass seedlings that are sure to be growing along with the plants desired. Therefore, irrigation is not warranted.

Fertilizer applications are recommended only if the area is essentially weed free in mid-July to early August. Apply 30-40 pounds per acre of nitrogen to give the warm season grasses a boost, but do not apply any after August 1 in the northern states or August 20 in the southern part of the region.

When broad-leaved weeds are a problem, Banvel and 2,4-D are the herbicides of choice. These can be used once the planted grasses are six inches tall with at least four leaves. All herbicides must be used following label requirements.

Second Year Management

There may be an opportunity to control cool season grasses by spot treatment during the spring. If sufficient growth occurs on the cool season grasses before any green growth appears on the warm season grasses, judicious use of Roundup is possible.

Annual weeds will be crowded by the developing stand of warm season grasses and are rarely a factor in stands with good density after year one.

For forage plantings, apply 60 lb. ac^{-1} of nitrogen after the grass has about six inches of growth. Forage harvests, as hay or pasture, should begin as the stems begin to elongate (early boot stage), and end six weeks before expected frost. Grazing should follow an intensive rotational system. Harvest should allow at least six inches height to remain. Consult other references for detailed harvest strategies.

Case Studies

New York/Northern New England

1. Franklin Co, NY (extreme northern NY), Plant Hardiness Zone 4. Gravel pit planting in 1975 comparing cool season and warm season grass varieties for long term droughty site persistence. Cool season grasses were ineffective for erosion control and wildlife habitat. Warm season grasses provided good cover and microsites for native woody vegetation establishment. Plantings were part of a 10-site 6-state test which was reported in the Journal of Soil and Water Conservation, Sept-Oct, 1987. These plots served as the basis for matching plant species selection to soils based on percent fines passing #200 mesh sieve.

2. Gravel pit near Montpelier, VT, Plant Hardiness Zone 4. Planted in 1985 using warm-season grass mix including ‘Niagara’ big bluestem, ‘Blackwell’ switchgrass, ‘Osage’ Indiangrass, and ‘Aldous’ little bluestem. This site was used as a demonstration of tracking in the seed with a bulldozer. This planting method has been found repeatedly to be superior on steep slopes where the use of a seed drill is impossible. The tracking technique following broadcasting (by hand, mechanically, or hydroseeder) results in excellent germination in the cleat tracks. The difference is typically dozens of seedlings per square foot vs. 0-2 seedlings per square foot where only surface application is done.

3. Soil bioengineering planting in November 1988, near Gaysville, VT on a steep, dry slope. ‘Cape’ American beachgrass [*Ammophila breviligulata* Fernald] planted between contour lines of ‘Streamco’ purpleosier willow [*Salix purpurea* L.] wattles. Cape performed well for a few years until the willows eventually dominated. This combination stabilized the slope by creating a favorable microclimate for seed recruitment from the adjacent native trees and.

4. Soil bioengineering, tidal stream, Wells, ME, Plant Hardiness Zone 5. Emergency Watershed Protection planting in June 1993 following severe spring flooding. Bank erosion within 8 ft from house foundations. Combination planting of 'Streamco' purpleosier willow, 'Bankers' dwarf willow [*Salix x cottetii* Jos. Kern], and 'Cape' American beachgrass were planted. Cape provided initial stabilization then was crowded out by willows. Homeowners expectations were exceeded by the results of the planting which were preferable to rip-rap to the top of the bank.

5. Warm season grass cover for landfill reclamation at Roxbury and Williston VT, and Cortland, NY, using mixtures of 'Shelter' switchgrass, 'Niagara' big bluestem, 'Atlantic' coastal panicgrass, 'Bend' sand lovegrass, and 'Osage' or 'Rumsey' Indiangrass. These sites have soils with low percent of fines, droughty cap materials, especially in eastern NY and New England. The major obstacle to using warm season mix was the relatively slow establishment and the resulting possibility of erosion during the first summer. 'Atlantic' and 'Bend' provide improved establishment during this process, then they are dominated by the other species over time. Due to winter injury, 'Atlantic' is only reliable for the first 2 years in NY and northern New England. Other landfill sites such as Fresh Kills on Staten Island and Pelham Bay in the Bronx are now using this approach to provide long-term, low maintenance, high value wildlife cover.

6. Warm season grass seeding at the East Corinth landfill in eastern Vermont. The native grass seed was tracked in with a dozer. Seeding was a success, but engineers insisted that the site had to be mowed. The cover struggled under mowing but has become well established since mowing was abandoned as a maintenance strategy.

7. The Elizabeth copper mine tailings site in central Vermont. The site was bare and highly erosive for 40 years with no native plant establishment except for broadleaved cattail [*Typha latifolia* L.] in a wet spot. Plantings of warm season grass plots in 1988 demonstrated the ability of the major species to tolerate the heavy metal concentrations and low pH at the site. A light lime (1000 lbs ac^{-1}) and fertilizer application (40 lbs ac^{-1}) was made at planting and tracked in with the seed. No soil was applied to the site.

8. A titanium and iron mine in Tahawas, NY (eastern Adirondacks) Zone 4, 1500 ft elevation. Warm season grass mix, 1000 lbs. of lime and 80 lbs. of N-P-K were applied per acre, then tracked in with a dozer.

9. Sand bluestem is not native to the Northeast. Like sand lovegrass it is very useful in mixes destined for use on droughty, low-fines sites. 'Goldstrike' sand bluestem from Nebraska is performing well after 10 years at the Swanton Airport in extreme northern Vermont, a few miles from Quebec Province (plant hardiness zone 3).

Southern New England/Mid-Atlantic

1. Watershed Protection Project in Berkshire Mountains, MA (elevation 1800') Indiangrass, big bluestem, and little bluestem were seeded in November 1997 along with cool season companion grasses, redtop and Canada wildrye. Light mulch was applied after seeding. The project site was fertilized in the early summer with a liquid fertilizer. By late summer 1998, seedlings of big and little bluestem were present on the site along with a good cover of redtop and scattered stands of Canada wildrye. After the second growing season (summer 1999), seedlings of all the native grasses seeded were evident throughout the project area with some individuals producing seedheads. Only very localized rill erosion had occurred during the native grass establishment period.

2. Hart-Miller Island, MD. This is a dredge containment facility for material dredged to keep the Baltimore Harbor shipping channel open. The containment dike is composed of unconsolidated coarse-textured sands and gravels. The dikes have a 1:1 slope (45 degree) slope which preludes the use of any seedbed preparation or seed drilling equipment on the slope. The grass mix composed of 'Atlantic' coastal panicgrass, 'Blackwell' switchgrass, weeping lovegrass [*Eragrostis*

curvula (Schrad.) Nees], partridge pea, and 'Lathco' flat pea *[Lathyrus sylvestus* L.] was hydroseeded onto the slope. A chain was then dragged across the slope to improve seed to soil contact. Also, a liquid fertilizer was added to provide some nutrients to the sterile soil. A fully established stand was present after two growing seasons. Seven years after seeding the warm season grasses are persisting well.

3. Hopatcong Civic Center northern New Jersey. Warm season grasses were seeded on a barren, gravelly to cobbly outwash slope. Prior attempts to establish cool season grasses on the site were unsuccessful. The native seeds were broadcast and tracked in with a bulldozer. A full stand of native grasses developed within two growing seasons and is persisting five years after seeding.

4. Coastal strip (NJ, DE, MD). 'Atlantic' coastal panicgrass was successfully seeded in back dune areas between rows of beachgrass. Seeding has been done with a simple garden seeder (Planter Jr.) set at a 1 1/2"-2" depth. Seedlings emerging the first year generally ranged from 2"-8" in height. Within three growing seasons, the coastal panicgrass crowded out American beachgrass, a pioneer plant, and dominated the site with the long-term cover.

Summary

Warm season grasses have become an important tool for conservation plantings in the Northeast. The benefits which these grasses bring to the planting site include long life, tolerance to acid and low fertility conditions, compatibility with forbs, superior root production, soil improvement, and exceptional wildlife habitat. Natural resource agencies should be finding ways to incorporate the use of these grasses in their programs, but are cautioned to utilize effective site selection and planting procedure criteria.

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Surface Mining Reclamation Revegetation Guide

D. P. Morris[1]

Abstract

Preparation for reclaiming a surface mine literally begins before ground disturbance and mineral recovery at a proposed mine, through the process of initially developing an environmentally sound mined land use plan. Most if not all reclamation objectives involve re-establishing a good vegetative cover on final land grades. The intention of this guide is to provide and encourage more ecologically diverse reclamation alternatives when considering the revegetation phases of mine closer. Plant material choices are limited to species, which will tolerate site specific growing mediums created at the time of final land grading. These choices have typically been further limited because many native species were not being propagated and available commercially. A wide variety of native and non-native species are now being cultured and available for use over a broad spectrum of reclaimed site conditions. This revegetation guide will provide assistance to landowners, miners, professional consultants and governmental staff during both the planning and development stages of reclamation so that more effective, alternative and economically feasible decisions are utilized. These goals are achieved by first advocating alternative revegetation methods and second by simplifying the planning and implementation processes of the multidisciplinary issues involved. This guide provides a brief description of the optimal planting conditions required by different species so that accurate preplanting site conditioning is performed. Chapter 1 introduces concepts of reclamation and long-range land use perspectives. Chapter 2 defines significant preplanting, planting, and erosion control considerations, which accommodate revegetation success. Site characteristics required by the different vegetation groups, trees, shrubs, forbs and grasses are explained within Chapter 3, and are intended to be assessed during the plant materials selection stage of a reclamation project. Chapter 4 outlines maintenance schedules to follow after the initial planting and recommends management practices used to overcome undesirable conditions. Finally, a list of commercial growers and nurseries offering plant materials and seed sources are referenced for the benefit of the user.

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Grasses and Other Native Plants in Designed and Managed Landscapes

Darrel Morrison[1]

Abstract

Since the 1970's, there has been a slow, but steadily growing, interest in the use of native plants in designed-and-managed landscapes. This is in response to the recognition that many traditionally designed landscapes are unnecessarily consumptive of resources and overly reliant on chemical pesticides. One step toward more sustainable landscapes, economically and ecologically, is the use of native plants – or better yet, communities of naturally associated species – in designed-and-managed landscapes.

This approach is, in a way, a return to one that was practiced in this country for the early decades of this century by such landscape architects as Jens Jensen, Frank Waugh, and Elsa Rehmann. Rehmann, with her colleague Edith Roberts, a plant ecologist, published a book in 1929, American Plants for American Gardens, in which they advanced the idea of using natural communities as models for designed landscapes.

Recent work, which takes this approach, will be presented with an emphasis on projects in the Eastern United States in which native grasses are incorporated. These projects, it is hoped, will illustrate not only an ecologically sound approach, but also the potential aesthetic richness of landscapes based on natural communities of the region in which they occur.

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Carbon Stored in Soils under Eastern Grasslands

Lloyd B. Owens and Daniel L. Hothem[1]

Organic matter has long been considered important in agricultural soils. But with global change issues and the possible role of CO_2 in those changes, it is important to evaluate the potential practices to mitigate CO_2 emissions through carbon storage. Many cropping practices need to be studied, including grasslands.

At the North Appalachian Experimental Watershed (NAEW) near Coshocton, OH different grazing/grassland management practices have been studied for over 20 years. Soil samples from these systems were taken and archived over much of the life of these studies. The objectives of the work presented in this paper were to use soil samples from four pasture management systems to (a) measure total carbon concentrations in the soil profile and to (b) assess the amount of total carbon in the soil profile. The results presented here are only a preliminary assessment of the soil data.

Methods

One management system (System I) was an unimproved pasture system (Owens, et al. 1996). It is a 28 ha (70 ac) watershed which was ungrazed from 1972-74; summer grazed without rotation by a beef cow/calf herd from 1975-79; grazed the entire year with hay brought in during the winter during 1980-87; and grazed the entire year with the stream and riparian woods fenced from 1988-99. Slopes range from 2 to 35% with an approximate average of 17%. Soils are residual silt loams C well drained (typic Hapludults and typic Dystrochrepts) above a clay outcrop; moderately well drained (aquultic and aquic Hapludults) below the outcrop. Vegetation included a thin stand of perennial grasses (Kentucky bluegrass [*Poa pratensis* L.]; orchardgrass [*Dactylis glomerata* L.]; red top [*Agrostis gigantea* Roth]); legumes (white clover [*Trifolium repens* L.]; red clover [*Trifolium pratense* L.]; alsike [*Trifolium hybridum* L.]; black medic, [*Medicago lupulina* L.]); and pasture weeds, e.g. dandelion [*Taraxacum officinale* Weber ex F. H. Wigg. Group], plantain [*Plantago* sp.], and yarrow [Achillea millefolium L.].

System II was a medium fertility, rotational pasture system (Owens, et al. 1992). It is a 17 ha (42 ac) area divided into four paddocks that were rotationally grazed by a beef cow/calf herd with one paddock being used for winter feeding (hay was brought in) and annually received 56 kg N ha^{-1} from 1974-78. During 1979-89, 168 kg N ha^{-1} was annually applied in 3 split applications to the same grazing scheme. From 1990-99, no N fertilizer was applied; two paddocks were grazed and hay was made on two paddocks; and there was no winter feeding on these paddocks. Slopes range from 12 to 25% with an approximate average of 20%. Soils are well-drained residual silt loams (typic Dystochrepts and Hapludults). Vegetation was predominantly orchardgrass and Kentucky bluegrass.

System III was a high fertility, rotational pasture system (Owens, et al. 1998). It is a 14 ha (34 ac) area divided into four paddocks that were rotationally grazed by a beef cow/calf herd in the summer from 1975-79. Annually, 224 kg N ha^{-1} was applied in 3 equal applications in the spring and summer. In 1980, legumes were sown into the grass and no N fertilizer was applied. The same grazing scheme was used through 1998. Slopes range from 2 to 18% with an approximate average of 12%. Soils are well-drained, residual silt loams (typic Hapludults) above a clay outcrop and moderately well drained (aquic Hapludalfs) below the clay outcrop. Vegetation was predominantly orchardgrass and then reseeded with orchardgrass and alfalfa [*Medicago sativa* L.].

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System IV was a high fertility area (10 ha, 25 ac) where hay was made in four paddocks and stored in them (Owens, et al. 1998). A beef cow/calf herd was rotated through the paddocks to eat the fall regrowth and to use the stored hay. From 1975-79, 224 kg N/ha was applied annually in 3 split applications; from 1980-98, legumes were sown into the grass and no N fertilizer was applied. Slopes range from 6 to 25% with an approximate average of 15%. Soils are well-drained residual silt loams (typic Dystrochrepts and Hapludults). Vegetation was predominantly tall fescue [*Festuca arundinacea* Schreb.] and was then reseeded with tall fescue and alfalfa.

Soil samples were taken from these pasture systems during many of the years since 1975, and were stored. Several of the samples were taken to a 150-cm depth. Total carbon was determined on selected soil samples over the various study periods. Results are preliminary, and the soil data are presented without any statistical analyses.

Results

Total carbon concentrations were observed as high as 5.1% in the 0-2.5 cm layer of System II (2.3% for the 0-15 cm layer) in the 1990 samples. Carbon concentrations dropped rapidly with soil depth. With some exceptions in the 15-30 cm layers of Systems III and IV and in the riparian woods of System I (Table 1), total carbon levels were $\leq$0.5% below 15 cm. In Texas, Potter et al. (1999) measured soil organic carbon in soils under agricultural practices, grass, and prairie C listed in increasing order of soil carbon. Although the total carbon decreased much more rapidly with depth in the Ohio soils, the carbon levels in the 0-15 cm levels were similar between this study and the levels reported for the grass soil in Texas. The total carbon concentrations in the 0-15 cm levels in all four systems were greater in 1998 samples than in the 1975 samples (Table 1). However, it is doubtful that the differences are significant.

Total carbon amounts (soil bulk density was included in the calculations) were also greatest in the upper soil layers, 30-37 Mg ha^{-1} in the 0-15 cm layer of most of the systems (Table 2). System III had the greatest amounts of carbon in the 0-60 cm layers (63-76 Mg ha^{-1}) of the four systems because of more carbon being present in the 15-30 cm layer than the other systems.

In addition to the pasture studies at the NAEW, research was conducted on similar soil types using a no-till corn/soybean rotation with a rye winter cover crop following the soybeans. Carbon levels in this agricultural use were lower than fertilized pastures, 1.0-1.6% in the 0-15 cm layer compared with 1.2-2.4% under pastures (Table 1). Similarly, total carbon amounts were lower in the no-till practice (31-36 Mg ha^{-1}) than under fertilized pastures (42-56 Mg ha^{-1}) (Table 2). Even the total soil carbon concentrations and amounts in the unfertilized, unimproved pasture were comparable or slightly higher than the corresponding values for the no-till corn/soybean-rye system.

Carbon to nitrogen ratios tended to be higher in the upper soil layers of the pastures with a 10 to 12 ratio in the soil layers in the top 30-cm. Between 30 and 60 cm, the C:N ratios ranged from 6 to 11. The highest C:N ratios observed were in the riparian woods where they ranged from 12 to 17 in the top 60-cm of the soil profile. With the exception of the first year of the corn/soybean-rye rotation (the previous year was grass), C:N ratios in the no-till areas was similar to the above values for pasture soils.

Summary

Total carbon concentrations in pasture systems on well or moderately-well drained, residual silt loams were found to be as high as 2.5% in the 0-15 cm layer (5.0% in the 0-2.5 cm layer) and as high as 3.0% in the 0-15 cm layer of riparian woods. Total amounts of carbon in pasture soils ranged from 50-75 Mg ha^{-1} for the 0-60 cm soil depth and tended to be slightly higher with higher fertility. Pastures had greater carbon concentrations and carbon amounts than no-till corn/soybeans-rye on similar soils. Very little variability of C:N ratios was observed among the systems studied. Exceptions were higher C:N ratios in riparian woods (12-17) and in the first year of no-till corn/soybeans-rye following grass (13-16). Preliminary data analyses have not shown major trends of carbon concentrations or carbon amounts over time within a pasture system.

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Table 1. Average Total Carbon concentration (%C) in various systems at three different sampling time

Depth (cm)	**1975**	**1985**	**1998**
I. Unimproved Pasture			
0-15	1.3	1.3	1.9
15-30	0.4	0.5	0.5
30-45	0.2		0.2
45-60	0.2		0.3
II. Riparian Woods			
0-15		3.0	2.8
15-30		0.8	1.1
30-45			0.5
45-60			0.3
III. Medium Fertility, Rotational Pasture			
0-15	2.0	2.3	2.4
15-30	0.6	0.4	0.5
30-45	0.3	0.2	0.2
45-60	0.2	0.2	0.2
IV. High Fertility, Rotational Pasture – Summer grazing			
0-15	1.6	2.0	2.2
15-30	1.0	0.9	0.9
30-45	0.3		0.4
45-60	0.3		0.5
V. High Fertility, Rotational Pasture – Winter-feeding/grazing			
0-15	1.2	1.7	1.8
15-30	0.6	0.9	0.8
30-45	0.2		0.4
45-60	0.3		0.5
	1984	**1990**	**1995**
No-till – Corn/Soybean-rye			
0-15	1.6	1.0	1.2
15-30	0.5	0.5	0.5

Table 2. Average Total Carbon amounts (Mg ha^{-1}) in the top soil profile layers for various systems at three different sampling times. Totals are in ***bold italics.***

Depth (cm)	**1975**	**1985**	**1998**
I. Unimproved Pasture			
0-15	24.4	30.4	30.2
15-30	10.5	11.4	10.1
30-45	4.9		5.5
45-60	5.0		6.8
Total	***44.8***		***52.6***
II. Riparian Woods			
0-15		54.7	32.4
15-30		16.6	16.4
30-45			10.3
45-60			6.9
Total			***66.0***
III. Medium Fertility, Rotational Pasture			
0-15	34.5	34.2	34.4
15-30	10.8	9.9	11.7
30-45	6.3	7.7	5.2
45-60	5.7	4.7	4.5
Total	***57.3***	***56.5***	***55.8***
IV. High Fertility, Rotational Pasture – Summer grazing			
0-15	29.4	37.7	36.0
15-30	20.0	17.8	18.6
30-45	7.2		9.3
45-60	6.6		12.0
Total	***63.2***		***75.9***
V. High Fertility, Rotational Pasture – Winter-feeding/grazing			
0-15	29.4	30.9	30.2
15-30	14.9	11.6	11.4
30-45	4.7		5.8
45-60	2.8		3.8
Total	***51.8***		***51.2***
	1984	**1990**	**1995**
No-till – Corn/Soybean-rye			
0-15	29.6	18.9	24.9
15-30	9.4	12.3	11.1

Rehabilitation of Sandy Soils with Native Species in the Northeast United States

A. J. Palazzo, T. Cary[1], and T. Lent[2]

Abstract

Sandy soils in the northeastern United States are difficult to rehabilitate due to their low moisture and nutrient-holding capacities, the short growing season, and the drying effects of winds. The added stress of intensive land use makes military lands even harder to rehabilitate. Sandy-soil rehabilitation is a problem at Fort Drum, New York; Fort McCoy, Wisconsin; the Canadian Forces Base in Petawawa, Ontario; and numerous US Army Corps of Engineer sites with dam embankments, mine-tailing sites, borrow pits, and roadsides.

A major problem in seeding native plants is their slow establishment. We explored methods of providing a suitable plant cover that will establish rapidly and provide a native plant stand over time. We looked at soil compaction, root growth of native and introduced plants during establishment, and field studies of seeding both types of plants together.

We found soil compaction, which increases water-holding capacity, to be important in both plant establishment and persistence. In field studies, we applied liquid cow manure at varying rates to modify surface soil temperature and retain moisture and found that all grass species grew better where the manure was applied. For short-and long-term cover, we tested a mixture of switchgrass [*Panicum virgatum* L.] (native), hard fescue [*Festuca brevipila* R. Tracey] (introduced), and weeping lovegrass [*Eragrostis curvula* (Schrad.) Nees] (introduced), which was sown with a no-till seeder into the manure cover. The weeping lovegrass provided greater than 80% cover in the first season. Highly susceptible to winterkill, weeping lovegrass shows promise as a nurse crop for slow-growing native species and for short-term rehabilitation of intensively used sites. After the initial season, the switchgrass and hard fescue grew through the dead weeping lovegrass and began to dominate the site. Previous studies have shown that hard fescue will persist for about five years; after that, native plants should dominate the site.

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Managing Switchgrass as Biofuels Feedstock

D.J. Parrish, D.D. Wolf, P.R. Peterson, and W.L. Daniels[1]

Abstract

Switchgrass [*Panicum virgatum* L.], a native perennial, is being studied as a model species for a system in which herbaceous plants would be grown for conversion into liquid fuels or for direct combustion. We are in the eighth year of an eight-location, five-state (KY, NC, TN, VA, WV) trial with six varieties or lines of switchgrass. The plants are receiving varying rates of N and two different cutting managements—once or twice per year. The first harvest of the two-cut management comes in late June, and the fall harvest with either one- or two-cut management comes near the end of October. These studies have focused on biomass yields and nutrients removed in the biomass. Parallel studies have looked at C and N fluxes within the biomass. The findings to date indicate that switchgrass productivity varies greatly with location and variety and to a lesser degree with N and cutting management. The lowland varieties used ('Alamo' and 'Kanlow' and two breeder's lines) showed little or no yield increase with two cuttings. The two upland types ('Indian" and 'Shelter') yielded 20 to 30% more when they were cut twice. With that boost in yield, they approached the lowland types in productivity. Parallel studies detected standing biomass declines of about 10% between August and late October. During that interval, tissue N concentrations decline in the aboveground portions of the plants and increase in belowground portions. It appears that the plants translocate significant amounts of biomass below ground at the end of the growing season. This would appear to be a strategy that conserves N and promotes growth in the following season. Cutting twice (with one cut taken in June, when the plants are relatively rich in N) appears to deplete the plants' N reserves. A response to N fertilization was evident primarily when the plots were harvested twice per year, i.e., there was no yield benefit of adding 100 kg N/ha to plots that were harvested only after the end of the growing season. The parallel studies also suggest that switchgrass has the potential to sequester significant amounts of C within its roots and the soil. This work was supported in part by funding from Oak Ridge National Laboratory, managed for the U.S. Department of Energy by Lockheed Martin Energy Research Corporation.

See: Parrish, D.J., D. Wolf, P.R. Peterson, and W.L. Daniels. 2000. Successful Establishment and Management of Switchgrass. Proceedings of the Second Eastern Native Grass Symposium (This volume)

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Successful Establishment and Management of Switchgrass

D.J. Parrish, D.D. Wolf, P.R. Peterson, and W.L. Daniels[1]

Abstract

Switchgrass [*Panicum virgatum* L.], a native perennial, has a reputation for being difficult to establish. Using no-till planting methods, we have found that we can get excellent stands and significant biomass production from switchgrass even in the establishment year. The keys to success include the interconnected factors of overcoming seed dormancy, optimizing planting date, and providing pest control. Seeds of switchgrass are highly dormant when first harvested; as few as 5% of the seeds in commercially obtained seedlots may be germinable, even though their seed tag can show 90^{+}% "pure live seed". This dormancy may be largely overcome by stratification -- exposing wet seeds to 5 to 10°C for 2 to 4 weeks. While it works quite well for breaking the dormancy, there are issues with scaling up stratification for large quantities of seeds and with a tendency for stratified seeds to regain dormancy when they are dried. Other dormancy-breaking techniques may be more commercially useful. Weeds can also be a serious threat to plantings. Good pre-planting weed control and planting (using non-dormant seeds!) after the soil is fully warmed (mid- to late-June in our area) are essential for success with no-till plantings. The late planting date allows the switchgrass seedlings to make such rapid growth that competition from most co-emerging weeds is minimal. We frequently find that insect control is crucial in the vigor of first-year growth. Although no products are currently labeled for this use, our experimental results suggest that including an insecticide to control flea beetle can have a dramatic effect on biomass production during the establishment year. There may be less difference between insecticide-treated and non-treated plots in years after planting, as long as other stress factors (such as germinable seed, drought, and weed pressure) are not experienced.

Introduction

Switchgrass is a tall-growing, warm-season, perennial grass that is native to much of the United States including Virginia. Switchgrass (SG) was widespread in open areas before European settlement. However, after European settlement livestock that were free roaming grazed the new switchgrass growth in the spring before the plants were leafy enough to withstand defoliation which weakened the stands and eventually led to their demise. Switchgrass and other warm-season grasses were replaced by introduced cool-season grasses such as bluegrass, tall fescue, and orchardgrass. These cool-season grasses begin growth much earlier in the spring and can tolerate early season grazing. As a result, the native warm-season grasses such as switchgrass were displaced and can now be found growing primarily in abandoned sites such as old cemeteries or roadsides.

In Virginia, switchgrass breaks winter dormancy in late April and can provide some grazing in late May, but makes most of its growth in June, July, and August. Since it is a tall-growing grass, the management must differ from that used for cool-season grasses. Switchgrass provides excellent erosion control when used as filter strips, grass hedges, or cover such as on river levee banks. It is also beneficial for wildlife. The upright growth provides wildlife some overhead cover for protection, quality nesting sites, and free movement which facilitates food searching. In established stands, there is little disease problem and essentially no insect pests. Since it is a perennial, when properly managed, switchgrass should never need to be replanted.

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Planting Year Management Strategies

Selecting the field: Switchgrass does well on a wide variety of soil types. Unlike cool-season grasses, it is drought-tolerant and produces well on shallow, rocky soils. It is also as tolerant of wet areas as reed canarygrass. Because no-till seeding is ideal for switchgrass, steep slopes can be planted without having to deal with such tillage problems as soil erosion and rock exposure. It is important when planting steep slopes to select a drill or make the necessary adjustments so that the disk opener follows the leading coulter. A drill with a rigid, fixed-position coulter-disk opener assembly will not caster downhill.

Soil pH should be 5.0 or above. If soil tests indicate medium or higher P_2O_5 and K_2O, no fertilizer is needed at planting. No N should be applied at planting; however, if a good weed-free stand is obtained by early August, 33 to 44 kg of N ha^{-1} (30 to 40 lb. N per acre) can be applied on fields where growth is slow and plants are a pale green color from N deficiency. Switchgrass is a good scavenger of nutrients; therefore, N is seldom needed in the establishment year.

Previous crop: Weeds can be a major obstacle for switchgrass establishment especially summer annuals such as barnyard grass, crabgrass, foxtail, and panic grass. Planning ahead can reduce these. One year before planting switchgrass, a smother crop such as dwarf pearl millet can be planted, followed by a cereal grain in the winter. Since foxtail (German) millet is a one-cut crop, dwarf pearl millet is preferred as a smother crop. It will grow longer and give several grazings or two hay cuts. Cereal grain can be grazed or cut for hay by late April or mid May, making it easier to control the regrowth of weeds before switchgrass planting.

Soybeans or corn can be used as a previous crop. If corn was harvested for grain, the stalks may need to be raked and bailed or incorporated into the soil to eliminate excess trash. A cereal grain could be planted after corn is removed for silage. One year prior to switchgrass planting, a field could be plowed or chisel plowed, if needed, to bury excess trash, increase infiltration, or smooth the land where it is too rough for operating machinery.

Minimize surface residue: As with no-till alfalfa and other small-seeded forages, switchgrass cannot be planted into very much surface residue. Many perennial grasses in pastures or hay fields accumulate too much trash, which prevents good seed-to-soil contact. The trash often is pushed down in front of the coulter and seed is placed in the fold (hair pinning). About 50 % or more bare surface is desirable before planting. Burning surface trash is ideal if it is dense enough to carry a fire. When properly timed, the burn will kill small weeds and be equivalent to the use of a contact herbicide. Local fire departments, soil conservation units, or forestry service personnel may be sources of help in safe burning.

Previous sod crop: In a geographic area such as Virginia, graze the planting site as closely as possible or make hay before May 1. If the area cannot be grazed or cut for hay then a herbicide may be needed in early April to prevent excessive growth. About mid to late May when adequate leaf area has developed on the vegetation, spray with glyphosate (Roundup). With low rate technology, 7.5 l ha^{-1} (2 qt $acre^{-1}$) will be adequate. Alternatively, paraquat (Gramoxone) at 0.9 5.49 (1 qt) can be used, if the weeds and grasses present are species that can be controlled with this contact herbicide. About 4 to 6 weeks later or as close to the day of planting as possible, spray again. Gramoxone at 0.5 l ha^{-1} should be sufficient for the second application. If persistent weeds or perennial grasses are present, use an application of Roundup. As mentioned earlier, excess trash can be a serious problem. Use of an herbicide followed by burning is an ideal combination. If burning is planned, Roundup in mid April or Gramoxone in early May will cause desiccation of vegetation so that fire in mid May will act as a herbicide. Then 3 to 4 weeks later another application of an herbicide can be used immediately before planting.

Selecting a variety: Indian is the preferred variety in much of Eastern USA where grazing or hay will be all or part of the intended usage. It is ready to graze in late May and has little growth in September. Alamo and Kanlow are better suited to wildlife and soil conservation plantings. They begin growth earlier in the spring and stay green later in the fall than Indian. Properly managed, they are good for grazing and may fit best in some forage systems where some grazing is needed in September. Due to their very stiff straw, they may be preferred for wildlife plantings and for hedge rows.

Seed germination and quality: Planting seed with a high degree of germination is important in obtaining a good stand. Switchgrass seed often has a high proportion of dormant seed when harvested. This dormancy evolved so that the seed could survive in nature. Dormancy is broken when seed is stored dry for 2 to 4 years in a warm place. Dormancy is also broken when exposed to cold-wet conditions (stratification) such as will occur in nature when left on the ground during the winter after falling from the plant in late summer. Adequate cold-wet conditions will occur naturally in the field if planted in late winter to about May 1. However, when planted early enough to be stratified in the soil, weed competition may be serious enough to crowd out small seedling switchgrass.

Seed should always be purchased on a pure live seed basis (PLS). The seed tag will usually indicate a very high germination, which has been obtained by official (ideal) conditions that include stratification. The hard (or firm) seed are those that are viable but will not germinate after stratification. When planting after the soil warms up, one cannot depend on using the official germination test printed on the seed tag as a true indicator of what seed germination will be. Instead, obtain, or conduct, a germination test without stratification. A "ragdoll" test, which a producer can easily conduct, is adequate if the instructions below are followed. If germination, without wet pre-chill, is less than 40 percent, one should plan to do a bulk stratification ("wet pre-chill") or use an increased seeding rate.

"Ragdoll" test for seed germination: Before planting, test your seed in a flower pot with soil or in a "ragdoll." A "ragdoll" is a rolled tube of wet paper containing the seeds to be tested for germination; it is placed in a jar or plastic bag and kept in a warm place for several days. Then the seedlings are counted as they are removed, giving the percentage germination.

Properly used, the ragdoll test is of great value, but some suggestions will help obtain the best results:

1. Use a firm paper towel such as a brown hand towel or its equivalent. The "soft," very absorbent paper toweling often used in a kitchen makes poor ragdolls. It allows roots and tops to penetrate the fiber, making seedlings difficult to remove for counting. If kitchen towels must be used, be sure to squeeze all excess water from them to prevent seed rotting. Too much water causes a lack of oxygen, and the roots of seedlings (radical) will be more retarded than the top.

2. After the towel has been squeezed rather firmly, lay the wet toweling flat. Count out 100 seeds and place them on one half of the towel. Fold the towel in half and roll it into a tube. Place the tube upright in a jar or plastic bag. This position causes roots to grow down and shoots to grow up so that seedlings are more easily removed during counting. The ragdoll should be kept in a warm place, preferably on top of a water heater or refrigerator. A temperature of 30°C (85°F) is best, but seeds will do fine at room temperature.

3. Make the first count in about 4 days. Open the towel and count the seedlings as removed. After another 3 to 4 days, make a second count. With 100 seeds, the number of seedlings removed equals the percentage germination. If seeds were not counted initially, count the remaining seeds and calculate percentage germination. Always save a small amount of any seed planted so that, if the stand is poor, you can check germination again to be sure the problem was not bad seed. If the seed won't germinate in an ideal

environment like a "ragdoll," don't expect much success when the seed is dealing with all the hazards found in a field situation.

It is always a good idea to test the ragdoll procedure by placing a few seeds of millet or alfalfa that will germinate wet. If these seeds germinate well, the ragdoll is working properly. If these seedlings are stunted, then the ragdoll may be too wet.

Wet-chill to break dormancy: If germination in the ragdoll test is low (less than 40 %), and one has a relatively small amount of seed to plant, seed should be wet-chilled to break the dormancy. In nature this wet-chill, called stratification, occurs naturally during the winter. If the wet-chill treatment is required, follow the procedure outlined below:

1. Put the seed in a cold place to be brought to a lower temperature (about 10^{o}C).
2. Soak the seed in cold water for about 24 hours in plastic-mesh feed sacks.
3. Remove the sacks from water and hang them in a cool place for about 24 hours to drip dry.
4. Monitor the temperature inside the wet bag of seed, if possible, to be sure of safe conditions. Place the outdoor sensor of an indoor/outdoor thermometer inside the bags. These units are inexpensive and can be used later for other purposes.
5. Place the sacks in a refrigerator and keep chilled at about 10^{0}C (50^{0}F) for 2 to 3 weeks. Freezing the seed doesn't harm it, but it does prevent the seed from breaking dormancy. Take seed samples at 7-day intervals during the chilling process and test them to see whether germination percentage has increased. Usually, it takes 21 days to break dormancy adequately.
6. Remove seed from the refrigerator and dry it by placing it less than 8 cm deep on a dry tarp with a fan blowing over it. Dry the seed until it flows freely. Plant the chill-treated seed as soon as possible. If planting must be delayed, chill-treated seed will be safe if stored in a dry place.

Seeding date (for a geographic area such as Virginia): Switchgrass germinates very slowly when soil temperature is below 16°C (60°F). If moist, non-dormant seed is maintained at 30°C (85°F) for 3 days, many of the seedlings will germinate and grow to a length of approximately 3 cm (1.2 inch) with a 3 cm long root. The planting time for switchgrass is much later than for corn but similar to that for millet or sorghum-sudan. Plant from June 1 to 15 for conventionally prepared seedbeds if soil moisture may be a concern. Plant no-till seedings between June 15 and July 15, because soil moisture will be less of a problem. In situations where weeds are not a problem, planting can be done 2 weeks earlier. Planting as late as possible will provide adequate time for preplanting weed seed germination and control and a better chance of controlling annual grassy weeds. Under favorable conditions, newly seeded switchgrass can be 25 to 50 cm (10 to 20 inches) tall and well established 8 weeks after planting. After a seedling develops basal tillers, it should survive the winter.

Seeding rate and gauging establishment success: Consider using 10 kg of pure live seed (germinable) per ha (9 lb. per acre) for conventional plantings. For no-till or drill seedings 7 kg per ha (6.3 lb. per acre) should be adequate. The germination should be based on a test made after stratification, if needed. Weight of bulk seed needed can be calculated [kg needed = kg ha^{-1} ÷ (germination x purity)] where germination and purity are expressed as decimal values. Planting seed that may not germinate is neither logical nor economical. As stated above, if the seed will not germinate in the ideal conditions of a ragdoll, it will not in a field environment. Stratification will increase the chance of germination. Indian switchgrass, and some other up-land types, usually have 500,000 seeds kg^{-1} (227,000 seeds per lb.). Alamo, and some other low-land types, may have 900,000 seeds kg^{-1} (454,000 seeds per lb.). Seven kg ha^{-1} will have about 350 potential seedlings m^{-2} (37 seedlings ft^{-2}). This should give about 71 seeds per linear m of row (22 per foot) if rows are 20 cm (8 inches) apart. [Drill calibration can be approximated using these numbers of seeds per linear row lengths]. At the end of the planting season, if one has 50 or so plants per m^{2} (about 10 per square foot) constitutes an excellent stand. Don't give up on a stand that seems to be poorly established, especially for wildlife and soil conservation plantings. Even stands with an average of 10 plants per m^2 can be adequate, since each plant can easily occupy 0.1 m^2 with two or three years of growth.

Seeding into a conventional seedbed: Field operations typically used for other small seeded forages can be used to prepare a clean seedbed. Take care to insure that the soil is especially firm at planting. If a pickup truck driving over the field leaves a noticeable wheel track depression, then more packing may be needed. Conventional seeding may not be ideal, because tillage will cause the soil to lose water in the warm, dry weather during mid June when these operations are needed. Seed can be broadcast and then cultipacked. Seed placement in rows with a grain drill that has a small seed attachment would be ideal. Seed should be placed no deeper than 7 to 12 mm (1/4 to 1/2 inch). Consider cultipacking after drill planting in order to obtain good seed-soil contact. Weed problems may be greater than with no-till plantings since germinable weed seeds will be brought to the soil surface during tillage.

No-till planting: No-till seeding methods conserve soil, require less time and fuel, and allow rocks to remain below the soil surface. Proper procedures will reduce water run-off and evaporation, which improves the water supply to the seedling. If herbicides are used to suppress existing vegetation during the 6 to 8 weeks before planting, there should be adequate water for rapid germination.

A standard grain drill with a box for small seed like clover can be used if there is minimal trash and the soil is soft, such as when planting into a preceding soybean, corn, millet, or cereal grain crop. A drag chain and packer wheel should follow each drill opener. If needed, a cultipacker should be used to firm the soil. With no-till methods, one may be tempted to plant when the soil is too wet and seed might be placed too deep. Ideally the soil surface should be rather dry. When trash is dry and soil is firm, the disk or coulter can cut a clean seed slot without hair pinning. The disk opener should displace some granular soil. Seed should be placed about 7 to 12 mm (1/4 to 1/2 inch) deep. Rainfall can wash soil to fill the furrow left by the disk opener and cover the seed much deeper than planted. When placed at a 12 cm (1/2 inch) depth, the seed will probably be in moist soil. Germination and emergence may occur in 5 to 7 days or less when the soil is warm and moist.

Insect concerns: Grasshoppers, crickets, corn flea beetles, and other insects can be a problem with new seedlings. When all green plants (forage for insects) in a field are killed with herbicides, insects may cause severe damage to newly emerging seedlings. Horse nettle is a host for corn flea beetle. If small pin-size holes appear in horse nettle leaves, corn flea beetles are likely present in the field and may damage switchgrass seedlings. No insecticide has label clearance for use on switchgrass, however, research data have shown a consistent advantage to the use of a granular systemic insecticide placed in the row with the seed at planting. An alternative may be to broadcast an insecticide along with the herbicide when applied just before planting. Careful monitoring of early seedling growth is essential. If seedlings become unthrifty or have necrotic streaks along the leaf, an insecticide may be needed.

Post emergence management in the seeding year: Grassy weed competition can be minimized by clipping weeds above the leaves of seedlings. Switchgrass leaf removal should not be made in the seedling year. Broadleaf weeds can be controlled with light rates of 2,4-D and/or Banvel, but apply only after the seedlings have four fully expanded leaves. Delay the use of herbicides as long as weeds are not competing for sunlight or soil water to reduce the potential for seedling damage. Growth by mid September may be 50 to 75 cm (20 to 30 inches) tall. At this time, cattle can be used to graze enough to remove about 1one-half the leaf area. Be careful not to over-graze, or the stand may be weakened. Once frost has killed the leaves, cattle can graze without restriction. The fine stems and leaves will have low protein, but will provide considerable value as stockpiled forage. After frost, the switchgrass also can be baled.

Management of Established Stands

Use of an herbicide would be ideal in the first year after seeding or any time weeds are a problem in an established stand. Research has shown established switchgrass to be very tolerant of simazine and atrazine; however, there is no label clearance for their use. Simazine at 2.2 a.i. kg ha^{-1} (2 lb. per acre) applied in early May has been effective for weed control in research tests. Simazine can be applied after switchgrass has developed leaf area with no concern for foliar burn. If perennial triazine-tolerant broadleaf weeds are present, a tank mix that includes simazine, 2,4-D, and/or Banvel can be used after switchgrass and problem weeds emerge. Gramoxone, if applied before switchgrass emerges can minimize growth of cool-season species.

Maintenance fertility: Soil samples should be taken no deeper than 10 cm for testing of soil-P and to about 20 cm for soil-K. Apply P and K as needed to maintain medium soil test levels. Applications of fertilizer may not be needed, especially if switchgrass is used for grazing, since animals return most of the nutrients as manure and urine. Soil pH of five or above is satisfactory for maximum potential yields. Nitrogen may be needed at about 44 to 55 kg ha^{-1} (40 to 50 lb $acre^{-1}$) after the first hay cut or the first time a paddock is rotationally grazed. Where early season growth is slow and yellowish or maximum first growth is needed, then N may be needed in mid May.

Hay harvest: First hay harvest should be taken at late boot stage of development. This will occur by June 15 to 25 for Indian and other upland types at a latitude such as Virginia's. Cutting at 20 to 25 cm (8 to 10 inches) will benefit regrowth. Cutting closer will not give much more hay value, because few leaves remain on the stubble. Leaving nodes (joints) on the stems in the stubble will give sites for axillary tiller formation. These tillers will provide early leaf area development and energy for fast regrowth. The stiff stubble will discourage overgrazing of regrowth if pastured. A second hay cutting can be expected in mid August.

Grazing management: Grazing can begin about May 20 to 25. Growth is very rapid for the first few weeks. Begin grazing when there is about 45 cm (18 inches) of growth for the first early growth and discontinue grazing to leave 30-cm (12-inch) of stubble. Controlled grazing is the best management. Begin early and initially rotate often. Under favorable conditions, about 5 weeks are needed for approximately 70 to 80 cm (28 to 32 inches) of regrowth before grazing a paddock again. If the next paddock is ready for grazing before the current paddock is grazed close enough, consider making hay and skipping to another paddock in the sequence. When switchgrass quality is low consider creep grazing where calves have access to high quality pasture as the cows clean up before moving on. Simply lifting the electric fence can allow for a creep. Continue grazing until late August if enough forage is available.

Grazing productivity: Each acre of switchgrass will produce about 200 animal unit days (AUD) of grazing when properly managed. This assumes one AUD is equivalent to feed required by one 1100 kg (1000 lb.) mature nonlactating cow maintaining constant body weight. One AUD is also equal to 19.4 kg (17.6 lb.) of forage intake per day (1.76 percent of body weight) if the feed source is 60% digestible (60% TDN). If the grazing season is 90 days, then each acre can support 2.2 animal units (AU). This would be 0.20 ha (0.45 acres) per AU. For controlled grazing, with 5 days of grazing per paddock before rotating and 35 days rest, eight paddocks would be needed in the system. A 270 kg (600 lb.) stocker (0.7 AU) should gain 0.9 kg (2 lb.) per day. Each ha could handle 1.3 stockers (3.2 per acre) which is equivalent to 7 kg live weight gain per day per ha (6.4 lb. per acre). For the 90-day season, there could be a potential of 300 kg live weight per ha (576 lb. per acre). Clipping pastures after grazing usually will not be needed. If a stubble of 25 to 30 cm (10 to 12 inches) exists then intense close spot grazing will be minimized.

The number of switchgrass acres needed depends on individual situations. A 12-month grazing system for beef cattle would be ideal. A 12-month system would perhaps require 0.4 ha (1 acre) of stockpiled tall fescue per animal unit. The tall fescue will provide pasture for 3 to 4 months in

December through March and some pasturage or hay in the spring. Switchgrass, as noted above, can provide forage for one AU for 90 days from 0.18 ha (0.45 acre). Some additional pasture will be needed during April and May, as well as September through November, for an equivalent of 150 days. If the additional pasture has a production potential of 150 AUD acre, one ha (2.45 acres) of pasture may be needed for a 12-month grazing program (1 acre tall fescue, 0.45 acre of switchgrass and 1 acre of native cool-season pasture). This would be 15 to 20% of the pasture acreage as switchgrass. Another option would be to have about 0.16 ha (0.4 acre) of switchgrass per AU.

Late season management: Little growth will occur after late August in latitudes above 35°. Growth in September until killed by frost will allow the plants to get ready for the winter. After leaves turn brown, cattle can graze without hurting the stand, since the plants are dormant. Where cool-season grasses or weeds occur in the spring, cattle can graze until new growth of switchgrass emerges in late April to early May. Gramoxone can be used any time the switchgrass is dormant and will suppress the cool-season species.

Establishment of Warm-season Grasses With and Without the Use of Compost Soil Amendments

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Increased interest in wildlife biodiversity and the restoration of wildlife habitats and populations makes it appropriate to study habitat enhancement techniques. Numerous types of soil amendments using organic compost materials have been tried in the past to improve soil quality (Garland et al. 1995), but little data are available that compare these materials from a wildlife perspective. Several areas of Patuxent Research Refuge (Laurel, MD) have been degraded by human activities and provide excellent study sites. The data gathered on enhanced habitats provide essential information for the proper management of wildlife habitats and populations. Special emphasis was placed on the role of compost in the establishment and retention of native warm-season grasses [big bluestem, *Andropogon gerardii* Vitman; little bluestem, *Schizachyrium scoparium* (Michx.) Nash, and Indiangrass *Sorghastrum nutans* (L.) Nash].

Many of the techniques developed from this study could be used for managing restored game and non-game wildlife populations that benefit from an abundance of plant seeds and invertebrates. The wild turkey [M*eleagris gallopavo*] is a species of interest to the hunting community and represents a native species that is being restored to its original range (Kennamer 1994, Lewis 1987). Other species that are of interest to hunters and could benefit from this management technique include the mourning dove [*Zenaida macroura*] and Northern bobwhite [*Colinus virginianus*].

Non-game species that have declined in recent years include the meadowlark [*Sturnella magna*] and grasshopper sparrow [*Ammodramus savannarum*]. Data from the Breeding Bird Survey (Robbins et al. 1995; Sauer et al. 1999) indicate that the meadowlark has declined an average of 4.6 % during the period 1966-1998 and the grasshopper sparrow has declined an average 6.3 % during the same period in Maryland. Causes of these declines have been loss and degradation of habitat (Smith 1963; Laughlin and Kibbe 1985).

The objective of this study was to evaluate the use of two compost materials (COMPRO and LEAFGRO) to enhance wildlife habitats in comparison to control plots, with and without warm-season grasses.

Methods

This study was conducted at two sites at Patuxent Research Refuge. One site (Range 20) was a degraded military firing range of the U. S. Army that used this land prior to 1992. The other site (Shaefer Farm) was an abandoned farm that had been intensively farmed until 1975. Two types of compost (COMPRO and LEAFGRO) were used to improve quality (nutrients and tilth) of the soil and both were commercially available. COMPRO is made from human sewage sludge and wood chips and LEAFGRO is made of organic yard waste (grass and leaves).

Two 50 x 100 meter sections of each site were plowed and disked in April and again in May 1996. The blocks were gridded into 8, 25 X 25 meter square plots (0.06 hectares) using PVC stakes in each corner. The two soil treatments and two types of controls were randomly assigned to the 8 plots and replicated two times. A 2.5 cm (one inch) layer of COMPRO and LEAFGRO was applied with a modified manure spreader and disked into the soil to a depth of 7.6 cm (3 inches). Control plots received no amendments and were of two types: one that was planted with a warm season grass mixture (*Andropogon gerardii, Schizachyrium scoparium*, and *Sorghastrum nutans*)

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and one that was not planted. Plots receiving compost were also planted with a warm season grass mixture. Five separate tests conducted to determine if weed seeds existed in the compost material, revealed no germination of plants.

Three randomly selected meter-square quadrats were established in each treatment and control plot and permanently marked with a PVC stake. Sampling of the quadrats was conducted in October 1996-99. October was selected as the sampling month because most warm-season grasses and other open-field plants had reached their maximum growth for the year. All plants were identified by species. Percent cover was estimated for each plot. Standard analysis of variance tests were used to detect differences between sites and among treatments.

Sampling for invertebrates was conducted four days each month (June-Oct 1997 and 1998) with the use of a 19-liter (five-gallon) bucket (pit-fall trap) placed in the soil in the middle of each plot level with ground surface. Invertebrates were also sampled by sweeping the vegetation with capture nets during August 1997. In addition, earthworms were counted from soil samples taken from each plot in August 1997. All invertebrates were identified and counted.

Pitfall traps also were used to capture small mammals, amphibians, and reptiles that use the areas. Trapping for small mammals with Sherman live traps placed in each plot was conducted during the four-day period that pit-fall trapping was conducted. Bird surveys were conducted from the outside of the plots and then immediately after by walking through the plots. All birds seen by each technique were recorded by plot number.

Results

In late October 1996, initial vegetation sampling was conducted in three randomly selected meter square quadrats in each plot. These preliminary results indicated that greatest vegetation cover occurred in plots treated with LEAFGRO and that plots treated with COMPRO had less vegetation cover than both types of control plots (with and without warm-season grasses). The reduced plant growth in the plots treated with COMPRO could have been related to the much higher soil pH of these plots on both sites (Table 1).

Table 1. Average soil variables for the two compost treatments and the two controls at Range 20 and Shaefer Farm, in 1996 at beginning of study.

	COMPRO	LEAFGRO	CONTROL PLANTED	CONTROL UNPLANTED
		3.8	1.7	
O. M.	3.6	6.7	6.3	1.8
pH	7.6	221	55	6.6
P_2O_5	165	363	82	91
K_2O	95			77

After four years of growth, however, the percent cover of the warm-season grasses was greater in the planted plots that did not receive soil amendments (Table 2). Indiangrass was more abundant on the sites than either of the other two species of warm-season grasses. There were differences between the sites with Range 20 having better growth of warm-season grasses than at Shaefer Farm.

Initial invertebrate sampling in pitfall traps in 1996 indicated that there were more invertebrates in the LEAFGRO plots. Increased invertebrates appeared to be directly related to the increased vegetative cover in the LEAFGRO plots. However, when data from 1996 and 1997 were combined (Table 3) there were no major differences in invertebrate abundance among the plots. A total of 12,861 invertebrates were recorded from 1996 and 1997 (3297 in COMPRO, 2586 in LEAFGRO, 3386 in Control/Planted, and 3592 in Control/Unplanted). The relatively smaller number of crickets [ERYLLIDAE] in the LEAFGRO plots is unexplainable. Analyses of invertebrates collected from soil samples and sweep nets also did not reveal major differences among the plots.

Table 2. Average percent cover of planted species, volunteer species, and no cover in meter square plots at Range 20 and Shaefer Farm, in 1999 after four years of growth.

	COMPRO	LEAFGRO	CONTROL PLANTED	CONTROL UNPLANTED
RANGE 20		18	60	
PLANTED	24	78	25	0
VOLUNTEER	73	3	15	98
NO COVER	3			2
SHAEFER FARM		36	41	
PLANTED	22	59	33	0
VOLUNTEER	58	5	26	88
NO COVER	20			12

Table 3. Total invertebrate organisms captured in pitfall traps at Range 20 and Shaefer Farm, in 1997-98.

TAXA	COMPRO	LEAFGRO	CONTROL PLANTED	CONTROL UNPLANTED
		336	354	
ARACHNIDA	328	840	832	394
COLEOPTERA	979	45	27	940
DIPLOPODA	36	878	1783	22
ERYLLIDAE	1515	67	25	1683
FORMICIDAE	49	97	64	94
GASTROPODA	25	32	15	69
LEPIDOPTERA	23	47	61	26
ORTHOPTERA	84	244	225	77
OTHERS	258			287
TOTAL	3297	2586	3386	3592

Although no mammals were captured in Sherman Live Traps in 1996, a total of 60 small mammals were captured in 1997 (Table 4). Overall, five mammal species were captured and most were in the plots treated with compost. A total of 21 mammals was caught in the COMPRO plots, 27 in the LEAFGRO plots, 11 in the Control Planted plots and 1 in the Control Unplanted plots. The meadow vole [*Microtus pennsylvanicus*] was the most commonly caught species with 12 in the COMPRO plots, 10 in the LEAFGRO plots, 3 in the Control Planted plots and 0 in the Control Unplanted plots.

Seven species of amphibians and one reptile species were recorded in the study sites from 1996 and 1997 sampling, but no trend due to treatment could be detected. Hopefully, more sampling in the future will provide additional data to determine if differences occur due to treatment. Nine species of birds were observed in the plots during surveys conducted in 1997 (Table 5). Sparrows were most commonly observed and most were in the plots treated with soil amendments.

Table 4. Total number of mammals captured in Sherman live traps at Range 20 and Shaefer Farm, in 1998.

SPECIES	COMPRO	LEAFGRO	CONTROL PLANTED	CONTROL UNPLANTED
		3	0	
Masked Shrew	1	2	0	0
Short-tailed shrew	0	10	3	0
Meadow Vole	12	3	0	0
White-footed mouse	2	9	8	0
House Mouse	6			1
TOTALS	21	27	11	1

Table 5. Total number of birds recorded in treatment and control plots at Range 20 and Shaefer Farm, in 1998.

SPECIES	COMPRO	LEAFGRO	CONTROL PLANTED	CONTROL UNPLANTED
Amer. goldfinch			2	3
Carolina chickadee				1
Dark-eyed junco	4	1		11
Eastern bluebird				
Eastern phoebe	1		2	
Mourning dove		15	2	
Savannah sparrow	7	8	5	5
Song sparrow	5	9	3	4
Swamp sparrow	2			
TOTAL	19	33	14	24

Conclusions

Numerous areas in the East have been degraded by human activities that could possibly benefit from soil enhancement with compost amendments. Two compost materials (COMPRO and LEAFGRO) were evaluated as soil amendments to enhance wildlife habitats, while maintaining optimal floral and faunal biodiversity. Results after one year indicated that at least one compost material (LEAFGRO) would increase the quality and quantity of vegetation. However, invertebrate populations did not increase in these areas. There did appear to be an increase in meadow voles in the LEAFGRO plots. Results from this study after four years, however, indicated that warm-season grasses and invertebrates did not benefit from compost, and only small mammals appeared to respond positively to the soil amendments. It is doubtful if larger quantities of compost would show more significant changes in the flora and fauna of these habitats.

Acknowledgments

Persons who provided technical advice included L. Brown, F. Gouin, R. Green, R. Hammerschlag, N. Melvin, G. Meyer, H. Obrecht, P. Peditto, and J. Patterson. L. Gordon and G. Sumeriski did agricultural preparation of the plots. Numerous assistants helped collect the data on this study including B. Bauman, R. Dault, D. Dubois, J. Fitzgerald, A. McDonald, T. Sliwa, J. Steinberg, C. Stoll, and S. Tanata. Partners on this study include the Environmental Protection Agency, Quail Unlimited, and MD Department of Natural Resources.

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Effect of Two Long-term Mowing Regimes on Vegetation

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Wildlife managers have for many years been interested in the role of mowing as a management technique to benefit wildlife. Patuxent Research Refuge (Laurel, MD) was established in 1936 and has conducted habitat management studies for many years. When the Refuge was established, the Snowden family residence (now called Snowden Hall) was surrounded by neglected overgrown lawns and old farm fields. Snowden Hall was immediately occupied by government workers and the lawns around the building were mowed on a fairly regular basis to maintain a satisfactory appearance. Three residences were constructed northwest of Snowden Hall between 1939 and 1941 and a similar lawn was maintained in front of these buildings. To the southeast of these two lawn areas and across a road, were two meadows that were maintained as hay fields as part of the farm wildlife program conducted at Patuxent.

The meadows were originally mowed 1-2 times a year for a hay crop, but in the mid 1960s the meadows were mowed annually with a brushhog to retard succession of woody vegetation and maintain the meadow habitat. All lawn and meadow areas at Patuxent received annual applications of fertilizer and lime until 1972 when these applications ended.

In 1997, all mowing at Patuxent was halted as a way to reduce maintenance costs. The lack of mowing and the subsequent growth of plants, with diagnostic fruiting parts, allowed a unique opportunity to identify all plants and estimate ground cover for each species. This paper reports the findings of this one-year study that was conducted to determine the dominant plants found growing under two mowing regimes.

Numerous studies have been conducted that evaluate the effect of mowing on vegetation and the resultant wildlife habitat (Frawley and Best 1991, Warner et al. 1992, Edge et al. 1995). Several researchers have implicated the mowing frequency or time of year as a factor causing declines of birds nesting in hayfields (Robbins et al. 1986, Warner and Etter 1989, Bollinger et al. 1990). These studies tend to show advantages to birds by delaying the time of mowing and reducing the frequency of mowing. No studies were found that compared the effects of two different long-term mowing regimes in the same area.

Methods

The mowing regimes for this study included areas that had been mowed with rotary mowers approximately every 2-4 weeks and meadow areas that were mowed approximately once a year with a brushhog. Each regime had two replications. The two lawn areas (Lawn A and B) were 0.63 ha and 0.33 ha and the two meadow areas (Meadow A and B) were 0.54 ha and 0.89 ha in size, respectively. Vegetation was sampled in 20 1-m^2 quadrats that were randomly selected in each area (n=80). All sampling of the plots was conducted between May 27 and June 11, 1997. Percent cover was estimated by species in each quadrat. Ground areas where no plants occurred were recorded as no cover.

On July 11, 1997, vegetation in all quadrats was cut with pruning shears at 10 cm above the ground and placed in paper bags. The bags were placed in an attic for drying from July 1997 to February 1998 during which temperatures ranged from 15-35°C. In February two of the samples were weighed and then placed in an oven at 38°C for six hours and checked several times to

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determine if a constant weight had been reached. Because of minor changes in weight all other samples were assumed to be dry and were weighed without further drying.

The average percent ground cover of each plant species was compared using a Wilcoxon non-parametric 2-sample test. The average weights of dried plant material from all quadrats were compared using a Student's t-test. A probability level of 0.01 was chosen for determining statistical significance in all tests.

Results

Analyses of data indicated that all but two plant species that accounted for over 1.00% of ground cover, showed significant differences between the two treatments (Table 1). The percent ground cover of the dominant vegetation on the lawn area was 40.0% red fescue [*Festuca rubra L.*], 26.5% white clover [*Trifolium repens* L.], and 18.0% Kentucky blue grass [*Poa pratensis* L.].

The percent ground cover of the dominant vegetation in the meadow area was 33.2% meadow fescue [*Festuca pratensis* Huds.], 9.9% sweet vernal grass [*Anthoxanthum odoratum* L.], 9.2% orchardgrass [*Dactylis glomerata* L.], 6.3% Japanese honeysuckle [*Lonicera japonica* Thunb.], and 5.2% red fescue. White clover was not found growing in the meadow areas. All percent ground covers for the dominant vegetation were significantly different ($P<0.01$) between the two regimes.

Species richness was higher in the meadow regime (74) versus the lawn regime (33). Frequently mowed lawn areas may provide better grazing forage for herbivores, such as geese, rabbits, and deer, however, meadow areas may provide greater biomass (232 vs. 63 g m^{-2}) and greater diversity of plant species. The meadow regime also appeared to have greater seed production and cover which is favored by a wider variety of wildlife species, especially passerine birds and small mammals.

The percent ground cover of the dominant species in the meadow area was 33.2% for meadow fescue, which was only recorded covering 5.0% of the lawn areas. Sweet vernal grass was the second most dominant plant species in the meadow covering 9.9% of the ground compared to 0.8% of the lawn area. Orchardgrass covered 9.2 % of the meadow quadrats, but was not recorded in the lawn areas. The exotic Japanese honeysuckle covered 6.3% of the meadow areas, but was not recorded in the lawn areas. All percent ground covers for the dominant vegetation were significantly different ($P<0.01$) between the two areas. The average percentage bare ground was 1.0% for the lawn area and 9.4% for the meadow areas, which was significantly different ($P<0.01$) between treatments.

Other species that accounted for less than 1.00% of ground cover in both treatments, but were significantly different ($P<0.01$) between treatments included wild onion [*Allium* sp.], dogbane [*Apocynum cannabinum* L.], mouse-eared chickweed [*Cerastium arvense* L.], deertongue, autumn olive [*Elaeagnus umbellata* Thunb.], velvet grass, yellow sorrel [*Oxalis stricta* L.], Virginia creeper, common cinquefoil, dandelion [*Taraxacum officinale* Weber ex F. H. Wigg. group], low hop clover, corn speedwell [*Veronica arvensis* L.], vetch [*Vicia* spp.], and grape [*Vitis* sp.]. The meadow areas had a total of 74 species, whereas the lawn area had only 33 species.

Biomass was significantly greater ($P<0.01$) in the meadow area with less frequent mowing than the lawn area. Weights of vegetation in meadow areas ranged from 103.7 g to 394.8 g, with an average of 232.2 g. Weights of clipped vegetation from the quadrats in the lawn areas ranged from 6.4 g to 166.4 g with an average of 63.0 g. Meadow A had six quadrats with woody vegetation that averaged 64.3 g per plot. The greater biomass produced by the meadow areas was expected.

Table 1. Average percent cover (±1 SD) of plants recorded (>0.05%) in quadrats of lawn and meadow areas[1] of Patuxent Research Refuge, June 1997.

SPECIES [2]		% COVER (±1 SD)	
SCIENTIFIC NAME	COMMON NAME	LAWN	MEADOW
Agrostis sp.	Bent grass	1.0 (0.7)	0.0 (0.0)
Anthoxanthum odoratum L.	Sweet vernal grass	0.8 (0.6)	9.9 (2.4)
Cerastium arvense L.	Mouse-eared chickweed	0.6 (0.2)	tr (tr)
Cynodon dactylon (L.) Pers	Bermuda grass	1.0 (0.7)	0.0 (0.0)
Dactylis glomerata L.	Orchard grass	0.0 (0.0)	9.2 (2.0)
Dichanthelium clandestinum (L.) Gould	Deertongue	1.7 (0.7)	0.0 (0.0)
Festuca pratensis Huds.	Meadow fescue	5.1 (1.3)	33.2 (4.1)
Festuca rubra L.	Red fescue	40.0 (4.1)	5.3 (2.0)
Holcus lanatus L.	Velvet grass	3.5 (0.8)	0.0 (0.0)
Lespedeza cuneata (Dum. Cours.) G. Don	Bush clover	0.0 (0.0)	3.9 (1.6)
Liquidambar styraciflua L.	Sweetgum	0.8 (0.4)	tr (tr)
Lonicera japonica Thunb.	Japan. Honeysuckle	0.0 (0.0)	6.3 (0.9)
Parthenocissus quinquefolia (L.) Planch.	Virginia creeper	0.0 (0.0)	1.9 (0.4)
Plantago lanceolata L.	English plantain	1.7 (0.4)	tr (tr)
Poa pratensis L.	Kentucky bluegrass	18.0 (2.2)	0.4 (0.2)
Potentilla simplex Michx.	Old-field cinquefoil	1.0 (0.3)	0.3 (0.2)
Rosa multiflora Thunb.	Multiflora rose	0.0 (0.0)	1.4 (0.5)
Rubus sp.	Blackberry	0.0 (0.0)	1.5 (1.3)
Rumex acetosella L.	Sheep sorrel	1.5 (0.6)	tr (tr)
Toxicodendron radicans (L.) Kuntze	Poison ivy	tr (tr)	3.1 (0.6)
Trifolium dubium Sibth.	Low hop clover	1.2 (0.3)	tr (tr)
Trifolium repens L.	White clover	26.5 (2.5)	0.0 (0.0)
No Cover		1.0 (0.3)	9.4 (1.3)

[1] All species and no cover significantly different (P<0.01) between treatments except Bent Grass and Bermuda grass.
[2] Scientific and common names follow Brown and Brown (1972, 1984).

CONCLUSIONS

Two long-term mowing regimes (60 years of similar management) were evaluated at Patuxent Research Refuge during the summer of 1997 to better understand the influence of mowing on vegetation communities. The results indicated greater species richness in areas with less mowing. The lawn area that was frequently mowed was dominated by plant species that grow to less height than those species in the meadow habitat. Lawn species were typically those that are preferred by grazing species such as geese, rabbits, and deer. Meadow areas had greater diversity of species, more plants that produce seed, and greater overall biomass. Unless managers especially want to favor herbivores that need large grazing areas, it appears from this study that a greater diversity of wildlife would benefit if habitats were mowed less frequently.

Less mowing would also discourage brown-headed cowbirds [*Molothrus ater*], which do not feed in fields with high vegetation, but use lawns extensively.

One concern that managers have with meadow management is the invasion of the areas by woody plants. These habitats in the East cannot be maintained without periodic mowing unless fire management is employed. The advantage of fire management over mowing is that it can be done less frequently and still control invading woody vegetation. Another aspect that was not evaluated in this study is the effect of mowing on nutrient quality of plants. It is most likely that the more frequently mowed areas have less fiber and higher protein in the plants, which would be expected based on numerous other studies (Harlow 1991). To better evaluate the various factors affecting the quality of wildlife habitat by management techniques such as mowing, it would be beneficial to conduct replicated studies with several techniques conducted concurrently.

Acknowledgments

Numerous assistants helped collect the data on this study including B. Bauman, R. Dault, D. Dubois, P. Osenton, J. Rigelman, and C. Stoll. Advice on statistical analyses was provided by J. Hatfield and review of manuscript was conducted by D. Boone, F. Fallon, M. Gormley, R. Hammerschlag, G. Meyer, H. Obrecht, III, and C. Rewa.

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Eastern Gamagrass Responses to Defoliation Management

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The lack of a dependable supply of high quality forage during summer is a major limitation to the profitability of ruminant livestock operations in the mid-Atlantic region. Cool-season perennial grasses predominate in the region's pastures and hayfields. Warm-season species are often limited to volunteer annuals and perennials that lack productivity and/or palatability.

Eastern gamagrass [*Tripsacum dactyloides* (L.) L.] is a native warm-season perennial grass that is receiving attention for its potential as livestock feed. Eastern gamagrass has demonstrated tremendous forage yield potential. In Southern Illinois, an established stand of 'PMK-24' eastern gamagrass receiving 133 lbs N acre^{-1} year^{-1} produced over 10 tons DM acre^{-1} in 3 to 4 cuttings year^{-1} to a 1.5-inch stubble height (Faix et al. 1980).

Animal performance on eastern gamagrass has also been favorable. Horner et al. (1985) reported 50 versus 53 lbs milk day^{-1} from dairy cows consuming eastern gamagrass versus alfalfa hay, respectively, with grain supplement. The superior milk production on alfalfa was attributed primarily to greater intake. With wethers however, eastern gamagrass and alfalfa hay had similar digestibility. Burns et al. (1992) reported steer gains of 1.8 lbs day^{-1} on continuously-stocked 'Pete' eastern gamagrass pasture as compared to only 0.7 lbs day^{-1} on similarly managed bermudagrass pasture in North Carolina. In Arkansas, steers gained 2.2 lbs day^{-1} on 'Pete' eastern gamagrass during early summer and up to 450 lbs acre^{-1} over the season under continuous stocking.

Information is lacking on defoliation management of eastern gamagrass. Brejda et al. (1996) reported that a 6-week harvest interval produced greater forage yield than a 4-week harvest interval in northern Missouri. We were interested in the combined influence of frequency and intensity of defoliation on yield and quality of eastern gamagrass forage in the mid-Atlantic region. Our goal was to identify a defoliation management regime that would optimize forage quality without sacrificing significant forage yield.

Methods

A field experiment was initiated on a 5-yr-old stand of 'Iuka' eastern gamagrass in spring 1997. The site was a Shottower cobbly loam at the Virginia Tech Kentland Farm, Whitethorne, VA (near Blacksburg). The soil pH was maintained at 6.1 to 6.3, and P and K were maintained at medium to high levels throughout the experiment.

Two treatment factors were imposed. One factor was cutting frequency: 2 vs. 4 cuttings per year. The second factor was residual height: either 5 or 10 inches. The experimental design was a split block in 3 replicates with cutting frequency as main plots and residual height as subplots. Cutting dates for the 3 years are shown in Table 1. Stage of maturation of eastern gamagrass harvested 2 times per year was boot to early head, whereas forage harvested 4 times per year was vegetative.

All plots received 100 lbs N acre^{-1} year^{-1} applied as ammonium nitrate in split applications of 50 lbs N acre^{-1}. The first N application occurred in early May each year. The second N application occurred after the 1st harvest for the 2-cut treatments, and after the 2nd harvest for the 4-cut treatments.

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Table 1. Cutting dates for eastern gamagrass at Whitethorne, VA.

Cutting treatment	1997	1998	1999
2 cuts year^{-1}	27 June 26 August	26 June 2 September	18 June 22 September
4 cuts year^{-1}	12 June 10 July 14 August 11 September	16 June 17 July 18 August 17 September	8 June 14 July 13 August 22 September

Forage yield was determined by harvesting a 4.3' x 17' swath out of each 7' x 20' plot with a sickle mower in 1997 and by harvesting a 3' x 17' swath with a flail mower in 1998 and 1999 to the designated residual heights. A representative sample of the harvested forage was obtained for dry matter and forage quality determinations. Samples were weighed fresh, dried in a forced air oven, and weighed dry to determine dry matter content of harvested forage, and ground to pass a 1 mm screen. Ground samples were analyzed for crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) concentrations at the Virginia Tech Forage Testing Lab. Total season yield, season average forage quality, and yield distributions were analyzed by ANOVA.

Results

Growing season precipitation deviated considerably from 30-yr averages during all 3 years of the trial (Table 2). In 1997, rainfall was below average every month from April through August except for July when it was somewhat above average. In 1998, rainfall was well above average from April through June and again in August, but considerably below average in July. In 1999, rainfall in April and May was slightly above average, well below average in June and August, but well above average in July and September. Temperatures were generally below average in 1997 and above average in 1998 (Table 3).

Total season forage DM yields are presented in Fig. 1. Total season yields of eastern gamagrass averaged 4.7, 5.9, and 4.4 tons acre^{-1} in 1997, 1998, and 1999, respectively, and ranged from 3.3 to 7.4 ton acre^{-1}. The high yields in 1998 can probably be attributed to ideal warm-season grass growing conditions, i.e. above normal temperatures and precipitation.

Four cuttings per year reduced ($p<0.05$) total season yields of eastern gamagrass 22% compared to two cuttings per year. The lack of a cutting frequency by year interaction ($p>0.05$) suggests that there was no negative carryover influence of frequent cutting from year to year during the 3 year of the trial.

Cutting to a 5-inch residual resulted in greater ($p<0.01$) harvested yield than cutting to a 10-inch residual, but there was evidence that the extent of the difference varied by year ($p<0.10$). In 1997, the yield difference between residual heights was 35%. In years 1998 and 1999, the difference was only 17%. This difference may have been due to the different harvesting machine used in 1998-99 versus 1997, but it may also reflect a decreasing yield advantage to close cutting over years due to reduced vigor. Indeed, the 10-inch residual had considerable green leaf remaining after harvest, whereas the 5-inch residual did not, particularly with 2 cuttings per year. There was no cutting frequency by residual height interaction ($p>0.05$).

Table 2. Monthly precipitation and departures from 30-year averages at the Virginia Tech Kentland Farm, Whitethorne, VA.

Month	1997		1998		1999	
	Precip.	Dep.	Precip.	Dep.	Precip.	Dep.
	inches					
Jan.	2.43	0.15	5.86	3.58	3.92	1.64
Feb.	1.94	-0.72	2.55	-0.11	2.07	-0.59
Mar.	4.11	1.06	4.69	1.64	2.50	-0.55
Apr.	2.13	-0.71	4.99	2.15	3.22	0.38
May	2.11	-1.70	5.86	2.05	4.30	0.49
June	3.33	-0.12	3.63	0.18	0.95	-2.50
July	4.79	0.87	1.94	-1.98	6.03	2.11
Aug.	1.88	-1.41	6.10	2.81	2.17	-1.12
Sept.	3.41	0.42	1.13	-1.86	4.60	1.61
Oct.	1.22	-2.12	2.44	-0.90	1.70	-1.64
Nov.	2.59	0.02	0.86	-1.71	2.10	-0.43
Dec.	2.19	-0.54	2.58	-0.15	1.80	-0.90
Total	**32.13**	**-4.80**	**42.63**	**5.70**	**35.36**	**-1.50**

Table 3. Monthly average temperatures from 1997 through 1999 and departures from 30-year averages at the Virginia Tech Kentland Farm, Whitethorne, VA.

Month	1997		1998		1999	
	Avg.	Dep.	Avg.	Dep.	Avg.	Dep.
	Degrees Fahrenheit					
Apr.	47.3	-3.6	52.6	1.7	53.7	2.8
May	55.3	-5.0	62.9	2.6	58.7	-1.6
June	64.4	-3.2	68.9	1.3	67.3	-0.3
July	72.3	1.0	71.9	0.6	74.6	3.3
Aug.	68.4	-1.8	70.8	0.6	70.8	0.6
Sept.	63.4	-0.3	68.8	5.1	63.2	-0.5

Yield distributions varied with year and residual height for both the 2- and 4-cut treatments (Fig. 2 and 3). During 1998 and 1999, greatest yields occurred in early summer harvests. The contrasting yield distribution in 1997 can probably be attributed to below average spring temperatures and precipitation. Yields were consistently less than 1000 lbs acre^{-1} for the 4th cutting of the 4-cut treatments. These data suggest that a defoliation regime with earlier and/or more frequent defoliation during the early summer might be feasible and, in fact, preferable.

Eastern gamagrass forage averaged 8.9% CP, 39.8% ADF, and 74.2% NDF (Fig. 4 and 5). Averaged over 3 years, four cuttings per year increased ($p<0.01$) eastern gamagrass CP concentration 2.7 percentage units and decreased ADF ($p<0.01$) and NDF ($p<0.05$) concentrations 2.9 and 2.2 percentage units, respectively, compared to two cuttings per year. There were significant year by cutting frequency interactions ($p<0.05$) for all forage quality measures because the difference in forage quality between cutting frequencies increased each year with four cuttings producing comparatively higher forage quality each year.

Residual height had small, inconsistent influences on forage quality, suggesting that managing for a taller residual did not offer a consistent forage quality advantage. The lack of a biological effect of residual height may be due to the leafiness of the basal area of eastern gamagrass plants.

The interaction of cutting frequency, residual height, and year was statistically significant for CP concentration ($p<0.01$), but probably not biologically important.

Conclusions

Our data confirm the forage potential of eastern gamagrass in the Mid-Atlantic region. Eastern gamagrass produced an average of 5.0 tons of forage DM per acre. During 3 years of varying defoliation regimes, eastern gamagrass did not demonstrate sensitivity to close defoliation (5"). This response contrasts to that of other tall-growing native warm-season perennials like switchgrass and big bluestem, and can probably be attributed to a high level of basal tillering and meristematic activity in eastern gamagrass.

Frequent defoliation appears to be an effective strategy to improve forage quality; however, grazing to taller residual height (10 inches) appears to offer no advantage. It should be noted that our forage quality data provides insight into comparisons within our experiment, but should not be extrapolated to predict animal performance. The research discussed earlier and considerable research by Reid et al. (1988) documents that animal performance on native warm-season grasses often far exceeds what would be anticipated based on a routine chemical analyses of forage quality.

Acknowledgments: The researchers express their sincere appreciation to the Virginia Agricultural Council (VAC) for funding this research; to the Virginia Forage and Grassland Council for supporting the request for funding from the VAC and for partially funding the forage harvester; and to Dean Andy Swiger, Dr. Bob Cannell, and Dr. Jack Hall for funding the forage harvester.

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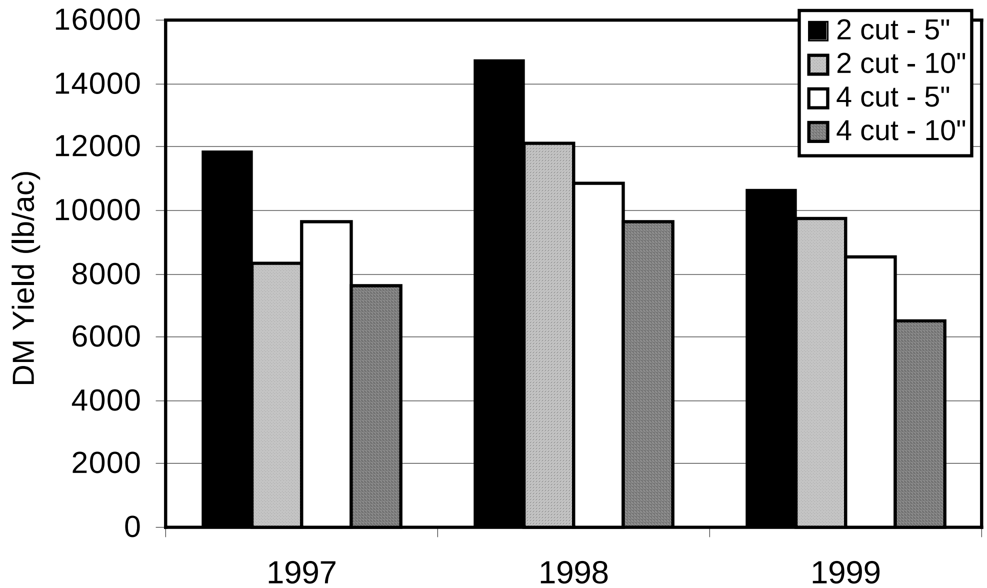

Fig. 1. Influence of defoliation frequency and residual height on total season forage yield of eastern gamagrass at Whitethorne, VA.

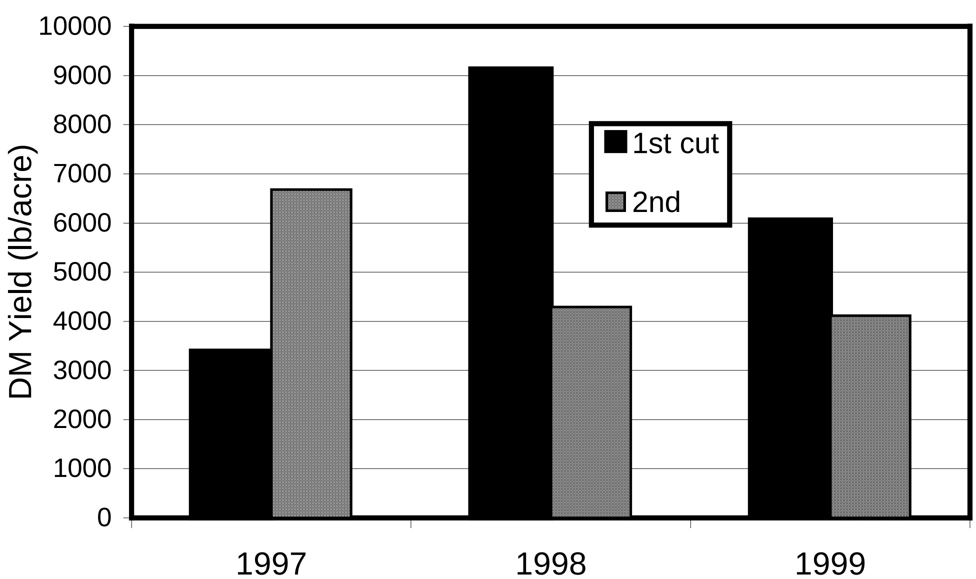

Fig. 2. Yield distribution of eastern gamagrass cut two times per year for 3 yr at Whitethorne, VA.

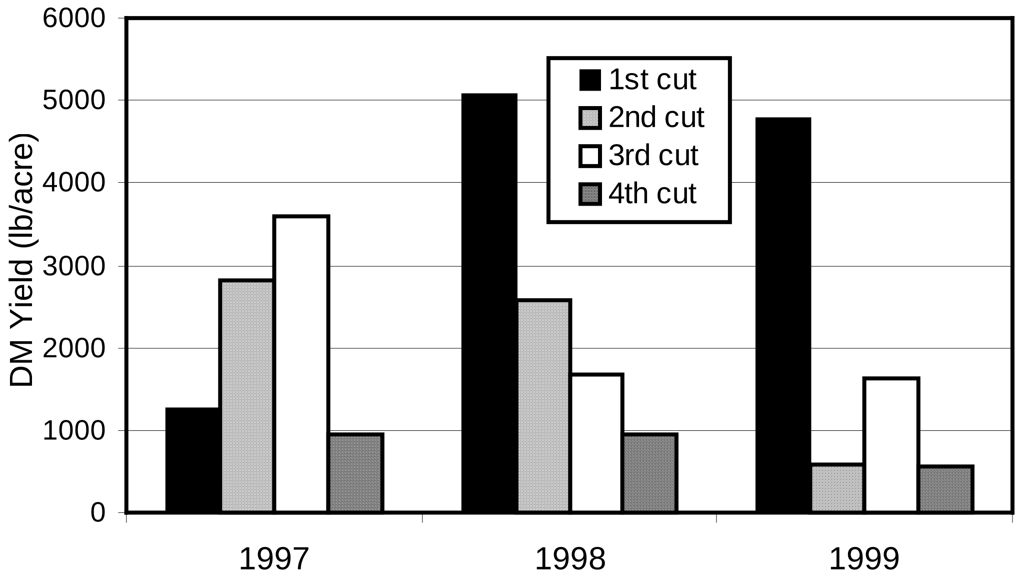

Fig. 3. Yield distribution of eastern gamagrass cut four times per year for 3 yr at Whitethorne, VA.

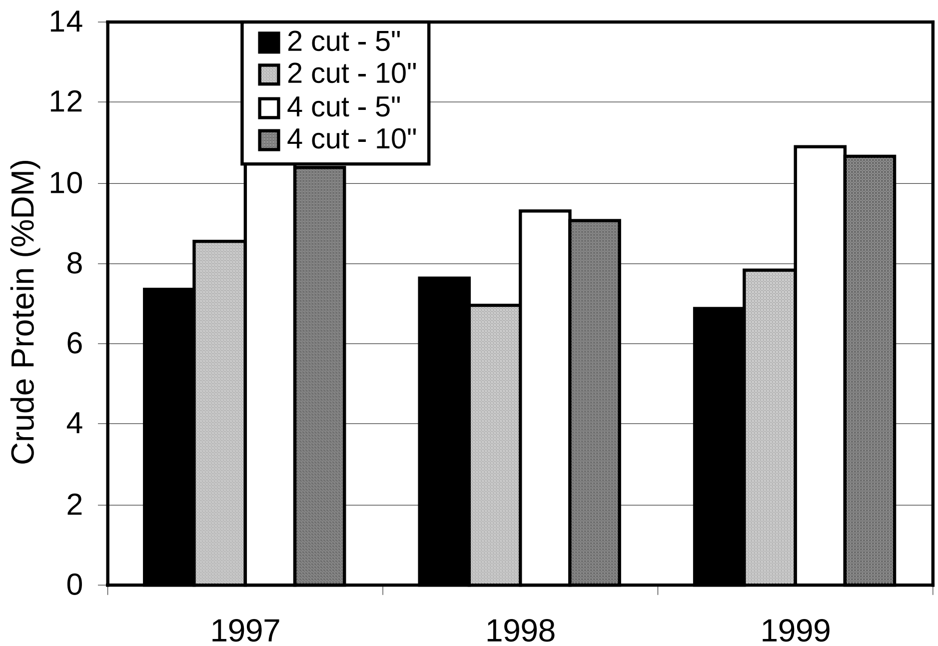

Fig. 4. Season average crude protein concentration of eastern gamagrass forage as affected by defoliation management at Whitethorne, VA.

Direct Seeding Native Species on Reclaimed Phosphate-Mined Lands

Sharon Pfaff and Mary Anne Gonter[1]

Abstract

The Florida phosphate industry would like to reclaim mined lands to native upland habitat. Lack of direct seeding expertise has hampered this effort. The Brooksville, FL Plant Materials Center has been working with the Florida Institute of Phosphate Research to develop direct seeding technology for native Florida upland species. A series of studies were conducted on a reclaimed mined land site of sand tails and sand tails capped with overburden, near Bartow, FL from 1997 through 1999. Research focused on the influence of three factors on establishment success of wiregrass [*Aristida beyrichiana* Trin. & Rupr.] and lopsided Indiangrass [*Sorghastrum secundum (Elliott) Nash*]: Seeding method, seeding rate and seeding date. Drilling was compared with broadcasting. Indiangrass and wiregrass that had been debreaded before seeding successfully emerged from drilled and broadcast treatments in 1997. However, debearding severely damaged a large percentage of the brittle wiregrass seed, making drilling uneconomical. In 1998, Indiangrass was planted at 215, 430 and 645 pure live seed m^{-2}. Plant densities were similar for the high and medium rates, and 2–3 times lower for the low rate. Wiregrass densities were 5 plants m^{-2} or less from 430, 645 and 860 pls m^{-2} treatments. Wiregrass could not overcome a droughty spring and high weed competition at any of the rates used. In 1999, wiregrass and Indiangrass were seeded in January and May to test influence of seeding date. Despite a droughty spring, both species emerged relatively well from both treatments. Winter seedings may be advantageous for wiregrass, but only if weed competition is low and adequate soil moisture is available.

Introduction

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

In 1995, under a previous agreement with the Florida Institute of Phosphate Research (FIPR), the Brooksville, FL Plant Materials Center (FLPMC) established seeding methodology trials on two reclaimed mined land sites near Bartow, FL, using wiregrass and lopsided Indiangrass (Pfaff and Gonter 1996). Plots were planted in May, at the beginning of the rainy season. Despite problems with severe competition from introduced pasture species, much information was gathered from these studies. Indiangrass readily established, although plant densities were low. Wiregrass did not establish. Low plant densities were thought to be primarily due to the season of seeding, seeding rate and weed competition. Problems associated with the three seeding methods employed in this study also contributed to poor stand establishment. Drilling showed potential for use in establishing Indiangrass. However, the drill used in the initial study was not capable of handling light chaffy seed.

Bisset (1995) was able to successfully establish several native species, including wiregrass, by broadcasting chopped mature native material on a reclaimed mined land site near Bartow, FL in December. Bisset estimated that wiregrass was distributed at a rate of 538 pure live seed m^{-2} (50 pls ft^{-2}) (personal conversation). In north Florida, Seamon (1998) reported successful wiregrass

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establishment when a wiregrass mix collected with a Flail-Vac Seed Stripper was broadcast on plots of bare mineral soils with a hay blower. The seed was planted in February. Possibly due to a dry spring, most seedlings did not emerge for two years. Seeding rate was estimated to be over 3,200 pls m^{-2} (300 pls ft^{-2}). Wiregrass seedlings emerged well from plots that had been disked prior to seeding. However, plots that were simply burned off or were not disturbed had no seedling emergence. It appears that planting into disturbed bare mineral soils is important for successful wiregrass stand establishment.

The purpose of this study is to determine the effect of seeding method, seeding rate, and planting date on the establishment of wiregrass and lopsided Indiangrass in monoculture and mix.

Materials and Methods

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

The study site is near Bartow, FL, on reclaimed mined lands provided by Cargill Fertilizer, Inc. It is composed of three acres of sand tailings, and an adjacent three acres of sand tailings capped with 6 or more inches of overburden soils. Sand tails soils are generally very consistent in texture, and very coarse and droughty. Texture of the overburden soils at the study site varied greatly. In areas where the overburden cap was thinnest, a large fraction of the soils were coarse sands with very low water holding capacity. Soils on the other end of the overburden plots have a large loam fraction, which has a high water holding capacity, and crusts heavily when dry.

The study site was freshly reclaimed in January of 1997, so no weed control was necessary. Vacant plots were disked and sprayed with glyphosate throughout the growing seasons from 1997 to 1999 to control weeds. However, heavy late summer rains often interfered with weed control and allowed [*Digitaria sanguinalis* (L.) Scop.], natalgrass [*Melinis repens (Willd.) Zizka*], and hairy indigo [*Indigofera hirsuta* L.] to establish seed banks on the overburden site.

All plots were rolled with a cultipacker before seeding. Plots were 10' x 50' in size. Due to a lack of seed, generally 4 reps were used on overburden soils and 3 reps on sand tailing soils. A total of six series of study plots were planted in January and May 1997 through 1999.

1997 Seedings: The first series was planted on both soil types January 28, 1997 as a randomized complete block. Monocultures of debearded seed of both grass species were seeded using an air drill built by Pounds Motor Company of Winter Garden, FL. This drill was specifically designed to handle light chaffy seed and keep it from bridging in the drill. It has an aggressive brush system in the hopper, and forced air blowing the seed through the drop tubes. An Indiangrass/wiregrass/*Liatris* spp. mixture of debearded seed was also drilled. All monoculture broadcast treatments used debearded seed, and were planted using a hand-held Cyclone seeder. A mixture of beards-on wiregrass, debearded Indiangrass and *Liatris* were broadcast using a seed blower. All broadcast plots were firmed with a cultipacker after seeding.

The lopsided Indiangrass and wiregrass seeding rate in drilled and broadcast monoculture treatments was 645 pls m^{-2} (60 pls ft^{-2}). The exception to this was the wiregrass drill treatment. It was seeded at a rate of 800 - 860 pls m^{-2} (75-80 pls ft^{-2}), due to the aggressive brush system of the air drill. In broadcast mix treatments, wiregrass and Indiangrass were planted at a rate of 645 and 430 pls m^{-2} (60 and 40 pls ft^{-2}) respectively. *Liatris* was also added to the January mix treatments at a rate of 130 pls m^{-2} (12 pls ft^{-2}).

The second series of plantings were seeded on May 20, 1997 as outlined above. However, drill treatments were planted using a Tye drill with a warm season grass attachment, borrowed from the Quicksand, KY PMC. Seeding rates were the same as for the January seeding, except that wiregrass was drilled at 646 pls m^{-2}.

1998 Seedings: The third series of study plots were seeded on both soil types January 21, 1998. The only seeding method used was broadcasting, with emphasis placed on seeding rates. Indiangrass was debearded for this planting, and broadcast with a Cyclone seeder. Beards-on wiregrass was broadcast in monoculture and mix with a seed blower. Plots were packed before and after seeding with a cultipacker.

January monoculture plots were broadcast at three rates: Wiregrass - high (860 pls m^{-2}), medium (645 pls m^{-2}) and low (430 pls m^{-2}); Indiangrass - high (645 pls m^{-2}), medium (430 pls m^{-2}), and low (215 pls m^{-2}); wiregrass/Indiangrass mixtures - high (430 and 215 pls m^{-2} respectively) and a low (430 and 108 pls m^{-2} respectively). Mixtures contained approximately 55 pls m^{-2} of *Liatris* species. Treatments were replicated four times on overburden soils and three times on sand tails soils in randomized complete blocks.

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

An additional Indiangrass seeding method was studied for both sand tails and overburden soils in May of 1998. Treatments compared broadcasting Indiangrass seed with a Cyclone seeder, versus drilling with a Truax grass drill. Seed was drilled at the approximate rates of 215 and 430 pls m^{-2}, and broadcast at a rate of 430 pls m^{-2}. Slight modifications had to be made to the Truax to keep the seed from bridging in the drop tubes. Each treatment was replicated 3 times on both soil types in a randomized complete block design.

1999 Seedings: The fifth series of plantings were made on January 12, 1999. The first study focused on the effect of seeding date on wiregrass and lopsided Indiangrass establishment. Wiregrass and Indiangrass were broadcast in monoculture at a seeding rate of 645 pls m^{-2} in January in a split plot design, which included May 1999 treatments. Plots were replicated three times on both overburden and sand tailing soils. Wiregrass seed was not debearded, and was broadcast with a seed blower. Debearded Indiangrass seed was broadcast with a cyclone seeder. Plots were packed before and after seeding with a cultipacker. In the second study, the effect of various rates of Indiangrass on wiregrass emergence was considered. Plots were planted in January on both soil types. Wiregrass was broadcast at 860 pls m^{-2} with three different rates of Indiangrass (0, 108 and 215 pls m^{-2}) and 55 pls m^{-2} *Liatris* seed Plots were replicated three times on both soil types in a randomized complete block design.

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

Meter square quadrats (two per plot) were randomly established on all plots at six months. These were used to evaluate treatments for plant density, size, vigor, percent canopy cover, and percent weed cover at 6, 12 and 24 months after seeding. Statistical analysis was conducted using MSTAT-C (1983).

Results and Discussion

Weather patterns varied greatly between the three years of this study. Rainfall amounts for Hooker's Prairie, which is located within five miles of the study site, are shown in Table 1. The spring of 1997 was wet, with 7 inches of rainfall recorded at Hooker's Prairie in April. March and April precipitation is very critical for winter-planted seedlings. The first three months of 1998 were reported as being exceptionally wet at Hooker's Prairie. However, almost no rainfall was received in the critical month of April. This dry period was also accompanied by high winds. Rainfall amounts were very low the first four months of 1999. High winds accompanied the dry conditions, and new seedlings were literally sand blasted on the coarser soils. Precipitation adequate to sustain May planted seedlings did occur during the summer season in 1998 and 1999.

Table 1. Inches of monthly Rainfall at Hooker's Prairie from 1996 through 1999.

	1996	1997	1998	1999
	Inches of Precipitation			
January	5.18	0.93	2.50	2.50
February	1.74	0.86	12.58	0.44
March	5.45	2.17	6.84	0.45
April	0.73	7.12	0.37	1.52
May	10.38	1.87	2.07	4.34
June	3.32	6.00	0.83	8.87
July	4.39	9.49	7.31	5.51
August	9.62	2.41	4.29	7.87
September	4.89	8.05	13.01	10.07
October	3.43	3.32	0.30	2.26
November	0.86	5.94	3.11	2.18
December	1.67	8.51	1.94	2.16

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

The Cyclone seeder distributed debearded wiregrass and Indiangrass very uniformly. The seed blower handled the chaffy wiregrass seed mix very well, though distribution over the surface of the plots was uneven. The ideal seedbed for this method was a moist soil surface with grooves for the air-blown seed to collect.

Overall, broadcasting produced the greatest plant densities for both species (Table 2). Direct seeding success criteria for Florida soils have not been developed. In the western US, 43 plants m^{-2} is considered a successful planting (Cook *et al* 1974). Coarse droughty soils in Florida may not be able to sustain such high densities. In its natural environment in Florida, mature wiregrass averages 5 plants m^{-2} (Clewell 1989). All of the January 1999 Indiangrass treatments met the success criteria of 43 plants m^{-2} on both soil types. A seeding rate of 646 pls m^{-2} was actually too high for Indiangrass. After two years Indiangrass densities in broadcast plots had diminished by approximately 60% on both soil types. Due to excessive competition between seedlings, plants in broadcast plots were smaller and less vigorous than those in drilled plots. Drilling provided more optimum seedling placement. Wiregrass, on the other hand, only met the 43 plants m^{-2} success criteria in the overburden broadcast plots. All other wiregrass treatments averaged at least 5 plants m^{-2} or more. Once established, wiregrass seedlings proved to be very persistent. After two years, wiregrass treatments suffered 10% or less seedling losses.

Table 2. Average plant densities of January 1997 broadcast and drilled Indiangrass and wiregrass in monoculture on overburden and sand tails soils 6 months after planting.

Treatment	Overburden	Sand Tails
	Plants m^{-2}	
Indiangrass – Broadcast (645 pls m^{-2})	177a*	46ab*
Indiangrass – Drilled (645 pls m^{-2})	96b	76a
Wiregrass – Broadcast (645 pls m^{-2})	65b	14bc
Wiregrass – Drilled (860 pls m^{-2})	36b	5c

*treatment means followed by different letters are significantly different by Tukey's HSD at $P \leq 0.05$

Wiregrass and Indiangrass were also drilled and broadcast as a mixture in January of 1997 (Table 3). Even at a reduced seeding rate, Indiangrass dominated the mix and inhibited wiregrass germination. After two years however, Indiangrass densities decreased 50% or more, while wiregrass treatments only decreased by 10% or less. Wiregrass actually became the dominant species in the mix. It appears wiregrass is very susceptible to competition at emergence, yet, once established this species has excellent persistence.

Table 3. Average plant densities of January 1997 broadcast and drilled mixtures of Indiangrass and wiregrass on overburden and sand tails soils 6 months after planting**.**

Treatment	Overburden	Sand Tails
	Plants m^{-2}	
Indiangrass in Mix – Broadcast (430 m^{-2})	88a*	26b*
Indiangrass in Mix – Drilled (430 pls m^{-2})	79ab	86a
Wiregrass in Mix – Broadcast (645 pls m^{-2})	39bc	4b
Wiregrass in Mix – Drilled (645 pls m^{-2})	17c	3b
Mix - Indiangrass & Wiregrass - Broadcast	128	30
Mix - Indiangrass & Wiregrass - Drilled	108	89

*treatment means followed by different letters are significantly different by Tukey's HSD at $P \leq 0.05$

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

Results for May 1997 Indiangrass and wiregrass treatments in monoculture are shown in Table 4. Greatest densities for both species were again obtained by broadcasting. Indiangrass met the western success criteria of 43 plants m^{-2} on overburden but not sand tails drilled treatments. The Tye drill was not successful in seeding wiregrass, although seeding date may have been a contributing factor. Broadcast wiregrass treatment densities were low, but still met natural Florida averages of 5 plants m^{-2}. Weed competition was observed to be higher in May overburden plots than in January plots, though herbicide treatments were applied prior to planting. Weed competition undoubtedly contributed to low wiregrass emergence in overburden plots. Competing weeds were primarily crabgrass, natal grass, and hairy indigo. Indiangrass again dominated mixture treatments in the May 1997 plantings (Table 5). However, all mixture treatments preformed poorly on sand tails soils. A dry, windy August may have contributed to seedling desiccation on the extremely droughty sand tails soils. Almost no wiregrass emerged from any of the mixture treatments.

Table 4. Average plant densities of May 1997 broadcast and drilled Indiangrass and wiregrass in monoculture on overburden and sand tails soils 6 months after planting.

Treatment	Overburden	Sand Tails
	Plants m^{-2}	
Indiangrass – Broadcast (645 pls m^{-2})	117a*	34a*
Indiangrass – Drilled (645 pls m^{-2})	57b	21a
Wiregrass – Broadcast (645 pls m^{-2})	7c	5a
Wiregrass – Drilled (860 pls m^{-2})	1c	0.2a

*treatment means followed by different letters are significantly different by Tukey's HSD at $P \leq 0.05$

Table 5. Average plant densities of May 1997 broadcast and drilled mixtures of Indiangrass and wiregrass on overburden and sand tails soils 6 months after planting.

Treatment	Overburden	Sand Tails
	Plants m^{-2}	
Indiangrass in Mix – Broadcast (430 m^{-2})	28a*	2a*
Indiangrass in Mix – Drilled (430 pls m^{-2})	46a	7a
Wiregrass in Mix – Broadcast (645 pls m^{-2})	2b	0.3a
Wiregrass in Mix – Drilled (645 pls m^{-2})	1b	0.2a
Mix - Indiangrass & Wiregrass - Broadcast	30	1
Mix - Indiangrass & Wiregrass - Drilled	47	7

*treatment means followed by different letters are significantly different by Tukey's HSD at $P \leq 0.05$

In May of 1998, a Truax grass drill was used to compare drilling with broadcasting Indiangrass. One of the advantages of drilling is that seed can be placed precisely at a given depth and row spacing. Seeding rates can also be reduced compared to broadcasting, which leaves approximately half of the seed on the soil surface. The Truax drill was able to handle the chaffy Indiangrass seed fairly well. It has a very vigorous auger system that keeps the seed from bridging, and aggressively pulls it into the drop tubes. As with all new equipment however, some problems had to be overcome. The disk openers would not turn in the dry sandy soils. The drop tubes of the chaffy seed box were positioned to open directly over the point where the two blades of the disk openers met. If these did not turn, the seed would collect there and not be metered out evenly. This problem was overcome by moving the drop tubes back to another hole. A few of the appendages on the Indiangrass seed remained after debearding, causing enough resistance to keep the seed from flowing easily. This problem could be overcome in the future by increasing processing times in the debearder to more fully polish seed hulls. Leaving Indiangrass seed in the debearder longer may cause more seed damage. However, better flowing seed would greatly increase consistent stand establishment. Broadcast treatments produced very high densities on both soil types (Table 6), well above success criteria. Drilled treatment densities were substantially lower than the 43 plant m^{-2} success criteria, due primarily to poor seed flow. Doubling drilled seeding rates to broadcast levels did not increase seedling densities. Future studies need to be conducted to precisely determine optimum drilled Indiangrass seeding rates, once mechanical difficulties are overcome.

Table 6. Average plant densities of May 1998 drilled and broadcast Indiangrass on overburden and sand tails soils at 6 months after planting.

Treatment	Overburden	Sand Tails
	Plants m^{-2}	
Indiangrass Broadcast -Medium Rate (430 pls m^{-2})	84a*	97a*
Indiangrass Drilled - Medium Rate (430 pls m^{-2})	8b	17b
Indiangrass Drilled - Low Rate (215 pls m^{-2})	9b	14b

*treatment means followed by different letters are significantly different by Tukey's HSD at $P \leq 0.05$

Seeding Rate: Indiangrass and wiregrass were broadcast in monoculture at three seeding rates in January of 1998 (Table 7). Unfortunately, erratic rainfall and heavy weed competition caused much variability in the data. Rainfall was unusually heavy the first three months of 1998. This appeared to stimulate high weed competition on both soil types early in the year, especially on overburden plots. Lack of any appreciable rainfall in April, coupled with high winds, decimated populations of the less vigorous native grasses that had emerged. Coarser, sandy overburden soils had lower weed competition than did overburden soils with a higher clay loam fraction. This translated to relatively high seedling densities for both species on the sandy replications, graduating to virtually no surviving seedlings on the heavier soils. The net result was that density data on overburden plots was erratic, e.g. high seeding rates produced lower seedling densities than did medium, or in the case of wiregrass, low rates. Some interesting observations could be made from the Indiangrass treatments. This was the species most able to overcome unfavorable conditions. Indiangrass seedling densities were similar for the high and medium rates on both soil types, and approximated success criteria of 43 plants m^{-2}. The low Indiangrass seeding rate produced substantially lower plant densities than did the medium rate. Based on these data, it appears that a 215 pls m^{-2} broadcast seeding rate is definitely too low to meet western success criteria of 43 plants m^{-2}.

It also appears there is no advantage to doubling the seeding rate to 645 pls m^{-2}. This high rate has in fact been observed to cause severe competition between seedlings, and high seedling mortality.

Wiregrass seedling densities were very low and generally did not reach the natural systems standard of 5 plants m^{-2} at any seeding rates used in this study. This species appears to be extremely sensitive to weed competition and rainfall, which had a greater effect on seedling emergence than did seeding rate.

To test wiregrass seedling sensitivity to competition with other species in a native mix, wiregrass was broadcast with Indiangrass at three differing rates in January of 1999 (Table 8). Unfortunately, weather patterns were once again very erratic in 1999. Only 4.9 inches of rain fell in the first four months of 1999, compared to an average of 15.5 inches for the first four months of the previous three years. Droughty conditions were accompanied by high winds. Remarkably, wiregrass densities for all treatments on overburden soils were above the natural system standard of 5 plants m^{-2}. Fortunately, weed competition was low, and had much less influence on seedling emergence compared to 1998. Indiangrass densities appeared to be too low to significantly effect wiregrass emergence under these droughty conditions at either rate. Stand densities on the sand tails plots were almost zero for all species. Droughty conditions and blowing sand killed most seedlings that did emerge. These studies provided a good opportunity to establish seeding rate thresholds for wiregrass and Indiangrass in monoculture and mixtures. Further experiments may be necessary to develop data under less extreme conditions.

Table 7. Average plant densities of January 1998 broadcast Indiangrass and wiregrass in monoculture at three seeding rates on overburden and sand tails soils one year after planting.

Treatment	Overburden	Sand Tails
	Plants m^{-2}	
Indiangrass - High Rate (645 pls m^{-2})	33ab	42a
Indiangrass - Medium Rate (430 m^{-2})	44a	35ab
Indiangrass - Low Rate (215 pls m^{-2})	14ab	14ab
Wiregrass - High Rate (860 pls m^{-2})	3b	4b
Wiregrass - Medium Rate (645 m^{-2})	4b	4b
Wiregrass - Low Rate (430 pls m^{-2})	5b	3b

*treatment means followed by different letters are significantly different by Tukey's HSD at $P \leq 0.05$

Table 8. Average plant densities of wiregrass broadcast at three different rates with Indiangrass January 1999 on two soil types at 6 months after planting.

Treatment	Overburden	Sand Tails
	Plants m^{-2}	
Rate 1:		
Wiregrass (860 pls m^{-2})	11ab*	0.3a*
Liatris (55 pls m^{-2})	3bc	1a
Rate 2:		
Wiregrass (860 pls m^{-2})	9ab	1a
Indiangrass – Medium Rate (108 pls m^{-2})	5abc	2a
Liatris (55 pls m^{-2})	3bc	2a
Rate 3		
Wiregrass (860 pls m^{-2})	8ab	0.3a
Indiangrass – High Rate (215 pls m^{-2})	7ab	4a
Liatris (55 pls m^{-2})	3bc	1a

*treatment means followed by different letters are significantly different by Tukey's HSD at $P \leq 0.05$

Seeding Date: Throughout these studies, seeding date often appeared to have a strong influence on seedling establishment. A final series of study plots were planted in 1999 to specifically address the affect of January verses May planting dates on wiregrass and Indiangrass emergence (Table 9). Droughty weather conditions in 1999 negatively influenced seedling emergence. However, good data were still obtained. Weed competition fortunately was not a significant factor in this study. There was no significant difference between wiregrass stand densities in January verses May on overburden soils. Had more rainfall been received in the spring of 1999, it is possible that January wiregrass plant densities would have been much higher. This conclusion is based on wiregrass performance in the 1997 studies. Both were well above the natural standard of 5 plants m^{-2}. Timely summer rains gave May seedlings a much needed boost to become established on overburden soils. However, conditions were too dry and windy for wiregrass to establish on sand tails soils at either seeding date.

Indiangrass established relatively well on both soil types on both dates. It was especially able to take advantage of summer rains to become established on overburden soils. Lopsided Indiangrass is a very good candidate for use in a native seed mix for reseeding critical area sites. It established relatively well on all soil types despite severe conditions. It may not persist on all sites, but may be an effective native "nurse crop" to help other species such as wiregrass become established.

Table 9. Average plant densities of wiregrass and Indiangrass broadcast in January and May of 1999 on overburden and sand tails soils at 1 year and 6 months after planting respectively**.**

Treatment	Overburden	Sand Tails
	Plants m^{-2}	
Indiangrass – January	107b*	21a*
Indiangrass – May	236a	30a
Wiregrass - January	15c	0.3b
Wiregrass - May	10c	0b

*treatment means followed by different letters are significantly different by Tukey's HSD at $P \leq 0.05$

Conclusions

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

Optimum broadcast seeding rate levels for Indiangrass were found to be 430 pls m^{-2} (40 pls ft^{-2}) on sand tails and overburden soils in this study. Drill seeding rates were not precisely determined. Typically, seeding rates for drilling are half of broadcast rates. Further research will be needed to verify this for Indiangrass. Initial studies did indicate doubling the seeding rate to broadcast levels did not significantly increase seedling densities.

Optimum wiregrass broadcast seeding rates could not be established in these studies. Rainfall and weed competition had a profound effect on wiregrass seedling establishment. Wiregrass could not establish in extremely harsh conditions regardless of the seeding rate. When conditions were favorable broadcast rates of 640 to 860 pls m^{-2} (60 to 80 pls ft^{-2}) produced adequate stands on both soil types.

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Increasing Establishment Success of Native Grasses -- Matching the Techniques with the Equipment

Larry Pollard[1]

Abstract

My presentation will stress features of grass and wildflower planting equipment. Native grass seed is expensive, whether purchased directly or accumulated through labor intensive harvest methods. Reducing the risk of establishment failure is important to individuals, consultant clients or answering to organizational management. Quality viable seed at planting time, using adapted ecotypes, site preparation, timing, weed control, favorable weather, and knowledge of planting techniques will not complete the job. Reliable equipment, designed to achieve the desired seed placement, seed depth, seed rate and that all-important seed to soil contract is key to those job specs. Then, someone still has to operate that equipment.

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Comparative Biomass, Composition, and Forage Quality of Greenhouse-grown Gamagrass Plants Differing in Age, Stage of Development, and Drought Tolerance

James B. Reeves, III[1], Donald T. Krizek[2], Charles D. Foy[2], and Jerry C. Ritchie[3]

Abstract

The primary objective of this work was to evaluate the biomass, composition, and forage quality of eastern gamagrass [*Tripsacum dactyloides* (L.) L.] differing in age, stage of development, and drought tolerance. Young plants were established in the greenhouse from seed. Also 2-year old plants selected from field plots for drought tolerance (DT) or drought sensitivity (DS) in Nov 1997 were transplanted into the greenhouse. Six samples of 15 young plants each were cut back to 25 cm at 80, 94, 108, 122, 147, 164, and 185 days from seeding. Three DT and three DS plants each were treated as above with regrowth harvested at 94, 108, and 122 days. Samples from each harvest were analyzed for neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, and crude protein (CP). The Least Significant Difference test was used to evaluate differences in composition, biomass, and drought tolerance over time. While little variation in NDF with age was found in young plants, DS plants had significantly higher NDF than DT plants regardless of age. Greater variations were found for ADF, lignin, and CP with age for young plants and for ADF, but not for lignin or CP, for the DT and DS plants. Also, DT plants generally had lower lignin content than DS plants regardless of age. Finally, biomass for young plants differed significantly with age, increasing to day 218**,** then decreasing. Biomass of DS plants was generally greater than DT plants of the same age. These results show that gamagrass displays complex variations in composition and thus forage quality during aging and in selected genotypes differing in drought tolerance. Overall, forage quality was excellent with CP ranging from 15-18%. Plants were also high in fiber with NDF, ADF, and lignin ranging from 77-85%, 38-43%, and 2.9 to 4.7%, respectively.

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Vegetative Propagation of Eastern Gamagrass: Effects of Root Pruning and Growth Media

Errol G. Rhoden[1], Jerry C. Ritchie[2], Donald T. Krizek[3] and Charles D. Foy[3]

Abstract

Eastern gamagrass [*Tripsacum dactyloides* (L.) L.] is currently being investigated as an alternative forage crop as well as a grass hedge against erosion. Methods of vegetatively propagating this crop are being explored in order to obtain cloned planting material. A 16-week greenhouse study (07/31/98-11/30/98) was conducted at the Agricultural Research Service facilities in Beltsville, MD to determine the minimal number of roots and the type of growth media needed for the successful propagation of 'Pete' eastern gamagrass. The treatments consisted of four growth media (Jiffy mix, a composted soil, Tatum clay loam and Turface) as the main effect, and severity of root pruning (one, two, three or four roots remaining on the culm) as sub-plot in a split plot design with three replicates. Overall, plant survival rate ranged from 16.7% in the composted soil to 75.0% for Tatum clay loam. Of those plants surviving the transplant process, tiller number, plant height, and foliage dry weights were greatest for plants grown in Jiffy mix. Foliage dry weights for plants grown in Tatum clay loam, Turface, composted soil and Jiffy mix averaged 3.9, 12.3, 23.8 and 34.2 g/plant, respectively. Root dry weight averaged 1.9 g/plant for Tatum clay loam to 13.4 g/plant for Jiffy mix. Shoot-root ratio ranged from 3.6 in Turface to 1.7 for plants grown in composted soil. The number of roots left on the transplanted culms had no effect on the shoot-root ratio of eastern gamagrass. Although eastern gamagrass plants grown in Tatum clay loam had the highest survival rates, these plants were the shortest, had the lowest plant dry weights, and the fewest number of tillers. After 16 weeks, plants obtained from culms with 2 or 3 roots transplanted into Jiffy mix had the overall best appearance of all root pruning/growth media treatments. It is feasible to vegetatively increase eastern gamagrass by transplanting a minimum of crown tissue into a porous, well-aerated growth medium.

Introduction

Due to the demand to use lands currently cropped that produce limited returns, eastern gamagrass [*Tripsacum dactyloides* (L.) L.] is being considered as an alternative in the southeastern United States as a grass barrier and forage crop. This has led soil and crop scientists to develop methods to propagate eastern gamagrass (Ahring and Frank 1968). As information is gathered, this will help us to improve the management of existing fields of eastern gamagrass and eventually increase the total acreage under cultivation. Advances resulting from such research would aid in the choices we could offer in eastern gamagrass propagation.

The plant root system is most noted for playing a major role in plant growth and development. The most important consideration that is ascribed to roots is absorbing moisture and nutrients. The other role that roots play in plant development is to provide mechanical support from seedling to maturity. Evans and Wardlaw (1976) have noted the role of roots in the synthesis of growth substances such as cytokinins, considered important in leaf functions and therefore, this may impact the propagation of eastern gamagrass. It is widely held that if plant roots do not proliferate abundantly in the rooting medium it might affect the plant's ability to absorb moisture and nutrients. Therefore, any factor that diminishes root development reduces the survival potential of the plants being propagated.

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A study of the interaction between roots and tillers is critical to the propagation process. Klepper et al. (1984) stated that cereals do not develop nodal roots until about two or three leaves have been formed. Belford et al. (1987) have noted that tiller roots would not develop and tillers do not provide the hormonal control necessary for root survival. Therefore, a delay in the initiation and development of root tissue during propagation would prevent tiller development and would ultimately impact plant survival.

One accession of eastern gamagrass (PMK 24) obtained as a composite from several collections found in Kansas and Oklahoma was released as 'Pete' (Fine et al. 1990). Foy (1997; 1999) working with a Tatum clay loam soil (fine kaolinitic, mixed, thermic typic hapludult) noted that eastern gamagrass was very tolerant of this highly acidic soil. Based on other work done by Rhoden et al. (1999a), rooting media studies should include an acidic soil because of the plants ability to grow under such high aluminum concentrations. Growth media must also be considered as propagation tools if wide-scale cultivation of eastern gamagrass is to be realized. A combination or modification of growth media currently available on the market might be effective for successful propagation.

Based on low germination rates of eastern gamagrass, these researchers needed a method to establish fields that have evenly-spaced cloned materials. Therefore, the following objectives were developed: 1) determine the effectiveness of commonly available growth media on the propagation of eastern gamagrass; 2) determine the effect of root pruning on eastern gamagrass survival; and 3) determine the effect of media and root pruning on eastern gamagrass growth and development.

Materials and Methods

This study was conducted in the greenhouse of the ARS research facilities in Beltsville, MD for 16 weeks (07/31/98 to 11/30/98). Single culms of eastern gamagrass were planted in 23-cm diameter pots containing different growth media on July 31, 1998 and the experiment was terminated on November 30, 1998. After planting, each pot was supplied with 250 ml of half strength Hoagland's solution. Thereafter, plants were watered daily or as needed and supplied with a solution of 20-20-20 (NPK) each week. The growth conditions in the greenhouse were maintained at a temperature of 30/25°C (day/night).

Growth Media

Four growth media of contrasting water holding capacities and bulk densities were used in this study. The growth media were arranged as main effects in a split plot design. The growth media were:

1) Jiffy mix (peat-lite mix);
2) Turface (Arcillite - a blend of illite, montmorillinite and silica);
3) Tatum clay loam soil (fine, kaolinitic, mixed, thermic, Typic, Hapludult);
4) A composted soil (containing peat and perlite).

The cultivar used in this study was 'Pete' eastern gamagrass. The culms were obtained from material grown in the greenhouse in Jiffy mix (February to July). Plants from which propagation material was procured averaged 24 tillers. They were washed free of Jiffy mix and separated into single culms making sure that roots were left intact and placed in water until time of transplanting. Roots were trimmed to a length of 10-cm. At planting, culms and roots were placed in an upright position, thus ensuring that both crowns and roots were below the growth media surface. Live plants were counted on August 20,1998, and survival percentage determined.

The experiment was terminated after 16 weeks (11/30/98) and biomass harvested. Plants were washed free of growth media, blotted, separated into foliage and roots, placed into separate paper sacks, and dried to a constant weight (70°C for 72 hours).

Data were collected on a) plant height, b) tiller number, c) foliage dry weight, and d) root dry weight. Data were subjected to Analysis of Variance and the Least Significant Difference test ($P<0.05$) used to separate mean differences where applicable.

Results and Discussion

Establishment using single culms of eastern gamagrass was significantly impacted by both growth media and number of roots remaining on the transplant. The culms transplanted into Tatum soil had an average survival rate of 75%, with Jiffy mix and Turface surviving at an average rate of 58.3% each (Table 1). Culms transplanted into composted soil had a very poor survival rate (16.7%). Culms with two roots and transplanted into either Tatum soil or Turface; those with three roots in Jiffy mix, and those with four roots in Tatum soil, all had 100% survival rates. On the other hand, culms with three or four roots and transplanted into composted soil showed no survival. Dewald and Sims (1981) reported a 70% survival rate for eastern gamagrass transplants during late July and a much higher survival percentage for transplants made from December to March, as plants were coming out of dormancy. The number of roots also affected the rate of survival. Plants with two roots on each culm averaged 67% survival. There was no difference between plants having either one or three roots remaining on the culm at time of transplanting. From other work conducted on root trimming of eastern gamagrass, it was noticed that plants tended to support root growth at the expense of foliage development (Rhoden et al. 1999b).

Table 1. Effect of root number and growth media on survival of eastern gamagrass

	Growth Media				
Root #	Jiffy Mix	Tatum Soil	Turface	Composted Soil	Avg.
		%			
1	66.7	66.7	33.3	33.0	50.0
2	33.3	100.0	100.0	100.0	66.7
3	100.0	33.3	66.7	-	50.0
4	33.3	100.0	33.3	-	41.8
Avg.	58.3	75.0	58.3	16.7	

Tiller number was measured as an indicator of the plants' ability to grow in various media. The greatest number of tillers formed on a transplanted culm was found in Jiffy mix. Culms transplanted with one root had an average of 12.5 tillers per plant (Table 2). This trend generally declined with an increase in roots on the transplanted culms. Culms placed in Jiffy mix averaged the highest number of tillers (10.7/plant). Among the four growth media, those plants that survived the transplanting process, culms with three roots had the greatest number of tillers (8.2 tillers/plant). Although plants in Tatum soil had a very high percent survival, they did not produce many tillers.

Plants transplanted into Jiffy mix grew taller than those in all other growth media did. Culms with two roots transplanted in Jiffy mix had an average height of 111.2 cm (Table 3). Regardless of growth media, culms transplanted with four roots grew the least. Plants grown in Tatum soil also remained very short (40.9 cm). It was expected that plant height would reflect the amount of vegetation that eastern gamagrass produces. Therefore, we expect that eastern gamagrass planted in Jiffy mix would out-produce those planted in Tatum soil.

Table 2. Effect of root number and growth media on tillering of eastern gamagrass.

	Growth Media					
Root #	Jiffy Mix	Tatum Soil	Turface	Composted Soil	$LSD_{.05}$	Avg.
			Tiller #/Plant			
1	12.5	1.0	5.0	12.0	2.6	7.3
2	9.0	2.0	4.0	6.0	2.2	4.1
3	11.0	1.0	7.5	-	2.7	8.2
4	8.0	2.3	3.0	-	2.9	3.6
$LSD_{.05}$	2.8	1.2	1.6	4.4		
Avg.	10.7	1.8	5.0	9.0		

Table 3. Effect of root number and growth media on stem elongation in eastern gamagrass

	Growth Media					
Root #	Jiffy Mix	Tatum Soil	Turface	Composted Soil	$LSD_{.05}$	Avg.
			Plant Height (cm)			
1	99.2	38.8	98.3	95.4	18.7	78.3
2	111.2	44.4	84.3	102.1	16.3	75.0
3	99.0	21.6	78.7	-	20.4	79.3
4	59.3	45.4	95.3	-	19.8	58.2
$LSD_{.05}$	14.7	9.3	8.8	NS		
Avg.	95.2	40.9	86.3	98.8		

The number of roots significantly impacted foliage development. Culms transplanted with three roots produced an average of 21.3g of foliage dry matter per plant (Table 4). There were significant differences in foliage dry weight among the growth media used in the vegetative propagation of eastern gamagrass. Dry matter of plants transplanted into Tatum soil averaged almost thirteen-fold less than those grown in Jiffy mix with the greatest difference in clums transplanted with one root. Plants in Jiffy mix averaged 18.6 times the dry matter production as those grown in Tatum soil.

Table 4. Effect of root number and growth media on foliage dry weight of eastern gamagrass

	Growth Media				
Root #	Jiffy Mix	Tatum Soil	Turface	Composted Soil	Avg.
		Foliage dry weight (g/plant)			
1	41.5	2.2	8.1	17.5	18.8
2	44.4	4.8	9.9	30.0	14.4
3	33.4	2.6	12.5	-	21.3
4	11.1	5.9	23.4	-	10.4
Avg.	34.1	3.9	12.3	23.8	

Root dry weight followed a similar trend to that of foliage dry weight. Plants transplanted with three roots from each treatment had the greatest root dry weight (Table 5). Roots of plants grown in Tatum soil had the least dry weight, followed by those transplanted in Turface. Those plants that survived on composted soil averaged the greatest root dry weight (15.1 g/plant).

Table 5. Effect of root number and growth media on root weight of eastern gamagrass.

	Growth Media				
Root #	Jiffy Mix	Tatum Soil	Turface	Composted Soil	Avg.
		Root wt.(g/plant)			
1	13.4	0.7	2.8	17.6	8.1
2	14.4	1.7	2.8	12.6	5.1
3	16.7	1.1	4.2	-	9.9
4	2.5	3.2	7.2	-	3.8
Avg.	13.4	1.9	3.9	15.1	

There was no significant difference in shoot:root ratio of eastern gamagrass regardless of the number of roots that were left on the culms during the transplanting process (Table 6). However, plants transplanted into Turface and Jiffy mix had the highest shoot:root ratios. One factor that might influence such shoot:root ratios among the growth media is the type and amount of root present. Roots of eastern gamagrass in the Tatum soil had an extensive mass of fibrous roots compared to a few large nodal roots seen on the plants in the Jiffy mix and Turface.

Table 6. Effect of root number and growth media on shoot-root ratio of eastern gamagrass.

	Growth Media					
Root #	Jiffy Mix	Tatum Soil	Turface	Composted Soil	$LSD_{.05}$	Avg.
			Shoot:root ratio			
1	3.1	3.3	2.9	1.0	2.1	2.8
2	3.1	2.1	4.2	2.4	1.7	3.0
3	2.6	2.3	3.2	-	2.3	2.8
4	4.5	2.1	3.3	-	2.9	2.8
$LSD_{.05}$	1.7	NS	NS	1.6		
Avg.	3.1	2.4	3.6	1.7		

Conclusion

It is critical that we establish methods of propagation that will enhance the distribution of eastern gamagrass. Vegetative development, including tillering, is an important aspect in the production equation. Therefore, management practices, including growth media, used in the vegetative propagation process will impact culm survival and tillering. It is also important to consider the number of roots that remain on the culm during the propagation process.

Using vegetative propagation in the establishment of eastern gamagrass might be an effective tool in producing large numbers of genetically identical plants. If we look at tiller number as an indicator of a plants' ability to develop after rooting, then Jiffy mix and Turface appear to be excellent media in achieving rapid development. However, Tatum soil, which is very acid and adheres to the culms, had excellent survival rates of plants. Therefore, methods that combine both media, or development of a medium that gives those qualities should be explored.

It would appear that the chances of successful survival of propagated material lie in the rapid development of roots on both the propagated culm and the successive tillers. Factors such as the carbohydrate reserves of the transplanted culm as well as temperature, nutrient status, and moisture will affect the successful survival of the propagated material. Coupled with the rate of vegetative propagated material survival, is the need to develop equipment that can easily plant these materials in the field. Without such equipment, large-scale vegetative propagation would not be a successful tool to increase eastern gamagrass acreage.

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Rhoden, E.G., J.B. Reeves, J.C. Ritchie, and D.T. Krizek. 2000. Influence of root removal on regrowth and forage quality of greenhouse-grown eastern gamagrass. Proceedings of the Second Eastern Native Grass Symposium, Baltimore, MD. (This Volume)

Influence of Root Removal on Shoot Regrowth and Forage Quality of Greenhouse-Grown Eastern Gamagrass

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Abstract

This study was conducted to determine the influence of root removal on shoot regrowth, composition, and forage quality of greenhouse-grown eastern gamagrass plants. On 27 July 1998, the root mass of 5-month old plants was pruned 25% or 50%, or left uncut and the plants were transferred to 20-cm diameter pots having a depth of 40 cm. Plants were grown in a peat-vermiculite mix and fertilized weekly. Shoots were clipped to 25 cm on 18 August (H1), 16 September (H2), 7 October (H3), and 28 October (H4). For each harvest, height and total biomass measurements were taken on shoot regrowth and samples were analyzed for neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, crude protein (CP), dry matter digestibility (DMD), and cell wall digestibility (CWD). Plants were vegetative at H1 and H2, in flower by H3, and starting to become dormant by H4. Trimming roots of eastern gamagrass plants at the time of transplanting had a negative effect on subsequent regrowth of shoots, particularly when 50% of the roots were removed. This was generally reflected in an increase in the number of senescent leaves, a decrease in the number of tillers and in a reduction in the dry weight of forage collected. Despite these reductions in vegetative growth, there was little or no effect of root removal or date of harvest on forage composition or quality. Root removal had no significant effect on NDF or ADF and little or no effect on DMD or CWD at H1-H4. Content of lignin and CP was variable, depending on the extent of root removal and the date of harvest. CP content of the forage samples ranged from 14% to nearly 20% which is higher than that typically reported for field-grown eastern gamagrass plants. The ability of eastern gamagrass plants to cope with the stress of root pruning without altering the quality of forage demonstrates the resilience of this species for adapting to adverse environmental conditions.

Introduction

Eastern gamagrass [*Tripsacum dactyloides* (L) L.] is a warm-season perennial bunchgrass that is recognized as a highly productive and palatable forage crop (Bidlack et al. 1999). Although it was a very popular forage in 19th century America (Magoffin, 1843), through overgrazing and advanced plow technology it all but disappeared as a forage species. Currently, it is regaining some of its prominence. Brejda et al. (1994; 1996) have looked at its use as silage using different nitrogen rates. Dickerson and van der Grinten (1990) have recommended it as an excellent crop for halage in the northeast.

Eastern gamagrass is a monoecious grass with morphology similar to corn. It is a long-lived perennial that is well adapted to a wide range of growing conditions (Faix et al., 1980). Hitchcock and Chase (1971) along with Harlan and DeWet (1977) have cataloged its range from the Atlantic Coast to the Rockies in North America, to Bolivia and Paraguay in South America. Due to its versatility and its range of adaptation, eastern gamagrass is ideally suited for a wide range of agricultural uses. Eastern gamagrass has been found to send its roots through compact soils (McGinty and Alberts, 1995; Rhoden et al., 1999). Not only is the plant capable of penetrating hardpans and claypans, it also tolerates high levels of aluminum as shown both in the greenhouse, using an acidic, Al toxic soil or nutrient solution and in the field using an acidic, Al toxic soil (Foy, 1997; Foy et al., 1999). Furthermore, eastern gamagrass, because of its ability to

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penetrate compact subsoil, provides root channels for subsequent crops (McGinty and Alberts, 1985; Alberts et al., 1996; Clark et al., 1998). Ritchie et al. (1997) have used it as a grass hedge for erosion control. While it is commended for its role in sustainable agricultural production, it also deserves praise for its high yield, protein content, digestibility, and palatability (Faix et al., 1980; Burns et al., 1992; Surrency et al., 1998). These researchers have recommended that the grass be grazed or clipped to a height of 25-40 cm and have found that it contains as high as 17% crude protein and total digestible nutrients of 65%. This has resulted in impressive steer gains (Aiken, 1977). Horner et al. (1985) and Cherney et al. (1994) have compared eastern gamagrass to alfalfa with good results. This makes eastern gamagrass an ideal candidate for further studies in the southeastern United States.

The response of eastern gamagrass to environmental and physiological stresses is thoroughly documented. Root trimming and growth media have been shown to influence shoot production in eastern gamagrass (Rhoden et al., 2000). Factors controlling shoot development are not fully understood but are linked to the ability of the plant to effectively utilize its carbohydrate, nutrient, and water supply. Roots contribute to the uptake of nutrients and water which in turn influence the survival of the plant. Klepper et al. (1984) have shown that root and shoot development are intrinsically connected with one another. Roots are believed to exert hormonal control and ultimately determine shoot morphogenesis. Belford et al. (1987) have postulated that the number and length of roots are important in determining whether a tiller aborts or survives on the parent plant under field conditions. In another study, Belford et al. (1986) were able to influence root length and initiation by increasing fertility during various stages of plant development.

The objective of this study was to determine shoot regrowth, composition, and forage quality of eastern gamagrass after initial removal of 0, 25% and 50% of its root system.

Materials and Methods

This study was conducted in a Climate Stress Laboratory greenhouse at ARS research facilities in Beltsville, MD for 16 weeks (27 July to 28 Oct 1998). Seeds of 'Pete' eastern gamagrass were placed in germination trays containing a peat-vermiculite mix (Jiffy mix) in the greenhouse on 20 March 1998 and growth was carefully monitored. Seedlings were selected for uniformity, and transplanted to 10-cm diameter plastic pots on 6 April and then to 15-cm diameter pots on 19 May. On 27 July 1998, plants were removed from the 15-cm pots and plant roots pruned 25% or 50%, or left intact. These three treatments were replicated three times in a complete randomized design.

Following treatment, the plants were transferred to 20-cm diameter pots of peat-lite mix having a depth of 40 cm and fertilized with 250 ml of half strength Hoagland's solution. Thereafter, plants were watered daily or as needed and supplied with a solution of 20-20-20 (NPK) each week. The growth conditions in the greenhouse were maintained at a day/night temperature of 30/25°C. The tops of eastern gamagrass plants were clipped to 25 cm on 18 August (H1), 16 September (H2), 7 October (H3) and 28 October (H4) as shown in Table 1. Plants from the first three harvests were in a vigorous stage of growth; however, by the third harvest plants were flowering (Table 1) and by the fourth harvest, all plants were starting to show signs of dormancy.

Data on number of tillers and number of senescent leaves were collected for the first two harvests. Data on the amount of shoot regrowth based on linear measurements and biomass were collected at all four harvests but are only presented for H1 and H2. Samples for forage composition and quality were taken at all four harvests and dried in a forced draft oven at 70°C for at least 72 hr. Analyses from each treatment at each harvest were run in duplicate for crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, cell wall digestibility (CWD), and dry matter digestibility (DMD) using the method of Goering and Van Soest (1970). The NDF was determined by boiling 1 g of the forage sample in a neutral detergent solution (pH 7.0), 2 ml decanaphthalene, and 0.5 g of sodium nitrite. This was left to reflux for 60 minutes. Contents were then filtered into a crucible and solids washed twice with hot water (90°C) and twice with acetone. Crucibles were then dried at 100°C overnight and weighed. NDF was calculated as a percentage of the original dry weight of the forage sample. Acid detergent fiber was determined in the same manner except that an acid detergent solution (pH 2.0) was used. Lignin was determined by digesting the ADF in 72% H_2SO_4 at 15° C for 3 hours and filtering. The residue was washed, dried, and ashed at 550°C for 12 hours. The loss in weight during ashing approximated the content of lignin present. Crude protein was determined by using the macro-Kjeldahl procedure. Data were subjected to Analysis of Variance and the Least Significant Difference test (P<0.05) used to separate mean differences where applicable.

Table 1. Harvest dates, condition, and stage of development of eastern gamagrass plants grown in the greenhouse in root removal study.

Harvest Number	Harvest Date	Plant Condition	Stage of Development
H1	18 Aug 1998	Vigorous	Vegetative
H2	16 Sept 1998	Vigorous	Vegetative
H3	7 Oct 1998	Vigorous	Flowering
H4	28 Oct 1998	Onset of dormancy	Flowering

Results and Discussion

There were no significant differences in the heights of regrowth of eastern gamagrass plants among any of the treatments at H1 although plants with roots cut back initially 25% appeared to show a slight stimulation in linear regrowth as compared to the other treatments (Table 2). Removal of 25% of the roots caused a 43% increase in the number of senescent leaves while removal of 50% of the roots caused a 135% increase in the number of senescent leaves. This is important to note as roots of all plants were observed emerging through the mesh at the bottom of the 40-cm deep pots in 10 days, including those cut back initially by 50%. Thus, the plants seem to have diverted some of their reserves from the leaves to the roots. The number of tillers was also significantly reduced by root trimming. Removing 25% of the roots at transplanting caused an average 26% reduction in the number of tillers produced while removing 50% of the roots caused an average 43% reduction in the number of tillers, as compared to unpruned controls at H1. Although removal of 25% of the roots had no effect on the average amount of forage dry matter produced at H1, removal of 50% of the roots reduced the average amount of forage dry matter by 41%.

Table 2. Effect of percent root removal on shoot regrowth, number of senescent leaves, number of tillers and forage dry weight (DW) of eastern gamagrass plants maintained in the greenhouse (1st Harvest).

Root Removal %	Shoot Regrowth	Senescent Leaves	Tillers	Dry Weight Forage
	cm	number		g/plant
0	67.7	32.7	38.7	26.6
25	87.0	46.7	28.7	25.6
50	68.0	76.7	22.0	15.7
LSD 0.05	19.3	27.6	11.6	5.9

The trend in linear regrowth at H2 was similar to that observed at H1 with plants having roots pruned initially 25% showing a slight stimulation in growth as compared to those left intact or those pruned 50% (Table 3). Root pruning had a marked effect on the number of senescent leaves produced at H2. Initial removal of 25% and 50% of the roots increased the number of senescent leaves at H2 an average of 120% and 164%, respectively, as compared to plants with intact roots. Tiller formation at H2 was greatly affected by root pruning and appeared to be a good way to measure recovery of eastern gamagrass plants following root removal. Plants with roots trimmed initially 25% had an average 14% decrease in number of tillers while those pruned 50% had an average 52% decrease. Forage yield at H2 was also significantly impacted with plants pruned 25% showing an average 15% decrease in dry matter and those pruned 50% showing an average 41% reduction (Table 3).

Table 3. Effect of percent root removal on shoot regrowth, number of senescent leaves, number of tillers and forage dry weight (DW) of eastern gamagrass plants maintained in the greenhouse (2nd Harvest).

Root Removal %	Shoot Regrowth	Senescent Leaves	Tillers	Dry Weight Forage
	cm	number		g/plant
0	73.0	61.7	63.3	51.9
25	87.0	135.7	54.3	44.0
50	68.0	162.7	30.7	30.4
LSD 0.05	11.3	73.1	24.3	12.1

At each harvest, forage samples were taken from each root pruning treatment and analyzed to determine forage composition and quality. NDF and ADF values showed only slight differences between any two harvests and between any two pruning treatments and these differences were not significant (Table 4). This is rather remarkable considering that samples were taken in the greenhouse over a two-month period from 18 August to 28 October. Lignin content varied considerably from harvest to harvest and among different pruning treatments. There was a significant increase in the lignin content between H1 and H2, irrespective of whether or not the roots were initially pruned 25% or left intact, suggesting that the shift may have been caused by an increase in maturity rather than as a result of pruning treatment. Although the lignin content at 0 and 25% root removal appeared to decline slightly from H2 to H3, this difference was not significant, nor were differences between H3 and H4 significant. There were no significant differences in lignin content with date of harvest when 50% of the roots were pruned initially.

Table 4. Effect of percent root removal on neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin content of eastern gamagrass at various harvest dates.

Harvest Number	Percent of Root Removal								
	0%	25%	50%	0%	25%	50%	0%	25%	50%
	NDF (% DM)			ADF (% DM)			Lignin (% DM)		
1	81.4a	82.0a	84.3a	36.3a	36.1a	36.8a	3.3b	3.5b	3.9a
2	80.5a	80.2a	81.7a	38.2a	37.9a	38.3a	4.3a	4.3a	4.3a
3	78.9a	80.0a	81.4a	35.3a	36.7a	37.2a	3.7ab	3.8ab	4.1a
4	82.2a	82.6a	79.9a	36.0a	35.8a	37.3a	3.8ab	3.4b	3.6a
LSD 0.05	3.5	4.2	5.6	3.3	2.7	3.9	0.9	0.6	1.1

Means of any two values for a single constituent within a column having a common letter are not significantly different at $P \leq 0.05$.

The CP content of the forage samples of greenhouse-grown eastern gamagrass plants was high, ranging in value from 14% to nearly 20%, even when flowering shoots were included as at H3 and H4. This attests to the excellent nutritive value of this species. These figures are higher than those reported for field-grown eastern gamagrass plants by Horner et al. (1985). This may reflect the high nutrient status under which the plants had been grown in the greenhouse (having been fertilized weekly). A comparison of any two harvests indicated that the CP content was quite variable, depending on the extent of root removal and on the date of harvest. Unpruned controls had a lower CP content at H2 than at H1, H3 or H4 (Table 5). When the plants were pruned 25%, the greatest CP content was obtained at H1 and H4 and samples at H2 and H3 were intermediate in value. There was no significant difference in CP content of eastern gamagrass foliage between any two harvest times when the roots of the plants were initially pruned 50% (Table 5).

Table 5. Effect of percent root removal on dry matter digestibility (DMD), cell wall digestibility (CWD), and crude protein (CP) content of eastern gamagrass at various harvest dates.

Harvest Number	Percent of Root Removal								
	0%	25%	50%	0%	25%	50%	0%	25%	50%
	DMD (% DM)			CWD (% DM)			CP (% DM)		
1	80.7a	81.6a	79.2ab	74.3a	75.7a	73.5ab	17.3a	19.6a	18.1a
2	78.2a	76.7b	75.7b	71.0a	69.0b	68.2b	13.6b	14.3c	16.2a
3	80.5a	81.1a	82.2a	73.8a	75.3a	76.8a	16.8a	16.5b	18.6a
4	79.9a	81.4a	81.9a	73.9a	76.1a	76.0a	17.9a	18.4a	17.9a
LSD 0.05	4.0	3.8	4.5	5.5	5.1	5.8	2.4	1.3	4.8

Means of any two values for a single constituent within a column having a common letter are not significantly different at $P \leq 0.05$.

The CP content was significantly lower at H2 than at H1 in unpruned controls and in those pruned 25%. In both cases, the content of CP and lignin showed an inverse relationship with lignin content increasing and CP content decreasing from H1 (Tables 4 and 5). The highest CP contents were obtained at H1 and H4 despite the fact that plants at H4 were at the onset of dormancy.

There was no change in DMD at successive harvests when the roots were left intact. However, when the roots were pruned 25%, forage samples at H2 were significantly lower in DMD than those taken at H1 and there was a recovery in DMD at H3 and H4. Similar results were obtained when the roots were pruned 50%. Cell wall digestibility showed a similar pattern with a decrease during H2 in plants that had been pruned 25% followed by an increase during H3 and H4. Since forage samples taken at H3 and H4 included flowering shoots, one might have expected that these samples would have had a greater lignin content and a lower DMD and CWD than those collected of vegetative shoots at H1 and H2. However, this was not the case (Tables 4 and 5). Bidlack et al. (1999) have also reported on the variability of CP and lignin content in the leaves and stems of several eastern gamagrass lines established vegetatively in the field in 1991 and harvested in 1992 and 1995. It has been suggested that lignin has a detrimental effect on the digestibility of grasses (Church 1977). Van Soest (1965) reported a negative correlation between digestibility and increasing lignin and ADF and Bidlack et al. (1999) also found a significant negative correlation between in vitro dry matter digestibility and lignin concentration.

Conclusion

Trimming roots of eastern gamagrass plants at the time of transplanting had a negative effect on subsequent regrowth of shoots, particularly when 50% of the roots were removed. This was generally reflected in an increase in the number of senescent leaves, a decrease in the number of tillers, and a reduction in the dry weight of forage collected during the first two harvests. Despite these reductions in vegetative growth, there was little or no effect of root removal or time of harvest on forage composition or quality. A slight increase in lignin content and slight decreases in CP, DMD, and CWD were obtained at H2 in plants that had been pruned 25% but these constituents tended to show a reversal in values at subsequent harvests. Removal of 50% of the roots surprisingly had little or no significant effect on CP or lignin content. It appears that one of the main ways in which eastern gamagrass plants coped with the stress of root pruning was to increase the number of senescent leaves. This is rather remarkable considering that these stress effects were not reflected in a decline of forage quality of the new shoots formed. These findings demonstrate the extreme versatility of eastern gamagrass in coping with environmental stress and in being able to compensate for adverse growth conditions.

Acknowledgements

Grateful acknowledgements are extended to Miguel McCloud, Climate Stress Laboratory for his valuable assistance in maintaining the eastern gamagrass plants in the greenhouse and for collecting, drying, and grinding forage samples; Louis Rose for his careful monitoring of environmental conditions in the greenhouse; and Roman Mirecki for his expert computer assistance. Partial funding provided by USDA Competitive Research Grant awarded to Donald Krizek.

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Grass Hedges for Erosion Control

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Abstract

Erosion is a major concern in agricultural areas around the world leading to soil loss, reduced soil productivity, and downstream offsite pollution. Grass hedges are widely used in the tropics to reduce soil loss, but few studies have produced quantitative data on these conservation practices. In studies at Beltsville, Maryland miscanthus [*Miscanthus sinensis* Andersson] and eastern gamagrass [*Tripsacum dactyloides* (L.) L] were used to establish grass hedges on the contour across swale areas. Quantitative data from these studies show that these narrow, stiff grass hedges act as filters to slow and broaden the water flow area, resulting in ponding that increases settling times for entrained material to be deposited in the low areas. Deposition rates measured using field surveys in 1991, 1995, and 1998 were 1-2 cm yr^{-1} up slope from these hedges. These deposition areas in the swales further reduced the steepness of the slopes giving even larger areas for the water to spread and slow. Grass hedges can be an alternative conservation practice for reducing soil loss and dispersing runoff from areas of erosion in agricultural fields. However, grass hedges should not be seen as a panacea, but as another tool in the arsenal to control soil loss and runoff. Continued efforts to control soil loss at the point of detachment are critical. The NRCS has developed a Conservation Practice Standard for using grass hedges for runoff and sediment control. While miscanthus is effective as a grass hedge, indigenous grasses (i.e., eastern gamagrass, switch grass [*Panicum virgatum* L.]) should be used when possible to reduce the potential for the introduction of exotic material into new environments.

Introduction

Erosion is a major problem around the world (Brown and Wolf 1984; Morgan 1995; Pimentel et al. 1995). Concerns about this erosion have led to the development of many methods to reduce soil loss. One such method, stiff, erect narrow grass hedges planted on the contour across swales, has been widely used to slow runoff and reduce soil loss from agricultural areas in the tropics (NRC 1993; Dabney et al. 1999). The United States Department of Agriculture (USDA) proposed using grass hedges for erosion control about forty years ago but until recently there has been little interest in the use of grass hedges in the United States (Kemper et al. 1992).

Research has shown grass hedges to reduce water erosion (Dabney et al. 1993, 1995, 1999) and wind erosion (Aase and Pikul 1995; Siddoway 1970). Grass hedges disperse runoff, trap eroding particles, prevent gullying (Dabney et al. 1993; Meyer et al. 1994), and enhance terrace formation (Aase and Pikul 1995: Dabney et al. 1999). Grass hedges are an inexpensive conservation technology compatible with many tillage systems (Dabney et al. 1993).

Grass hedges differ from other types of grass barriers (i.e., buffer strips, filter strips) because they are narrow, planted with stiff, erect grasses, and are designed to stimulate the formation of benches by deposited materials. A uniform stand of stiff grass stems in a hedge across concentrated flow paths and swales, causes temporary ponding of runoff water up slope of the hedge that allows time for entrained particles to be deposited. The deposited material fills low places in the field so that future runoff is broadly dispersed and less erosive. Narrow grass hedges are planted on the contour across swales in the field to slow water flow (Kemper et al.

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1992). Design, spacing, and lateral extent for hedges in swales depend on runoff rates, topography, and other factors (Dabney et al. 1993; Kemper et al. 1992).

In 1991 the Hydrology Laboratory, Agriculture Research Service (ARS), USDA, at the Beltsville Agricultural Research Center (BARC) in cooperation with the USDA Natural Resource Conservation Service (NRCS), National Plant Material Center at Beltsville, MD began a program to study the use of grass hedges to control soil loss from concentrated flow erosion areas. In 1991 shoots of miscanthus [*Miscanthus sinensis* Andersson] were transplanted into hedges in agricultural fields with concentrated flow channels. In 1994 and 1995, eastern *gamagrass* [*Tripsacum dactyloides* (L.) L.] was planted using seed at several sites with the miscanthus hedges to extend the length and to fill gaps in the hedges.

The purpose of this study was to establish grass hedges across concentrated flow areas and to determine the effectiveness of grass hedges for slowing concentrated flow gully development and capturing soil moving from the field.

Methods

Miscanthus shoots were transplanted into hedges across an eroding area on the South Farm at the BARC, Beltsville, MD (Fig. 1). This field has a history of row cropping on the contour with alternating years of corn [*Zea mays* L.] and soybeans [*Glycine max* (L.) Merrill] on adjacent contoured strips. Contour strips are between 36 to 40 m wide with slopes of 10 to 15%. Corn and soybeans are no-till planted. Concentrated flow erosion areas had developed in the field. Starting near the crest of the slope, evidence of these concentrated flow erosion areas could be traced across three contour strips before joining near the base of the slope to exit the field. On April 17, 1991, the miscanthus shoots were transplanted into four (4) hedges across swales and concentrated flow erosion areas. Hedges were placed in the borders between contour strips of crops to minimize interference with farm operations and to reduce disturbance to the hedge rows during the field and harvest operations. The grass hedge at hedge B (Fig. 1) was destroyed during farm operations in preparation for planting in 1992.

In 1994 and 1995 miscanthus shoots were used to fill gaps in the hedges and the length of the existing hedge rows was extended by planting eastern gamagrass seeds. In 1994, eastern gamagrass germinated successfully and developed robust stands. However, the eastern gamagrass planted in 1995 did not germinate, probably due to six weeks of dry weather immediately after the seeding.

A topographic survey at hedge A (Fig. 1) was made using conventional surveying techniques (i.e., level and rod) in April 1991. Survey lines were made 5 cm down slope and 5 cm and 100 cm up slope of the hedge. In August 1995 and August 1998, these lines were resurveyed. The 1998 survey was expanded to make measurements at 1 m grid intervals for an area 100 x 36 m up slope of hedge A.

A second site was chosen on the East Farm at the BARC (Fig. 2). The field had a history of being planted in corn or soybeans. This field also had a slope of 10 to 15% with a total slope length of about 150 m. A major concentrated flow erosion area had developed in the field. In April 1991, a tile drain was installed in the lower part of the field in the approximate location of the concentrated flow area between hedge A and hedge B (Fig. 2). On May 23, 1991, after the installation of the tile drain, miscanthus shoots were transplanted into five hedge rows (A to E) in this field. In 1991 and 1992, corn was planted after the field was conventionally tilled. After the corn was harvested in September 1992, clover was no-till planted in the field to provide a winter cover. Between fall and spring of 1992/1993 a conservation plan for agricultural operations on the field was developed changing the farming practices on this field from a single field with a slope length of 150 m to a field with five contoured strips of approximately 30 m. In March 1993, two of the 1991 miscanthus hedges B and C were moved to hedge G and hedges D and E were moved to hedge F to be in the borders between the new contour strips in the field. Hedge A at the lower edge of the field was not affected. The three miscanthus hedges (A, F, and G) grew actively during 1993 and are now well established. After the 1993 growing season, farm operations in the field changed from row cropping to small grain/clover which continued from 1993 to 1998. In 1998 and 1999 alternate contour strips were no-till planted in corn.

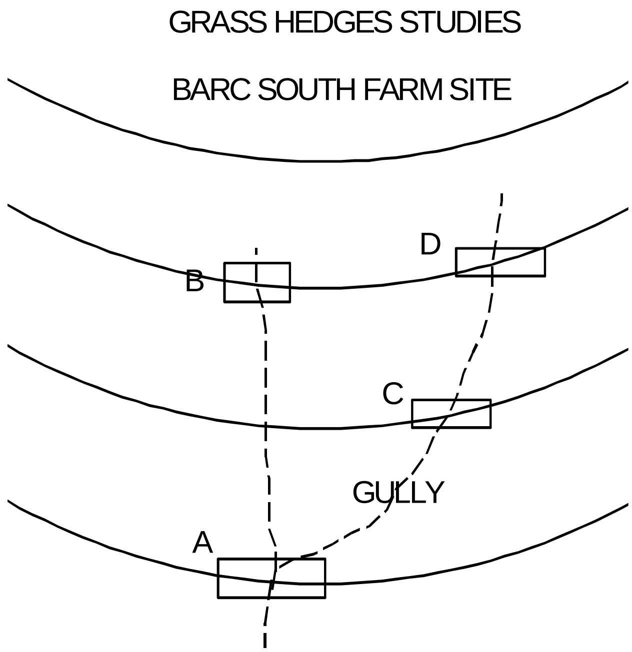

Figure 1. Grass hedges at the BARC South Farm study site. Letters and boxes indicate location of miscanthus plantings. Solid lines represent borders between strips of crops and dashed lines represent the approximate location of concentrated flow areas (Not to scale).

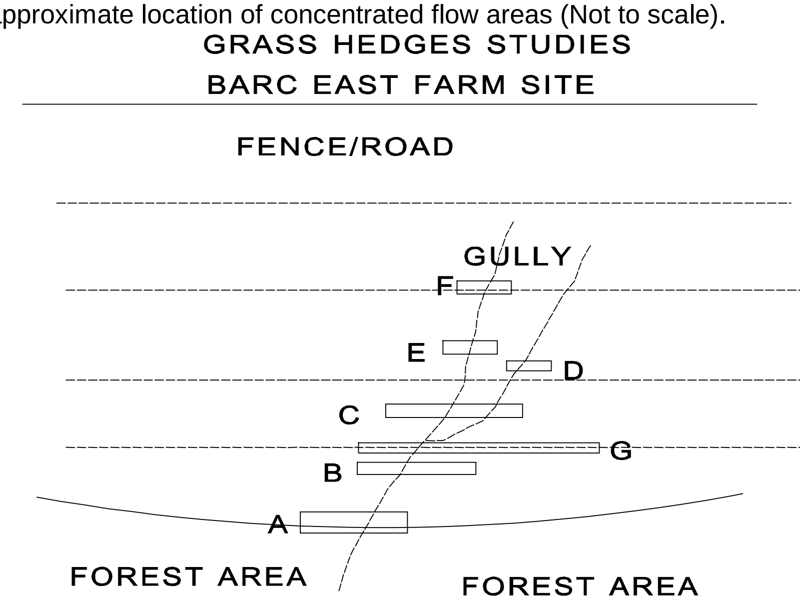

Figure 2. Grass hedges at the East Farm study site. Letters and boxes indicate the location of the miscanthus plantings in 1991 (A-E) and the new location (A, G and F) after 1993. Dashed lines represent borders between contour strips and the approximate location of the concentrated flow area. (Not to scale).

In 1994 and 1995 the lengths of existing hedges were extended using eastern gamagrass. Plantings in 1994 were successful but as with the South Farm site, eastern gamagrass seeds did not germinate in 1995. Topographic surveys were made along hedge A in 1991 and 1995. Lines were surveyed 5 cm behind and 5 cm and 100 cm up slope of the hedge row.

Results

Miscanthus grew rapidly and expanded from the transplanted shoots. Beginning with 2-5 cm plants transplanted 10 to 15 cm apart in 1991 and 1992, hedge A in both fields has grown to a width of 30-50 cm and a height of 1.5 to 2.5 m. At hedge A on the South Farm field the miscanthus was two meters tall at the end of the first (1991) growing season. Trimming half of this hedge to 75 cm each year has not affected its growth or expansion. Miscanthus quickly put out new growth and continues to expand after each trimming. No differences were noted in growth between the trimmed and untrimmed portions of the hedge but a reduction of crop production was measured adjacent to the untrimmed hedge when compared to the trimmed hedge (Ritchie et al. 1997).

In 1994, eastern gamagrass seeds were planted to fill gaps and expand hedge lengths at both field sites. High rates of seed germination occurred in 1994, although eastern gamagrass is known to be difficult to germinate (Dewald et al. 1996). Seedlings grew rapidly to form a hedge 30-60 cm tall and 10-15 cm wide by the end of the growing season. Since 1995 the eastern gamagrass hedges have continued to grow and developing into dense hedge rows.

In 1995, eastern gamagrass seeds were again planted but germination did not occur. The 1994 and 1995 seeds were purchased from the same source and the seeds were planted in the same way. In 1995 rains (~12 mm) occurred the day after the seeds were planted. However, no rain occurred for the following 38 days. Although eastern gamagrass has many properties desired for a stiff grass hedge row (Dewald et al. 1996), the great difference in germination between the germination in 1994 and 1995 highlights a problem of using eastern gamagrass. Dewald et al. (1996) discuss the proper techniques for establishing eastern gamagrass along with other management concerns.

Topographic surveys (Fig. 3) of the miscanthus hedge row at hedge A on the East Farm showed 10-15 cm of deposition up slope of the hedge row after four years. The deposition extends at least 1 meter upslope of the hedge row. More surveys need to be made to determine the full extent of the deposition pattern near this hedge row. This hedge row at the lower edge of the field is capturing eroding particles that have moved from the field. However, this field is now in continuous grass/clover cover so that the soil loss and concentrated flow area development each year have been noticeably reduced. Field observation in 1995 noted the lack of a well defined concentrated flow area as had been seen in early spring in 1991 and 1992. However, field observation in 1999 noted the recurrence of a ephemeral gully mid way between hedges A and G.

Surveys of the miscanthus hedge A on the BARC South Farm site made in April 1991, August 1995, and August 1999 along the same survey line (5 cm up slope of the center of the hedge row) also showed 8-15 cm of deposition up slope of the hedge row (Fig. 3). Greater deposition occurred in the areas where concentrated flow areas (depressions in the topographic survey) cross the border between the strips of crops. A general smoothing of the topography up slope of the hedge row occurred. This smoothing is probably due to the hedge row slowing and spreading the water across a wider area as it crossed the hedge row barrier. This temporary ponding of water would allow the sediment load carried in the runoff to be deposited over a wider area.

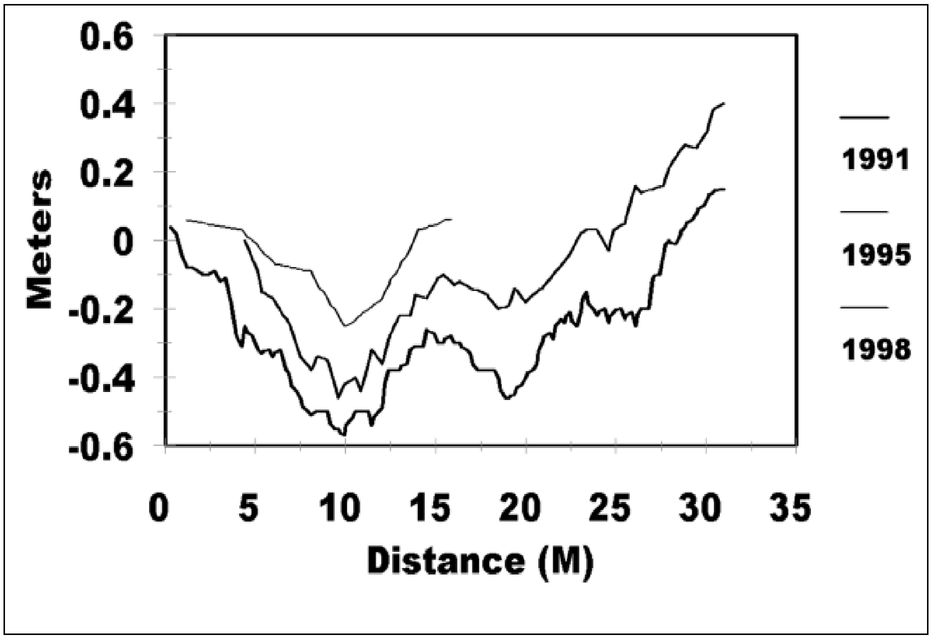

Figure 3. Comparison of topographic surveys at hedge A on the BARC South Farm made along the same line in April 1991, August 1995 and August 1999.

There is a general leveling along the survey line by the time of the August 1995 survey that is especially evident in the 1998 survey. A Digital Elevation Model (DEM) created from the 1998 topographic survey up slope of the hedge A shows the topography (Fig. 4). The remnants of the concentrated flow channel up slope of hedge A is still evident on the DEM. Field observations noted an extensive area of deposition approximately 5-15 m up slope and 40-50 m west of the center of the hedge A. This leveling area is also evident on the topographic survey. Whether this deposition area is due to the hedge is not clear but it has developed since the hedge was established. There is also evidence of the development of new concentrated flow areas below the hedge row that is of concern.

During the four-year study no evidence was found that miscanthus produced viable seeds at any of the hedge rows. Expansion of the miscanthus has been by shoot production that has been rapid and vigorous in most of the hedge rows. While these miscanthus hedge rows have been very robust, the cost of purchasing miscanthus shoots and labor needed to transplant the shoots may reduce farmer acceptance and application of this conservation practice to concentrated flow erosion areas. The miscanthus, once established, appears not to be affected by farm operations including the application of herbicides used in minimum and no-till farm operations in the fields at BARC. Minimum maintenance is required to keep the hedge effective and actively growing.

Eastern gamagrass, another candidate for use in the stiff grass hedges, was also planted successfully at both sites. It has the advantage of being planted by seed that will make the establishment of hedge rows easier and cheaper. Farmers can use conventional farm equipment to plant eastern gamagrass hedges. As shown by our 1994 and 1995 eastern gamagrass seedings, one must carefully manage the seed, the seed bed preparation, and the planting of the eastern gamagrass seeds to insure germination (Dewald and Lougthan 1979; Dewald et al. 1996).

While this effort with grass hedges has been successful, grass hedges should not be seen as a panacea, but as another tool in the arsenal to control soil loss and runoff. Continued efforts to control soil loss at the point of detachment are critical. The NRCS has developed a Conservation Practice Standard for using grass hedges for runoff and sediment control. While miscanthus is effective as a grass hedge, indigenous grasses (i.e., eastern gamagrass, switchgrass [*Panicum virgatum* L.]) should be used when possible to reduce the potential for the introduction of exotic material into new environments.

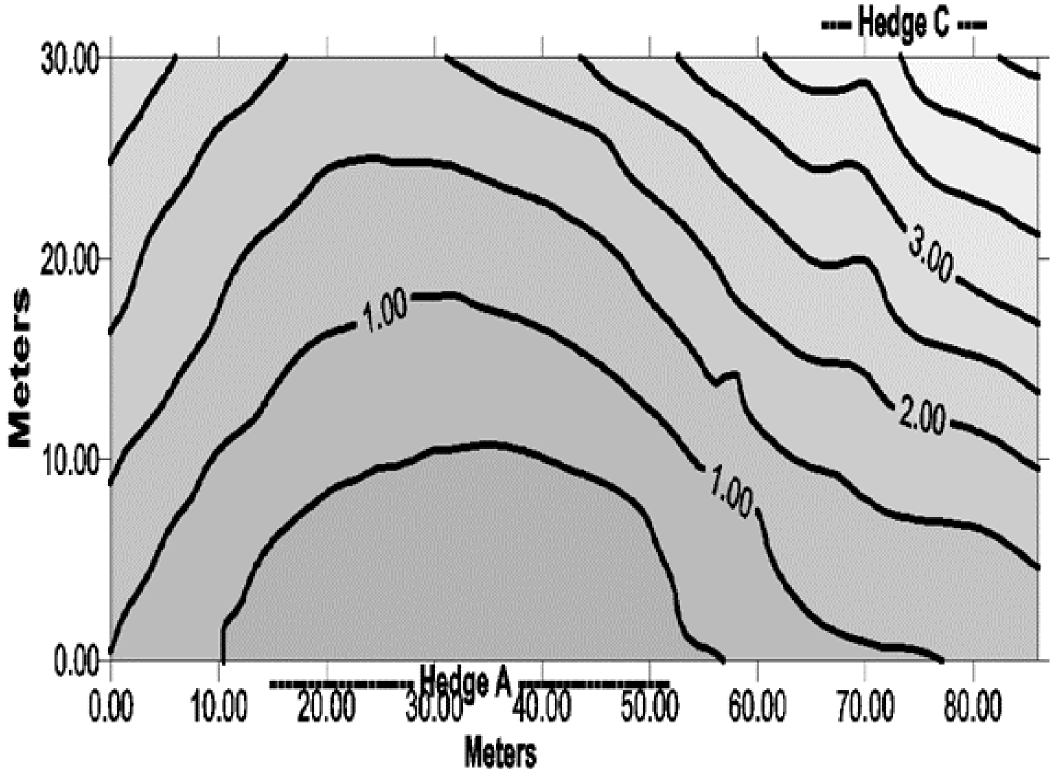

Figure 4. Digital Elevation Map made from 1999 survey data of the area up slope of hedge A on the BARC South Farm.

Acknowledgments

We would like to express our appreciation to Personnel from the NRCS National Plant Material Center at Beltsville, MD who helped transplant the miscanthus. We also thank Tim Badger, Farm Manager at the Beltsville Agricultural Research Center, who helped find good study sites and allowed us to plant strange grasses in the fields where he tries to keep competitors from the field crops.

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Eastern Gamagrass Breeding in New York and Oklahoma

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Introduction

There has been increased interest in breeding eastern gamagrass [*Tripsacum, dactyloides* (L.) L.] in recent years due to the discovery of gynomonoecious variants with their increased seed production potential, and the inherent superior forage quality and production potential of this species over other warm season grasses. This paper reviews the reproductive biology and breeding systems of eastern gamagrass and reviews the breeding efforts conducted at the USDA-NRCS Big Flats Plant Materials Center (PMC) in Big Flats New York and the USDA-ARS Southern Plains Range Research Station (SPRRS) in Woodward Oklahoma.

Eastern gamagrass is a tall, highly productive, long-lived, perennial, warm-season native grass. Eastern gamagrass is palatable and highly digestible to all classes of livestock. It can be used for hay, silage, and intensively managed pastures. It produces forage earlier in the spring than most other warm-season grasses and later than most cool season grasses and legumes. The perennial nature of gamagrass offers advantages over annual forages including lower fuel, labor, and production costs.

Taxonomy

Eastern gamagrass is in the family Poaceae, tribe Andropogoneae, and subtribe Tripsacinae. It shares the same subtribe as corn [*Zea mays L.*]. It is now accepted that teosinte [*Zea mays L.* subsp. *mexicana*] is the progenitor of corn and it hybridizes freely with corn in the wild. Eastern gamagrass hybridizes with corn under experimental conditions and frequently their chromosomes pair during meiosis.

Tripsacum comprises 15 species in 2 sections and is native only to the Western Hemisphere (Brink and de Wet 1983). *Tripsacum dactyloides* is the most widespread and morphologically variable of the species.

Distribution

Eastern gamagrass is widely distributed from Connecticut to Nebraska south to Texas and Florida in the United States and south to Paraguay and Brazil in South America. There are forms of *Tripsacum* adapted to North American prairies and eastern coastal plains, deep sandy soils, semi arid regions, rocky out-crops, river banks and tropical rain forests (Harlan and de Wet 1977).

Cytology

Eastern gamagrass occurs predominately at the diploid (2n=2x=36), triploid (2n=3x=54), and tetraploid (2n=4x=72) levels although pentaploids (2n=5x=90) and hexaploids (2n=6x=108) have been reported (Farquharson 1955).

Mode of Reproduction

The reproduction process in *Tripsacum* is by both sexual and facultative apomixis. Apomixis is a form of reproduction in which seeds are produced asexually. An unreduced egg cell in the

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embryo sac develops into a zygote without the union of the egg and sperm. Since the egg cell has developed from mitotic rather than meiotic cell division and fertilization is absent the zygote is genetically identical to the maternal plant from which it originated. Embryological analysis demonstrated diploids to be exclusively sexual while the polyploid cytotypes reproduced as facultative apomicts (Burson et al. 1990 and Sherman et. al. 1991). The predominant form of apomictic reproduction in *Tripsacum* is characterized as being diplosporous pseudogamy of the *Antennaria* or mitotic type. In diplosporous apomixis, the megaspore mother cells tend to elongate prior to nuclear division. The absence of a linear tetrad and the presence of a single elongated cell with the nucleus closer to the micropyle is characteristic of diplosporous apomixis. The nucleus then divides mitotically to form the 8 nucleate embryo sac. In pseudogamy, pollination is required for endosperm development. It has been found that 2-4% of the time apomixis occurs by the *Taraxacum* type of diplosporous apomixis where a partial meiosis allows for some pairing and crossing over to occur (Leblanc et. al. 1995; Kindiger and Dewald 1996). This creates some genetic variability in the offspring without a change in chromosome number. In the *Taxaracum* type of diplospory, a megaspore mother cell differentiates from the nucleus and begins meiosis, but meiosis is inhibited at a particular stage by unknown mechanisms and the nucleus is restored to a form that enables mitosis to occur (Kultunow 1993). This is called first division restitution.

Monoecious and Gynomonoecious Inflorescence

Inflorescences of gamagrass typically have a female section below and a male section above on the same raceme (monoecious). The female portion is composed of a few (1-12) solitary spikelets that normally contain a single fertile floret each. Male spikelets are born in pairs at each node of the rachis and contain two functional florets each with three anthers. There is a mean of 65 times more anthers than pistils (Dewald and Jackson 1988). The inflorescence exhibits protogyny in which the female portion flowers before the male. The flowering in eastern gamagrass is indeterminate flowering from June to September in New York.

In 1981 a gynomonoecious sex form GSF-I, (PI 483447) *T. dactyloides* (L.) L. forma *prolificum* was discovered in an evaluation at the USDA-NRCS Manhattan Kansas Plant Materials Center from a seed collection made in Ottawa County, Kansas. GSF-II (PI 483448) was found in 1982 at the collection site of GSF-I. These plants exhibit gynomonoecy with pistillate spikelets below and perfect spikelets above on the same raceme. The lowermost pistillate spikelets and the thick rachis form a cupulate fruitcase structure similar to that of the monoecious form (MSF). The basal solitary spikelets have two fertile pistillate florets instead of one. Each of the paired spikelets, which are normally male, contains two functional female florets and rudimentary stamens. At the extreme apex of the inflorescence a few paired spikelets contain two functional perfect (male and female) florets. The cupules in the basal portion of the GSF racemes are generally well developed but become progressively more shallow and eventually disappear in the apical portion of the raceme (Dewald and Dayton 1985). The GSF variant averaged 22 times more pistils than the MSF inflorescence indicating a seed increase potential of 20 fold. The anthers on the GSF inflorescence is only 22% of those of the MSF type resulting in unsatisfactory seed set (Dewald and Jackson 1988). The size and weight of the caryopses originating in the region of paired spikelets on the GSF raceme are about 25% less than the size and weight of those originating on the lower solitary spikelets of the MSF plants. Seed produced by GSF plants have good germination (Jackson 1992).

The GSF trait is governed by a recessive gene. The progeny of selfed and intermated F_1 hybrids segregated 3 MSF to 1 GSF indicating the gynomonoecious condition is under recessive monogenic control. There was sufficient deviation to suspect the presence of structural modifiers in certain cross combinations. (Dewald et. al. 1987).

Breeding
Purpose

The characteristics of gamagrass which have limited its development and cultivation have been low seed production, inferior seed quality, and establishment difficulties. Breeding efforts have increased since the discovery of the gynomonoecious form with the hope to solve some of these problems. Eastern gamagrass has a wide geographic range and is adapted to many soils and climate conditions. There is a vast amount of genetic diversity within eastern gamagrass and between *Tripsacum* species which can be tapped for increased yield, seed production, and disease and insect resistance. The inherent forage quality is very good and should be maintained or improved during the breeding process. Its area of adaptation may be moved northward with improvements in winter hardiness and frost heaving resistance. Variability has been observed in the leaf width, stem heights and width, disease resistance, forage quality, maturity date, yield, plant architecture, degree of center persistence, and seed head shatter resistance.

History of Present Varieties

'Pete' eastern gamagrass (PI 421612), formerly designated PMK-24, originated from seed collections made in 1958 from native stands in Kansas and Oklahoma. In 1960, seventy original seed lots were bulked to establish the first generation of a composite strain. The strain was advanced through three generations via combine harvesting and replanting of open-pollinated seed. The first generation varied considerably in maturity; some selection for uniformity of maturity is presumed to have occurred during this process. The third generation of the composite was both the breeders seed field and the foundation field. The strain was released on a germplasm basis in 1974. A formal release of foundation 'Pete' was made to certified growers in 1989 by the USDA-SCS, USDA-ARS and Kansas and Oklahoma Agricultural Experiment Stations (Fine et. al. 1990).

'Iuka' is based on a collection of over 500 accessions from Oklahoma, Texas, Kansas, and Arkansas. In 1979 a 21-plant selection based on apparent forage value was made from the original collection. A one-acre block was vegetatively established then advanced two generations.

Breeding at the Diploid Level Using GSF Germplasm

Considerable work has been done breeding eastern gamagrass at the USDA-ARS Southern Plains Range Research Station (SPRRS) at Woodward Oklahoma. Many initial hybrids were made from crosses using a wide array of MSF accessions onto the GSF-I and GSF-II variants as well as backcrossing and intercrossing with GSF hybrids to come up with unique and vigorous germplasm.

In 1983-84 over 450 northern accessions from collections located at the USDA-ARS SPRRS and the USDA-NRCS Manhattan Kansas Plant Materials Center were divided and brought to the Big Flats Plant Materials Center. After several years of over-wintering in this climate superior accessions were selected and used as pollinators onto GSF-I. After intercrossing the F1 generation, 320 GSF genotypes were produced. 25 genotypes were selected for further evaluation based on good agronomic and seed production characteristics.

At the USDA-ARS SPRRS shatter resistance, a primary goal, has not been achieved in the breeding program. Some progress has been made in identifying and selecting for reduced rachis internodes for shatter resistance. Accessions have been identified in which seeds mature prior to disarticulation of rachis internodes which would allow harvest before shattering. More determinate flowering, which occurs in material with branched lateral inflorescences, would make timing of harvest easier to pinpoint.

The lack of an adequate amount of pollen in the GSF inflorescence has always been acknowledged as a problem for seed production. A solution to this problem was to use heterozygous MSF plants in pollinator rows similar to corn seed production (Salon et. al. 1990). An alternative is the use of intermediate sex forms that are a product of the vast number of hybrids being produced in Oklahoma. They are characterized by having solitary, sometimes paired, female spikelets on the basal portion of the racemes with paired female fertile florets extending upwards for one-fourth to one-half the length of the tassel section. Spikelets of the intermediate type have two fertile florets instead of one, and seed production potential is increased by 10-15 fold compared to the MSF type. There is a sufficient increase in pollen production over the GSF type to insure adequate pollination. In certain genetic backgrounds, partial sex reversal (feminization of ¼ to ¾ of the male-paired spikelets in the tassel) occurs in diploids, which are heterozygous for the gsf1 gene, i.e. gsf1/GSF1 genotypes. When intermediate sex form plants are selfed the normal ratio of progeny is 1 gynomonoecious: 2 intermediate: 1 MSF sex form.

Selection at the Tetraploid Level

A 450-accession evaluation nursery was established at Big Flats, other collections were made including five from near Beltsville Maryland. These plants exhibited growth characteristics and maturity dates much different than the bulk of the collection, with wider lighter green leaves upright growth habit and later flowering. Divisions of these plants were made and a seed increase block was formed (PI 591483). Flow cytometry data showed that these were tetraploid. They flowered about 2 weeks later than 'Pete' and yielded about 25% more biomass. There have been no molecular studies done to differentiate between the initial clones and their progeny to determine if they are genetically different. Progeny from this composite are very uniform. Observations at Big Flats indicate problems with winter hardiness during establishment in some years; therefore this composite will be targeted for use in southern Pennsylvania and the Mid-Atlantic region.

Breeding for Forage Quality

A study was conducted at the USDA-NRCS Big Flats Plant Materials Center and Cornell University looking at the forage quality of eastern gamagrass as measured by crude protein (CP), neutral detergent fiber (NDF), acid digestible fiber (ADF), lignin, in vitro true digestibility (IVTD) and digestible NDF. The reproductive and vegetative tillers of six gamagrass accessions plus the cultivar (cv) 'Pete' were evaluated for three first cutting dates in 1997 and 1998. There were significant differences between genotypes for vegetative tillers for all variables measured, except for ADF in 1997 and for lignin in 1998. For reproductive tillers, there were significant differences except for NDF and lignin in 1998. It seems that variability exists between eastern gamagrass accessions that could be used in a breeding program. Only minor forage quality differences, which varied by year and tiller type, were found between reproductive and vegetative tillers when averaged across accessions and cutting dates.

Breeding for Frost Heaving Resistance

Frost heaving is a major problem in some years reducing the successful establishment of eastern gamagrass in the Northeast since many of the poorly drained soils that gamagrass could grow on due to its aerenchyma cells in the roots are prone to frost heaving. A field of 'Pete' gamagrass, which exhibited good spring establishment in 1996, had severe frost heaving over the winter with over 75% of the plants killed. Four hundred of the surviving plants were dug up in 1998 when dormant and immediately replanted into a crossing block at the Big Flats PMC. Seed was harvested in 1999 and will be replanted into a frost heaving prone soil in the year 2000 for a second cycle of selection.

Incorporation of the GSF Trait in Polyploids to Stabilize with Apomixis and the Production of Sexual Tetraploids

The GSF trait increases the seed production potential of eastern gamagrass several fold and is being utilized in several breeding programs. It occurs in nature at the diploid level. The GSF trait is governed by a recessive gene. Tetraploids are apomictic and many are found to be more robust and productive than the diploids with later maturity dates but have the MSF seed head. The GSF inflorescence does not produce enough pollen for adequate seed set or for the production of true breeding lines in seed production fields. The transfer of the GSF trait from the diploid level to the tetraploid level, therefore, has several advantages. It will allow, by crossing apomictic plants as pollen parents and intermating progeny, the ability to fix the GSF trait with apomixis. Eastern gamagrass shows a high degree of shattering. Breeding apomixis into the genotypes used in seed production fields would practically eliminate the production of "off" types from the shattered seed and would reduce genetic drift. This would increase the length of time seed production fields can be maintained. The stabilization of other traits as well as the potential to maintain hybrid vigor may be possible with the use of apomixis in eastern gamagrass breeding programs.

On the other hand, sexually reproducing tetraploid eastern gamagrass will permit recombination and conventional breeding at the tetraploid level. The tetraploid gamagrass plants found along the Northeast and Mid-Atlantic coastal areas are larger, more robust, and flower around 2 weeks later than the diploids obtained from the Midwest. The tetraploids are less winter-hardy and appear to decline with center dieback more quickly than the diploids. It would be beneficial to be able to improve winter hardiness and longevity in these tetraploids by conventional breeding methods. Sexual tetraploids will also be useful for future genetic studies of the inheritance of apomixis and for study of the inheritance of the GSF trait at the tetraploid level (Salon and Earle 1998).

Chromosome Doubling of GSF Eastern Gamagrass in Tissue Culture

Tissue culture techniques were used to double the chromosome number of eastern gamagrass at the Big Flats Plant Materials Center and Cornell University. Shoots of diploid (2n=2x=36) GSF-I (PI-483447) plants were derived from callus initiated from immature inflorescences and embryos. These shoots were induced to microtiller in the presence of 3 mg l^{-1} benzyladenine. Amiprophosmethyl and colchicine were used to induce chromosome doubling to rapidly dividing microtillers. These plants were tetraploid (2n=4x=72) as determined by flow cytometry and root tip chromosome counts. These plants were morphologically normal and produced seed with the GSF inflorescence. Test crosses were made with a known diploid. Flow cytometry and chromosome counts showed that the progeny were triploid, proving that the induced tetraploids reproduced sexually (Salon and Earle 1998). The induced sexual GSF tetraploid (PI-591482) was released as germplasm by the USDA-NRCS and Cornell University and registered as SG4X-1 (Salon and Pardee 1996).

Genome Accumulation

A method to transfer genes from the diploid level to the tetraploid level and from polyploids down to the diploid level is being used by the USDA-ARS SPRRS in Woodward Oklahoma. It is referred to as genome accumulation. In this method fertile apomictic triploids are formed by 2x X 4x crosses. Triploid hybrids of eastern gamagrass are largely sterile, but a few 1-10% are partially female fertile due to apomictic reproduction. Four of these released by the USDA-ARS SPRRS, were selected out of 832 triploids from four hybrid combinations evaluated for seed set, pollen fertility, and agronomic attributes (Dewald et al. 1992). Fertile triploids can be used to provide an intermediate step for the creation of new and genetically unique tetraploid germplasm. These triploids are crossed using diploids as the pollen parent and due to the formation of unreduced gametes by the triploids, tetraploid progeny are formed. Fertile triploid eastern gamagrass hybrids often produce tetraploid progeny at a frequency of 10-30% (Dewald and

Kindiger 1994 a&b). These tetraploids carry three genomes (54 chromosomes) from the triploid maternal parent and one genome (18 chromosomes) from the reduced gamete of the diploid parent. They are called B_{III} hybrids resulting from a 2n + n mating (Bashaw and Hignight 1990; Bashaw et al. 1992). These tetraploids are apomictic but now carry genes from their diploid parent. The introgression of diploid germplasm into apomictic tetraploid germplasm provides for the enrichment of the genetic diversity at the tetraploid level.

Hexaploids can also be formed by genome accumulation. Using tetraploid apomictic germplasm as the maternal parent crossed with other apomictic tetraploids, B_{III} hybrids are formed 5-8% of the time. An experimental hybrid, WW-2190 selected for high fertility, was reported to produce B_{III} hybrid offspring 50% of the time. These hybrids receive 72 chromosomes from the maternal parent from unreduced embryos and 36 chromosomes from the reduced pollen parent resulting in a (2n=6x=108) hexaploid. These hexaploids have proven useful as a bridge for moving apomictic tetraploid germplasm to the sexual diploid level. When crosses are made between diploids as the maternal parent and hexaploids as pollen parents, 99% of the resulting progeny are diploids. It is suspected that hexaploids produce pollen of many ploidy levels and that the pollen carrying the haploid number is far more competitive resulting in diploid progeny. Diploids generated from this 2x X 6x cross are highly variable and possess a wide diversity of alleles contributed from the apomictic polyploid genotypes (Kindiger and Dewald 1997).

This method has been successfully used to move the GSF trait from the diploid level to the triploid level where it was stabilized by apomixis. FGT-1 a fertile gynomonoecious apomictic triploid, was released by the USDA-ARS SPRRS in Woodward, Oklahoma (Dewald and Kindiger 1996). FGT-1 was developed by combining recessive genes for gynomonoecy from diploids (2n=2x=36) with genes for apomixis from polyploids in three generations of interploidy matings. A first generation fertile triploid hybrid was produced from a GSF plant as the maternal parent. This triploid was crossed with a mixture of pollen from 7 heterozygous diploids for the gsf trait creating a B_{III} tetraploid. This tetraploid was crossed onto a GSF diploid; out of 90 triploid progeny recovered three were gynomonoecious and one was relatively fertile (35-55% seed set) exhibiting both gynomonoecy and apomictic reproduction.

Interspecific Hybridization in Tripsacum

Crosses between *Tripsacum dactyloides* and all other *Tripsacum* species (Cutler and Anderson 1941) are readily accomplished, regardless of ploidy or the taxonomic section a species had been assigned (Brink and de Wet 1983). No interspecific crossing barriers have been observed by work conducted at the USDA-ARS in Woodward Oklahoma on *T. dactyloides, T. andersonii* J.R. Gray, *T. floridanum* Porter ex Vasey, *T. maizar* Hern.-Xol. & Randolph, and *T. zopilotense* Hern.-Xol. & Randolph. Various interspecific hybrids have identical reproductive characteristics with the production of B_{III} hybrids. Most *Tripsacum* species can be crossed to yield viable hybrids. *T. floridanum* crosses with *T. dactyloides* to yield viable sexually fertile hybrids and the two species should probably be considered one. Sexual diploids crossed with apomictic tetraploids of a different species will yield allotriploids, some of which will be seed fertile due to apomixis. These can then be crossed by diploids to yield allotetraploids by genome accumulation. Interspecific crosses provide an opportunity to expand the genetic diversity across the species (Kindiger and Dewald 1997).

Hybridization of Tripsacum and Maize

Corn was crossed with gamagrass as early as 1931 (Manglesdorf and Reeves 1931). Many workers have since made similar crosses using corn as the female parent and these hybrids are female fertile. Further backcrossing to corn results in recovery of pure corn with slight to no introgression of gamagrass germplasm after 4 to 8 backcrosses with corn. Recent work has been conducted at the USDA-ARS SPRRS crossing *Tripsacum* onto corn for the purpose of transferring genes for apomixis from eastern gamagrass into corn.

Until recently, attempts to use gamagrass as a female parent in crosses with corn have resulted in only a few sterile hybrids. In 1995, the first fertile hybrid produced by crossing gamagrass as the female parent with corn was achieved at the USDA-ARS SPRRS. This hybrid had 18 chromosomes of gamagrass and 10 from corn. When the hybrid was backcrossed to corn, plants with thirty-eight chromosomes (18 gamagrass + 20 corn) resulted. In further backcrossing to corn, all gamagrass chromosomes were eliminated leaving only corn chromosomes in a gamagrass cytoplasm. It is expected that the cytoplasmic gene pool of gamagrass will interact with the nuclear genes of corn to result in an improved product. Test on disease, insect, and stress tolerance, nutritive value, yield and adaptation are in progress (Dewald et al. 1999).

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Eastern Gamagrass Forage Quality as Influenced by Harvest Management

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Introduction

Eastern gamagrass [T*ripsacum dactyloides* (L). L.] is a highly productive native perennial, warm season grass, which is palatable and highly digestible. Eastern gamagrass can be utilized for hay, silage, and intensively managed pasture. Most forage quality and yield information for eastern gamagrass has been generated in the Midwest and South (Brejda et al. 1994 and 1996; Burns et al. 1992; Faix et al. 1980; Horner et. al. 1985; and Wright et al. 1983). It is suspected that although yields maybe lower in the Northeast, the forage quality of warm season grasses may be superior to those grown in warmer regions (Van Soest 1994). Information on forage quality and yield is needed in the Northeast to help to determine the feasibility of using gamagrass in the region. It is of interest to determine the proper growth stage to cut eastern gamagrass and to ascertain its rate of decline during maturity. Information is needed about forage quality variability within eastern gamagrass. Reproductive and vegetative tillers were looked at separately in order to determine if selecting for specific tiller types in a breeding program would influence total herbage forage quality and to compare eastern gamagrass with other warm season grasses studied in a similar fashion (Griffin and Jung 1983; Perry and Baltensperger 1979 and Twidwell et al. 1988). Objectives were to 1) evaluate the forage quality of eastern gamagrass grown in the Northeast, 2) determine the effects of cutting dates and intervals on forage quality, 3) assess forage quality differences between accessions for reproductive and vegetative tillers, and 4) evaluate the difference in forage quality between reproductive and vegetative tillers of eastern gamagrass.

Materials and Methods

Two forage quality studies were conducted in 1997 and 1998. A time of cutting study was conducted on an established 6-year-old stand of eastern gamagrass, cultivar ‘Pete’, on a Unadilla silt loam soil at Big Flats, New York. The stand received 112 kg ha^{-1} yr^{-1} of nitrogen on June 4, 1997 and May 27, 1998. Three replicated plots were harvested (4 individual plants per rep) at three 1st cutting dates, starting on 6/13/97 and 5/28/98 and taken at weekly intervals. A second cutting was sampled at three intervals, four, five and six weeks.

A forage quality study was conducted evaluating the vegetative and reproductive tillers of six agronomically superior accessions and ‘Pete’. Four individual plants were sampled at the three 1st cutting dates for each accession. Plants were dried at 60°C. Material was ground to pass through a 2-mm screen in a Wiley mill, and were then reground to pass a through a 1-mm screen in a cyclone mill (Udy Corp., Fort Collins, Co) in preparation for quality analyses. Samples (0.5 g) were sequentially analyzed for neutral detergent fiber (NDF), acid detergent fiber (ADF), and sulfuric acid lignin according to procedures described by Van Soest et al. (1991), except that the filter bag technique was used with the ANKOM 200/220 Fiber Analyzer. In vitro true digestibility (IVTD, 0.25 g), and digestible NDF (dNDF) were determined according to Cherney et al. (1997) using the rumen fluid buffer described by (Marten and Barnes 1980) and using the Dairy II 200/220 In Vitro Incubator and the ANKOM 200/220 Fiber Analyzer. The buffer contained urea (0.5g l^{-1}) as supplemental N. Ruminal fluid inoculum was obtained from a non-lactating, rumen-fistulated, Holstein cow fed a medium quality orchardgrass hay diet for ad libitum intake. Nitrogen was determined by a Dumas type N combustion analyzer (Leco, St. Joseph, MI).

Results and Discussion

Time Of Cutting Study

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The NDF, ADF, and lignin all increased with advancing initial spring harvest date, while IVTD and dNDF declined in first cutting samples, as expected (Table 1). The CP content of eastern gamagrass was not as influenced by harvest date as were other variables, such that no differences were detected in 1998 (P>0.05). This may have been due to a cold wet June in 1998, with average temperatures 2.4^{o}C cooler and 3.8 cm more rain than the 25-yr average. The rate of maturity for the eastern gamagrass was slower in 1998 than in 1997. Although the dates of the initial first cutting varied by two weeks (June 13, 1997 and May 29, 1998), growing degree days (GDD) at that point were similar (363 and 339, respectively, for 1997 and 1998). There were significant differences for most variables measured between first cutting dates so that timing appears to be as important in gamagrass as it is in most perennial forages (Cherney et al. 1993). The date of the initial first cutting will be dependent on an acceptable yield and how it impacts subsequent cuttings (Table 2). The second cutting yield increased significantly as the length of the cutting interval increased 1.9, 2.3, and 2.9 Mg ha^{-1} for the 4, 5, and 6 week cutting interval respectively. The NDF of eastern gamagrass was relatively high in comparison to perennial cool season grasses grown in NY (Cherney et al. 1993), but digestibility of both dry matter and NDF was high. The higher than expected NDF may have been due to a low cutting height of 4 inches. The CP in both years was higher than the average for perennial grasses analyzed at the Northeast Dairy Herd Improvement Laboratory, Ithaca, NY from May 97-April 98. Crude protein in both years was higher than that reported by Brejda et al. (1996) even at their rate of fertilizer N application of 224 kg ha^{-1}. This data suggests that acceptable forage quality can be achieved with proper management.

Table 1. Influence of harvest date on forage quality parameters (g kg^{-1}) of eastern gamagrass, first cutting.

Harvest Date	NDF[1]	ADF	Lignin	IVTD	dNDF	CP
1997						
June 13	693[a]	312[a]	33[a]	798[a]	727[a]	163[a]
June 20	773[b]	381[b]	62[b]	751[b]	668[ab]	164[a]
June 27	770[b]	396[b]	68[b]	752[b]	673[b]	159[b]
1998						
May 29	709[a]	319[a]	23[a]	843[a]	778[a]	135[a]
June 4	721[b]	338[b]	26[a]	815[ab]	744[ab]	131[a]
June 12	746[b]	355[c]	30[b]	794[b]	724[b]	130[a]

[1]NDF = neutral detergent fiber, ADF = acid detergent fiber, IVTD = in vitro true digestibility, dNDF = digestible NDF, CP = crude protein.

[a,b,c] Least squares means in the same column and year with different superscripts differ (*P*<0.05).

Table 2. Total eastern gamagrass yield[1] (Mg ha^{-1}) 1998**.**

Hdi[2]	1st cut	2nd cut	3rd cut	Total
5/29	2.20^{a}	2.06^{b}	2.25^{a}	6.51^{a}
6/4	2.38^{ab}	2.70^{a}	1.75^{a}	6.83^{a}
6/12	3.26^{b}	2.29^{b}	1.58^{a}	7.13^{a}

[1] To convert Mg ha^{-1} to tons ac^{-1} multiply by 0.446
[2] Initial harvest date
[a,b] Least squares means in the same column with different superscripts differ (P<0.05).

Second-cutting samples were affected by initial harvest date and cutting interval, as well as the interaction between the two (Table 3). There were significant interactions between initial harvest date and cutting interval for NDF, ADF, and lignin. Results varied by year and treatment regime, although the range in NDF between cutting regimes was not large in either year (Table 4). The mean crude protein was clearly reduced for the six week second cutting interval regardless of the first cutting date (Table 4). The CP for second cuttings was lower than for first cuttings. There was no topdressing following first cutting. The interaction between initial harvest date and cutting interval was not significant in 1997 or 1998 for IVTD and dNDF, allowing for discussion of main effects. Initial first cutting date had no effect on regrowth IVTD and dNDF in 1997 (Table 5). In 1998, delaying initial harvest resulted in lower second cutting IVTD and dNDF. Differences between years are likely due to environmental differences. Increasing cutting interval decreased IVTD and dNDF in both 1997 and 1998 (Table 5). Results of this cutting study clearly indicate that the third cutting interval (6 weeks) is too long to insure acceptable quality. A 5-week cutting interval or less depending on forage yield is recommended. Delaying harvest until later in spring may also adversely impact forage quality of the second cutting, though this is dependent on climate.

Variety study

There were significant differences between the genotypes for vegetative tillers for all variables measured except for ADF in 1997 and for NDF and Lignin in 1998 (Table 6). For reproductive tillers only lignin in 1998 was not significantly different. Later harvest date resulted in higher (P<0.05) NDF, ADF, and lignin, as might be expected. In vitro digestibility, dNDF, and crude protein generally declined with advancing harvest date in 1997 and 1998. There appears to be little difference in forage quality between reproductive and vegetative tillers when cut at the appropriate time. There are only minor differences between their means with high forage quality indicator values switching between tiller types between years for some of the variables measured.

Conclusions

Eastern gamagrass provides good quality forage, provided that adequate harvest management is maintained. Crude protein levels of 1st cuttings in 1997 averaged 16%. Although NDF was high, the fiber digestibility and the total digestibility were very high. Based on data in this study, a 5-week cutting interval is recommended unless there is sufficient yield to warrant an earlier cut.

There were significant differences between accessions for most forage quality variables measured for both tiller types. IVTD and dNDF had the most variability between accessions for both tiller types and CP for reproductive tillers. This was noted by the spread in the mean separations between accessions for these parameters. Only minor differences in forage quality were found between reproductive and vegetative tillers when averaged across accessions.

Table 3. Mean square errors as influenced by initial harvest date, cutting interval, and initial harvest date x cutting interval.

Source **dNDF**	**NDF** **CP**	**ADF**	**Lignin**	**IVTD**
<u>1997</u>				
Initial harvest date	45.13	61.63	1.62	132.76
	165.76	15.70		
	(0.01)[1]	(0.01)	(0.01)	(0.01)
	(0.01)	(0.01)		
Cutting Interval	0.38	1.18	0.23	194.02
	362.51	28.96		
	(0.83)	(0.49)	(0.11)	(0.01)
	(0.01)	(0.01)		
Hdi[2] x Cutting Interval	27.85	13.74	0.77	19.57
	27.21	7.87		
	(0.01)	(0.01)	(0.01)	(0.27)
	(0.39)	(0.01)		
<u>1998</u>				
Initial harvest date	10.42	107.80	6.43	79.74
	105.90	83.98		
	(0.02)	(0.01)	(0.04)	(0.01)
	(0.01)	(0.01)		
Cutting Interval	11.39	179.09	4.16	333.63
	584.90	173.03		
	(0.01)	(0.01)	(0.04)	(0.01)
	(0.01)	(0.01)		
Hdi[2] x Cutting Interval	14.39	32.49	7.54	6.64
	19.34	2.91		
	(0.01)	(0.01)	(0.01)	(0.26)
	(0.08)	(0.04)		

[1] Probability level
[2] Initial harvest date

Table 4. Influence of harvest date on forage quality parameters (g kg^{-1}) of eastern gamagrass, second cutting.

Hdi[1]	CI[2]	NDF	ADF	Lignin	IVTD	dNDF	CP
1997							
6/13	4 wk	705	354	43	777	684	128
1	5 wk	708	366	46	717	601	109
1	6 wk	733	379	51	698	589	106
6/20	4 wk	711	364	49	728	617	121
2	5 wk	726	367	48	705	594	127
2	6 wk	719	371	49	698	582	100
6/27	4 wk	711	355	47	770	677	134
3	5 wk	699	341	44	744	634	124
3	6 wk	681	335	43	739	618	123
1998							
5/29	4 wk	743	354	41	815	751	159
1	5 wk	723	357	32	793	713	126
1	6 wk	722	364	29	747	647	108
6/4	4 wk	715	345	31	818	745	129
2	5 wk	713	359	29	782	694	113
2	6 wk	735	409	40	742	649	82
6/12	4 wk	726	361	32	778	694	119
3	5 wk	728	395	39	761	679	101
3	6 wk	738	422	52	729	634	80

[1]Hdi = initial harvest date, [2]CI = cutting interval,

Table 5. Influence of initial first cutting and cutting interval on forage quality parameters (g kg^{-1}) of eastern gamagrass second cutting

	IVTD[1]	dNDF
Harvest Date		
1997		
June 13	729[a]	622[a]
June 20	711[a]	598[a]
June 27	751[a]	643[a]
1998		
May 29	786[a]	707[a]
June 4	782[a]	697[a]
June 12	756[b]	668[b]
Cutting Interval		
1997		
4-wk	757[a]	658[a]
5-wk	721[b]	609[b]
6-wk	711[b]	596[b]
1998		
4-wk	804[a]	729[a]
5-wk	778[b]	696[b]
6-wk	739[c]	643[c]

[1]IVTD = in vitro true digestibility; dNDF = digestible neutral detergent fiber.
[a,b,c] Least squares means in the same column, year and main effect with different superscripts differ (P<0.05).

Table 6. Neutral Detergent fiber (NDF; g kg^{-1}), crude protein (CP; g kg^{-1}) and in vitro true digestibility (IVTD; g kg^{-1}) of vegetative and reproductive tillers of eastern gamagrass as influenced by accession.

	NDF		**CP**		**IVTD**	
Accession	Vegetative	Reproductive	Vegetative	Reproductive	Vegetative	Reproductive
<u>1997</u>						
215	714^{ab}	676^{b}	131^{b}	121^{b}	84.1^{ab}	86.0^{a}
316	688^{bc}	692^{a}	129^{b}	109^{cd}	81.2^{d}	81.1^{c}
519	713^{ab}	676^{bc}	123^{b}	102^{d}	83.4^{bc}	83.6^{b}
521	699^{abc}	662^{cd}	129^{b}	105^{cd}	81.3^{d}	81.8^{c}
538	673^{c}	660^{d}	133^{ab}	121^{b}	82.1^{cd}	81.5^{c}
716	720^{a}	663^{bcd}	127^{b}	113^{cb}	85.3^{a}	85.6^{a}
‘PETE’	695^{abc}	653^{d}	147^{a}	132^{a}	82.2^{cd}	84.0^{b}
<u>1998</u>						
215	673^{ab}	685^{bcd}	156^{a}	168^{ab}	82.8^{b}	82.8^{b}
316	673^{ab}	700^{ab}	142^{bc}	152^{cd}	79.9^{d}	77.6^{e}
519	670^{ab}	690^{bcd}	136^{bc}	146^{d}	82.5^{b}	82.4^{cb}
521	664^{abc}	691^{bc}	137^{bc}	161^{bc}	80.6^{cd}	80.5^{cd}
538	674^{d}	664^{abc}	135^{bc}	152^{d}	81.7^{cb}	83.1^{b}
716	658^{bc}	682^{cd}	146^{ab}	171^{a}	86.2^{a}	87.1^{a}
‘PETE’	670^{ab}	709^{a}	132^{c}	132^{e}	81.5^{bcd}	79.8^{d}

$^{a, b, c, d}$Least squares means in the same column and year with different superscripts differ (P<0.05).

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Eastern Gamagrass Response to Accent (nicosulfuron), Basis (rimsulfuron), and Plateau (imazapic) Herbicides in Comparison to a Few Common Corn Herbicides

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Introduction

Eastern gamagrass [T*ripsacum dactyloides* (L). L.] is a native perennial, productive and digestible warm season grass being used for forage production. It can be used in areas of low pH and will provide better forage production than cool season grasses and legumes during hot dry summers. It is longer lived than most forage legumes. Eastern gamagrass establishes slowly and competes poorly the first year with annual grasses and broadleaf weeds. It is frequently sown in 30-36 inch rows with a corn planter to facilitate mechanical harvest, this allows space for weed proliferation. This row spacing and the inherent slow first year growth prevent canopy closure until the second year. Eastern gamagrass requires a herbicide to reduce weed competition for consistent successful establishment. Follow up weed control for annual and perennial weeds may be necessary the second year depending on the density of the planting.

Eastern gamagrass is tolerant to many herbicides used in corn production. Dicamba and 2,4-D are labeled for pastures and hayland but no residual herbicides are registered for use on annual grasses. A study by Fick (1995) compared preemergence applications of Ally (metsulfuron), Glean (chlorsulfuron), Pursuit (imazethapyr) and Arsenal (imazapyr) on eastern gamagrass. Ally is labeled for broadleaf control in pastures and Glean is labeled for broadleaf control in small grain. There was no seedling density reduction found with these 2 products at their highest rates tested 48 g ha^{-1} and 120 g ha^{-1} respectively. The Pursuit and Arsenal are in the imidazolinone (IMI) family, there was a stand reduction with the 35 g a^{-1} rate during a dry year. The following year the eastern gamagrass tolerated the IMI herbicides at 140 g a^{-1} but grass weeds were not controlled at that rate. This study compares two, new, low rate corn herbicides with good annual grass control, Accent (nicosulfuron) (Dobbels and Kapusta 1993; Mekki and Leroux 1994), and Basis (rimsulfuron) (Mekki and Leroux 1994) with Plateau (imazapic) a herbicide for native prairie restoration (Becker and Miller 1998) and a few standard corn herbicides. A spray chamber study was also conducted comparing Accent, Basis and Plateau herbicides postemergence on eastern gamagrass.

Material and Methods

Field Study

The study was conducted at the USDA-NRCS Big Flats Plant Materials Center in Corning New York (42^{o} 07'N and 76^{o} 57' W, 271-m elevation). "Pete" eastern gamagrass was planted on 5/22/97 after 8 weeks of stratification using a Tye drill with 32 inch row spacing. The seed was planted at 7.8 lbs ac^{-1} PLS. The soil type was a deep well-drained Unadilla silt loam, (Typic Dystrochrepts). Soil test indicated a pH of 6.3, with 3.2% organic matter, high P and moderate K. No fertilizer was applied. The herbicide was sprayed with a bicycle mounted compressed air sprayer at 2 mph, with 25 gallons of water ac^{-1} at 40 psi, 20 inches above the surface using nozzle 8002. The preemergence spray was done on 6/5/97 and the postemergence on 6/23/97. A nonionic surfactant at 1.0% v v^{-1} was applied for postemergence applications. The gamagrass, pigweed [*Amaranthus viridis* L.], lambsquaters [*Chenopodium album* L.], and foxtail [*Setaria* spp] were 2-4 inches tall at the time of postemergence spraying. The gamagrass was at the 2-4 leaf stage. Bladex was applied preemergence to the Banvel and 2,4-D postemergence treatments to

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control annual grasses. The control was hand weeded on 6/27/97. The herbicides, application rates, and timing are listed in Table 1a. The plot size was 10 x 25 ft with 4 rows of gamagrass being sprayed. There were 4 replications per herbicide treatment.

Evaluations were conducted on 7/2/97 to determine gamagrass population and leaf height (cm). Three 2-meter rows were counted per replication for population. The height (cm) was measured as leaf length of the tallest leaf on 10 plants per replication. On 8/20/97 average tiller number of 5 plants per replication, a visual weed rating, and a leaf length on 5 plants per replication were measured. On 10/15/97 15 plants were dug up, dry weight of tops was measured for each replication and leaf number was counted on 7 of those plants.

Spray Chamber Study

"Pete" eastern gamagrass was planted after an 8 week stratification on 3/31/97 in metromix. The seeds were planted in 65-celled, 7.5 by 13.5 inch Rootrainers. There were three replications per treatment. An Allen track spray chamber was used with a 20 gallon ac^{-1} rate of water, at 35 psi with an 8001 nozzle sprayed 20 inches above the canopy. The herbicides and application rates are listed in Table 2. The plants were sprayed postemergence on 4/25/97 at the 3 leaf stage. They were grown in a greenhouse then evaluated for plant height and leaf number on 5/5/97. A final visual evaluation was made on 6/6/97.

Results and Discussion

Field trial

The weed control was not as effective as expected for the preemergence herbicides except for Bladex which worked excellently. This may have been due to a lack of rainfall for 7 days following spraying. The Bladex and the Bladex plus Banvel (post) and Bladex plus 2,4-D (post) had the best weed control in the study with 12.5, 11.7 and 35% weed cover when evaluated on 10/15/97. The control plots were hand weeded resulting in 55% cover when evaluated on 10/15/97. This was similar in percent cover to the other herbicide treatments.

Since the test germination of the seed lot was low (20%), 39 lbs ac^{-1} of bulk seed was planted. A high average population was achieved due to a germination rate much higher than the test results. The population for Dual treatment was significantly lower (30.0 plants 2 m^{-1}) than the Atrazine (39.0), Bladex (39.0) and control treatments (37.0). No plants were lost from the postemergence sprays. The Banvel treatment which followed a preemergence spraying of Bladex had a significantly lower population (29.0) than the control and Bladex alone although no mortality was observed from the Banvel.

The Plateau preemergence treatment caused some phytotoxicity especially at the 8 oz ac^{-1} rate. This was characterized by yellowing, necrosis, delayed emergence, and stunting. This was apparent when looking at the tiller number (2.0) and tolerance rating (4.6) when compared to the control and Bladex tiller number (3.8 and 5.0) and tolerance rating (1.0 and 1.6) respectively. The Dual treatment also resulted in yellowing and stunting, this was shown by a low tiller number of 3.2 and a tolerance rating of 4.0.

There was some yellowing from all of the postemergence sprays but the plants recovered well with final dry weights not statistically different $P<0.05$ than the control. The Accent and Basis treatments were not significantly different than the control for tiller number or leaf number. The dry weights per 15 plants for the Accent, Basis (0.33 oz ac^{-1}) and Plateau were not statistically different ($P<0.10$) than the control (47.1 g) but were less than Bladex (74.0 g). The Basis 0.66 oz ac^{-1} rate resulted in the highest dry weight (78.4 g). There were no significant differences for leaf height for any of the treatments. See Tables 1a and 1b for a summary of the data for the field trial.

Spray Chamber Study

The spray chamber study compared postemergence spraying of Accent, Basis and Plateau with a control. The Plateau herbicide resulted in severe injury to the gamagrass seedlings at all rates. There were significantly fewer and shorter leaves with Plateau treatments at all rates compared with the control (Table 2). The 12 oz ac^{-1} rate resulted in 0% survival. The Accent and Basis showed some chlorosis but had no effect on plant height, leaf number, or vigor.

Conclusions

The Plateau herbicide, post emergence, at all rates was phytotoxic to eastern gamagrass. When Plateau was sprayed preemergence at the 8 oz ac^{-1} rate; stunting, delayed emergence, chlorosis, and necrosis was observed. Dry weight was among the lowest in the trial at both the 4 and 8 oz rate but was not statistically different than the control. Additional trials at the 4 oz ac^{-1} rate is warranted. Dual, when sprayed preemergence, significantly reduced the stand. Accent, Basis, Banvel, and 2,4-D, when sprayed post emergence, caused some chlorosis early which was outgrown and had no significant effect on final biomass**.** The Basis herbicide treatment (0.66 oz ac^{-1}) resulted in the highest dry weight measurement in the trial. The Atrazine, Bicep and Bladex treatments performed well with no apparent phytotoxicity.

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TABLE 1a Eastern Gamagrass Herbicide Field Study

Herbicide	Rate ac^{-1}	10/15/97 DW[1]	10/15/97 leaf #	10/1/97 % Weeds	8/20/97 Tiller #	7/2/97 Tolerance[2]	7/2/97 Plants $2m^{-1}$
Accent 1x (Post)	0.66 oz	39.9	22.0	56.3	3.5	3.3	39
Accent 2x Post)	1.32 oz	45.6	22.5	67.5	4.1	4.5	35
Atrazine (Pre)	1.8 lb	65.6	27.3	75.0	4.3	1.6	39
Banvel (Post)	1.0 pt	54.0	22.8	11.7	3.0	3.6	29
Basis 1x (Post)	0.33 oz	55.7	24.0	65.0	4.7	4.3	44
Basis 2x (Post)	0.66 oz	78.4	24.8	75.0	4.2	4.8	42
Bicep (Pre)	3.0 qt	51.2	24.8	68.8	4.2	2.3	35
Bladex (Pre)	2.25 qt	74.0	24.5	12.5	5.0	1.6	39
Control		47.1	18.5	55.0	3.8	1.0	37
Dual (Pre)	2.5 pt	45.5	20.5	61.3	3.2	4.0	30
Plateau 1x (Pre)	4 oz	40.8	20.0	72.5	2.9	3.5	37
Plateau 2x (Pre)	8 oz	41.1	19.8	87.5	2.0	4.6	36
2,4-D (Post)	2.0 pt	43.2	23.3	35.0	3.3	2.6	36
LSD.05		23.7[3]		34.6	1.26	1.9	7.3
P		0.09	0.34	0.0008	0.0015	0.0015	0.0130

[1] gram weight of 15 plants, [2] 1 = best 9 = worst, [3] $LSD_{0.10}$

TABLE 1b Eastern Gamagrass Herbicide Field Study

Herbicide	Rate ac^{-1}	7/2/97 ht (cm)	7/2/97 weed rating[1]	8/20/97 ht (cm)	8/20/97 weed rating[1]
Accent 1x (Post)	0.66 oz	12.4	4.5	36.2	5.6
Accent 2x Post)	1.32 oz	11.8	5.8	39.0	4.9
Atrazine (Pre)	1.8 lb	13.3	1.3	40.1	5.3
Banvel (Post)	1.0 pt	10.8	1.3	30.8	1.0
Basis 1x (Post)	0.33 oz	12.3	2.8	35.2	4.3
Basis 2x (Post)	0.66 oz	10.6	3.3	36.0	4.5
Bicep (Pre)	3.0 qt	12.3	1.7	38.1	3.3
Bladex (Pre)	2.25 qt	13.1	1.1	36.6	1.4
Control		12.2	1.0	35.4	3.8
Dual (Pre)	2.5 pt	10.9	3.5	33.2	3.8
Plateau 1x (Pre)	4 oz	11.4	3.0	32.8	5.9
Plateau 2x (Pre)	8 oz	10.1	3.3	33.3	5.0
2,4-D (Post)	2.0 pt	11.2	1.4	32.6	3.3
LSD.05			1.6		2.0
P		0.735	0.00001	0.650	0.0001

[1] 1 = best 9 = worst

TABLE 2 Spray Chamber Study[1]

Herbicide	Rate ac^{-1}	Ht (cm)	Leaf #
Plateau	4 oz	11.5	2.6
Plateau	8 oz	8.5	2.3
Plateau	12 oz	10.1	2.5
Accent	0.66 oz	22.6	4.1
Accent	1.32 oz	24.1	4.1
Basis	0.33 oz	23.1	4.0
Basis	0.66 oz	20.8	4.0
Control	******	22.3	4.3
$LSD_{.05}$		2.0	0.45
P		0.00001	0.00001

1) Sprayed 4/25/97, Evaluated 5/5/97

Chromosome Doubling and Mode of Reproduction of Induced Tetraploids of Eastern Gamagrass

Paul R. Salon[1] and Elizabeth D. Earle[1]

Abstract

Eastern gamagrass, [*Tripsacum dactyloides* (L.) L.] is a perennial, warm season grass that is being developed as a forage. Shoots were derived from callus initiated from immature embryos and immature inflorescences of diploid (2n=2x=36) gynomonoecious eastern gamagrass. Gynomonoecious plants have the potential to increase seed production twenty fold. These shoots were induced to microtiller in the presence of 3 mg l^{-1} of benzyladenine (BA). Amiprophosmethyl (10, 15, or 20 µM) was applied to 27 microtillers for 3 to 5 days to induce chromosome doubling. All 14 surviving plants were tetraploid, (2n=4x=72), as determined by flow cytometry or chromosome counts. These plants were morphologically normal and produced seed. Test crosses were made with a known diploid. Flow cytometry and chromosome counts showed that the progeny were triploid, proving the induced tetraploids reproduce sexually. Naturally occurring tetraploids are apomictic, monoecious, more robust, and less winter hardy than diploids. We are interested in using these sexual tetraploids to increase biomass, winter hardiness and seed production of eastern gamagrass for the Northeast.

Salon, P.R. and E.D. Earle. 1998. Chromosome doubling and mode of reproduction of induced tetraploids of eastern gamagrass (Tripsacum dactyloides L.). Plant Cell Reports 17:881-885.

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Beach Dune and Critical Area Stabilization with Native Plants

Samuel Sanders and USDA NRCS Florida Plant Materials Center Staff[1]

Abstract

Each year thousands visit the sandy white beaches along the Gulf of Mexico, including John Beasley Park in Okaloosa County, FL. Construction of this park, located near Ft. Walton, began in 1992. The Plant Materials Specialist and the Plant Materials Center were requested to assist in the establishment of vegetation around the newly installed pavilion and several adjacent blowout areas. The dunes at Beasley Park were almost completely devoid of vegetation, and subject to severe erosion. In 1993 the PMC, working in cooperation with the local SWCD, the County, the RC&D Council and numerous volunteers from various agencies began revegetation effort of this new park.

Among the plant species used to revegetate the areas were four varieties released from the Brooksville PMC: 'Northpa' and 'Southpa' bitter panicum [*Panicum amarum* Elliott], 'Sharp' marshhay cordgrass [*Spartina patens* (Aiton) H.L. Muhl.], and 'Flora Sun' beach sunflower [*Helianthus debilis* Nutt.]. The effort took several years (1993 – 1996) to be completed. All of the above plants were established using vegetative transplants propagated at the PMC. The project was fertilized and irrigated.

Beasley Park has been in the direct path of several tropical storms, Hurricane Opal in 1995 and Hurricane George in 1998. Opal's strong winds destroyed over 125 miles of primary dune system along the northwest Florida Gulf coastline. Primary and secondary dunes in Beasley Park were still intact after the storm. Marshhay cordgrass and bitter panicum had a 95% survival rate. The beach sunflowers were severely burnt but recovered.

'Northpa' bitter panicum is being used extensively by the US Army Corp of Engineers in a 25-mile beach dune revegetation project in North Carolina. The project leader reports that it has had a 92% survival rate and is out-performing sea oats. Though it is a coastal plant, bitter panicum also performs well on critical area sites inland. Eglin Air Force Base, near Pensacola, is revegetating several borrow pit sites. Erosion from these pits was causing sedimentation in the streams where the endangered Okaloosa darter is found, further threatening the existence of this species. Native species, which could colonize in dry, sterile soils and establish rapidly, were preferred. 'Northpa' and 'Southpa' were able to fit these requirements, and are successful on these sites.

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Development of Direct Seeding Techniques to Restore Native Groundcover in a Sandhill Ecosystem

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Abstract

The Nature Conservancy's Apalachicola Bluffs and Ravines Preserve was a windrowed slash pine plantation until it was selectively logged in the mid 1980's. Since then restoration has been underway and has included planting longleaf pine [*Pinus palustris* Mill.] and wiregrass [*Aristida beyrichiana* Trin. & Rupr.] plugs by hand. This method of restoring groundcover is limited by the on-site nursery's capacity to restore only 5 acres of groundcover annually. Methods of directly seeding native groundcover species are needed to efficiently restore over 2500 acres of sandhill on the preserve. Direct seeding trials were initiated in 1994. Attempts at sowing a mixture of seed with a shaker fertilizer spreader and a conical fertilizer spreader were unsuccessful. A third attempt using a leaf blower adequately spread the seed but resulted in minimal seedling establishment. Wiregrass seedlings were successfully established in 1995 using a leaf blower to sow seed on a bulldozed site. In 1996 wiregrass seedlings were successfully established by sowing with a hay blower in a harrowed site. In January 1997, windrows were bulldozed and smoothed so that all existing vegetation was removed. Plots were established in the bulldozed area and then seeded with a mixture of wiregrass and other native seed. Control plots were established which were bulldozed but otherwise untreated. Treatments were applied in a randomized complete block design for sowing native seed alone or with winter rye, rolling the seed in or not following sowing, and watering for the first four months after seeding or no watering. Monitoring conducted in September 1997 showed high species richness in all study plots. Rolling seed in immediately after sowing increased wiregrass seedling establishment and survival. This direct seeding method successfully restored wiregrass and other understory species and was considerably less expensive and more efficient than planting plugs. The experimentation has continued with methods of site preparation for sowing seed in 1999 including prescribed burning and roller chopping. In addition various other types of equipment have been used for seeding, including a different type of hay blower, a modified fertilizer spreader, and a hydroseeder.

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Production and Nutrient Uptake by Native Warm-Season Grasses

K.W. Staver[1]

Warm-season grasses are being widely promoted in Maryland through the Conservation Reserve Program to enhance wildlife habitat and reduce nonpoint source pollution from agriculture. Switchgrass [*Panicum virgatum* L.] rooting depth can exceed 3 m (Moser and Vogel 1995), and nitrogen (N) isotope studies have indicated its ability to transport N into above ground tissue from below a depth of 1.2 m (Huang 1994). This suggests that these grasses may be useful in riparian settings for attenuating subsurface nitrate loads from up-gradient source areas.

There also is interest in the potential for using warm-season grasses as biofuels. Switchgrass is considered to have potential for use as feedstock in ethanol production (Cherney et al. 1991; McLaughlin 1992) as well as fuel in direct combustion applications (Downing et al. 1995). Warm-season grasses are known for their ability to thrive on low-fertility sites and have the potential for producing large quantities of biomass per unit of plant nutrient. However, little information presently exists on their nutrient uptake and retention capacity in high-fertility settings where they are currently being planted in Maryland. The primary objectives of this study were to evaluate the biofuel potential and nutrient uptake capabilities of switchgrass and eastern gamagrass [*Tripsacum dactyloides* (L.) L.] under high nutrient loading rates.

Approach

This study was conducted at the Wye Research and Education Center in Queen Anne's County, Maryland. The study site is nearly level with soils classified primarily within the Matapeake and Mattapex Series (fine-loamy, mixed, mesic typic/aquic Hapludults) which are moderately well-drained and widely used for grain production on the Maryland Eastern Shore. The soil surface at the study site is approximately 6 m above sea level and the water table is located at a seasonally variable depth from 2 to 4 m below the soil surface.

Twelve plots (30 m x 25 m) each of eastern gamagrass and switchgrass (Kanlow) were planted in 1996. Eastern gamagrass was planted in 76 cm rows and switchgrass drilled in 38 cm rows. No nutrients were applied to any plots during 1996 or 1997. In April 1998 all plots were cut and baled prior to onset of spring growth. On June 2, new growth in all plots was cut to a height of 15 cm and removed to facilitate even application of poultry litter. Poultry litter was surface applied on June 8 at 0, 6.7, and 13.4 Mg ha^{-1}. The poultry litter contained 4% N and 1.4% phosphorus (P), and 1.9% potassium (K), resulting in N application rates of 0, 269, and 538 kg ha^{-1}, P application rates of 0, 94, and 188 kg ha^{-1}, and K applications rates of 0, 127, and 255 kg ha^{-1}.

Nitrate leaching was monitored in the plots continuously using gravity lysimeters installed at a depth of 60 cm. Above-ground dry matter and nutrient content were measured in early September 1998 by collecting 2 m row sections from each plot. All remaining 1998 above-ground growth was cut, baled, and weighed in early April 1999 just prior to the onset of new growth. Bales from each plot were subsampled to determine tissue nutrient content. Switchgrass subsamples also were sent to the Federal Energy Technology Center in Pittsburgh for analysis of combustion characteristics.

Results and Discussion

Approximately 2.0 tons $acre^{-1}$ of 1997 growth was harvested from both eastern gamagrass and switchgrass plots in April 1998. An additional 1.5 ton $acre^{-1}$ of new growth was removed on June 2, 1998, just prior to application of poultry litter. All plots receiving poultry litter showed an

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obvious growth response, apparently in response to increased N availability, since soil P and K levels were adequate for maximum production prior to poultry litter applications. Above-ground dry matter in early September 1998 in the 13.4 Mg ha^{-1} poultry litter plots was 7.4 and 11.6 Mg ha^{-1} in the eastern gamagrass and switchgrass treatments, respectively, approximately double the dry matter levels measured in the control plots (Table 1). By early April 1999, above ground dry matter had decreased in all treatments, with the greatest reductions (37.5 %) occurring in the treatments where 13.4 Mg ha^{-1} of poultry litter had been applied. The late summer to spring comparisons must be viewed with caution since small subsamples were collected in September versus whole-plot harvesting in April. Aboveground biomass in the Eastern gamagrass plots was approximately 40-50% less than in switchgrass plots receiving the same poultry litter applications.

Tissue N and K levels tended to be higher in the Eastern gamagrass plots relative to comparable switchgrass plots in late summer and concentrations of both nutrients tended to increase with increasing poultry litter application rates (Table 1). Total uptake of N and K was higher in switchgrass plots due to higher biomass production. Late summer tissue P concentrations were similar in all treatments at approximately 0.2% (dry mass basis). By April 1999, tissue concentrations of all plant nutrients had decreased, although to a widely varying degree. Tissue N concentrations in the switchgrass plots decreased approximately 25% from September through April to an average for all plots of 0.47%. In the eastern gamagrass plots the decrease in tissue N averaged 14%, and average spring concentrations were 0.67%. It is not clear whether these reductions were due to loss of N from tissue or were due to a disproportionate loss of N-enriched tissue (leaves versus stems) during winter or harvesting. In the case of P and K, which tend to be present in plant tissue in forms that are readily leached when cell membranes lyse, much larger reductions in tissue concentrations occurred between September and April. In both eastern gamagrass and switchgrass treatments, tissue P concentrations decreased between 60 and 70% from September to April. During the same period decreases in tissue K concentrations averaged 85% in the switchgrass treatments and 90% in the Eastern gamagrass treatments. Tissue carbon concentrations in both fall and spring in all tissue samples were approximately 45% on a mass basis.

The loss of large fractions of tissue nutrients from fall to spring greatly reduced nutrient removal rates in harvested biomass. Although higher biomass yields were achieved with fall harvesting, the quantity of biomass harvested per unit of plant nutrient tended to be much higher in the spring. In the switchgrass high poultry litter application treatment plots, total N uptake into above-ground tissue was equivalent to approximately 44% of the plant available N (approximately half of the total N) supplied by the poultry litter (15 kg N Mg^{-1}). P uptake in the same treatment was equivalent to only 12% of the total quantity applied, while for K total uptake was equal to 52% of that applied in the poultry litter. By spring, the imbalance was even more pronounced. Although N removal in the switchgrass harvested from the high poultry litter treatments dropped to only 18% of applied plant available N, the sharp decreases in tissue P and K levels reduced removal rates in harvested biomass to less than 3 and 5% of the P and K applied, respectively.

Although only a minor fraction of the total N applied in poultry litter was accounted for in above-ground biomass, nitrate leaching patterns indicated that pore-water nitrate concentrations in the upper regions of the soil profile (0-60 cm) remained low. Nitrate leaching was minimal (<3 kg ha^{-1} nitrate-N yr^{-1}) in all plots from when the grasses were planted in 1996 through the spring of 1998. Despite the poultry litter applications in June 1998, leachate nitrate-N concentrations during the following winter remained below 1 mg L^{-1} in all plots until late February when average concentrations briefly exceeded 1 mg L^{-1} in the two poultry litter treatments. By early April 1999 average leachate nitrate-N concentrations had decreased to approximately 0.5 mg L^{-1}, similar to concentrations in the control treatments.

The spring harvested switchgrass had a heating value of 17.8 MJ kg^{-1} (7660 Btu lb^{-1}) and a total ash content of 2.05%. The primary constituents in the ash were SiO_2 (57.1%), CaO (12.6%), K_2O (6.9%), MgO (5.7%), Fe_2O_3 (5.5%), and Na_2O (3.7%). The heating value is similar to those generally reported for summer harvested switchgrass, but the total ash content is lower (Johnson et al. 1995). The loss of a large percentage of tissue K during winter months reduced the alkali index to a range that suggests a low potential for fouling problems during combustion (Jenkins et al. 1998).

Conclusions

Switchgrass and eastern gamagrass production can be approximately doubled with surface applied poultry litter, primarily in response to increased N availability. Under a single cut management system, switchgrass produces more above-ground biomass per unit of N and K, but P utilization is similar. Although only a small fraction of total N applied in poultry litter was accounted for in above-ground production of both grasses, nitrate leaching was minimal, suggesting that major quantities of N were sequestered in below-ground biomass. Delaying harvest until early spring caused only moderate reductions in total biomass yield, but major reductions in tissue nutrient concentrations. This resulted in retention of P and K in the soil system and an improvement of the suitability of the harvested biomass for fuel in direct combustion applications. In a spring harvest management system, poultry litter applications (high rate) would only be necessary every 20 to 30 years to replace P and K removed in harvested biomass, while annual applications would likely be needed to prevent reduced production due to N availability. Even with harvesting during the growing season, only a small fraction of the P supplied in poultry litter is removed with harvest. Consequently, using poultry litter to supply N or K requirements of an intensively managed grass system would result in a rapid increase in soil P levels.

The tendency for N-limitation of production suggests that both switchgrass and eastern gamagrass could be highly effective in retaining N in riparian settings where nitrate is supplied via subsurface flow from up-gradient cropland. The critical question is how effectively these grasses are able to utilize nitrate moving through riparian areas in subsurface flow. If nitrate is accessible, relatively high production could be maintained with minimal inputs of P and K by delaying harvest until late winter or early spring. Higher short-term yields could be achieved with multiple harvests during the growing season but soil reserves of P, and especially K, would be more rapidly depleted. In the no-harvest/no-fertilizer situation mandated for grass buffers installed under the Conservation Reserve Program, it is likely that N retention would remain effective for many years due to the potential for grasses to sequester large quantities of carbon in the soil profile.

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Table 1. Above-ground biomass production and nutrient content of switchgrass and eastern gamagrass on September 10, 1998 and April 14, 1999 as affected by differing rates of surface-applied poultry litter (PL).

Treatment	Biomass	Nitrogen		Phosphorus		Potassium	
	Kg ha^{-1}	%	kg ha^{-1}	%	Kg ha^{-1}	%	Kg ha^{-1}
Switchgrass							
Sept-10-98							
Control	5394	0.57	31.1	0.20	10.7	0.89	47.5
6.7 Mg PL ha^{-1}	8804	0.59	52.6	0.17	15.5	0.86	77.6
13.4 Mg PL ha^{-1}	11600	0.74	88.3	0.19	21.9	1.14	132.7
April-14-99							
Control	5098	0.46	23.3	0.06	3.2	0.14	7.3
6.7 Mg PL ha^{-1}	6521	0.47	31.1	0.06	4.0	0.12	7.6
13.4 Mg PL ha^{-1}	7382	0.48	35.0	0.07	5.1	0.17	12.2
Eastern Gamagrass							
Sept-10-98							
Control	3596	0.70	25.3	0.18	6.2	1.26	45.2
6.7 Mg PL ha^{-1}	4873	0.78	38.1	0.19	9.2	1.33	65.2
13.4 Mg PL ha^{-1}	6844	0.88	60.1	0.20	13.8	1.61	110.9
April-14-99							
Control	2536	0.62	15.8	0.06	1.4	0.09	2.2
6.7 Mg PL ha^{-1}	3968	0.68	26.9	0.07	2.8	0.14	5.5
13.4 Mg PL ha^{-1}	4350	0.72	31.5	0.08	3.6	0.20	8.9

Mid Atlantic Region Grass Collections Efforts at the University of Maryland in Support of the NRCS-PMCs

Harry Jan Swartz, Gwen Meyer, Jennifer Kujawski, Norman Melvin, John Englert, Chris Miller, Bill Skaradek, and Valerie Hopkins[1]

Collections

Over the last half of this decade, seed of perennial native Piedmont and Coastal Plain Mid-Atlantic States grasses has been intensively collected for use in environmental restoration projects. These efforts have been designed to develop regional grasses as few NRCS grass releases have originated here. Seed is being imported from the Midwest, thereby contaminating our natives. The University of Maryland has aided the NRCS-Plant Materials Centers (PMC) in these collections and with research on their culture.

From 1996, over 180 accessions of 30 species have been harvested (>100 lbs of seeds in total). Collections have been in pristine areas such as from forest clearings near back bays and ocean estuaries, from river scours, from xeric or impoverished locations, from clayey beds, on armed services fortifications or governmental installations, and under power lines and right of ways kept grassy by constant mowing or herbicide use. Seed collections were planted at two University of Maryland farms (Queenstown and Antietam) for initial evaluation and increase. Over a half-acre of seed producing native grasses are now being managed for the NRCS. Resulting plants and seed were also planted at the Beltsville, MD and Cape May, NJ Plant Material Centers for evaluation and production of composite selected releases. Throughout our collections, these warm season grasses were *never* observed as agricultural pests.

The "big four" grasses of Midwestern tall grass prairies, are found in the Mid-Atlantic; however, big bluestem [*Andropogon gerardii* Vitman] (2 collections) is comparatively rare here. Our largest collection was near the C&O Canal just outside of Washington DC. As feed for draft animals was commonly transported along the canal; it is questionable whether this material is exotic or native. By contrast, Indiangrass [*Sorghastrum nutans* (L.) Nash] (15 collections) is relatively easy to establish and it was found everywhere.

Switchgrass [*Panicum virgatum* L.] (12 collections) is more common on the coastal plain but is found throughout the region in the wettest to driest upland sites. It can be too aggressive in mixed plantings and should be planted in occasional solid stands. Plateau residual herbicide selectively controls most weeds in our grass collections but can hurt switchgrass. Separating plantings of solid switchgrass seedings from a Mid-Atlantic grass mix plantings would allow the use of moderate to high concentrations of Plateau away from the switchgrass.

Little bluestem [*Schizachyrium scoparium* (Michx.) Nash] (14 collections inc. coastal bluestem [*Schizachyrium scoparium* var *littoralis* (Nash) Gould] can also be established well with the use of Plateau. The fluffy seed it produces can be processed for seeding. We have been quite successful establishing plants in areas overspread in the fall with little bluestem straw. Most collections were made along the coast and in sandy, poor soils in the Pine Barrens of NJ and VA and on the sandy areas near the ocean. One collection from a clayey bottom in N VA (ACC # 9080068) was noticeably different.

[1]Natural Resource Conservation Service, Plant Material Centers and University of Maryland Department of Natural Resource Sciences and Landscape Architecture. This research supported by contract from the Wetland Science Institute, USDA. The authors express their gratitude, particularly to the foresight of its director, Dr. Billy Teels.

Our native savannas commonly contain other grasses. Purpletop [*Tridens flavus* (L.) Hitchc.] (8 collections) naturally introduces itself in many upland grassy areas and can flower in the first year from seed. Eastern gamagrass [*Tripsacum dactyloides* (L.) L.] (12 collections) grows well in wetland and upland conditions. Dark brown eastern gamagrass seed tend to have viable embryos; light colored ones are empty. These can be separated in water. Dry eastern gamagrass seed benefits, on occasion, from 3-10 minutes sulfuric acid scarification and subsequent moist stratification.

Less common grasses add to our diversity. We have had some establishment of broadcast Split Beard Bluestem [*Andropogon ternarius* Michx.] (2 collections); however, we did not "clean" these fluffy seeds. When we plant small quantities of fluffy seed, we rototill, rake, and roll over the seed, usually with a vehicle. Beaked panicum [*Panicum anceps* Michx.] (10 collections) establishes slowly, but by the second year, is quite noticeable. By contrast, Florida paspalum [*Paspalum floridanum* Michx.] (7 collections) establishes rapidly the first year. Both grasses tolerate mowing well.

Some wetland grasses were also collected. Bushy bluestem [*Andropogon glomeratus* (Walt.) B.S.P.] (3 collections), Walter's millet [Echinochloa *waleri* (Pursh) Heller] (1 collection), and giant foxtail [*Setaria magna* Griseb] (1 collection) were harvested in occasionally inundated conditions. Bushy bluestem from the southern range of this region tends to be much more vigorous and ornamental. This vigor is maintained in common plantings. Giant foxtail, an annual, was harvested in slightly brackish water inside a mature stand of *Phragmites*. Sugarcane plumegrass [*Saccharum giganteum* (Walter) Pers.] (10 collections) and brown plumegrass [*Saccharum brevibarbe* (Michx.) Pers. (4 collections) are the most spectacular of our native grasses. They are established well from plug plants and can reach 10 ft in height. Our collection is being grown at the Cape May NJ PMC.

Of the shade tolerant species, bottlebrush grass [*Elymus hystrix* L.] (3 collections) and slender wildoats [*Chasmanthium laxum* (L.) H. O. Yates] (7 collections) grew in the deepest shade. However, one collection of slender wild oats (ACC # 9080113) grew at least 500 feet from the nearest tree. Virginia wild rye [*Elymus virginicus* L.] (18 collections) is easy to establish, tolerates Plateau herbicide, and grew at the edges of forests and in cleared areas.

Smaller collections were made of prairie three awn [*Aristida oligantha* Michx.], arrowfeather [*Aristida purpurascens* Poir.] and sand dropseed [*Sporobolus cryptandrus* (Torr.) A. Gray]. These are being maintained in a greenhouse bed and as seed. Little barley [*Hordeum pusillum* Nutt.], little foxtail [*Alopecurus carolinianus* Walter] and poverty oat grass [*Danthonia* spicata (L.) F. Beauv.] were collected for possible use as "living mulches" or as winter cover in agricultural situations. Each may be of use as companion species for restoration efforts. Of the three, little barley is easy to culture; currently 0.1 acre is being cultured at the University of Maryland. The NRCS National PMC has a more diverse collection.

Several of these species are being used to augment collections made by the Mid Atlantic PMCs. Potential USDA-NRCS releases using these collections include: Indiangrass, little barley, bottlebrush grass, Virginia wild rye, paspalum, beaked panicum, purpletop, and, perhaps, switchgrass.

Research

Germination of most of the tall stature, freshly harvested native grasses is greatly aided by warm, fluctuating temperatures (86-68ºF) and moist prechilling (40ºF) for around 6 weeks (see Table 1). Light is not required for seed germination in most of these species; however, it helps. Recommendations for a compact seedbed and seed drilling to a depth of one half to one inch is appropriate. Cleaning the seed bed of excessive vegetation would seem important for obtaining required fluctuating temperatures in early spring. In contrast, having bare ground could increase the chance of poor germination due to insufficient moisture, especially in later plantings.

Application of Plateau herbicide maintains competition free seedbeds. In comparison to repetitive mowing, Plateau treated seed beds actually look like a warm season grass planting in their first year of growth. Seed stored for longer periods (>1 year) does not seem to need stratification. Finally, late harvested seed, i.e. after some shatter, generally germinated at higher percentages.

Possible companion cool season grass species were also investigated for use in initial soil stabilization. Compared to red fescue [*Festuca rubra* L.] and tall fescue [*Festuca arundinacea* Schreb.], red top [*Agrostis gigantea* Roth], and annual rye [*Lolium multiflorum* Lam.] permitted the most growth of closely growing warm season grass plug plants. Native grasses potentially of use as companion or establishment species, which sprout quickly and do not out compete the warm season grasses, are Virginia wild rye, Florida paspalum, and little barley. Little barley is an early fall planted annual with potential as a “living mulch” as it seeds and dries by June 15th. Planting ratios for these species, in comparison to warm season grass seeding rates, need to be established.

Visually, the success of a warm season grass prairie or savanna seems to require at least 10,000 to 20,000 plants per acre or one plant every 2 to 4 square feet. Establishment of more plants may reduce the size of the individuals in the third and subsequent years, leading to little overall difference in how the planting may be perceived. To test this, plug plants of various grasses were planted in rows of increasing spacing the further away from the center of the rows. Six rows were planted at 60 degrees to form an asterisk pattern to provide competition from other rows as well as competition from the next plant in the row. Above ground dry weights of these grasses were recorded after 2 years of growth. The data given in Table 2 indicate vigorous tall grass species plants produce 10 times the above ground biomass if planted at the 9-inch” between-plant spacing (listed as 22.5 inches from the center) as compared to 3-inch spacing. Thus, a thin planting of these species will fill out in a relatively short period, in spite of large numbers of plants, if other weeds are controlled. In the case of switchgrass grown in clay loam soil, a field with 700,000 plants (with 3-inch spacing) would produce 22 T per acre above ground biomass. A field with 78,000 plants (9-inch spacing) would produce 18 T per acre. By the second year, little difference in biomass is observed in the two widely varying plant densities; less variation would be expected in subsequent years.

Table 1. Classification of native grass species by germination requirements. Number of weeks of moist stratification in soil at 39ºF required for germination is given in the parentheses.

Germination Requirements	Grass Species
Fluctuating temperatures (86/68ºF) Light aids in germination	Beaked panicum (>6) Indiangrass (6) Switchgrass (6) Purpletop (6) Eastern gamagrass (6).
Enhanced germination in fluctuating temperatures	Sugarcane plumegrass (6) Brown plumegrass (6)
Not Sensitive to light or fluctuating temperatures	Slender wild oats (6) Annual rye(0) Tall fescue (0) Red fescue (0) Florida paspalum(4).

Table 2. Mean dry weight in grams of the above ground portion of warm season grass plants set at various spacings in an asterisk shaped planting. Plants in the center, 3-inch, 7.5-inch, 13.5-inch, and 22.5-inch away from the center are listed across the top distances. As there were six lines of plants radiating from a single center plant, each distance was replicated six times in each asterisk. Each asterisk was replicated three times at each site. The SL site had sandy loam soil (Beltsville, MD) and the CL site had clay loam soil (Wye, Queenstown, MD).

		Location in asterisk-distance from center (Mean dry weight ft^{-2})				
Species	Site	Center	3-inch	7.5-inch	13.5-inch	22.5-inch
Big bluestem	SL	4	19	27	56	57
Big bluestem	CL	17	22	27	69	92
Deertongue	SL	6	9	16	34	77
Deertongue	CL	11	6	19	42	61
Beaked panicum	SL	7	6	18	22	33
Switchgrass	SL	25	26	38	107	216
Switchgrass	CL	26	30	60	130	221
Florida paspalum	SL	22	18	33	73	133
Florida paspalum	CL	20	31	54	119	302
Indiangrass	SL	4	10	19	31	49

Improving Seedling Establishment by Modifying Seedling Photomorphogenic Characteristics of Warm-Season Grasses

C.R. Tischler[1], J.D. Derner[1] and W.R. Ocumpaugh[2]

Panicoid (warm season) and Festucoid (cool season) grasses have different seedling morphologies, which affect the dependability of establishment of these two types of grasses (Fig. 1). In both groups, the primary root (derived from the radicle in the embryo) is short-lived, and must be replaced by adventitious roots arising at the crown node. In warm season grass seedlings, the crown node is located near the soil surface, as the mesocotyl (or subcoleoptile internode) elongates to bring the coleoptile tip to the soil surface. In cool season grasses, the coleoptile itself elongates, thus keeping the crown node near planting depth. Hyder et al. (1971) attributed the generally poor seedling establishment of blue grama [*Bouteloua gracilis* (Kunth) Lag. ex Griffith] to so called “Panicoid” morphology. They also noted that in many blue grama seedlings, the crown node is actually above the soil surface, where initiation and elongation of adventitious roots is very unlikely. Olmsted (1941) and Tischler and Voigt (1987) made similar observations for sideoats grama [*Bouteloua curtipendula* (Michx.) Torrey] and kleingrass [*Panicum coloratum* L.], respectively.

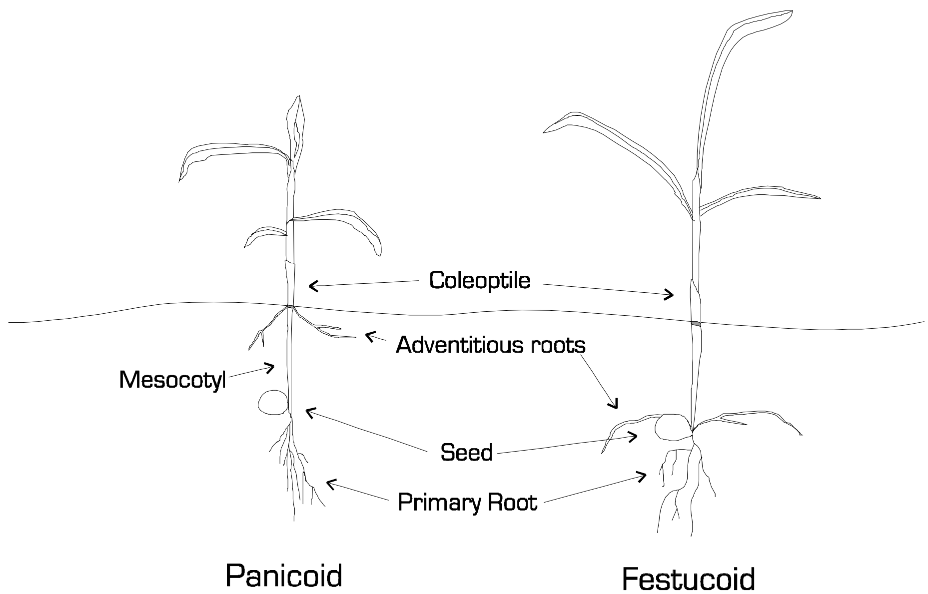

Figure 1. Panicoid (warm-season) and Festucoid (cool-season) seedling morphologies. The crown node is the site of origin of adventitious roots, which must develop to replace the primary root if the seedling is to become established. Note the absence of an elongated mesocotyl in the Festucoid seedling.

In warm season grasses, elongation of the mesocotyl ceases when the coleoptile tip receives adequate (red light) stimulus (van Overbeek 1936). Although phytochrome is involved in sensing the light signal, the sequence of events involved in converting the light signal into a cessation of mesocotyl elongation is quite complex (Duke and Wickliff 1969; Vanderhoef et al. 1979; Parks and Poff 1986).

Although the problem of crown node elevation is well described in the literature, Tischler and Voigt (1993) were the first to propose a selection method to overcome the problem. They grew

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various grasses in low, continuous light (1.5 μ mol m^{-2} s^{-1}) for 7 days, and observed that for many grasses, there was considerable variation in crown node placement above the soil surface. The use of low, continuous light circumvented complications arising because of different times of emergence during normal day-night cycles. Tischler and Voigt (1993) proposed a recurrent selection protocol in which seedlings with the least and greatest amounts of crown node elevation are saved, crossed in the field, and allowed to produce seed. This seed is subsequently grown in the low light environment to produce advanced populations of plants with low (LC) or elevated (EC) crown nodes.

This paper describes the application of the Tischler and Voigt (1993) protocol to kleingrass and switchgrass [*Panicum virgatum* L.] and the development and properties of the new germplasms. Applications of this methodology to other species are discussed. Also, we argue for developing native grass populations with altered photomorphological properties to facilitate establishment in disturbed sites.

Methods

The cultivars 'Selection 75' kleingrass and 'Alamo' switchgrass were used as parental materials. Three cycles of recurrent selection for low or elevated crown nodes were completed (see Tischler and Voigt 1995 for details of plant culture). All polycross seed was produced in the field at Temple, TX. Subsequently, populations of cycle 3 germplasm were established at College Station, TX. The cycle 3 germplasm (EC-3 and LC-3) of each species was evaluated first in the low-light environment in which selection was performed, and subsequently in various field environments over two years. Additional work was performed with sorghum [*Sorghum bicolor* (L.) Moench] inbreds and hybrids (using the low light system) to gain information about the inheritance of crown node placement (Tischler et al. 1997).

Results

Selection for crown node placement was effective in kleingrass (when germplasm was evaluated in low light), although most of the progress for lower crown node placement was made in the first cycle of selection (Table 1). Shoot length was also modified, with EC-3 being greater than Selection 75 which in turn was greater than that for LC-3. The standard deviations of node elevations tended to parallel crown node elevation (as expected). The EC-3 population had the greatest standard deviation of crown node elevation, indicating much genetic variability for this trait was present.

Additional testing of parental and new kleingrass and switchgrass germplasms was performed in complete darkness and at a number of different low light levels (Elbersen et al. 1998). In darkness, coleoptiles of LC-3 seedlings were longer than coleoptiles of EC-3 seedlings. To prevent crown node elevation in kleingrass (in continuous light), light levels of 5, 30, and >30 μ mol m^{-2} s^{-1} were required for LC-3, Selection 75, and EC-3, respectively. Light threshold levels required to stop mesocotyl elongation were lower for switchgrass. In LC-3 populations of both kleingrass and switchgrass, rates of mesocotyl elongation were lower (in darkness) than for the parental or EC-3 populations. These observations suggest that our selection protocol had acted at several different physiological loci.

Although we were successful in selecting for the crown node placement in the low light system, testing was needed to determine how the newly-developed germplasm would perform in the field. The seed production blocks of EC-3, LC-3, and parental populations of both kleingrass and switchgrass were very similar in appearance at the mature plant stage. Presently, we have completed field evaluation of seedling establishment only for the switchgrass populations. Values for various seedling parameters of field grown seedlings (averaged across experiments at Stephenville, Beeville, and College Station, TX) are given in Table 2. While mesocotyl length and crown node depth differed among the three populations, shoot length and leaf number were not significantly different. This later result is important because in selecting for lower crown node placement, there is a danger that one may also be selecting for slower growth rate.

Table 1. Crown node elevation and shoot length means and standard deviations (SD) of selected and unselected kleingrass.

	Node Elevation		Shoot Length	
Population	Mean	SD	Mean	SD
	----------cm----------			
EC-3	1.94 a[1]	0.566	2.56 a	0.560
Unselected	0.87 b	0.443	2.36 b	0.551
LC-3	0.04 c	0.081	2.18 c	0.324

[1] Values within columns followed by the same letter are not significantly different at the 0.05 probability level.

Table 2. Crown depth, mesocotyl length, shoot length, and leaf number of Alamo, LC-3 and EC-3 switchgrass at three locations in Texas in Summer, 1996.

Genotype	Crown Depth	Mesocotyl Length	Shoot Length	Leaf Number
	----------cm----------			
Alamo	0.34 ab[1]	0.84 a	8.87 a	4.5 a
LC-3	0.39 a	0.59 b	6.66 a	4.2 a
EC-3	0.28 b	0.91 a	9.02 a	4.4 a

[1] Values within a column followed by the same letter are not significantly different at the 0.05 probability level

Additional data was collected to determine the number of “loose” seedlings at Stephenville. “Loose” seedlings were those that were poorly anchored to the soil, caused by seedlings being held to the soil by only the primary root and in some cases one additional adventitious root. There was a significant genotype effect for this phenomenon, with the following percentages of poorly anchored seedlings: LC-3 14%, EC-3 38%, and Alamo 31% (p=0.05). A complicating factor in this series of experiments is that seed mass of EC-3 and LC-3 was inadvertently increased by the selection protocol (Elbersen et al. 1999). Values for seed mass [mg per 100 seed)] were Alamo (67), LC-3 (75), and EC-3 (76). Also, because only vigorous seedlings were measured and saved in developing the cycle 3 populations, it is possible that we also inadvertently selected for seedling vigor in EC-3 and LC-3. Observations supporting this possibility were made for kleingrass by Young and Tischler (1994).

Elberson et al. (1999) unequivocally demonstrated that selection for crown node placement in the low light system also modifies crown node placement in the field. Because rainfall was timely in 1996, Elberson et al. (1999) did not observe an effect of crown node placement on seedling survival and establishment, as would be expected in drier years. However, their data on "loose" seedlings support the hypothesis that lower crown node placement aids in seedling establishment.

Because mass selection was used to develop the EC-3 and LC-3 populations, (and the grasses are outcrossing and self-sterile), no information can be obtained concerning inheritance of crown node placement. To address this question, we used sorghum inbred lines and their hybrids in several experiments to quantify parental and hybrid crown node placement (Tischler, Voigt and Monk 1997). Results of this study demonstrated that heterosis was not observed for crown node placement in commercial sorghum hybrids, although seedling stage heterosis for other characteristics is quite apparent (Table 3).

Table 3. Mesocotyl and shoot length of three groups of sorghum inbreds and their hybrids in low light.

Entry	Mesocotyl Length	Shoot Length
	--------------------------------cm	--------------------------------------
Group 1		
Atx 399 (Inbred)	2.8 c[1]	8.4 c
RTx2783 (Inbred)	3.2 a	9.3 b
Hybrid	3.0 b	10.0 a
Group 2		
ATx2752 (Inbred)	2.9 a	8.2 b
RTx 430 (Inbred)	1.9 c	7.0 c
Hybrid	2.7 b	8.6 a
Group 3		
ATx399 (Inbred)	3.0 a	8.1 b
RTx430 (Inbred)	1.9 b	7.0 c
Hybrid	3.0 a	10.2 a

[1] Values in a column and group followed by the same lower case level are not significantly different at the 0.05 probability level.

Although heterosis for shoot length was observed in each of the three groups, mesocotyl length never exceeded the high parent value. This indicates that factors controlling mesocotyl length are under stringent genetic control, to prevent genetic interactions (heterosis) which could negatively impact seedling establishment.

Conclusions

Experiments described here indicate that selection for crown node placement under low, continuous light modifies the photomorphogenic responses of two species of *Panicum* under low light, and in the case of switchgrass, under field conditions. We expect analogous field responses for kleingrass. This selection system is economical while not being labor intensive (Tischler and Voigt 1993). We advocate the use of this system to improve establishment of other warm season grasses.

At the present time, we are producing seed from cycle one EC and LC plants of sideoats grama. The observations of Olmsted (1941) and our own observations (Tischler et al. 1997) suggest that crown node placement in this species is detrimental to seedling establishment. In general, seedling establishment characteristics of native prairie grasses need to be studied in more detail. Seedling photomorphological traits have reached equilibrium in climax stands of vegetation. Prairie restoration projects often take place on disturbed sites, or even on clean till sites where conversion of marginal farmland to prairie is a management objective. Perhaps different suites of photomorphological characteristics would be desirable under such clean seedbed situations. The development of EC and LC populations of sideoats grama will allow us to determine establishment characteristics of the populations on sites ranging from dense native prairie with gaps (or safe sites) to clean till prairie restoration scenarios. The current interest in converting marginal farmland to prairie underscores the importance of developing genetic and other techniques to facilitate establishment of native grasses.

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Restoration of an Indigenous Serpentine Grassland and Oak Savanna Ecosystem in Maryland

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Abstract

Serpentine soils are derived from serpentinite, a hydrated ultramafic rock. In eastern North America, serpentinite is distributed in a discontinuous band from Newfoundland, Canada to Alabama, USA. In the eastern USA, more than 90% of extant, native serpentine vegetation occurs in Maryland and Pennsylvania. Serpentine vegetation in Maryland and Pennsylvania evolved under conditions of severe nutrient stress, summer drought, and frequent and widespread AmerIndian fires. These ecological factors contributed to the maintenance of expansive C_4 grassland and savanna communities until AmerIndian extirpation *circa* 1730. The term "barrens" was used by settlers in the late 1600s and early 1700s to refer to the lack or paucity of timber-size trees on the serpentine outcrops. Between 1750 and the early 1900s, livestock grazing and selective clearing of woody plants inhibited afforestation of many outcrops, while ungrazed barrens became forested. Today, very little grassland and oak savanna remain in Maryland and Pennsylvania, and the term barrens is sometimes confusingly used to refer to openings that have not yet become forested. On the largest serpentine outcrop in the eastern United States, Soldiers Delight (700-800 acres), more than half of the indigenous vegetation has been invaded by Virginia pine [*Pinus virginiana* Mill.] and greenbriar [*Smilax sp.]* since the removal of livestock by the 1930s. Once the rapid rate of conifer expansion was recognized, a research program was initiated in 1989 to examine the response of indigenous vegetation to conifer clearing-and-prescribed burning as well as to clearing only. This paper will focus on the results of this ongoing research and its incorporation into an ecosystem restoration strategy.

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Vegetated Erosion Control Mats for Site Stabilization

Martin van der Grinten and Linda L. Gregory[1]

Introduction

Erosion control mats have been utilized effectively for stabilizing erosion-prone slopes allowing the seed mix to become established. Over time, the mats biodegrade, and the established vegetation stabilizes the soil from erosion.

The technique has some limitations on sites where the disturbance is created by high-energy water flows or from concentrated foot traffic. At Acadia National Park, one of the most heavily visited Parks, the problem exists in stabilizing and vegetating drainage ditches that experience high water flows from concentrated rainstorms. Erosion control mats have been utilized to stabilize the soil, but the seeded erosion control mix may fail to establish. This is due to a combination of the flowing water washing seed from the site, late seeding dates, and environmental limitations of the site.

To overcome these factors, a technique was proposed to grow the erosion control vegetation directly into the erosion control mat in a nursery setting. Once the vegetation is established, this erosion control mat sod would be transported to the site, rolled out and tacked down with pins. The site would benefit with immediate erosion control provided by the mat and with the vegetation immediately being able to continue growing and send down roots, thereby stabilizing the site. We saw a potential use by Acadia National Park to help stabilize the critical area sites.

Preliminary Study

The types of erosion control mats available on the commercial market were reviewed to determine their merits. An initial test was conducted at the USDA, Natural Resources Conservation Service, Big Flats Plant Materials Center (PMC), using two types of matting that had promise, including: (1) Bon Terra's Bogmat (100% bio-degradable coir fiber mat 2 inch thick) and (2) Bon Terra HP90 (100% bio-degradable coir fiber mat ½ inch thick). A plastic fiber mat of ½ inch thickness could have been used, but we preferred to use a biodegradable mat in the national park.

At the PMC, seeds of grasses and forbs were sown onto both the Bog Mat and HP90 mat. The mats were spread out over black plastic on greenhouse benches and then various depths of greenhouse potting media (Metro-Mix 360) were spread over the mats. Seeds were spread, and a light covering of potting media applied. The best results were obtained with the HP90 (½ inch thick coir fiber mat) utilizing approximately ½ inch potting soil over the mat then seeded with red fescue [*Festuca rubra* L]. The two inch thick mat did not perform well in the methods we followed. The growing media tended to settle/subside into the fibrous mat after being watered, so a vibration technique had to be refined during applications. Various grasses and forbs were tested with limited success.

The HP90 with red fescue provided a solid, well rolled "carpet" in a few months. In late summer, three-foot sections of the vegetated mats were placed in drainage ditches along the Carriage Road near Eagle Lake, in Acadia National Park. We wanted to be sure the grass roots would grow into the soil and hold the mats in place, especially under high water flows. Monitoring continued for a year with the mats successfully surviving the winters and anchoring to the soil to withstand the spring and summer run-off waters. With this success, it was decided to test this technique on a larger scale at various sites in the park.

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Field Trials

Growing the vegetated mats in a nursery setting was relatively simple. To facilitate the ease in handling the potting media, a frame 4 feet wide and 66 feet long, was constructed of ½ inch x 4 inch lumber. Weed barrier mat was placed inside the frame, and the erosion control mat (4 ft x 66 ft) then rolled out. Greenhouse potting media was spread over the mat to a one-inch thickness (after being watered, the media settled to a ½ inch final thickness). A wood board, cut to the proper depth that rests on the frame can be pulled along as the potting media was placed, to create uniform depth. The grass seed was spread over the media. Red fescue was seeded at 18 lbs acre^{-1}. A light covering of potting media was hand spread and watered. During the summer months, the mats were kept moist and an application of 15-15-15 fertilizer applied. After 3 months, the mats had a solid stand of grass with an extensive root system into the coir fiber mat.

In mid-September, we cut 10 ft lengths of the vegetated erosion control mats, rolled them up and transported them to Acadia National Park. Seven sites were selected in the park that included two drainage ditch sites along Carriage Road at Eagle Lake that have concentrated water flows: two drainage ditch sites on Carriage Road at Bubble Pond, one site near spillway at Jordon Pond which was shaded and can have high water flows in major storms, and two sites along the footpath near Otter Point (near cliffs by the Atlantic Ocean).

The park personnel placed of the vegetated erosion control mats. First, a two inch layer of topsoil was spread on all the sites except at Jordan Pond. Then the 10-foot rolls of vegetated erosion control mats were rolled out and tacked down using standard steel pins. When placing two mats together, they were overlapped as you would shingles on a roof. The upper ends of the mats were tacked securely to prevent any under-cutting from the flowing waters.

The installation at all seven sites went quickly and easily. It should be noted that the weight of the 10 foot lengths was the limit for two people to handle without mechanical equipment. The extensive root system of the grass held everything together to maintain the physical structure of the growing media on the mats, and the mats held up well during the transport.

Results

The sites have been maintained for two years during which time there have been both occasions for high water flows and periods of drought. At all sites, the vegetation has survived with the roots growing well into the soil. In the high flow drainage ditches along the Carriage Road at Eagle Lake, one of the mats started to tear loose at upper edge losing some of the vegetation. The mats placed along the path at Otter Cliffs have done well, withstanding foot traffic for two summer seasons. At Jordon Pond, the mats have remained in place with concentrated flows of water in the spillway area.

Conclusion

The technique of growing vegetation on erosion control mats in a nursery setting and then installing them on highly erodible sites is a viable erosion control revegetation system. For less than $2.00 per linear foot for a four-foot wide coir fiber mat, a vegetated mat can be produced that will effectively stabilize the soil and provide instant erosion control. This system was utilized in Acadia National Park in a number of situations including stabilizing water drainages and steep slopes and for revegetating critical areas and hiking trails. The installation of the mats was done by park personnel with immediate visual and site stabilization benefits. Further studies are needed to determine how forbs can be incorporated successfully into the seed mixes.

This system can be utilized at any site where establishing permanent vegetation is difficult due to adverse human or environmental factors. The vegetated erosion control mat system is a simple method that can be used to provide immediate site stabilization. Trade names are used solely to provide specific information and should not be considered a recommendation or endorsement by the USDA-NRCS or the USDI-NPS.

Native Plants for National Parks

Martin van der Grinten, Judy Hazen Connery, Linda L. Gregory and John Dickerson[1]

Ensuring the integrity of vegetative ecosystems within National Parks is an increasing concern for the National Park Service. In recent years, the use of native plant materials for revegetation projects in Parks has received increased interest. Construction, maintenance, and visitor use activities have resulted in the disturbance of soil and vegetation. To maintain natural conditions in Parks, resource managers face the challenges of controlling erosion by blending revegetated areas with the existing landscape while maintaining genetic integrity of the flora and preventing the introduction of exotic species.

The National Park Service is also concerned with the preservation of threatened or endangered species and with using locally native plant materials to perpetuate or recreate period plantings at historic sites.

The USDA-Natural Resources Conservation Service (NRCS) Plant Materials Program (PMP) and the USDI-National Park Service (NPS) developed a cooperative agreement to share technical expertise and develop native plants for use in Park revegetation programs.

Through this agreement, the NRCS-PMP can be used to propagate ecotypes of native grasses, wildflowers, shrubs and trees for individual National Parks and historic sites.

The NRCS maintains 26 Plant Material Centers (PMC) throughout the United States including Alaska and Hawaii. These centers have been developing plant materials for conservation programs since the 1930’s. Each center is located to take advantage of the characteristics of soil, climate and topography common to certain parts of the country. The NRCS program has screened a large number of species and has developed technologies used in revegetation work. Each center has the seed cleaning and plant propagating facilities to handle a wide variety of different species and produce seeds and transplants to high quality standards.

At the beginning of a project under the cooperative agreement, the PMC staff works with NPS Park resource specialists at an individual Park to identify their needs. These include a list of plant species, amount of plant materials requested, and projected planting dates. Seeds or plants are then collected in the Park and sent to a nearby plant materials center. At the center, the seeds or plants are reproduced, ensuring that the original genetic characteristics are preserved by isolating the seed production fields. When the Park is preparing to initiate their revegetation work, the seed and transplants are shipped to them to re-establish the native plant communities. Staffs from both the Park and the PMC work together to ensure good survival through proper methods of planting and seeding and placarding with signs to prevent trampling of plants by Park visitors.

The NRCS, Big Flats Plant Materials Center is currently cooperating with Acadia National Park in Maine. Species are propagated to revegetate areas disturbed during roadway and facilities construction in the Park. This work at Acadia National Park involves over 25 species of grasses, forbs, shrubs, and trees. The activities have focused on seed and plant collections in the Park, establishing seed increase fields and propagating plants, seed processing and conditioning ,and delivering plant materials back to the Park. Numerous sites and roadway shoulders have been revegetated by these seeds and plants with excellent survival. The good cooperation and coordination of the Park’s resources management staff and the maintenance staff have ensured proper planting and maintenance of the revegetated sites. Through their efforts, the Park has met the challenges of controlling erosion and stabilizing sites with native plants, blending revegetated sites with existing landscapes, and maintaining the genetic integrity of the plant ecosystems.

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Converting Tall Fescue Grasslands to Native Warm-Season Grasses

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Tall fescue [*Festuca arundinacea* Schreb.] has been planted for hay, pasture, turfgrass, surface mining reclamation, and revegetation of Conservation Reserve Program (CRP) lands on more than 14 million hectares in the United States (Burns and Chamblee 1979; Ball et al. 1993). Over 90% of this tall fescue is infected with a fungal endophyte [*Neotyphodium coenophialum* (Morgan-Jones & Gams) Glenn, Bacon & Hanlin] that forms a symbiotic relationship with tall fescue (Bacon and Siegel 1988), making the tall fescue more competitive, increasing its ability to survive, and making it very difficult to kill. Tall fescue has been shown to affect the nutritional ecology of songbirds and Canada geese (Conover and Messmer 1996a; Conover and Messmer 1996b) and these grasslands do not provide quality habitat for northern bobwhite quail and cottontail rabbits because they form dense monocultures with low botanical diversity, lack sufficient bare ground, and have poor vertical structure (Barnes et al. 1995).

Habitat manipulation and disturbance improves tall fescue-dominated grasslands by converting these fields into habitat more suitable for wildlife (Washburn et al. 2000). A preliminary disturbance study evaluated prescribed burning, herbicide application, and disking. The results showed the most effective treatment for eliminating tall fescue was a spring glyphosate (product name Round-Up™) application (Madison et al. 1995). Unfortunately, tall fescue is difficult to kill (Defelice and Henning 1990), and habitat disturbances (e.g. burning, herbicide application, or disking) provide short-term tall fescue control (Madison et al. 1995). Killing the tall fescue sod and seeding native grass mixtures is a more effective, long-term solution (Washburn et al. 2000) and provides better wildlife habitat, quality hay, and summer forage for domestic livestock.

In the past, native warm-season grasses (NWSG) have developed a reputation for being difficult to establish because they require special seeding equipment, took three to five years to become fully established, and the seed was expensive. Recent advances in herbicide technology, increased availability of NWSG seed, and increased access to seeding equipment capable of planting NWSG has increased the amount of NWSG seeded. More importantly, NWSG can now be successfully established in one growing season (Washburn et al. 1999).

During the past three years our research program has focused on determining effective methods of killing tall fescue with herbicides and replacing fescue sod with NWSGs. This paper summarizes the results of these experiments and will challenge many of the preconceived ideas about the difficulty of killing tall fescue and establishing NWSG. We also want to provide recommendations to managers who desire to establish NWSG.

Methods

All experiments were conducted in tall fescue-dominated fields located in several Kentucky physiographic regions. Study plots were established in a range of soil types, drainage types, and fertility levels. Soils on the various study sites included loams, silt loams, silty clay loams, and flaggy silty clays (Washburn et al. 1999, Washburn and Barnes 2000a, Washburn and Barnes 2000b, Washburn et al. 2000). Soils ranged from shallow to very deep, had slow to moderately rapid permeability, were somewhat poorly drained to well-drained, and were low to moderately high in natural fertility. Sites ranged from flat (0-2% grade) to steeply sloping (15-20% grade). The fields were primarily tall fescue monocultures (Barnes et al. 1995) with a few other plant species such as goldenrods [*Solidago* spp.], horse nettle [*Solanum carolinense* L.], and purple-top grass [*Tridens flavus* (L.) Hitchc.] were also present.

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Several studies were designed to evaluate the efficacy of single spring or fall herbicide applications or a combination of imazapic (product name Plateau™) plus glyphosate (product name Round-Up PRO™) tank mixtures. These were applied during four different tall fescue growth stages (spring vegetative growth stage, boot stage, summer dormancy stage, and fall vegetative growth stage) and evaluated two months after treatment and the following growing season (Table 1).

Table 1. Herbicides and herbicide mixtures evaluated for efficacy in killing tall fescue in field experiments conducted during 1996-1998 in Kentucky.

Herbicide(s)	Rate (oz. acre^{-1})	Rate (kg ai ha^{-1})	Application Timing
Glyphosate	64	2.24	Spring Growth or Fall Growth Stage
Imazapic[1]	12	0.21	Spring Growth, Boot Stage, Summer Dormancy, or Fall Growth Stage
Imazapic[1] plus glyphosate	12 + 16	0.21+ 0.56	Spring Growth, Boot Stage, Summer Dormancy, or Fall Growth Stage
Imazapic[1] plus glyphosate	12 + 32	0.21+ 1.12	Spring Growth, Boot Stage, Summer Dormancy, or Fall Growth Stage

[1] Surfactant (Sun-It II™) at 1 quart acre^{-1} and 28-0-0 liquid fertilizer at 1 quart acre^{-1} were included with all imazapic applications.

Three field experiments were completed to meet the objective of establishing NWSG in fescue sod during the spring or fall (Table 2). Fields were burned in March prior to herbicide applications to remove residual standing crop biomass. Herbicides were applied in April using an ATV-mounted sprayer equipped with flat fan nozzles. NWSG were seeded in May/June using a Truax™ or Tye™ no-till drill. Indiangrass [*Sorghastrum nutans* (L.) Nash], big bluestem [*Andropogon gerardii* Vitman], and little bluestem [*Schizachyrium scoparium* (Michx.) Nash] were planted in pure stands or as part of a NWSG mixture at a rate of 6 lbs. PLS acre^{-1}, a rate recommended for wildlife plantings (Capel 1995). Post-emergence imazapic applications (Table 2) were applied when post-planting vegetation reached 10-12 inches in height during the initial growing season (July - September) to some treatment combinations. Tall fescue control, NWSG establishment, and resulting habitat characteristics for wildlife were evaluated by estimating plant species coverage in ten 1-m^2 herbaceous sampling plots in each treatment plot during the first two or three growing seasons following treatment application (Bonham 1989).

A further experiment was conducted to evaluate current CRP label rates. We evaluated treatments that utilized 4 oz. acre^{-1} of imazapic applied pre-emergence, a tank mixture of glyphosate and imazapic (4 oz. acre^{-1}), or applying a glyphosate application followed by 4 oz. acre^{-1} of imazapic applied at the time of planting (Table 2). Because imazapic is relatively expensive and high rates are best for killing fescue (Washburn et al. 1999), we designed an experiment to evaluate using imazapic plus 2,4-D Amine for controlling weeds using conventional tillage prior to seeding. Study areas were deep-moldboard plowed, disked, and cultipacked to kill the tall fescue sod and prepare a firm seedbed. NWSG (Indiangrass, big bluestem, and little bluestem) and four native forbs (purple coneflower [*Echinacea purpurea* (L.) Moench], lance-leaved coreopsis [*Coreopsis lanceolata* L.], Illinois bundleflower [*Desmanthus illinoensis* (Michx.) MacMill. ex B. L. Rob. & Fernald], and purple prairie clover [*Dalea purpurea* Vent.] were handseeded in pure stands at 6 lbs. PLS acre^{-1}, followed by cultipacking. Herbicides (4-12 oz. acre^{-1} of imazapic alone and in combination with an equal amount of 2,4-D Amine) were applied pre-emergence (at planting) or post-emergence (at the 4-6 leaf stage) to evaluate their efficacy for weed control and assistance in NWSG establishment. Density (number of seedlings m^{-2}) of native grass and forb plants was determined during the initial two growing seasons.

Table 2. Treatments tested for efficacy of converting tall fescue to native warm-season grasses during three experiments conducted in Kentucky from 1996 - 1999.

Prescribed burn	Pre-emergence herbicide	Time of Planting	Post-emergence herbicide
None	Glyphosate[1]	Spring	None
Spring	Glyphosate[1]	Spring	None
Spring	Glyphosate[1]	Spring	8 oz. Imazapic[2]
Spring	Glyphosate[1]	Spring	12 oz.Imazapic[2]
None	Glyphosate[1]	Fall	None
Fall[3]	Glyphosate[1]	Fall	None
Fall[3]	Glyphosate[1]	Fall	8 oz. Imazapic[2]
Fall[3]	Glyphosate[1]	Fall	12 oz. Imazapic[2]
Spring	4 oz. Imazapic[4]	Spring	None
Spring	8 oz. Imazapic[4]	Spring	None
Spring	12 oz. Imazapic[4]	Spring	None
Spring	12 oz. Imazapic[4]	Spring	8 oz. Imazapic[2]
Spring	12 oz. Imazapic[4]	Spring	12 oz. Imazapic[2]
Fall[3]	12 oz. Imazapic[4]	Fall	None
Fall[3]	12 oz. Imazapic[4]	Fall	8 oz. Imazapic[2]
Fall[3]	12 oz. Imazapic[4]	Fall	12 oz. Imazapic[2]
Spring	Glyphosate plus 4 oz. Imazapic[4]	Spring	None
Spring	Glyphosate	Spring	4 oz. Imazapic[4] (At planting)[5]

[1] Glyphosate was applied at a rate of 2 quarts acre^{-1}.
[2] Post-emergence herbicides were applied during the initial growing season.
[3] Pre-emergence herbicides were applied prior to prescribed burns.
[4] Surfactant (Methylated Soybean Oil) at 1 quart acre^{-1} and 28-0-0 liquid fertilizer at 1 quart acre^{-1} were included with the imazapic application.
[5] The imazapic was applied the same day as the seed was planted

The tolerance of many native forbs and legumes to various rates of imazapic is currently unknown. Determining the tolerance of native species to imazapic may increase the number of native wildflowers appropriate for inclusion in NWSG mixtures. We implemented a greenhouse study to examine the effects of pre-emergence imazapic applications on the germination and growth of seedlings of 2 native grasses, 3 native legumes, and 11 native forbs. Imazapic was applied pre-emergence at a rate of 0, 1, 2, and 4 oz. acre^{-1} to soil containing seed from each species. The total number of seedlings for each plant species was determined for each imazapic level and compared using chi-squared analyses.

The addition of fertilizer to first-year plantings may aid in the establishment of NWSGs. During 1998, we conducted an experiment to determine if NWSG coverage and plant height were increased by the addition of fertilizer during the initial growing season. The study area was burned in March, an herbicide tank mixture (imazapic @ 12 oz. acre^{-1} plus glyphosate @ 2 quarts acre^{-1}) was applied during April, and a NWSG mixture was no-till seeded @ 6 lbs. PLS acre^{-1} during early May. Four fertilizer treatments (Control, Water only, 25 lbs. 10-10-10 acre^{-1}, and 50 lbs. 10-10-10 acre^{-1}) were applied using a handsprayer six weeks after seeding. Eight weeks after fertilizer application, NWSG cover (%), NWSG seedling density (number ft^{-2}), and seedlings height (inches) were determined in each treatment.

In addition to examining pre-emergence use of imazapic for weed control, we also wanted to explore how imazapic could be used to "release" NWSG stands that were "struggling" from weed competition. The NWSG stands we examined were previously planted (2 or more years old) or were naturally occurring NWSG on Kentucky barrens. We applied imazapic at 12 oz. acre^{-1} post-emergence to 6 glyphosate treatments at 3 study sites during April of 1998. The glyphosate treatments had less than 30% NWSG cover prior to the imazapic application. NWSG cover (%) was determined at the end of the 1998-growing season. Also, we determined the effectiveness of prescribed burning and imazapic applications for tall fescue control and increasing NWSG coverage in native barrens. We designed an experiment and implemented combinations of prescribed burning and post-emergence applications of imazapic (4-12 oz. acre^{-1}), with and without non-ionic surfactant (Aquagene 90™) during 1999 at the Raymond Athey Barrens in Kentucky. Tall fescue cover (%) and NWSG cover (%) were determined in each treatment plot during the fall of 1999.

Results and Discussion

Tall Fescue Control -- Glyphosate and imazapic can be used to kill existing tall fescue sod. The best treatment to control tall fescue is a spring prescribed burn followed by a single application of glyphosate at 2 quarts acre^{-1} (2.24 kg active ingredient (ai) ha^{-1}) or imazapic at 12 oz. acre^{-1} (0.21 kg ai ha^{-1}) in April or May (Table 3; Washburn et al. 1999, Washburn et al. 2000). Imazapic applications should include surfactant (i.e. methylated soybean oil) at 1 quart acre^{-1} and 28-0-0 liquid fertilizer at 1 qt acre^{-1}. These two treatment combinations effectively reduced or eliminated tall fescue at all study sites (Washburn et al. 1999, B. E. Washburn, University of Kentucky, unpubl. data). The prescribed burn removes the heavy litter layer and stimulates tall fescue growth, thus increasing herbicide efficacy and plant-herbicide contact. Herbicides should be applied when the tall fescue reaches a height of 6-8 inches.

Although spring herbicide applications appeared to be the most effective, our research examining the effects of application timing on tall fescue control demonstrated that imazapic will effectively kill tall fescue at any physiological stage (Washburn and Barnes 2000a). Imazapic was more effective than glyphosate for totally eliminating tall fescue from treatment plots throughout our experiments. Imazapic has a 40-45 day soil half-life and plant uptake of imazapic occurs both through the leaf surfaces and the roots (Shaner and O'Conner 1991). Glyphosate is a foliar-acting herbicide with no residual effect (Grossbard and Atkinson 1985). The additional plant uptake via the soil-root pathway may account for the greater efficacy of imazapic in eradicating fescue.

NWSG Establishment -- Our results indicate that a spring prescribed burn followed by a pre-emergence imazapic application at 12 oz. acre^{-1} (0.21 kg ai ha^{-1}) and no-till seeding NWSG is the most effective method for establishing NWSG directly into tall fescue sod (Table 4; Washburn et al. 2000). Moreover, this treatment combination resulted in established stands of NWSG during the first growing season at most study sites (Washburn et al. 1999, B. E. Washburn, University of Kentucky, unpubl. data). In addition to providing tall fescue control, applying imazapic pre-emergence provides weed control and reduces plant competition during the initial growing season, allowing planted NWSG seed to germinate and establish.

Table 3. Percent tall fescue remaining at 2-3 months post-treatment of imazapic and imazapic plus glyphosate tank mixtures.[1]

Season of Application	Imazapic 12 oz. acre^{-1}	Imazapic 12 oz. acre^{-1} + Glyphosate 1 pint acre^{-1}	Imazapic 12 oz. acre^{-1} + Glyphosate 1 quart acre^{-1}
Spring Vegetative Growth	0.8[2]	0.5	0.1
Boot Stage	0.8	0.4	0.6
Summer Dormancy	0.7	0.3	0.1
Fall Vegetative Growth	1.1	0.1	0.1

[1] Data from Washburn and Barnes (2000a).
[2] No difference (p<0.05) among means using Fisher's protected LSD test.

Spring treatments that included a pre-emergence glyphosate application were less successful in establishing NWSG. High amounts of annual and perennial weeds were present (due to a lack of weed control) and apparently resulted in severe competition (Bragg and Sutherland 1989, Schramm 1990) and deterred NWSG establishment. Similarly, high levels of residual tall fescue and a lack of weed control from pre-emergence herbicides applied in the fall (prior to the growing season) resulted in severe weed interference and deterred NWSG establishment in the fall treatments. Fall seedings generally failed which has been previously reported (Gaynor and Meyer 1999).

Table 4. Percent NWSG in no-till treatments cover after one or two growing seasons at 10 study sites in Kentucky during 1997-1998.[1]

Treatment	Year 1	Year 2
	------------- *NWSG (%)*	-----------
Spring Burn - Glyphosate - Seed NWSG	0.4	11
Spring Burn - Imazapic - Seed NWSG	27	60
Spring Burn - Glyphosate - Seed NWSG - 8 oz./ac POST Imazapic	-----[2]	18
Spring Burn - Glyphosate - Seed NWSG - 12 oz./ac POST Imazapic	-----	19
Spring Burn - imazapic - Seed NWSG - 8 oz./ac POST Imazapic	-----	53
Spring Burn - Imazapic - Seed NWSG- 12 oz./ac POST Imazapic	-----	63

[1] Data from Washburn et al. (1999) and Washburn et al. (2000).
[2] Not evaluated because POST Imazapic was applied at the end of year 1.

We recommend a spring burn followed by a pre-emergence application of imazapic at 12 oz. acre^{-1} and no-till seeding to establish Indiangrass, big bluestem, and little bluestem, both in pure stands and in mixtures. A seeding rate of 6 lbs. PLS acre^{-1} is appropriate for establishing NWSG for wildlife habitat. However, seeding high rates (8-12 lbs. PLS acre^{-1}) would be more appropriate for NWSG stands being established for hay forage and/or livestock grazing. Switchgrass, sideoats grama [*Bouteloua curtipendula* (Michx.) Torrey], and Eastern gamagrass [*Tripsacum* *dactyloides* (L.) L.] are intolerant to this level of imazapic and this treatment is not recommended for establishing these species (Vollmer 1998).

Table 5. NWSG seedling density (no. m^{-2}) in treatments for CRP lands at the end of the first growing season at 3 study sites in Kentucky during 1999.

Treatment	TLWMA		YWMA		Hardin Co.	
	no. m^{-2}	*% Cover*	*no. m^{-2}*	*% Cover*	*no. m^{-2}*	*% Cover*
Big Bluestem						
Imazapic 4 oz.	4.3	9	1.1	1	1.1	1
Glyphosate + Imazapic 4 oz.	6.5	15	0	9	2.2	4
Glyphosate + 4 oz. Imazapic At Planting	43.0	79	7.5	10	5.4	9
Indiangrass						
Imazapic 4 oz.	1.1	1	0	1	0	0
Glyphosate + Imazapic 4 oz.	16.1	18	1.1	3	1.1	1
Glyphosate + 4 oz. Imazapic At Planting	23.7	46	9.7	16	5.4	4
Little Bluestem						
Imazapic 4 oz.	2.2	4	0	2	0	0
Glyphosate + Imazapic 4 oz.	9.7	20	0	4	0	1
Glyphosate + 4 oz. Imazapic At Planting	10.8	21	9.7	11	4.3	4

For NWSG establishment on CRP lands, our research indicates that spring burning followed by a pre-emergence application of glyphosate at 2 quarts $acre^{-1}$ (2.24 kg ai ha^{-1}), no-till seeding, and applying imazapic at 4 oz. $acre^{-1}$ (0.07 kg ai ha^{-1}) at the time of planting is a very effective treatment (B. E. Washburn, University of Kentucky, unpubl. data). This treatment combination allows the glyphosate to kill the tall fescue and the imazapic to provide weed control for germinating and establishing NWSG plants (Table 5). In contrast, the treatments utilizing imazapic at 4 oz. $acre^{-1}$ or a glyphosate and imazapic tank mixture provided tall fescue control but did not provide sufficient weed control to allow NWSG establishment. Conventional tillage provides an alternative method of tall fescue conversion and NWSG establishment on acreage not susceptible to severe erosion problems. Indiangrass, big bluestem, and little bluestem were successfully established in one growing season using conventional tillage, handseeding or drilling NWSG seed, and applying imazapic to provide weed control (Table 6; Washburn and Barnes 2000b). We recommend applying a pre-emergence application of imazapic at 4 oz. $acre^{-1}$ (0.07 kg ai ha^{-1}) at the time of planting.

Table 6. Grass seedling density (number m^{-2}) 8 weeks after planting and pre-emergence herbicide applications.

Treatment	Big Bluestem	Indiangrass	Little Bluestem
Control	7.0*[1]	7.2*	4.1*
Imazapic 4 oz.	20.4	19.1	16.8
Imazapic 8 oz.	14.7	20.7	13.9
Imazapic 12 oz.	16.4	14.4	17.7
Imazapic 4 oz. + 2,4-D 4 oz.	12.8	16.1	16.0
Imazapic 8 oz. + 2,4-D 8 oz.	13.3	14.6	16.9
Imazapic 12 oz. + 2,4-D 12 oz.	11.2	12.1	18.6

[1] Control was different (p<0.05) from herbicided treatments using Fisher's protected LSD test.

Forbs -- Many native forbs are intolerant to high rates of imazapic (Vollmer 1998). Although the tolerance of many species is unknown, our research indicates blackeyed susans [*Rudbeckia hirta* L.], lance-leaved coreopsis, partridge pea [*Chamaecrista fasciculata* (Michx.) Greene], Illinois bundleflower, purple prairie clover, and ironweed [*Vernonia gigantea* (Walter) Trel. ex Branner & Coville] are tolerant to imazapic at 12 oz. $acre^{-1}$ and are appropriate for inclusion in NWSG mixtures. If plant species intolerant to imazapic are desired, we recommend interseeding those species into the establishing NWSG stand during the second growing season.

Two legumes and 7 forbs were tolerant of a pre-emergence application of imazapic at 4 oz. $acre^{-1}$ (Table 7). Although the pre-emergence application of imazapic did not reduce the number of seedlings (germination rate), the growth and development of plant seedlings in the treatments that received the higher rates of imazapic were slower compared to the controls. The number of seedlings in the treatment cells receiving imazapic at 2 or 4 oz. $acre^{-1}$ was significantly lower for the 2 grasses, 1 legume, and 4 forbs. The 4 oz. $acre^{-1}$ imazapic application reduced the number of emerging seedlings by 25-60% compared to the controls (Table 7).

Consequently, our results suggest the 9 species tolerant to 4 oz. $acre^{-1}$ of imazapic may be appropriate for inclusion in NWSG mixtures being established with imazapic, whereas those exhibiting no or very little tolerance to imazapic may be species to avoid. However, more field testing and greenhouse studies are needed to determine which other forb and legume species may also be appropriate for inclusion in NWSG mixtures being established using imazapic.

Fertilizer -- The application of fertilizer to an establishing NWSG stand during the initial growing season did not increase NWSG seedlings density or NWSG cover compared to non-fertilized treatments (Table 8). However, the application of fertilizer did increase the average height of planted NWSG seedlings. Our results suggest the application of 25 lbs. of 10-10-10 fertilizer per acre when planted NWSG seedlings are 6-8 inches tall can increase the size of establishing NWSG plants and may increase their chance of survival through the first winter.

We recommend the application of fertilizer only when sufficient weed control is provided by pre-emergence herbicides and no weeds are present. The application of fertilizer to mixed stands of NWSGs and weeds provides much more benefit to the weeds and will result in high amounts of weed coverage and increased competition for the NWSG seedlings.

Table 7. Tolerance of selected grasses, legumes, and forbs to imazapic (0-4 oz. acre^{-1}) and percent reduction in seedling number by 4 oz. acre^{-1} imazapic during a greenhouse study conducted at the University of Kentucky.

Species	Maximum Rate[a] (oz. acre^{-1})	Percent Reduction by 4-oz. acre^{-1}
Grasses		
Prairie cordgrass [*Spartina pectinata* Link]	1[1]	45
Junegrass [*Koeleria macrantha* (Ledeb.) Schult.]	0[1]	35
Legumes		
Roundheaded bushclover [*Lespedeza capitata* Michx.]	4	0
Leadplant [*Amorpha canescens* Pursh]	4	0
Showy Tick Trefoil [*Desmodium canadense* (L.) DC.]	1[1]	40
Forbs		
Butterfly milkweed [*Asclepias tuberosa* L.]	4	0
Rough blazingstar [*Liatris aspera* Michx.]	4	0
Purple coneflower [*Echinacea purpurea* (L.) Moench]	4	0
New England aster [*Aster novae-angliae* L.]	4	0
Heath aster [*Aster ericoides* L.]	1[1]	50
Smooth aster [*Aster laevis* L.]	1[1]	35
Sky Blue aster [*Aster oolentangiensis* Riddell]	4	0
Canada goldenrod [*Solidago canadensis* L.]	1[1]	25
Sweet black-eyed susan [*Rudbeckia subtomentosa* Pursh]	4	0
Brown-eyed susan [*Rudbeckia triloba* L.]	4	0
Wild Bergamot [*Monarda fistulosa* L.]	0[1]	60

[1] Exceeding the maximum rate significantly (p<0.05) reduced the number of germinating seedlings.

Enhancing NWSG Stands -- Our results indicate applying post-emergence imazapic (12 oz ac^{-1}) to "struggling" NWSG during the second or third growing season is highly effective for controlling reinvading tall fescue and enhancing NWSG (Washburn et al. 1999). The number of NWSG plants and percent cover of NWSG increased after imazapic was applied (Table 9). The post-emergence imazapic application apparently decreased competition from annual and perennial weeds, resulting in increased growth of NWSGs. Overall, plant species sensitive to imazapic, such as tall fescue, hairy crabgrass [*Digitaria sanguinalis* (L.) Scop.] and johnsongrass [*Sorghum halepense* (L.) Pers.], were removed by the post-emergence imazapic application. In contrast, species tolerant to imazapic, such as NWSGs, broomsedge bluestem [*Andropogon virginicus* L.], and Kentucky bluegrass [*Poa pratensis* L.], increased considerably due to decreased competition from the removal of dominant "weedy" species.

Table 8. Seedling density, seedling height, and NWSG cover (%) six weeks after application of fertilizer treatments during a field experiment in Kentucky during 1998.

Treatment	Seedling density (number ft^{-2})	NWSG Cover (%)	Seedling Height (inches)
Control	6.3	60.4	14.4*
Water Only	3.7*[1]	46.8*	15.3*
25 lbs.	5.5	62.5	26.9
50 lbs.	6.3	75.8	30.0

[1] Differences (p<0.05) among means using Fisher's protected LSD test.

Table 9. Percent NWSG cover in fall 1998 following a post-emergence application of imazapic at 12 oz. $acre^{-1}$ in April 1998.

Treatment	Fayette	Muhlenberg	Caldwell
Spring Glyphosate	49*[1]	90*	100*
Spring Burn & Spring Glyphosate	82*	100*	100*
Fall Burn & Spring Glyphosate	24	94*	43
Fall Glyphosate	0	25	0
Fall Burn & Fall Glyphosate	2	30	12
Spring Burn & Fall Glyphosate	0	75*	27

[1] Differences (p<0.05) among means using Fisher's protected LSD test.

Post-emergence herbicide applications may be useful for enhancing the quality of native tallgrass prairie ecosystems in Kentucky and other states. Our results indicate that spring burning followed by a post-emergence application of imazapic at 10 oz. $acre^{-1}$ (0.175 kg ai ha^{-1}) with nonionic surfactant at 1 quart $acre^{-1}$ is the most effective treatment for eradicating tall fescue and increasing the coverage of existing NWSG (Table 10). Prescribed burning followed by an imazapic application of 10 oz. $acre^{-1}$, 4 oz. $acre^{-1}$ + NIS, and 8 oz. $acre^{-1}$ + NIS also reduced tall fescue and increased NWSGs. Similarly, if the use of prescribed burning is not an option, we recommend using a single post-emergence application of imazapic at 10 oz. $acre^{-1}$ with nonionic surfactant at 1 quart $acre^{-1}$. Indiangrass, big bluestem, little bluestem, broomsedge bluestem, and tall dropseed [*Sporobolus compositus* (Poir.) Merr.] are NWSG species that responded very well to the imazapic applications in our studies. However, due to the fact that many forb species are intolerant to imazapic or their tolerance is currently unknown, we recommend caution in using imazapic if important, rare, or endangered native forbs are present.

Conclusions

Glyphosate and imazapic are effective tools for eradicating tall fescue. Spring prescribed burning followed by an application of glyphosate at 2 quarts $acre^{-1}$ or an application of imazapic at 12 oz. $acre^{-1}$, surfactant at 1 quart $acre^{-1}$, and 28-0-0 fertilizer at 1 quart $acre^{-1}$ provides effective tall fescue control. Additionally, imazapic will kill tall fescue in any physiological stage.

Table 10. Tall fescue cover (%) and NWSG cover (%) at the end of the initial growing season following burning and herbicide applications at Raymond Athey Barrens in Kentucky during 1999.

Treatment	Tall fescue (%)	NWSG cover (%)
Control	72.0*[1]	14.2*
Burn Only	41.4	15.4*
4 oz. Imazapic	44.4	29.2
8 oz. Imazapic	33.0	33.4
10 oz. Imazapic	22.6	36.4
4 oz. Imazapic + NIS[2]	25.6	35.6
8 oz. Imazapic + NIS[2]	40.4	23.2
10 oz. Imazapic + NIS[2]	8.2	52.4
Burn, 4 oz. Imazapic	13.8	36.2
Burn, 8 oz. Imazapic	13.2	49.8
Burn, 10 oz. Imazapic	4.5	39.8
Burn, 4 oz. Imazapic + NIS[2]	8.0	45.8
Burn, 8 oz. Imazapic + NIS[2]	8.5	42.4
Burn, 10 oz. Imazapic + NIS[2]	3.4	60.4

[1] Control was different ($p<0.05$) from herbicided treatments using Fisher's protected LSD test.
[2] Non-ionic surfactant (Aquagene 90™) was included at a rate of 1 quart acre^{-1}.

Mixed and pure stands of Indiangrass, big bluestem, and little bluestem can be successfully established in one growing season using both no-till and conventional tillage methods and a pre-emergence imazapic application. A rate of 12 oz. acre^{-1} is recommended for no-till situations. This rate kills tall fescue sod and provides sufficient weed control for establishing NWSG seedlings. Under current regulations, the best method for NWSG establishment on CRP acreage is to apply glyphosate at 2 quarts acre^{-1} to kill the tall fescue and 4 oz. acre^{-1} of imazapic at planting to provide weed control. Conventional tillage kills the tall fescue sod, and 4 oz. acre^{-1} of imazapic applied at the time of seeding provides the necessary weed control for NWSG establishment.

Imazapic is also effective in enhancing existing NWSG stands with a significant tall fescue component. Prescribed burning followed by a post-emergence imazapic (10 oz. acre^{-1} plus nonionic surfactant) application is an effective method for eradicating tall fescue and increasing NWSG coverage in previously planted NWSG stands or degraded tallgrass prairie ecosystems.

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Appendix A: Alphabetic List of Common Names of Plants. Common names are as used in this Proceedings. Scientific names are in accordance with GRIN (Germplasm Resources Information Network) the official ARS site for plant names. More information on GRIN can be found at: http://www.ars-grin.gov/npgs/.

Common Name	**Scientific Name**
Alfalfa	Medicago sativa L.
Alsike clover	Trifolium hybridum L.
American beachgrass	Ammophila breviligulata Fernald
Annual ryegrass	Lolium multiflorum Lam.
Arrowfeather	Aristida purpurascens Poir.
Aster	Aster furcatus E.S. Burgess
Autumn olive	Elaeagnus umbellata Thunb.
Barnyard grass	Echinochloa crus-galli (L.) P. Beauv.
Beach sunflower	Helianthus debilis Nutt.
Beaked panicum	Panicum anceps Michx.
Bermuda grass	Cynodon dactylon (L.) Pers.
Blackberry	Rubus sp.
Black medic	Medicago lupulina L.
Blackeyed Susan	Rudbeckia hirta L.
Big bluestem	Andropogon gerardii Vitman
Birdsfoot trefoil	Lotus corniculatus L.
Bitter panic grass	Panicum amarum Elliott var. amarulum (Hitchc. & Chase) P.G. Palmer
Bluebonnets	Lupinus subcarnosus Hook.
Blue grama	Bouteloua gracilis (Kunth) Lag. ex Griffiths
Blue maidencane	Amphicarpum muhlenbergianum (Schult.) Hitchc.
Bush clover	Lespedeza cuneata (Dum. Cours.) G. Don
Bottlebrush grass	Elymus hystrix L.
Broomsedge bluestem	Andropogon virginicus L.
Brown-eyed susan	Rudbeckia triloba L.
Browncane plumegrass	Saccharum brevibarbe (Michx.) Pers.
Bur marigold	Bidens aristosa (Michx.) Britton
Bushy bluestem	Andropogon glomeratus (Walter) Britton et al.
Butterfly milkweed	Asclepias tuberosa L.
Canada bluejoint	Calamagrostis canadensis (Michx.) P. Beauv.
Canada brome	Bromus pubescens Muhl. ex Willd.
Canadian goldenrod	Solidago canadensis L.
Canada wildrye	Elymus canadensis L.
Cardinal Flower	Lobelia cardinalis L.
Carolina jointtail grass	Coelorachis cylindrica (Michx.) Nash
Carostan flaccidgrass	Pennisetum flaccidum Griseb.
Cattail	Typha latifolia L.
Caucasian bluestem	Bothriochloa caucasica (Trin.) C.E. Hubb.
Chewing’s fescue	Festuca rubra var. commutata Gaudin
Chalky bluestem	Andropogon glomeratus (Walter) Britton et al. var. glaucopsis
Clasping coneflower	Dracopis amplexicaulis (Vahl) Cass.
Coastal bermuda grass	Cynodon dactylon (L.) Pers.
Coastal little bluestem	Schizachyrium scoparium subsp. littoralis (Nash) Gandhi & Smeins
Coastal panic grass	Panicum amarum Elliott
Coastal panic grass	Panicum amarum var. amarulum (Hitchc. & Chase) P.G. Palmer
Corn	Zea mays L.
Corn speedwell	Veronica arvensis L.
Costus	Costus allenii Maas

Cotton	Gossypium hirsutum L.
Crabgrass	Digitaria sanguinalis L. Scop.
Crinkled hairgrass	Deschampsia flexuosa (L.) Trin.
Dandelion	Taraxacum officinale Weber ex F. H. Wigg. group
Deertongue	Dichanthelium clandestinum (L.) Gould
Delphinium	Delphinium nelsonii Greene
Dogbane	Apocynum cannabinum L.
Dropseed	Sporobolus indicus var. flaccidus (Roem. & Schult.) Veldkamp
Drummondii phlox	Phlox drummondii Hook.
Dwarf willow	Salix x cottetii Jos. Kern
Eastern hemlock	Tsuga canadensis (L.) Carriere
Eastern gamagrass	Tripsacum dactyloides (L.) L.
English plantain	Plantago lanceolata L.
Espeletia	Espeletia schultzii Wedd.
Fall panicum	Panicum dichotomiflorum Michx.
Field chickweed	Cerastium arvense L.
Flat pea	Lathyrus sylvestris L.
Florida paspalum	Paspalum floridanum Michx.
Foxtail	Setaria spp.
Setaria magna Griseb.	Giant foxtail
Gamagrass	Tripsacum andersonii J.R. Gray
Gamagrass	Tripsacum dactyloides (L.) L.
Gamagrass	Tripsacum floridanum Porter ex Vasey
Gamagrass	Tripsacum maizar Hern.-Xol. & Randolph
Gamagrass	Tripsacum zopilotense Hern.-Xol. & Randolph
Gentianella	Gentianella germanica (Willd.) Borner ex E.F. Warb
Giant foxtail	Setaria faberi R. Herrm.
Giant foxtail	Setaria magna Griseb.
Goldenrods	Solidago spp.
Grape	Vitis sp.
Grass-leaved golden aster	Pityopsis graminifolia (Michx.) Nutt.
Greenbriar	Smilax sp.
Green and yellow foxtails	Setaria spp.
Hairy clover	Lespedeza hirta (L.) Hornem.
Hairy crabgrass	Digitaria sanguinalis (L.) Scop.
Hairy indigo	Indigofera hirsuta L.
Hard fescue	Festuca brevipila R. Tracey
Heath Aster	Aster ericoides L.
Hog peanut	Amphicarpaea bracteata (L.) Fernald
Horse nettle	Solanum carolinense L.
Hypoxis	Hypoxis decumbens L.
Illinois bundleflower	Desmanthus illinoensis (Michx.) MacMill. ex B. L. Rob. & Fernald
Indiangrass	Sorghastrum nutans (L.) Nash
Ipomopsis	Ipomopsis aggregata (Pursh) V. E. Grant
Ironweed	Vernonia gigantea (Walter) Trel. ex Branner & Coville
Japanese honeysuckle	Lonicera japonica Thunb.
Jewel weed	Impatiens capensis Meerb.
Johnsongrass	Sorghum halepense (L.) Pers.
Junegrass	Koeleria macrantha (Ledeb.) Schult.
Kentucky bluegrass	Poa pratensis L.
Kleingrass	Panicum coloratum L.
Knawel	Scleranthus annuus L.
Lambsquaters	Chenopodium album L.
Lance-leaved coreopsis	Coreopsis lanceolata L.
Large crabgrass	Digitaria sanguinalis (L.) Scop.
Leadplant	Amorpha canescens Pursh

Leafy spurge	Euphorbia esula L.
Least hop clover	Trifolium dubium Sibth.
Little barley	Hordeum pusillum Nutt.
Little bluestem	Schizachyrium scoparium (Michx.) Nash
Little bluestem	Schizachyrium scoparium (Michx.) Nash var. scoparium
Little foxtail	Alopecurus carolinianus Walter
Longleaf pine	Pinus palustris Mill.
Lopsided Indiangrass	Sorghastrum secundum (Elliott) Nash
Lyre-leaf Sage	Salvia lyrata L.
Maize	Zea mays L.
Marshhay cordgrass	Spartina patens (Aiton) H.L. Muhl.
Meadow beauty	Rhexia mariana L.
Meadow fescue	Festuca pratensis Huds.
Millet	Pennisetum spp.
Miscanthus	Miscanthus sinensis Andersson
Mouse-eared chickweed	Cerastium arvense L.
Multiflora rose	Rosa multiflora Thunb.
Napier grass	Pennisetum purpureum Schumach.
Natalgrass	Melinis repens (Willd.) Zizka
New England aster	Aster novae-angliae L.
Oats	Avena sativa L.
Old-field cinquefoil	Potentilla simplex Michx.
Orchardgrass	Dactylis glomerata L.
Partridge-pea	Chamaecrista fasciculata (Michx.) Greene
Perennial ryegrass	Lolium perenne L.
Pigweed	Amaranthus viridis L.
Plains coreopsis	Coreopsis tinctoria Nutt.
Plantain	Plantago sp.
Poison ivy	Toxicodendron radicans (L.) Kuntze
Potato	Solanum tuberosum L.
Poverty oatgrass	Danthonia spicata (L.) P. Beauv. ex Roem. & Schult.
Prairie cordgrass	Spartina pectinata Link
Prairie sandreed	Calamovilfa longifolia (Hook.) Scribn.
Prairie three awn	Aristida oligantha Michx.
Purple coneflower	Echinacea purpurea (L.) Moench
Purpleosier willow	Salix purpurea L.
Purpletop	Tridens flavus (L.) Hitchc.
Red clover	Trifolium pratense L.
Red fescue	Festuca rubra L.
Red pine	Pinus resinosa Aiton
Red spruce	Picea rubens Sarg.
Redtop	Agrostis gigantea Roth
Reed canarygrass	Phalaris arundinacea L.
Rice	Oryza sativa L.
Rivercane	Arundinaria gigantea (Walter) Muhl.
River oats	Chasmanthium latifolium (Michx.) H.O. Yates
Round-headed bush clover	Lespedeza angustifolia (Pursh) Elliott
Rough blazingstar	Liatris aspera Michx.
Rush	Juncus effusus L.
Saltmeadow cordgrass	Spartina patens (Aiton) H.L. Muhl.
Sand bluestem	Andropogon hallii Hack.
Sand Dropseed	Sporobolus cryptandrus (Torr.) A. Gray
Sand lovegrass	Eragrostis trichodes (Nutt.) A.W. Wood
Sea oats	Uniola paniculata L.
Sheep fescue	Festuca ovina L.
Sheep sorrel	Rumex acetosella L.

Showy Tick Trefoil	Desmodium canadense (L.) DC.
Sideoats grama	Bouteloua curtipendula (Michx.) Torr.
Sky Blue aster	Aster oolentangiensis Riddell
Slender wildoats	Chasmanthium laxum (L.) H. O. Yates
Smooth aster	Aster laevis L.
Smooth cordgrass	Spartina alterniflora Loisel.
Smooth bromegrass	Bromus inermis Leyss.
Sorghum-sudangrass	Sorghum x drummondii (Nees ex Steud.) Millsp. & Chase
Sorghum	Sorghum bicolor (L.) Moench
Soybeans	Glycine max (L.) Merr.
Stout woodreed	Cinna arundinacea L.
Sugarcane plumegrass	Saccharum giganteum (Walter) Pers.
Sunflower	Helianthus annuus L.
Sweet black-eyed susan	Rudbeckia subtomentosa Pursh
Sweetgrass	Hierochloe odorata (L.) P. Beauv.
Sweet vernal grass	Anthoxanthum odoratum L.
Switchcane	Arundinaria gigantea (Walter) Muhl.
Switchgrass	Panicum virgatum L.
Swamp pink	Helonias bullata L.
Swamp rose-mallow	Hibiscus moscheutos L. subsp. lasiocarpos (Cav.) O.J. Blanchard
Sweetgum	Liquidambar styraciflua L.
Tall dropseed	Sporobolus compositus (Poir.) Merr.
Timothy	Phleum pratense L.
Tall fescue	Festuca arundinacea Schreb.
Velvetgrass	Holcus lanatus L.
Vetch	Vicia spp.
Virginia creeper	Parthenocissus quinquefolia (L.) Planch.
Virginia pine	Pinus virginiana Mill.
Virginia wildrye	Elymus virginicus L.
Wall-rue	Asplenium ruta-muraria L.
Walter’s millet	Echinochloa walteri (Pursh) A. Heller
Weeping lovegrass	Eragrostis curvula (Schrad.) Nees
Western wheatgrass	Pascopyrum smithii (Rydb.) A. Love
Wheat	Triticum aestivum L.
White clover	Trifolium repens L.
Wild Bergamot	Monarda fistulosa L.
Wild indigo	Baptisia tinctoria (L.) R. Br.
Wild onion	Allium sp.
Wiregrass	Aristida beyrichiana Trin. & Rupr.
Yarrow	Achillea millefolium L.
Yellow nutsedge	Cyperus esculentus L.
Yellow sorrel	Oxalis stricta L.

Appendix B. Alphabetic List of Scientific Names. Scientific names are in accordance with the GRIN (Germplasm Resources Information Network) the official ARS site for plant names. More information on GRIN can be found at: http://www.ars-grin.gov/npgs/. Common names are as used in this Proceedings.

Scientific Name	Common Name
Achillea millefolium L.	Yarrow
Agrostis gigantea Roth	Redtop
Allium sp.	Wild onion
Alopecurus carolinianus Walter	Little foxtail
Amaranthus viridis L.	Pigweed
Ammophila breviligulata Fernald	American beachgrass
Amorpha canescens Pursh	Leadplant
Amphicarpaea bracteata (L.) Fernald	Hog peanut
Amphicarpum muhlenbergianum (Schult.) Hitchc.	Blue maidencane
Andropogon gerardii Vitman	Big bluestem
Andropogon glomeratus (Walter) Britton et al.	Bushy bluestem
Andropogon glomeratus (Walter) Britton et al. var. glaucopsis (Elliott) C. Mohr	Chalky bluestem
Andropogon hallii Hack.	Sand bluestem
Andropogon ternarius Michx.	Split beard bluestem
Andropogon virginicus L.	Broomsedge bluestem
Anthoxanthum odoratum L.	Sweet vernal grass
Apocynum cannabinum L.	Dogbane
Aristida beyrichiana Trin. & Rupr.	Wiregrass
Aristida oligantha Michx.	Prairie three awn
Aristida purpurascens Poir.	Arrowfeather
Arundinaria gigantea (Walter) Muhl.	Rivercane or switchcane
Asclepias exaltata L.	
Asclepias tuberosa L.	Butterfly milkweed
Asplenium ruta-muraria L.	Wall-rue
Aster ericoides L.	Heath aster
Aster furcatus E.S. Burgess	Aster
Aster laevis L.	Smooth aster
Aster novae-angliae L.	New England aster
Aster oolentangiensis Riddell	Sky Blue aster
Avena sativa L.	Oats
Baptisia tinctoria (L.) R. Br.	Wild indigo
Bidens aristosa (Michx.) Britton	Bur marigold
Bothriochloa caucasica (Trin.) C.E. Hubb.	Caucasian bluestem
Bouteloua curtipendula (Michx.) Torr.	Sideoats grama
Bouteloua gracilis (Kunth) Lag. ex Griffiths	Blue grama
Bromus pubescens Muhl. ex Willd.	Canada brome
Bromus inermis Leyss.	Smooth bromegrass
Calamagrostis canadensis (Michx.) P. Beauv.	Canada bluejoint
Calamovilfa longifolia (Hook.) Scribn.	Prairie sandreed
Chamaecrista fasciculata (Michx.) Greene	Partridge-pea
Chasmanthium latifolium (Michx.) H.O. Yates	River oats
Chasmanthium laxum (L.) H.O. Yates	Slender wildoats
Chenopodium album L.	Lambsquaters
Cinna arundinacea L.	Stout woodreed
Clarkia tembloriensis Vasek	
Coelorachis cylindrica (Michx.) Nash	Carolina jointtail grass
Coreopsis lanceolata L.	Lance-leaved coreopsis
Coreopsis tinctoria Nutt.	Plains Coreopsis
Costus allenii Maas	Costus

Cerastium arvense L.	Field chickweed
Cynodon dactylon (L.) Pers.	Coastal bermudagrass
Cynodon dactylon (L.) Pers.	Bermudagrass
Cyperus esculentus L.	Yellow nutsedge
Dactylis glomerata L.	Orchardgrass
Danthonia spicata (L.) P. Beauv. ex Roem. & Schult.	Poverty oatgrass
Delphinium nelsonii Greene	Delphinium
Deschampsia flexuosa (L.) Trin.	Crinkled hairgrass
Desmanthus illinoensis (Michx.) MacMill. ex B. L. Rob. & Fernald	Illinois bundleflower
Desmodium canadense (L.) DC.	Showy Tick Trefoil
Dichanthelium clandestinum (L.) Gould	Deertongue
Digitaria sanguinalis (L.) Scop.	Hairy crabgrass
Digitaria sanguinalis (L.) Scop.	Large crabgrass
Dracopis amplexicaulis (Vahl) Cass.	Clasping coneflower
Echinacea purpurea (L.) Moench	Purple coneflower
Echinochloa crus-galli (L.) P. Beauv.	Barnyardgrass
Echinochloa walteri (Pursh) A. Heller	Walter's millet
Elaeagnus umbellata Thunb.	Autumn olive
Elymus canadensis L.	Canada wildrye
Elymus hystrix L.	Bottlebrush grass
Elymus virginicus L.	Virginia wildrye
Eragrostis curvula (Schrad.) Nees	Weeping lovegrass
Eragrostis trichodes (Nutt.) A.W. Wood	Sand lovegrass
Espeletia schultzii Wedd.	Espeletia
Euphorbia esula L.	Leafy spurge
Festuca arundinacea Schreb.	Tall fescue
Festuca brevipila R. Tracey	Hard fescue
Festuca pratensis Huds.	Meadow fescue
Festuca rubra L.	Red fescue
Festuca rubra var. commutata Gaudin	Chewing's fescue
Festuca ovina L.	Sheep fescue
Gentianella germanica (Willd.) Borner ex E. F. Warb	Gentianella
Glycine max (L.) Merr.	Soybeans
Gossypium hirsutum L.	Cotton
Grevillea barklyana F. Muell. ex Benth.	
Helianthus annuus L.	Sunflower
Helianthus debilis Nutt.	Beach sunflower
Helonias bullata L.	Swamp pink
Hibiscus moscheutos L. subsp. lasiocarpos (Cav.) O.J. Blanchard	Swamp rose-mallow
Hierochloe odorata (L.) P. Beauv.	Sweetgrass
Holcus lanatus L.	Velvetgrass
Hordeum pusillum Nutt.	Little barley
Hypoxis decumbens L.	Hypoxis
Impatiens capensis Meerb.	Jewel weed
Indigofera hirsuta L.	Hairy indigo
Ipomopsis aggregata (Pursh) V. E. Grant	Ipomopsi
Juncus effusus L.	Rush
Koeleria macrantha (Ledeb.) Schult.	Junegrass
Liatris aspera Michx.	Rough blazingstar
Lathyrus sylvestris L.	Flat pea
Leavenworthia crassa Rollins	
Lespedeza angustifolia (Pursh) Elliott	Round-headed bush clover
Lespedeza capitata Michx.	Round-headed bush clover
Lespedeza cuneata (Dum. Cours.) G. Don	Bush clover

Lespedeza hirta (L.) Hornem.	Hairy clover
Liquidambar styraciflua L.	Sweetgum
Lobelia cardinalis L.	Cardinal flower
Lolium multiflorum Lam.	Annual ryegrass
Lolium perenne L.	Perennial ryegrass
Lonicera japonica Thunb.	Japanese honeysuckle
Lotus corniculatus L.	Birdsfoot trefoil
Lupinus subcarnosus Hook.	Bluebonnets
Medicago lupulina L.	Black medic
Medicago sativa L.	Alfalfa
Melinis repens (Willd.) Zizka	Natalgrass
Miscanthus sinensis Andersson	Miscanthus
Monarda fistulosa L.	Wild Bergamot
Oryza sativa L.	Rice
Oxalis stricta L.	Yellow sorrel
Panicum amarum Elliott	Coastal panic grass
Panicum amarum Elliott var. amarulum (Hitchc. & Chase) P. G. Palmer	Coastal/Bitter panic grass
Panicum anceps Michx.	Beaked panicum
Panicum coloratum L.	Kleingrass
Panicum capillare L.	
Panicum dichotomiflorum Michx.	Fall panicum
Panicum miliaceum L.	
Panicum laevifolium Hack.	
Panicum virgatum L.	Switchgrass
Parthenocissus quinquefolia (L.) Planch.	Virginia creeper
Pascopyrum smithii (Rydb.) A. Love	Western wheatgrass
Paspalum floridanum Michx.	Florida paspalum
Pennisetum spp.	Millet
Pennisetum flaccidum Griseb.	Carostan flaccidgrass
Pennisetum purpureum Schumach.	Napier grass
Phalaris arundinacea L.	Reed canarygrass
Phleum pratense L.	Timothy
Phlox drummondii Hook.	Drummondii phlox
Picea rubens Sarg.	Red spruce
Pinus palustris Mill.	Longleaf pine
Pinus resinosa Aiton	Red pine
Pinus virginiana Mill.	Virginia pine
Pityopsis graminifolia (Michx.) Nutt.	Grass-leaved golden aster
Plantago sp.	Plantain
Plantago lanceolata L.	English plantains
Poa pratensis L.	Kentucky bluegrass
Potentilla simplex Michx.	Old-field cinquefoil
Rhexia mariana L.	Meadow beauty
Rosa multiflora Thunb.	Multiflora rose
Rubus sp.	Blackberry
Rudbeckia hirta L.	Blackeyed Susan
Rudbeckia subtomentosa Pursh	Sweet black-eyed susan
Rudbeckia triloba L.	Brown-eyed susan
Rumex acetosella L.	Sheep sorrel
Salix x cottetii Jos. Kern	Dwarf willow
Salix purpurea L.	Purpleosier willow
Saccharum alopecuroideum (L.) Nutt.	
Saccharum brevibarbe (Michx.) Pers.	Browncane plumegrass
Saccharum giganteum (Walter) Pers.	Sugarcane plumegrass
Salvia lyrata L.	Lyre-leaf sage

Schizachyrium scoparium (Michx.) Nash	Little bluestem
Schizachyrium scoparium subsp. littoralis (Nash) Gandhi & Smeins	Coastal little bluestem
Schizachyrium scoparium (Michx.) Nash Subsp. scoparium	Little bluestem
Scleranthus annuus L.	Knawel
Setaria spp.	Green and yellow foxtails
Setaria faberi R. Herrm.	Giant foxtail
Silene alba (Mill.) E. H. L. Krause	
Smilax sp.	Greenbriar
Solanum carolinense L.	Horse nettle
Solanum tuberosum L.	Potato
Solidago spp.	Goldenrods
Solidago canadensis L.	Canadian goldenrod
Sorghastrum nutans (L.) Nash	Indian grass
Sorghastrum secundum (Elliott) Nash	Lopsided Indiangrass
Sorghum x drummondii (Nees ex Steud.) Millsp. & Chase	Sorghum-sudangrass
Sorghum bicolor (L.) Moench	Sorghum
Sorghum halepense (L.) Pers.	Johnsongrass
Spartina alterniflora Loisel.	Smooth cordgrass
Spartina patens (Aiton) H.L. Muhl.	Marshhay cordgrass
Spartina patens (Aiton) H.L. Muhl.	Saltmeadow cordgrass
Spartina pectinata Link	Prairie cordgrass
Sporobolus compositus (Poir.) Merr.	Tall dropseed
Sporobolus cryptandrus (Torr.) A. Gray	Sand Dropseed
Sporobolus indicus var. flaccidus (Roem. & Schult.) Veldkamp	Dropseed
Taraxacum officinale Weber ex F. H. Wigg. Group	Dandelion
Toxicodendron radicans (L.) Kuntze	Poison ivy
Tridens flavus (L.) Hitchc.	Purpletop
Trifolium dubium Sibth.	Least hop clover
Trifolium hybridum L.	Alsike clover
Trifolium pratense L.	Red clover
Trifolium repens L.	White clover
Tripsacum andersonii J.R. Gray	Gamagrass
Tripsacum dactyloides (L.) L.	Eastern gamagrass
Tripsacum floridanum Porter ex Vasey	Gamagrass
Tripsacum maizar Hern.-Xol. & Randolph	Gamagrass
Tripsacum zopilotense Hern.-Xol. & Randolph	Gamagrass
Triticum aestivum L.	Wheat
Tsuga canadensis (L.) Carriere	Eastern hemlock
Typha latifolia L.	Cattail
Uniola paniculata L.	Sea oats
Veronica arvensis L.	Corn speedwell
Vernonia gigantea (Walter) Trel. ex Branner & Coville	Ironweed
Vicia sp.	Vetch
Vitis sp.	Grape
Zea mays L.	Maize, Corn

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Appendix D. Program Planning Committee for the Second Eastern Native Grass Symposium held in Baltimore, Maryland, November 17-19, 1999.

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