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STATE HIGHWAY ADMINISTRATION

RESEARCH REPORT

DEVELOPMENT OF NATIVE SEED FOR SHA PROJECTS

REPORT NO. 1: SELECTING APPROPRIATE SPECIES AND WILD COLLECTING THEIR SEED

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16. Abstract

The highly disturbed soils that SHA must revegetate are diverse, tough environments for plant life. The chances that some of the seed purchased will be well adapted to a particular stabilization site are optimized if that seed originated from a genetically diverse local collection. The use of locally native seed also preserves Maryland's natural heritage and supports local agriculture. Our goal is to make such seed more affordable and more available to SHA. In this report we develop a quantitative, non-arbitrary process for reviewing species being considered for use in roadside soil stabilization projects: the Attributes review process. The Attributes are 14 plant characteristics that must be understood to decide whether or not a plant is suitable for roadside use. Using this process, a panel of experts selected 3 species: gray goldenrod, beaked panicgrass, and Virginia wildrye, for further development. Gray goldenrod is a short, showy, drought-tolerant flower. Beaked panicgrass is a three-foot tall, warm season grass. Virginia wildrye is a three-foot tall, showy, cool season grass. Seed of each species was wild collected using methods that maximize the capture of genetic diversity. NPMC staff helped the authors to establish breeder blocks. Seed from the blocks will be certified as source-identified by the MDA and Maryland farmers have commenced seed production. A tremendous amount of relevant data was generated for each of the three species (Attributes, wild populations, breeder block establishment, field production work, 2008 harvest weights) and these are presented in supplemental reports. If the project is continued, the supplemental reports will be updated.

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Executive Summary

The goal of this project was to make locally native seed more affordable and readily available to the State Highway Administration (SHA). Locally native seed is an excellent choice for soil stabilization projects, and its use preserves Maryland's natural heritage and supports local agriculture.

CNI assembled experts from local nonprofits, government agencies, and academia to form a Species Advisory Panel (SAP). This panel developed a list of 14 Attributes that should be assessed for any species being considered for use in roadside soil stabilization projects. This report provides guidance and examples for using the 14 Attributes.

From a list of 30 native species that are commonly observed in Maryland meadows, the SAP selected the 10 most promising candidates. After surveying wild populations across the state, three species were selected: gray goldenrod, beaked panicgrass, and Virginia wildrye. The National Plant Materials Center (NPMC), one of the SAP members, worked with us to establish breeder blocks of the selected species. Seed from the blocks is being certified as source-identified and made available to Maryland farmers for seed production.

Seed was collected from Maryland wild populations in the fall of 2006. The highly disturbed soils that SHA must revegetate are particularly diverse and tough environments for plant life. To ensure that the seed in any consignment will contain sufficient diversity to adapt to such wide-ranging conditions, we collected from many parent populations. The wild collection methods were tailored to ensure that we captured both diversity within populations and diversity among populations of the three target species. These three species are discussed further in the 2nd, 3rd and 4th reports of this series.

We recommend that the SHA continue working with the Species Advisory Panel and the Attributes process for reviewing species to be used on roadsides. SHA should continue working with the NPMC to add new locally native stock to the breeder blocks to become certified as source-identified seed for increase by Maryland farmers.

1 Introduction

In this report the authors (CNI) discuss research on soil stabilization plantings conducted with the Landscape Operations Division of the Maryland State Highway Administration (SHA). In CNIs project work plan, we described four project phases:

- Species Selection Phase conducted in 2006
- Wild Collection Phase conducted in 2006
- Germination Phase conducted from 2007 to 2008
- Production Trial Phase conducted from 2007 to 2009

This report covers the first two phases, Species Selection and Wild Collection. The subsequent phases are covered in the 2nd, 3rd and 4th reports of this series, and are discussed in the context of the species that ultimately advanced to the Germination and Production Trials: Virginia wildrye, beaked panicgrass, and gray goldenrod, respectively.

Most of our readers will not be familiar with the environmental components of SHAs mission, or familiar with its relationship to the specific components of this project. Therefore, throughout these reports, we will touch back upon the SHA mission statement (Table 1) and discuss how it relates to our findings.

Table 1: SHAs Environmental Components

1) Efficiently provide mobility for our customers
2) through a safe,
3) well-maintained
4) and attractive highway system
5) that enhances Maryland's communities,
6) economy
7) and environment.

This project supports SHA Objective to develop and maintain Maryland state highways in an environmentally responsible manner, to stabilize soils and prevent erosion that would ultimately pollute waterways, to control the spread of invasive plants on its right of ways and to beautify the highway system by planting more meadows.

SHA contractors stabilize soils by establishing vegetation, usually by sowing seed. Individual areas of soil disturbance can be small or large (as with new highway construction), but the cumulative annual impact ranges from hundreds to thousands of acres.

To date there have been no precise estimates of how much local native seed would need to be produced to meet the demand for roadside revegetation projects along Maryland's 30,494 miles (49,075km) of government-maintained roadways (USDOT 2000). William Klingelhofer[1] has estimated that thousands of pounds of seed are required to sustain roadside revegetation across the State each year. Another estimate of the potential demand for native seed in Maryland can be taken from a study conducted in Minnesota, where a producer survey estimated that 127,000 pounds (57,600kg) of native grass and wildflower seed were produced in 1991, and that the market was growing at an annual rate of 20 to 30% (Dale 1993). Yet, the only seed currently available to SHA in such large quantities or at affordable prices (a few dollars per pound) are unattractive, aggressive, alien species.

SHA is at an impasse: it cannot stabilize soils affordably and use local Maryland native seed. It is the goal of this current project to make affordable, locally grown, locally native wildflower and grass seed available for soil stabilization requirements in Maryland. By so doing, SHA will better fulfill its mission in beautifying Maryland's roads and protecting our environment (Table 2: 4, 7). SHA will also be supporting local agriculture by developing alternative crops for Maryland farmers (Table 2: 6).

[1] William Klingelhofer, Landscape Operations Division, Maryland State Highway Administration 2005. Personal communication.

2 Literature Review

2.1 The History of Stabilizing Soil with Alien Plants

The importance of revegetating disturbed soils (soil stabilization) became apparent during the dustbowl era of the 1920s and 1930s. In 1933, the United States Department of Agriculture (USDA) established the Soil Conservation Service (now the Natural Resources Conservation Service) to change the common agricultural practices that led to the loss of so much of the nation's topsoil. Since then the USDA has been searching the globe for fast growing, rapidly spreading plant species whose foliage and root systems reduce soil erosion. Once found, a species is normally selected for desirable qualities for several generations until an improved and clearly distinguishable form (a cultivar) of the species can be released to the public. Multiple testing trials ensure that the cultivar's distinguishing traits are heritable, i.e., the cultivar is reliably genetically different from the wild stock, and that the cultivar is even more vigorous and fertile than its wild ancestors.[2]

One of the earliest examples of plants promoted for erosion control in the United States is kudzu (*Pueraria montana* var. *lobata*), introduced from Japan in the 1890s and promoted for use by the USDA Plant Introduction Service (Mack 1991). Other examples include Russian olive (*Elaeagnus angustifolia*), quackgrass (*Elytrigia repens* [= *Elymus repens*]), sericea or Chinese lespedeza (*Lespedeza cuneata*), multiflora rose (*Rosa multiflora*), Japanese bristlegrass or giant foxtail (*Setaria faberi*), and the now infamous tamarisk or salt cedars (*Tamarix* spp.) (Reichard & White 2001; Zheng *et al.* 2004, 2005). In 1998, Booze-Daniels *et al.* provided the following statement about the alien species used to stabilize soils in Virginia. "The current list of species that are suitable to roadside use in Virginia is brief. The tall and fine fescues (*Festuca arundinacea* [= *Schedonorus phoenix*], *F. ovina, F. longifolia* [= *F. brevipila*], *F. rubra*, *F. rubra* ssp. *commutata* [= ssp. *fallax*]), bermudagrass (*Cynodon dactylon*), weeping lovegrass (*Eragrostis curvula*), birdsfoot trefoil (*Lotus corniculatus*), and crown vetch (*Coronilla varia* [= *Securigera varia*])".

Even now, most forage, turf, and conservation plantings in the United States consist of fertile, introduced grasses, such as tall fescue (*Schedonorus phoenix*) and smooth brome (*Bromis inermis*) (Vogel *et al.* 2006). One good example of a problematic alien currently commonly applied in soil stabilization projects (Maryland SHA 2008) is sericea lespedeza. In contrast to SHAs mission, this species is not attractive, it is produced out of state[3] so it doesn't support the local economy, and although it helps to stabilize soil, it is otherwise a poor choice for our environment (Table 1: 4, 6, 7). However, it stabilizes soils, and its seed is affordable and available in very large quantities. As pointed out in

[2] This is a discussion of history. With time, the USDA evolved to work on developing cultivars of native species, and more recently has moved toward development of source-identified releases. The change over time can be seen in a list published by the NPMC (Davis *et al.* 2002).
[3] Lois Capshaw, Manager of Seed Testing Lab, Maryland Department of Agriculture. 2005. Personal communication.

the white paper by Beck *et al.* (2008), introduced species are only considered invasive once society determines that the harm caused by them outweighs the benefit derived. Groups around the country are reaching the conclusion that the costs of using sericea lespedeza does indeed outweigh the benefits, as indicated by its inclusion on numerous state invasive species lists (plants.usda.gov/java/profile?symbol=LECU). The North Carolina Department of Transportation, for example, has recommended discontinuing the use of sericea lespedeza. They have placed the species on their "Threat" list (Smith 2008). This is their highest ranking, reserved for species that are a known threat to native habitats and natural areas.

As roads are excellent transportation corridors for people, roadsides are excellent transportation corridors for plants. The spread of exotic plants from roadsides into adjacent habitats has been documented in Florida (Greenberg *et al.* 1997, Jenkins *et al.* 2004), Oregon (Parendes & Jones 2000), Utah (Gelbard & Belnap 2003), and Wisconsin (Watkins *et al.* 2003). Here in Maryland, Mortensen *et al*. (2009) studied the impact of roads on the spread rate of Japanese stiltgrass (*Microstegium vimineum*). They found that the natural dispersal rate of stiltgrass is 1 to 2 meters per year, whereas along roadsides stiltgrass had spread 100 to 200 times more rapidly. They believe that roadside maintenance practices and water transportation in roadside ditches are responsible. It would appear that of all the places to introduce a fertile alien plant, roadsides might be the worst.

2.2 Choosing to Revegetate with Local Natives

By the 1960s, the beautiful grasses and flowers that once represented our nation's unique character were limited to tiny remnants along railways and in graveyards (Gustafson *et al.* 2005). In the Mid-Western states, agriculture has reduced the American prairie to less than one percent of its original area (Noss 1999). Closer to home, estimates of native grasslands lost in Pennsylvania are even more dramatic (Latham 2006). Long before scientists were publishing studies proving that roadways are transportation corridors for plant material, Mrs. Ladybird Johnson was promoting roadside revegetation projects as ideal opportunities to beautify America and reintroduce native wildflowers (Highway Beautification Act 1965; Johnson & Lees 1993; Koman 2001; Gould 2000), thus restoring ecological integrity and indigenous character to an area. As regards to the beautification movement and highway legislation, Mrs. Johnson once said, "I have always been a natural tourist … Wherever I go in America, I like it when the land speaks its own language in its own regional accent" (Johnson & Lees 1993).

It is not merely our grassland heritage and our beautiful wildflowers that are at stake. The very web of life is affected by our landscaping choices. To understand how this could be true, we must for a moment leave our focus on plants as agents for soil stabilization and think instead of their role in the food chain. Plants convert carbon dioxide, water and sunlight into living tissue. All other forms of life (animals, fungi, bacteria, etc.) in the web either eat plants or something that ate plants. In this way carbon and energy are transferred from plants to animals. Tallamy (2007) points out that the main channel for energy from the sun is through plants to herbivorous insects. Examples of just a few categories of herbivorous insects are caterpillars, some beetles, aphids,

spittlebugs and grasshoppers. Once converted to insect tissue, the carbon and energy become available to predators. It is this conversion of sunlight to plants to insects that drives the entire web of life responsible for the populations of butterflies, birds, and wildlife that are such an integral component of Maryland's unique aesthetic (Table 1: 4), recreational economy (6)[4], and environment (7). For example, the young of every songbird species depend strictly on insects for food.

So where is the problem? Tallamy (2007) has shown that herbivorous insects in the Mid-Atlantic region mostly eat native vegetation. In Maryland, much of our native vegetation has been replaced by urbanization and agriculture. Even where wild plants remain, one in every four species encountered is alien (777 of 3,069)[5]. One consequence will be fewer songbirds. Anything that makes it more difficult for parent birds to collect insects to feed their young directly reduces the number of songbirds. So much native vegetation has been replaced by development and by the spread of invasive species that Tallamy states "When extinction adjusts the number of species to the land area that remains for the plants, mammals, reptiles, birds, and invertebrates of North America (something that will happen within the lifetimes of most of us), we will have lost 95% of the species that greeted the Pilgrims."

As a result of the Highway Beautification Act, a new era in roadside revegetation was underway, and many Mid-Western companies began producing native seed to meet highway project demands. As the first few states turned to the use of native species for roadside revegetation, they found that native plants perform better than aliens. It has even been shown that locally native (often referred to as local ecotype) seed outperforms seed of the same species from a distant origin (see for example the comparison of Texas vs. Florida ecotype *Rudbeckia hirta* for Florida roadsides, Norcini 1998; Henderson 2002; McKay *et al.* 2005; Schmidtling 2001; Tangren - unpublished observations). In an overview of the biological principles surrounding plant selection for re-vegetation, Linhart (1995) states that "if there is revegetation to be done, the very worst option is to use seeds (of the same species) from very far away, even if the seeds come from a similar environment, because if the non-native plants would grow to reproduce, they would introduce new alleles and therefore new features (growth form, flowering phenology, breeding system) into the local populations of the same species. "Gustafson *et al*. (2004) found non-local and cultivar seed sources to be so genetically different from the local seed that they cautioned, "Translocating non-local seed in order to increase diversity, or using cultivars, is likely to alter the genetic structure of remnant populations and potentially influence the associated community and affect ecosystem structure and function in unforeseen ways."

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[4] The following 2006 statistics are from Carver (2009): 19% of Maryland residents consider themselves to be bird watchers. Of all the people who watched birds in Maryland, 16% were tourists. Nationwide, birders spent $36 billion on travel and equipment, generating 671,000 jobs and paying $4.4 billion in federal and $6.1 billion in state taxes.

[5] Davdison, L. (2009). Maryland Dept. of Natural Resources. Ms. Davidson obtained these data from various sources, including information provided to the NatureServe database by Dr. John Kartesz.

2.3 The Affordability of Local Ecotype Seed

The USDA Forest Service has found that locally adapted native seed performs so much better for roadside revegetation than any other product, they will collect seed on site a year or more before construction to have it contract grown ("increased") by local farmers to ensure it's availability. In 2004, the Forest Service Regional Seed Increase Contract approach procured locally native seeds ranging from $6 per pound for grasses to $73 per pound for native wildflowers (Landis *et al.* 2005). In this way, the Forest Service secures the large quantities of seed it needs for soil stabilization at affordable prices.

Fortunately for Maryland's roadside vegetation managers, locally native seed can be produced in quantities that are large enough and at prices that are low enough to be practical for standard use in state highway soil stabilization practices. Several jurisdictions have demonstrated this (Dale 1993; Federal Highway Administration 2002; Wildflower Seed And Plant Growers Association, Inc. 2005; Landis *et al.* 2005). In Florida and Iowa, for example, this has been accomplished through a coalition of academia, agriculture, and the state department of transportation. These coalitions have provided growers with local ecotype foundation seed and production technologies on the one hand, while working with their state highway departments to develop applications for the seed such as soil stabilization and aesthetic improvements.

2.4 Deciding which Native Species to Use

Booze-Daniels *et al.* (1998) are proponents of selecting a native species that already has the desired qualities for a particular use, rather than breeding a species to acquire features that it does not naturally possess. For example, if they wanted a short grass, they would pick a species that happened to be short, rather than picking a tall grass and then breeding a short variety through generations of selection.

They used the following eight criteria to determine whether or not they would recommend a native grass species for use in Virginia roadside plantings:

a. The grass is a native of North America.

b. The grass does not exhibit aggressive behavior.

c. The plant is not on the *Invasive Alien Plant Species in Virginia* (Virginia Department of Conservation and Recreation and Virginia Native Plant Society 1997) list.

d. The grass adapts well to drastically disturbed sites.

e. The grass has potential to persist in the roadside environment.

f. The grass performs as well as species currently used on the roadside.

g. The seed is available or has the potential to be available from native grass seed vendors.

h. Cost will not be a determining factor. Even though the cost of some of this seed is expensive at this time, increased demand may eventually drive the price down."

Shortly after Booze-Daniels *et al.* published their list, articles began to appear in the literature that described the error in a. and b. above. For example, Ayres *et al.* (1999) demonstrated that just because a grass is native somewhere on our continent (a) does not make it an environmentally sound choice for introduction elsewhere on the continent. Released from its native range, a plant may become free of the diseases and herbivores that otherwise restrict it, and it can exhibit previously unobserved "aggressive behavior" (b). Our locally native saltmarsh grass, Mid-Atlantic cordgrass (*Spartina alterniflora* L.), has been introduced to the Pacific Coast of North America and to Europe. Even though the species is not aggressive in its native range, when it was introduced outside its native range, it was found to be moderately aggressive. Furthermore, when it cross-pollinated with the cordgrasses native to its new range, Mid-Atlantic cordgrass formed very aggressive hybrids (Ayres *et al.* 1999; National Academy of Sciences 2003). Introducing new genetic material can affect ecosystem structure and function in unforeseen ways (Gustafson 2004).

2.5 Wild Collecting Seed for Increase and Use in Revegetation

The genetic diversity of the seed that farmers will produce for use on Maryland roadsides is set during the Wild Collection Phase of the project. Rogers (2004) warns that mistakes made during wild collection can inadvertently cause genetic erosion during the course of large-scale planting and reseeding activities. The genetic diversity of CNIs initial collections will determine how robust Maryland's soil stabilization seed mix will be, and how well it will adapt to diverse roadside conditions.

Poor collection methods can lead to a genetically skewed breeder block collection. Examples of poor methods include only collecting from one site, a few patches of plants at a site, sites on one type of soil, plants with large seed heads, tall plants with seed heads located at a comfortable height for the collector, short plants because the collector likes them better, and from plants with seeds that ripen early. Plantings founded from a seed collection that lacks adequate genetic diversity can have difficulty thriving and setting seed, a situation called the founder's effect (Rogers 2004).

As the authors discussed in the introduction, SHAs roadside plantings will ultimately contain millions of plants that will exchange genes with every other plant of its kind throughout Maryland. SHA can make sure that this exchange is beneficial to both the wild populations and the roadside populations by using native plants that contain genetic material that is both diverse and representative of our state.

3 Methods

3.1 Method of Species Selection: The Species Advisory Panel

This phase of the project was an opportunity to bring in expert advice from all the stakeholders, and to build a community (Table 1: 5) among diverse organizations. Our coalition was named the Species Advisory Panel (Table 2). Similar to the Booze-Daniels *et al.* approach, our first method was to define a set of qualities we would want in a soil stabilization species.

Table 2: Experts on the Species Advisory Panel (SAP)

Name	Organization
Bill Klingelhofer, Don Cobur, Bruce Knott	Landscape Operations Division, Maryland SHA
Marc Imlay	Maryland Native Plant Society
John Englert, Shawn Belt, R. Jay Ugiansky	USDA NRCS National Plant Materials Center
Sara Tangren	Chesapeake Natives, Inc.
Dick Weismiller	University of Maryland, Dept. Environmental Science & Technology

To develop a list of species suitable for the SAP to review, the lead author provided her observations of native, mesic and xeric meadows across Maryland. From these, a list of 30 typical species was presented (Table 3).

In the course of examining the 30 species, the SAP developed a list of 14 Attributes that should be understood for any species being considered for use in roadside soil stabilization. Using the Attributes to evaluate species is a process, or a method, and as such could be discussed further here in the methods section of the report. However, the 14 Attributes process is a unique result of this project; no review process like it has been published before. Therefore, the Attributes are presented in more detail in the Results section of this report.

A "NO" vote from any panel member resulted in the species being eliminated from consideration. The list was whittled down to ten species. In the hopes that this pilot project would include one species each of a grass, a legume, and a showy flower, representatives of each category were included on the short list.

Table 3: Species Commonly Found in Maryland Meadows

#	Common Name	Scientific Name
1	Broomsedge	*Andropogon virginicus*
2	Common milkweed	*Asclepias syriaca*
3	Butterfly milkweed	*Asclepias tuberosa*
4	Frost aster	*Aster dumosus*
5	Maryland goldenaster	*Chrysopsis mariana*
6	Virginia wildrye	*Elymus virginicus*
7	Purple lovegrass	*Eragrostis spectabilis*
8	Philadelphia fleabane	*Erigeron philadelphicum*
9	Daisy fleabane	*Erigeron strigosus*
10	Blue mistflower	*Eupatorium coelestinum*
11	Virginia strawberry	*Fragaria virginiana*
12	Purple sneezeweed	*Helenium flexuosum*
13	Woodland sunflower	*Helianthus divaricatus*
14	Camphorweed	*Heterotheca subaxillaris*
15	Little barley	*Hordeum pusilum*
16	Round Headed bushclover	*Lespedeza capitata*
17	Intermediate bushclover	*Lespedeza intermedia*
18	Slender bushclover	*Lespedeza virginica*
19	Blue toadflax	*Linaria canadensis*
20	Spotted mint	*Monarda punctata*
21	Beaked panicgrass	*Panicum anceps*
22	Florida paspalum	*Paspalum floridanum*
23	Foxglove beardtongue	*Penstemon digitalis*
24	Narrowleaf mountainmint	*Pycnanthemum tenuifolium*
25	Pasture rose	*Rosa carolina*
26	Lyre-leaved sage	*Salvia lyrata*
27	Little bluestem	*Schizachyrium scoparium*
28	Gray goldenrod	*Solidago nemoralis*
29	Indiangrass	*Sorghastrum nutans*
30	Purpletop	*Tridens flavus*

3.2 Methods of Wild Collection

Gustafson (2004) described the two elements that are pivotal to the wild collection phase of this project. First, from the seed-user's point of view (in our case, the SHA), locally native seed is hard to wild collect. The patches of native grassland that remain are small, scattered, and difficult to find. So users are driven to purchase seed, but on the market they find only non-local seed and non-local cultivars. Gustafson's concern is that the market seed may not have the genetic diversity necessary for project success, and its "introduction may lead to loss of unique local genotypes".

CNIs methods were chosen to facilitate 1) finding the desired species, 2) capturing their genetic diversity in the seed collection, and 3) certifying the origin of the seed.

We began the Wild Collection Phase in search of all 10 species even though our objective for this grant was to produce only three. We assumed (correctly) that as the project progressed other factors would pare our selection down.

3.2.1 Methods to Support Objective 1: Find the Species

To discover the location of meadow remnants in Maryland, specimens held at the Norton Brown Herbarium at the University of Maryland were examined. Records from the Smithsonian's D.C. Flora Database were also queried (collections.nmnh.si.edu/emuwebbotweb/pages/nmnh/bot/DtlQuery.php?collection=dcflora). Information regarding potential Delmarva peninsula populations was obtained from Adkins Arboretum. Professional botanists and members of the Maryland Native Plant Society were interviewed to provide data on the native meadow remnants.

Some species are easier to locate and identify while in flower. Beardtongues bloom in June, lespedezas in July, goldenasters in August, and goldenrods from August to October. Grasses are easier to locate and key out while they are in seed. Similarly, each species had to be wild-collected when the seed was ripe. Species on the short list of ten ripened from July through November. Often a site was visited to discover the seed wasn't quite ripe yet, and had to be revisited a week later for collection. As a result, each parent population was visited many times.

Brown and Brown (1984) was used as the initial taxonomic reference for plant identification, and the Norton Brown Herbarium was used for verification. As our fieldwork began in 2006, plant taxonomists with the Flora of North America project were reclassifying species within the composite and legume plant families. Taxonomic work on the legumes continues at the time of this writing. The primary key used for this report is the Flora of North America (see for example: Freckmann & Lelong 2003 - *Panicum*; Barkworth *et al.* 2006 – *Elymus*; Semple & Cook 2006 - *Solidago*). Nomenclature follows Kartesz and Meacham (1999), Synthesis of the North America Flora. Further specific information on plant taxonomy is given in the results section.

3.2.2 Methods to Support Objective 2: Maximize Diversity for Better Soil Stabilization

Gustafson's second concern was obtaining the genetic diversity that would secure project success while protecting the local environment ("preserving the genetic integrity of local populations").

Seed was collected throughout Maryland, with the exception of the far western counties of Garrett, Allegany and Washington (SHA Region 1, Figure 1). These counties were excluded because of their different climate and soils, indicating the probability that ecotypic adaptations would be significantly different from the rest of the state – in other words, they would constitute a new seed transfer zone. With additional financial resources this project could be expanded into SHA Region 1, and possibly parts of West Virginia and Pennsylvania.

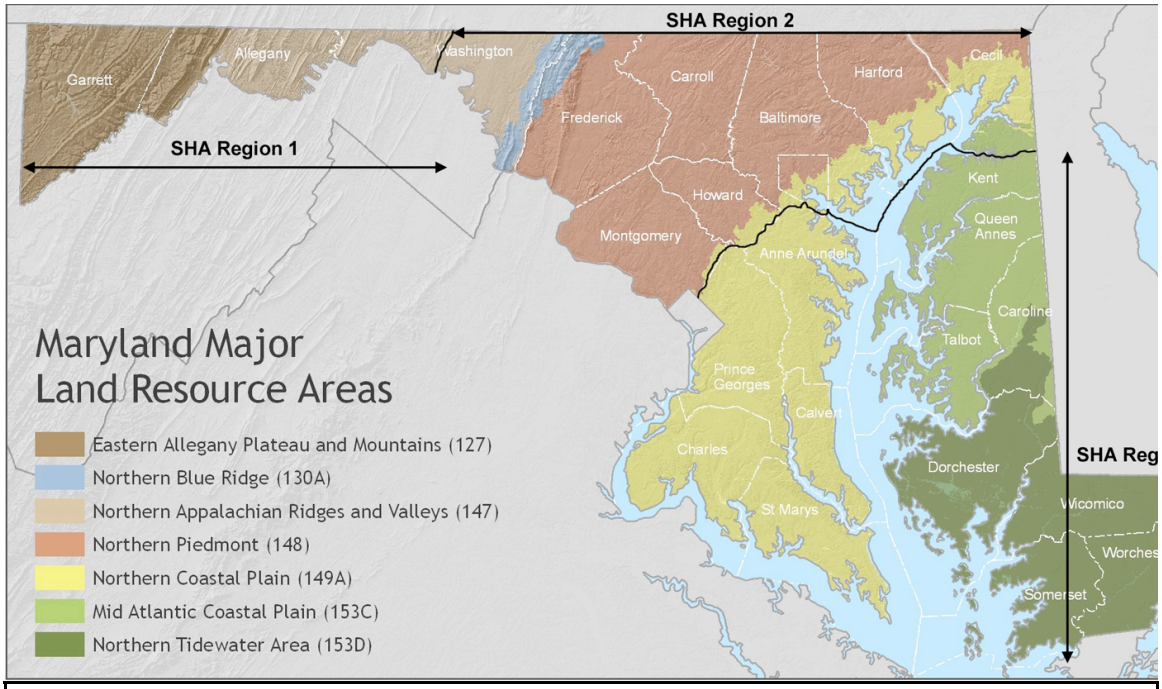

Figure 1: SHA Regions and Geologic Provinces of Maryland (based on Moore 2008).

This is a Maryland map showing the physiographic provinces from the Coastal Plain in the east to the Mountains in the west, and how those provinces relate to the USDAs Major Land Resource Areas. It also shows SHAs management regions, 1 through 3 from west to east.

Within a given species, wild plants contain two types of genetic diversity: that found among individuals within the same population, and that found among populations (Linhart 1995). CNIs goal was to capture both types of diversity in the wild collections. To do this, we followed the seed collection advice outlined by Rogers (2004) and the Bureau of Land Management (2008). For example, we sought 10 to 20 parent populations for each species. Breaking with tradition in a profession where propagules were usually taken from a limited number of individuals with distinctive traits, plant breeders from the USDAs Tucson Plant Materials Center (Munda & Smith 1995) also emphasize the importance of collecting from multiple populations of a species. They note that for highly disturbed desert soils (and SHA typically works on highly disturbed soils), seed from just one population, the closest population, is not necessarily the best-adapted seed for re-vegetation. This is because the disturbed soils may be so dissimilar to nearby natural soils, that one local population may not contain adequate genetic diversity for the plants to adapt to and successfully revegetate the disturbed site. In an overview of the biological principles surrounding plant selection for re-vegetation, Linhart (1995) concurs, stating that "seeds from a few (or many) individuals from one population only will be inadequate."

Species were discarded from consideration if too few parent populations were found, or if parent populations could not be found in both SHA Regions 2 and 3 (Figure 1). We

collected from at least 50 individuals within each population, except in those populations where fewer than 50 individuals occurred[6].

We followed guidelines for ethics in seed collection, for example not taking more than 20% of the seed available on a given visit (Bureau of Land Management 2008), not damaging the surrounding flora, and getting permission from all property owners (Maryland Native Plant Society 2002). In populations with many individuals we collected randomly within each stratum: for example, some from tall plants and some from short, some from the bottom of the hill and some from the top, some from shade and some from sun, etc. This technique is called stratified random sampling. Furthermore, care was taken to acquire approximately the same amount of seed from each plant.

After wild collection, seed was brought back to the University of Maryland Research Greenhouse Complex for germination testing and plug production. The plugs were then moved into seed production plots. The Germination and Production Phases are discussed in the next three reports in this series, organized according to species: Virginia wildrye, beaked panicgrass and gray goldenrod.

3.2.3 Methods to Support Objective 3: Seed Certification

SHA cannot compare the value of seed offered by multiple vendors unless that seed is certified as to its species, origin, purity, and germination rate. Young (1995) states that "verification of genetic origin and purity of these (local ecotype) germplasms is just as important as it is for traditional cultivars". Certification of seed starts years prior to the actual sale, when the original germplasm is wild collected. During the wild collection and production phases of this project, we have worked closely with the Maryland Department of Agriculture (MDA) Seed Testing Lab, which is the local member of the Association of Official Seed Certifying Agencies (AOSCA). The plan has been to follow AOSCAs guidelines for "natural track" germplasm development and receive the Source Identified Class pre-variety germplasm certification for seed produced as a result of this project. On AOSCA's natural track, germplasm accessions are an unrestricted representation of the intact wildland plant population, and genetic manipulation is purposefully avoided during the seed increase process (Young *et al.,* 2003).

So that the wild collection effort could be validated, MDA staff visited each parent population to confirm the presence of the species that we reported. They also visited the breeder blocks at the National Plant Material Center (NPMC) to confirm that those blocks are consistent with the parent populations as claimed. In the future, MDA will also visit the private farms to confirm that the crops being produced appear to be consistent with the breeder blocks. They will also count the number of generations between the wild population and the final product. Too many generations in cultivation can result in a product that is not suitable for roadside use. After germination testing, they will have all the information necessary to issue the desired source identification tags on bags of seed to be sold by the farmers to the SHA.

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[6] The Bureau of Land Management recommends against collecting from populations with fewer than 50 individuals; They suppose we could choose to collect from a larger population somewhere else. In our project that was not the case.

4 Results & Discussion

4.1 Desired Attributes of Species Used for Roadside Soil Stabilization

In 2006, our Advisory Panel deliberated over the qualities a native plant would need to facilitate successful roadside soil stabilization projects. The Attributes list (Table 4) is the result of those deliberations. It contains some of the same considerations as the aforementioned Booze-Daniels list, albeit in a more specific or refined form. The Attributes fall into four categories: Ecological, Soil Stabilization, Roadside Maintenance, and Affordability/Agriculture.

Table 4: Attributes that Determine Species Suitability for Soil Stabilization Use on Maryland Roadsides.

Ecological Considerations:	
1	Native status
2	Abundance and distribution
3	Ecology, genetics, and taxonomy
Soil Stabilization Considerations:	
4	Special site condition abilities or requirements
5	Germination/sowing requirements
6	Speed of growth
7	Height
8	Winter cover
9	Root structure
Roadside Maintenance Considerations:	
10	Safety and interactions with wildlife
11	Aesthetics
12	Mowing requirements and tolerances
13	Herbicide compatibilities for roadside use
14	Road salt tolerance (for the low mow zone),
Affordability/Agricultural Considerations:	
15	Ease of weed control
16	Abundance of seed
17	Ease of harvest
18	Ease of seed cleaning
19	Shelf life

The development of these lists is the first accomplishment of this project and is a stand-alone result. The entire list can be used to guide future selection of species for seed development efforts. The first three sections can be put to use immediately to evaluate seed (or plant) recommendations made by vendors, contractors, and other government agencies.

Throughout this series of reports, when the authors capitalize the word attribute, it will indicate that we are referring specifically to the Attributes listed by the SAP. In the sections that follow the authors will discuss why the Advisory Panel placed each Attribute on the list.

Then we will discuss the process that SHA or its contractors can use to evaluate each Attribute when considering a seed stock for roadside use. So that SHA staff may conduct a review of any species on their own, or so that they

can judge the quality of reviews provided by contractors, we offer multiple standard references that should be consulted, at a minimum, for determination of each Attribute.

4.1.1 The Ecological Considerations

Reviewing a species' ecological Attributes enables SHA to make plant choices that are in alignment with the seventh component of the SHA mission statement (Table 1), enhancing Maryland's environment.

Attributes 1 & 2: Range, Distribution, and Abundance

A. State Native: The Species Advisory Panel wants reviewers to consider whether or not a plant is native to Maryland. A State Native is any plant that existed in the current boundary of Maryland before the presence of Europeans. It was the consensus of the Advisory Panel that the SHA should target native species for use in roadside stabilization. Performance, conservation of the local flora, and preservation of a local aesthetic are the bases for the recommendation, as discussed in the Introduction. To determine whether a plant species is native, the following references should be consulted:

i. **Shetler and Orli (2000 & 2002)** list species native to the larger Baltimore-Washington area;

ii. **Brown and Brown (1972, 1984)** occasionally indicate whether a plant is native or escaped;

iii. **Metzger (1995)** has compiled the only list of plants native to our State; and

iv. **Experts** familiar with the local flora (for example at the Maryland Native Plant Society).

Ideally all these references should be consulted because occasionally one will be misleading or in error. These references are primarily based upon voucher specimens held in herbaria and by field observations.

B. State Rarity: The Species Advisory Panel wants reviewers to determine how abundant a species is within Maryland, and what its natural distribution within the state is like? One reason is to avoid any undesirable environmental, legal or political consequences of working with state-rare species. Upon first consideration, many readers may think that we should target rare species for roadside use, thus helping to propagate them and spread them around. However, doing so incorrectly could have irreversible genetic consequences for our wild populations and that would be in conflict with SHAs mission statement (Table 1) to enhance Maryland's environment. Doing a good job of using a listed species on roadsides would typically require extensive preparatory research, acquisition of permits, planning and expenditures that SHA may not wish to invest in. The use of seed from out of state, while technically legal, would likely have even more negative ecological consequences than the use of local seed. To determine whether or not a species is rare within Maryland, the reference to consult is Rare, Threatened, and Endangered Plants of Maryland

(Maryland Department of Natural Resources, 2007, available on-line at www.dnr.state.md.us/wildlife/espaa.asp). If a plant is listed, that typically means there are fewer than 15 remaining populations left in our state. In most cases, the consideration of a species should stop once it is found to occur on this list.

C. **State Abundance:** However, we are not just targeting species that aren't rare, we are looking for truly representative Maryland species. If we use a species that occurs in Maryland, but only rarely, or is at the limit of its natural range, we may not get the good roadside performance that we desire, and we lose the opportunity to show off Maryland's own aesthetic. In addition to the reviewer's personal observations on abundance and distribution, the following references should be consulted and reported:

   i. **Brown and Brown (1984):** typically provide comments on a species' abundance, geographic distribution, and the habitats in which it grows.

   ii. **Plant lists at the Maryland Native Plant Society Website:** (www.mdflora.org/plantinfo/plantlists/lists_by_county.html)[7] are a great resource for evaluating Attribute 2.

   iii. **Parks/Government Properties:** sometimes have lists of plants that occur on their grounds. For example, a plant list was published for the Beltsville Agricultural Research Center (Terrell *et al.* 2000). The Center occupies 6,866 acres and the plant list is actually a small book.

   iv. **Marylandica/Maryland Naturalist:** Many Maryland plant lists are available in small society journals. Consequently they are missed by computerized literature searches and overlooked by librarians. But they are immensely valuable for the question of native status and distribution. These small journals are Marylandica (available on-line www.mdflora.org), and the Maryland Naturalist (www.marylandnature.org/stmdnat.htm).

   v. **U.S. Fish and Wildlife Service (Slattery *et al.* 2003):** has published a helpful booklet on garden-worthy plants native to the Chesapeake watershed. It will not include many of the species appropriate for roadside use. We recommend it here with the caveat that it does contain a few errors, and a few state rare species. The best feature for our purposes is that it indicates which geologic provinces a species occurs in naturally: Coastal Plain, Piedmont, and Mountain.

   vi. **University of Maryland Norton Brown Herbarium:** Specimens preserved in herbaria provide an excellent indication of a plant's distribution over time. With over 70,000 specimens, the Norton Brown Herbarium is the premier collection covering Maryland.

   vii. **Smithsonian National Museum of Natural History:** a searchable database of the collection is available online at http://collections.nmnh.si.edu.

D. **Habitat:** To apply a species to roadside projects successfully, we need to know if the species is typically found in particular habitats or ecoregions, or if it is a generalist

[7] The lists at the MNPS website are highly recommended with one exception, Native Plants for Anne Arundel County, which contains a handful of rather significant errors.

species. To vegetate the roadsides of Maryland, with all their diverse conditions of soil, sun, moisture, pH, and salinity, we will need both specialist and generalist species. The references to use for habitat are the same as those for abundance, above.

E. National/International: New resources are making it easier to determine a plant species' broader range.

i. The PLANTS database (www.PLANTS.usda.gov, USDA NRCS, 2006+) has recently added a map toggle that allows the visitor to view both distribution and native range[8]. PLANTS database maps are often available for the multiple varieties or forms of a species, and these tend to be affiliated with particular geographic areas. As you will read in the gray goldenrod results, there can be important differences between a variety native to one part of the country and another. The PLANTS database also typically offers additional links to follow.

ii. Wikipedia (www.wikipedia.org) can be an excellent source for an overview of a species. Pages that are well written offer valuable information about international distribution and recent research. For many species, no page will be available yet. Occasionally there are serious errors or very opinionated pieces because this is not a refereed information source. Double check any pivotal information obtained from this resource.

It is not uncommon for the above references to provide conflicting information. In most cases it is probably best to "keep it simple" and stick to those species that are clearly native according to all authors. However, there are resources to call upon if SHA should wish to resolve such a conflict: any of the authors listed in this section, faculty at local colleges and universities, experts at the Maryland Native Plant Society, Chesapeake Natives, the Smithsonian Institution, and The Nature Conservancy.

Attribute 3: Ecology, Genetics & Taxonomy

Why does the Advisory Panel recommend that we understand the ecological and genetic character of a species before we begin using it on Maryland roadsides? This type of knowledge can be very useful in all stages of our project from the initial species selection and wild collection through to the actual roadside placement and maintenance. Unfortunately, very little such information is available. So you have to take what you can get from the literature for each species, and see how it is (or isn't) relevant to your work. Here are some of the types of relevant things you might learn in studying the literature on a species: how the species is pollinated; whether it tends to self pollinate; whether it tends to hybridize within its genus or family; whether its invasive elsewhere; what types of bacteria, fungi, insects, mammals, birds, etc., are affiliated with it and in what ways; whether there are multiple ploidy levels, forms, varieties, and races within the species and what their geographic distribution is; whether it colonizes disturbed habitats

[8] Caution should be taken however as the improvement is new and the database is huge, there are still occasional errors that will no doubt be worked out in time. Also, even isolated or geographically extreme records of species occurrence can cause the entire state to be colored "native".

or has high fidelity to mature ecosystems; and how it relates to other plants in its habitat (allelopathy for example).

We will see concrete examples of the importance of ecological, genetic and taxonomic information later in this paper. We will discuss the wildryes, which are a product of natural hybridization between species within the wheat tribe of grasses. We will discuss recent taxonomic revisions within the Virginia wildrye complex. We will discuss how introducing alien grasses can lead to the evolution of new, and sometimes invasive, hybrid grasses. We will also discuss the two varieties of gray goldenrod, one west of the Appalachians and one to the east. The western race is a weedy, aggressive tetraploid organism, very unlike our eastern race.

To determine the ecological and genetic Attributes of a species, a good place to start is a thorough review of the species' taxonomy. Taxonomic classifications are changing as DNA analysis rearranges our understandings of plant relationships. An examination of synonymy is also in order, as many species have gone by other names in the past and some literature may only be found if the researcher uses the appropriate synonyms. An excellent starting point for work in Maryland remains the 25 year-old publication by Brown and Brown (1984), however it would be negligent to leave any plant identification at that point now. From there one should proceed to the PLANTS database (www.plants.usda.gov, USDA NRCS 2006+) for synonyms and additional links. The Flora of North America (Flora of North America Editorial Committee, 1993+) is available on line and contains the most current understanding of plant taxonomy for our area. It also provides useful references for further reading.

To obtain the information needed it is necessary to review any available literature on the species. Databases in agriculture, biology, and entomology will often lead the way to relevant literature. Access to these databases can be obtained through government agencies and universities. Some botanical literature is in local journals that are not included in scientific databases. The National Agricultural Library is an excellent resource whose reference technicians will assist in such searches.

As one reviews the collection of literature for a species, it is necessary to keep in mind that results and conclusions reflect the understanding of that species at the time the article was written. Only within the last few years have we become aware of the existence and impact of the race, variety or ploidy level found in plants. Most of these variations are geographic in nature: the further away an author is from Maryland, the more likely he was writing about a different form, race, variety or subspecies of the plant in question.

In reaching out to experts for additional help in understanding or interpreting taxonomic and genetic findings, we have had success in contacting authors directly. Experts at the National Plant Materials Center, the USDA Forest Service, the Maryland Natural Heritage Program (the State Botanist's office), and the National Park Service can often provide needed insights. Because these institutions have different missions, they will sometimes provide opposing points of view, so obtaining several opinions can be quite informative.

4.1.2 The Soil Stabilization Considerations

Many species would be excellent choices for roadside use, but would not necessarily have the special qualities ideal for soil stabilization. Understanding special abilities, germination behaviors, speed of growth, plant height, root structure and winter cover enables us to use a species most effectively. For example, at one of our meetings, Species Advisory Panel member Don Cober stated that understanding germination and speed of growth would allow us to include species that would provide rapid cover in the first years, and species that would provide long term cover and aesthetics in the years that follow.

Attribute 4: Special Site Condition Abilities or Requirements

The Species Advisory Panel recommends an understanding of any special abilities or requirements that a species has. After all, not every species suitable for soil stabilization will be ideal for every stabilization site. Is it limited to certain soil types, exposures, or moisture regimes? Does it have an exceptional drought tolerance, or the ability to grow on south-facing rocky slopes? Often the limitation and the requirement are the same, for example, some plants that have the unusual ability to grow in excessively well-drained sandy soil, can only grow there. Much information on this topic will be revealed in the literature search conducted for previous Attributes. If the National Plant Materials Center has published a Plant Fact Sheet or Plant Fact Guide, relevant information can be found there.

Attribute 5: Germination and Sowing Requirements

The Species Advisory Panel recommends an understanding of the species' germination requirements because most soil stabilization projects use seed. Seed is the most affordable method of introducing thousands, even millions, of propagules to a site – if it germinates. Seed is also easier to store than potted plants or plugs. To succeed with each species, we will need to understand how to store the seed, how the storage impacts seed dormancy and germination rates, how to sow the seed (for example, can it be hydroseeded?), when to sow the seed, and when to expect germination.

To determine the germination and sowing requirements, there are a few books on germination biology to check (Deno 1993; Baskin & Baskin 1998), and some data posted on-line (Native Plant Network and USDA Plants www.plants.usda.gov/). Again, it is imperative to look for relevant literature. For a few species, like gray goldenrod, extensive literature on germination biology is available. Occasionally you can find someone who has personal experience working with the seed and who is willing to share what they have learned.

Attributes 6 & 7: Growth and Height

The Advisory Panel recommends understanding growth rate and height because these two Attributes determine how the plant will be used in soil stabilization mixes. Species that germinate quickly and then grow quickly are desirable for soil stabilization. Not all species in the mix need to grow quickly. In fact, the Panel expressed a specific interest in more slow growing species that might mature into the site and improve function and aesthetics with time. However, at least some of the species in the mix need to demonstrate rapid growth and good vigor.

Tall species are desirable in some roadside applications like windbreaks, snow breaks, and visual screens. However, placed incorrectly they can obscure motorists' view of merging traffic. Short species are desirable for maintaining lines of sight, and adjacent to shoulders where motorists may need to walk if they have to pull over.

Determining speed of growth is difficult. The information is typically only available if the species has been used in some horticultural setting, in which case it may be found in gardening books and magazines, or by talking with staff at the NPMC, a botanic garden, or the MNP*S*. Determining height is easy. The height in Brown and Brown (1984) will typically reflect what you will find in wild settings or roadside plantings. Gardeners and gardening references may give you slightly greater heights because native plants tend to grow bigger in formal gardens.

Attributes 8 & 9: Winter Cover and Root Structure

The Species Advisory Panel recommends an understanding of a species' roots and leaves because these are the working parts that actually stabilize soil. A plant's leaves and stems cover the soil surface and intercept raindrops. When a raindrop hits bare soil, the kinetic energy of the raindrop is transferred from the drop into dislodging soil particles. If that raindrop is intercepted by a leaf or stem, the soil is protected. All plants provide some cover for the soil during the growing season. In the fall, some herbaceous plants wither away completely, not to be seen again until spring. Many turn brown, but retain their vegetation into spring. Brown vegetation is as effective at intercepting raindrops as green vegetation. A few native plants retain some green growth during winter (Figure 2). It is not necessary that every plant in a soil stabilization mix offer winter cover, but it is necessary that the mix should contain several species that offer this benefit.

Figure 2: Early April Foliage and Roots on Gray Goldenrod.

This photograph shows the gray goldenrod plant being dug from the field. Basal foliage rosette is green and full. Root mat is fibrous and large.

As anyone who has weeded a garden knows, there are a diversity of root structures that occupy different underground niches, and all are important components of a sustainable meadow. Gray goldenrod, for example, has a robust fibrous root mat that anchors the top few inches of soil (Figure 2) very well. Some plants have a taproot, which acts more like a spike, anchoring the topsoil to the subsoil, and cycling nutrients up from several feet below. Butterfly milkweed (*Asclepias tuberosa*), horseflyweed or wild false indigo (*Baptisia tinctoria*) and shrubby lespedeza (*Lespedeza intermedia* = *L. fructescens*) are examples of native plants with taproots. Several native plants have rhizomes, commonly referred to as runners. Rhizomes not only allow a plant to spread quickly and form vegetative colonies, they also form great subterranean bands, literally strapping the ground into place. The Panel has added Attribute 9 – root structure – so that designers of stabilization mixes will remember to include a diversity of root structures.

Another important factor to understand about a species' roots are the micro-organismal relationships. Some species' roots have symbiotic relationships with mycorrhizae. The plant gains an extended system for collecting water and nutrients from a larger volume of soil. The fungus gains sugars produced through photosynthesis. And we benefit, too, because soils with healthy microorganism communities gain a crumb-like soil texture that reduces soil erosion. Typically, disturbance-adapted plants do not have mycorrhizal symbiosis. Plant species that have a high degree of fidelity to mature ecosystems are likely to have some micro-organismal affiliations. In most mesic soils, even those that have been disturbed, the appropriate microorganisms are present and will flourish when their symbionts are planted. A lack of soil microorganisms can be responsible for planting failure in excessively well-drained soils (Miller 1997).

A plant's root structure can usually be determined by reference to Brown and Brown (1984). Root structure can also be determined by speaking with nursery production staff, gardeners, or by digging up a plant.

4.1.3 The Roadside Maintenance Considerations

A combination of special conditions, needs, and maintenance procedures make highway roadsides a unique environment for growing plants. Some of these conditions are:

- Constructed and compacted soils,

- Cut slopes,
- Lines of sight and corresponding vegetation heights that provide safety for motorists, pedestrians and wildlife,
- Obstructed lines of sight to minimize headlight glare,
- Vegetation that deters wildlife from being near the road in the first place,
- Vehicle exhaust that impacts plant communities,
- Melt water from de-icing chemicals.

Many of the species we would otherwise nominate will not be compatible with roadside conditions and maintenance procedures. We must have any available knowledge as to how our candidate species will respond.

Attribute 10: Safety and Interactions with Wildlife

Plants that offer good opportunities to watch wildlife are unsafe choices for the roadside. (see Table 1). This is why woodland sunflower (*Helianthus divaricatus*) and common milkweed (*Asclepias syriaca*) were quickly eliminated from consideration despite other highly desirable qualities. Many drivers will instinctively brake or swerve to avoid obliterating a beautiful animal, and both people and wildlife can suffer from these interactions.

Gardening books are often written with an eye toward attracting birds and large butterflies, so they are a great resource for determining which animals visit various plants. Gardening books also tend to mention which native plant species are least desirable to rabbits and deer.

On the other hand, all native plants provide some support for wildlife and this is part of why we are trying to preserve them. They are the basis of the food chain that supports all of the wildlife we hope to pass on to future generations of Marylanders (Tallamy, 2007). What is the happy medium? Many native plants do not draw noticeable numbers of the big vertebrate herbivores, but they do attract the tiny, invertebrate herbivores – insects like aphids, crickets, and mealybugs that are not traffic hazards. Through careful consideration, we can select these plants for close proximity to roadsides, and save great bird watching plants like woodland sunflower for our rest stops.

Attribute 11: Aesthetics

The Advisory Panel recommends that we understand the aesthetic qualities of each species considered for roadside use. This is not to suggest that every species in a stabilization mix have tremendous aesthetic value, but certainly none should be unsightly. Horseweed (*Conyza canadensis*) is an example of a plant that is so unattractive it would probably be disqualified from consideration. The tall fescue and sericea lespedeza currently in common use are quite plain. Maintaining the roadside in an aesthetic manner is part of the SHA mission statement (Table 1), so at least some of the species included in a stabilization mix should beautify the roadway.

To determine aesthetic qualities, a quick internet search should reveal images of most species. Since we are working with abundant and representative species (Table 4, Attribure 2) it should not be too difficult to locate some wild plants to observe personally during the course of a few seasons.

Attribute 12: Mowing Requirements and Tolerances

The Advisory Panel recommends a familiarity with the mowing requirements and tolerances of any species to be used along the roadsides. The area immediately adjacent to the road shoulder is referred to as the "low mow zone". The mowed area beyond this is referred to as the "high mow zone". Vegetation beyond the high mow zone typically is not managed, except occasionally to eradicate noxious weeds. To understand the placement of the proposed species within these zones, it will be necessary to understand how they respond to periodic mowing.

For most species it is very difficult to determine mowing tolerances. There is very little information on the topic in the literature, and gardeners don't mow their plants, so the information is not present in gardening books. One technique the authors have had success with is to visit roadsides where the plants occur, and observe how they respond to the mowing regimen there. Given time, one could find or plant and then mow the species of interest for a few seasons to observe the response.

Attribute 13: Herbicide Compatibilities

The Species Advisory Panel would like to see information on herbicide compatibilities, although there is very little available. Most of the research on herbicides and native plants focuses on killing native plants, not growing them. Native plants have only recently become crop plants. The Plant Materials Centers and some Agricultural Extension Services have begun publishing field studies in which herbicide use is recorded. Some research has been conducted in using herbicides, especially Plateau, to establish native meadows. Herbicide labels list the crops they can be used with. The Plateau label, for example, can be found at the BASF website, www.vmanswers.com/lib/productslist.aspx?CategoryID=268&SiteID=-1 .

A specific concern is compatibility with the herbicide typically used to control Canada thistle (*Cirsium arvense*), a listed noxious weed in Maryland. SHA prefers to control Canada thistle with spot treatments of Transline (Maryland SHA 2003). Clopyralid is generally safe on grasses and particularly damaging to members of the tomato family (Solanaceae) and the daisy family (Asteraceae).

Attribute 14: Road Salt Tolerance

The Species Advisory Panel recommends obtaining information on the tolerance of species to the chemicals used for de-icing. Unfortunately, we have not been able to find any such information in the literature. However, there is some information on the tolerance of various species to sea salt spray. It seems likely that species tolerant to sea

salt spray will be easier to find on the Eastern Shore, whereas more road salt is probably applied west of the Bay.

One way to approach the question is to observe which species can be found close to road shoulders. Unfortunately, these areas are also low-mow zones, and species there can be hard to identify. This may simply be one of those factors that will have to be determined with experience.

4.1.4 Affordability and Agricultural Considerations

Although the SHA does not typically need to contemplate the agricultural qualities of a seed crop, the Species Advisory Panel needed to do so in order to evaluate and recommend species to be targeted for development of local ecotype seed availability. SHAs stake in this issue is that it wants to be able to buy local ecotype seed at reasonable prices. SHAs interests can only be promoted by selecting those species that have qualities that lend themselves to affordable seed production. The agricultural considerations put forth by the Advisory Panel are:

1. Ease of controlling weeds in production fields - Weed control is a significant cost in the production of any crop. Weeds compete with all crops for moisture, nutrients and light. Weeds can be even more of a problem in seed crops. If the weed produces seeds that resemble those of the crop in size and weight, it can be very difficult (and expensive) to remove them during the seed cleaning process.
2. Abundance of seed - Species that produce a large number of viable seeds per unit field area will sell for less money per seed. Many small-seeded plants produce thousands of seeds per square foot of farm field.
3. Ease of harvest - Native seed can be difficult to harvest. For example, in some species seed ripens over a long period of time such that some portion of the seed is shattering or blowing away while another portion of the seed on each plant is not ripe yet. Others hold their seed until all is ripened, and then begin to disperse it. The latter species are easiest to harvest. Species that can be produced in large fields and harvested mechanically can be produced affordably.
4. Ease of seed cleaning - Some species have seed that is nearly clean as harvested, or clean very easily after harvest. Other species can require considerable machine processing. The worst case scenario occurs when the machines break stems and leaves down into pieces that resemble the seeds in shape or weight, making them time-consuming to impossible to remove with sieves and blowers.
5. Shelf life - Some species will store at room temperature and humidity for more than three years, and will keep even longer in cold storage. Others have very short shelf lives, in some cases less than a few weeks. From the seed producer's point of view, shelf life is an insurance policy, allowing a seed crop that did not sell one year to have additional years of marketability. Seed that has a very short shelf life will be more expensive and/or less available due to the risk that the grower may not sell the crop at all.

4.2 Application of the Attributes List to Example Species

In this section we illustrate the proper use of the Attributes List (Table 4) through the analysis of three species.[9] Although commonly recommended for roadside meadows and Conservation Reserve Plantings in Maryland, we will find that these species do not have the qualities we are seeking for roadside use. Each of these species was carefully selected because their review illustrates how to avoid a misstep in the Attributes review process. All the same, review of these three species is short because they are quickly eliminated.

In each of the 2nd, 3rd and 4th reports of this series, we will review a species that ultimately advanced to field trials. In those reports, the review not only serves as an example of how to use the Attributes List, but also as an introduction to the species discussed in the remainder of that report.

4.2.1 A Straight Forward Example of Attribute 1

In some instances, review of the Native Status Attribute is quite straightforward. Blanket flower (*Gaillardia pulchella* Foug.) has compelling qualities for roadside use, with its short stature and brilliant color. However, references indicate it is not native to any part of Maryland.

1. A. Native Status
    a. **Shetler and Orli (2000)** do not list the species as a member of the Baltimore-Washington flora.
    b. **Brown and Brown (1984):** The species is not even indexed in Herbaceous Plants of Maryland.
    c. The alien status is confirmed by several other sources (**USDA PLANTS database**, 2009; Flora of North America, 1993).

Consideration of the additional Attributes is not warranted, and the entire Attributes review process required only a few minutes.

4.2.2 A Complex Example of Attribute 1

In other instances, comparison of the species with even just Attribute 1 is complicated. Take for example common yarrow (*Achillea millefolium*).

1. A. Native Status
    a. **Shetler and Orli (2000)** indicate that the species is native,
    b. **Brown and Brown (1984)** describe the species as "a common and abundant weed, chiefly in pastures and permanent meadows; also roadsides and waste areas" and then go on to describe a cultivar that is known to escape.
    c. **Metzger (1995)** indicates that the species is an exotic that has naturalized in Maryland, but that some races may be native.

[9] The reader may wonder why the authors are discussing a method, specifically a method of evaluation, in the results section of this report. We are in the awkward position of all authors whose result is a method.

d. **The PLANTS Database** (USDA NRCS 2009) indicates that 12 varieties of *Achillea millefolium* are currently recognized within North America. One is native in Maryland, whereas the others are not. One is not native anywhere in North America, and is on some invasive species lists. This raises several questions. If there is a variety of yarrow native to Maryland, how would we recognize it, and is it rare or common? Are vendors offering the native or the invasive variety? For this species, consideration of Attribute 1 alone will be very time consuming. It would be best to delay the use of this species until an expert can review the complexities.

4.2.3 Examples of References that Provide Conflicting and Faulty Information

Big bluestem (*Andropogon gerardii* Vitman) easily passes Attribute 1, with all references indicating that it is native to Maryland (Brown & Brown, 1984; Metzger, 1985; Shetler & Orli, 2002; USDA Plants 2009). Proceeding to Attribute 2, we ask how abundant or representative the species is of Maryland meadows, and what its natural distribution is like.

2. Abundance and Natural Distribution

   a. **State Rarity:** The book Rare, Threatened, and Endangered Plants of Maryland (Maryland Department of Natural Resources 2007) indicates there are no rare *Andropogon* in Maryland. There are no synonyms for big bluestem that start with a different genus name.

   b. **Brown and Brown (1984)** describe the occurrence of big bluestem in Maryland as "Dry or wet soils and in open woodland; infrequent throughout". At this point in our review, we can conclude that the plant is probably infrequent but not so rare as to be tracked by the Maryland Heritage Program.

   c. The Maryland Native Plant Society Website

   i. Contains plant lists for many of their field trip sites throughout the State (www.mdflora.org/plantinfo/plantlists/lists_by_county.html). The lists do not separate plants that are native to the field trip site from those that might have been introduced. None of the field trip lists mention big bluestem, another indication that it is not common. If the species were listed, we might contact the list's author for more information.

   ii. Also contains plant lists developed by others (www.mdflora.org/survey_data/survey_data.html). The book Native Plants for Anne Arundel County is a compilation of other plant lists prepared by the Master Gardeners of Anne Arundel County (Gallagher *et al.* no year given). They have listed big bluestem as native. I contacted the lead author to determine the information used to determine native status. The list was based on information provided in Brown and Brown (1984) and the statement "infrequent throughout" was interpreted as "present throughout, but infrequent", which would mean that the plant was native to Anne Arundel County. The list is a good example of citizens stepping in to fill a void where scientists have failed to provide needed information.

d. **Park/Government Property Lists:** *Plants of Jug Bay Wetland Sanctuary* is a list of several plants that can be seen in that park. Big bluestem is on the plant list, and at first review of the list one might easily think that this means big bluestem is native to the park. Therefore I contacted the list author, who stated that the big bluestem is thought to be a remnant of old Conservation Reserve Plantings in the farm fields there (Karyn Molines, list author, pers. comm. 2009).

e. **Marylandica:** contains a plant list for natural communities in the Anacostia watershed (Simmons *et al.* 2008). The authors list *Andropogon glomeratus*, *A. ternarius*, and *A. virginicus,* but not *A. gerardii*.

f. **University of Maryland Norton Brown Herbarium:** If we were truly proposing the species for consideration, we would visit the herbarium, which only requires an hour or so of effort.

g. **Author's Observations:** In our fieldwork in Maryland, we have only seen big bluestem in the permanent meadows of serpentine barrens. We have never seen it within the Coastal Plain geographic province.

These data support Brown and Brown's assertion that big bluestem is infrequent, and would lead a reviewer to suspect that *Andropogon gerardii* is not a species that represents Maryland very well. Unless it had some compelling quality not possessed by a more representative native grass species, it should not be considered for use on Maryland roadsides. One potential example of a compelling quality would be if big bluestem were the only native grass capable revegetating some particular type of highly disturbed soil environment. In such a scenario, using the knowledge gained through the Attributes review process, we would be in a better position to consider the genetic impact that large-scale roadside use of big bluestem might have on the tiny and highly specialized populations adapted to life in Maryland's serpentine ecosystems.

4.3 Species Selected

After a cursory review of the list of common Maryland native meadow plants relative to the Attributes (Table 4), it was the opinion of our Advisory Panel that the species listed in Table 5 are ten of the most appropriate for use on Maryland roadsides. Although resources limit us from moving forward with the development of local ecotypes of all ten species immediately, we did choose from this list for our inaugural species. Future species to be developed could also be chosen from this list. The first step in such a development should be a thorough review of the Attributes of each species. The development of this list is the second accomplishment of this project and is a stand-alone result. It can be used now to purchase what seed is available from Maryland sources or to guide future development of additional seed sources. In addition, this list was used to guide the next phase of our project, the wild-collection phase.

Table 5: Top Ten Species for Use on Maryland Roadsides

Common Name	Scientific Name
Maryland goldenaster	*Chrysopsis mariana* (L.) Elliot
Virginia wildrye	*Elymus virginicus* L.
Purple lovegrass	*Eragrostis spectabilis* (Pursh) Steud.
Shrubby lespedeza	*Lespedeza frutescens* (L.) Hornem.
Nuttall's lespedeza	*Lespedeza nuttallii* Darl.
Beaked panicgrass	*Panicum anceps* Michx.
Florida paspalum	*Paspalum floridanum* Michx.
Talus slope beardtongue	*Penstemon digitalis* Nutt. ex Sims.
Gray goldenrod	*Solidago nemoralis* Aiton
Canada germander	*Teucrium canadense* L.

4.4 Wild Collection

We began the Wild Collection Phase looking for sources of all ten species on the list approved by our Species Advisory Panel (Table 5), assuming (correctly as it turned out) that our success or failure in the hunt would become the limiting factor. Some of the species were eliminated from the program because we were unable to locate the minimum number of parent populations. Maryland goldenaster was eliminated because we were unable to collect from any of the Piedmont locations – they were mowed before the seed ripened. Although we made many successful collections of purple lovegrass, we had better luck with the other warm season grass on our list, beaked panicgrass. The latter also appeared to be more of a generalist in habitat requirements, and so we eliminated the purple lovegrass from consideration. Nuttall's lespedeza was difficult to locate in the wild. We were unable to locate any populations of Florida paspalum in the Piedmont, and in this inaugural project we wanted to select species with a statewide distribution. It was surprisingly difficult to find wild populations of foxglove beardtongue, a rather aggressive and once very common wildflower. We were only able to locate one population east of the Bay, two in the Coastal Plain west of the Bay, and two in the Piedmont. The results for Germander were even more surprising. Anyone who has grown it in the garden knows it is a thug, and once it was very common in Maryland. We only found one population in the state.

In a few cases we were unable to comply with all the collection recommendations mentioned in our methods section. For example, the Bureau of Land Management (2008) recommends collecting seed on multiple dates, but we were only able to collect seed for some species from some parent populations on one date. This raises the possibility of a genetically skewed collection if variation in ripening date were related to genetic variation among individuals. We did not notice variation of ripening date among individuals within the same population. However, we did notice variation on the same plant, especially the goldenrods, with seed in one part of a panicle ripe while the remainder was still ripening. Since all that variation is within the individual, coming back a second time would not improve the genetic diversity of the seed collection. We

also noticed variation in ripening date among populations. In the case of one population of beaked panicgrass, we think that was because it had been mowed. Variation among populations was adequately sampled by our technique because each population was sampled when the seed was ripe.

We found enough gray goldenrod, beaked panicgrass and Virginia wildrye populations to satisfy the needs of the project, and so these were the three species that were advanced to the production trials. Greater detail on wild collection results of these three species is provided in the individual reports that follow.

5 Conclusions and Recommendations for Implementation

1. A Species Advisory Panel was developed to provide expertise from local agricultural, environmental and roadside vegetation management organizations (Table 2). The Panel members provided hours of useful consultation at no cost. The Panel can be re-convened by SHA whenever needed to provide further recommendations on appropriate species for roadside use.
2. The Attributes review process presented in this report (Table 4) is a reproducible, non-arbitrary method for evaluating species prior to approving them for use in roadside stabilization projects.
3. From the initial list of 30 locally native species considered for this project, the Species Advisory Panel selected a short list of ten (Table 5) that should be further investigated for both roadside slope stabilization and large-scale, affordable, agricultural production potential. This project has brought three of the ten species to the production phase.
4. The three species of seed that were wild-collected across the state are Virginia wildrye, beaked panicgrass, and gray goldenrod. Wild seed was used to study germination behaviors and to produce plugs for breeder block and production plots at private farms and at the National Plant Materials Center in Beltsville. The Attributes of these three species and the results of our work are discussed in the next three reports of this series.
5. Recently a number of authors have indicated that local ecotype seed is both the most successful in roadside revegetation projects, and the best choice for preserving the genetic integrity of local populations. Since it can only be produced locally, it is always the best choice for supporting Maryland's economy. This makes local ecotype seed the choice most consistent with SHAs mission statement. We recommend that SHA begin preferentially purchasing locally native seed whenever certified source-identified stock is available.

6 Future Work

1. **Build Our Coalition:** We should cultivate and expand the alliances built during this project.
   a. The Maryland Department of Agriculture would make a valuable addition to the Species Advisory Panel.
   b. Iowa has demonstrated the value of a vigorous department of transportation-university-nonprofit-USDA team like ours. Like our Advisory Panel, they formed to "promote commercial availability and affordability of Source Identified seed". Since 1939, the USDAs 27 Plant Material Centers have made 466 releases; 29 of these were made in cooperation with the Iowa team since their inception in 1990 (Belt & Englert 2009). The Iowa team estimates that, since their founding in 1999, they have helped restore 10,000 roadside acres to native vegetation. They have released 81 ecotypes of 33 species for commercial production. Their farmers produce over 60,000 pounds of source-identified seed annually (www.tallgrassprairiecenter.org /).
2. **Review the Attributes of More Species:**
   a. Begin review of the remaining 7 species on the short list of 10. Having the review results available will direct the future development of soil stabilization seed releases, and it will help SHA design consultants select species for wildflower meadows and formal landscapes.
   b. Use the Attributes review process to reevaluate the existing species lists in the SHA Standard Specifications for Construction and Materials (2008). There are many good recommendations on those lists, and the review process will point out any species SHA should reconsider.
3. **Attributes vs. Criteria:** The Attributes review process empowers SHA to work from a position of knowledge. It is not a set of criteria. The option of developing a set of criteria, or possibly assigning a point system to the species evaluation process should be investigated.
4. **Secure Success by Adding Species:** Stabilization projects occur on all types of soil, slope, slope aspects, light, and climate. To ensure success under these diverse conditions, it is necessary to add species to the initial cadre of three. It is also necessary if we are to ensure that our activities enhance Maryland's environment (Table 2: 7). Much as we have come to learn the environmental cost of planting the same few alien species on all disturbed soils, we are likely to learn that there is also an environmental cost to planting only three native species on all disturbed soils. We have a list of species to target (Table 5). Given the level of expertise and the diversity of perspectives present on the SAP, the short list has tremendous value for SHA. We recommend that the Attributes of the remaining seven species undergo vigorous review. If appropriate, local ecotype breeder blocks of these species should also be developed for agricultural production and roadside use.

7 Glossary

Several references were used in developing this glossary, but especially Davis *et al.* (2002), Smith and Halbrook (2004), and Ogle and Englert (2008). The glossary is botanically focused and ignores meanings or differences in meaning that terms may have when applied to other types of life.

Accession – Something added to a collection. In this paper it refers to a sample of seed collected from a wild parent population. It may also refer to the plants grown from that seed, since the two are genetically identical. In contrast, parent population refers to the group of plants at the wild location where the seed was collected.

Adjuvant – Another chemical that is mixed in with the primary herbicide that makes it even more effective than it would be alone, often a chemical that breaks down water tension and allows spray to spread evenly over the surface of a plant.

Alien species – A plant that was not present in a determined place prior to the arrival of humans. The determined place can be narrowly defined as the place under your feet with its peculiar ecotypical conditions (niche), or as widely as the entire continent.

Alloploid – A hybrid individual having two or more sets of chromosomes derived from two different species. (The same as Allopolyploid.)

Apical dominance – Hormonal domination of lower buds by the bud at the apex or tip of the plant. When this bud is cut off, lower buds along the stem and rhizomes are released and begin to grow.

AOSCA– Association of Seed Certifying Agencies.

Apomixis – Reproduction in which the ovary takes part, but there is no fertilization by the pollen grain. The plant produces a seed that is genetically identical to the mother plant.

Autogamy – Reproduction without contribution of male genes (pollen). Offspring are genetically identical to the mother plant.

Breeder block – A collection of plants grown directly from wild seed (or other propagules). It has a genetic composition representative of the wild population from which it was taken and is considered Generation 0. Breeder blocks are typically used by the people who will be releasing foundation seed to farmers.

Caryopsis – a type of fruit characterized by a dry outer layer attached to the single seed inside. This type of fruit is characteristic of many grasses and often referred to as a grain.

Clopyralid –A selective herbicide (3,6-dichloro-2-pyridinecarboxylic acid) used for control of broadleaf weeds, especially thistles and clovers.

CNI – Abbreviation for Chesapeake Natives, Inc. CNI is a 501(c)3 nonprofit organization that was founded in 2005. Both authors are affiliated with CNI.

Cotyledon –The seed-leaves of a plant embryo. These are very easily seen in bean seeds, they wither away as the first true leaves emerge. The number of cotyledons is used to divide the flowering plants into monocots (grasses, lilies, etc.) and dicots (beans, maples, etc.).

Culm – The aerial stem of a grass or sedge.

Cultivar – An assemblage of cultivated plants clearly distinguished by heritable (genetic) traits (morphological, physiological, cytological, chemical, other). USDA cultivars have been through replicated testing at multiple sites over two or more generations to prove and document the heritability of these traits, the superiority and/or performance, and the range of adaptation.

Diploid – An organism with two copies of each chromosome, one from each parent. If you visualize the chromosomes in the nucleus as a collection of letters in the alphabet, mostly looking like distorted x's, y's and k's, a diploid organism has a full set of the letters normal for its species.

Founder's effect – A reduction in genetic diversity that occurs when a fragment of a population founds (or is used by people to found) a new population. Generations of inbreeding within the small gene pool leads to an increase in the expression of recessive traits, including some mutations and susceptibility to diseases. The current Wikipedia page (en.wikipedia.org/wiki/Founder_effect) has several interesting examples of Founder's effect in human populations.

Generation one – The generations of offspring since the initial material was collected are counted, with generation zero representing the wild parent material or seed that was wild collected. Plants face selection pressures in cultivation, and these are not the same selection pressures they face in the wild. With each generation in cultivation, the population becomes less and less like its wild ancestors.

Genetic erosion – The accelerated loss in genetic diversity of crop species or of native plant species caused by human activities.

Genetic diversity –The total amount of genetic variation present in a population or species. Diversity allows individuals to react differently to external conditions. The classic example of the danger of a lack of genetic diversity to plant (and human) survival is the potato blight of the 1840s. All the potatoes responded the same way to the infection.

Germination – The initiation of the growth of a plant from a seed.

Glumes – The bracts that enclose the spikelet of a grass (often also applied to sedges). The glumes may enclose one or more flowers. Details of glume morphology are important in species identification. Glumes, lemma and palea are part of the chaf that are threshed out from grains of wheat and rice prior to consumption.

Glyphosate – a broad spectrum herbicide, trade name Roundup, also sold under other trade names since Monsanto's patent expired in 2000.

Habitat fragmentation – The parsing of once large tracts of habitat into ever smaller tracts. Fragmentation leads to the genetic isolation of plants into unnaturally small populations. Isolation puts these small populations at increased risk for obliteration by

random events, including generational genetic developments that are random rather than adaptive (population bottlenecking).

Haplome (Haploid) – A single set of chromosomes in the Triticae half of a diploid set that has come from an intergeneric hybridization event. If you visualize the chromosomes in the nucleus as a collection of letters in the alphabet, mostly looking like distorted x's and k's, a haplome is a set consisting of half of each of those letters, half of the x, half of the k, etc.

Hostplant – A plant that hosts insects and other organisms, usually but not always larval insects (like caterpillars) that cannot feed on other types of plant tissue. The most famous example of a hostplant and its larval insect is probably the milkweed and the monarch butterfly caterpillar.

Imazapic - A selective herbicide **Plateau use for the release of native warm season grasses**

Lemma – The outer, leaf-like bract of a grass-flower, and enclosing a single grass seed.

MDA – Maryland Department of Agriculture.

Multipot – Trademark product of the Ropak Corporation, a re-usable, deep plug tray made to grow seedlings for transplant into the field.

Native species – A type of plant that was present in a determined place prior to the arrival of humans. The determined place can be narrowly defined as the place under your feet with its peculiar ecotypical conditions (niche), or as widely as the entire continent.

Niche – The place an organism occupies in its habitat. The place is not merely a physical location, but also the place in the food web, and the place along environmental gradients (moisture, salinity, light, soils, etc.).

NPMC – The National Plant Materials Center, the lead Plant Materials Center of the USDA, NRCS located in the Beltsville Agricultural Research Center, Beltsville, Maryland.

NRCS – Abbreviation for the Natural Resources Conservation Service, one of 27 Agencies within the USDA. Prior to 1997 NRCS was known as the Soil Conservation Service.

Oryzalin- A preemerge herbicide for control of grass common trade name Surflan

Panicle – A compound flower head (inflorescence) containing a main stem and many branching branches, often plume-like or loosely pyramidal in outline. The flowers on one panicle do not all bloom at the same time (indeterminate). Both beaked panicgrass and gray goldenrod hold their flowers in panicles.

Polyploidy – The condition of having more than two fully paired sets of chromosomes (see for example alloploidy).

Population – A group of plants that can breed with each other, exchanging genetic information through the transfer of pollen or spores.

Parent population – In any field of science, a group of individuals from which a smaller sample is drawn. In our work, the group of individuals is a collection of wild plants at one location, and the sample is a seed collection.

Radicle – The first root to emerge from a seed, the embryonic root.

SHA – Maryland State Highway Administration.

Source-identified -Seeds or plants from a naturally growing population occupying a known or defined geographic area. No selection or testing of the parent population has been made. There is no performance or adaptation data available for the collection. Offspring is produced to ensure genetic purity and identity from rigidly defined natural stands, seed production areas, seed fields, or orchards.

spp. – Standard abbreviation for two or more species of a genus.

ssp. – Standard abbreviation for subspecies.

Stratification – A pre-treatment of seed, often to cold, moist conditions, that enhances germination rates, mimicking natural conditions.

Tetraploid – An organism with four copies of each chromosome. If you visualize the chromosomes in the nucleus as a collection of letters in the alphabet, mostly looking like distorted x's and k's, a tetraploid organism has two full sets of the letters normal for its species. However, in some species, all the members are tetraploid.

Tribe – **S**cientific classification of species usually include the following levels: Kingdom, Phylum, Order, Family, Subfamily, Genus, Species. Some authors, including Brown and Brown (1984), use Tribe as a level in classifying the Grass Family. The tribe Triticeae includes wheat, rye, barley, wheatgrass and wildrye.

Trifluralin a preemerge herbicide for control of grasses common trade name Treflan

var. – The botanical convention abbreviation of "variety", a taxonomic category subordinate to species. Variety can also have other meanings, even with respect to plants, depending upon the context.

USDA – United States Department of Agriculture.

8 References

Annotated Code of Maryland**.** The Erosion And Sediment Control Regulations (COMAR 26.17.01). http://www.dsd.state.md.us/comar/. Accessed 11/27/09.

Ayres, D.R., D. Garcia-Rossi, H.G. Davis & D.R. Strong (1999). Extent and degree of hybridization between immigrant (*Spartina alterniflora*) and native (*S. foliosa*) cordgrass (*Poaceae*) in California, U.S.A. determined by random amplified polymorphic DNA (RAPDs). *Molecular Ecology* **8**: 1179-1186.

Barkworth, M.E., J.J.N. Campbell & B. Salomon (2006). *Elymus* L. *In*: Flora North America Editorial Committee (Eds.). *Flora of North America North of Mexico* Vol. **24**: 288-343. Magnoliophyta: Commelinidae (in part) Poaceae, part 1. Oxford University Press, New York. Manuscript. version also available at www.herbarium.usu.edu/webmanual (accessed on 5/01/09).

Baskin, C.C. and J.M. Baskin (1998). Seed Ecology, Biogeography, and Evolution of Dormancy and Germination. Academic Press, San Diego, CA. 666pp.

Beck, K.G, K. Zimmerman, J.D. Schardt, J. Stone, R.R. Lukens, S. Reichard, J. Randall, A.A. Cangelosi, D. Cooper & J.P. Thompson (2008). Invasive Species Defined in a Policy Context: Recommendations from the Federal Invasive Species Advisory Committee. *Invasive Plant Science and Management*. **1**: 414–421.

Belt, S.V. & J.M. Englert (2008). Improved Conservation Plant Materials Released by NRCS and Cooperators Through December 2007. USDA Natural Resources Conservation Service, National Plant Materials Center.

Booze-Daniels, J., D.R. Chalmers & R.E. Schmidt (1998). Native Grasses on the Roadsides of Virginia - A Review of Literature. A Report to Virginia Department of Transportation submitted by Department of Crop, Soil and Environmental Science, Virginia Polytechnic Institute and State University.

Brown, M.L. & R.G. Brown (1984). *Herbaceous Plants of Maryland*. Port City Press, Inc., Baltimore, Maryland. 1127pp.

Brown, M.L. & R.G. Brown (1984). *Woody Plants of Maryland*. Port City Press, Inc., Baltimore, Maryland. **pp.

Bureau of Land Management (2008). Technical Protocol for the Collection, Study, and Conservation of Seeds from Native Plant Species for Seeds of Success. www.cbgseedbank.org/forms/CBG%20Collection%20Protocol.pdf (accessed 2008).

Carver, E. (2009). Birding in the United States: A Demographic and Economic Analysis. United States Fish and Wildlife Service, Report 2006-4. Arlington, VA.

Chesapeake Natives, Inc. (2009). The Species Webpages. www.chesapeakenatives.org/Chesapeake_Natives_Draft/Species.html Accessed June 2009.

Dale, C.G. (1993). LCMR Final Status Report: Native Grass and Wildflower Seed. Minnesota Dept. of Agriculture.

Davis, K.M., J.M. Englert & J.L. Kujawski (2002). Improved Conservation Plant Materials Released by NRCS and Cooperators Through September 2002. USDA NRCS National Plant Materials Center. www.plant-materials.nrcs.usda.gov/mdpmc/publications.html

Deno, N.C. (1993). *Seed Germination Theory and Practice*. 2nd Edition. Published by the author: 139 Lenore Dr., State College Pennsylvania 16801

Federal Highway Administration (2002). Greener Roadsides: An FHWA Quarterly Newsletter for Roadside Decision Makers. Summary of the 2002 Seeds of the Future Conference in Orlando, Florida. www.fhwa.dot.gov/environment/greenerroadsides/winter02.htm#toc

Freckmann, R.W. & M.G. Lelong (2003). *Panicum.* pp. ***-***. *In*: Flora of North America Editorial Committee (Eds). *Flora of North America North of Mexico* Vol. 25 Magnoliophyta: Commelinidae (in part) Poaceae, part 2. Oxford University Press, New York. www.herbarium.usu.edu/webmanual (accessed 7/01/09).

Gelbard, J.L. & J. Belnap (2003). Roads as conduits for exotic plant invasions in a semiarid landscape. *Conservation Biology* 17(2): 420-432

Grabowski, Janet, B. Baldwin and P. Meints. 2004. Selecting for Improved Seedling Establishment in Beaked Panicum. *Jamie L. Whitten Plant Materials Center 2004 Annual Technical Report.* p.16-17.

Greenberg, C., S.H. Crown & D.R. Gordon (1997). Roadside soils: A corridor for invasion of xeric scrub by nonindigenous plants. *Natural Areas Journal* **19**: 99-109.

Gould, L. (2000). *Lady Bird Johnson: Our Environmental First Lady*. University of Kansas Press, Lawrence, Kansas.

Gustafson, D.J., D.J. Gibson & D.L. Nickrent (2004). Conservation genetics of two codominant grass species in an endangered grassland ecosystem. *Journal of Applied Ecology* **41**: 389-397.

Gustafson, D.J., D.J. Gibson and D.L. Nickrent (2005). Using Local Seeds in Prairie Restoration: Data Support the Paradigm. *Native Plants Journal* **6**(1): 25-28.

Henderson, K. (2002). The Iowa Ecotype Project, a presentation to the Seeds of the Future Conference, Orlando, Florida. www.fhwa.dot.gov/environment/greenerroadsides/win02p5.htm

Highway Beautification Act (1965). www.oah.org/pubs/magazine/firstladies/koman-doc1.html (accessed 12/31/05).

(accessed 8/28/09).

Jenkins, A.M., D.R. Gordon, M.T. Renda (2004). Native alternatives for non-native turfgrasses in central Florida: germination and responses to cultural treatments. *Restoration Ecology* **12**(2): 190-199.

Johnson, Lady Bird, & C.B. Lees (1993). *Wildflowers Across America*. Abbeville Press. New York. 312 pp.

Kartesz, J. & C.A. Meacham (1999). *Synthesis of the North America Flora*. Version 1.0 (CD-ROM). North Carolina. www.bonap.org/synth.html

Koman, Rita G. (2001). ". . . to leave this splendor for our grandchildren": Lady Bird Johnson, Environmentalist Extraordinaire, Org. of Am. Historians Mag. of History, v15.

Landis, T.D., K.M. Wilkinson, D.E. Steinfeld, S.A. Riley & G.N. Fekaris (2005). Roadside revegetation of forest highways: new applications for native plants. *Native Plants Journal* **6**(3): 297-305.

Latham, R. (2006). Native Grasslands and Meadows in Pennsylvania. *In*: M. Sanderson (Ed.). Proceedings of the 5th Eastern Native Grass Symposium. Omni Press, Wisconsin.

Linhart, Yan B. (1995). Restoration, revegetation, and the importance of genetic and evolutionary perspectives. In *Proceedings: Wildland Shrub and Arid Land Restoration Symposium 1993*. US Forest Service General Technical Report INT-GTR-315. Roundy, B., D. MacArthur, E. Durrant, J. Haley and D. Mann, eds.

Mack, R.N. (1991). The commercial seed trade: An early disperser of weeds. *Economic Botany* **45**: 257-273.

Maryland Department of Environment (2004). Maryland Standards and Specifications for Soil Erosion and Sediment Control.

Maryland Department of Natural Resources (2007). Rare, Threatened and Endangered Plants of Maryland. www.dnr.state.md.us/wildlife/espaa.asp

Maryland Department of Transportation (2007). Fiscal Year 2008 Through Fiscal Year 2011 Business Plan. www.marylandroads.com/oc/shabusinessetnl.pdf , accessed 6/1/09

Maryland Native Plant Society (2002). Guidelines for Collecting Seeds From Native Plants. www.mdflora.org/publications/gguidelines02.pdf

Maryland State Highway Administration (2003). Integrated Vegetation Management Manual for Maryland Highways.Maryland Dept. of Transportation. 144 pp.

Maryland State Highway Administration (2008). State Highway Administration's Standard Specifications for Construction and Materials. 792 pp.

McKay, J., C. Christian, S. Harrison & K. Rice (2005). How Local is Local? *Restoration Ecology* **13**(3): 432–440.

Metzger, J. 1995. Maryland Native Plants: A Master Checklist. www.mdflora.org/publications/mdchecklist.pdf

Miller, R.M. (1997). Prairie Underground *in* The Tallgrass Restoration Handbook. Stephen Packard and Cornelia F. Mutel (eds.) The Society for Ecological Restoration. Island Press. Washington, D.C.

Moore, A. (2009). Map of the Major Land Resource Areas of Maryland. Prepared for this report by the State Soil Scientist, USDA Natural Resources Conservation Service.

Munda, B. and S. Smith (1995). Genetic variation and revegetation strategies for desert rangeland ecosystems. US Forest Service General Technical Report INT-GTR-315. Roundy, B., D. MacArthur, E. Durrant, J. Haley and D. Mann, eds.

National Academy of Sciences (2003). *Predicting Invasions of Nonindigenous Plants and Plant Pests*. Richard N. Mack, Chair. National Academy Press, Washington, D.C.

Norcini, J.G., J.H. Aldrich, L.A. Halsey & J.G. Lilly (1998). Seed Source Affects Performance of Six Wildflower Species. *Proceedings of the Florida State Horticultural Society* **111**: 4-9.

Noss, R. (1999). Restoring Grassland Ecosystems: An Opportunity to Save the Pieces in Roadside Use of Native Plants, Bonnie Harper-Lore, (ed.) Federal Highway Administration. www.fhwa.dot.gov/environment/rdsduse/ (accessed 12/21/05).

Ogle, D. & J. Englert (2008). *Glossary of Terms for Use in Plant Materials*. USDA Natural Resources Conservation Service. Boise, Idaho. 48 pp.

Parendes, L.A. & J.A. Jones (2000). Role of light availability and dispersal in exotic plant invasion along roads and streams in the H.J. Andrews Experimental Forest, Oregon. *Conservation Biology* **14**: 64-75

Pfaff, S. (2002). *Florida Native Seed Production Manual*. USDA NRCS, Brooksville, Florida. 76 pp.

Reichard, S.H. & P. White (2001). Horticultural introductions of invasive plant species: a North American perspective. *In*: McNeely, J.A. (ed.). *The Great Reshuffling: Human Dimensions Of Invasive Alien Species.* International Union for Conservation of Nature and Natural Resources, Gland, Switzerland.

Richardson, S. (1997). Development of Native Seed Sources and Establishment Methods for Native Upland Reclamation. USDA NRCS Plant Materials Center, Brooksville, Florida. 23 pp.

Richardson, S. (1999). Development of Native Seed Sources and Establishment Methods for Native Upland Reclamation. USDA NRCS Plant Materials Center, Brooksville, Florida. 23 pp.

Rogers, D. (2004). Genetic Erosion. *Native Plants Journal* **5**(2): 113-122.

Schmidtling, R.C. (2001). Southern Pine Seed Sources. US Forest Service. General Technical Report SRS-44.

Shetler, S. & S.S. Orli (2000, 2002). *Annotated Checklist of the Vascular Plants of the Washington-Baltimore Area.* Part I and Part II. Dept. of Botany, National Museum of Natural History, Smithsonian Institution, Washington, D.C.

Simmons, R.H., J.M. Parrish, M.D. Tice, and M.T. Strong (2008). Conservation Priorities and Selected Natural Communities of the Upper Anacostia Watershed. *Marylandica* **12**(1): 1-23.

Slattery, B.E., K. Reshetiloff & S.M. Zwicker (2003). *Native Plants for Wildlife Habitat and Conservation Landscaping: Chesapeake Bay Watershed*. U.S. Fish & Wildlife Service, Chesapeake Bay Field Office, Annapolis, Maryland. 82 pp.

Smith, C. (2008). *Invasive Exotic Plants of North Carolina*. North Carolina Dept. of Transportation. www.se-eppc.org/northcarolina/NCDOT_Invasive_Exotic_Plants.pdf (accessed 8/27/09).

Smith, S.E. and K. Halbrook (2004). A plant genetics primer. *Native Plants Journal* **2004** (Fall): 106-111.

Tallamy, D.W. (2007). *Bringing Nature Home: How Native Plants Sustain Wildlife in Our Gardens*. Timber Press, Portland, Oregon. 288 pp.

Tangren, S. (2002). A photographic comparison of the performance of Lake Erie ecotype natives vs. Chesapeake ecotype natives during the drought of 2002. Unpublished observations available on request.

Terrell, E.E., J.L. Reveal, R.W. Spjut, R.F. Whitcomb, J.H., Kirkbride Jr., M.T. Cimino, & M.T. Strong (2000). Annotated list of the flora of the Beltsville Agricultural Research Center, Beltsville, Maryland. USDA, Agricultural Research Service. ARS-155.

U.S. Census Bureau (2000). quickfacts.census.gov/qfd/states/24000.html

USDA NRCS (2006+). The PLANTS database. National Plant Data Center, Baton Rouge, LA 70874-4490 USA. Baton Rouge (LA). www.plants.usda.gov (accessed 2006 through 2009).

United States Department of Transportation, Bureau of Transportation Statistics (2000). Maryland Transportation Profile. www.bts.gov/publications/state_transportation_statistics/maryland/pdf/entire.pdf

Virginia Department of Conservation and Recreation and the Virginia Native Plant Society (2003). *Invasive Alien Plant Species of Virginia*. www.dcr.virginia.gov/natural_heritage/documents/invlist.pdf

Vogel, K.P., A.A. Hopkins, K.J. Moore, K.D. Johnson & I.T. Carlson (2006). Genetic Variation among Canada Wildrye Accessions from Midwest USA Remnant Prairies for Biomass Yield and other Traits. *Crop Science* **46**: 2348–2353.

Watkins, R.Z., J. Chen, J. Pickens & K.D. Brosofske (2003). Effects of forest roads on understory plants in a managed hardwood landscape. *Conservation Biology* **17**: 411-419.

Wildflower Seed & Plant Growers Association, Inc. www.floridawildflowers.com (accessed 12/20/05).

Young, Stanford A. (1995). Verification of germplasm origin and genetic status by seed certification agencies. In *Proceedings: Wildland Shrub and Arid Land Restoration*

Symposium 1993. US Forest Service General Technical Report INT-GTR-315. Roundy, B., D. MacArthur, E. Durrant, J. Haley and D. Mann, eds.

Young, S.A., B. Schrumpf, and E. Amberson. (2003). The AOSCA Native Plant Connection: The Need for Native Plant Genetic Information. Bulletin of the Association of Official Seed Certifying Agencies. Meridian, Idaho.

Zheng, H., Wu, J.,Ding, J., Binion, D., Fu, W. and .Reardon, R. (2004). *Invasive Plants of Asian Origin Established in the United States and Their Natural Enemies*. Vol. I. USDA Forest Service, Forest Health Technology Enterprise Team, Morgantown, WV, 26505. www.invasive.org/weeds/asian/

Zheng, H., Wu, J., Ding, J., Binion, D., Fu, W. and .Reardon, R. (2005). *Invasive Plants of Asian Origin Established in the United States and Their Natural Enemies*. Vol. 2. USDA Forest Service, Forest Health Technology Enterprise Team, Morgantown, WV, 26505.

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Maryland Department of Transportation
State Highway Administration

Beverly K. Swaim-Staley, *Secretary*
Neil J. Pedersen, *Administrator*

STATE HIGHWAY ADMINISTRATION

RESEARCH REPORT

DEVELOPMENT OF NATIVE SEED FOR SHA PROJECTS: REPORT NO. 2. VIRGINIA WILDRYE

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CHESAPEAKE NATIVES, INC.

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STEVEN A. BERG NATIONAL PLANT MATERIALS CENTER, NRCS, USDA

Project number SP608B4K
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16. Abstract

Our goal is to make locally native seed more affordable and more available to SHA. This report covers the work we have done from 2006 through 2008 with the promising candidate species, Virginia wildrye. We begin with a review of the 14 Attributes. Virginia wildrye is a 3 ft tall, showy, perennial, cool-season grass. It has fibrous roots and grows well in many soil types. It may tolerate some salt spray. It will be damaged if mowed annually in June, as per the SHA guidelines for wildflower meadows. It does not attract wildlife that would present a traffic hazard. Virginia wildrye is a common and representative native species found in every geologic province of our state. Unlike most of the species SHA will work with, Virginia wildrye is largely self-pollinated. The genetic diversity is found among populations rather than within them. Therefore we put special effort into wild collecting from as many populations as we could find, **41 in total**. Virginia wildrye germinates in cool moist weather with or without prior cold stratification. We discuss our work establishing breeder blocks at the NPMC, and working with two local farmers to establish production fields. We spend some time discussing agricultural methods because they have future application to roadside establishment and maintenance practices. Large scale production methods will be similar to those used for wheat and barley grain production. Virginia wildrye set a respectable seed crop in its first year, the 2008 field season. The plants that did bloom produced approximately **350,00 seeds (1.1 lb)**. Seed set will be considerably higher in 2009. Virginia wildrye is likely to become a valuable and affordable soil stabilization and nurse crop seed for use along Maryland highways.

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Executive Summary

This report summarizes the work that we are doing to make affordable, locally native Virginia wildrye seed available to SHA. The work described in this report was done between 2006 and 2008. Work continues, and the reader may anticipate subsequent updates/revisions. It is the second report in a series, the first was general in scope and dealt primarily with the selection of species for use in roadside revegetation.

This project began with a thorough review of Virginia wildrye with respect to the 14 Attributes developed by the SAP. We determined that Virginia wildrye is very appropriate for use on Maryland's roadsides. It is native over most of North America. However, there are various forms, subspecies, varieties, and synonyms that have been the subject of recent taxonomic reworking. Virginia wildrye is found in every geologic province of our state, and is a representative grass of our meadows and young woodlands.

Virginia wildrye is a 2.0 to 4.8 ft tall, cool season, perennial grass that resembles its domestic relative, wheat. It has a fibrous root system. It germinates quickly, is semi - evergreen, and may tolerate some salt spray. It does not attract the type of wildlife that would present a traffic hazard.

Virginia wildrye is largely self-pollinated, so the individuals within a given population are nearly identical to each other. Therefore, to capture the genetic diversity that is needed to ensure adaptability to a wide range of roadside conditions, it was necessary to wild collect from many parent populations. Seed was acquired from 44 populations to establish the NPMC breeder blocks for this project.

Virginia wildrye germinates and grows best in spring and fall. Germination occurs 3 to 10 days after sowing and is followed by rapid leaf growth. Plants reach reproductive maturity in their first year. This biology will not only facilitate Virginia wildrye's use in soil stabilization projects, it might also make it a valuable cool season nurse crop.

We will discuss our work establishing production fields at two private farms, and the agricultural methods we developed working with the farmers there. These methods have future application to roadside establishment and maintenance practices. The farm field establishment and maintenance practices discussed as part of this project are appropriate for breeder block and establishment but not large-scale production. Our team includes farmers and NPMC staff who have prior experience growing wildrye and/or its relatives in larger plots and harvesting it with a combine. This is the promising avenue for economical production of this seed.

All of the 3,100 plants from the three separate farm fields set a small quantity of seed in their first year, the 2008 field season. The establishment year harvest for Virginia wildrye was 22.8 pounds, over 2 million seeds. The plants are expected to produce a larger quantity of seed in their second year.

As a result of this project, two Maryland farmers are producing annual crops of locally native Virginia wildrye seed. Virginia wildrye is on track to become a valuable and affordable component of Maryland’s future soil stabilization mixes.

1 Introduction

Our goal is to make locally native seed more affordable and more available to SHA. This report is the second in a series on that topic. The first report was general in scope. It provided the reader with:

1. an introduction to the Species Advisory Panel and the Attributes review process, a method of evaluating a species' potential for use in roadside revegetation projects,
2. a summary of the literature on the many aspects of selecting and using locally native seed in revegetation projects, including a review of how genetically diverse, locally native seed is of specific benefit to soil stabilization projects, and
3. an outline of methods of wild seed collection that will ensure the desired genetically diverse, locally native seed is obtained.

This report is more specific in scope. It covers the work done from 2006 through 2008 with a locally native cool season grass that shows promise for seed production and soil stabilization, Virginia wildrye. The authors will discuss the wild collection, germination, plug production, farm plot establishment and maintenance, and first year harvest of this species. Fieldwork with Virginia wildrye continues, and that work will be summarized in subsequent updates/revisions.

The third and fourth reports of this series will be similar in structure to this one, but will feature our work with the warm season grass, beaked panicgrass (*Panicum anceps* Michx.), and the showy wildflower, gray goldenrod (*Solidago nemoralis* Aiton), respectively.

2 Attributes Review of Virginia Wildrye

In 2006, our Species Advisory Panel (SAP) deliberated over the qualities a plant would need to facilitate successful roadside soil stabilization. Here we provide a detailed review of Virginia wildrye using the SAP's first 14 Attributes, those that pertain to determining a species' suitability for roadside use. In these reports, where ever the authors capitalize the word Attribute, the reader will know the word refers specifically to the Attributes developed by the SAP.

1& 2: Range, Distribution, and Abundance

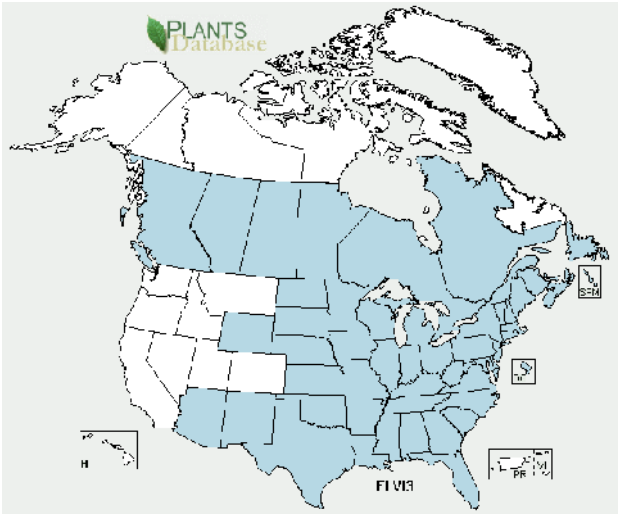

Figure 1: Native Range.

This map shows that the range of Virginia wildrye covers most of North America except for the circumpolar regions and these eight western states: Washington, Oregon, California, Idaho, Montana, Nevada, Utah and Colorado. Maps from Plants Database (USDA 2006+).

1. **Native Status:** To determine whether or not Virginia wildrye (*Elymus virginicus* L.) is native, we consulted these references:
    i. **Shetler and Orli (2002):** list it as native in DC, MD and VA.
    ii. **Brown and Brown (1984):** do not explicitly state whether the plant is native or introduced.
    iii. **Metzger (1995):** includes the plant on his checklist of Maryland natives.
    iv. **Expert:** For this project we interviewed Maryland Native Plant Society botanist Rod Simmons, who indicated the species is native in Maryland.

2. **Abundance & Distribution:** Since the data on abundance and distribution are often found in the same references, it is more concise to review them together:
    i. **MD DNR (2007):** *Elymus trachycaulus* is the only species of *Elymus* on the Rare, Threatened and Endangered Plants of Maryland list (Maryland Department of Natural Resources, 2007). That name is in no way synonymous with *E. virginicus* (PLANTS database, USDA NRCS 2006+). In our fieldwork for this project, we were able to locate 40 accessions of Virginia wildrye.
    ii. **Brown and Brown (1984):** describe it as "widely found in rich forest margins and along shores". They report the variety *halophilus* from wet sands and brackish habitats in Worcester County; *glabriflorus* as frequent in rich soils of the Piedmont and Coastal Plain; and the forma *hirsutiglumis* as occurring over most of the Midland Zone.
    iii. **Maryland Native Plant Society Website:** Virginia wildrye is on the following local plant lists that can be referenced through the MNPS website (www.mdflora.org/survey_data/survey_data.html)
        - Parrish & Steinman (2003+): moist, open areas of the Sligo Creek watershed, Montgomery County

- Molines, Karyn (no year): Plants of Jug Bay Sanctuary

- **Parks/Government Property Lists:** The Patuxent Wildlife Refuge has published a list of plants that occur on their grounds (www.pwrc.usgs.gov/history/herbarium/category.htm). Virginia wildrye is listed as native to the refuge.
- **Marylandica:** We reviewed back issues of Marylandica and Native News and were unable to find any references to plants in the genus *Elymus* (www.mdflora.org/publications/publications.html).
- **U.S. Fish and Wildlife Service (Slattery *et al.* 2003):** lists Virginia wildrye as native to the Mountain, Piedmont, and Coastal Plain regions of the Chesapeake watershed. Found in dry to mesic, rich thickets, shores, and in meadows, in part sun to full shade. Soil pH ranging from 5 to 7, and a wide range of soil textures from clay to sand and even organic soils.
- **Herbarium Records:** Specimens of *Elymus virginicus* were observed at the University of Maryland's Norton Brown herbarium**.** Every geologic province and nearly every county in the state were represented: Allegany, Anne Arundel, Baltimore, Calvert, Caroline, Carroll, Cecil, Charles, Dorchester, Frederick, Garrett, Harford, Howard, Kent, Montgomery, Prince George's, Queen Anne's, St. Mary's, Talbott, Washington, Wicomico, and Worcester. Given the excellent data provided by this herbarium, the authors did not review records from other herbaria.
- **Author's Observations:** In the wild, we have found the plant in moist to dry, rich to poor soils, and full sun to part shade, throughout Maryland.
- **National/International: The USDA PLANTS Database** (USDA NRCS, 2006+): lists *Elymus virginicus* L., Virginia wildrye, as native over most of North America with the exception of eight western states and the circumpolar provinces of Canada. However, the various synonyms, varieties and forms listed by the website are not yet in sync with the revised taxonomy, so we will have to wait to delve more deeply into the issue of the PLANTS geographic distribution maps.

3: Taxonomy, Ecology, and Genetics

Figure 2. Botanical Drawing.

Elymus virginicus var. *virginicus* line drawing (Britton and Brown 1913)[1].This line drawing shows the spike or "ear" at left, and a close up of one spikelet at right. Each spikelet contains two pairs of glumes (tinted for ease of recognition). Within each pair of glumes are three caryopses. Each caryopsis contains a single seed.

Virginia wildrye is a cool season grass, similar to wheat and annual rye in appearance, but unlike those grasses, it is perennial. The wheat-like ears, technically referred to as spikes, begin to flower in June, when the plant reaches its full height of around 3 feet. Plants become somewhat dormant in summer and may even turn brown. Fresh foliage appears in fall and persists through winter. Many of the seeds remain in the spikes beyond December (Chesapeake Natives 2009).

Brown and Brown (1984) list three species of *Elymus* in Maryland: *E. virginicus, E. villosus,* and *E. canadensis*. They offer two common names for *E. virginicus*: Virginia wild-rye and Terrell grass. They describe three subspecies: *halophilus* (Bickn.)[2]Wieg.; the variety *glabriflorus* (Vasey) Bush; and the forma *hirsutiglumis* (Scribn.) Fern.

Shetler and Orli (2002) give similar common names, and the alternate scientific names *E. australis* Scribn. & C.R. Ball, *E. glabriflorus* (Vasey) Scribn. & C.R. Ball, *E. hirsutiglumis* Scribn., and *E. striatus* Willd.

Recent taxonomic revisions of *Elymus* have delimited the genus as naturally-occurring alloploids (Barkworth *et al.* 2006). All species native to North America are tetraploid (2n=4x=28). They descend from at least

[1] downloaded from USDA-NRCS PLANTS Database / Britton, N.L., and A. Brown (1913). *An illustrated flora of the northern United States, Canada and the British Possessions* 1: 292

[2] In this report, we will introduce a species with both its common and its formal botanical name. The latter will be followed by the unwieldy but necessary botanical authors' attributions, sometimes abbreviated or in parentheses as per the convention of the International Code of Botanical Nomenclature, as currently published on the USDA PLANTS website. The majority of our readers will not be botanists, so other than the first mention of a species, we only use the common name.

one hybridization event between a species of *Pseudoroegneria* (the wheatgrasses)[3] and a species of *Hordeum* (the barleys), followed by chromosome doubling. American taxa with different haplome (haploid parent) configurations have been (or will be) excluded from the genus.

As a result of this work, Barkworth *et al*. have developed a new *Elymus* key for the Flora of North America. Some grasses that were once considered varieties or subspecies of *E. virginicus* are now split into separate species. In the next few years it is possible that additional lumping and splitting could occur within the complex of grasses closely related to Virginia wildrye. The new nomenclature either is not being accepted at USDA or is just so recent that it has not yet appeared on the PLANTS database (USDA NRCS 2006+). By wild collecting Virginia wildrye from across the state, we have captured the genetic contribution of several members of the complex, and this is in fact the diversity we were seeking. For the purpose of this report, the authors will continue to refer to the Virginia wildrye complex simply as Virginia wildrye.

Although Virginia wildrye is primarily self-pollinating (Huff *et al*. 2006, Saha *et al*. 2009) it can cross-pollinate with nearby populations of Canada wildrye (*E. canadensis*), forming yet another set of vigorous hybrid offspring that sometimes defy taxonomic classification and may exhibit low fertility (Church 1958; Nelson & Tyrl 1978; Vogel *et al.* 2006; Barkworth 2006).

Another consequence of the self-pollinating behavior is that most of the genetic diversity in the species is held among populations, not within them (Huff *et al*. 2006, Saha *et al*. 2009). Individuals within any given wildrye population are very closely-related, sometimes even genetically identical. If a Virginia wildrye plant does well under the conditions where it is growing, it can produce many seeds that are genetically identical to itself, and therefore have many successful offspring. It's a great strategy if a plant happens to be well adapted to its site, but a failing strategy otherwise. In a report prepared for the USDA Forest service, Aubry *et al*. (2005) criticize the USDA Plant Materials Centers' approach of developing genetically narrow wild collections into cultivars that are ultimately used for revegetation. Aubrey *et al*. state that such cultivars lack the adaptive potential required for successful revegetation projects. One of several examples that they give involves a close relative of Virginia wildrye, blue wildrye (*Elymus glaucus*). Tying together precisely the same wild collection, self-pollination, and target use issues that we are dealing with in this report, the authors state, "The NRCS sampling strategy will thus result in a blue wildrye release that is essentially a clonal entity with extremely limited genetic diversity and questionable adaptive potential when inserted into wildland settings. A more ecologically appropriate sampling strategy for the species would have involved at least 50 to 60 individuals from as many source locations as possible within the proposed seed use area..."

How does all this information impact the use of Virginia wildrye by the SHA? The following considerations arise out of the information on the genetics of *E. virginicus*:

[3] The genus contains wild grasses mostly found in the west, not to be confused with the genus of wheat, *Triticale*.

a. The new taxonomic keys make it easier to identify specific members of the Virginia wildrye complex. Keeping abreast of these taxonomic developments allows seed producers, seed certification agencies, seed vendors and seed consumers to communicate accurately with one another.

b. Caution is needed in placement of *E. virginicus* breeder block and production fields. They should not be situated near wild populations, roadside plantings, or production fields of *E. canadensis*. To do so could result in generations of low fertility seed coming from both the production field (bad for the producer), along the roadside (bad for roadside populations), and in the wild (bad for Maryland's environment).

c. The native wildryes are prone to form hybrids with other members of the tribe *Triticeae*. The origin of new species within the tribe is related to this sort of gene transfer (Barkworth *et al.* 2006). Hybrid offspring can be vigorous and some are fertile. This suggests the possibility that introducing more foreign species from this tribe (and there are many Eurasian tribe members that have not yet been imported) could result in the formation of new species with possibly negative consequences for Maryland's wild populations. A similar scenario has occurred in the genus *Spartina*, when our local Maryland native cordgrass was introduced into Californian and European salt marshes, where it promptly hybridized with *Spartinas* native there to create a new invasive species (Ayres *et al.* 1999).

d. The self-pollinating nature of the genus *Elymus* requires that we be particularly diligent in sampling from several parent populations to capture the broad range of genetic diversity that roadside revegetation projects demand (Munda and Smith 1995).

4: Special Site Conditions or Abilities

If wild collection sites are an indication, Virginia wildrye is tolerant of a wide range of conditions from moist to dry soil, full sun to part shade, coarse to fine substrate, early successional to mature meadow communities, acid to neutral pH's, and even salt tolerance. Although this generalist nature, this genetic diversity, is possessed within the Virginia wildrye complex, it is not necessarily represented within each population. As our work continues with the species, we are likely to learn more about how special adaptations to specific site conditions are distributed among members of the complex.

Virginia wildrye germinates quickly and provides excellent winter cover (see the discussion in the sections that follow). These qualities suggest that it may make an excellent substitute for the alien nurse crop seed that is often included in soil stabilization seed mixes. Shawn Belt of the NPMC is aware of a National Park that has begun using wildrye in lieu of nurse crop seed in their roadside stabilization work.

5: Germination and Sowing Requirements

As indicated by our own results and literature from various labs around the country, Virginia wildrye germinates within 7 to 10 days once sown in moist soil. It will germinate even faster if cold stratified for a week or two first. Our findings and literature on this topic are explored in more depth below. We have had success establishing it at sites by broadcasting seed over the soil at any time from Halloween to early June. Seed

was then incorporated into the soil either by roughing the soil surface (dragging a fence, for example) or by burial with a thin topcoat of soil. We have also plugged it into slopes to great effect in spring. Jennifer Kujawski of the National Plant Materials Center (pers. comm. 2001) says the best time to sow it is fall, but spring sowings are also quite successful.

Staff at the National Plant Materials Center in Beltsville also worked on plug production protocols for Virginia wildrye[4] (Davis & Kujawski 2001). Seed was wild-collected from Kentucky, Maryland, and Washington, D.C., between 1990 and 1998. The seeds were sown in multipots and moved into the greenhouse in December with day/night temperatures around 75/68F. Germination was quick, with an average of over 92%, varying with collection site and year of collection. Two weeks of cold stratification promoted more uniform germination but was optional. Seeds germinated well at moderate temperatures but seed did not germinate and seedlings did not grow well in the greenhouse during the summer.

Staff at the Hiawatha National Forest also developed protocols for Virginia wildrye[5] plug production (Schultz 2001). Seed was hand-collected from wild populations in Michigan, where the plants were found in low woods and thickets, especially along stream banks and floodplains, marshy shores and in meadows. The author recommends drying collected seed for two weeks in paper bags or bins, then moving the seed into cold dry storage for up to three years. The seed was cold stratified (33 to 42F) for a month prior to sowing in equal parts with damp perlite or vermiculite. Then the seeds were sown in plug trays and moved into the greenhouse. The germination, 75%, was rapid. In cases where germination has not occurred by 2 months, the author recommends trying an even longer cold stratification period.

Staff at the Appalachian Plant Materials Center also worked on plug production protocols for Virginia wildrye[6] seed (Vandevender 2008). Seed was wild-collected from Stones River in West Virginia. Not much information is given on germination technique other than that 2 weeks of cold stratification were provided. The seeds were de-awned prior to being sown in plug trays. The trays were placed in a misthouse with minimum temperature of 70F. Germination typically occurred between days 7 and 10.

Prairie Moon Nursery (2009) recommends simple cold dry storage of the seed, and indicates that no stratification is required thereafter.

6: Speed of Growth

Seed cold stratified and sown by Kathy Davis on June 10, 2003, averaged 5 inches tall within 30 days. Seedlings reach full height and reproductive maturity in their first year. Each year thereafter, a clump of grass gains in diameter. Active growth occurs in spring and fall. Culms and blades become brown in the heat of summer, and new blades grow

[4] Shortly we will have the opportunity to examine the accession and confirm that it would still be classified as Virginia wildrye.
[5] The genus *Elymus* has been reclassified since this work was conducted and it is possible that the plant material would no longer be considered *E. virginicus*.
[6] Same as previous footnote.

in the fall. These blades remain green and vigorous through the winter, resuming growth again in early spring (Chesapeake Natives 2009).

Figure 3. Winter Foliage.

The green basal foliage of Virginia wildrye during the cool season is shown in this photograph showing green grass blades about 5" tall. University of Maryland Arboretum and Botanic Garden.

7: Height

Plant height varies strongly according to which parent population the accession was obtained from. The height of accessions was measured at the National Plant Materials Center in September of the establishment year, when plants are at their full height. Most of the accessions ranged from 2.5 to 3.5 feet tall. The shortest accession was number 19 (Potomac, Montgomery County MD), with an average height of 2.03 ft (±0.07). The tallest accession was number 38 (Charlestown, Jefferson County WV)[7], with an average height of 4.78 ft (±0.06).

8: Winter Cover

The wildryes are cool season grasses. Much like lawn grasses, they are green and quite alive in late fall, winter, and early spring when the warm season grasses are dormant (Figure 3). Wildryes provide good soil cover during winter months.

9: Root Structure

Virginia wildrye has a rather ordinary, fibrous root mat.

10: Interactions with Wildlife & Roadside Use

Virginia wildrye is a host plant for, of all things, fungus flies (Bultman *et al.* 1995). Specific species of flies have recently been discovered to "pollinate" certain types of fungus, which in turn, grow only on certain types of grass. In the act of laying their eggs in the fungus, they carry spores from one bit of fungus to another. When the eggs hatch, the larvae consume some of the fungus. The fungus and the fly larvae are perfect examples of the ways native plants serve as the basis for our food chain. Many organisms higher on the food chain – some of which motivate us a little more than fungus and flies (songbirds and hawks, for example) – depend on insect herbivores for food (Tallamy 2007).

Scott (1986) does not list Virginia wildrye as a host plant. We have observed that certain types of small spiders are prone to build webs in the spikes, another sign that wildrye is an effective source of plant tissue for insect herbivores –small prey insects must be abundant or the spiders would not be common. Also, we have observed that small,

[7] Staff at the NPMC added two accessions from counties immediately adjacent to Maryland.

secretive, ground-dwelling sparrows consume the fallen seed in fall. The insects and the ground sparrows are not traffic hazards. In many years of working with the plant at farms and in gardens, the authors have never seen any large animal grazing, or any grazing damage. Virginia wildrye is not a center of wildlife activity, and perhaps that is why Miller and Miller (1999) do not include *Elymus* in their book.

Figure 4. Successfully Stabilized Cut Slope.

This photograph shows a steep slope supported at the base by gabion baskets. The slope has several native grasses and flowers that stabilize it and provide color. The brown grasses are Virginia wildrye. University of Maryland.

11: Aesthetics

Virginia wildrye is attractive enough for use in formal gardens. It has been featured many years at the Montgomery County native plant demonstration garden, a collaboration of Chesapeake Natives and the Chesapeake Climate Action Network (http://www.chesapeakenatives.org/Chesapeake_Natives_Draft/Elym_virg_%28Photos%29.html). Through the winter the plant has attractive clumps of green and growing grass blades. In summer, aesthetic wheat-like spikes form, and these remain attractive until December or January. As SHA may occasionally wish to use the plant in a formal garden,

note that it will require full sun there. In part shade plants tend to lodge as the seed heads become heavy. On the roadside, however, it is quite attractive in part shade. For example, the lodging habit causes graceful bunches of seed heads to droop in unison down the slope at the University of Maryland slope stabilization project (Figure 4).

12: Mowing Requirements & Tolerances

Virginia wildrye does not require mowing. It will persist at an unmown site as the plant community succeeds from meadow to scrub shrub and then into a young woodland. As the forest matures, it will become less common and ultimately fade out.

We have been unable to find any literature regarding the impact of mowing on wildrye. However, based on our personal observations of the seasonal growth pattern of this cool season grass, we can easily deduce the following. From fall to spring, wildrye sports a clump of green blades about 5 inches tall. Any mowing between Thanksgiving and St. Patrick's day, and above 4 or 5 inches, shouldn't affect it. From spring through summer, wildrye sends up flowering culms that look much like wheat. Mowing wildrye before the seeds are ripe will interfere with that year's seed set.

Sandersen *et al*. (2004) discussed Virginia wildrye's potential as a forage grass. In an effort to understand response to grazing, they cut plants to a height of 3 inches (7 cm) in April/May, and then again in June/July. They discovered there was little regrowth after the first cutting and even less after the second. Although Sandersen *et al.* were not conceptualizing the foliage as a protective cover for soil, their data do confirm our deduction that mowing between April and July would remove grass blades that could not be fully replaced until fall, when cool season grasses resume their growth.

There are local examples of Virginia wildrye persevering under various mowing regimens.

1. In the fall of 2001, the Maryland National Capitol Park and Planning Commission included local ecotype Virginia wildrye in a roadside meadow mix on Rte. 118 in Germantown, Maryland. The meadow is located on a steep slope. To prevent forest succession, half of the meadow is mowed during the dormant season every other year. Therefore every wildrye in the meadow is mowed every two years. The survival rate is high and wildrye remains an important component of the Rt. 118 meadow in 2009.
2. In the summer of 2005, the University of Maryland Facilities Management staff plugged wildrye into a steep slope behind the Research Greenhouse Complex (Figure 4). The slope is never mowed. Staff spot spray saplings to prevent forest succession. Virginia wildrye remains an important component of the meadow four years later.
3. Most of CNI's wild collection sites are places that are mowed occasionally: utility lines, maintained ditch banks, and two roadside sites behind guardrails. The latter two are examples of SHA Priority 3 areas that would be mowed to a height of 5" to 7" once, or at most twice, per year (Maryland SHA 2003).

In summary, we have several examples, from populations behind guard rails to planted slopes, that Virginia wildrye tolerates mowing once per year or mowing once every other

year quite well. However, the recommended mowing practice for highway wildflower plantings and natural meadows is to mow in late May or June (Maryland SHA 2003). Mowing at this time of year maximizes damage to both leaf cover and seed set. Mowing in spring and summer is also very detrimental to insect, amphibian and avian members of the grassland community.

13: Herbicide Compatibilities for Roadside Use

Jennifer Kujawski (NPMC, pers. comm. 2001) indicated that they had used broad-leaf weed killers on their trial production fields with considerable success. The pre-emergent herbicide Treflan (trifluralin) had caused some stunting, and she planned to investigate Surflan (oryazalin).

We have used Surflan (Oryzalin) at both the Plutschak farm and at the NPMC, with no apparent side effects. At the NPMC we also used three-way amine successfully. We were unable to locate any specific literature on the effect of clopyralid (the chemical SHA preferentially uses to control Canada thistle (*Cirsium arvense*), trade names are Transline and Stinger) on wildrye (Maryland SHA 2003). However, clopyralid is the herbicide of choice for barley crops (Turner *et al.* 2001), and barley and wildrye are in the same tribe of grasses (Triticeae). Also, in a letter explaining that clopyralid has been banned in counties with sandy soils, New York State otherwise approved clopyralid for use on grasses, including grasses used for seed production (Jackling 2004).

The Plateau label (www.cdms.net/LDat/ld2LP012.pdf) indicates that 8 to 12 oz/acre applied in the fall is safe on Russian wildrye grass, but does stunt Virginia wildrye grass. Stunted grasses generally recover. Apparently the impact of Plateau depends partly on the variety of the species, site soil texture, the season of the application, the rate, the adjuvant, and whether it is used as a pre or post emergent. No further information is provided.

14: Road Salt Tolerance

No direct data is available on the tolerance of Virginia wildrye to roadside salt. However, some of our parent populations were found at the edge of brackish marshes, and others along roadsides. Accessions 21 (Prince George's County) and 30 (Talbot County) were found directly behind guardrails along major highways where they quite likely receive some splash or runoff containing road salt. Accession 31 was found at the edge of a brackish marsh (Talbot County).

3 Methods

3.1 Methods: Wild Collection

Since wild collection methods follow similar principles for all species, they are presented in the first report and is not repeated here. As a largely self-pollinated species, the majority of the genetic diversity of Virginia wildrye is contained between populations rather than within them. Therefore, it was even more important to sample from many populations than it would be for a cross-pollinated species, and much effort was focused towards this end. Otherwise, Virginia wildrye presented no reason to deviate from the wild collection methods as described in the first report.

3.2 Methods: Germination

After wild collection, seed was brought back for germination testing and plug production. The volume of seed from each wild collection site was typically quite small, often only a half-cup (125 mL) or so.

Our germination methods were designed to accomplish two goals simultaneously: confirm our understanding of germination behavior and produce plugs to plant at farms. Accordingly, we opted for potting soil and nursery trays, similar to the methods employed at Plant Materials Centers (see for example Kujawski & Davis 2001), rather than Petri dishes and damp filter paper such as would be used in a professional seed testing lab or in a university germination experiment that did not involve plug production (see for example Deno 1993; Walck *et al.* 1997a).

Sowing: The individual wildrye spikelets were sown by hand by volunteers from Chesapeake Natives, Master Gardeners, and the Anacostia Watershed Society. For both the cold stratification and the no-stratification treatments, the seed was sown into 288-cell plug trays cut in half, filled with germination mix. Spikelets are the individual units that disarticulate from the rye culm. They consist of a pair of glumes that form a U-shaped structure that surrounds the florets (Figure 2). Typically the lower two florets produce seed and the upper floret does not.

The potting medium was Sungro germination mix. Separate trays were prepared for each species/accession/germination treatment, resulting in hundreds of trays. Indoor cold stratification was at 40°F and 50% humidity. Outdoor cold stratification occurred between December 2006, and February 2007. Soil was kept lightly moist throughout the stratification period. We followed the annotation of Deno (1993) regarding stratification treatment: Temperature (Duration) Light. For example, 40(30)D means that seed was stratified at 40°F for 30 days in the dark. 70L is shorthand for 70(0)L (70F, zero days cold stratification, sown at the surface where seed receive light). Seedling trays were moved to a climate-controlled misthouse for incubation. In seed testing labs, germination is counted when the radicle first emerges from the seed. We could not see the emergence of the radicle because of the potting medium, so a germination was counted when the cotyledon(s) appeared. Accordingly, our reports of days to first germination will be a day or two longer than those reported by the Petri dish method. Similarly, we could not see seeds that didn't germinate. Using the Petri dish method, such seeds are examined with tweezers and tetrazolium to see if they contain viable embryos. If they do, they are

counted as dormant; if they don't, they were never viable to begin with. We tallied germinations each week. For plug production, seedlings were potted up to Ropak 37-cell multipots before being transplanted out to the farms.

3.3 Methods: Production Trial

The rigorous field planning, marking and maintenance described in this section facilitate the establishment of seed transfer zones, if any, and the AOSCA wild certification process, scheduled to begin in 2009. As consumers of native seed, SHA staff may be interested in reviewing some of the agricultural methods behind quality native seed production. Observing the accession tracking methods described here will empower SHA staff to ask seed vendors more pointed questions about seed origin tracking methods and quality control. The crop maintenance methods section will be useful to those trying to maintain roadside plantings of wildrye. Other readers may prefer to advance to the Results and Discussion section.

3.3.1 Farmers' Fields

Generation zero Virginia wildrye plants were established at three farms, one from each of the geographic areas covered in our wild collection (Figure 5). Plugs were produced in 2007 and planted in the spring of 2008. Climatic conditions at the three farms are fairly similar, as shown in . Soils are somewhat more variable, and are discussed in the paragraphs that follow.

Table 1: Climate Data for the Three Farm Sites.

Farm	White	NPMC	Plutschak
County	Carroll	Prince George's	Caroline
Average Annual Precipitation	42.0"	43.8"	43.2"
Average Summer Temperature	73.7°F	74.7°F	74.9°F
Average Winter Temperature	34.0°F	35.1°F	36.7°F
Average Frost Free Days	181	176	187

30-year averages reported in the Brief Economic Facts series, Maryland Department of Business & Economic Development.

The Virginia wildrye breeder blocks were established at the Norman A. Berg National Plant Materials Center (NPMC) in Beltsville (39.016 N, 76.853 W). The field is on level ground, surrounded on three sides by second growth forest, and receives shade in the early morning and late afternoon. Soils at the NPMC evolved through the weathering of loamy and sandy fluviomarine sediments underlain by clayey marine sediments. In the area of the Virginia wildrye breeder blocks, the soils are moderately well-drained and mapped as Russett-Christiana Complex (fine-loamy, mixed, semiactive, mesic Aquic Hapludults/ Fine, kaolinitic, mesic Aquic Hapludults, Soil Survey Staff 2009). Soil tests (A&L Eastern Laboratories, 11/2/07) indicate that the soil pH of the top 6 inches (15 cm) was 4.8, soil P was high, and soil K was low. Boron was very low. Pelletized lime was applied in April of 2008.

The Plutschak farm is in Preston (38.726 N, 75.952 W). The field where the Virginia wildrye foundation blocks were planted is a level area just north of a wet forest. It receives shade in the early morning and sun the rest of the day. The moderately well to

somewhat poorly-drained soils are mapped as Sassafras sandy loam (Soil Survey Staff 2009), however, the primary author thinks that this is an error due to the scale of interpretation of the soil map. The immediately adjacent map unit Woodstown sandy loam (fine-loamy, mixed, active, mesic Aquic Hapludults) more accurately describes the field's conditions. These soils evolved through the weathering of sandy marine and old alluvial sediments. Site specific soil test results will be included in the next update of this report. A typical pH for an un-limed Woodstown soil would be 4.6.

The White farm is in Westminster (39.474 N, 77.059 W). The field where the Virginia wildrye foundation blocks were planted is a level area in an open pasture. It receives full sun all day. The moderately well-drained soils are mapped as Glenville silt loam (Fine-loamy, mixed, active, mesic Aquic Fragiudults, Soil Survey Staff 2009). They formed primarily in colluvium or residuum affected by soil creep. The parent material is weathered from phyllite, micaceous schist, granitic gneiss and other acid crystalline rocks. Site specific soil test results will be included in the next update of this report.

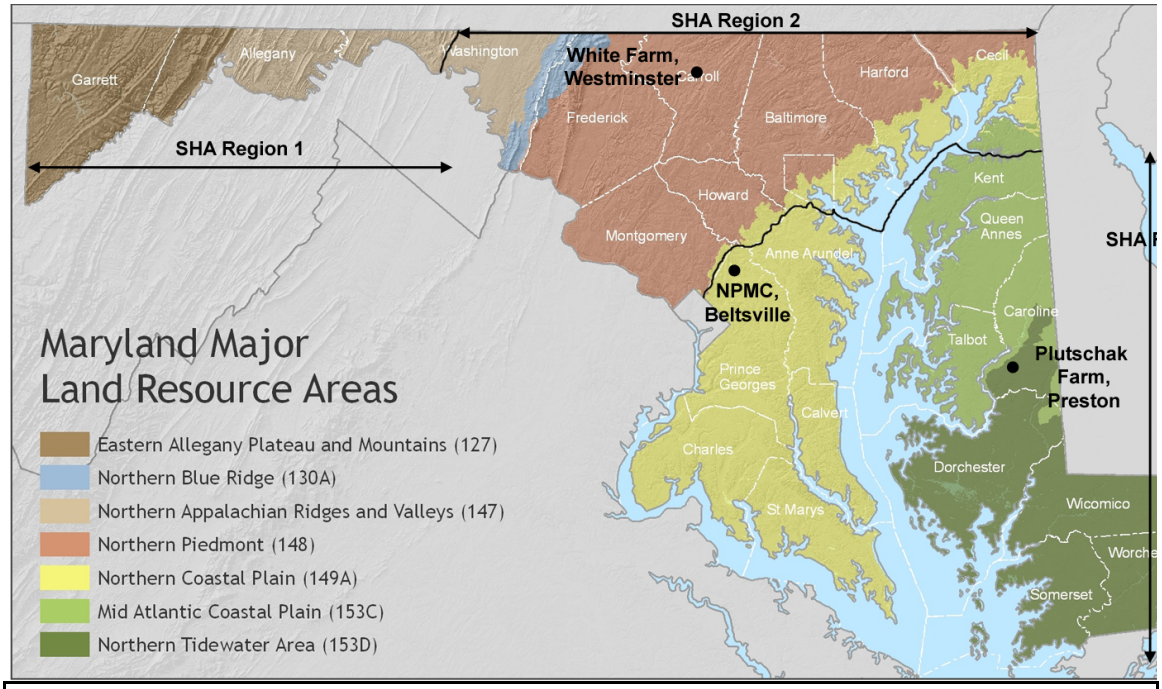

Figure 5: Farm Fields and Geologic Provinces.

This map shows the three farms, the SHA maintenance zones, and a geologic base map by Moore (2009).

3.3.2 Farm Field Layout

Working with the NPMC, the authors decided to place plants in individual holes burnt through weed block mat, both to suppress weeds and to allow us to keep track of plants from the different accessions during the course of the project. The first step was to plan the field layout. Considerations included the width of the weed mat and of the farmer's mower (used to cut grass between the weed mats), the number of accessions for each species, and the number of replicate blocks to be planted (Figure 6).

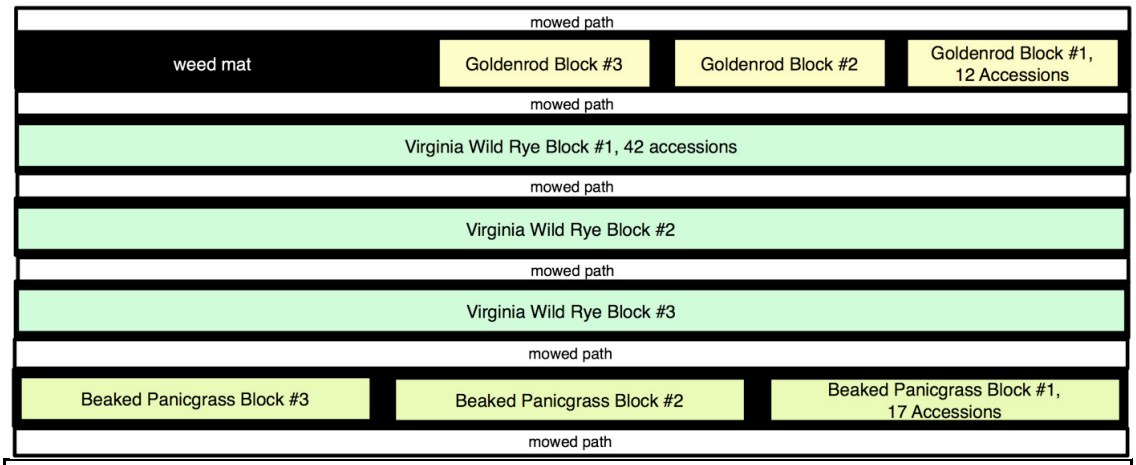

Figure 6: Farm Field Planning.

This diagram shows colored rectangles located within larger black rectangles that indicate the rows of weed mat. The colored rectangles indicate the positions of Virginia wildrye, beaked panicgrass, and gray goldenrod planting blocks with respect to each other. Each block contains a complete set of accessions. The mowed paths between rows of weed mat are shown by white stripes. This diagram shows the Plutschak farm field, which is 120 feet long by 52 feet wide. The layouts at the NPMC and at the white form are slightly different due to constraints of equipment and field size.

The authors have adopted the term "accession plot" to describe a grouping of plants that all came from the same accession/parent population. At the private farms, one accession plot consists of a row of 5 plants (Figure 7). At the NPMC, one accession plot consists of a 3x5 rectangle of 15 plants.

The accession plots allow us to increase the amount of seed we have, they serve as breeder plantings, and they enable us to evaluate differences among the parent populations. Since we needed to be certain that the differences among accessions are real rather than the result of random events, three replicate accession plots were distributed at each farm (randomized complete block design, Figure 6). The rows of weed mat were convenient for this purpose.

Figure 7: Accession Plots.

This photograph shows rows of 5 Virginia wildrye in black plastic weed mat. Painted labels for the Beretta Telephone Line (1) and Grange Hall Road (39) accession plots are visible on the mat. Accession plots of gray goldenrod are blooming in the background.

3.3.3 Farm Field Establishment

The second step was to prepare the ground to receive the weed mat. Ground was sprayed with glyphosphate. Once the weeds died and new growth began, glyphosphate was sprayed again. Then the ground was tilled and disced. The third step was placement of the mat. The NPMC staff used their mat-layer attachment to place the weed mat at each farm. Coordinating the schedules of all parties (NPMC, the primary investigator, and the four farmers who all work at other jobs during the week) presented the usual challenges, further complicated by spring weather: wet soils do not allow for enough traction to use the mat-layer attachment (model 1275FA mulch layer, Holland Transplanter Company). The weather factor was so confounding that we had to drop one farm from the project. Once on-site, the centerline was laid out for each piece of weed mat by placing one stake at each end of the field. The mat-layer attachment was placed on a farm tractor possessing hydraulic-powered hitches. The tractor was centered over the first flag. Adjustments were made to the side discs to ensure that side trenches for burying the long edges of the weed mat would be positioned properly. At the start of the row of weed mat, a trench was hand dug to a depth of 1 to 2 ft. The loose end of the beginning of the roll was then buried in this trench. The tractor slowly advanced toward the second flag as the mat layer dug side trenches and unrolled the weed mat behind it (Figure 8: Farm Field Preparation.). The tractor advanced about 2 ft beyond the terminal centerline flag, and the weed mat was cut. Another trench was hand-dug at the end of the row, and the extra 2 ft of weed mat was buried. Soil was raked over the long edges of the weed mat to close the trenches and secure the mat. Fine fescue was sown between the rows of weed mat.

Figure 8: Farm Field Preparation.

This photograph shows NPMC staff members R Jay Ugiansky and Dan Dusty using the mulch layer attachment to prepare a field to receive plants for the NPMC breeder blocks.

The final step was planting. To get the plants in the right pattern (Figure 8), holes were burnt in the weed mat for each plant location. The holes were burnt with a modified gas grill lighter developed by the staff at the NPMC. Holes were dibbled and seedling plugs were firmed into place. Accession numbers were painted onto the weed mat next to each accession plot using permanent paint pens. In the weeks after planting, supplemental irrigation was applied as needed.

At the White, Plutschak, and NPMC farms all the Virginia wildrye was planted into weed mat in this way. At the Pheobus organic farm, the wildryes were placed into a tilled field and then mulched. The organic farmer later withdrew from the program.

3.3.3 Crop Maintenance

Maintenance of the Breeder Blocks at the NPMC in 2008

A tractor with a 15' boom sprayer applied Surflan (Oryzalin A.I., 3oz/gal), a pre-emergent herbicide, in mid-April 2008. A backpack sprayer was used to apply chemicals to both the crops in the weed mat and the turf growing in the aisles between the rows of weed mat. Surflan (Oryzalin A.I., 3oz/gal), a pre-emergent herbicide, was applied in mid-April. Three Way Amine (Dicamba, MCPP & act. ingred., 0.75oz/gal), a broad-leaf weed killer, was applied in mid-April. The aisles were mowed regularly to keep turf grasses from going to seed.

Figure 9: Farm Field Planting.

This photograph shows three people placing grass plugs through holes burnt into weed mat at the White family farm. Each row of weed mat contains a complete set of Virginia wildrye accessions (a block).

Maintenance of the Plutschak Farm in 2008

No pre-emergent herbicide was used at the Plutschak farm during the establishment year. A large number of weeds germinated inside the holes with the wildrye crops. In spring, Mrs. Plutschak hand-weeded and then placed leaf mulch around some of the wildrye plants, and this resulted in less weed pressure during the remainder of the season. The worst of the weeds was hairy crabgrass (*Digitaria sanguinalis* (L.) Scop.). Because this plant sent out long horizontal stems across the weed mat before it set seed, we were able to attack it with spot treatments of glyphosphate. The following year, weeds in the wildrye continued to be a challenge. Weeds continued germinating in the burned holes, and now they were also germinating on top of the weed mat wherever the lawnmower had side-cast its clippings. In April, we began sweeping the debris off the weed mat, but later stopped this practice because having this unintended "straw" present kept the black weed mat from over heating in the summer sun. In late April, Mr. Plutschak tested Surflan (oryzalin) on two of the rye blocks. Pleased with how the pre-emergent kept the crabgrass from germinating on top of the weed mat, he sprayed the third rye block in late May. On May 30th, Mr. Plutschak applied 30 pounds of water soluble10-10-10 fertilizer to the wildrye.

Maintenance of the White Farm in 2008

Pre-emergent herbicides were not applied at the White farm. In the establishment year considerable time was spent hand-weeding the wildryes. An experimental rust was released to contain a mild farm-wide infestation of Canada thistle (*Cirsium arvense* (L.) Scop.). Japanese bristlegrass (Giant foxtail) (*Setaria faberi* Herrm.) and horseweed (*Conyza canadensis* (L.) Cronquist) were among the significant weed problems. Canada thistle was coming up between the weed mats and in the holes that were burned for the crop plants. Canada thistle thorns made hand-weeding much more painful. Otherwise, weeds were controlled at all three farms by hand pulling.

3.3.4 Harvest

Seeds were harvested during the establishment year. Volunteers either stripped Virginia wildrye (*Elymus virginicus* L.) spikelets from the culms in the field, or harvested the culms with a bread knife and bagged them for stripping over winter. The latter is much more time-consuming, not only because of the additional cutting and the volume of materials to be transported and stored, but because the rooted culms provide resistance to the stripping motion, whereas cut culms do not.

At harvest, each lot of seed was placed in a separate, labeled, paper bag. It was necessary to have the clean weight of each of these small samples, so we chose manual seed cleaning methods.

In practice, farmers will harvest the Virginia wildrye seed with combines, much as wheat, rye and barley crops are harvested. Preliminary work done at the NPMC on harvesting wildrye with a plot combine (a Massey Ferguson 8XP plot combine) indicates that the combined seed may be clean enough for market without further processing.

Other authors disregard first year harvests (see Vogel *et al.* 2006, for example) with good reason. Some results, for example cost benefit analysis, will not be valid because perennial crops typically produce little or no seed during their establishment year. However, we wanted to produce estimates of the total yield seed producers can expect during an establishment year. We also need the seed for future work.

After the second year harvest, in late 2009, we will be able to examine the harvest weights for any interaction between accession site and production site. This will tell us whether there are seed transfer zones within Maryland. As we have discussed, the work of Sandersen et al. (2004) contains data that suggest there may be seed transfer zones for Virginia wildrye within the Vermont-New York-Pennsylvania-Maryland region. Our data will indicate whether or not seed from one part of Maryland can be used with equal success in another part of Maryland.

4 Results & Discussion

4.1 Wild Collection

Wild collection methods were presented in the first report of this series, since the reasoning is roughly the same for all species. The results, however, are not. Here we discuss the product of our efforts wild collecting Virginia wildrye from across the state of Maryland. We were able to collect from all three geographic areas covered by this project: Coastal Plain east of the Bay, Coastal Plain west of the Bay, and Piedmont (**Figure 10**). As a result of our wild collection efforts, 42 accessions were advanced to field trials. A more detailed description of each parent population is provided in Appendix 1.

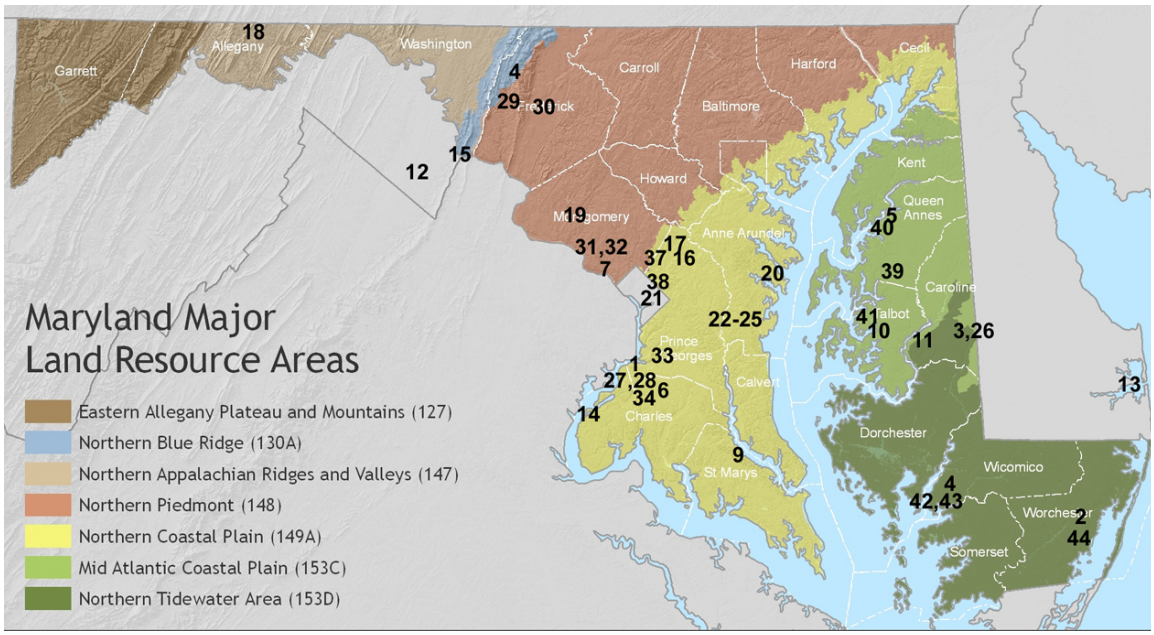

Figure 10: Parent Populations and Geologic Provinces.

The NRCS propagation numbers have been added to a geologic map of Maryland to indicate the location of the Virginia Wildrye parent populations. (Base map by Moore 2009).

4.2 Germination

Our Results

From February through April of 2007, we conducted germination tests on seed wild collected in 2006 for this project. In three of three replications, seed without any stratification treatment began germination within 11 days, and seed with seven days of cold moist stratification began germination within only three days. The latter result is so impressive that it should be replicated in an additional trial for confirmation.

The germination percentages for these latter seeds should not be regarded too critically, for we were experiencing two problems at the time in the mist-house where the tests were conducted. First, the mist nozzles were either dripping or clogging. Dripping nozzles splash the soil and the seed out of cells. Clogged nozzles allow the cells to dry out, and if this is not noticed quickly, germinating seeds die. If that were not enough trouble, mice moved into the mist-house and commenced eating seedlings before they could be counted. All of this argues for the more formal methods of counting germinations used by seed testing labs. That being said, in 5 replications, the seed without any stratification treatment germinated 52%, whereas the seed with stratification treatment germinated 51%. Actual germination rates were probably higher. However, seed in the field also face the tribulations of mice, downpours and dry spells. We unintentionally demonstrated that Virginia wildrye germinate well regardless of such challenges.

To examine the shelf life of Virginia wildrye seed, we conducted un-replicated germination tests on 2005 and 2006 seed lots, seed we had harvested prior to the

beginning of this contract, from January through March of 2007. The seed was generation one seed grown in Chesapeake Natives' demonstration gardens. The parent seed was collected on private property in Waldorf, Maryland with the kind permission of Chaney Enterprises. Between the time of harvest and the time of germination, seed was stored in dark cabinets at room temperature (70F). Seed that had been harvested in the summer/fall of 2006 germinated 85%; seed collected in the summer/fall of 2005 germinated 74%. We did not have older seed for experiment.

The findings of the Hiawatha National Forest staff that seed could be stratified for even longer than 2 months (Schultz 2001) are different from our results and from those of Davis and Kujawski's (2001): we found stratification to be optional. In fact, during the course of this study, one bag of Virginia wildrye seed and damp vermiculite was accidentally left in the cooler in for 42 days, and when we removed it, we found that the seed had already germinated. It is possible that the observed differences could be correctly attributed to genotype, since Schultz's seed came from Michigan, where the average winter is colder and longer than here in Maryland. However, since the taxonomic reclassification of the genus *Elymus*, we may now find that we were actually conducting germination tests on separate races of Virginia wildrye, or even on other *Elymus* species.

Implications for Use in a Soil Stabilization Mix

Our results indicate that seed may be stored, even by affordable, room temperature methods, for at least two years prior to use. Schulz (2001) indicates that seed may be stored under cold, dry conditions for up to three years. The ability to store seed after harvest means that farmers will be able to offer the commodity more affordably, and buyers may expect their purchases to have some shelf life.

Table 2: 2008 Virginia Wildrye Harvest

Farm	Weight	# Seeds
NPMC	17.9 lb (8,115 g)	1,827,798
Plutschak	2.8 lb (1,275 g)	287,177
White	2.2 lb (1,001 g)	225,462
Totals	22.9 lb (10,391 g)	2,340,438

Slopes that are sown in fall or spring will typically have conditions suitable for rapid wildrye germination. It seems logical that planting too late in the fall, if hard freeze is expected within a month, would only allow the seed to germinate in time for tender seedlings to be killed by a late frost. This may not be true and has not been confirmed by experiment or experience. Wildrye seed naturally shatters in the fall; this suggests the opposite, that the seedlings have some adaptation to the sudden drops in temperature occurat this time of year.

The results of Davis and Kujawski (2001) imply that wildrye will not germinate if sown in summer, even if the site is irrigated. There are two possibilities, then, for wildrye seed sown in summer. It may be consumed or it may lie dormant until cooler weather. It seems likely that summer sowing of rye would be successful, although it might be necessary to sow at a somewhat higher rate to compensate for anticipated seed loss over the summer season.

4.3 Results & Discussion: Production Trial Phase

As a result of this project, the USDA NPMC now has 45 more breeder blocks of Maryland ecotype Virginia wildrye (they possessed three before this project began). The NPMC uses breeder blocks to develop local ecotype releases and to provide growers with seed for establishing genetically appropriate production fields. Wild collection, establishment, certification, and maintenance of a genetically diverse foundation planting requires money and expertise that many potential seed producers do not possess. When farmers offer seed grown from these breeder blocks for sale, SHA will know that the seed is descended from Maryland wild populations, and that it contains a diverse and representative gene pool. The NPMC breeder blocks will also be a valuable tool for increasing the number of Maryland farmers interested in producing native seed. This will help ensure that Maryland's roadside vegetation managers have access to large quantities of locally native seed at reasonable prices.

4.3.1 Harvest

Weights of the first year harvest (2008) are presented in the second column of Table 1. Perennial plants such as the wildryes typically produce little or no seed in their first year. We expect yields to be even higher in the second year.

Seed counts are provided in the third column of Table 1. These counts were calculated from the harvest weight and from the number of seeds in fifty 0.005g samples[8]. It is typically recommended to sow 40 seeds per square foot, however we have had excellent experience using Virginia wildrye seed at 20 seeds per square foot (Figure 11). In our first year, we have produced enough seed to sow 1.3 acres at the 20 seeds/s.f. rate. If we estimate that the average roadside maintenance zone in Maryland is 10 feet wide, this is enough wildrye to sow a swath a mile long.

Our proposed slope stabilization demonstration plots (see Future Work) are 12' wide and 135' long, or one $^{1}/_{27}$th of an acre. We propose to build three of these. We have much more seed than needed to sow the demo plots.

4.3.2 Virginia Wildrye Production and Seed Cleaning

When left to shatter naturally, or when stripped from the plant by hand, wildrye seeds disarticulate from the rachis with the glumes intact. The individual units within the harvested seed usually consist of two seeds surrounded by their glumes (Figure 2). Due to the small sample sizes, we had to harvest our 2008 seed by hand. We measured that one person can hand strip 3 oz. of seed from wildrye every 15 minutes. Seed harvested in this way is compact enough to store efficiently and reasonably flowable for broadcasting into a meadow, so we determined that no further processing was warranted for use in germination testing and future use. However, hand stripping at this pace is not an economical alternative for large-scale seed production.

[8] Data provided from our own seed samples by Mr. Victor Vankus of the USDA National Tree Seed Lab in Macon, Georgia.

Our plots were not large enough to harvest or clean mechanically, however staff at the National Plant Materials Center in Beltsville worked on mechanical harvest and seed cleaning methods for Virginia wildrye (Davis and Kujawski, 2001). Seed that had been harvested from their increase fields with a Massey Ferguson 8XP plot combine was efficiently polished with a two-screen clipper. It stored well for four years in cloth bags at 40ºF and 35% relative humidity. They calculated 117,000 seeds per kg. R. Jay Ugiansky (pers. comm. 2001) relayed two of the challenges faced at the National Plant Materials Center in their efforts to determine methods to clean this seed. First, some of the seed separate readily from the glumes, while others do not. Second, the seed that had been processed through the combine was roughly the same size and weight as quackgrass (*Elymus repens* L. Gould) seed. Quackgrass is an alien species that has been declared noxious in 26 states (Alaska Natural Heritage Program, 2006). Farmers who choose to process their seed in this way should be particularly careful to prevent quackgrass from invading their production fields. A useful guide to quackgrass management has been prepared by Curran and Lingenfelter (no year given).

Figure 11: Twenty seeds per square foot.

The photograph shows a roadside meadow project started by Mr. Carl Senos of Maryland State Highway Administration. The meadow is at the Bay Country Rest Stop. It was sown with 20 seeds per square foot. Most of the grass is Virginia wildrye. The swath of pink flowers in the background is swamp milkweed (*Asclepias incarnata* L.) increased from an on-site seed source. The swath of yellow in the foreground is brown buttons or purplehead sneezeweed (*Helenium flexuosum* Raf.).

Further support that Virginia wildrye can be harvested economically comes from Prairie Moon Nursery (2009), a cooperative of Minnesota farmers. They sell Virginia wildrye seed with glumes intact. They have determined that it contains 4,200 seeds per ounce, and offer it at $8.00 per pound of pure live seed. Clearly they are not hand-stripping the seed, or it would cost more. Since cooperatives are non-profits, we plan to offer a copy of this report in hopes they may be willing to share their seed cleaning techniques.

4.3.4 Notes on the Timing and Use of Weed Mat in Seed Production

We learned several important lessons that could benefit seed producers. The way the weed mat was used in this project is suitable for tracking accessions of breeder blocks but not very good for weed control. Growers could choose to make their own local wild collections and establish breeder blocks. In that case, they may wish to use weed mat and burn holes in it to keep track of individual plants from various wild populations, the way

we did for this project. In that case, we recommend using pre-emergent herbicide both in the burn holes and in the mown paths between the mats, for all manner of weeds germinate there and crawl up over the mat.

We learned that it is easier and more effective to put weed mat down in the fall. It is easier because in the spring soils can be too wet to get a tractor in the field. It is more effective because weed mat put down early enough in fall to capture some of the hot days of late autumn bakes more weed seeds before winter arrives. As it happened, the spring of 2008 was the 8th wettest in Maryland's recorded history (National Oceanographic and Atmospheric Administration). The disadvantage of placing the weed mat in fall is that a winter wheat crop cannot be sown.

Holes for the plants should not be burned through the weed mat until planting time because they reduce the mat's heat holding capacity, and weeds quickly sprout up through the holes.

Farmers attempting large-scale organic production might wish to consider growing any of these three species *between* rows of weed mat, using mulch to suppress weeds in the crops. Farmers interested in large scale conventional production will probably produce wildrye the way wheat and barley are grown, and use pre-emergent and broad leaf herbicides to control weeds.

5 Conclusions and Recommendations for Implementation

1. **Appropriateness:** The authors have conducted a thorough review of Virginia wildrye with respect to the 14 Attributes and conclude that it is indeed an appropriate species for roadside use in Maryland.
2. **Distribution and conservation:** The USDA PLANTS Database website indicates that *Elymus virginicus* L. is native over most of North America, however, the various varieties, synonyms and forms listed are not (yet) in synch with the revised taxonomy. Multiple sources indicate that Virginia wildrye is native throughout our state. It is common in Maryland, not rare. It is found in all the physiographic provinces of Maryland. Virginia wildrye occurs naturally in a diversity of habitats and soil types.
3. **Description:** Virginia wildrye is a 3 ft tall (our accessions averaged from 2.0 to 4.8 ft), cool season, perennial grass that resembles its domestic relative, wheat. It has a fibrous root system.
4. **Wild collection:** To capture the genetic diversity that is needed to ensure adaptability to a wide range of roadside conditions, it was necessary to wild collect from many parent populations of this self-pollinated species. We have wild collected from 41 wild populations of Virginia wildrye. The NPMC has contributed seed from an additional three populations, one within Maryland and two from sites immediately adjacent to Maryland.
5. **Germination and speed of growth:** We used wild seed to study germination behaviors and to produce plugs for breeder block/production plots at private farms and at the National Plant Materials Center in Beltsville. Virginia wildrye seeds are borne in terminal spikes that disarticulate when ripe. The seeds can be sown at any time of year, and germination will tend to occur in spring and fall, within 7 to 10 days of exposure to moisture. Even more rapid uniform germination, if desired, can be promoted with brief cold stratification. In the spring plants reach 5 inches tall within 30 days of germination. Plants reach full height and reproductive maturity in their first year. While it is not necessary for every plant in a soil stabilization mix to have these qualities, it is necessary for some to have rapid germination and growth. Virginia wildrye fills that role.
6. **Special abilities for roadside use:** Virginia wildrye has special abilities that will be useful in the establishment of roadside cover. It has the ability to grow in dry or moist soils, coarse or fine soils, acid or neutral pH, full sun or part shade, disturbed or mature meadows. Because it is a cool season grass it will provide cover for soils in the winter while many plants are dormant. Naturally occurring populations of Virginia wildrye have been observed to tolerate some salt spray.
7. **Wildlife:** Although Virginia wildrye does support the food web, it does not attract the sort of wildlife that would present a traffic hazard. It does not attract large herbivores like the turf grasses currently in use do.

8. **Mowing:** Late spring and early summer are probably the most damaging times of year to mow Virginia wildrye. In addition to this, other environmental considerations lead us to advise against mowing native meadows from spring through fall. The best times to mow a native meadow in our region are between Halloween and St. Patrick's Day. Virginia wildrye will tolerate annual mowing, but will not be a successful choice for frequently mowed areas.
9. **Herbicides:** Oryazalin and three-way amine have been used successfully on Virginia wildrye crops and would likely be successful in a roadside application as well. Trifluralin caused minor damage to the crops, but no decrease in survival. The literature indicates clopyralid could probably be used successfully on Virginia wildrye.
10. **Seed production and harvest:** The establishment year harvest for Virginia wildrye was 22.9 pounds, over 2 million seeds from 3,100 plants. At a density of 20 seeds per square foot, the 2008 harvest provides enough wildrye seed to sow 2 miles of roadside in a swath 10 feet wide. The plants are expected to produce a larger quantity of seed in their second year.
11. **Seed availability:** Two private farms have locally native Virginia wildrye seed ready for sale as a result of this project.
12. **Seed purchase:** Whenever SHA can use Virginia wildrye seed instead of alien cool season grasses like tall fescue, it is in maximal alignment with its mission (see first report). Specifically, Virginia wildrye supports a safer highway because it does not draw large herbivores like rabbits and deer. By purchasing locally native Virginia wildrye, SHA can rest assured that it is protecting the local environment by preserving the genetic integrity of local populations. By purchasing from Maryland farmers, SHA is supporting the local economy. We recommend that SHA begin preferentially purchasing locally native Virginia wildrye seed to alien grass seed, and local ecotype seed to seed of distant ecotypes or cultivars. As a consequence, production will increase with time, ensuring availability and reducing cost.
13. **Seed purchase:** We also recommend that SHA consider purchasing other local ecotype seed as it comes on the market, providing that the wild populations are certified by an independent source, the collection methods are responsible, and the species stand up well to a rigorous review using the Attributes outlined by our Species Advisory Panel.
14. **Ecological concerns:** Virginia wildrye is partially self-pollinated and otherwise wind cross-pollinated. The entire tribe of grasses of which Virginia wildrye is a part is prone to hybridize and form new species, some are fertile and some are not. Potential ecological consequences of moving *Elymus* species (or relatives) outside their natural range are difficult to forecast. Local ecotype is the safest bet for performance and for preservation of local ecosystems.

6 Future Work:

1. **Test on Slopes:** We recommend that a portion of the Virginia wildrye seed produced during the establishment year of this project be used in slope demonstration trials across the state. The demonstrations can be used to document the effectiveness of Virginia wildrye as the cool season grass component of a soil stabilization mix, and to host field trips for roadside vegetation managers from SHA and other organizations.
2. **Test Summer Sowing:** Work in the literature indicates that Virginia wildrye may not germinate in warm temperatures even if moisture is supplied. How would Virginia wildrye respond if sown on a slope in summer and irrigation was supplied?
3. **Explore Virginia Wildrye as a Potential Nurse Crop:** Like many popular nurse crops, Virginia wildrye seeds germinate rapidly and reliably. It may eliminate the need for a nurse crop in fall and spring plantings.
4. **Hydroseeding:** Virginia wildrye seed needs to be tested for compatibility with the practices typically used for sowing seed at roadside stabilization sites. Can Virginia wildrye be hydroseeded? Can it be tracked into the slope with heavy machinery? Are nurse crops necessary? If so, can the standard nurse crops be used? Or will Virginia wildrye become the standard spring/fall substitute for a nurse crop? Will Virginia wildrye seed germinate and grow effectively under curlex?
5. **Work with AOSCA:** Have seed tested by a certified Association of Official Seed Certifying Agencies laboratory and seed germination testing protocols proposed. The germination test results in this document will support their work. Once AOSCA has published official testing protocols, the MDA will have access to the most appropriate testing protocols when testing locally native Virginia wildrye seed.
6. **Acquire Economy of Scale in Production:** The authors, participating farmers, and the NPMC have learned much that can be applied to cost effective production of Virginia wildrye as a seed crop in small plots, but to acquire economy of scale and to meet projected demand, we need to move up to large-scale production. Farm field establishment methods, weed control (herbicidal and nonchemical), combine harvest, mechanical seed cleaning, storage and marketing methods must be developed and published.
7. **Increase Economy:** Develop the concept of cost per viable seed proposed by Ugiansky (2004). It is a common misconception that the most affordable seed is that which costs the least per pound. A pound of larger seeds contains fewer seeds than a pound of smaller seeds. If the germination rate and price per pound are the same, the larger seed will cost SHA 10 to 100 times more per seedling. For some species, it will make sense to compare the cost of plugging to the cost of seeding.

8. **Consider Contract Growing:** To ensure the availability of large quantities of Virginia wildrye seed at known prices, SHA should consider a contract agreement with individual seed producers. The US Forest Service is willing to share a contract that may serve as a template.
9. **Establish Seed Transfer Zones:** Second year harvests should be cleaned and weighed to detect any variations in seed yield caused by the distance between an accession's collection site and its production site. This data can be used to detect seed transfer zones for Virginia wildrye within Maryland, if they exist. For economy of scale we hope for the largest seed transfer zones possible. For the most effective soil stabilization, the best aesthetic quality, and to protect the environment, we do not want to recommend a larger seed transfer zone than is ecologically appropriate (Doede 2005).
10. **Special Aptitudes within the Virginia Wildrye Complex:** Even as we were in the field collecting wild seed, Barkworth *et al.* (2006) were reworking the taxonomy of *Elymus virginicus* L. There may subtle differences in aptitudes among the members of the Virginia wildrye complex that will have great relevance to their roadside use (salt tolerance, for example). For comparison and communication purposes, our accessions need to be documented in terms of the new taxonomy. For documentation and the future reference needs of SHA and others, voucher specimens should be deposited in two herbaria. It may benefit SHA to explore the special aptitudes of the various accessions in the Maryland wildrye collection.
11. **Herbicide compatabilities:** The value of herbicides for establishment and maintenance of roadside stands should be explored. For example, the impact of one potentially useful herbicide, Imazapic (Plateau), on Virginia wildrye is unknown.
12. M**aintain the Breeder Blocks:** The value of the NPMC to this project cannot be overstated. In addition to helping in all the concluded phases of this project, it is they who will carry the agricultural aspects of the project into the future. They will continue to maintain the breeder blocks, they will make the seed from the breeder blocks available to all interested farmers around our state as "local ecotype releases", and they will support those farmers with the technical information they need to become successful producers. Additional collaborations of this nature are warranted if SHA is to secure genetically appropriate seed of the additional seven species recommended by the SAP for use on Maryland roadsides (see first report).

7 Glossary

Several references were used in developing this glossary, but especially Davis *et al.* (2002), Smith and Halbrook (2004), and Ogle and Englert (2008).

Accession – Something added to a collection. In this paper it refers to a sample of seed collected from a wild parent population. It may also refer to the plants grown from that seed, since the two are genetically identical. In contrast, parent population refers to the group of plants at the wild location where the seed was collected.

Adjuvant – Another chemical that is mixed in with the primary herbicide that makes it even more effective than it would be alone, often a chemical that breaks down water tension and allows spray to spread evenly over the surface of a plant.

Alien species (pg 14 etc) – A plant that was not present in a determined place prior to the arrival of humans. The determined place can be narrowly defined as the place under your feet with its peculiar ecotypical conditions (niche), or as widely as the entire continent.

Alloploid (pg 50) – A hybrid individual having two or more sets of chromosomes derived from two different species. (The same as Allopolyploid.)

Apical dominance – Hormonal domination of lower buds by the bud at the apex or tip of the plant. When this bud is cut off, lower buds along the stem and rhizomes are released and begin to grow.

Caryopsis – a type of fruit characterized by a dry outer layer attached to the single seed inside. This type of fruit is characteristic of many grasses and often referred to as a grain.

Clopyralid –A selective herbicide (3,6-dichloro-2-pyridinecarboxylic acid) used for control of broadleaf weeds, especially thistles and clovers. Trade names are Transline and Stinger.

CNI – Abbreviation for Chesapeake Natives, Inc. CNI is a 501(c)3 nonprofit organization that was founded in 2005. Both authors are affiliated with CNI.

Cotyledon –The seed-leaves of a plant embryo. These are very easily seen in bean seeds, they wither away as the first true leaves emerge. The number of cotyledons is used to divide the flowering plants into monocots (grasses, lilies, etc.) and dicots (beans, maples, etc.).

Culm – The aerial stem of a grass or sedge.

Cultivar – An assemblage of cultivated plants clearly distinguished by heritable (genetic) traits (morphological, physiological, cytological, chemical, other). USDA cultivars have been through replicated testing at multiple sites over two or more generations to prove and documents the heritability of these traits, the superiority and/or performance, and the range of adaptation.

Diploid – An organism with two copies of each chromosome, one from each parent. If you visualize the chromosomes in the nucleus as a collection of letters in the alphabet,

mostly looking like distorted x's, y's and k's, a diploid organism has a full set of the letters normal for its species.

Generation one – The generations of offspring since the initial material was collected are counted, with generation zero representing the wild parent material or seed that was wild collected. Plants face selection pressures in cultivation, and these are not the same selection pressures they face in the wild. With each generation in cultivation, the population becomes less and less like its wild ancestors.

Genetic diversity –The total amount of genetic variation present in a population or species. Diversity allows individuals to react differently to external conditions. The classic example of the danger of a lack of genetic diversity to plant (and human) survival is the potato blight of the 1840s. All the potatoes responded the same way to the infection.

Germination – The initiation of the growth of a plant from a seed.

Glumes – The bracts that enclose the spikelet of a grass (often also applied to sedges). The glumes may enclose one or more flowers. Details of glume morphology are important in species identification. Glumes, lemma and palea are part of the chaf that are threshed out from grains of wheat and rice prior to consumption.

Habitat fragmentation – The parsing of once large tracts of habitat into ever smaller tracts. Fragmentation leads to the genetic isolation of plants into unnaturally small populations. Isolation puts these small populations at increased risk for obliteration by random events, including generational genetic developments that are random rather than adaptive (population bottlenecking).

Haplome (Haploid) – A single set of chromosomes in the Triticae half of a diploid set that has come from an intergeneric hybridization event. If you visualize the chromosomes in the nucleus as a collection of letters in the alphabet, mostly looking like distorted x's and k's, a haplome is a set consisting of half of each of those letters, half of the x, half of the k, etc.

Hostplant – A plant that hosts insects and other organisms, usually but not always larval insects (like caterpillars) that cannot feed on other types of plant tissue. The most famous example of a hostplant and its larval insect is probably the milkweed and the monarch butterfly caterpillar.

Multipot – Trademark product of the Ropak Corporation, a re-usable, deep plug tray made to grow seedlings for transplant into the field.

Native species – A plant that was present in a determined place prior to the arrival of humans. The determined place can be narrowly defined as the place under your feet with its peculiar ecotypical conditions (niche), or as widely as the entire continent.

NPMC – The National Plant Materials Center, the lead Plant Materials Center of the USDA, NRCS located in the Beltsville Agricultural Research Center, Beltsville, Maryland.

NRCS – Abbreviation for the Natural Resources Conservation Service, one of 27 Agencies within the USDA. Prior to 1997 NRCS was known as the Soil Conservation Service.

Population – A group of plants that can breed with each other, exchanging genetic information through the transfer of pollen or spores.

Parent population – In any field of science, a group of individuals from which a smaller sample is drawn. In our work, the group of individuals is a collection of wild plants at one location, and the sample is a seed collection.

Radicle – The first root to emerge from a seed, the embryonic root.

SHA – Maryland State Highway Administration.

Source-identified -Seeds or plants from a naturally growing population occupying a known or defined geographic area. No selection or testing of the parent population has been made. There is no performance or adaptation data available for the collection. Offspring is produced to ensure genetic purity and identity from rigidly defined natural stands, seed production areas, seed fields, or orchards.

spp. – Standard abbreviation for two or more species of a genus

ssp. – Standard abbreviation for subspecies

Stratification – A pre-treatment of seed, often to cold, moist conditions, that enhances germination rates, mimicking natural conditions.

Tetraploid – An organism with four copies of each chromosome. If you visualize the chromosomes in the nucleus as a collection of letters in the alphabet, mostly looking like distorted x's and k's, a tetraploid organism has two full sets of the letters normal for its species. However, in some species, all the members are tetraploid.

Tribe – **S**cientific classification of species usually include the following levels: Kingdom, Order, Family, Subfamily, Tribe, Genus, Species. For example some authors, including Brown and Brown (1984), use Tribe in classifying the Grass Family. The tribe Triticeae includes wheat, rye, barley, wheatgrass and wildrye.

var. – The botanical convention abbreviation of "variety", a taxonomic category subordinate to species. Variety can also have other meanings, even with respect to plants, depending upon the context.

USDA – United States Department of Agriculture.

8 References

Alaska Natural Heritage Program, 2006. Non-Native Plant Species of Alaska: Quackgrass. akweeds.uaa.alaska.edu/pdfs/species.../Species_bios_ELRE_ed.pdf (accessed 12/01/2009).

Aubry, C., R. Shoal & V. Erickson (2005). Grass Cultivars: Their origins, development, and use on national forests and grasslands in the Pacific Northwest. USDA Forest Service.

Ayres, D.R., D. Garcia-Rossi, H.G. Davis & D.R. Strong (1999). Extent and degree of hybridization between immigrant (*Spartina alterniflora*) and native (*S. foliosa*) cordgrass (*Poaceae*) in California, U.S.A. determined by random amplified polymorphic DNA (RAPDs). *Molecular Ecology* **8**: 1179-1186.

Barkworth, M.E., J.J.N. Campbell & B. Salomon (2006). *Elymus* L. *In*: Flora North America Editorial Committee (Eds.). *Flora of North America North of Mexico* Vol. **24**: 288-343. Magnoliophyta: Commelinidae (in part) Poaceae, part 1. Oxford University Press, New York. Manuscript. version also available at www.herbarium.usu.edu/webmanual (accessed on 5/01/09).

Britton, N.L. & A. Brown (1913). *An illustrated flora of the northern United States, Canada and the British Possessions*. Vol. 1-3 (artwork downloaded from USDA NRCS PLANTS Database, www.plants.usda.gov).

Brown, M.L. & R.G. Brown (1984). *Herbaceous Plants of Maryland*. Port City Press, Inc., Baltimore, Maryland. 1127pp.

Chesapeake Natives, Inc. (2009). The Species Webpages. www.chesapeakenatives.org/Chesapeake_Natives_Draft/Species.html Accessed June 2009.

Church, G.L. (1958). Artificial hybrids of *Elymus virginicus* with *E. canadensis*, *interruptus*, *riparius*, and *wiegandii*. *American Journal of Botany* **45**(May): 410-417.

Curran, William and Dwight Lingenfelter. Agronomy Facts 5, Quackgrass Managementt: An Integrated Approach. College of Agriculture, Pennsylvania State Univ. pp. 6.

Davis, K.M. & J.L. Kujawski (2001). Propagation protocol for production of container *Elymus virginicus* L. plants (Container plugs); USDA NRCS - Beltsville National Plant Materials Center, Beltsville, Maryland. *In*: Native Plant Network. www.nativeplantnetwork.org (accessed 7/01/2009).

Davis, K.M., J.M. Englert & J.L. Kujawski (2002). Improved Conservation Plant Materials Released by NRCS and Cooperators Through September 2002. USDA NRCS National Plant Materials Center. www.plant-materials.nrcs.usda.gov/mdpmc/publications.html

Deno, N.C. (1993). *Seed Germination Theory and Practice*. 2nd Edition. Published by the author: 139 Lenore Dr., State College Pennsylvania 16801

Ferdinandez, Y.S.N., B.E. Coulman & Y.-B. Fu (2005). Detecting Genetic Changes over Two Generations of Seed Increase in an Awned Slender Wheatgrass Population Using AFLP Markers. *Crop Science* **45**: 1064–1068.

Gu, X.-Y., S.-J. Ren, C.-G. Chu, K. Glover, S.S. Xu, J.D. Faris, T.L. Friesen & A. Ibrahim (2008). Identification of seed dormancy for four populations derived from synthetic hexaploid wheat. *Annual Wheat Newsletter* **5 4**: 8.

Huff, David, A. Palazzo, M. van der Grinten (2006). Relationships Between Geographic Distance and Genetic Differentiation: Or Why Don't You Write Home More Often? *In*: M. Sanderson (Ed.). Proceedings of the 5th Eastern Native Grass Symposium. Omni Press, Wisconsin.

Jackling, S. (2004). Clopyralid, monoethanolamine NYS DEC Letter – New Pesticide Product Registration 4/04. www.pmep.cce.cornell.edu/profiles/herb-growthreg/cacodylic-cymoxanil/clopyralid_mono_salt/clopyralid_let_404.html (accessed 8/28/09).

Kartesz, J. & C.A. Meacham (1999). *Synthesis of the North America Flora*. Version 1.0 (CD-ROM). North Carolina. www.bonap.org/synth.html

Maryland Department of Business & Economic Development. Brief Economic Facts series. Available online at www.ChooseMaryland.org. [Accessed 1/25/10]

Maryland Department of Natural Resources (2007). Rare, Threatened and Endangered Plants of Maryland. www.dnr.state.md.us/wildlife/espaa.asp

Maryland State Highway Administration (2003). Integrated Vegetation Management Manual for Maryland Highways.Maryland Dept. of Transportation. 144 pp.

Metzger, J. 1995. Maryland Native Plants: A Master Checklist. www.mdflora.org/publications/mdchecklist.pdf

Miller, J.H., & K.V. Miller (1999). Forest plants of the southeast and their wildlife uses. *Southern Weed Science Society*.

Moore, A. (2009). Map of the Major Land Resource Areas of Maryland. Prepared for this report by the State Soil Scientist, USDA Natural Resources Conservation Service.

National Oceanographic and Atmospheric Administration. State of the Climate National Overview Annual 2008. http://www.ncdc.noaa.gov/sotc/?report=national&year. (Accessed January 15, 2010).

Nelson, E.N. & R.J. Tyrl (1978). Hybridization and introgression between *Elymus canadensis* and *Elymus virginicus* (Poaceae). *Proceedings of the Oklahoma Academy of Science* **58**: 32-34

Ogle, D. & J. Englert (2008). *Glossary of Terms for Use in Plant Materials*. USDA Natural Resources Conservation Service. Boise, Idaho. 48 pp.

Parendes, L.A. & J.A. Jones (2000). Role of light availability and dispersal in exotic plant invasion along roads and streams in the H.J. Andrews Experimental Forest, Oregon. *Conservation Biology* **14**: 64-75

Parrish, J. & R.G. Steinman (2003+). Native Plants of Sligo. Available through the Friends of Sligo Creek at www.fosc.org/PlantInventory.htm (accessed 08/2009).

Prairie Moon Nursery (2001). On-line catalog with germination guidelines. www.prairiemoon.com/seeds/grasses-sedges-rushes/*Elymus-virginicus*-virginia-wild-rye/ (ccessed 7/01/09).

Reichard, S.H. & P. White (2001). Horticultural introductions of invasive plant species: a North American perspective. *In*: McNeely, J.A. (ed.). *The Great Reshuffling: Human Dimensions Of Invasive Alien Species.* International Union for Conservation of Nature and Natural Resources, Gland, Switzerland.

Richardson, S. (1997). Development of Native Seed Sources and Establishment Methods for Native Upland Reclamation. USDA NRCS Plant Materials Center, Brooksville, Florida. 23 pp.

Saha, Malay, C. Young, and A. Hopkins (2009). Genetic variation within and among wildrye (*Elymus canadensis* and *E. virginicus*) populations from the southern Great Plains. Crop science 49(May-June):913-922.

Sanderson, M.A., R.H. Skinner, J.Kujawski, and M. van der Grinten (2004). Virginia wildrye evaluated as a potential native cool-season forage in the northeast USA. *Crop Science* **44**:1379-1384.

Schultz, J, P. Beyer & J. Williams (2001). Propagation protocol for production of container *Elymus virginicus* L. plants. USDA FS - Hiawatha National Forest, Marquette, Michigan. *In*: Native Plant Network. www.nativeplantnetwork.org (accessed 6/01/2009).

Scott, J.A. (1986). *The Butterflies of North America: A Natural History and Field Guide*. Stanford University Press, Stanford, California.

Shetler, S. & S.S. Orli (2000). *Annotated Checklist of the Vascular Plants of the Washington-Baltimore Area.* Part II. Dept. of Botany, National Museum of Natural History, Smithsonian Institution, Washington, D.C.

Slattery, B.E., K. Reshetiloff & S.M. Zwicker (2003). *Native Plants for Wildlife Habitat and Conservation Landscaping: Chesapeake Bay Watershed*. U.S. Fish & Wildlife Service, Chesapeake Bay Field Office, Annapolis, Maryland. 82 pp.

Smith, S.E. and K. Halbrook (2004). A plant genetics primer. *Native Plants Journal* 2004 (Fall): 106-111.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/ accessed [9/1/2009].

Turner, W.J., J. Yenish, R.F. Line and Xianming Cheng (2001). Crop Profile for Barley in Washington. www.ipmcenters.org/cropprofiles/docs/wabarley.html (accessed 7/02/09).

Ugiansky, R.J. (2004). Final Report: Development of Sustainable Native Wildflower Meadows for Highway Roadsides. USDA-NRCS National Plant Materials Center, Beltsville MD, 39pp.

USDA NRCS (2006+). The PLANTS database. National Plant Data Center, Baton Rouge, LA 70874-4490 USA. Baton Rouge (LA). www.plants.usda.gov (accessed 2006 through 2009).

Vandevender, John (2008). Propagation protocol for production of container *Elymus virginicus* L. plants (1+0 container plug); USDA NRCS Appalachian Plant Materials Center, Alderson, West Virginia. *In*: Native Plant Network. www.nativeplantnetwork.org (accessed 8/01/2009).

Vogel, K.P., A.A. Hopkins, K.J. Moore, K.D. Johnson & I.T. Carlson (2006). Genetic Variation among Canada Wildrye Accessions from Midwest USA Remnant Prairies for Biomass Yield and other Traits. *Crop Science* **46**: 2348–2353.

Watkins, R.Z., J. Chen, J. Pickens & K.D. Brosofske (2003). Effects of forest roads on understory plants in a managed hardwood landscape. *Conservation Biology* **17**: 411-419.

Appendix 1: Wild Collection Location Data

NPMC Propagation #	NRCS Accession #	Town	County (MD unless noted)	Site Description	#plants in pop	#collected	N Latitude degrees	W Longitude degrees
1	9094225	---	Prince George's	Rt 210, Beretta Telephone Line	50	50	38.145	-77.042
2	9094226	---	Worcester	under TL across rd from Oakley's Farm Mkt	---	---	---	---
3	9094227	---	Caroline	Sand Hill Road	---	---	---	---
4	9094228	Wicomico City	Wicomico	Rt 349, Wicomico City	6	6	38.312	-75.869
5	9094229	---	Queen Annes	Camp Pecometh, Land's End Road	---	---	---	---
6	9094230	---	Charles	old sand and gravel mine	100	50	38.633	-76.871
7	9094231	---	Montgomery	stream bank, Cabin John Power Line	10	10	39.032	-77.150
9	9094233	Mechanicsville	St. Marys	shady dirt road, Dos Santos Way	200	50	38.427	-76.639
10	9094234	---	Talbot	behind guard rail on Rt 50 northbound	10	10	---	---
11	9094235	Preston	Caroline	ditch banks, Bethlehem Road	24	24	---	---
12	9078782	Charlestown	Jefferson, WV	Rte 51 Altona Swamp	---	---	---	---
13	9080017	Sussex	Sussex, DE	LA Bay S Canal Mouth N side	---	---	---	---
14	9080167	Pomonkey	Charles	Jct 224/225 Mattawoman Creek	---	---	---	---
15	9085127	---	Washington	C&O Canal from Harper's Ferry RR bridge	---	---	---	---
16	9085131	Bowie	Prince George's	Lemon's Br Rd., Uhler Natural Area	---	---	---	---
17	9085132	Laurel	Prince George's	Patuxent Wildlife Research Center	---	---	---	---
18	9085137	Flintstone	Allegany	Marley Branch S of Flintstone, Williams Rd.	---	---	---	---
19	9085141	---	Montgomery	Between Seneca Creek and Tschiffely Rd.	---	---	---	---
20	9085154	---	Anne Arundel	Bembe Beach Rd and Port Annapolis Dr.	---	---	---	---
21	9080003	Oxon Run?			---	---	---	---
22	9094250	Lothian	Anne Arundel	Patuxent River bank	5000	44	38.837	-76.699
23	9094251	Lothian	Anne Arundel	Patuxent River Road a.k.a. Harwood Road	31	31	38.897	-76.672
24	9094252	Lothian	Anne Arundel	dry sand, part shade, Sands Road	1000	70	38.861	-76.683
25	9094253	Lothian	Anne Arundel	dry sand, morning shade, Sands Road	28	28	38.868	-76.675
26	9094254	---	Caroline	stream along Sand Hill Rd	---	---	---	---
27	9094255	Accoceek	Charles	wet meadow, Marshall Hall Road	200	50	38.693	-76.988

NPMC Propagation #	NRCS Accession #	Town	County (MD unless noted)	Site Description	#plants in pop	#collected	N Latitude degrees	W Longitude degrees
28	9094256	Accoceek	Charles	wet meadow, Marshall Hall Road	100	50	---	---
29	9094257	---	Frederick	part shade, Gambrill Pk Rd	1000	50	39.560	-77.499
30	9094258	---	Frederick	dry, part shade, Old Frederick Rd	1000	20	39.500	-77.401
31	9094259	Potomac	Montgomery	Potomac Power Line	1000	50	39.070	-77.233
32	9094260	Potomac	Montgomery	dry steep bank, Potomac Power Line	10	10	39.068	-77.228
33	9106011	Indianhead	Prince George's	Ted's Towing & Auto Service, Rt. 210	24	24	38.694	-76.988
35	9106013	Beltsville	Prince George's	Sellman Road Power Line	---	---	39.037	-76.938
36	9106014	Beltsville	Prince George's	Sellman Road Power Line	---	---	---	---
37	9106015	Beltsville	Prince George's	Sellman Road Power Line, wet meadow	---	---	---	---
38	9106016	Hyattsville	Prince George's	sandy engineered bank, Anacostia River	---	---	---	---
39	9106017	Starr	Queen Annes	part shade, Grange Hall Rd.	---	---	---	---
40	9106018	---	Queen Annes	Spaniard Neck Rd	---	---	---	---
41	9106019	---	Talbot	edge of dock, tidal, Skipton Landing Rd.	7	7	---	---
42	9106020	Nanticoke	Wicomico	sandy, Nanticoke Telephone Line	24	24	38.264	-75.907
43	9106021	Nanticoke	Wicomico	young woods, Ragged Point Cove	12	12	38.288	-75.901
44	9106022	Snow Hill	Worcester	dry, sunny railroad tracks E of Snow Hill	200	50	38.185	-75.376

Appendix 1: Wild Collection Location Data

NPMC Propagation #	NRCS Accession #	Wild Collection Date	Town	County (MD unless noted)	Site Description	#plants in pop	#plants collected	N Latitude	W Longitude
1	9094236	9/26/2006	Odenton	Anne Arundel	Piney Orchard Power Line	10	10	39.086	76.688
2	9094237	10/12/2007	Lothian	Anne Arundel	Sands Road Telephone Line	100	50	---	---
3	9094238	10/10/2006	Parkton	Baltimore	Parkton Verizon Power Line	50	50	39.629	76.655
4	9094239	11/18/2006	Indian Head	Charles	Kabin on the Korner	---	50	38.630	77.071
5	9094240	9/15/2006	Thurmont	Frederick	Auburn Road	millions	50	39.562	77.431
6	9094241	8/31/2006	Potomac	Montgomery	Potomac Power Line	1000	50	39.066	77.227
7	9094242	9/22/2006	Beltsville	Prince George's	Sellman Road Power Line	1000	50	39.034	76.940
8	9094243	11/18/06	Accokeek	Prince George's	Foust Road Telephone Line	1000	50	38.692	76.990
9	9094244	11/24/2006	---	Queen Anne's	Lands End Rd Telephone Line	24	24	39.130	76.062
10	NA	9/29/2006	Mechanicsvl.	St. Mary's	Abandon lawn, Queens Landing Rd	---	---	---	---
11	9094246	11/26/2006	Salisbury	Wicomico	Rt 352 Telephone Line	10000	50	38.303	75.790
12	9094247	11/25/2006	Berlin	Worcester	Rt 376 Telephone Line	12	12	38.292	75.156
13	9094248	10/16/2006	Denton	Caroline	Sand Hill Road, Rt 404 & Noble Rd	10,000	50	38.804	75.731
14	9078739	---	Bowie	Prince George's	Patuxent Wildlife Research Center	---	---	---	---
15	9078740	---	St. Michael's	Talbot	roadside in St. Michael's	---	---	---	---
16	9078763	---	Centreville	Talbot	Centerville, Rd.	---	---	---	---
17	9080047	---	---	Dinwiddie, VA	Ft. Picket Pine Rd, W Gate B47A	---	---	---	---
18	9080170	---	---	Prince George's	Jct Rt 210/227, N of McDonalds	---	---	---	---

Martin O'Malley, *Governor*
Anthony G. Brown, *Lt.*

Maryland Department of Transportation
State Highway Administration

Beverley K. Swaim-Staley,
Secretary

STATE HIGHWAY ADMINISTRATION

RESEARCH REPORT

DEVELOPMENT OF NATIVE SEED FOR SHA PROJECTS: 3. BEAKED PANICGRASS

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The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Maryland State Highway Administration. This report does not constitute a standard, specification, or regulation.

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16. Abstract

Our goal is to make locally native seed more affordable and more available to SHA. This report covers the work we have done from 2006 through 2008 with the promising candidate species, beaked panicgrass. We begin with a review of the 14 Attributes. Beaked panicgrass is a 3 ft tall, warm season, perennial grass. The subspecies anceps has a stout rhizomatous/fibrous root system that expands in a ring pattern with each year of growth. It grows in sunny places with a range of soil textures and moistures. It does not attract the sort of wildlife that would present a traffic hazard. Seeds are borne in large, terminal and lateral panicles. We know of roadside populations that persist through a regimen of two or three mowings per year. Beaked panicgrass is a common and representative native species found in every geologic province of our state. Beaked panicgrass germinates in warm moist weather if given prior cold stratification. We discuss our work establishing breeder blocks at the NPMC, and working with two local farmers to establish production fields. We spend some time discussing agricultural methods because they have future application to roadside establishment and maintenance practices. Our small plots set a respectable seed crop in their first year, the 2008 field season (11 lb). Seed set will be considerably higher in 2009. Beaked panicgrass is likely to become a valuable and affordable soil stabilization and nurse crop seed for use along Maryland highways.

17. Key Words	18. Distribution Statement: No restrictions
Native plant, seed, soil stabilization, beaked panicgrass, *Panicum anceps*	This document is available from the Research Division upon request.

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Executive Summary

This report summarizes the work that we are doing to make affordable, locally native beaked panicgrass seed available to SHA. The work described in this report was done between 2006 and 2008. Work continues, and the reader may anticipate subsequent updates/revisions. It is the third report in a series, the first was general in scope and dealt primarily with the selection of species for use in roadside revegetation. Our work with beaked panicgrass seed production is ongoing, so the reader should anticipate updates to or revisions of this report.

This project began with a thorough review of beaked panicgrass with respect to the 14 Attributes developed by the SAP. We determined that beaked panicgrass is very appropriate for use on Maryland's roadsides. It is native across southeastern North America, and is found in every geologic province of our state. It is a representative grass of our meadows and young woodlands. There are two subspecies. The subspecies *anceps* is native throughout Maryland, whereas the subspecies *rhizomatum* is only native in SHA Region 1.

Beaked panicgrass is a three-foot tall, warm season, perennial grass that bears a little resemblance to its taller relative, switchgrass. The underground structure consists of a ring of stout, scaly rhizomes from which a fibrous root system spreads. Germination is encouraged by fall/winter sowing or by cold stratification. Project managers who want all of their seed to germinate immediately will provide a lengthy cold stratification, whereas those who would like to bank some seed in the soil, will provide less cold stratification. Germination of stratified seed begins seven days after sowing and is followed by rapid leaf growth. Plants reach reproductive maturity in their first year. It does not attract the type of wildlife that would present a traffic hazard.

Very little information on the ecology and genetics of beaked panicgrass was available in the literature. Therefore, to capture the genetic diversity that is needed to ensure adaptability to a wide range of roadside conditions, we wild collected from as many parent populations as we could find. Seed from 17 populations established the NPMC breeder blocks for this project.

We will discuss our work establishing production fields at two private farms, and the agricultural methods we developed working with the farmers there. These methods have future application to roadside establishment and maintenance practices. The farm field establishment and maintenance practices discussed as part of this project are appropriate for breeder block and establishment but not large-scale production.

All of the 1,020 plants from the three separate farm fields set a small quantity of seed in the 2008 field season, their first year. The establishment year harvest potential for beaked panicgrass was 11 pounds, over 4.6 million seeds. The plants are expected to produce a larger quantity of seed in their second year.

As a result of this project, two Maryland farmers are producing yearly crops of locally native beaked panicgrass seed. Independent of this project, Ernst Conservation Seed is currently offering an Eastern Shore ecotype of beaked panicgrass. This species is on track to become a valuable and affordable staple of Maryland's future soil stabilization mixes.

1 Introduction

In CNIs project work plan the authors described four project phases. The first was the Species Selection Phase, followed by the Wild Collection Phase, and both were conducted in 2006. These phases were described in the first report of this series. Our work with the native cool season grass, Virginia wildrye, was described in the second report.

In this report, the third in the series, we discuss our work with beaked panicgrass, a native warm season grass. The work was conducted in 2007 and 2008. We begin with a literature review. The review will be organized according to the Attributes List. The Species Advisory Panel (SAP) developed the list of Attributes to provide guidance on all the issues that should be evaluated when considering a species for use in roadside soil stabilization (see first report).

Beaked panicgrass has tremendous potential for soil stabilization, and the SAP is not the first group to recognize that. In the 1940s, the US Forest Service (Georgia) began experimenting with meadow establishment and germination requirements (Matthews 1947). In the 1960s, the Quicksand PMC (Kentucky) began evaluating accessions of the species, believing it would have value for forage production on poor soils and surface mine stabilization. In the 1980s, the Coffeeville PMC (Mississippi) began evaluating accessions of beaked panicgrass with an eye toward developing a cultivar for soil stabilization purposes (Coffeeville PMC 1990). At the turn of the millennium, staff from the nature Conservancy and the University of Florida selected beaked panicgrass as one of only 5 native grasses to test for soil stabilization applications (Jenkins *et al.* 2004). And most recently, the North Carolina Department of Transportation placed beaked panicgrass on a short list of seeds recommended for soil stabilization (Smith 2008).

2 Attributes Review of Beaked Panicgrass

In this section we introduce beaked panicgrass and then review it with respect to the Attributes List (discussed in detail in the first report of this series). Beaked panicgrass is one of the three species that was approved by the Species Advisory Panel and then advanced to field trials. The Attributes review process will serve as a useful summary of the state of our knowledge regarding this species.

Figure 1: Botanical Drawing.

Panicum anceps Michx. line drawing from Britton & Brown (1913) shows a culm (stem), blade, and panicle (seed head). Each spikelet contains a pair of glumes (tinted in view at far right) that enclose a single caryopsis (grain or seed).

Introduction and Taxonomy

Beaked panicgrass (*Panicum anceps* Michx.) is a clump-forming, warm-season, perennial grass. In the spring, the plants appear as a circle of thick green grass sprouts. The circle becomes larger each year, and empty in the center, like a donut. Large, terminal panicles emerge in July. At this time the plant reaches maximum height, which on roadsides and in natural meadows is between two to three feet. In rich soils it can reach over three feet. Smaller, axillary panicles continue to arise as the summer progresses. The blades are a little wider than for most grasses (about 1 cm wide), with colors ranging from a noticeable lime-green to a more typical grass green, often tipped with burgundy. Seeds ripen in August and September and begin to shatter shortly after ripening.

Brown and Brown (1984) offer the common name flat-stemmed panicgrass because the culms are somewhat flattened. They mention the variety *rhizomatum* as occurring in Maryland, and having glumes (Figure 1) with fewer nerves than the species. The grass begins to bloom in June and continues through October.

Shetler and Orli (2002) give the alternate common name flat-stemmed panic grass, and the alternate scientific name *P. rhizomatum* Hitchc. & Chase.

Freckmann and Lelong (2003) report two subspecies, spp. *anceps* and ssp. *rhizomatum*, and offer very helpful illustrations (herbarium.usu.edu/webmanual/info.asp?name=*Panicum_anceps*&type=illustration). The illustrations show that the upper glume and lower lemma (leafy bracts containing the seed) are curved and give the spikelet (in this case a single seed) the appearance of a bird's beak in profile, hence the common name "beaked". The subspecies *anceps* is evenly distributed throughout the range (Figure 2), but the subspecies *rhizomatum* is only found in the Coastal Plain. Both species are rhizomatous, but *Rhizomatum*'s rhizomes are longer. Also, the spikelets are less beaked,

smaller, and may be purplish. *Rhizomatum* also has more axillary panicles. Subspecies *anceps'* rhizomes are shorter and therefore the habit is more caespitose (clump-forming growth habit).

1 and 2: Range, Distribution and Abundance

A. State Native: To determine whether beaked panicgrass is native to Maryland, we consulted these references:

i. **Shetler and Orli (2002):** list the plant as native in DC, MD and VA.

ii. **Brown and Brown (1984):** make no comments as to whether the plant is native.

iii. **Metzger (1995):** Lists the plant as native in Maryland.

iv. **Experts:** Maryland Native Plant Society member Nancy Adamson (Adamson 2000) introduced this species to the lead author as one that is highly characteristic of local meadows.

B. State Rarity: A dozen species of *Panicum* are included on the Rare, Threatened and Endangered Plants of Maryland list (2007). Beaked panicgrass is not among them and is not synonymous with any of the names listed there.

C. State Abundance & D. Habitats:

i. **Brown and Brown (1984):** describe the plant as occurring in moist sandy soils, and more abundant in the Piedmont than the Coastal Plain.

ii. **Plant Lists on MNPS Website:** The only list containing beaked panicgrass is the one for the Sligo Creek watershed, Montgomery County (Parrish & Steinman, 2003+), and it indicates that beaked panicgrass occurs in moist, open areas.

iii. **Park/Government Property Lists:** The Patuxent Wildlife Refuge (www.pwrc.usgs.gov/history/herbarium/category.htm). Lists beaked panicgrass as native to the refuge.

iv. **Marylandica:** We reviewed back issues of Marylandica and Native News and were unable to find any references to beaked panicgrass (www.mdflora.org/publications/publications.html).

v. **U.S. Fish and Wildlife Service (Slattery *et al.* 2003):** Does not discuss beaked panicgrass, probably because it is not a particularly garden-worthy plant.

vi. **Herbarium Records**: Specimens of *Panicum anceps* Michx. were observed at the University of Maryland's Norton Brown herbarium**.** Maryland's Coastal Plain and Piedmont geologic provinces are both represented. The herbarium contains specimens from Anne Arundel, Baltimore, Calvert, Cecil, Charles, Frederick, Harford, Howard, Montgomery, Prince George's, Queen Anne's, St. Mary's and Talbot Counties.

vii. **Author's Observations:** In our field studies, we have found beaked panicgrass to be roughly as common in Maryland's Piedmont as its Coastal Plain, in dry, average and moist soils. We typically find it in full sun or very little shade, where it is one of the grasses most representative of locally native meadows (Chesapeake Natives 2009). Although beaked panicgrass was once regarded as common throughout the state (Brown and Brown 1984), we were only able to locate 12 isolated populations of for the wild collection phase of this project. No doubt, these 12 are only a fraction of the state's remaining beaked panicgrass populations, however it is an indication that Marylanders need to treat the native meadows we have left with some respect.

E. National/International:

i. **PLANTS Database:** Beaked panicgrass is native across the southeastern North America (Figure 2, USDA NRCS 2006+).

ii. **Literature:** Anderson *et al.* (2000) summarize the literature on the habitats in which beaked panicgrass occurs as open barrens, prairies, woodlands, borders of streams, and roadside ditches. Texas A&M and Grazingland Management (2008) lists it as a climax community member of the Post Oak Savannah plant community in Texas. Newman and Gates (2006) appear to have studied beaked panicgrass in Louisianna, although that is not explicitly stated. They state that beaked panicgrass is already in use for revegetation of mined land, logging sites, timber roads and other disturbed areas. We have not seen these uses in our area, and have been unable to find any other references to these uses in the literature. Newman and Gates also note that the plant occurs in well-drained soils, but is adapted to marshes, swamps, and bottomlands. They note that it grows best in 30 to 35% shade; we have not yet had the opportunity to grow it in partial shade, although in the wild we often find it either in full sun or at the edge of the woods. Two comments made in Newman and Gates suggest that they may be describing the variety *rhizomatum*. They note that the seeds are purple, and that the plant is rhizomatous to the extent that it forms large, pure stands. These are not attributes observed in our project, where we are working with var. *anceps*.

3: Taxonomy, Ecology, and Genetics

As for the species, very little information is available in the literature on the mating system or genetics of beaked panicgrass. It has a chromosome number of 2n=18, occasionally 36. Two subspecies are currently recognized, one a lowland ecotype (ssp. *rhizomatum*) and the other an upland ecotype (ssp. *anceps*, Freckman & Lelong 2003). Freckman & Lelong state that some hybridization, polyploidy, autogamy and apomixis occur in the genus, but do not address these issues with respect to the species.

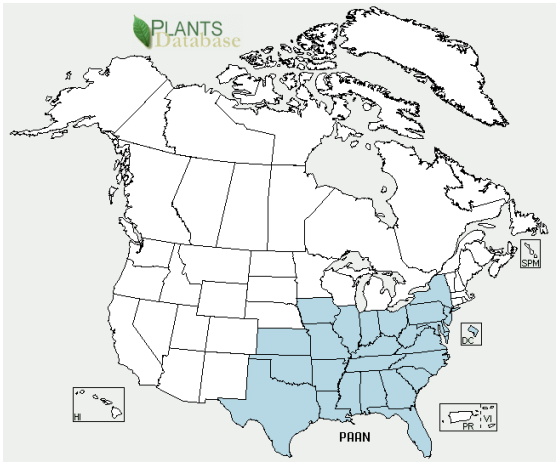

Figure 2: Native Range.

This map shows that the range of beaked panicgrass covers the southeastern third of North America, as far west as Texas, as far north as New York, and as far south as Florida. Maps from Plants Database (USDA 2006+).

Perhaps a closely related member of the genus, switchgrass, possesses genetic qualities and reproductive traits similar to beaked panicgrass. The relevant literature on switchgrass was recently summarized by Rogers & Montalvo (2004) and is quoted here:

> *Switchgrass (Panicum virgatum L.) also has an impressive polyploid series from 2x=18 to 12x =108. When populations have mixtures of cytotypes, primarily tetraploids and octoploids occur and there is a geographic pattern to the frequency of the different common cytotypes. Martínez-Reyna, and Vogel (2002) found that mating between tetraploids and octoploids results in a high proportion of inviable seeds which was worse when the tetraploid served as the mother, explaining the rarity of hexaploids in the mixed populations. In addition, this species has distinct upland and lowland cytotypes that tend to be genetically and morphologically distinct. Casler and others (2004) showed that cytotype and complex correlations with habitat*

explained most of the variation in crossing success among cytotypes and populations from different latitudes.

In various tables, Rogers & Montalvo also mention that switchgrass is wind pollinated, self incompatible, and that there may be examples of outbreeding depression.

Newman and Gates warn against planting beaked panicgrass too far from its point of origin (Newman & Gates 2006). They recommend the seed not be moved more than 300 miles north, 200 miles south, or 100 miles east or west of its point of origin.

Two issues related to taxonomy, genetics, and ecology will require us to take special care whenever ordering beaked panicgrass seeds.

First, we must make sure to order the subspecies appropriate for the SHA region where the seed will be sown. While either subspecies may be used in the Coastal Plain (SHA Region 1), only the subspecies *anceps* may be used in the Piedmont (SHA Region 2).

Second, local vendors don't always sell locally native seed. Most seed purchasers are unaware that seed vendors regularly exchange seed amongst themselves so that they can fill customer orders. Even though an order is placed with a seed vendor on the east coast, the seed used to fill it may come from anywhere in the United States.
For both of these reasons, it will be necessary for SHA to ask for independent, third-party, AOSCA certification of both the provenance and the subspecies of beaked panicgrass seed used on roadside projects.

4: Special Site Conditions or Abilities

Beaked panicgrass appears to be a generalist species that will grow in most soil-moisture conditions and in sun to light shade. If it possesses adaptation to any extreme or special site conditions we are not yet aware of it.

5: Germination & Sowing Requirements

Interest in the use of beaked panicgrass for soil stabilization dates back to the 1940's. Staff at the US Forest Service in Georgia made repeated attempts to establish stands by sowing seed in spring (Mathews 1947), all of which failed completely. A single attempt to establish a stand by sowing in September, however, was a great success. Conducting greenhouse germination experiments in cooperation with the Soil Conservation Service, Mathews discovered that germination was greatly improved by 6 weeks of cold, moist storage. Furthermore, the benefit of stratification was maintained despite an additional 6 months of room temperature, dry storage.

In 1990, the Coffeeville PMC published the following recommendations for the germination of beaked panicgrass seed: "the simplest and only treatment considered necessary to enhance germination was cold stratification. This resulted in seeds of some accessions being conditioned in a damp mixture of 50% sand and 50% shredded peat moss on January 24, 1984. The seeds were stratified at about 40°F until planted on May 30, 1984."

In 1998 staff at the National Plant Materials Center in Beltsville worked on cleaning and propagation protocols for beaked panicgrass seed collected in the Great Smoky Mountains, Tennessee, from 1996 to 1998 (Kujawski & Davis 2001). Seed was stored in bags in a seed cooler (40ºF and 35% relative humidity) until sown in Fafard germination mix on 9/11/98 and then cold-stratified for 8-10 weeks at 40ºF and 35% relative humidity. Germination began within 7 days of return to the greenhouse. Over 50% of the seedlings that ultimately germinated emerged within 30 days; the rest took up to 45 days. Germination of the 1997 seed was 64%. They were able to produce 187 plugs per gram of seed.

Germination tests conducted by Dr. Harry Swartz at the University of Maryland indicated that light and fluctuating stratification temperatures provided no additional increase in germination rates beyond the rates obtained with simple cold stratification (pers. comm. 2000).

Grabowski *et al.* (2004) from the Coffeeville, Mississippi Plant Materials Center worked with beaked panicgrass seed collected from east Texas. They found that a sample of seed dry stored two years was less dormant than another that had only been dry stored for one year. However both samples had fairly low germination rates (12% and 36%). These authors believe beaked panicgrass has potential for critical area stabilization, but state that stratified seed "would be difficult to plant using conventional equipment"[1]. Therefore they are undertaking a program to develop a new release of beaked panicgrass with non-dormant seed. To accomplish this they will apply artificial selection[2]: growing multiple generations of grass, each time selecting only seedlings that germinated without stratification for the next round of breeding. The end product will be released as a cultivar of beaked panicgrass.

The Coffeeville beaked panicgrass project is but one component of a nationwide effort to "improve" native species for conservation purposes (see for example Davis *et al.* 2002, Aubry *et al.* 2005). This effort has its roots in the dust bowl era of the 1920s and 1930s, when the USDA Plant Introduction Service began improving foreign plant species for domestic soil stabilization purposes (Mack 1991)[3]. As the problems with using fertile alien plants for conservation work became apparent, the USDA moved toward development of native species cultivars[4]. The hope was that native cultivars would provide the environmental benefits of using native plants with the predictability benefits of using cultivars.

Authors from the Tucson PMC have argued against the development of native cultivars (Munda and Smith 1995) for soil stabilization. Breaking with tradition in a profession where propagules are usually taken from a limited number of individuals with distinctive traits, these plant breeders emphasize the importance of collecting from multiple populations of a species. They found that having a collection of genetically diverse, local plant material maximizes the chances for success in stabilization of highly disturbed soils. The work that Chesapeake Natives is currently doing with the NPMC is in alignment with the approach expressed by Munda and Smith. In general, PMCs across the nation are increasing their volume of source-identified releases[4].

We don't know if the Coffeeville beaked panicgrass cultivar is intended for release as far north as Maryland. In any event, SHA has already committed to focus on the use of locally native species. However the project does raise some interesting questions, and there is likely to come a time when SHA needs more beaked panicgrass seed than it can acquire from local sources. At that moment, SHA will have to decide whether or not to purchase the Coffeeville cultivar seed, or possibly some other as-yet-undeveloped cultivar of beaked panicgrass, or shift focus to another warm season grass species. The first question is whether or not a beaked panicgrass cultivar should be considered a native plant. A cultivar might look just like beaked panicgrass, but would lack the seed dormancy mechanisms that ensure population survival[5]. Aubry *et al.*

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[1] In personal communication (2009), the author expressed her concern that stratified seed might be more easily damaged by the planting equipment than un-stratified seed.

[2] In contrast to natural selection.

[3] See the discussion in the first report of this series, 2.1 The History of Stabilizing Soil with Alien Plants.

[4] The change over time can be seen in the list published by the NPMC (Davis et al. 2002).

[5] For a discussion of the role seed dormancy plays in plant population ecology, see the discussion of gray goldenrod germination (fourth report of the series).

(2005) state that seed dormancy is also important for the success of soil stabilization plantings[6]. If beaked panicgrass were naturally a species with non-dormant seed, it would certainly occupy a different niche within the meadow community.

The second question is whether the exchange of wind borne pollen between cultivar and wild beaked panicgrass populations could result in adverse ecological consequences? It could if the pollen exchange resulted in a change in the germination behavior of wild seed. Gustafson *et al.* (2004) found non-local and cultivar seed sources to be so genetically different from the local seed that they cautioned, "Translocating non-local seed in order to increase diversity, or using cultivars, is likely to alter the genetic structure of remnant populations and potentially influence the associated community and affect ecosystem structure and function in unforeseen ways".

Returning to Grabowski's concern, it is unclear why stratified seed of beaked panicgrass should be more sensitive to equipment than other types of stratified seed. All the same, our "future work" needs to include testing the use of stratified seed in various types of sowing equipment. Booze-Daniels (1998) would suggest that we select species that already possess the desired characteristics (in this case non-dormant seed) rather than breeding these characteristics into species that do not naturally have them. In effect that's what we have done with this project by including the gray goldenrod and the Virginia wildrye (see the 2nd and 4th reports) - two species with much less seed dormancy than beaked panicgrass - in our inaugural mix.

Even though SHA will not benefit directly from the Coffeeville PMC cultivar release, there are still exciting opportunities to share information on beaked panicgrass crop maintenance, harvest, sowing, and seed cleaning techniques.

Working with the USDA in Louisiana, Newman and Gates (2006) recommend sowing beaked panicgrass seed in fall or early winter, or planting rhizomes. Rhizomes planted after April should be heavily watered.

6&7: Speed of Growth & Height

Newman and Gates (2006) recommend against sowing beaked panicgrass with cool season grasses in cooler climates, but do not specify whether this would be native cool season grasses or alien turf grasses. They state that the cool season grasses germinate first and will overtake the slower beaked panicgrass. This is counter to our own observations where we have seen beaked panicgrass competing well for space with roadside fescues and pasture grasses. Possibly the cooler climates they were referring to are north of Maryland.

Kujawski and Davis (2001) note that seedling plugs started in a greenhouse in winter languish until naturally warm weather and long days begin, despite artificial measures taken to simulate summer conditions.

In the production fields at the NPMC, we are impressed with how quickly beaked panicgrass can cover bare soil. In May of 2008, we planted year-old beaked panicgrass multipot-plugs in three rows of eight (24 plants) in a 9 ft x 15 ft area (135 sq.ft.), and achieved 100% groundcover early in the 2009 growing season.

Beaked panicgrass consist primarily of low basal foliage until the culms begin to send up panicles in June. By July the plants are approximately three feet tall, with the upper foot or so consisting primarily of panicles that do little to block the view. The plants continue to produce new panicles into the fall.

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[6] For a discussion of the role genetic diversity plays in soil stabilization success, see section 3.2 Methods of Wild Collection (first report of this series), and the review of Attribute 3: Taxonomy, Ecology, and Genetics in the Virginia wildrye report (second report of this series).

8: Winter Cover

Reports from Louisiana (Newman & Gates 2006) indicate that the ring of grass blades is semi-evergreen in winter. Here in Maryland we are more likely to see the plants turn completely brown and mostly weather away in the winter. In fact, the lack of an overwintering rosette of basal foliage is one salient feature that distinguishes the genus *Panicum* from the closely related genus *Dicanthelium* (Brown & Brown 1984, Freckman & Lelong 2003). Beaked panicgrass is not an ideal source of winter ground cover.

Figure 3: Appearance of Whole Plant.

This photograph looks down on a clump of beaked panicgrass. The characteristic growth ring of beaked panicgrass is just becoming apparent in this two-year-old plant. Grass blades radiate outward from an empty circle.

9: Root Structure

In Maryland, beaked panicgrass roots grow in circles that expand in diameter each year (Figure 3). This circle is so distinctive it can be used to identify the plant in the dormant season. The large fibrous root mat follows this circular structure. During the dormant season, the circle is easily divided into sections containing the stout, scaly rhizomes that will give rise to the next season's growth. We have not examined the root structure of subspecies *rhizomatum.* The internodes of the rhizomes are markedly longer and so the overall root pattern must be somewhat different.

10: Wildlife Interactions

The USDA Plants website cites Miller and Miller (1999) as indicating that the plant has moderate value as a food for both terrestrial and aquatic birds (probably as a seed food source).

In Texas, Helms and Vinson (2000) discovered that beaked panicgrass is one of approximately 100 host grasses for the invasive Rhodesgrass legless mealybug (*Antoninagraminis*). The scale of the impact of the alien mealybug on native grasses is unknown. Newman and Gates (2006) indicate that beaked panicgrass is grazed by cattle, horses, and deer. The seeds are consumed by most species of upland bird and several species of waterfowl. They indicate that it has no known pests or problems.

Scott (1986) lists several skippers that use grasses in the genus *Panicum* as host plants, but never mentions *Panicum anceps* specifically. It is likely that beaked panicgrass has some limited value as a butterfly host plant.

The lead author's experience with beaked panicgrass consists of about five years of growing the plant in crop rows and of observing it in native meadows and wild-collecting seed across the Maryland. In this time we have concluded that beaked panicgrass does not attract noticeable quantities of wildlife of any kind. We have seen many species of grasshoppers living in the grasses, and noticed that small quantities of plant tissue are consumed by generalist herbivorous insects like the two-lined spittlebug (Figure 4). Late in the season we occasionally notice a ground sparrow consuming fallen seed. We have never noticed any browsing or grazing by large invertebrates or any damage to indicate that there had been browsing. These observations indicate that beaked panicgrass is a valuable member of the base of the food web while not attracting the types of wildlife that could present a traffic hazard.

Figure 4: Wildlife is Not a Traffic Hazard.

Close-up photograph shows a two-lined spittlebug, a small black bug with a red face and two bright orange stripes across its back, pausing on a grass blade. Typical of the wildlife that visits beaked panicgrass, this is herbivorous insect is not a traffic hazard.

11: Aesthetics

Beaked panicgrass is not remarkable one way or the other in aesthetic quality. It is reasonably short at 3 feet. The upper foot or so tends to be quite open and airy, affording a good view of any wildflowers taller than 2 feet.

12: Mowing Requirements & Tolerances

No information the impact of mowing on beaked panicgrass was found in the literature. However, we did read that beaked panicgrass responds well to prescribed burning, flowering culms increased from 2,050 to 7,818 per hectare following a single fire (Anderson & van Valkenburg 1977).

The authors' have observed beaked panicgrass growing in the company of turf grasses along non-residential and non-commercial areas. In such settings it is mowed too frequently to set seed. The characteristic rhizome rings do expand each year, though. According to the Integrated Vegetation Management Manual for Maryland Highways, the preferred mowing regimen for such areas is 3.5" to 4.5" frequently enough to keep height below 30" (Maryland SHA 2003). Perhaps beaked panicgrass would be a candidate for the turf seed mix of these types of roadsides. The authors' also typically find beaked panicgrass under telephone and electric utility lines, these tend to be mown annually.

July through September would be the most damaging time of year to mow beaked panicgrass because it is expending energy to develop seeds that are not yet mature. A late summer mowing would cost the plant a significant fraction of its reproductive capacity for the year. The best times to mow a native meadow in our region are between Halloween and St. Patrick's Day.

While the exact mowing tolerance of beaked panicgrass is unknown, we can conclude that it will not be a successful choice for short lawn areas.

13: Herbicide Compatibilities for Roadside Use

Jenkins *et al.* (2004) selected beaked panicgrass as one of only 5 native grasses to test for soil stabilization applications in Florida. Despite good germination test results, none of the grasses sown in the test plots performed well. The authors attributed this to drought, however half of the experimental plots were irrigated. The authors failed to discuss the possibility that the low success rate might be attributable to residual activity of the herbicide imazapyr (trade names Stalker, Arsenal, Chopper), which had been used to prepare the study plots, and which is known to have a lengthy residual activity in soil. It can even be transferred from the roots of a targeted plant to the roots of non-target plants. In one study imazapyr was shown to reach peak activity 231 days *after* application (Lee *et al.* 1991, as cited on www.invasive.org/gist/products/handbook/17.Imazapyr.pdf). We mention Jenkin's results here because they may be an indication that beaked panicgrass has high sensitivity to the residual activity of imazapyr.

The authors could not locate any publications on the use of herbicides to promote the abundance of beaked panicgrass in meadows. However, the closely related switchgrass has been the focus of many publications because it is used in wildflower meadows, Conservation Reserve Plantings,

restoration projects, and as a biofuel crop.[7] Techniques recommended by the USDA (2006) include mowing at a height of 4" to 6" during the establishment year to control light-blocking weeds such as ragweed and mare's tale. Prescribed burns are listed as an effective approach to maintaining switchgrass stands. Controlled burns were also discussed in the Mowing Attributes section above.

Imazapic (Plateau) is a chemical that is often used to establish and maintain stands of native warm-season grasses, but it does cause some stunting of beaked panicgrass' close relative switchgrass (www.vmanswers.com/lib/productslist.aspx).

Cloparylid (Transline, Stinger) is the chemical SHA preferentially uses to control Canada thistle (*Cirsium arvense* (L.) Scop.), on beaked panicgrass (Maryland SHA 2003). It seems likely that clopyralid will not damage beaked panicgrass. Clopyralid is the herbicide of choice for brush control in Texas prairies where beaked panicgrass is a climax species (Texas A&M and Grazingland Management Systems, Inc. 2008). Also, in a letter explaining that clopyralid has been banned in counties with sandy soils, New York otherwise approved clopyralid for use on all grasses, including grasses used for seed production (Jackling 2004).

14: Road Salt Tolerance

There is no information in the literature on the tolerance of beaked panicgrass to road salt. However, we often find beaked panicgrass growing in with turf grasses on the road shoulder where there would be occasional exposure to road salts.

3 Methods

3.1 Wild Collection

Since the principles behind wild collection are similar for all species, they are presented in the first report and not repeated here. We would tailor these methods accordingly for species that are primarily inbred or outbred. For example, Gustafson *et al.* (2004) found that as few as two parent populations could be adequate to capture the necessary genetic diversity of native grasses that tend to cross-pollinate. Unfortunately, the literature provides no guidance on the degree to which beaked panicgrass might be self- or cross-pollinating. In the absence of such information, we simply collected from 50 individuals in as many parent populations as we could possibly find.

3.2 Germination

Our methods were designed to accomplish two goals simultaneously: confirm our understanding of germination behavior and produce plugs to plant at farms. Accordingly, we opted for potting soil and nursery trays, similar to the methods employed at Plant Materials Centers (see for example Kujawski & Davis 2001), rather than Petri dishes and damp filter paper such as would be used in a professional seed testing lab or in a university germination experiment that did not involve plug production (see for example Deno 1993; Walck *et al.* 1997a).

From January through April of 2007, we conducted germination tests on the 12 accessions of seed wild collected in 2006 by Chesapeake Natives. There was not enough seed from the six NPMC accessions for germination testing, but seed from both pools of accessions were used for plug production. Germination treatments included origin of the seed (parent population), cold

[7] Switchgrass was not chosen for our project primarily because it is not a representative component of wild Maryland meadows, and becomes increasingly less representative westward.

stratification duration (30, 60, or 90 days), cold stratification temperature, and light or dark. Our germination trials consisted of 23,074 cells in 179 trays (98 and 144-cell trays). The treatments were marked on each tray using the the annotation of Deno (1993). We were able to accomplish this level of experimentation thanks to the work of our volunteers, the donation of misthouse space by the University of Maryland Research Greenhouse Complex, and the donation of time on a seed-sowing machine by Behnkes' Nurseries.

Between the time of wild collection and sowing, seeds were stored in zip lock bags in a dark, room temperature/humidity cabinet. Seed was occasionally exposed to light when removed from the cabinets for handling. Seed was never air cleaned, so empty seed coats remained in the lot in the same percentages as in the wild. Indoor cold stratification was at 40°F and 50% humidity. Outdoor cold stratification occurred between December 2006 and February 2007. Soil was kept lightly moist throughout the stratification period. Seedling trays were moved to a climate-controlled misthouse for incubation.

The emergence of the radicle was obscured by the potting medium, so a germination was counted when the cotyledon appeared. Accordingly, our reports of days to first germination will be a day or two longer than any reported by the Petri dish method. Similarly, we could not see seeds that didn't germinate. Using the Petri dish method, such seeds are examined with tweezers and tetrazolium to see if they contain viable embryos. If they do, they are counted as dormant; if they don't, they were never viable to begin with. We had no way of estimating dormant seed percentages. We tallied germinations each week.

For plug production, seedlings were potted up to Ropak 37-cell multipots before being transplanted out to the farms in May 2008.

3.3 Production Trial

3.3.1 Farmers' Fields

One farm field was located in each of the three physiographic provinces included in this project (Figure 5). At the two family farms, the beaked panicgrass was planted in the same field as the Virginia wildrye and the gray goldenrod. These fields were described in detail in the second report of the series, the report on Virginia wildrye, so those descriptions will not be repeated here.

At the NPMC, space constraints dictated that the beaked panicgrass be planted in a separate field. The field is on level ground in a part of the NPMC campus that receives full sun all day. The soils are mapped as Christiana-Downer Complex (fine, kaolinitic, mesic Aquic Hapludults/coarse-loamy, siliceous, semiactive, mesic Typic Hapludults; Soil Survey Staff 2009). During the course of fieldwork, the authors found the soil to be coarse and rapidly drained, therefore the Downer sandy loam is the more accurate concept for the site. Soil tests (A&L Eastern Laboratories, 11/2/07, sample B-2) indicate that the soil pH of the top 6 inches (15 cm) was 4.9, soil P was high, and soil K was low. Boron was very low. Pelletized lime was applied in April of 2008.

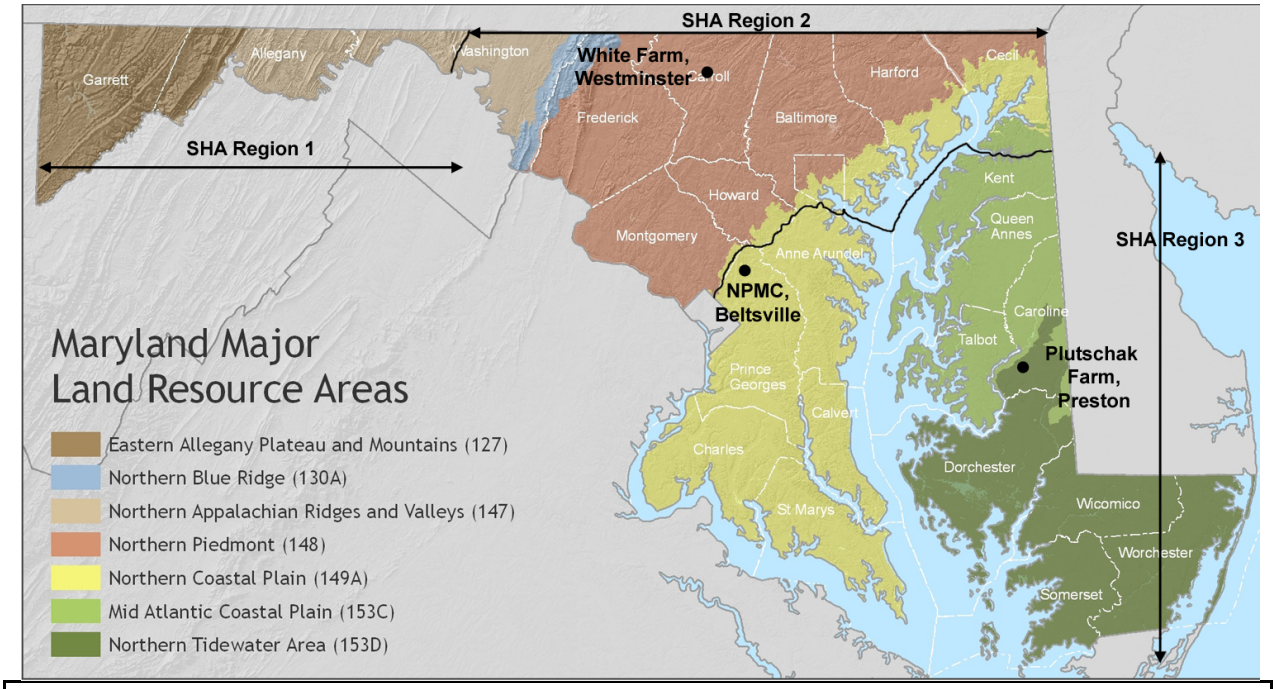

Figure 5: Farm Fields, Geologic Provinces, and SHA Regions.

This map shows the location of the three farms involved in this project with respect to the geologic provinces of Maryland and the SHA management regions.

3.3.2 Farm Field Planning and Establishment

Accession plots were planted in May of 2008. The term "accession plot" is used by the authors to describe a grouping of plants that all came from the same lot of seed, seed all collected from one particular parent population. Each farm has a complete set of three accession plots.

At the two family farms, each beaked panicgrass accession plot consists of a short row of five plants planted into weed mat using the same techniques described for planting Virginia wildrye (second report of this series).

At the NPMC farm, each accession plot consists of a row of ten plants planted into bare ground. Ground preparation began in 2007. The ground was sprayed with glyphosphate (trade name Roundup). After weeds died and new weed growth began, glyphosphate was sprayed again. Then the ground was tilled and disced.

All farms have three complete sets (blocks) of accession plots. With 17 accessions, each farmer's field has 255, and the NPMC breeder block field has 510 beaked panicgrass plants.

3.3.3 Crop Maintenance

No pre-emergent herbicide was used at the family farms during the establishment year (2008). A large number of weeds germinated inside the planting holes with the beaked panicgrass. The panicgrass crops were thoroughly hand-weeded twice.

Figure 6: Accession Plots.

This photograph shows long rows of beaked panicgrass growing in a sandy loam at the National Plant Materials Center in Beltsville, Maryland. July 17, 2009.

Three factors made hand pulling weeds at the White farm in 2008 much more time consuming than at the Plutschak farm and less effective.

1. Canada thistle (*Cirsium arvense* (L.) Scop.), Japanese bristlegrass (a.k.a. giant foxtail, *Setaria faberi* Hermm.) and horseweed (*Conyza canadensis* (L.) Cronquist) were the most significant weed problems. Canada thistle was coming up in the aisles between the weed mats and in the holes that were burned for the crop plants. Canada thistle thorns made hand-weeding much more painful.
2. The White farm had previously been in pasture, whereas the field at the Plutschak farm had been in crops.
3. Also, the soils at the White farm were finer in texture.

Since the NPMC accession plots were not planted in weed mat, their maintenance is a little different than the maintenance regimen of the family farms. A tractor with a 15' boom sprayer applied Surflan (Oryzalin A.I., 3oz/gal), a pre-emergent herbicide, in mid-April. Three Way Amine (Dicamba, MCPP & act. ingred., 0.75oz/gal), a broad-leaf weed killer, was applied in mid-April. The aisles between accession plots were tilled regularly to keep weeds from establishing. Weeds between the plants were hand-pulled as necessary throughout the growing season.

Figure 7: Crop Maintenance.

The photograph shows a volunteer in the short rows -accession plots - of beaked panicgrass growing at the Plutschak family farm. Despite the use of weed mat, hand-pulling weeds was a constant chore for this crop in 2008. Photograph taken July 13, 2009.

3.3.4 Harvest

Seeds were harvested during the establishment year. Other authors disregard first year harvests (see Vogel *et al.* 2006, for example) with good reason. Some results, for example cost benefit analysis, will not be valid because perennial crops typically produce little or no seed during their establishment year. However, we wanted to produce estimates of the total yield seed producers can expect during an establishment year. We also need the seed for future work.

To prevent any seed loss, spikelets were carefully hand-stripped from culms bent over plastic bins. Seed from each accession plot was placed in a separate, labeled, paper bag. Our hand-stripped seed was so clean that it was perfectly flowable. However, using a clipper would have helped to remove empty seed coats.

Kujawski and Davis (2001) described methods used to clip beaked panicgrass seeds collected at Cades Cove. Seeds were run through a large two-screen clipper three times—once with screen sizes 10 and 1, and twice with screen sizes 8 and 1. Airflow was adjusted to a low-medium rate. The cleaned product was 82% pure and contained approximately 1,250,000 seeds/kg.

The first year harvest can be used for slope stabilization demonstration trials. The second year harvest can be used to examine the harvest weights for any interaction between accession site and production site. This will tell us whether there are beaked panicgrass seed transfer zones within Maryland.

4 Results & Discussion

4.1 Wild Collection

Wild collection methods were presented in the first report of this series, since the collection principles are roughly the same for all species. Wild collection results, however, are not. Here we discuss our work at wild collecting beaked panicgrass from across the state of Maryland.

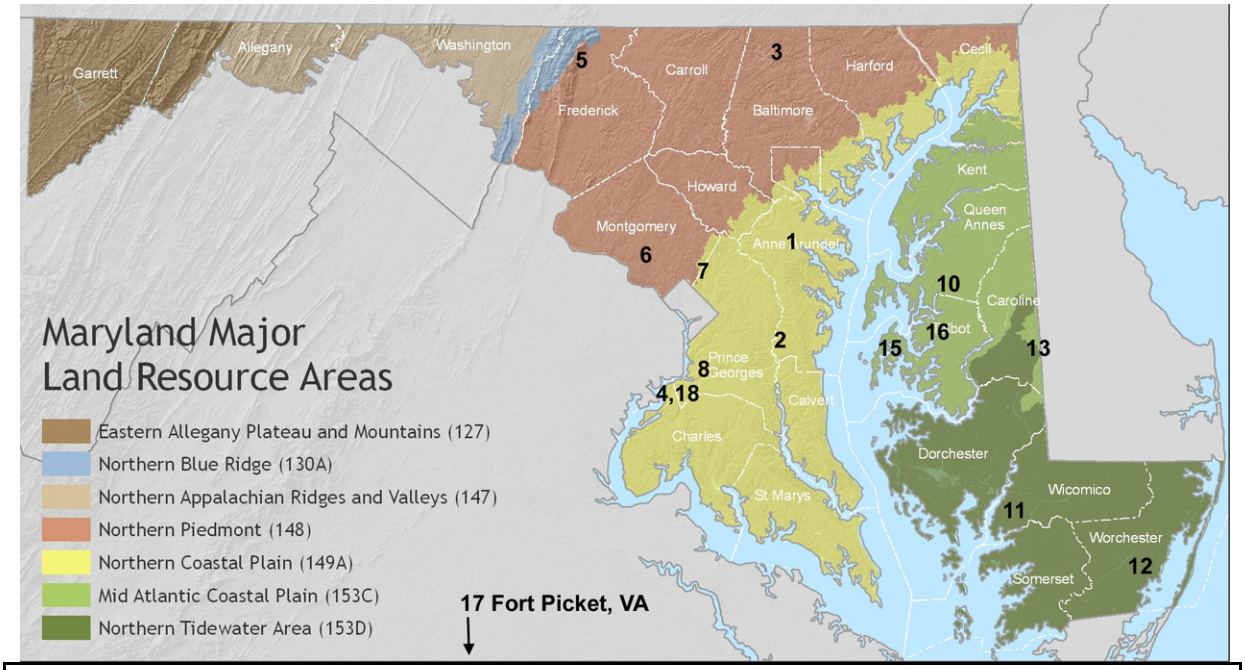

Figure 8: Parent Populations and Geologic Provinces.

The NRCS propagation numbers have been added to a geologic map of Maryland to indicate the location of the beaked panicgrass parent populations. (Base map by Moore 2009).

As part of this project, 12 accessions of beaked panicgrass were collected. Accessions were obtained from all three geographic areas targeted in this project: Coastal Plain east of the Bay, Coastal Plain west of the Bay, and Piedmont. An additional 7 accessions were acquired from the seed storage room at the NPMC in Beltsville, MD. Six were from Maryland and one from Virginia. Seventeen accessions produced an adequate number of seedlings to be advanced to the production trials. The provenance of all 18 accessions is shown in Figure 8 and Appendix 1.

4.1 Germination

Beaked panicgrass seeds germinated well and in ways that support their use in a soil stabilization mix, as described below.

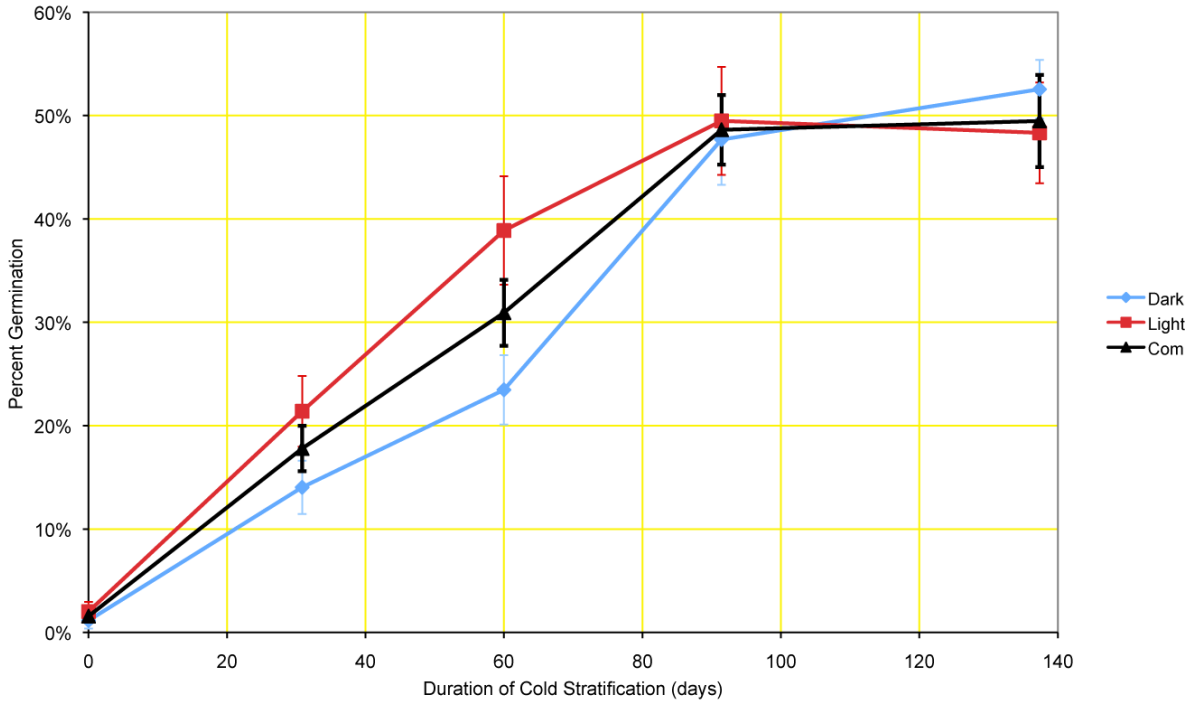

Figure 9: Germination Increases with Cold Stratification.

The graph has three lines showing the percent of germination and how it increases with days in cold stratification. All three lines level off at 90 days. The upper line shows that seeds exposed to light germinate a little better than the lower line, seeds buried in the soil. The central line is the average of the light and dark trends (com=combined).

Seeds responded positively to cold, moist stratification. As the duration of stratification increases, the percentage of seed that germinates increases, until about 90 days, and then the germination rate levels off (Figure 9). Seeds germinated whether stratified while buried in the soil (the dark treatment), or surface sown (the light treatment), with a slight advantage to the light treatment. The advantage of light is lost after about 90 days of cold stratification, at which point the average percentage of germination in dark exceeds that we sampled for light. However, the standard error bars overlap, so all we can say is that beyond 90 days, the germination rates for the dark and light treatments are similar. Furthermore, an additional 50 days of cold storage beyond the 90-day period did not reduce germination rates. This is reminiscent of Matthews' (1947) finding that benefit of stratification was maintained despite an additional 6 months of room temperature, dry storage did not reduce germination rates.

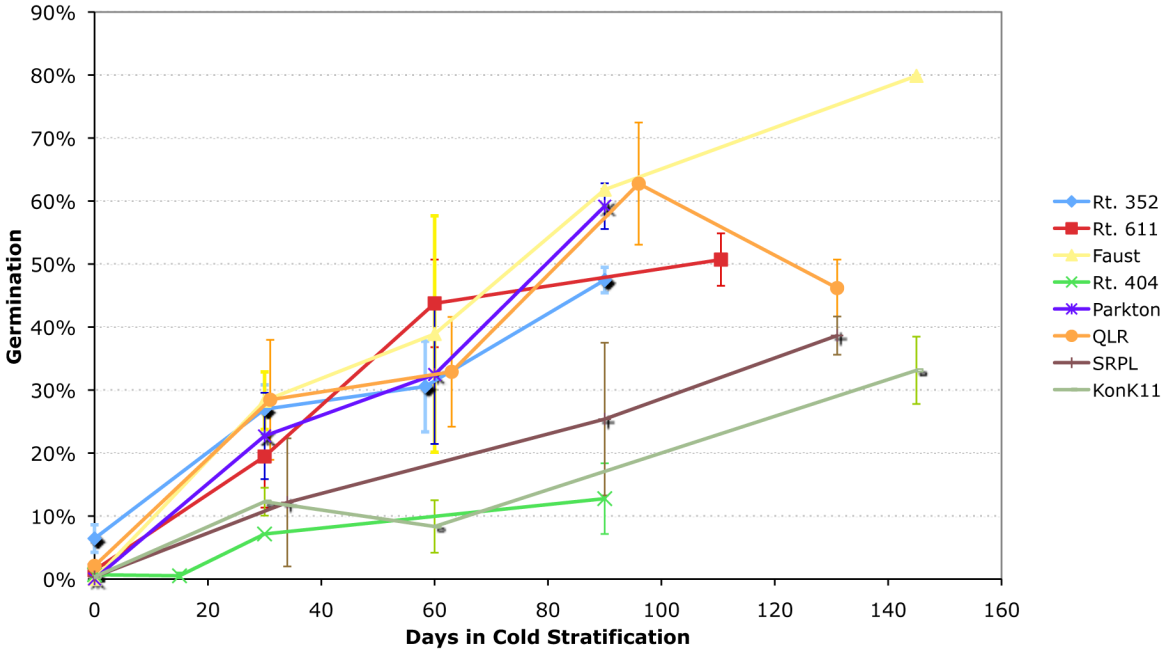

Figure 10: Germination vs. Days in Cold Stratification, Sorted by Wild Collection Site.

The graph has eight lines showing the percent of germination and how it increases with days in cold stratification. All eight lines increase with time, but the slopes vary dramatically.

Wild-collection site (Figure 10) turned out to be a significant source of variation in the germination experiments. We do not know whether the differences observed are strictly due to the parent population (i.e. genetic) or whether there are other causes such as the date of collection, insect damage to the seed lot (seeds were hand-cleaned and not fumigated), or other factors we are unaware of (mowing history, perhaps). Such a determination would require multiple collections from the same sites within and across years.

The lowest germinations were obtained from the Rt. 404 wild collection site in Caroline County, Maryland. Three features were noted at the time of collection that distinguished this site from others the lead author had seen. First it seemed likely that the site, a moist meadow under a telephone line, had been mowed earlier in the year. This guess was made because the plants all seemed very uniform in height and the seed seemed a little late in ripening. Second, with an estimated 10,000 or more plants it was an unusually large population. And most notably, the seeds seemed a little smaller than normal, but were otherwise quite typical. The habitat, location, and seed size suggest that this may be a population of subspecies *rhizomatum*. If so, perhaps the plants are mostly clonal in origin and too closely related for effective cross-pollination, resulting in seed with low germination rates. The seed sown from this accession only produced 5 plugs and we were unable to advance it to the trials. It seems likely that there was something wrong with the seed collection, or perhaps the seed production for that site that year, so the germination data was treated as an outlier and removed from the statistical analyses in this report.

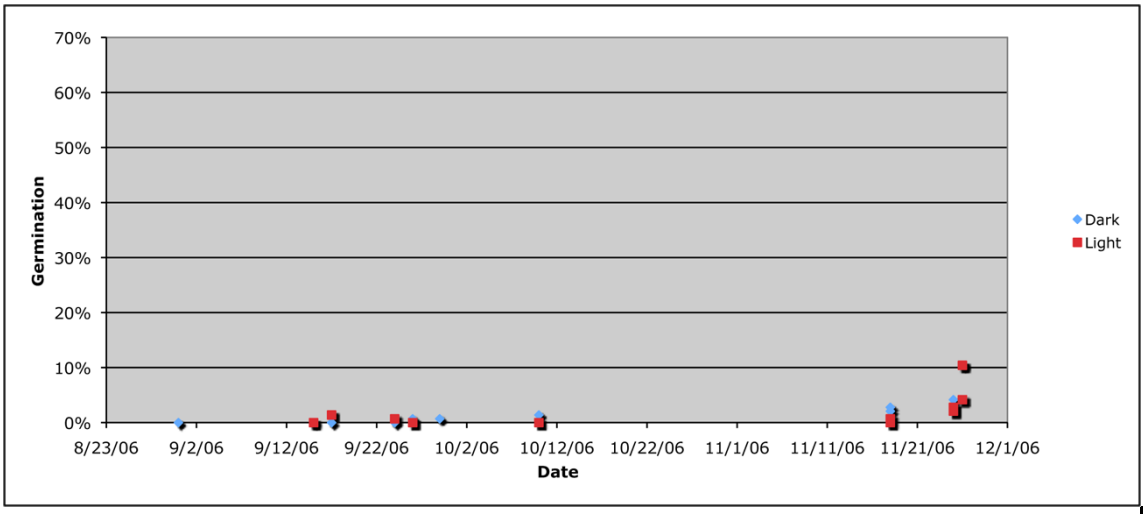

Figure 11: Germination vs. Collection Date: No Cold Stratification

The scatter diagram shows that there was almost no germination for seed collected prior to November. Seed that was collected in late November shows germination up to 10%, with those seed exposed to surface light performing a little better than those buried in the soil.

There was evidence that wild collection date affected percent germination. For those trays that received no cold stratification, almost no germination occurred if the seed had been wild collected in August or September. However, if the seed had been collected in November, about half the trays would show a little germination, ranging from 1% to 10% (Figure 11). Germination rates increased dramatically with just 30 days of cold stratification. Still, seed collected in August and early September did not germinate as well as seed collected from late September through November (Figure 12). With 60 days of cold stratification, the effect of wild collection date is no longer apparent (Figure 13). One possible explanation for this phenomenon is that the wild seed was actually receiving some cold stratification benefit while still attached to the parent plant.

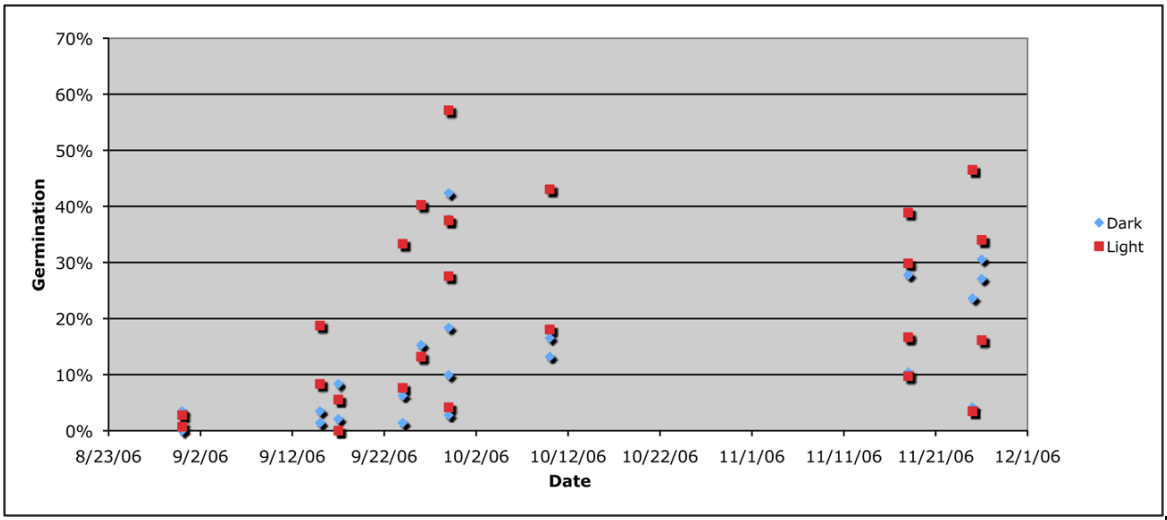

Figure 12: Germination vs. Collection Date: 30 Days Cold Stratification

The scatter diagram shows that seed collected in early September germinated less than 20%. Seed that was wild collected later germinates up to 50%.

Our observation that beaked panicgrass can receive some cold stratification on the mother plant if left in the field until late fall is consistent with Mathews' (1947) observation that simple cold storage provides a stratification benefit. It is probable then that the cold storage used by Kujawski & Davis (2001) imparted as much germination benefit as their cold stratification treatment. Cold storage is a factor that will need to be considered by producers, purchasors, and seed testing agencies working with beaked panicgrass.

We were present to observe 57 of the 179 trays on the date of first leaf emergence. Speed of germination is a function of the seed stratification treatment. Without cold stratification, germination is not only low, it is slow, taking 25 ±9.9 days. With increasing cold treatment, the seed germinates more quickly, reaching a speedy 7 ±0.9 days at 92 days of cold treatment.

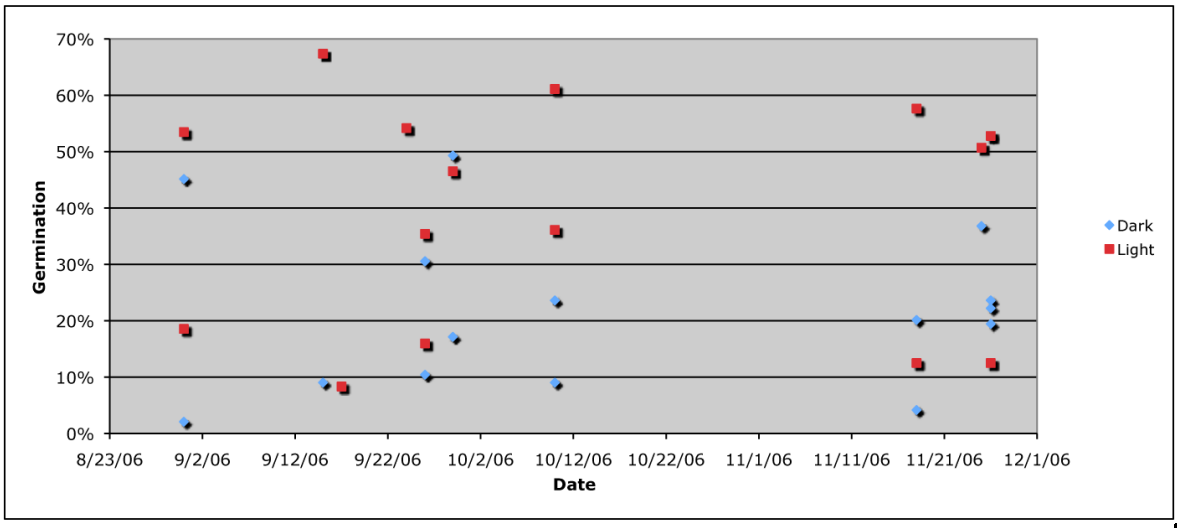

Figure 13: Germination vs. Collection Date: 60 Days Cold Stratification.

The scatter diagram shows that seed is germinating up to 70%, regardless of collection date.

Implications for Use in a Soil Stabilization Mix

Beaked panicgrass has a strong need for cold stratification. At first this may seem a disadvantage for our purposes, but if we understand it, it is a powerful tool. Seed dormancy and natural variability in the number of days to onset of germination provide insurance against project failure. If the first seedlings suffer high mortality due to frost, drought, herbivory, etc., more seedlings will be produced through additional waves of germination.

To use the seed dormancy to our best advantage, we need to know the storage and stratification history of the seed lot we plan to sow at a stabilization site. If, after all, wild collecting seed later in the season produces a stratification benefit, then any activity that exposes the seed to ambient humidity and fall temperatures might stratify the seed. Likely examples would include cold-dry seed storage, harvesting the seed late, or drying and cleaning the seed in an unheated building after harvest. We also need to plan storage methods for the time after the seed has been purchased and before it is sown.

From the data we have collected in the literature, we can make predictions about how seed would respond to sowing at various times of year (Table 1).

Table 1: Germination Behavior According to Season.				
Common Name	**Fall**	**Winter**	**Spring**	**Summer**
Unstratified seed	No	No	After warm weather >10%	1-10%
Stratified 30 days	No	No	After warm weather >10-50%	10-50%
Stratified 90 days	No	No	After warm weather >50%	>50%

Germination rates of 50-80% are high for wild seed. Furthermore, we didn't remove empty seed from the germination test, as most seed testing labs would do, and still achieved these rates.

4.2 Production Trial

Wild collection, establishment, certification, and maintenance of a genetically diverse foundation planting requires money and expertise that many potential seed producers do not possess. This is where the NPMC plays a vital role. The NPMC will use the breeder blocks to develop a local ecotype release and to provide growers with seed for establishing genetically appropriate production fields. When farmers sell seed descended from these breeder blocks, SHA will know that the seed is from Maryland wild populations, and that it contains a diverse and appropriate gene pool. This will help ensure that Maryland's roadside vegetation managers have access to large quantities of locally native seed at reasonable prices. As a result of this project, the NPMC now has 12 more accessions and 16 new breeder blocks of Maryland ecotype beaked panicgrass.

To determine whether or not the species on the SAP's top ten list (see the first report of this series) are commercially available yet, we contacted Ernst Conservation Seed, the only vendor currently offering any Maryland ecotype seed. The only species that currently available as Maryland ecotype seed is the beaked panicgrass. Working with one farmer on Maryland's Eastern Shore, Ernst is now offering (August 2009) Eastern Shore Maryland Ecotype beaked panicgrass seed at $36/per pound. We need to find out how genetically diverse the seed is, but it is genetically appropriate at least to SHA Region 1. However if it is subspecies *rhizomatum*, or, if it is not identified to the subspecies level, it should not be used outside SHA Region 1. The two farmers involved in this project will also have the option to offer their seed for sale through Ernst Conservation Seed.

The beaked panicgrass yielded much more seed, an estimated 11 pounds, than what we anticipated for an establishment year. Of this, we only harvested an eighth of the fields (1.41 pounds). Due to the combined presence of weed seeds and a lack of time, about 7/8 of the crop had to be left in the field.

Based on a count of 10 half-gram samples, the US Forest Service estimates that our beaked panicgrass samples contain an average of 4,640,260 seeds per pound (Victor Vankus, personal communication). At a rate of 20 seeds per square foot, each pound contains enough seeds to plant over 5 acres, or a 10 foot wide strip that is 4.4 miles long.

Farmers attempting large-scale organic production might wish to consider growing any of these three species *between* rows of weed mat, using mulch to suppress weeds in the crops. Farmers interested in large scale conventional production will probably produce the grasses in fields much the way commercial switchgrass seed is produced, using pre-emergent and broad leaf herbicides to control weeds, and a flail-vac or a combine to harvest seeds.

5 Conclusions and Recommendations for Implementation

1. **Appropriateness:** The authors have conducted a thorough review of beaked panicgrass with respect to the 14 Attributes and conclude that it is a promising species for use on Maryland roadsides.
2. **Distribution:** Beaked panicgrass is native across southeastern North America. There are two subspecies, subspecies anceps is evenly distributed, and subspecies rhizomatum has a more limited Atlantic/Gulf Coastal Plain distribution. Multiple references indicate that beaked panicgrass is native and common throughout Maryland. It is found in all the physiographic provinces of Maryland. It is one of the grasses that is most representative of Maryland meadows.
3. **Description:** Beaked panicgrass is a 3 ft tall, warm season, perennial grass. It has a stoutly rhizomatous/fibrous root system that expands in a ring pattern with each year of growth. It grows in sunny places with a range of soil textures and moistures. It does not attract the sort of wildlife that would present a traffic hazard. Seeds are borne in large, terminal and lateral panicles. Seeds shatter when ripe.
4. **Wild collection:** To capture the genetic diversity that is needed to ensure adaptability to a wide range of roadside conditions, we wild collected from as many sites as we could locate. We wild collected from 12 sites in Maryland, and the NPMC has contributed seed from an additional 5 populations, 4 within Maryland and 1 from Virginia.
5. **Germination and seed storage:** We used wild seed to study germination behaviors and to produce plugs for breeder block/production plots at the National Plant Materials Center in Beltsville and at two private farms. Dormant beaked panicgrass seed can be sown summer, fall or winter and will germinate when warm weather arrives in spring. Dormant beaked panicgrass seed can be sown in the spring and will exhibit partial germination with the remainder going into the soil seed bank. Cold-stratified seed can be sown at any time of year and when germinate rapidly in warm weather. Simple cold storage imparts some cold stratification benefit to the seed. Cold storage is a factor that will need to be considered by producers, purchasers, and seed testing agencies working with beaked panicgrass.
6. **Special abilities for roadside use:** Beaked panicgrass is a generalist species without any extreme abilities that we are aware of.
7. **Wildlife:** Although beaked panicgrass does support the food web, it does not attract the sort of wildlife that would present a traffic hazard. It does not attract large herbivores like the turf grasses currently in use do.
8. **Mowing:** The exact mowing tolerance of beaked panicgrass is not known, but it will not be a successful choice for short lawn areas. It does tolerate mowing more than once per year, and the authors have often observed it mixed in with infrequently mown turf grasses. It may be a good candidate for inclusion in turf seed mixes for rural roads and utility lines. July through September would be the most damaging time of year to mow beaked panicgrass because it has expended energy to put out seeds that are not yet mature. For many reasons, the best time to mow a native meadow in our region is between Halloween and St. Patrick's Day.
9. **Herbicides:** No literature is available on the compatibility of beaked panicgrass with various herbicides. There is some literature on the compatibility of switchgrass with

mowing regimens, burning, and various herbicides. Beaked panicgrass might respond similarly.

10. **Seed production and harvest:** The 1,020 beaked panicgrass plants in this project produced an establishment year yield of 11 pounds. The plants are expected to produce a larger quantity of seed in their second year. A pound of beaked panicgrass contains over 4.6 million seeds.
11. **Seed certification and ecological concerns:** Source-identified certification tags are always desirable because they certify that seed comes from a local source. In the case of beaked panicgrass, these tags will need to identify contents to the subspecies level. The subspecies *rhizomatum* forms large colonies through its rhizomatous root structure, is a lowland ecotype, and is only native to the Coastal Plain. The subspecies *anceps* is clump forming, is an upland ecotype, and is native throughout Maryland. Both could become valuable components of roadside stabilization mixes, but since they would have different applications, SHA would need seeds to be labeled accurately. Furthermore, to protect the integrity of Maryland's native plant communities, the subspecies *rhizomatum* should not be used in SHA zones 1 and 2.
12. **Seed availability:** Two private farms have locally native beaked panicgrass seed ready for sale as a result of this project. This seed is from a genetically diverse and appropriate wild collection. Ernst Conservation Seed is now offering locally native beaked panicgrass seed, labeled as Maryland Eastern Shore ecotype. We need to gather more information on the genetic diversity of the wild collection, it is likely genetically appropriate for use on the Eastern Shore at least. If it contains the subspecies *rhizomatum*, it would not be genetically appropriate for use west of the Bay.
13. **Seed purchase:** The authors recommend that SHA begin preferentially purchasing and using local ecotype beaked panicgrass seeds to build demand for the new Maryland product. As a consequence, production will increase with time, ensuring availability and reducing cost. We also recommend that SHA consider purchasing other local ecotype seed as it comes on the market, providing that the wild populations are certified by an independent source, the collection methods are responsible, and the species stand up well to a rigorous review using the Attributes outlined by our Species Advisory Panel (first report).
14. **Stabilization site design:** As a reliable, representative, warm season grass, beaked panicgrass is likely to become a workhorse species of future roadside seed mixes in Maryland.

6 Future Work

1. **Test the seed on slopes:** We recommend that a portion of the beaked panicgrass seed produced during the establishment year of this project be used in slope demonstration trials across the state. The demonstrations can be used to document the effectiveness of beaked panicgrass as the warm season grass component of a soil stabilization mix, and to host field trips for roadside vegetation managers from SHA and other organizations.
2. **Germination:** Determine the degree to which simple cold storage can be used to produce the same results as cold stratification. Does one day in cold storage have the same impact as one day of cold stratification? Is outside cold storage (fluctuating temperatures) the same as storage in a cooler? The cold storage option could allow producers, vendors and even users to easily stratify their seed without the use of expensive, climate-controlled cold rooms.
3. **Techniques for plugging stabilization sites**: The rhizomatous nature of beaked panicgrass suggests the potential for a special application. The dormant rhizomes of subspecies *anceps* are stout and rather tough. They may tolerate some mechanical manipulation. In the spring, perhaps dormant rhizomes could be chopped and incorporated into surface soils. This would allow very rapid establishment of mature warm season grass stands. Fields could be maintained with pre-emergent and broad-leaf herbicides. This approach could be particularly useful for long-term control of Canada thistle infestations. Newman and Gates (2006) have tried establishing stands from rhizome transplants, and we may be able to learn from their work.
4. **Techniques for sowing seed at stabilization sites:** Beaked panicgrass seed needs to be tested for compatibility with the practices typically used for sowing seed at roadside stabilization sites. Can it be hydroseeded? Can it be tracked into the slope with heavy machinery? Are nurse crops necessary? The Kentucky PMC has expressed concern that stratified beaked panicgrass seed might be damaged by mechanical sowing equipment, this concern requires field testing.
5. **Work with AOSCA:** Have seed tested by a certified Association of Official Seed Certifying Agencies laboratory and seed germination testing protocols proposed. The germination test results in this document will support their work. Once AOSCA has accepted the proposed testing protocols, the MDA will have access to the most appropriate testing protocols when testing locally native beaked panicgrass seed.
6. **Acquire economy of scale in production:** The authors, participating farmers, and the NPMC have learned much that can be applied to cost effective production of beaked panicgrass as a seed crop in small plots, but to acquire economy of scale and to meet projected demand requires large-scale production. Farm field establishment methods, weed control, mechanical harvest, mechanical seed cleaning, storage and marketing methods must be developed and published.
7. **Increase economy:** Develop the concept of cost per viable seed proposed by Ugiansky (2004). It is a common misconception that the most affordable seed is that which costs the least per pound. A pound of larger seeds contains fewer seeds than a pound of smaller seeds. If the germination rate and price per pound are the same, the larger seed will cost SHA 10 to 100 times more per seedling.

8. **Compatible herbicides:** A better understanding of herbicide compatibility could increase both the economy of seed production and the economy of seed use. Imazapic (Plateau) is a chemical that is often used to establish and maintain stands of native warm-season grasses, but it does cause some stunting of beaked panicgrass' close relative switchgrass (www.vmanswers.com/lib/productslist.aspx). Imazapic and other herbicides should be tested on beaked panicgrass.
9. **Consider contract growing:** To ensure the availability of large quantities of beaked panicgrass seed at known prices, SHA should consider a contract agreement with individual seed producers. The US Forest Service is willing to share a contract that may serve as a template.
10. **Establish seed transfer zones:** Second year harvests should be cleaned and weighed to detect any variations in seed yield caused by the distance between an accession's collection site and its production site. This data can be used to detect seed transfer zones for beaked panicgrass within Maryland, if they exist. For economy of scale we hope for the largest seed transfer zones possible. For the most effective soil stabilization, the best aesthetic quality, and to protect the environment, we do not want to recommend a larger seed transfer zone than is ecologically appropriate (Doede 2005).
11. **Certify and maintain the breeder blocks:** The value of the NPMC to this project cannot be overstated. It is they who will carry the agricultural aspects of the project into the future. They will continue to maintain the breeder blocks, they will make the seed from the breeder blocks available to interested farmers as "local ecotype releases", and they will support those farmers with the technical information they need to become successful producers. Additional collaborations of this nature are warranted if SHA is to secure genetically appropriate seed of the additional seven species recommended by the SAP for use on Maryland roadsides (see first report).
12. **Update or revise this report:** the report that you are reading now covers fieldwork from 2006 through 2008. Additional fieldwork with beaked panicgrass is ongoing, and this report will need to be updated or modified in the future.

7 Glossary

Several references were used in developing this glossary, but especially Davis *et al.* (2002), Smith and Halbrook (2004), and Ogle and Englert (2008).

Accession – Something added to a collection. In this paper it refers to a sample of seed collected from a wild parent population. It may also refer to the plants grown from that seed, since the two are genetically identical. In contrast, parent population refers to the group of plants at the wild location where the seed was collected.

Apomixis – Reproduction in which the ovary takes part, but there is no fertilization by the pollen grain. The plant produces a seed that is genetically identical to the mother plant.

Autogamy – Reproduction without contribution of male genes (pollen). Offspring are genetically identical to the mother plant.

Caryopsis – a type of fruit characterized by a dry outer layer attached to the single seed inside. This type of fruit is characteristic of many grasses and often referred to as a grain.

Clopyralid –A selective herbicide (3,6-dichloro-2-pyridinecarboxylic acid) used for control of broadleaf weeds, especially thistles and clovers. Trade names are Transline and Stinger.

CNI – Abbreviation for Chesapeake Natives, Inc. CNI is a 501(c)3 nonprofit organization that was founded in 2005. Both authors are affiliated with CNI.

Cotyledon –The seed-leaves of a plant embryo. These are very easily seen in bean seeds, they wither away as the first true leaves emerge. The number of cotyledons is used to divide the flowering plants into monocots (grasses, lilies, etc.) and dicots (beans, maples, etc.).

Culm – The aerial stem of a grass or sedge.

Cultivar – An assemblage of cultivated plants clearly distinguished by heritable (genetic) traits (morphological, physiological, cytological, chemical, other). USDA cultivars have been through replicated testing at multiple sites over two or more generations to prove and documents the heritability of these traits, the superiority and/or performance, and the range of adaptation.

cytotype -

Diploid – An organism with two copies of each chromosome, one from each parent. If you visualize the chromosomes in the nucleus as a collection of letters in the alphabet, mostly looking like distorted x's, y's and k's, a diploid organism has a full set of the letters normal for its species.

Genetic diversity –The total amount of genetic variation present in a population or species. Diversity allows individuals to react differently to external conditions. The classic example of the danger of a lack of genetic diversity to plant (and human) survival is the potato blight of the 1840s. All the potatoes responded the same way to the infection.

Germination – The initiation of the growth of a plant from a seed.

Glumes – The bracts that enclose the spikelet of a grass (often also applied to sedges). The glumes may enclose one or more flowers. Details of glume morphology are important in species identification. Glumes, lemma and palea are part of the chaf that are threshed out from grains of wheat and rice prior to consumption.

hexaploid - – having six fully paired sets of chromosomes.

Lemma – The outer, leaf-like bract of a grass-flower, and enclosing a single grass seed.

Host plant – A plant that hosts insects and other organisms, usually but not always larval insects (like caterpillars) that cannot feed on other types of plant tissue. The most famous example of a hostplant and its larval insect is probably the milkweed and the monarch butterfly caterpillar.

Multipot – Trademark product of the Ropak Corporation, a re-usable, deep plug tray made to grow seedlings for transplant into the field.

Native species – A plant that was present in a determined place prior to the arrival of humans. The determined place can be narrowly defined as the place under your feet with its peculiar ecotypical conditions (niche), or as widely as the entire continent.

Niche – The place an organism occupies in its habitat. The place is not merely a physical location, but also the place in the food web, and the place along environmental gradients (moisture, salinity, light, soils, etc.).

NPMC – The National Plant Materials Center, the lead Plant Materials Center of the USDA, NRCS located in the Beltsville Agricultural Research Center, Beltsville, Maryland.

NRCS – Abbreviation for the Natural Resources Conservation Service, one of 27 Agencies within the USDA. Prior to 1997 NRCS was known as the Soil Conservation Service.

octoploid – having eight fully paired sets of chromosomes.

Panicle – A compound flower head (inflorescence) containing a main stem and many branches, often plume-like or loosely pyramidal in outline. The flowers on one panicle do not all bloom at the same time. Both beaked panicgrass and gray goldenrod hold their flowers in panicles.

PMC – Abbreviation for USDA NRCS Plant Materials Center, usually follows a place name

Polyploidy – The condition of having more than two fully paired sets of chromosomes (c.f. alloploidy).

Population – A group of plants that can breed with each other, exchanging genetic information through the transfer of pollen or spores.

Parent population – In any field of science, a group of individuals from which a smaller sample is drawn. In our work, the group of individuals is a collection of wild plants at one location, and the sample is a seed collection.

Radicle – The first root to emerge from a seed, the embryonic root.

SHA – Maryland State Highway Administration.

Source-identified - Seeds or plants from a naturally growing population occupying a known or defined geographic area. No selection or testing of the parent population has been made. There is no performance or adaptation data available for the collection. Offspring is produced to ensure genetic purity and identity from rigidly defined natural stands, seed production areas, seed fields, or orchards.

spp. – Standard abbreviation for two or more species of a genus

ssp. – Standard abbreviation for subspecies

Stratification – A pre-treatment of seed, often to cold, moist conditions, that enhances germination rates, mimicking natural conditions.

Tetraploid – An organism with four copies of each chromosome. If you visualize the chromosomes in the nucleus as a collection of letters in the alphabet, mostly looking like

distorted x's and k's, a tetraploid organism has two full sets of the letters normal for its species. However, in some species, all the members are tetraploid.

var. – The botanical convention abbreviation of "variety", a taxonomic category subordinate to species. Variety can also have other meanings, even with respect to plants, depending upon the context.

USDA – United States Department of Agriculture.

8 References

Adamson, N. (2000). Establishing Native Grasses Along Maryland Roadways. Masters' Thesis. Dept. of Natural Resource Sciences and Landscape Architecture, University of Maryland, Maryland.

Anderson, R.C. & C. van Valkenburg (1977). Response of a southern Illinois grassland community to prescribed burning. *Transactions of the Illinois Academy of Science* **64**: 287-291.

Aubry, C., R. Shoal & V. Erickson (2005). Grass Cultivars: Their origins, development, and use on national forests and grasslands in the Pacific Northwest. USDA Forest Service.

Belt, S.V. & J.M. Englert (2008). Improved Conservation Plant Materials Released by NRCS and Cooperators Through December 2007. USDA Natural Resources Conservation Service, National Plant Materials Center.

Britton, N.L. & A. Brown (1913). *An illustrated flora of the northern United States, Canada and the British Possessions*. Vol. 1-3 (artwork downloaded from USDA NRCS PLANTS Database, www.plants.usda.gov).

Brown, M.L. & R.G. Brown (1984). *Herbaceous Plants of Maryland*. Port City Press, Inc., Baltimore, Maryland. 1127pp.

Booze-Daniels, J., D.R. Chalmers & R.E. Schmidt (1998). Native Grasses on the Roadsides of Virginia - A Review of Literature. A Report to Virginia Department of Transportation submitted by Department of Crop, Soil and Environmental Science, Virginia Polytechnic Institute and State University.

Casler, M. D., K. P. Vogel, C. M. Taliaferro, and R. L. Wynia. 2004. Latitudinal adaptation of switchgrass populations. Crop Science 44:293-303.

Coffeeville Plant Materials Center (1990). Initial Evaluation of Beaked Panicum (1984-1988). Technical Notes No. 1. United States Dept. of Agriculture.

Davis, K.M., J.M. Englert & J.L. Kujawski (2002). Improved Conservation Plant Materials Released by NRCS and Cooperators Through September 2002. USDA NRCS National Plant Materials Center. www.plant-materials.nrcs.usda.gov/mdpmc/publications.html

Deno, N.C. (1993). *Seed Germination Theory and Practice*. 2nd Edition. Published by the author: 139 Lenore Dr., State College Pennsylvania 16801

Ferdinandez, Y.S.N., B.E. Coulman & Y.-B. Fu (2005). Detecting Genetic Changes over Two Generations of Seed Increase in an Awned Slender Wheatgrass Population Using AFLP Markers. *Crop Science* **45**: 1064–1068.

Freckmann, R.W. & M.G. Lelong (2003) as revised by Mary Barkworth (2007). *Panicum. In*: Flora of North America Editorial Committee (Eds). *Flora of North America North of Mexico* Vol. 25 Magnoliophyta: Commelinidae (in part) Poaceae, part 2. Oxford University Press, New York. 41 pp. www.herbarium.usu.edu/webmanual (accessed 7/01/09).

Grabowski, Janet, B. Baldwin and P. Meints. 2004. Selecting for Improved Seedling Establishment in Beaked Panicum. *Jamie L. Whitten Plant Materials Center 2004 Annual Technical Report.* p.16-17.

Gustafson, D.J., D.J. Gibson & D.L. Nickrent (2004). Conservation genetics of two codominant grass species in an endangered grassland ecosystem. *Journal of Applied Ecology* **41**: 389-397.

Helms, K.R. & S.B. Vinson (2000). New host records for the "legless" mealybugs of Texas. *Southwestern Entomologist Scientific Note* **25**(3): 229-231.

Jackling, S. (2004). Clopyralid, monoethanolamine NYS DEC Letter – New Pesticide Product Registration 4/04. www.pmep.cce.cornell.edu/profiles/herb-growthreg/cacodylic-cymoxanil/clopyralid_mono_salt/clopyralid_let_404.html (accessed 8/28/09).

Jenkins, A.M., D.R. Gordon, M.T. Renda (2004). Native alternatives for non-native turfgrasses in central Florida: germination and responses to cultural treatments. *Restoration Ecology* **12**(2): 190-199.

Kujawski, J. & K.M. Davis (2001). Propagation protocol for production of container *Panicum anceps* plants; USDA NRCS - Beltsville National Plant Materials Center, Beltsville, Maryland. *In*: Native Plant Network. www.nativeplantnetwork.org (accessed 7/13/2009).

Latham, R. (2006). Native Grasslands and Meadows in Pennsylvania. *In*: M. Sanderson (Ed.). Proceedings of the 5th Eastern Native Grass Symposium. Omni Press, Wisconsin.

Linhart, Yan B. (1995). Restoration, revegetation, and the importance of genetic and evolutionary perspectives. In *Proceedings: Wildland Shrub and Arid Land Restoration Symposium 1993*. US Forest Service General Technical Report INT-GTR-315. Roundy, B., D. MacArthur, E. Durrant, J. Haley and D. Mann, eds.

Lee, A., P.E.Gatterdam, T.Y. Chiu, N.M. Mallipudi & R. Fiala (1991). Chapter 11: Plant metabolism. *In*: Shaner D.L. & S.L. O'Connor (Eds.). *The Imidazolinone Herbicides*. CRC Press. Boca Raton, Florida. 290 pp. [as cited in Weed Control Methods Handbook, The Nature Conservancy, Tu *et al.* at] www.invasive.org/gist/products/handbook/17.Imazapyr.pdf (accessed 7/20/09).

Mack, R.N. (1991). The commercial seed trade: An early disperser of weeds. *Economic Botany* 45: 257-273.

Maryland State Highway Administration (2003). Integrated Vegetation Management Manual for Maryland Highways.Maryland Dept. of Transportation. 144 pp.

Mathews, Andrew (1947). Observations on methods of increasing the germination of Panicum anceps Michx. and Paspalum notatum Flugge. Journal of the American Society of Agronomy 39(5):439-442.

Metzger, J. 1995. Maryland Native Plants: A Master Checklist. www.mdflora.org/publications/mdchecklist.pdf

Miller, J.H., & K.V. Miller (1999). Forest plants of the southeast and their wildlife uses. *Southern Weed Science Society*.

Moore, A. (2009). Map of the Major Land Resource Areas of Maryland. Prepared for this report by the State Soil Scientist, USDA Natural Resources Conservation Service.

Munda, B. and S. Smith (1995). Genetic variation and revegetation strategies for desert rangeland ecosystems. US Forest Service General Technical Report INT-GTR-315. Roundy, B., D. MacArthur, E. Durrant, J. Haley and D. Mann, eds.

Newman, S.D. & M. Gates (2006). Plant Guide: Beaked Panicgrass. USDA NRCS Louisiana State Office, National Plant Data Center, & the Grazing Land Conservation Initiative-South Central Region.

Parrish, J. & R.G. Steinman (2003+). Native Plants of Sligo. Available through the Friends of Sligo Creek at www.fosc.org/PlantInventory.htm (accessed 08/2009).

Rogers, D. and A. Montalvo (2004). Genetically appropriate choices for plant materials to maintain biological diversity. University of California. Report to the USDA Forest Service, Rocky Mountain Region, Lakewood, CO. Online: http://www.fs.fed.us/r2/publications/botany/plantgenetics.pdf

Scott, J.A. (1986). The Butterflies of North America: A Natural History and Field Guide. Stanford University Press, Stanford, California.

Shetler, S. & S.S. Orli (2002). *Annotated Checklist of the Vascular Plants of the Washington-Baltimore Area. Part II Monocotyledons*. Dept. of Botany, National Museum of Natural History, Smithsonian Institution, Washington, D.C. 95 pp.

Slattery, B.E., K. Reshetiloff & S.M. Zwicker (2003). *Native Plants for Wildlife Habitat and Conservation Landscaping: Chesapeake Bay Watershed*. U.S. Fish & Wildlife Service, Chesapeake Bay Field Office, Annapolis, Maryland. 82 pp.

Smith, C. (2008). *Invasive Exotic Plants of North Carolina*. North Carolina Dept. of Transportation. www.se-eppc.org/northcarolina/NCDOT_Invasive_Exotic_Plants.pdf (accessed 8/27/09).

Smith, S.E. and K. Halbrook (2004). A plant genetics primer. *Native Plants Journal* 2004 (Fall): 106-111.

Texas A&M and Grazingland Management Systems, Inc. (2008). Land-based water conservation & water Yield Practices in Region L: Influence of Land Based Conservation Practices on Water Yield. A report submitted to Region L South Central Texas Regional Water Planning Group. 56 pp. earip.tamu.edu/OtherMeetings/Jun0208/Region%20L-influence%20of%20land%20based%20conservation%20practices%20on%20water%20yield-2.1.08.pdf (accessed 7/03/09).

Ugiansky, R.J. (2004). Final Report: Development of Sustainable Native Wildflower Meadows for Highway Roadsides. USDA-NRCS National Plant Materials Center, Beltsville MD, 39pp.

USDA NRCS (2006+). The PLANTS database. National Plant Data Center, Baton Rouge, LA 70874-4490 USA. Baton Rouge (LA). www.plants.usda.gov (accessed 2006 through 2009).

USDA NRCS National Plant Materials Program (2006). Plant Fact Sheet: Switchgrass.

Appendix 1: Wild Collection Location Data

NPMC Propagation #	NRCS Accession #	Town	County	Site Description	# plants in pop.	# plants collected	N Latitude	W Longitude
1	9106024	Accokeek	Prince George's	Beretta Telephone Line	6	6	38.692	-76.655
2	9106025	Denton	Caroline	Sand Hill Road	20	—	38.768	-75.706
3	9106026	Thurmont	Frederick	Rt 15 CF State Park Entrance	5	5	38.292	-77.071
4	9106027	Potomac	Montgomery	Potomac Power Line	100	50	39.067	-77.479
5	9106028	Berlin	Worcester	Rt 376 Telephone Line	30	30	38.292	-77.434
6	9106029	Assateague	Worcester	Rt 611 Telephone Line	10	10	38.260	-77.399
7	9106030	Indian Head	Charles	Kabin on the Korner	100	50	38.630	-77.500
8	9106031	Harmon	Frederick	Gambrill Park Rd	47	47	39.543	-77.227
9	9106032	Parkton	Baltimore	Parkton Verizon Power Line	20	20	39.629	-77.391
10	9106033	Thurmont	Frederick	Catoctin Hollow/Mink Farm Rd	3	3	39.601	-76.989
11	9106034	Poolesville	Montgomery	River Road	25	25	39.084	-75.163
12	9106035	Hansonville	Frederick	Rt 15 1/4mi N of Cemetery Dr.	25	25	39.499	-75.156

Martin O'Malley, *Governor*
Anthony G. Brown, *Lt.*

Maryland Department of Transportation
State Highway Administration

Beverley K. Swaim-Staley, *Secretary*

STATE HIGHWAY ADMINISTRATION

RESEARCH REPORT

DEVELOPMENT OF NATIVE SEED FOR SHA PROJECTS: 4. GRAY GOLDENROD

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Project Number MD-2009-SP608B4K
FINAL REPORTS
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The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Maryland State Highway Administration. This report does not constitute a standard, specification, or regulation.

Technical Report Documentation Page

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Chesapeake Natives, Inc. 326 Boyd Avenue, #3 Takoma Park, MD, 20912	LEAVE BLANK
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Maryland State Highway Administration Office of Policy & Research 707 North Calvert Street Baltimore MD 21202	Final Report
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Our goal is to make locally native seed more affordable and more available to SHA. This report covers the work we have done from 2006 through 2008 with the promising candidate species, gray goldenrod. We begin with a review of the 15 Attributes. Gray goldenrod is a short, showy, perennial, drought tolerant flower. It has fibrous roots and grows well in many soil types. It is semi-evergreen, and may tolerate some salt spray. It will be damaged if mowed annually in June, as per the SHA guidelines for wildflower meadows. It does not attract wildlife that would present a traffic hazard. A weedy, aggressive subspecies occupies all territory west of the Appalachian Mountains, making it imperative that SHA limit itself to the purchase of locally native, certified, source-identified seed. Gray goldenrod is found in every geologic province of our state, and was once a common wildflower here. We discuss our work locating and wild collecting genetically diverse seed from 12 Maryland populations. We learn that gray goldenrod's germination biology ensures its persistence in the wild, and should make it ideal for roadside use. We discuss our work establishing breeder blocks at the NPMC, and working with two local farmers to establish production fields. We spend some time discussing agricultural methods because they have future application to roadside establishment and maintenance practices. The seed production method employed as part of this project will yield millions of goldenrod seeds per year from small numbers of plants growing in weed mat. The method requires no chemical input, and very limited hand weeding. It is a promising avenue for reliable and affordable production. Approximately half of the plants did not bloom in their first year, the 2008 field season. The plants that did bloom produced approximately 350,00 seeds (1.1 lb). Seed set will be considerably higher in 2009. It appears that gray goldenrod will become a valuable and affordable component of future soil stabilization mixes along Maryland highways.

17. Key Words	18. Distribution Statement: No restrictions
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Executive Summary

This report summarizes the work that we did with gray goldenrod from 2006 through 2008. Fieldwork continues into the 2009 season and beyond, and that work will be summarized in subsequent updates/revisions.

We begin this report by using the 15 Attributes process, described in the first report of this series, with respect to gray goldenrod. Gray goldenrod is a short, showy, perennial wildflower that is drought tolerant. It has a fibrous root system and grows well in a wide range of soil types. Semi-evergreen basal foliage provides some soil cover in winter. Gray goldenrod will tolerate infrequent mowing, and possibly some salt spray. It does not attract wildlife that would present a traffic hazard.

Recent research on gray goldenrod has shown that there are distinct eastern and western varieties in North America. The western variety is an aggressive tetraploid, strongly rhizomatous, and widely regarded as an agricultural weed. Care should be taken that SHA does not inadvertently purchase any gray goldenrod of western origin. If SHA restricts its purchasing to certified, source-identified seed from Maryland, accidental purchase of western seed will not be an issue.

Gray goldenrod seeds have dormancy mechanisms that allow them to accumulate in a soil seed bank. Seed banks ensure the persistence of the species at wild sites, and should perform a similar service in roadside plantings. In general, gray goldenrod seeds germinate well and quickly under a variety of conditions, in spring, summer and fall. By understanding the goldenrod's dormancy mechanisms, roadside vegetation managers can manipulate the seed to provide rapid and nearly complete germination, or manipulate it so that the seeds germinate over a more extended period of time.

In the fall of 2006, we located 12 wild populations of gray goldenrod throughout Maryland's Coastal Plain and Piedmont geologic provinces. Seed was wild collected and informal germination tests were conducted to confirm results already reported in the literature. We have established twelve breeder blocks at the National Plant Materials Center using plugs produced from the germination tests. Production blocks were also established at two private farms, one in the Coastal Plain east of the Bay, and one in the Piedmont.

Lessons learned in farm field planning and establishment, crop maintenance and harvest will have direct application to future work in roadside establishment, roadside maintenance, and stabilization project success, so they are reported here. Approximately half of the plants did not bloom in their first year, the 2008 field season. The plants that did bloom produced 1.1 pounds of seed. Seed set is expected to be considerably higher in 2009.

It appears likely that gray goldenrod will become a valuable and affordable component of future soil stabilization mixes along Maryland highways.

1 Introduction

In CNIs project work plan, we described four project phases. The first was the Species Selection Phase, followed by the Wild Collection Phase, both conducted in 2006. These phases were described in the first report of this four-report series.

Gray goldenrod is one of the first species to be recommended by the Species Advisory Panel for roadside use, to compare favorably when reviewed against the 15 Attributes, and to be advanced to field production trials. In this report, the fourth in the series Development of Native Seed for SHA Projects, we will discuss the Germination Phase and Production Trial Phase of our work with gray goldenrod, conducted in 2007 and 2008. We will begin with a review of the literature. The review will be organized according to the Attributes List, a list developed by the SAP to provide guidance on all the issues that should be evaluated when considering a species for use in roadside soil stabilization. Where the authors have capitalized the word Attribute, the reader will know they are referring specifically to the Attributes developed by the SAP. The SAP and the Attributes List are discussed in detail in the first report.

2 Attributes Review of Gray Goldenrod

In this section we introduce gray goldenrod (*Solidago nemoralis* Aiton) by reviewing it with respect to the Attributes List (see first report in this series). This section is useful as a summary of the state of our knowledge regarding the species.

1 and 2: Range, Distribution and Abundance

A. State Native: To determine whether gray goldenrod is native, we consulted these references:

i. **Shetler and Orli (2000)** list the plant as native in DC, MD and VA.

ii. **Brown and Brown (1984)** do not indicate whether the plant is native or escaped.

iii. **Metzger (1995)** also lists the plant as native and refers to it as oldfield goldenrod.

iv. **State Rarity:** Thirteen species of goldenrods are included on the Rare, Threatened and Endangered Plants of Maryland list (Maryland Dept. Natural Resources 2007). Gray goldenrod is not one of them and is not synonymous with any of the plants listed.

B. State Abundance & D. Habitats

i. **Brown and Brown (1984)** describe gray goldenrod as occurring in poor, dry soils, in fields or open woods throughout Maryland.

ii. **Plant Lists on MNPS Website:** gray goldenrod is listed as occurring in dry fields of the Sligo Creek watershed, Montgomery County (Parrish & Steinman 2003+) but not at some other dry, sunny sites where one might expect to find it, including Buck Lodge in Prince George's County, Jug Bay in Anne Arundel County, and Bear Island in the C&O Canal National Historical Park. (www.mdflora.org/survey_data)

iii. **Author's Observations:** In our work for this project, we found it in the Piedmont as well as in the Coastal Plain on both sides of the Chesapeake Bay, in dry fields under utility lines and road banks, in full sun or light shade.

iv. **Norton Brown Herbarium:** Unfortunately the facility is temporarily closed due to lack of funding.

v. **Smithsonian national Museum of Natural History herbarium:** As of January 1, 2010, there were 46 records of gray goldenrod occurring in Maryland. All records were from the coastal plain west of the bay, or the Piedmont region. (http://collections.memnah.si.edu)

C. National/International:

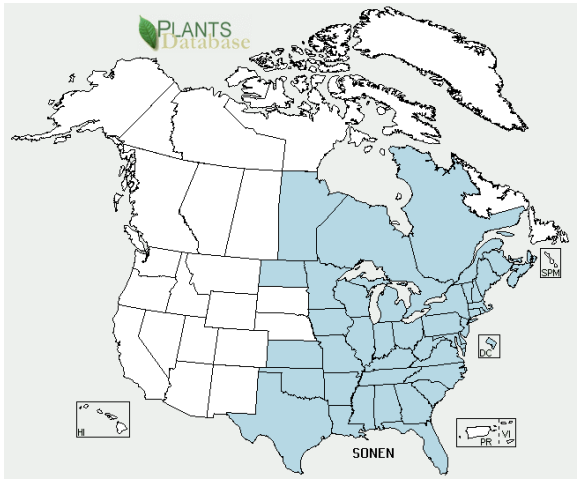
i. **PLANTS Database:** Gray goldenrod is native over much of the United States and Canada (**Figure 1**, USDA NRCS 2006+).

ii. **EMPPO**: European/Mediterranean highway departments seeking new plant species for roadside stabilization are reportedly planning to include gray goldenrod because of its beauty and ability to spread in poor, disturbed soils. Removed from its natural range, it will be freed of all the insects and diseases that have adapted to it here, and that increases its potential for invasiveness. For these reasons, the European and Mediterranean Plant Protection Organization (2004) issued a quarantine (www.eppo.org/QUARANTINE/Alert_List/invasive_plants/SOONE.htm, accessed 6/01/09). As for the North American distribution of the plant, EMPPO reports that it occurs in prairies (black soils, gravel, sand), dry sandy fields, sandy roadsides, railroads, dunes, oak savannas, eroded clay banks, and abandoned fields.

iii. **Plant Fact Sheet:** Belt (2009) describes gray goldenrod habitats as meadows, dry open woods, upland prairies, pastures, savannas, fallow fields, thickets, roadsides, railroads, eroded slopes, and sand dunes.

iv. **Literature:** Keever (1979) discusses gray goldenrod as one of the most prominent successional species in abandoned farm fields of Lancaster County, Pennsylvania. Chmielewski and Semple (2004) and literature cited therein describe the conditions for a range of habitats where gray goldenrod is found. Soils are generally reported as nutrient poor but one author reported a humus rich soil. Textures range from gravelly sands, sands, silts and clays. Walck *et al.* (1997a) describe gray goldenrod as occurring in both stable and successional habitats.

Solidago nemoralis var. *longipetiolata*



Solidago nemoralis var.*nemoralis*

Figure 1: Native range of gray goldenrod.

The left map shows that the range of var. longipetiolata [now=ssp. *decemflora*] is wide across southern Canada, from British Columbia on the west coast to Ontario around the Great Lakes. In the United States, var. *longipetiolata* [=ssp. *decemflora*] is native between the Rockies and the Mississippi River, and as far south as Texas. The right map shows that the range of spp. *nemoralis* is limited to the eastern half of North America, roughly east of a line from Manitoba to Texas. Neither variety is found in the circumpolar provinces. Maps from Plants Database (USDA 2006+).

3: Taxonomy, Ecology, and Genetics

Gray goldenrod is an herbaceous perennial plant that blooms in late summer and fall. It is called "gray" because many, short, stiff hairs give the stems and foliage a powdery blue cast. Basal leaves are larger than stem leaves, and they broaden and become toothed toward the distal end. Each individual ramet (division in common gardening terminology) sends up its own flowering stem. Bud formation and flowering is triggered by shortening of daylight hours (Allard & Garner 1940). As bloom time begins in July, gray goldenrod reaches it's maximum height of two to three feet. Gross and Werner (1983) report that on the same plant, these stems flower throughout the season, rather than all at the same time.[1] Flowering heads are plume-like and large relative to the short plants (**Figure 2**). As winter progresses, the seeds blow away and the flowering stems senesce, but the plants maintain their semi-evergreen basal foliage. The buds that will form next year's growth, lie just below the soil surface.

We refer to *Solidago nemoralis* as gray goldenrod, but it has many alternate common names: compass goldenrod[2], dwarf goldenrod, Dyer's weed, field or old-field goldenrod, gray-stemmed goldenrod, showy goldenrod, verge d'or des bois and wild quinine (Chmielewski & Semple 2004, and literature cited therein; Metzger 1995; Shetler & Orli 2000).

Although Chmielewski and Semple (2004) indicate that cultivars are available, a Google search did not reveal any available for sale in June 2009. The USDA Plant Materials Fact Sheet does not mention any cultivars. Unfortunately, however, people are selling and trading gray goldenrod outside its native range (see for examples www.calfloranursery.com/pages_plants/pages_s/solnem.html and www.uk.gardenweb.com/forums/load/exchange/msg0118165226886.html). For a plant that can produce up to 5,000 fertile, wind-borne seed per stem per year, that's a certain invitation to ecological trouble.

Taxonomy of the goldenrods was updated in 2006 (Semple and Cook), and the Flora of North America was revised accordingly. We will follow their nomenclature in this report. The PLANTS database does not yet reflect these changes.

Sampling 218 populations of gray goldenrod across North America, Brammall and Semple (1990) discovered that gray goldenrod has eastern and western races . Populations west of the Appalachians (*Solidago nemoralis* ssp. *decemflora* (DC.) Brammall ex Semple) are tetraploid (2n=36) whereas populations to the east (*S. nemoralis* ssp. *nemoralis*) are predominantly diploid (2n=18). *Solidago nemoralis* ssp. *nemoralis*, where it is sympatric with *S. nemoralis* ssp. *decemflora*, west of the Appalachians are usually tetraploid. It is speculated that the two subspecies descended from three ancestral populations in the Texas/Mexico vicinity. These expanded northward as glaciers retreated at the end of the Wisconsin Glaciation, about 25,000 Y.B.P. Although considered the same species, the western race is adapted to coexist with the prairie flora, and the eastern race is adapted to coexist with the eastern forests (Chmielewski & Semple 2004). A detailed map of the geographic limits of the races and a taxonomic key based on features observable in the field are provided in Semple *et al.* (1990).

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[1] We don't think we are seeing this in the farm rows, although Gross and Werner weren't working in farm rows.

[2] Literature cited in Chmielewski and Semple (2004) indicates that bent flower heads point north (Jaeger 1964).

What implications does all this genetic information have for the use of gray goldenrod seeds on Maryland highways? McKay *et al.* (2005) caution against introducing genotypes with ploidy levels different from those of the local populations. Husband and Sabara (2003), for example, found that crossing between the diploid and tetraploid forms of fireweed was prevented by various factors, including geographic distance, and bringing them back together would have evolutionary consequences. Introduction of the tetraploid race of gray goldenrod into our area should be avoided.

Figure 2: Appearance of whole plants.

This photograph was taken in August of 2009 at the White family farm. It shows two people discussing weed removal at the White family farm. At left is student intern Wenji Li, who weighed many of the samples for this project. At right is the primary author. In the foreground is a row of gray goldenrods in full bloom, they reach just above the knees of the people standing behind them. Gray goldenrod is a short plant with large, composite flowering heads.

As SHA or its contractors bid for the purchase of gray goldenrod seed, the more local the seed source the better. However, the use of seed from vendors west of the Appalachians should be specifically excluded. Most consumers are unaware that seed vendors regularly exchange seed amongst themselves so that they can fill customer orders. When ordering seed, even from eastern vendors, it is necessary to ask for certification of the provenance to ensure that the western race is not the one being sold.

Gray goldenrod, like many goldenrods, is self-incompatible, and requires an insect to transfer pollen among individuals if successful seed set is to occur. A discussion of the diversity of pollinators that visit gray goldenrod is included in the review of the Interactions with Wildlife Attribute, below.

Chmielewski and Semple (2004) indicate that the nature of the plumes and hairs on the windborne seed varies from one population to another. These hairs provide the seed their loft and determine how widely offspring may be dispersed. These differences are probably evolutionary adaptations to local habitat (Werner 1976).

A number of authors recognize that gray goldenrod is an important component of two types of plant community: mature prairie and old field (for example Werner 1976; Chmielewski & Semple 2004). The importance for roadsides is that the mature prairie is a stable ecosystem (similar to the concept of the climax forest), where as the old field is a successional phase, a result of the disturbance of some pre-existing ecosystem. It bodes well for the performance of gray goldenrod on our roadsides that it can tolerate disturbance and it can persist over the long haul. Werner (1976) has observed individual goldenrods more than 50 years old in her field studies.

4: Special Site Conditions or Abilities

The authors are familiar with gray goldenrod performance in natural meadows, planted meadows, and formal gardens. In all settings we have found the species to be highly drought

tolerant. Gray goldenrod sown on a slope in the fall of 2001 germinated beautifully during the drought of 2002 (**Figure 3**). Gray goldenrods occupy the driest position on the soil moisture gradient among all the common species of goldenrods found in old fields and prairies. Werner (1976) describes the specific physical adaptations that gray goldenrod has when compared with other goldenrods that allow it to compete and succeed in dry soils.

5: Germination and Sowing Requirements

The literature on gray goldenrod germination is extensive. Hetrick *et al.* (1992) report that gray goldenrod established on sterile soil cannot obtain adequate phosphorous without either mycorrhizal inoculation or fertilizer amendment. This would be a concern for stabilization projects, which often occur on cut slopes – sterile soils as opposed to topsoils rich with soil organisms. However, we have sown gray goldenrod and planted it on bare subsoils (cut slopes) with considerable success in both Germantown and College Park, Maryland. Perhaps the tires on the equipment used to cut the slope or sow the seed, or even the soles of workers' shoes, transmitted enough of the mycorrhizal organisms to colonize the planting sites.

Authors in New Jersey and Kentucky have noted that seed dispersed in the fall generally germinates the following spring, with some seed remaining in the soil seed bank to germinate the following fall, and even the spring following that (Beimborn 1973; Walck *et al.* 1997). Fresh seed will not germinate at the temperatures that normally prevail in the fall until they have been through cold stratification, then they will germinate at those same temperatures in spring. However, unusually warm weather in fall will cause fresh seed to germinate. As you will read later, our own results support the observations of these authors (page 7).

In studies of old fields in New Jersey, Beimborn (1973) observed that gray goldenrod seedlings appear in both spring and fall. This concurs with our own observations, made while maintaining educational gardens and farm fields that feature gray goldenrod. The seed biology behind this fall/spring germination pattern was examined in a series of extensive experiments by Walck *et al.* (1997a, b, c, d, and e, 1998). The authors weren't actually interested in gray goldenrod *per se*. They were trying to understand how seed germination biology might contribute to the rarity of the federally endangered Short's goldenrod (*Solidago shortii* Torr. & Gray), a species that can only be found along the Kentucky-Indiana border. Gray goldenrod and tall goldenrod (*S. altissima* L.)[3] were chosen because they are common species with wide geographic distributions whose seed germination attributes could be used for comparison with Short's goldenrod. Even though their work was conducted with a different objective, it yields a wealth of information relevant to soil stabilization applications.

They found that light, temperature, and year of wild collection all impacted germination in gray goldenrod, and that these factors interacted with each other. For example, light did not affect germination in seed collected one year the same way it affected seed collected another year.

Exposure to light increases seed germination rates in gray goldenrod. Light may strike the seed either during stratification (as a seed on the surface of the soil in winter) or during incubation (the warm moist period that encourages germination, as a seed on the surface of the soil in

[3]The PLANTS website (7/1/09) common name for tall goldenrod is Canada goldenrod, but to local readers that would indicate the similar *S. canadensis*. With recent reclassification the lines between *S. altissima* and *S. canadensis* blurred. For this paper, we are using the common name tall goldenrod for *S. altissima*, as given in Brown and Brown (1984).

spring), or both (Walck *et al.* 1997b, c). The benefit of exposure of seed to light was also found for the other common goldenrod in their study, tall goldenrod. The authors conclude that factors that restrict germination under certain conditions, such as this light requirement, allow the common goldenrods to build a seed bank, and this seed bank assures their long-term survival and wide distribution. Walck *et al.* found that buried, ungerminated seeds were still viable at the end of the 34.5-month study period (1997b). So there's excellent potential for the goldenrods to build a seed bank that will ensure the survival of their population through hard times that eliminate all the plants above ground. In contrast, the rare goldenrod's seeds germinate in the dark, and while this may or may not result in more plants for that moment, their seed bank is diminished by this near-constant germination.

Beimborn (1973) also noticed that gray goldenrod seedlings appeared in the field after extended summer rains. Walck *et al.* (1997b) conducted experiments that show that mature gray goldenrod seed is "conditionally dormant" when it is released from the parent plant. However, a very warm autumn is one "condition" that will break the dormancy. If that does not occur, cold winter weather induces dormancy that is not broken until several more weeks of cold have passed and spring conditions occur. Percent germination (in spring) increases with the duration of the cold period, up to 12 weeks, and the presence of light; seeds near the soil surface are more likely to germinate than seeds that are buried. Seeds that do not germinate that spring become dormant again. Brief periods of wetting and drying (recurring cycles of 1 or 2 wet days alternating with 5 dry days) typical of Kentucky summers will not induce germination in gray goldenrod or tall goldenrod, but do for the rare goldenrod. Extended periods of wet weather (3 to 5 wet days to 5 dry days) were needed break summer dormancy for the common goldenrods. The authors conclude that a tendency to germinate after short rains, when the soil is more likely to dry up quickly in the summer heat, may be one of the reasons Short's goldenrod is the rarest of these three species.

Figure 3: Special abilities: establishment during a drought.

This landscape photograph shows a roadside slope covered with goldenrod in bloom. Gray goldenrod seed germinated well on Rt. 118, Germantown, despite the drought of 2002.

Of the three species, gray goldenrod germination rates were most diminished (down to 35%) when trying to germinate in (conditions simulating) light filtered through the leaves of other plants (Walck *et al.* 1997c).

6 & 7: Speed of Growth & Height

Germination is rapid and followed by first year development of basal rosette and root system. Some plants flower the first year. As bloom time begins in July, gray goldenrod reaches it's maximum height, which on roadsides and in natural meadows is typically two feet or less. In formal gardens or rich soils, it can reach over three feet.

8: Winter Cover

Both the senescent flower stems and the semi-evergreen basal foliage provide cover of soil in winter (**Figure 4**).

Figure 4: Winter cover and root structure.

This photograph shows a gray goldenrod plant being dug from the field. Basal foliage rosette is green and full. Root mat is fibrous and large.

9: Root Structure

While most goldenrods are rhizomatous, gray goldenrod is one of the few exceptions. Werner (1976) discussed this as one of gray goldenrod's adaptations to life in dry soil. Gray goldenrod has a fibrous root structure. Stout rhizomes, to the minimal degree they are present, form short extensions that lead to new basal rosettes crowded around the mother plant. These rosettes give rise to the next year's flowering stems. In her published study on field ecology, Werner (1976) suggested that the relative lack of rhizome activity relative to other goldenrod species is an adaptation to dry habitat, where an increase in vegetative growth would cause more demand for water than the soil could provide.

10: Wildlife Interactions and Appropriateness for Roadside Use

In our experience, large animals are not attracted to the plants. Many gardening websites concur, indicating that goldenrods are resistant to herbivory from deer, rabbits and other mammals. However, Miller and Miller (1999) have noted that white-tailed deer, eastern cottontail, ruffed grouse, and wild turkey will all consume a minor amount of the semi-evergreen basal foliage in the winter. Additionally, Miller and Miller note the seeds are a minor component of the diet of some songbirds, especially the American goldfinch. We suspect that they may have been referring to the western variety, for we have never seen gold finches eating the seed here in Maryland. We frequently observe secretive, ground-dwelling sparrows hiding in the foliage, and consuming seeds in the fall.

Chmielewski and Semple (2004) review several articles on the use of gray goldenrod as a host plant by small insects. Twelve species of aphids in Canada and Michigan are known to use gray goldenrod as their food plant, and of these, three will accept only gray goldenrod at certain times of year. Two species of fly use gray goldenrod as a host plant for their leaf-mining larvae. Three species of grasshopper have been studied for their herbivory on gray goldenrod. If the reader has any difficulty conjuring excitement for the conservation of such small and sometimes homely plant-eaters, it may help to remember that these insects ultimately feed our songbirds. For example, Shealer *et al.* (1999) note that gray squirrels and woodpeckers break open the rounded stem galls of goldenrods to extract the larvae of flies and wasps that formed them. The insect larvae are an important winter food source.

In the Lepidoptera, the caterpillars of the goldenrod casebearer moth consume gray goldenrod flowers, reducing seed set an average of 5.4% (Gross & Werner 1983). Goldenrods are also host plants for streamside and eastern checkerspot butterflies (Scott 1986).

Despite these records of occasional browsing and host plant use, in thirteen years of growing gray goldenrod in demonstration gardens and observing it in the wild, the authors have only ever seen one caterpillar (yellowstriped armyworm, *Spodoptera ornithogalli*) actually consuming leaf tissue. This infrequency may be due to rich concentrations of chemical compounds found in goldenrods, especially diterpenes, which are known to have anti-feedant and allelopathic properties (Cooper-Driver 1987). The locust-borer beetle is the most abundant herbivore to visit gray goldenrods in our area (Figure 5). It spends late summer grazing on goldenrod blossoms before laying its eggs in black locust trees. The black locust is an example of a North American native species that was intentionally introduced to parts of North America beyond its natural range. It is now spreading uncontrollably (refer back to the discussion of Booze-Daniels *et al.* (1998) criteria for highway plant selection, in the first report of this series).

Figure 5: The types of animals that visit gray goldenrod do not present a traffic hazard.

Close-up shows a black and orange/red beetle with very long antennae crawling through goldenrod blossoms. The locust borer beetle is typical of insects that visit gray goldenrod.

What we have observed is a fair amount of pollinator activity: flies, smaller bees, wasps, smaller butterflies and moths. Gross and Werner (1983) found that seed set in gray goldenrod, especially in the early flowering ramets, is limited by competition for pollinators, and many of the pollinator visits were going to summer blooming alien weeds. It is possible that this is a factor in what appears to be the regional decline in gray goldenrod populations (as evidence by the fact that we were only able to locate twelve populations of this supposedly very common native plant). They found that gray goldenrod is pollinated by a diversity of insects, but is a particular favorite of the honeybee (*Apis mellifera*). Other frequent visitors are small native bees (*Ceratina* spp. and *Halictus* spp.), wasps (*Polistes* spp.) and soldier beetles, especially the epinonymous goldenrod beetle (*Chauliognathus pensylvanicus*).

Belt (2009) also reports a diversity of pollinators, "A wide range of insects visit the flowers for pollen and nectar, including long-tongued bees, short-tongued bees, Sphecid and Vespid wasps, flies, butterflies, moths and beetles. Bee pollinators include honeybees, Little Carpenter bees, Halictid bees and Plasterer bees. Fly pollinators include Syrphid flies, Tachinid flies, Flesh flies, Blow flies and Muscid flies. The caterpillars of many moths, including the goldenrod scarlet plant bug, net-veined beetle and leaf-footed bug, feed on the foliage and other parts of this plant."

11: Aesthetics

Chiemelewski and Semple (2004) indicate that gray goldenrod is used in rock gardens, and that several cultivars are available. In a project to maximize aesthetic value of Nebraska roadsides, Salac *et al.* (1973) selected gray goldenrod as one of only three species to test for optimal mowing regimens.

Gross and Werner (1983) note that each plant has a number of flowering stems that bloom at different times, with some ramets sending up flowers in early summer, then continuously through the goldenrod season until early frosts terminate activity for the year. Gray goldenrod has a very long bloom season that will benefit roadside aesthetics.

12: Mowing Requirements & Tolerances

The experience of the authors comes from two cut slopes. The first of these is the aforementioned slope on Route 118 in Germantown Maryland. Gray goldenrod was one type of seed included in the meadow mix sown in the fall of 2001 (**Figure 3**). Half of the meadow is mowed during the dormant season every other year. Therefore every gray goldenrod in the meadow is mowed every two years. The survival rate is high and gray goldenrod remains an important component of the Rt. 118 meadow in 2009.

The second of these is a steep slope cut into terrace gravel deposits behind the University of Maryland's Research Greenhouse Complex. Gray goldenrod was plugged into the slope during the summer of 2005. Irrigation was supplied. The slope is never mode. Woody plants are controlled through spot applications of herbicide.Gray goldenrod remains an important component of the meadow four years later.

The two research papers discussed in the paragraphs below were written before the awareness that gray goldenrod possessed eastern and western subspecies. The authors present the results of studies conducted west of the Appalachians. Since there are substantial differences between eastern and western gray goldenrods, we must use caution in interpreting the implications of these studies for us here in Maryland.

In the first study, Salac *et al.* (1973) are trying to determine a mowing regimen that will maximize the aesthetic potential of gray goldenrod in Nebraskan roadside meadows. They mowed their experimental plots at a height of 4 inches, which is also the recommended height for mowing turf along Maryland highways (Maryland SHA 2003). Plots were mowed once, the date of that one mowing ranging in two-week increments from early May to early October. Apical dominance is broken by mowing, releasing both any surviving lateral buds on the mowed stem and any below ground buds on rhizomes. Gray goldenrod was not impacted by early May mowings because it was still shorter than the mower blade. Plants impacted by subsequent mowings were shorter, more compact. However, the authors note that roadside stands tend to be shorter and more compact than the ones in their experimental plots were anyhow. Mowed plants had delayed bloom seasons. Plants that were mowed in mid-May or June produced more flowering stems, but the flowering heads were somewhat smaller. Mowing in July resulted in few flowering stems and no fertile seed, and plants that were mowed after August 7 did not bloom at all. From an aesthetic point of view, plants that were mowed in late May and June received the highest ratings because they were more compact and had more flowering heads.

In the second study, Peters and Lowance (1978) examine the use of mowing to control gray goldenrod as a weed in Missouri pastures. They use the principle that mowing a perennial at the time of year when its root carbohydrate reserves are lowest will be the most damaging. The two times of year when gray goldenrod's roots have the lowest carbohydrate reserves are when it is dedicating it's energy to a rapid summer growth spurt (June in our area) and when it is dedicating it's energy to flowering (August to October in our area). They mowed their experimental plots at a height of 5 cm (2 inches). Their trials included mowing periods from May through July. All were highly effective at reducing gray goldenrod stands. Repeat mowings in one season, or single mowings repeated over years were even more effective at controlling gray goldenrod.

What does this mean for maintaining gray goldenrod on roadsides here in the east? It is likely that the western race of gray goldenrod responds more aesthetically to mowing than our local plants would. Mowing the eastern variety of gray goldenrod, which is not rhizomatous, would not produce runners sporting even more flowering heads. The current SHA practice for management of wildflower areas and meadows is to mow to a height of 5" to 7", once per year in late June, and if needed once again in the fall. It is likely that our eastern goldenrod will respond adversely to late June mowing. Furthermore, it is standard practice for natural resource managers (park agencies, etc.) to move their meadows in winter. They do this to avoid damaging perennial flowers, caterpillars, ground nesting birds, and box turtles. In our area it is best to mow after seed set and before the ground nesting birds arrive, generally between Thanksgiving and St. Patrick's Day.

However, if there is to be a short meadow zone between the low-mow zone (immediately adjacent to the shoulder) and the rest of the meadow, that will need to be mowed at least once per year and during the growing season. Mowing each year in May might reduce the occurrence of turf grasses, these are undesirable weeds in any meadow. Mowing every year at a height of 5 to 7 inches in May could support the existence of gray goldenrod in a short Meadows zone. As noted above however, mowing in May is detrimental to several forms of wildlife and many perennial wildflowers.

The thoughtful reader may now be concerned that if Peters and Lowance were studying control of gray goldenrod as a weed, that we may be working with a weedy species. In fact, Peters and Lowance are not alone. Several western scientists have written repeatedly about controlling weedy gray goldenrods in pastures, orchards, and crop fields (Chmielewski & Semple 2004). However, the subspecies of gray goldenrod that occurs in the west is tetraploid and strongly rhizomatous, whereas the gray goldenrod found in our area is neither. As long as we work with our local ecotypes of gray goldenrod, we do not need to be concerned that we are spreading a plant that will become a weed hazard to local agriculture. We have never seen gray goldenrod present in an active agricultural field in Maryland. In fact, Maryland's gray goldenrods are so non-aggressive, that it was a struggle to find an adequate supply of wild populations from which to collect seed for this project.

13: Herbicide Compatibilities for Roadside Use

Literature from the Mid-West, where the tetraploid race is an aggressive, weedy species, indicates that gray goldenrod can be killed by any of a range of general purpose or broad-leaf herbicides (Lowance & Peters 1976).

We were unable to locate any specific literature on the effect of clopyralid, the chemical SHA preferentially usesto control Canada thistle (*Cirsium arvense*), on gray goldenrod (Maryland SHA 2003). We do know that clopyralid is generally damaging to plants in the daisy family (Asteraceae), the family that includes thistles and goldenrods. The University of Minnesota (2008) is monitoring the damage clopyralid causes to prairie forbs, and for the three goldenrod species on their list they indicate moderate damage (stunting, yellowing, twisting, possible failure to flower, but recovery after the application year, no impact on germination the next season).

Imazapic (Plateau) is a chemical that is often used to establish and maintain stands of native warm-season grasses and wildflowers. The Plateau label (www.vmanswers.com/lib/productslist.aspx?CategoryID=268&SiteID=-1) offers no information specific to goldenrods, but does indicate several other members of the daisy family that are tolerant of post emergent applications, and even a few that are tolerant of pre-emergent applications.

14: Road Salt Tolerance

Griffiths and Orians (2003) discovered that gray goldenrod has more tolerance to the salt in sea spray than most species, and this is why it occupies a heathland niche between the sand dunes and forest along the Massachusetts coast.

The exact relationship between road salt and gray goldenrod is unknown. However, many of our parent populations are located under telephone lines adjacent to rural roads. Some of these, though, are on banks that slope down to the road, and others are on the Eastern Shore. In both cases, there may not be much road salt exposure.

3 Methods

3.1 Wild Collection

Since wild collection methods follow similar principles for all species, they are presented in the first report and not repeated here. Gray goldenrod presented no reason to deviate from the wild collection methods as described in the first report.

3.2 Germination

After wild collection, seed was brought back for germination testing and plug production. The volume of seed from each wild collection site was typically quite small, often only a half-cup (125 mL) or so.

Our germination methods were designed to accomplish two goals simultaneously: confirm our literature-based understanding of germination behavior and produce plugs to plant at farms. Accordingly, we opted for potting soil and nursery trays, similar to the methods employed at Plant Materials Centers, rather than Petri dishes and damp filter paper such as would be used in a professional seed testing lab or in a university germination experiment that did not involve plug production (see for example Deno 1993; Walck *et al.* 1997a).

In the fall of 2007, 0.3 g of freshly harvested seed was mixed with damp play sand ant scattered lightly over the surface of an 11" x 20" nursery tray filled with Sungro germination mix. One tray from each accession was placed directly in mist (70L), the other was placed in a cooler for

90 days, then moved into the warm mist 40(90)L. Indoor cold stratification was at 40°F and 50% humidity. All trays germinated profusely. No attempt was made to count the approximately one thousand seedlings that germinated in each tray.

For plug production, seedlings were potted up to 50-cell plug trays before being transplanted out to the farms.

3.3 Production Trial Phase

3.3.1 Farmers' Fields

Farm fields were located in all three physiographic provinces included in this project (Figure 6). The soils and climate at each of these farms is described in detail in the second report of this series.

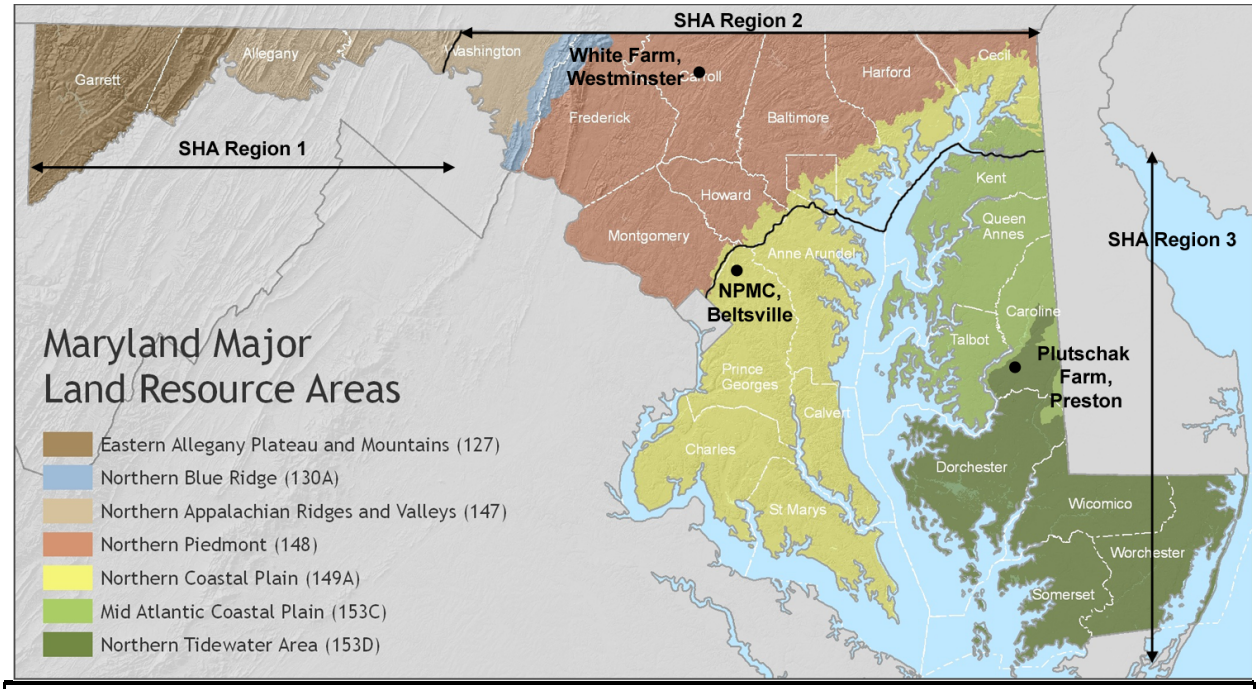

Figure 6: Location of Farm Fields.

This map shows the location of the three farms involved in this project. Base map by Moore (2009).

3.3.2 Farm Field Planning and Establishment

The process of farm field planning and establishment for gray goldenrod is similar to that already described in the report on Virginia wildrye, the second report of this series. The agricultural aspects of this project will also be described in greater detail in our report to the USDA. For now, the reader needs to understand the term "accession plot", which is used by the authors to describe a grouping of plants that all came from the same accession/parent population. At the private farms, one accession plot consists of a row of 5 plants. At the NPMC, one accession plot consists of a 3x5 rectangle of 15 plants. So, for example, at the NPMC farm, the 15 goldenrods descended from the seed (the "accession") collected from the native meadow on Mink Farm Road (the parent population) constitute one accession plot.

The accession plots allow us to increase the amount of seed we have, they serve as breeder blocks, and they enable us to evaluate differences among the parent populations. Since we needed to be certain that the differences among accessions are real rather than the result of random events, three replicate accession plots were distributed at each farm (randomized complete block design). Rows of weed mat were not only used for weed suppression, but also for keeping the accession plots organized and labeled (**Figure 7**).

Figure 7: Accession plots of gray goldenrod.

This photograph shows black plastic weed mat in a lawn at the Plutschak farm. Within the weed mat are three sets of five goldenrod plants arranged in rows. Each row has a painted label that indicates the accession. Each set of five plants is an accession plot. The accession plot at left (labeled R), has green flower buds. The accession plot in the center (labeled P) is a little past full bloom and starting to set some seed. The accession plot on the right (labeled O) is at the peak of bloom.

3.3.3 Crop Maintenance

The gray goldenrod growing in weed mat required almost no maintenance at all. At the NMPC, a pre-emergent herbicide was applied (Surflan, Oryzalin A.I., 3oz/gal), whereas at the private farms no pre-emergent herbicide was used. In either case, the gray goldenrods remained nearly weed free.

3.3.4 Harvest

Seeds were harvested during the establishment year. Other authors disregard first year harvests (see Vogel *et al.* 2006, for example) with good reason. Some results, for example cost benefit

analysis, will not be valid because perennial crops typically produce little or no seed during their establishment year. However, we wanted to produce estimates of the total yield seed producers can expect during an establishment year. We also need the seed for future work. After the second year harvest, in late 2009, we will be able to examine the harvest weights for any interaction between accession site and production site. This will tell us whether there are gray goldenrod seed transfer zones within Maryland.

Staff at the National Plant Materials Center report good success harvesting $^{1}/_{4}$-acre fields of similar crops with a modified street vacuum (R. Jay Ugiansky, pers. comm. 2003). Gray goldenrod produces so many seeds per pound, there may never be enough demand to support quarter acre fields of it. When harvesting with any kind of vacuum, the farmer must be aware of weed seeds that might also be easily picked up by vacuum and could contaminate and devalue the crop.

Barbour (2007) has published the most efficient seed cleaning method for gray goldenrod as determined by the U.S. Forest Service Lab in Macon, Georgia. She ran the flower heads through a Westrup Brush Machine one time. She used the medium-coarse wire (size 10) shell and medium-stiff brushes. This extracted the seeds from the flower heads. The seeds were then aspirated at 0.01 inches of water column to remove light trash. A 45/1000" screen was used to remove larger trash. The equipment used to clean seed this way costs several thousands of dollars and would be beyond reach or reason for most farmers beginning wildflower seed production.

We were unable to test a large-scale seed cleaning method on the small amount of seed set the first year. Therefore, we merely cut individual stems and placed them in paper bags to dry. Then we tapped the stems against the inside surface of a container to release the seed. Because of small sample sizes, there was no attempt to clean the seed in any way that would remove the pappus. Each sample was weighed and recorded.

Figure 8: Gray goldenrod panicles ripe for harvest.

Photograph shows wands of goldenrod fluffy with seed against the background of a blue sky.

Gray goldenrod panicles were cut from the plants when ripe (**Figure 8**). The time of ripening varied according to accession, necessitating multiple trips to each farm for harvest. At harvest, each lot of seed was placed in a separate, labeled, paper bag and allowed to air dry indoors.

It was necessary to have the clean weight of each of these samples, so we chose manual seed cleaning methods that are suited to small lots of seed. Panicles were removed from a sample bag and placed on a large table at the University of Maryland Research Greenhouse Complex. Volunteers ran a rolling pin over each stem, separating seed and many other bits of plant from the stems. The stems were then discarded and the fine materials processed through a mesh screen.

4 Results & Discussion

4.1 Wild Collection Phase

Wild collection methods were presented in the first report of this series, since the reasoning behind collection methods is roughly the same for all species. Wild collection results, however, are not. Here we discuss the product of our efforts wild collecting gray goldenrod from across the state of Maryland.

Brown and Brown (1984), Walck *et al.* (1997a), describe the plant as common, and a generalist having widespread distribution, respectively. So, the lead author was surprised to find only 12 wild populations in her travels across the state (Figure 9). It was enough though that we were able to collect from all three geographic areas covered by this project: Coastal Plain east of the Bay, Coastal Plain west of the Bay, and Piedmont. More detailed information on the wild collection sites will be given in subsequent reports. All 12 accessions have been advanced to field trials. A more detailed description of each location site is provided in Appendix 1.

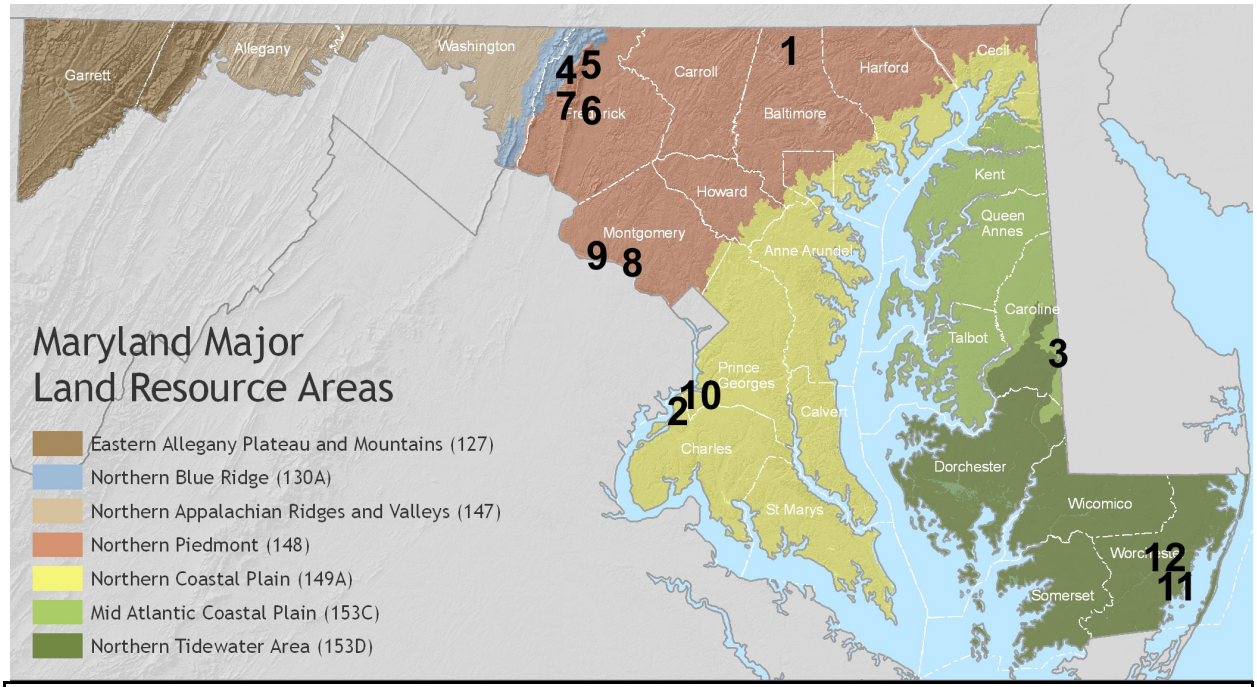

Figure 9: Distribution of wild collection sites.

NRCSs Major Land Resource Areas map (Moore 2009) showing gray goldenrod parent populations. Numbers have been added to a Maryland map to indicate where goldenrod seed was collected.

4.2 Germination Phase

Gray goldenrod seeds germinated well and in ways that support their use in a soil stabilization mix, as described below.

4.2.1 Our Results

Extensive research has already been conducted on *Solidago nemoralis* var. *nemoralis* germination, and this was discussed previously (Attribute 5). Therefore our approach was to test to make sure that our seeds from Maryland's populations behaved in the same way as those in the literature. Our results were consistent with the findings of others. In brief, all accessions of gray goldenrod germinated heavily with or without prestratification treatment (40(90)L, 70L). Onset of germination took less than 7 days in all cases. The first true leaves develop between weeks two and three.

4.2.2 Implications for Use in a Soil Stabilization Mix

In general, gray goldenrod seed germinates well and quickly under a range of conditions, in spring, summer and fall, and thanks to various dormancy mechanisms, will continue to germinate for some time to come. We can manipulate the seed to provide rapid and nearly complete germination, or we can manipulate it so that the seed germinates over an extended period of time. Here are the specific implications for its use:

1. Fresh seed, typically harvested in October or November, is not dormant, but will germinate poorly unless warmer and moister conditions prevail than are typical for fall. If we are using fresh seed, for example in rolling the mowings from one meadow over to another, we can expect immediate germination if weather is still warm, otherwise germination will begin when spring temperatures arrive.
2. Fresh seed will become dormant if exposed to cold. Germination rates will be low, but will increase as cold stratification progresses toward 90 days.
    a. Therefore, if we wanted to encourage dormancy in fresh seed, in order to prevent fall germination, we could chill it for a week. It would germinate in spring.
    b. If we want to encourage high germination percentages in fresh seed, we must not let it chill, for example by storing it outdoors on a cold fall evening.
3. Seed exposed to light is less dormant. We should surface sow this seed when we want more of the seed to germinate immediately, and mix the seed into the surface of the soil for more extended germination and seed banking.
4. Cold-stratified seed will become dormant again if it dries out. We need to keep cold-stratified seed cool and moist until it is sown. If a project is delayed, cold-stratified seed could be forced back into dormancy by allowing it to dry out.
5. With or without stratification, gray goldenrod seed will germinate in summer if there is light and adequate moisture. So summer sowings are possible with irrigation. According to Walck *et al.* (1997d) germination was low if seeds were watered for 1 or 2 days alternating with 5 days dry. With 3 or more days of watering for every 5 days of dry, germination accelerates. Note that the authors did not monitor whether this regime was adequate to promote seedling survival, since that is not their objective. However, we found that seedlings germinating in spring of 2002, during the drought, survived well (**Figure 3**).
6. Some cultivars of native species have been bred for "rapid and uniform germination"; in other words, the seed dormancy is perceived as an obstacle and it has been intentionally removed through a selective breeding program (see Grabowski 2005, for example). Gu

et al. (2008) point out that, "Seed dormancy is a key adaptive trait for wild species"[4]. In the case of goldenrods, Walck *et al.* (1997a, b, 1998) have shown that a lack of seed dormancy mechanisms is related to species rarity. Gray goldenrod seed has dormancy mechanisms that likely affect the species' viability and the role it plays within our meadow ecosystems. The safest strategy for protecting Maryland's environment would be to avoid the use of any goldenrod cultivar that has been bred for "rapid and uniform germination". Spreading something so very "genetically different" along our highways could affect ecosystem structure and function in unforeseen ways and lead to loss of unique local genotypes (paraphrased from Gustafson 2004).

Table 1. Summary of germination requirements.

Common Name	**Scientific Name**	**Germination Pre-treatment**
Gray goldenrod	*Solidago nemoralis*	Fresh or cold Stratified, Light

From the data we have collected and the literature, we can make predictions about how fresh seed would respond to sowing at various times of year (**Table 2**). Truly fresh seed is only available in fall, so that is the first column. Any seed used in winter, spring or summer has been stored somehow, and those storage conditions need to be understood.

Table 2. Germination responses of fresh seed sown during a season.

Common Name	**Fall**	**Winter**	**Spring**	**Summer**
Gray goldenrod	Yes (if warm)	No	Yes	Yes (if moist)

[4]After millennia of domestication, wheat has lost seed dormancy to such a degree that wheat grains are now literally germinating on the crops before they can be harvested. Gu and co-authors are trying to breed dormancy mechanisms back into wheat. Gu's team is introducing dormancy genes from wild wheat relatives, related to the wildryes discussed in the second paper, to help prevent this phenomenon, called PHS (preharvest sprouting).

4.3 Production Trial Phase

4.3.1 Establishment

As a result of this project, the USDA NPMC now has 12 breeder blocks of Maryland ecotype gray goldenrod (they possessed none before this project began). The NPMC uses breeder blocks to develop local ecotype releases and to provide growers with seed for establishing genetically appropriate production fields. Wild collection, establishment, certification, and maintenance of a genetically diverse foundation planting requires money and expertise that many potential seed producers/small farmers do not possess. The NPMC breeder blocks will also be a valuable tool for increasing the number of Maryland farmers interested in producing native seed. When farmers offer seed grown from these foundation blocks for sale, SHA will know that the seed is descended from Maryland wild populations, and that it contains a diverse and appropriate gene pool. Therefore the establishment of these breeder blocks will help ensure that Maryland's roadside vegetation managers have access to large quantities of locally native seed at reasonable prices.

4.3.2 Crop Maintenance

The weed mat was more effective at suppressing weeds in the gray goldenrod blocks than it was for the two grass species discussed in the two previous reports of this series. We think the low weed pressure is the result of gray goldenrod's growth habit. The basal foliage, which grew quickly and covered the planting hole, blocked the light needed for germination of many weed seeds. The basal foliage is typically present even in winter, which is important because many weeds germinate in winter. By using weed mat, farmers can produce gray goldenrod seed without the use of chemicals. This makes goldenrod seed production a viable option for organic farms.

4.3.3 Harvest

There were distinct differences in first year (2008) seed set among the plants from different accessions (**Table 3**). Some accessions produced a few small flowering stems the first year whereas others produced none. We anticipate that all accessions will produce seed in their second year. Literature reports of the seed set per stem in wild meadows range from lows of 200 (Werner & Platt 1976) up to 5,153 (Havercamp & Whitney 1983). Caution must be used in interpreting these results, like most perennials, gray goldenrod only supports a few blossoms during its establishment year.

Table 3: Harvest weights for gray goldenrod seed during the establishment year (grams).

Pluts.	NPMC	White	NPMC #	NRCS Accession #	Town	County	#plants in pop	#collected	N Latitude	W Longi
38.3	30.1	37.1	2	9106025	Denton	Caroline	20	20	37.063	75.069
18.3	22.5	11.4	5	9106028	Berlin	Worcester	30	30	38.292	75.156
8.1	34.4	6.0	6	9106029	Assateague	Worcester	10	10	38.260	75.163
3.8	18.4	28.3	9	9106032	Parkton	Baltimore	20	20	39.629	76.655
3.6	2.2	0.0	1	9106024	Accokeek	Prince George's	6	6	38.692	76.989
8.8	8.6	8.2	7	9106030	Indian Head	Charles	100	50	38.630	77.071
7.7	8.6	4.1	4	9106027	Potomac	Montgomery	100	50	39.067	77.227
1.5	0.7	0.0	11	9106034	Poolesville	Montgomery	25	25	39.084	77.391
NA	6.1	NA	12	9106035	Hansonville	Frederick	25	25	39.499	77.399
5.0	7.1	2.6	3	9106026	Thurmont	Frederick	5	5	39.589	77.434
0.0	7.2	0.0	10	9106033	Thurmont	Frederick	3	3	39.601	77.479
4.1	9.8	13.3	8	9106031	Harmon	Frederick	47	47	39.543	77.500

5 Conclusions and Recommendations for Implementation

1. **Description:** Gray goldenrod is a short, showy, perennial wildflower that is drought tolerant. It has a fibrous root system that grows well in a wide range of soil types. Semi-evergreen basal foliage provides some soil cover in winter. It tolerates some mowing, and it may also tolerate some salt spray. It does not attract the sort of wildlife that would present a traffic hazard. The flowers are cross-pollinated by a diversity of small pollinators. The seeds are windborne.
2. **Distribution and conservation:** Gray goldenrod is found in all the geographic provinces of Maryland. Our references and herbarium records indicate that it is one of the more common wildflowers representative of dry meadows. However, it was surprisingly difficult to locate a dozen wild populations for this project. Werner (1976) indicated that gray goldenrod populations were competing with summer blooming alien weeds for pollinator visits. This factor combined with others, especially isolation of gray goldenrod populations from one another, could be causing a regional decline in gray goldenrod populations. The use of gray goldenrod in highway seed mixes could compensate for the downturn.
3. **Site design:** In planning a wildflower or soil stabilization seed mix, gray goldenrod can be used as both an early successional species and as a flower that will persist in the meadow as it matures.
4. **Seed purchase:** In the case of gray goldenrod seed, specifically, is particularly important to purchase locally native certified source-identified seed. A separate race of gray goldenrod exists on the west side of the Appalachian Mountains. It is distinctly more aggressive than the eastern race. It is tetraploid-having twice the number of chromosomes-and more rhizomatous then our local gray goldenrod. Hybridization of the two forms of gray goldenrod could have undesirable evolutionary consequences.
5. **Germination:** Our germination tests reveal that even tiny quantities of seed (0.3g) can yield hundreds of seedlings. Under the conditions of our testing, surface sown seed germinated well with or without cold stratification.
6. **Germination:** Gray goldenrod seeds have dormancy mechanisms that allow them to accumulate in a soil seed bank. Seed banks ensure the persistence of this species at wild sites, and should also ensure their persistence in roadside plantings. In general, gray goldenrod seed germinates well and quickly under a variety of conditions, in spring, summer and fall. By understanding the dormancy mechanisms described in this report, roadside vegetation managers can manipulate the seed to provide rapid and nearly complete germination, or manipulate it so that the seed germinates over an extended period of time.
7. **Mowing**: The current SHA practice for management of wildflower areas and meadows is to mow to a height of 5" to 7", once per year in late June, and if needed once again in the fall. It is likely that our eastern goldenrod will respond adversely to late June mowing. Furthermore, it is standard practice for natural resource managers (park agencies, etc.) to move their meadows in winter. They do this to avoid damaging perennial flowers,

caterpillars, ground nesting birds, and box turtles. In our area it is best to mow after seed set and before the ground nesting birds arrive, generally between Thanksgiving and St. Patrick's Day.

8. **Seed production and harvest:** Using weed mat, production of gray goldenrod seed requires little effort and no chemicals. Once affordable harvest and seed cleaning measures are worked out, SHA will have a source of affordable soil stabilization seed in this species. The establishment year harvest for gray goldenrod is 1.1 pounds, over 350,000 seeds from less than 900 plants. The second year harvest will be considerably larger.

6 Future Work:

1. **Test the Seed on Slopes:** We recommend that a portion of the seed produced during the establishment year of this project be used in slope demonstration trials across the state. Although the authors have successfully established gray goldenrod seed on two separate cut slopes with out fertilization or inoculation, some work should be done to check on the report of Hetrick *et al.* (1992), who have observed that gray goldenrod established on sterile soil cannot obtain adequate phosphorous without either mycorrhizal inoculation or fertilizer amendment. This would be a concern for stabilization projects, which often occur on cut slopes – sterile soils as opposed to topsoils rich with soil organisms.
2. **Techniques for Sowing Seed at Stabilization Sites:** Gray goldenrod seed needs to be tested for compatibility with the practices typically used for sowing seed at roadside stabilization sites. Can it be hydroseeded? Can it be tracked into the slope with heavy machinery? Would the standard nurse crops block too much light, thus retarding germination? Could Virginia wildrye and beaked panicgrass become the standard spring/fall substitute for a nurse crop? Will gray goldenrod seed germinate and grow effectively under curlex?
3. **Herbicides:** A better understanding of weed control options would allow more affordable seed production and better roadside management.
4. **Work with AOSCA:** Have seed tested by a certified Association of Official Seed Certifying Agencies laboratory and seed germination testing protocols proposed. The literature review and germination test results in this document will support their work. Even more than for many other species, germination protocols will be a function of prior storage conditions. Once AOSCA has published official testing procedures, the MDA will have access to the most appropriate testing protocols for testing locally native gray goldenrod seed.
5. **Acquire Economy of Scale in Production:** The authors, participating farmers, and the NPMC have learned much that can be applied to cost effective production of gray goldenrod as a seed crop in small plots. Gray goldenrod plants produce so many seeds per square foot, large plots may never be needed. The results of our 2009 harvest will provide more information. Seed cleaning, storage and marketing methods must be developed and published.
6. **Increase Economy:** It is a common misconception that the most affordable seed is that which costs the least per pound. Develop the concept of cost per viable seed proposed by Ugiansky (2004) as it pertains specifically to gray goldenrod. If the germination rate and price per pound are the same, the larger seeds will cost SHA 10 to 100 times more per seedling. This type of information will tell SHA precisely how economical gray goldenrod seed is in comparison to other soil stabilization options.
7. **Establish Seed Transfer Zones:** Second year (2009) harvests should be cleaned and weighed to detect any variations in seed yield caused by the distance between an accession's collection site and its production site. This data can be used to detect seed transfer zones for gray goldenrod within Maryland, if they exist. For economy of scale

we hope for the largest seed transfer zones possible. For the most effective soil stabilization, the best aesthetic quality, and to protect the environment, we do not want to recommend a larger seed transfer zone than is ecologically appropriate (Doede 2005).

8. **Certify and Maintain the Breeder Blocks:** The NPMCs breeder blocks should be maintained and certified by the Maryland Department of Agriculture. The value of the NPMC to this project cannot be overstated. In addition to helping in all the concluded phases of this project, it is they who will carry the agricultural aspects of the project into the future. They will continue to maintain the breeder blocks, they will make the seed from the available to interested farmers as "local ecotype releases", and they will support those farmers with the technical information they need to become successful producers. Additional collaborations of this nature are warranted if SHA is to secure genetically appropriate seed of the additional seven species recommended by the SAP for use on Maryland roadsides (see first report).
9. **Update or revise this report:** the report that you are reading now covers fieldwork from 2006 through 2008. Additional fieldwork with gray goldenrod is ongoing, and this report will need to be updated or modified in the future.

7 Glossary

Several references were used in developing this glossary, but especially Davis *et al.* (2002), Smith and Halbrook (2004), and Ogle and Englert (2008).

Accession – Something added to a collection. In this paper it refers to a sample of seed collected from a wild parent population. It may also refer to the plants grown from that seed, since the two are genetically identical. In contrast, parent population refers to the group of plants at the wild location where the seed was collected.

Alien species– A plant that was not present in a determined place prior to the arrival of humans. The determined place can be narrowly defined as the place under your feet with its peculiar ecotypical conditions (niche), or as widely as the entire continent.

Apical dominance – Hormonal domination of lower buds by the bud at the apex or tip of the plant. When this bud is cut off, lower buds along the stem and rhizomes are released and begin to grow.

Clopyralid –A selective herbicide (3,6-dichloro-2-pyridinecarboxylic acid) used for control of broadleaf weeds, especially thistles and clovers.

CNI – Abbreviation for Chesapeake Natives, Inc. CNI is a 501(c)3 nonprofit organization that was founded in 2005. Both authors are affiliated with CNI.

Cultivar – An assemblage of cultivated plants clearly distinguished by heritable (genetic) traits (morphological, physiological, cytological, chemical, other). USDA cultivars have been through replicated testing at multiple sites over two or more generations to prove and documents the heritability of these traits, the superiority and/or performance, and the range of adaptation.

Diploid – An organism with two copies of each chromosome, one from each parent. If you visualize the chromosomes in the nucleus as a collection of letters in the alphabet, mostly looking like distorted x's, y's and k's, a diploid organism has a full set of the letters normal for its species.

Genetic diversity –The total amount of genetic variation present in a population or species. Diversity allows individuals to react differently to external conditions. The classic example of the danger of a lack of genetic diversity to plant (and human) survival is the potato blight of the 1840s. All the potatoes responded the same way to the infection.

Germination – The initiation of the growth of a plant from a seed.

Haplome (Haploid) – A single set of chromosomes in the Triticae half of a diploid set that has come from an intergeneric hybridization event. If you visualize the chromosomes in the nucleus as a collection of letters in the alphabet, mostly looking like distorted x's and k's, a haplome is a set consisting of half of each of those letters, half of the x, half of the k, etc.

Lemma – The outer, leaf-like bract of a grass-flower, and enclosing a single grass seed.

Hostplant – A plant that hosts insects and other organisms, usually but not always larval insects (like caterpillars) that cannot feed on other types of plant tissue. The most famous example of a hostplant and its larval insect is probably the milkweed and the monarch butterfly caterpillar.

Multipot – Trademark product of the Ropak Corporation, a re-usable, deep plug tray made to grow seedlings for transplant into the field.

Native species – A plant that was present in a determined place prior to the arrival of humans. The determined place can be narrowly defined as the place under your feet with its peculiar ecotypical conditions (niche), or as widely as the entire continent.

Niche – The place an organism occupies in its habitat. The place is not merely a physical location, but also the place in the food web, and the place along environmental gradients (moisture, salinity, light, soils, etc.).

NPMC – The National Plant Materials Center, the lead Plant Materials Center of the USDA, NRCS located in the Beltsville Agricultural Research Center, Beltsville, Maryland.

NRCS – Abbreviation for the Natural Resources Conservation Service, one of 27 Agencies within the USDA. Prior to 1997 NRCS was known as the Soil Conservation Service.

Panicle – A compound flower head (inflorescence) containing a main stem and many branches, often plume-like or loosely pyramidal in outline. The flowers on one panicle do not all bloom at the same time. Both beaked panicgrass and gray goldenrod hold their flowers in panicles.

Population – A group of plants that can breed with each other, exchanging genetic information through the transfer of pollen or spores.

Parent population – In any field of science, a group of individuals from which a smaller sample is drawn. In our work, the group of individuals is a collection of wild plants at one location, and the sample is a seed collection.

SHA – Maryland State Highway Administration.

Source-identified -Seeds or plants from a naturally growing population occupying a known or defined geographic area. No selection or testing of the parent population has been made. There is no performance or adaptation data available for the collection. Offspring is produced to ensure genetic purity and identity from rigidly defined natural stands, seed production areas, seed fields, or orchards.

spp. – Standard abbreviation for two or more species of a genus

ssp. – Standard abbreviation for subspecies

Stratification – A pre-treatment of seed, often to cold, moist conditions, that enhances germination rates, mimicking natural conditions.

Tetraploid – An organism with four copies of each chromosome. If you visualize the chromosomes in the nucleus as a collection of letters in the alphabet, mostly looking like distorted x's and k's, a tetraploid organism has two full sets of the letters normal for its species. However, in some species, all the members are tetraploid.

var. – The conventional abbreviation of "variety", a taxonomic category subordinate to species. Variety can also have other meanings, even with respect to plants, depending upon the context.

USDA – United States Department of Agriculture.

8 References

Allard, H.A. & W.W. Garner (1940). Further observations of the response of various species of plants to length of day. *USDA Agriculture Technical Bulletin* No. 727.

Barbour, J.R. (2007). Propagation protocol for production of *Solidago nemoralis* seeds; USDA Forest Service - National Seed Laboratory, Dry Branch, Georgia. *In*: Native Plant Network. www.nativeplantnetwork.org (accessed 7/01/2009).

Beimborn, W.A. (1973). Physical Factors Affecting Establishment of *Solidago nemoralis* on the New Jersey Piedmont. Thesis, Rutgers University, New Jersey.

Belt, S. (2009). Plant Fact Sheet for Gray Goldenrod (*Solidago nemoralis* Aiton). USDA Natural Resources Conservation Service, National Plant Materials Center Beltsville, Maryland.

Booze-Daniels, J., D.R. Chalmers & R.E. Schmidt (1998). Native Grasses on the Roadsides of Virginia - A Review of Literature. A Report to Virginia Department of Transportation submitted by Department of Crop, Soil and Environmental Science, Virginia Polytechnic Institute and State University.

Brammall, R.A. & J.C. Semple (1990). The cytotaxonomy of *Solidago nemoralis* (Compositae: Asteraceae). Canadian *Journal of Botany* **68**(10): 2065-2069.

Britton, N.L. & A. Brown (1913). *An illustrated flora of the northern United States, Canada and the British Possessions*. Vol. 1-3 (artwork downloaded from USDA NRCS PLANTS Database, www.plants.usda.gov).

Brown, M.L. & R.G. Brown (1984). *Herbaceous Plants of Maryland*. Port City Press, Inc., Baltimore, Maryland. 1127pp.

Chmielewski, J.G. & J.C. Semple (2004). The biology of Canadian weeds. 130. *Solidago nemoralis* Ait. *Canadian Journal of Plant Science* **84**: 4 1221-1233.

Cooper-Driver, G.A. & P.W. LeQuesne (1987). Chapter 48: Diterpenoids as insect antifeedants and growth inhibitors: role in *Solidago* species. *American Chemical Society Symposium Series* **330**: 534-550

Davis, K.M., J.M. Englert & J.L. Kujawski (2002). Improved Conservation Plant Materials Released by NRCS and Cooperators Through September 2002. USDA NRCS National Plant Materials Center. www.plant-materials.nrcs.usda.gov/mdpmc/publications.html

Deno, N.C. (1993). *Seed Germination Theory and Practice*. 2nd Edition. Published by the author: 139 Lenore Dr., State College Pennsylvania 16801

Doede, D.L. (2005). Genetic variation in broadleaf lupine (*Lupinus latifolius*) on the Mt. Hood National Forest and implications for seed collection and deployment. *Native Plants Journal* 2005(spring): 37-48

European and Mediterranean Plant Protection Organization (2004). www.eppo.org/QUARANTINE/Alert_List/invasive_plants/SOONE.htm (accessed 6/01/09).

Federal Highway Administration (2002). Greener Roadsides: An FHWA Quarterly Newsletter for Roadside Decision Makers. Summary of the 2002 Seeds of the Future Conference in Orlando, Florida. www.fhwa.dot.gov/environment/greenerroadsides/winter02.htm#toc

Freckmann, R.W. & M.G. Lelong (2003). *Panicum.* pp. ***-***. *In*: Flora of North America Editorial Committee (Eds). *Flora of North America North of Mexico* Vol. 25 Magnoliophyta: Commelinidae (in part) Poaceae, part 2. Oxford University Press, New York. www.herbarium.usu.edu/webmanual (accessed 7/01/09).

Grabowski, Janet, B. Baldwin and P. Meints. 2004. Selecting for Improved Seedling Establishment in Beaked Panicum. *Jamie L. Whitten Plant Materials Center 2004 Annual Technical Report.* p.16-17.

Griffiths, M.E. & C.M. Orians (2003). Salt spray differentially affects water status, necrosis, and growth in coastal sandplain heathland species. *American Journal of Botany* **90**: 1188-1196

Gross, R.S. & P.A. Werner (1983). Relationships among Flowering Phenology, Insect Visitors, and Seed-Set of Individuals: Experimental Studies on Four Co-occurring Species of Goldenrod (*Solidago*: Compositae). *Ecological Monographs* **53**(1): 95-117.

Gu, X.-Y., S.-J. Ren, C.-G. Chu, K. Glover, S.S. Xu, J.D. Faris, T.L. Friesen & A. Ibrahim (2008). Identification of seed dormancy for four populations derived from synthetic hexaploid wheat. *Annual Wheat Newsletter* **5:** 4-8.

Gustafson, D.J., D.J. Gibson & D.L. Nickrent (2004). Conservation genetics of two codominant grass species in an endangered grassland ecosystem. *Journal of Applied Ecology* **41**: 389-397.

Havercamp, J. & G.G. Whitney (1983). The life history characteristics of three ecologically distinct groups of forbs associated with the tallgrass prairie. *American Midland Naturalist* **109**: 105-119.

Helms, K.R. & S.B. Vinson (2000). New host records for the "legless" mealybugs of Texas. *Southwestern Entomologist Scientific Note* **25**(3): 229-231.

Hetrick, B.A.D., G.W.T. Wilson, and T.C. Todd (1992). Relationships of mycorrhizal symbiosis, rooting strategy, and phenology among tallgrass prairie forbs. *Canadian Journal of Botany.* **70**:1521-1528.

Husband, B.C. & H.A. Sabara (2003). Reproductive isolation between autotetraploids and their diploid progenitors in fireweed, *Chamerion angustifolium* (*Onagraceae*). *New Phytologist* **161**: 703-713.

Kartesz, J. & C.A. Meacham (1999). *Synthesis of the North America Flora*. Version 1.0 (CD-ROM). North Carolina. www.bonap.org/synth.html

Keever, C. (1979). Mechanisms of plant succession on old fields of Lancaster County, Pennsylvania. *Torrey Botanical Club* **106**: 4 299-308.

Lowance, S.A. & E.J. Peters (1976). Herbicide Treatments for controlling ironweed (*Vernonia*) and goldenrod (*Solidago nemoralis*). Abstract only. *In*: *Proceedings of the Annual Meeting of the North Central Weed Control Conference*. p. 62

Maryland Department of Transportation (2007). Fiscal Year 2008 Through Fiscal Year 2011 Business Plan. www.marylandroads.com/oc/shabusinessetnl.pdf , accessed 6/1/09.

Maryland State Highway Administration (2003). Integrated Vegetation Management Manual for Maryland Highways.Maryland Dept. of Transportation. 144 pp.

McKay, J., C. Christian, S. Harrison & K. Rice (2005). How Local is Local? *Restoration Ecology* **13**(3): 432–440.

Metzger, J. 1995. Maryland Native Plants: A Master Checklist. www.mdflora.org/publications/mdchecklist.pdf

Miller, J.H., & K.V. Miller (1999). Forest plants of the southeast and their wildlife uses. *Southern Weed Science Society*.

Moore, A. (2009). Map of the Major Land Resource Areas of Maryland. Prepared for this report by the State Soil Scientist, USDA Natural Resources Conservation Service.

Ogle, D. & J. Englert (2008). *Glossary of Terms for Use in Plant Materials*. USDA Natural Resources Conservation Service. Boise, Idaho. 48 pp.

Parrish, J. & R.G. Steinman (2003+). Native Plants of Sligo. Available through the Friends of Sligo Creek at www.fosc.org/PlantInventory.htm (accessed 08/2009).

Peters, E.J. & S.A. Lowance (1978). Effects of multiple mowing on western ironweed (*Vernonia baldwinii*) and gray goldenrod (*Solidago nemoralis*). *Weed Science* **26**(2): 190-192.

Salac, S.S., J.F. Hesse & J.O. Young (1973). Effects of mowing on three species of wild flowers (*Hesperis matronalis, Asclepias tuberosa, Solidago nemoralis*). *American Society for Horticultural Science Journal* **98**(4): 406-409.

Scott, J.A. (1986). *The Butterflies of North America: A Natural History and Field Guide*. Stanford University Press, Stanford, California.

Semple, J.C., J.G. Chmielewski & R.A. Brammall (1990). A multivariate study of *Solidago nemoralis* (Compositae: Astereae) and comparison with *S. californica* and *S. sparsiflora*. *Canadian Journal of Botany* **68**(10): 2070-2082.

Semple, J.C. & R.E Cook (2006). *Solidago*. pp. 107-166. *In*: North America Editorial Committee (Eds.). *Flora of North America North of Mexico*. Vol. **20**. Asteraceae Part 2. Astereae and Senecioneae. Oxford University Press, New York.

Shealer, D.A., J.P. Snyder, V.C. Dreisbach, D.F. Sunderlin & J.A. Novak (1999). Foraging Patterns of Eastern Gray Squirrels (*Sciurus carolinensis*) on Goldenrod Gall Insects, a Potentially Important Winter Food Resource. *The American Midland Naturalist* **142**(1): 102-109.

Shetler, S. & S.S. Orli (2000). *Annotated Checklist of the Vascular Plants of the Washington-Baltimore Area.* Part I. Dept. of Botany, National Museum of Natural History, Smithsonian Institution, Washington, D.C.

Simmons, R.H., J.M. Parrish, M.D. Tice, and M.T. Strong (2008). Conservation Priorities and Selected Natural Communities of the Upper Anacostia Watershed. *Marylandica* **12**(1): 1-23.

Slattery, B.E., K. Reshetiloff & S.M. Zwicker (2003). *Native Plants for Wildlife Habitat and Conservation Landscaping: Chesapeake Bay Watershed*. U.S. Fish & Wildlife Service, Chesapeake Bay Field Office, Annapolis, Maryland. 82 pp.

Smith, S.E. and K. Halbrook (2004). A plant genetics primer. *Native Plants Journal* **2004** (Fall): 106-111.

Ugiansky, R.J. (2004). Final Report: Development of Sustainable Native Wildflower Meadows for Highway Roadsides. USDA-NRCS National Plant Materials Center, Beltsville MD, 39pp.

USDA NRCS (2006+). The PLANTS database. National Plant Data Center, Baton Rouge, LA 70874-4490 USA. Baton Rouge (LA). www.plants.usda.gov (accessed 2006 through 2009).

University of Minnesota (2008). Minnesota Rankings for Native Forb Tolerance to Aminopyralid and Clopyralid Herbicides. http://appliedweeds.cfans.umn.edu/pubs.html (accessed 8/28/09).

Vogel, K.P., A.A. Hopkins, K.J. Moore, K.D. Johnson & I.T. Carlson (2006). Genetic Variation among Canada Wildrye Accessions from Midwest USA Remnant Prairies for Biomass Yield and other Traits. *Crop Science* **46**: 2348–2353.

Walck, J.L., J.M. Baskin & C.C. Baskin (1997a). A comparative study of the seed germination biology of a narrow endemic and two geographically widespread species of *Solidago* (Asteraceae). 1. Germination phenology and effect of cold stratification on germination. *Seed Science Research* **7**: 47-58.

Walck, J.L., J.M. Baskin & C.C. Baskin (1997b}. A comparative study of the seed germination biology of a narrow endemic and two geographically widespread species of *Solidago* (Asteraceae). 2. Germination responses of buried seeds in relation to seasonal temperature cycles. *Seed Science Research* **7**: 209-220.

Walck, J.L., J.M. Baskin & C.C. Baskin (1997c). A comparative study of the seed germination biology of a narrow endemic and two geographically widespread species of *Solidago* (Asteraceae). 3. Photoecology of Germination. *Seed Science Research* **7**: 293-301.

Walck, J.L., J.M. Baskin & C.C. Baskin (1997d). A comparative study of the seed germination biology of a narrow endemic and two geographically widespread species of *Solidago* (Asteraceae). 4. Role of soil moisture in regulating germination. *Seed Science Research* **7**: 303-309.

Walck, J.L., J.M. Baskin & C.C. Baskin (1997e). A comparative study of the seed germination biology of a narrow endemic and two geographically widespread species of *Solidago* (Asteraceae). 5. Effect of dry storage on after ripening and survivorship. *Seed Science Research* **7**: 311-318.

Walck, J.L., J.M. Baskin & C.C. Baskin (1998). A comparative study of the seed germination biology of a narrow endemic and two geographically widespread species of *Solidago* (Asteraceae). 6. Seed bank. *Seed Science Research* **8**: 65-74.

Werner, P.A. (1976). Ecology of plant populations in successional environments. *Systematic Botany* **1**: 246-268.

Werner, P.A. & Platt, W.J. (1976). Ecological relationships of co-occurring goldenrod species (*Solidago*: Compositae). *American Naturalist* **110**: 959-971.