2005

The use of native plants for revegetation along West Virginia highways

Christina Venable
West Virginia University

The Use of Native Plants for Revegetation along West Virginia Highways

Christina Venable

Thesis submitted to the
College of Agriculture, Forestry, and Consumer Sciences
at West Virginia University
in partial fulfillment of the requirements
for the degree of

Master of Science
In
Plant and Soil Science

Jeffrey Skousen, Ph.D.
Louis McDonald, Ph.D
Sven Verlinden, Ph.D

Division of Plant and Soil Sciences

Morgantown, West Virginia
2005

Keywords: Native plant establishment, Roadside vegetation, Revegetation

ABSTRACT

The Use of Native Plants for Revegetation along West Virginia Highways

Christina Venable

The West Virginia Division of Highways is required to develop seeding mixtures comprised of native plants for revegetating highway corridors and thereby reducing the potential for introduction of non-native species along roads. The objectives of this project were to compare establishment and growth of plants in five different seed mixtures and two fertilizer treatments, to develop surface treatments to enhance the establishment of native plants along highways, and correlate native species establishment to soil physical and chemical properties. Fertilizer was not found to increase the cover of the seeded natives, but did increase total cover. The seeded natives were not found to be able to establish through the thick cover contributed by the more aggressive species typically used for revegetation by the Division of Highways. Removing the vegetation by tilling or herbicide did allow the natives to become established. However, the seeded natives did not contribute any significant cover until the second and third growing season.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

TABLES IN APPENDIX

1. Introduction

Due to the mountainous nature of West Virginia, the process of highway construction often involves the blasting and removal of large amounts of geologic material from one area to be used as fill for other areas. These "cut and fill" areas are highly disturbed and easily eroded. Therefore, a fast and effective ground cover is required to control erosion. The current method is to provide a vegetative cover that is fast-growing and easy-to-establish. However, owing to their known ability to control erosion, ease of establishment, and cost-effectiveness, nearly all species used for this control are non-native and/or invasive (Skousen and Fortney, 2003). Once established, the non-natives can persist indefinitely and can use vehicular traffic as a vector to expand their range. Thus, the use of these species is of special concern to West Virginia and the environment.

Native species can be defined as, with respect to a particular ecosystem, those plants that historically occurred or currently occur in an ecosystem without having been originally introduced. Invasive species are those non-natives that cause, or are likely to cause, harm to the economy, environment, or human health (Executive Order 13112, 1999). However, this definition for invasives leaves out what is often a key aspect of their behavior: proliferation and spread. To be sure, not all non-natives are invasive, nor are all invasives non-native.

Invasive plants cause an estimated $137 billion a year in environmental damage. Over 40% of the species listed as threatened or endangered under the Endangered Species Act are there primarily because of competition from non-native species (Nature Conservancy, 2003). Former president Bill Clinton signed the Executive Orders on Invasive Species (EO 13112) and Greening the Government through Leadership in Environmental Management (EO 13148) in 1999 and 2000, respectively. These orders were designed to prevent the introduction of invasive species, control their spread, and implement cost-effective, environmentally sound landscaping practices. This is to be done by both using existing programs to limit the introduction and spread of invasives, as well as creating new programs to promote the use of native plant species.

However, the use of native plants on roadsides has two major problems. First, these are highly disturbed and rigorous sites which tend to inhibit the successful establishment of the competitively disadvantaged natives. Second, the seeds of native plants are often unavailable in large quantities and/or are too expensive to be cost effective for seeding large areas.

Much research has been done on using native plants on roadsides (Ahern et al. 1992, Barton et al. 2002, Corley 1995, Fiedler et al. 1990, Harper 1988, Morrison 1981, Swan et al. 1993). Many have found it to be a viable and economical option.

The goals of this research are:

1) To identify native plants suitable for seeding along highways and document the growth and establishment of these species on highway cut and fill sites.
2) To develop methods to enhance native species establishment in roadside environments.
3) To correlate the establishment of native plants used for highway revegetation to physical and chemical soil properties.

2. Literature Review

2.1. Current West Virginia Division of Highways (WVDOT) Revegetation Practices

Most state highway departments have developed revegetation strategies through years of testing. The mountainous nature of West Virginia makes the construction of highways very similar to surface mining. To maintain moderate grades, the mountainous topography is blasted and the blasted rock material is then used to backfill lower areas. The topsoil is removed and kept separate to be placed only when the entire roadway is finished. Topsoil may also be obtained and hauled from sites outside of the construction area. Before placement, the subsoil is scarified to promote bonding with the topsoil. After spreading the soil, it is raked to remove all large clods, brush, litter, or other foreign material, and rocks larger than 2 inches (Facemire et al., 2000).

The application of limestone is determined prior to seeding and is based on a lime requirement test. The area to be seeded is scarified to create a seed bed and seed is sown immediately. All legume seed is inoculated with appropriate cultures and when a hydroseeder is to be used, the inoculant is increased five times the normal rate. Rates and seeding combinations used by the WVDOT can be found in Table 1. Fertilizer is typically applied concurrently with the seeding at a rate of 1,120 kg/ha of 10-20-10. An additional 336 kg/ha of slow release urea

Table 1. Species, mixtures and rates used by the WVDOT for revegetation after highway construction. Units are kg/ha.

Variety of Seed	Area of Use	
	Medians, Shoulders, Waterways, and Mowable Areas of Interchange	Cut and Fill Slopes (Including Benches and Bifurcated Median)
Kentucky 31 fescue (*Festuca arundinacea* Schreb.)	73	22
Red fescue var. Pennlawn (*F. rubra* L.)	22	22
Crownvetch (*Coronilla varia* L.)	--	22
Hard fescue Mix*	--	--
White Dutch Clover (*Trifolium repens* L.)	3	--
Annual Ryegrass (*Lolium multiflorum* Lam.) August 1 to May 15	8	8
or		
Weeping lovegrass (*Eragrostis curvula* (Schrad.) Nees) May 15 to August 1	3	3

*A combination of varieties with no one variety exceeding 50% of the total.

formaldehyde fertilizer is added whenever second step seeding and fertilizing is not feasible due to time constraints. On areas with slopes 1.5 to 1 or flatter, straw mulch is applied at approximately the rate of 4.48 Mg/ha and is anchored with 935 L/ha of asphalt (it may also be anchored with a type of netting). On steeper slopes, wood cellulose fiber is applied concurrently with the fertilizer and seed, at a rate of approximately 1,680 kg/ha (Facemire et al., 2000).

A second and/or third step seeding is usually required. Application rates of fertilizer, seed, and mulch are based on the condition and growth of the grass stand and the severity of erosion. Areas with less than 50% stand establishment or subject to severe erosion receive the total amount of seed, fertilizer, and mulch as given in the original seeding. Areas with over 50% stand establishment and slight to moderate erosion receive one half the original seed and fertilizer. If erosion is a problem, one-half the original wood fiber mulch is applied. Third step seeding, mulching, and fertilizing consist of spot applications on areas with unsatisfactory stands after second step applications. Rates are determined on the same basis as the second step applications (Facemire et al., 2000).

Tall fescue (*Festuca arundinacea* Schreb.) and Crownvetch (*Coronilla varia* L.) are aggressive and non-native and as such have been recently identified as species that should either not be seeded along highways or seeded less. They also inhibit the ability of native plants to move into areas along highways due to their competitive nature.

2.2. Problems with the Use of Native Plants for Revegetation

As previously mentioned, the spread of introduced, aggressive species is a problem, and Executive Orders 13112 and 13148 have stated that native plants should be substituted whenever possible. However, there are two major problems with the use of native plants for revegetation. Seeds of native plants are often unavailable in large quantities and/or are too expensive to be cost effective for seeding large areas. Many seed suppliers don't carry native varieties or when they do, it is often of poor quality (low purity, germination, and/or viability). Also, species typically used in revegetation cost much less than the natives (Harrington, 1991). For instance, Tall and Red fescue (*F. rubra* L.) cost approximately $1.00 per pound; while four commonly used native grasses, Big Bluestem (*Andropogon gerardii* Vitman), Little Bluestem (*Andropogon scoparius* Michx.), Switchgrass (*Panicum virgatum* L.), and Indiangrass (*Sorghastrum nutans* (L.) Nash), cost more than $5.00 per pound of pure live seed (Ernst Conservation Seed, 2005). The harsh environment found on roadsides tends to inhibit the successful establishment of the competitively disadvantaged natives. Roadsides are typically seeded with aggressive species at high rates. Once established, they form an almost impenetrable ground cover that makes the establishment of native species nearly impossible

2.3. Revegetation Techniques

Cool season grasses begin growth in early spring and are generally highly productive in the spring and early summer and again in the fall. Late spring and early summer warm season grass plantings often fail due to dry soil conditions and competition from cool season grasses and broadleaf weeds. Since both soil moisture and weed competition are affected by planting date, early planting may take advantage of a larger amount and more even distribution of rainfall. Some warm season grasses, such as Switchgrass, have large percentages of dormant seed, so early planting may increase germination by exposing the seeds to cool moist conditions in the seedbed. A study conducted in eastern Nebraska found that early plantings, especially those done in March, produced Switchgrass seedlings that were more advanced developmentally and had greater shoot and adventitious root biomass than later plantings performed in May. May plantings did not catch up developmentally until July and never caught up in biomass (Smart and Moser, 1997). Other research suggests seeding Big Bluestem, Indiangrass, and Switchgrass in mid-April to mid-May to maximize emergence percentage and reduce the risk of high temperature and moisture stress, although successful stand establishment could be achieved with later seeding dates provided there is ample precipitation after seeding (Hsu and Nelson, 1986; Vassey et al., 1985).

It has been suggested that the addition of fertilizer does not greatly benefit native species plants, but rather it encourages the growth of invasives. An Australian study found that the addition of nutrients to low fertility soils is a critical prerequisite for invasion by non-native plants (Lake et al., 2004). Swan et al. (1993) found soil amendments were not needed to obtain good establishment of natives on Tennessee roadsides. A study looking at non-native invasive, non-native non-invasive, native invasive, and native non-invasive plant species response to additional nutrients also found this to be true. There was a strong biomass response to additional nutrients for all plant types except native non-invasives, and non-native invasive species had better survival than all other plant types. The same study also showed that while physical disturbance did not affect survival, phosphorus levels did. Non-native species had better survival than native species on high phosphorus soils, and non-native invasives had the strongest biomass response to high phosphorus soils while native and non-native non-invasives showed smaller growth responses (Leishman and Thomson, 2004). Thompson et al. (2001) found that after two years, native plant establishment was better promoted by disturbance and less so by increased fertility. But after five years, native plant establishment was greatest where the highest levels of fertility and disturbance coincided. In another study, Thomson and Leishman (2004) found that the survival of native seedlings declined with increasing nutrient addition (particularly phosphorus) and that the decline was less obvious in native species that were adapted to higher nutrient soils. The researchers also looked at six month old transplants and found them to be less sensitive to nutrient addition than the seedlings. This is an important finding for the revegetation process as it suggests that mature plants can overcome the nutrient enrichment by having deep roots. However in the long term, the inability of seedlings to establish in a nutrient enriched environment may result in the decline of the native population in that area.

Conversely, Richardson and Diseker (1962) found that fertilizer treatment of 560 kg/ha of 4-12-12 followed by 56 kg N one to three months later resulted in vigorous growth and development of naturally seeded native species as a protective cover. Further, dry matter yields of Switchgrass and Big Bluestem increased from 4 Mg/ha to 8 Mg/ha with the application of 150 kg/ha of nitrogen (Hall et al., 1982). However, in this instance, the grasses were not grown in the presence of aggressive species that would compete for the nutrients.

Effective weed control is required for successful revegetation. Swan et al. (1993) found the use of herbicides very effective in controlling weeds during native wildflower establishment. glyphosate [*N*-(phosphonomethyl)glycine] was applied at recommended rates to the research areas, and then two weeks later the areas were mowed and lightly tilled. After two weeks, researchers either made another application of glyphosate to kill any plants that had germinated after being brought to the surface by the tilling, or used a flail mower and seeded immediately. Other research found that when atrazine was used for weed control, a Switchgrass seeding rate of 3.4 kg PLS/ha (Pure Live Seed/hectare) is sufficient for good stand establishment, but without atrazine 6.7 kg PLS/ha is better under competitive stress conditions (Vassey et al., 1985). Vogel

(1987) found good stands of Switchgrass and Big Bluestem could be established at seeding rates as low as 107 PLS/m^2 with the use of either 2.2 or 3.0 kg a.i./ha of atrazine. Conversely, while a trend was shown for higher yields of Big Bluestem and Switchgrass when atrazine was used, Hintz et al. (1998) found no significant statistical difference between the yields.

2.4. Species Descriptions – Native Species

Indiangrass (*Sorghastrum nutans* (L.) Nash)

Indiangrass is one of the major species of the tall grass prairie region, and is widely distributed throughout the US east of the Rocky Mountains. Culms grow from rhizomes and are 1-2 meters tall. Panicles are 15-30 cm long and bronze to yellow in color. Tillers of Indiangrass are mostly biennial and produce a rhizome, root system, and aerial leaves the first year, and leaves, roots and sometimes an inflorescence the second. Seed dormancy can reduce establishment, however, moist chilling of the seed can reduce the dormancy (Voight and MacLauchlan, 1985).

Switchgrass (*Panicum virgatum* L.)

Switchgrass is a variable species that produces culms 1-2 meters tall from rhizomes. It grows in association with the other important species of the tall grass region and occurs throughout the contiguous US except the far west. Seed production and establishment are relatively easy compared to some of the other tall grasses, and switchgrass responds well to N fertilization (Voight and MacLauchlan, 1985).

Big Bluestem (*Andropogon gerardii* Vitman)

A dominant species of the tall grass prairie region, Big Bluestem is found throughout the contiguous US except for several western states. It is a bunchgrass, 1-2 meters tall with leaves 5-10 mm wide, that occurs with or without rhizomes and is well adapted to loamy soils (Voight and MacLauchlan, 1985).

Little Bluestem (*Andropogon scoparius* Michx.)

Similar to Big Bluestem, Little Bluestem is also a primary grass of the tall grass prairie region. It is a bunchgrass with or without rhizomes and grows to a height of about 1 m. It is found throughout the contiguous US except for Nevada and the Pacific Coast states. It is more drought resistant and can persist on loamy to clay soils in drier climates than Big Bluestem, Indiangrass, or Switchgrass (Voight and MacLauchlan, 1985).

Butterfly Weed (*Asclepius tuberosa* L.)

Butterfly Weed is a very desirable, showy and low-maintenance plant. It has a long period of bloom and responds well to mowing (Swan et al., 1993). It is easily grown in average, dry to medium wet, well-drained soils in full sun, is drought tolerant, and does well in poor, dry soils. Butterfly Weed can be grown easily from seed and frequently self-seeds, but is slow to establish and can take 2-3 years to produce flowers. It has a long, tuberous taproot and grows in a clump to 1m tall. Butterfly Weed occurs in dry/rocky open woods, glades, prairies, fields and roadsides (Missouri Botanical Garden, 2005).

Early Goldenrod (*Solidago juncea* Ait.)

Early Goldenrod is one of the earliest blooming goldenrods. It is an attractive, slender plant with a delicate appearance. The root system consists of a short caudex (on old plants), which may produce rhizomes and vegetative offshoots. It prefers full to partial sun, and mesic to slightly dry conditions, although moist conditions are tolerated if the soil is reasonably well-drained. It grows to 1m and is often found in dry, open woods, rocky banks, and roadsides (Illinois Wildflowers, 2005).

Ox-eye Sunflower (*Heliopsis helianthoides* (L.) Sweet)

Ox-eye Sunflower is a fast-growing relative of the true sunflowers. It is a clump-forming, upright, perennial found in open or rocky woods, thickets, prairies and along railroads. It grows 1 to 2m tall and has an abundance of bright yellow flowers that appear in June and will often bloom into September. Ox-eye Sunflower tolerates drought, some shade, and a wide range of soils. It does not spread by rhizomes, but self-sows readily on open soil (Prairie Nursery, 2005, and Missouri Botanical Garden, 2005b).

Brown-eyed Susan (*Rudbeckia triloba* L.)

Brown-eyed Susan is a biennial or short lived perennial that grows very erect to about 1m tall, and is spreading and bushy. It is very drought, heat, and pest tolerant. It is a self seeder and can spread slowly by rhizomes. Brown-eyed Susan can be found in rocky woods and old fields (North Creek Nurseries, 2005).

Gray Beardtongue (*Penstemon canescens* Britton)

Gray Beardtongue is a clump-forming, rhizomatous perennial which typically grows to 1m tall. It is native to dry slopes and woods primarily in the Appalachian Mountains from Pennsylvania south to North Carolina and Alabama. It is easily grown in average, dry to medium wet, well-drained soils in full sun (Missouri Botanical Garden, 2005c).

Wild Senna (*Cassia hebecarpa* Fernald)

Wild Senna is an upright perennial legume that grows from 1 to 2m tall. It prefers moist soil and can be found in thickets, moist open woods, and disturbed areas (Connecticut Botanical Society, 2005).

Partridge Pea (*Chamaecrista fasciculata* Michx.)

Partridge Pea is a reseeding annual legume often used for land stabilization, erosion control, and reclamation, from where it frequently escapes. It grows to 1m tall and has several branches that grow both erect and prostrate, forming dense stands. The root system consists of a central taproot and smaller axillary roots. The bloom season is long, lasting from mid-summer to fall. It grows well in several soil types, but favors poor soil and disturbed areas because of reduced competition from other plants. Partridge Pea is easy to grow, and can spread readily in dry, open situations (Bamert Seed, 2005 and Illinois Wildflowers, 2005b).

American Vetch (*Vicea americana* Muhl.)

American Vetch is a climbing perennial legume that can grow to 1m. Often the stems are tangled and sprawled along the ground or climbing on other plants. Often found in open or mixed forests, fields, clearings, and roadsides (Boreal Forest, 2005).

2.5. Species Descriptions – Non-Native Species

Tall fescue (*Festuca arundinacea* Schreb.)

Tall fescue was introduced from Europe sometime in the 1800's. It is a cool-season, perennial tufted bunchgrass that may or may not have short rhizomes. Culms are erect, stout, and smooth, achieving a maximum height of 2 m. It has numerous shiny, dark green leaves and branched, panicle-type heads 10-35 cm long. It is well adapted to the humid temperate areas of the US and is grown from Florida to Canada. It is typically taller, more drought tolerant, forms denser stands, more competitive with weeds, and thrives on a wider range of soils than other *Festuca* species; and is the major cool season grass species in the US, covering an estimated 12-14 million ha in pure and mixed stands. Although Tall fescue grows best on good, moist soils that are heavy to medium textured and high in humus, it can exist on soils that vary from strongly acid (pH 4.7) to alkaline (pH 9.5). It thrives and conserves soils on thin, droughty slopes and can form dense sods on poorly drained soils where few other cool season grasses survive. Its massive root structure is often attributed to its adaptability to many soil types and conditions, as well as being credited with decreasing bulk density, improving soil structure and reducing erosion. Tall fescue is not difficult to establish under adverse conditions, however it does best on high fertility soils (Buckner, 1985).

Red fescue (*F. rubra* L.)

Red fescue is a cool-season grass primarily used for lawns and turf, especially in shaded areas. It is a very fine bladed grass with a deep green color. Red fescue has two distinct growing habits. Creeping Red fescue spreads very slowly by short rhizomes and Chewings fescue is a bunchgrass with an upright habit. It is a low maintenance grass that does not require much fertilizer or need excessive amounts of water (UC IPM On-line, 2005).

Annual ryegrass (*Lolium multiflorum* Lam.)

Annual ryegrass is a native of Europe. It is adapted to temperate regions and is used widely throughout the world as pasture and hay. It grows best on fertile, well-drained soils, but can be grown in areas where the soil is so wet at certain times of the year that few other grasses will survive and grow satisfactorily. Annual ryegrass tends to perform poorly with extended low or high temperatures, drought, or poor fertility. Where well adapted, Annual ryegrass is very competitive with other grasses, legumes, and weeds. It has a bunch-type growth and gets as tall as 120 cm plants are leafy and dark green in color. Culms are erect or spreading, and the spike type inflorescence can be up to 30 cm in length (Riewe and Mondart, Jr., 1985).

Crownvetch (*Coronilla varia* L.)

Crownvetch is a non-native herbaceous perennial legume with creeping stems up to 2m long, and leaves consisting of 15-25 pairs of oblong leaflets. It has a reclining growth habit and rhizomes that can grow up to ten feet long, thereby contributing to rapid and extensive vegetative spread. Flower clusters occur in umbels on long, extended stalks, range in color from pinkish-lavender to white, and bloom from May through August. Crownvetch has been planted extensively in the northern two-thirds of the United States on road banks and other areas prone to erosion. It readily escapes cultivation and may be found invading remnant prairies, woodland edges, agricultural fields, hayfields, pastures, and the banks and gravel bars of streams (Wisconsin Department of Natural Resources, 2005).

Birdsfoot Trefoil (*Lotus corniculatus* L.)

Birdsfoot Trefoil is a low, mat-forming perennial legume. It has a tap root and develops rhizomes and stolons from which it can spread to form dense patches. Birdsfoot Trefoil is often used to stabilize soil or as a forage crop, and is found on roadsides, old fields, and disturbed areas. It tolerates a wide range of soil types and moisture conditions and can be an indicator of low soil fertility (Weed Alert, 2005).

2.6. Disturbed Soil Properties

Roadside soils typically contain little organic matter and microorganism activity, are low in plant available nutrients, have poor structural and textural properties, lack sufficient water holding capacity, drainage, and aeration, and are often highly susceptible to erosion (Franks, 1973). Due to the highway construction process, roadside soils are very similar to minesoils, and as such can be compared. Studies have found that mine soils typically have more rock fragments, higher bulk densities, lower porosities, and lower water retention differences than native soils. Additionally, soil pH, cation exchange capacity (CEC), electrical conductivity (EC), and exchangeable bases are generally lower (Daniels and Amos, 1982; Daniels and Zipper, 1997; Johnson and Skousen, 1995; Thurman and Sencindiver, 1986). Johnson and Skousen (1995) correlated plant cover to soil properties and found the most suitable mine soil for plant growth to have low exchangeable acidity, high base saturation, pH from 5.0 to 7.4, high CEC, high total sulfur, and low rock fragment content.

Rock fragment content can vary quite considerably on mine and other disturbed soils depending on differences in the parent materials hardness, blasting and handling techniques. Rock fragment content is highest initially and decreases with age due to weathering. The majority of plant available water in soils is held in pores formed by particles less than 2 mm in size. Soils high in rock fragments have larger pores that are unable to hold enough plant available water to sustain plant growth over the dry summer months (Daniels and Zipper, 1997).

Soil compaction limits plant growth by inhibiting root growth through high bulk density soils. The bulk density of productive natural soils typically ranges from 1.1 to 1.5 g/cm^3. Many mine soils are highly compacted as a result of the construction process and have bulk densities greater than 1.6 g/cm^3. A study of 5 to 20 year old mine soils found compaction to be the major soil factor limiting revegetation success (Daniels and Amos, 1981). As with soils high in rock fragments, high bulk density soils are also unable to hold enough plant available water to sustain plant growth through a drought (Daniels and Zipper, 1997).

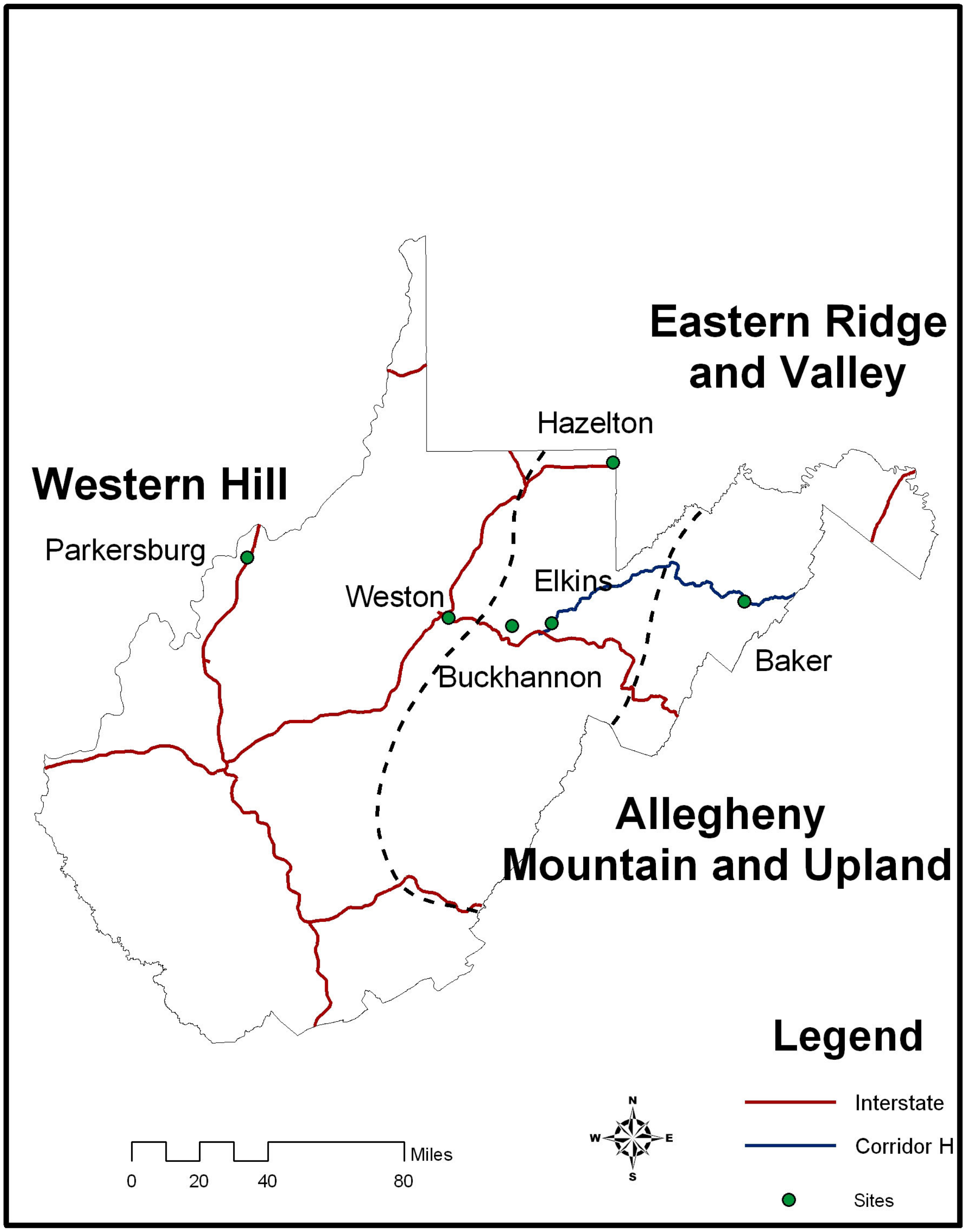
3. <u>Materials and Methods</u>

All sites were located along major highways in West Virginia. For a map showing the locations of the sites, see Figure 1.

<u>Objective 1</u> **-** Compare establishment and growth of plants in five different seed mixtures and two fertilizer treatments.

West Virginia can be divided into three distinct physiographic provinces: Eastern Ridge and Valley, Allegheny Mountain and Upland, and Western Hill. A research site was chosen in each province. The first site was located along a newly completed section of Appalachian Corridor H

Figure 1. Map of research sites including physiographic provinces.



near Baker, Hardy County. This is in the Eastern Ridge and Valley province, which is a lowland, above which rises longitudinal ranges. The area has a trellis-type drainage pattern and is dominated by farmland and oak-hickory-pine forests (Strausbaugh and Core, 1977).

The second site is located on I-79 at the West Virginia Welcome Center, near Hazelton, Preston County, in the Allegheny Mountain and Upland province of the state. This area is composed of northeast-southwest oriented mountain ranges, with deep intervening valleys. Drainage is dendritic in nature (Skousen and Fortney, 2003) and the vegetation can be described as belonging to the Northern Evergreen and Hardwood forest types (Strausbaugh and Core, 1977).

The third site is located near the intersection of I-77 and U.S. Route 50 in Parkersburg, Wood County, in the Western Hill province of the state. It is characterized as a mature plateau of strong to moderate relief. The drainage pattern is dendritic and the vegetation is classified as the Central Hardwood forest type (Strausbaugh and Core, 1977).

The study consists of testing five seed mixtures with two fertilizer treatments in a completely randomized design with four replications per treatment combination (40 plots per site). Plots measure 2m by 2m, with a 1-m buffer area between plots and were established in four rows of ten plots each, covering an 11m by 29m area. Seeded species and seeding rates within each seed mixture are shown in Table 2. Native species were chosen according to several criteria. They should be documented to occur naturally throughout the state (i.e. not specific to one location within the state), have the potential for sediment and erosion control, have esthetic or wildlife value, be widely available for purchasing from suppliers, and be cost-effective for large scale plantings.

Plots were established in April 2002. The soil was lightly tilled prior to seeding and plot boundaries were established with wooden stakes and twine. Fertilizer and seed was spread by hand on designated plots. The fertilizer used was a 10-20-20 N-P-K fertilizer at a rate of 150 kg/ha. After fertilizing and seeding, straw mulch was spread over the plots at an approximate rate of 1500 kg/ha to obtain about 80% coverage, then covered with a light plastic erosion control blanket to hold the straw in place. Plots were surveyed in June and October 2002 and 2003, and in June and September 2004 for total plant cover and dominant species. This was done by visually estimating projected cover contributed by the vegetation in four, randomly selected, 0.25m by 0.25m sub-plots. Cover was recorded as a class (Table 3) and the midpoint of

Table 2. Seeded species and seeding rates (kg/ha) of the four seed mixtures used in Objective 1 of the Native Plant Highway Study in West Virginia (DOH, Native, DOH-Native, and ½ DOH-Native seed mixtures).

	Seed Mixtures			
Seeded Species	DOH	Native	DOH-Native	½ DOH-Native
	---------------------------kg/ha---------------------------			
Tall fescue (*Festuca arundinacea* Screb.)	5		5	2.5
Red fescue (*F. rubra* L.)	5		5	2.5
Annual Ryegrass (*Lolium multiflorum* Lam.)	1.75		1.75	0.875
Birdsfoot Trefoil (*Lotus corniculatus* L.)	2.5		2.5	2.5
Indiangrass (*Sorghastrum nutans* (L.) Nash)		1.25	1.25	1.25
Big Bluestem (*Andropogon gerardii* Vitman)		1.25	1.25	1.25
Early Goldenrod (*Solidago juncea* Ait.)		0.5	0.5	0.5
Butterfly weed (*Asclepius tuberosa* L.)		0.25	0.25	0.25
Brown-eyed Susan (*Rudbeckia triloba* L.)		0.25	0.25	0.25
Gray Beardtongue (*Penstemon canescens* Britton)		0.25	0.25	0.25
Wild Senna *(Cassia hebecarpa* Fernald)		1.25	1.25	1.25

Table 3. Values used for the estimation of vegetative cover.

Cover Class	Range, %	Midpoint of Cover Class, %
1	0-5	2.5
2	5-25	15.0
3	25-50	37.5
4	50-75	62.5
5	75-95	85.0
6	95-100	97.5

the class range was used for averaging across sub-plots (Daubenmire, 1968).

Fall plantings were also established on the Baker and Hazelton sites in October 2002 using the same methods as above to evaluate differences between times of seeding. These sites were also surveyed in June and October 2003 and June and September 2004 for total plant cover and dominant species.

Objective 2 - Develop surface treatments to enhance the establishment of native species plants along highways.

Three sites were chosen along U.S. Route 33 in West Virginia. The first site is located near Weston, Lewis County, on the bench of a cut slope, which was constructed about 30 years ago. The second site is located in Barbour County, approximately 10 miles east of Buckhannon, on the bench of a fill area, constructed about 20 years old. The third site is located east of Elkins, Randolph County, in a fill area and was constructed three years ago.

The study consists of testing five surface treatments and two fertilizer rates in a completely randomized design with four replications per treatment combination. Plots are 2m by 2m with a 1m buffer zone between plots. Due to spatial constraints plots were established in a single row spanning 119m on the Weston and Buckhannon sites, and in four rows of ten plots each covering an 11m by 29m area on the Elkins site. Surface treatments were as follows: 1) mow and seed, 2) till and seed, 3) herbicide and seed, 4) control (no treatment) and seed, and 5) control (no treatment) with no seed. Plots were established in April 2003. Once plot boundaries were established with wooden stakes and twine, the designated surface treatments were applied. The herbicide used was Glyphosate and was applied two weeks before seeding. This is the recommended length of time for the herbicide to become inactive in the soil and thus not harm or prevent the germination and establishment of the seeded plants.

Plots were hand seeded and fertilized at a rate of 300 kg/ha of 10-20-20 N-P-K fertilizer. Seeded natives were chosen in accordance with the same criteria as Objective 1 and rates can be found in Table 4. Plots were surveyed in June and October 2003 and in June and September 2004 for total plant cover, as well as individual species cover.

Fall plantings were established on the Elkins site in October 2003 using the same methods as above to evaluate differences between times of seeding. These plots were also surveyed in June and September 2004 for total plant cover and dominant species.

Table 4. Seeded species and seeding rates (kg/ha) used for Objective 2 in the Native Plant Highway Study in West Virginia.

Seeded Species	Rate
	kg/ha
Switchgrass (*Panicum virgatum* L.)	5
Little Bluestem (*Andropogon scoparius* Vitman)	5
Partridge Pea (*Chamaecrista fasciculate* Michx.)	5
American Vetch (*Vicea Americana* Muhl.)	2
Ox-Eye Sunflower (*Heliopsis helianthoides* (L.) Sweet)	2
Brown-eyed Susan (*Rudbeckia triloba* L.)	2

Objective 3 – Correlation of native species establishment to soil physical and chemical properties.

In Spring 2004, soil samples were obtained using a shovel from a 0-10 centimeter depth at three different locations on each of the six previously mentioned sites. Soil samples were taken at different locations on the sites due to the differing spatial arrangements of the sites. At Weston and Buckhannon, samples were taken approximately every 60m in a linear transect, while the remaining sites were sampled approximately every 31m on a diagonal transect. The samples were brought back to the laboratory, air-dried, and passed through a 2 millimeter sieve to remove rock fragments prior to analysis.

Soil pH was measured with a Fisher Scientific Accumet pH meter on a 1:1 soil/water paste (Soil Survey Staff, 1996) and electrical conductivity (EC) was measured with a Markson Solution Analyzer on a 1:1 soil/water paste (Gartley, 1995). Organic matter was determined by a loss of weight on ignition (Nelson and Sommers, 1996). Total carbon, nitrogen, and sulfur were determined using a LECO C-N-S 2000 analyzer. A 1M ammonium acetate extraction at pH 7.0 was used to determine cation exchange capacity (CEC) and extractable bases (Ca, Mg, Na, and K) (Soil Survey Staff, 1996). Samples were then analyzed with a Tecator Kjeltec Auto 1030 analyzer to determine CEC, with a Perkin Elmer Plasma 400 ICP Spectrometer for Ca and Mg, and a Perkin Elmer AAnalyst 100 atomic absorption spectrometer for Na and K. Soils underwent a Mehlich-3 extraction and were analyzed with a Perkin Elmer AAnalyst 100 atomic absorption spectrometer to determine phosphorus, zinc, copper, and manganese (Mehlich, 1984).

Bulk density was determined using the frame excavation method and was adjusted for rock fragments (Grossman and Reinsch, 2002). Rock fragment percentages were determined from bulk density data, assuming a particle density of 2.65 g/cm^3. Texture was determined on the <2mm fraction by the pipette method (Soil Survey Staff, 1996). Samples were pretreated with hydrogen peroxide to remove organic matter and with sodium acetate to remove carbonates. Water retention difference (WRD) was calculated as the difference in soil moisture percentage between 1/3 and 15 bar as determined on a pressure plate apparatus. These moisture differences were adjusted for bulk density and volume of material <2mm (Soil Survey Staff, 1996).

Data for all three objectives were analyzed using SAS (SAS Institute, 2001). P-values below 0.05 were considered statistically significant.

4. Results and Discussion

4.1. Objective 1

This portion of the study assessed the establishment of species typically used by the DOH and some selected native species at three sites in West Virginia. Due to similarities in data trends, unless specified otherwise, only data from the Fall vegetation surveys will be discussed.

Total Plant Cover

Baker. Trends were similar for all three years at the Baker site, with slightly more significant effects after one growing season than after the second or third. By Fall 2002 (one growing season), the average cover was 28% (Table 5). This increased to 68% after two growing seasons, where it remained through the third growing season (Fall 2004). Fertilizer treatment was not significantly different and varied at most by 10% (73% for fertilized plots and 63% for unfertilized). The DOH, DOH-Native, and ½ DOH-Native plots had significantly higher total cover when compared to the Native and Control plots. Seed Mix-Fertilizer interactions followed this same trend. Little difference was seen for total cover between Native and Control plots.

For the Fall established plots at Baker, fertilizer only significantly increased total cover during the first growing season (Fall 2003) (Table 6). Overall, trends were similar to the Spring established plots. After one growing season, all seed mixes resulted in greater total cover than

Table 5. Total plant cover of Spring plantings at Baker with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Baker	Baker	Baker
	Sep-02	Sep-03	Sep-04
Fertilizer	-------------%-------------		
Fertilized	30 a*	69 a	73 a
Unfertilized	26 a	67 a	63 a
Seed Mix			
DOH	38 a	86 a	83 a
DOH-Native	35 a	89 a	81 a
½ DOH-Native	29 ab	81 a	82 a
Native	23 ab	43 b	48 b
Control	15 b	42 b	44 b
Interactions			
DOH Fertilized	38 a	88 a	81 a
DOH Unfertilized	38 a	85 a	85 a
DOH-Native Fertilized	38 a	86 a	85 a
DOH-Native Unfertilized	32 ab	91 a	77 a
½ DOH-Native Fertilized	32 ab	87 a	88 a
½ DOH-Native Unfertilized	26 abc	74 a	76 a
Native Fertilized	26 abc	43 b	59 b
Native Unfertilized	21 bc	43 b	37 c
Control Fertilized	15 c	40 b	50 bc
Control Unfertilized	15 c	44 b	38 c

*Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

the unseeded Control. However, after two growing seasons Native cover declined from 61% to 40%, and was no longer significantly different from the Control. Also, DOH and Control plots were the only ones to respond significantly to fertilizer.

Hazelton. Trends were also similar for all three years at the Hazelton site (Table 7). Total cover increased significantly each year (63% in Fall 2002, 77% in Fall 2003, and 89% in Fall 2004). Fertilizer only significantly increased total cover the first year of growth. After one growing season (Fall 2002), DOH, DOH-Native, and ½ DOH-Native plots had higher total covers compared to Native and Control plots, but after two growing seasons, the DOH and

Table 6. Total plant cover of Fall plantings at Baker with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Baker	Baker
	Sep-03	Sep-04
Fertilizer	---------%---------	
Fertilized	66 a*	65 a
Unfertilized	54 b	59 a
Seed Mix		
DOH	68 a	81 a
DOH-Native	65 ab	71 a
½ DOH-Native	55 ab	72 a
Native	61 ab	40 b
Control	52 b	46 b
Interactions		
DOH Fertilized	75 a	87 a
DOH Unfertilized	62 a	75 ab
DOH-Native Fertilized	67 a	69 bc
DOH-Native Unfertilized	64 a	74 b
½ DOH-Native Fertilized	62 a	74 b
½ DOH-Native Unfertilized	47 b	69 bc
Native Fertilized	61 a	38 d
Native Unfertilized	60 a	41 d
Control Fertilized	65 a	57 c
Control Unfertilized	38 b	34 d

*Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

DOH-Native plots were significantly different from the ½ DOH-Native, Native, and Control plots. Similar trends were found for the Seed Mix-Fertilizer interactions.

Total cover was similar across all of the Fall established plots at Hazelton for all surveys (Table 8). The only significant interactions were found for the Summer 2003 survey (Table 29, Appendix). At the beginning of the first growing season (Summer 2003), only the DOH plots were found to respond significantly to fertilizer.

Table 7. Total plant cover of Spring plantings at Hazelton with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Hazelton Sep-02	Hazelton Sep-03	Hazelton Sep-04
Fertilizer		-------------%-------------	
Fertilized	67 a*	78 a	88 a
Unfertilized	60 a	76 a	90 a
Seed Mix			
DOH	65 a	82 a	86 a
DOH-Native	71 a	86 a	82 a
½ DOH-Native	65 a	72 a	92 a
Native	59 a	71 a	91 a
Control	56 a	75 a	92 a
Interactions			
DOH Fertilized	68 ab	80 ab	76 bc
DOH Unfertilized	63 bc	83 ab	96 a
DOH-Native Fertilized	79 a	88 a	92 ab
DOH-Native Unfertilized	63 bc	84 a	73 c
½ DOH-Native Fertilized	74 ab	68 bc	91 ab
½ DOH-Native Unfertilized	56 c	75 abc	93 ab
Native Fertilized	63 bc	78 abc	88 abc
Native Unfertilized	56 c	64 c	94 a
Control Fertilized	50 c	78 abc	93 ab
Control Unfertilized	63 bc	71 abc	92 ab

*Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

Unfertilized DOH plots had significantly less total cover when compared to all other plots. Most significant effects disappeared by the Summer 2004 sampling, with unfertilized Control plots having less total cover than all others.

Parkersburg. The Parkersburg site had very similar total cover averages across all treatments, especially in the October 2002 sampling (Table 9). This is due to Department of Highway crews inadvertently hydro-seeding over the plots in the summer of 2002. Because of this, the vegetation in all plots was nearly 100% and composed of DOH seeded species. As a result, no significant differences were found for Fall surveys and few were found for Summer

Table 8. Total plant cover of Fall plantings at Hazelton with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Hazelton Sep-03	Hazelton Sep-04
Fertilizer	---------%---------	
Fertilized	89*	96
Unfertilized	83	97
Seed Mix		
DOH	87	96
DOH-Native	84	97
½ DOH-Native	85	98
Native	86	96
Control	88	97
Interactions		
DOH Fertilized	90	95
DOH Unfertilized	83	98
DOH-Native Fertilized	90	97
DOH-Native Unfertilized	78	97
½ DOH-Native Fertilized	83	98
½ DOH-Native Unfertilized	88	98
Native Fertilized	90	95
Native Unfertilized	82	97
Control Fertilized	91	97
Control Unfertilized	84	97

*There were no significant differences found.

surveys (Table 30, Appendix). The Summer 2003 survey found total cover to be significantly decreased in plots seeded with a pure DOH seed mix. By Summer 2004 (beginning of the third growing season), significant interactions had been reduced to unfertilized DOH plots having less total cover than fertilized DOH plots.

Seeded Native Plant Cover

The ground cover contributed by the seeded natives was minimal at all sites until 2004. The Native plots had the highest seeded native coverages. The Parkersburg site had the highest seeded native coverages in spite of the hydro-seeding, and Hazelton had the lowest. Fertilizer was not found to be significant across sites, treatments and years. No significant differences

Table 9. Total plant cover of Spring plantings at Parkersburg with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Parkersburg Sep-02	Parkersburg Sep-03	Parkersburg Sep-04
Fertilizer		-------------%-------------	
Fertilized	98*	96	96
Unfertilized	98	96	96
Seed Mix			
DOH	98	95	94
DOH-Native	98	96	96
½ DOH-Native	98	97	97
Native	98	98	98
Control	98	96	98
Interactions			
DOH Fertilized	98	98	96
DOH Unfertilized	98	93	93
DOH-Native Fertilized	98	95	94
DOH-Native Unfertilized	98	96	98
½ DOH-Native Fertilized	98	98	98
½ DOH-Native Unfertilized	98	97	97
Native Fertilized	98	98	98
Native Unfertilized	98	98	98
Control Fertilized	98	95	98
Control Unfertilized	98	97	98

*There were no significant differences found.

were found for either the Spring or Fall established plots at the Hazelton site (Tables 10 and 11), nor were there any significant differences at the other sites until 2004.

For the Spring established plots at Baker, the Native plots had significantly higher seeded native cover when compared to the other seed mixtures and fertilized Native plots had significantly higher cover than unfertilized (Table 12). Native and ½ DOH-Native plots were found to have significantly higher seeded native covers for Fall established plots (Table 13).

At Parkersburg, Native and ½ DOH-Native plots had the highest seeded native covers, and the unfertilized ½ DOH-Native plots had significantly higher cover than the fertilized (Table 14).

Table 10. Seeded native cover of Spring plantings at Hazelton with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Hazelton Sep-02	Hazelton Sep-03	Hazelton Sep-04
Fertilizer		-------------%-------------	
Fertilized	0*	0	0
Unfertilized	0	0	0
Seed Mix			
DOH	0	0	0
DOH-Native	0	0	1
½ DOH-Native	0	0	0
Native	0	0	0
Control	0	0	0
Interactions			
DOH Fertilized	0	0	0
DOH Unfertilized	0	0	0
DOH-Native Fertilized	0	0	0
DOH-Native Unfertilized	0	0	2
½ DOH-Native Fertilized	0	0	0
½ DOH-Native Unfertilized	0	0	0
Native Fertilized	0	0	0
Native Unfertilized	0	0	0
Control Fertilized	0	0	0
Control Unfertilized	0	0	0

*There were no significant differences found.

Summary

Site had a significant effect on total plant cover, with Parkersburg having the highest coverages and Baker the lowest. It did not have an effect on seeded native cover, however. The Parkersburg site had very similar total cover averages across all treatments, especially in the Fall 2002 sampling. This is due to Department of Highway crews inadvertently hydro-seeding over the plots in the summer of 2002. The hydro-seeded mixture included fertilizer and a mixture of Annual ryegrass, Tall fescue, and Red clover (*Trifolium pratense* L.). The Baker site, on the other hand, was the newest of the sites and had very little vegetation established prior to seeding, thus resulting in low coverages, particularly on the Native and Control plots.

Table 11. Seeded native cover of Fall plantings at Hazelton with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Hazelton Sep-03	Hazelton Sep-04
Fertilizer	---------%---------	
Fertilized	0*	0
Unfertilized	0	0
Seed Mix		
DOH	0	0
DOH-Native	0	0
½ DOH-Native	0	0
Native	0	0
Control	0	0
Interactions		
DOH Fertilized	0	0
DOH Unfertilized	0	0
DOH-Native Fertilized	0	0
DOH-Native Unfertilized	0	0
½ DOH-Native Fertilized	0	0
½ DOH-Native Unfertilized	0	0
Native Fertilized	0	0
Native Unfertilized	0	0
Control Fertilized	0	0
Control Unfertilized	0	0

*There were no significant differences found.

Fertilizer and seed mix were also found to have significant effects on total cover, while only seed mix was significant for seeded native cover. Fertilized, and DOH and DOH-Native plots had the highest total cover (Fertilized = 71%, DOH = 73%, DOH-Native = 74%), while unfertilized, and Control and Native plots had the lowest (Unfertilized = 67%, Control = 62%, Native = 63%). For seeded native cover, Native plots followed by ½ DOH-Native plots, had the highest cover (Native = 4%, ½ DOH-Native = 2%). It is important to point out that for total cover, the Control plots were not significantly different from Native plots (Control = 62%, Native = 63%). However, they were significantly different for seeded native cover (Control = 0%, Native = 4%). That is to say that seeding with natives only, did not increase the total cover, but only affected the composition. The ½ DOH-Native plots had significantly greater total cover

Table 12. Seeded native cover of Spring plantings at Baker with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Baker Sep-02	Baker Sep-03	Baker Sep-04
Fertilizer		-------------%-------------	
Fertilized	0*	0	6 a[1]
Unfertilized	0	0	4 a
Seed Mix			
DOH	0	0	0 b
DOH-Native	0	0	0 b
½ DOH-Native	0	0	1 b
Native	0	1	24 a
Control	0	0	0 b
Interactions			
DOH Fertilized	0	0	0 c
DOH Unfertilized	0	0	0 c
DOH-Native Fertilized	0	0	0 c
DOH-Native Unfertilized	1	0	0 c
½ DOH-Native Fertilized	0	0	2 c
½ DOH-Native Unfertilized	0	0	0 c
Native Fertilized	1	2	29 a
Native Unfertilized	0	0	19 b
Control Fertilized	0	0	0 c
Control Unfertilized	0	0	0 c

*No significant differences were found for the September 2002 and 2003 surveys.

[1]Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

(72%) when compared to the Control and Native plots. However, it is believed that this significance is largely due to the Baker site. When looking at each sampling on each site, differences among the ½ DOH-Native plots and Control and Native plots were only apparent on that site. The Baker site was a newer site that did not have any vegetation established prior to this experiment, resulting in a smaller seed bank from which revegetation could occur. It is highly compacted and contains 40% rock fragments (compared to 10% for Parkersburg and 25% for Hazelton). More individual seeded native plants were observed at this site when compared to

Table 13. Seeded native cover of Fall plantings at Baker with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Baker Sep-03	Baker Sep-04
Fertilizer	---------%---------	
Fertilized	0*	1 a[1]
Unfertilized	0	3 a
Seed Mix		
DOH	0	0 b
DOH-Native	0	1 ab
½ DOH-Native	0	6 a
Native	0	4 ab
Control	0	0 b
Interactions		
DOH Fertilized	0	0 b
DOH Unfertilized	0	0 b
DOH-Native Fertilized	0	0 b
DOH-Native Unfertilized	0	3 ab
½ DOH-Native Fertilized	0	2 b
½ DOH-Native Unfertilized	0	9 a
Native Fertilized	0	4 ab
Native Unfertilized	0	3 ab
Control Fertilized	0	0 b
Control Unfertilized	0	0 b

*No significant differences were found for the September 2003 survey.

[1]Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

the other sites. However, probably as a result of compaction, their size was small so they did not contribute much ground cover. Both Hazelton and Parkersburg had pre-existing vegetation. It is believed that this difference between the sites is the reason why there were many more significant differences found at the Baker site.

The Hazelton site had been hydro-seeded two years prior to plot establishment, resulting in a large seed bank remaining in the soil. The tilling used in plot establishment may have brought much of that seed to the surface for germination and as a result may have competed and

Table 14. Seeded native cover of Spring plantings at Parkersburg with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Parkersburg	Parkersburg	Parkersburg
	Sep-02	Sep-03	Sep-04
Fertilizer		-------------%-------------	
Fertilized	0*	0	9 a[1]
Unfertilized	0	1	13 b
Seed Mix			
DOH	0	0	0 c
DOH-Native	0	0	11 b
½ DOH-Native	0	1	20 a
Native	0	1	25 a
Control	0	0	0 c
Interactions			
DOH Fertilized	0	0	0 c
DOH Unfertilized	0	0	0 c
DOH-Native Fertilized	0	0	9 b
DOH-Native Unfertilized	0	1	14 b
½ DOH-Native Fertilized	0	0	15 b
½ DOH-Native Unfertilized	0	1	25 a
Native Fertilized	0	0	23 a
Native Unfertilized	0	2	28 a
Control Fertilized	0	0	0 c
Control Unfertilized	0	0	0 c

*No significant differences were found for the September 2002 and 2003 surveys.

[1]Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

impacted the establishment of the seeded natives. At Parkersburg, the inadvertent hydro-seeding a month after plot establishment essentially nullified any real and meaningful results at this site. However, a portion was inadequately hydro-seeded, as evidenced by the plots in that portion having lower plant cover estimates overall, as well as containing fewer of the hydro-seeded species. It was in this portion that the seeded natives were primarily observed. While not many individual plants were seen, those present were larger than those observed at the Baker site.

Results indicate that one cannot seed the natives tested in combination with typical DOH species, or into established stands, and achieve a significant amount of native cover. The natives performed better in areas where there was a lack of pre-existing vegetation and a small seed bank due to a lack of competition for resources.

The results of this study varied from that of other studies in reference to time of planting. Previous work found that early spring plantings of warm-season grasses performed best (Hsu and Nelson, 1986, Smart and Moser, 1997, and Vassey et al., 1985). This study found only minor differences in time of planting at the Baker site (none at Hazelton), where for one sampling date, the Fall established natives had significantly higher cover than the Spring established. However, the previously mentioned studies did not test Fall planting times, but were focused on timing during the spring and summer months. It was hypothesized that by seeding in the Fall, the cold winter temperatures would help to break dormancy of the native seeds, thereby increasing germination, as well as to allow for an early start to their growth so that they could better compete with the aggressive cool-season grasses. However, there was no strong evidence that this occurred.

This study agrees with Leishman and Thomson (2004), who found there was an increased biomass response to fertilizer for non-native species. While increasing total cover, fertilizer had no effect on seeded native cover. It is believed that the natives often found on disturbed soils established themselves on areas of low fertility, and therefore the addition of nutrients is of little benefit to them.

4.2. Objective 2

This objective was developed to determine the effect of disturbance (mowing, tilling, and herbicide) on native species establishment in three different aged stands in West Virginia. Due to similarities in data trends, unless specified otherwise, only data from the Fall surveys will be discussed.

Total Plant Cover

Site and disturbance treatment had significant effects on total cover. The Elkins site, which was the newest of the sites since highway construction, had the lowest total plant cover (52%),

Table 15. Total plant cover of Spring plantings at Weston with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Weston Sep-03	Weston Sep-04
Fertilizer	---------%---------	
Fertilized	80 a*	84 a
Unfertilized	81 a	90 a
Disturbance		
Control	93 a	88 ab
Seed	88 a	84 ab
Mow	92 a	93 a
Till	77 b	89 ab
Herbicide	52 c	79 b
Interactions		
Contol Fertilized	88 a	82 bc
Control Unfertilized	98 a	94 ac
Seed Fertilized	88 a	74 b
Seed Unfertilized	88 a	94 ac
Mow Fertilized	94 a	95 a
Mow Unfertilized	91 a	90 ac
Till Fertilized	70 bc	88 ac
Till Unfertilized	83 ab	91 ac
Herbicide Fertilized	58 cd	79 b
Herbicide Unfertilized	47 d	80 b

*Treatments within main effects (fertilizer, disturbance, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

and Weston, the oldest, had the highest (79%). Control, Mowed, and Seeded plots had the highest total plant cover (all at 74 %), while the Herbicide treated and Tilled plots had the lowest (45% and 52%, respectively).

Weston. Herbicide treated plots had significantly less total cover than all other disturbance treatments (Table 15). The fertilized Tilled plots had significantly less total cover than all but the Herbicide treated plots. After two growing seasons, there were fewer differences among disturbance-fertilizer combinations. The only significant differences found in Fall 2004 were between fertilized and unfertilized Control and Seeded plots (unfertilized plots had higher total

Table 16. Total plant cover of Spring plantings at Buckhannon with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Buckhannon Sep-03	Buckhannon Sep-04
Fertilizer	---------%---------	
Fertilized	69 a*	76 a
Unfertilized	66 a	75 a
Disturbance		
Control	89 a	84 a
Seed	88 a	89 a
Mow	82 a	88 a
Till	39 b	57 b
Herbicide	41 b	57 b
Interactions		
Contol Fertilized	87 ab	86 a
Control Unfertilized	91 a	83 a
Seed Fertilized	88 ab	85 a
Seed Unfertilized	88 ab	93 a
Mow Fertilized	90 a	91 a
Mow Unfertilized	74 b	85 a
Till Fertilized	43 c	53 b
Till Unfertilized	36 c	60 b
Herbicide Fertilized	40 c	63 b
Herbicide Unfertilized	42 c	51 b

*Treatments within main effects (fertilizer, disturbance, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

cover averages). Fertilized Seeded and Herbicide treated plots had the lowest total cover averages at 74% and 79%, respectively.

Buckhannon. Trends were similar for all surveys of the Buckhannon site (Table 16). Control, Mowed, and Seeded plots had significantly higher total cover averages than Herbicide treated and Tilled plots. Both fertilized and unfertilized Herbicide treated and Tilled plots were not significantly different from one another, nor were the fertilized Control, Mowed, and Seeded plots.

Table 17. Total plant cover of Spring plantings at Elkins with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Elkins	Elkins
	Sep-03	Sep-04
Fertilizer	---------%---------	
Fertilized	68 a*	67 a
Unfertilized	54 b	57 b
Disturbance		
Control	74 a	66 a
Seed	71 a	67 a
Mow	72 a	70 a
Till	51 b	62 a
Herbicide	38 b	44 b
Interactions		
Contol Fertilized	81 a	69 ab
Control Unfertilized	66 b	63 b
Seed Fertilized	83 a	75 a
Seed Unfertilized	60 b	59 bc
Mow Fertilized	82 a	74 ab
Mow Unfertilized	62 b	67 ab
Till Fertilized	56 bc	67 ab
Till Unfertilized	45c	58 bc
Herbicide Fertilized	38 c	50 cd
Herbicide Unfertilized	38 c	38 d

*Treatments within main effects (fertilizer, disturbance, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

<u>Elkins.</u> Trends were similar for all surveys of the Elkins site (Table 17). Herbicide treated plots had the lowest total cover and were significantly different from other disturbance treatments, and fertilizer was found to significantly increase total cover.

For the Fall established plots at the Elkins site (Table 18), fertilizer significantly increased total cover. Control, Seeded, and Mowed plots had significantly higher total cover than Tilled and Herbicide treated plots. When comparing Fall and Spring established plots it was found that Fall established plots had significantly lower total cover for Mow, Tilled, and fertilized Control plots compared to Spring established plots.

Table 18. Total plant cover and seeded native cover of Fall plantings at Elkins with and without fertilizer, seeded with various mixtures, and treatment combinations, September 2004.

Treatment	Total	Seeded Native
Fertilizer	---------%---------	
Fertilized	57 a*	2 a
Unfertilized	42 b	6 a
Disturbance		
Control	55 a	0 b
Seed	60 a	1 b
Mow	55 a	0 b
Till	42 b	6 a
Herbicide	37 b	11 a
Interactions		
Contol Fertilized	61 a	0 b
Control Unfertilized	50 ac	0 b
Seed Fertilized	68 a	0 b
Seed Unfertilized	51 ac	2 b
Mow Fertilized	68 a	0 b
Mow Unfertilized	43 bc	0 b
Till Fertilized	47 bc	1 b
Till Unfertilized	38 bc	12 a
Herbicide Fertilized	44 bc	8 a
Herbicide Unfertilized	30 b	15 a

*Treatments within main effects (fertilizer, disturbance, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

Seeded Native Plant Cover

Percent cover contributed by the seeded natives was minimal at all sites until the second growing season (2004). In 2003, seeded native cover was greatest at 16% in Tilled and Herbicide treated plots at the Elkins site, while in 2004 it had increased to 30-45% in the same plots. Fertilizer had no significant effect on seeded native cover, but disturbance did. While having the lowest total plant cover, the Tilled and Herbicide treated plots consistently had the highest cover contributed by the seeded natives (14% and 15%, respectively).

Table 19. Seeded native cover of Spring plantings at Weston with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Weston Sep-03	Weston Sep-04
Fertilizer	---------%---------	
Fertilized	3*	9 a[1]
Unfertilized	3	10 a
Disturbance		
Control	0	0 c
Seed	1	1 c
Mow	0	1 c
Till	8	13 b
Herbicide	7	33 a
Interactions		
Contol Fertilized	0	0 b
Control Unfertilized	0	0 b
Seed Fertilized	0	2 b
Seed Unfertilized	2	0 b
Mow Fertilized	0	0 b
Mow Unfertilized	0	1 b
Till Fertilized	7	13 b
Till Unfertilized	8	13 b
Herbicide Fertilized	10	29 a
Herbicide Unfertilized	5	38 a

*No significant differences were found for the September 2003 survey.

[1]Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

No significant effects were found for seeded native cover at Weston and Buckhannon until 2004. At the Weston site, Herbicide treated plots were significantly different from all others, with Herbicide treated plots having the highest seeded native cover (33%), followed by Tilled plots (13%) (Table 19). In Buckhannon, Herbicide treated and Tilled plots had significantly higher seeded native cover than the other disturbance treatments (Table 20). The Elkins site found Tilled plots to have the highest seeded native cover at 43%, with Herbicide treated and

Table 20. Seeded native cover of Spring plantings at Buckhannon with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Buckhannon	Buckhannon
	Sep-03	Sep-04
Fertilizer	---------%---------	
Fertilized	3	13 a[1]
Unfertilized	5	15 a
Disturbance		
Control	0	0 b
Seed	3	1 b
Mow	3	8 b
Till	9	31 a
Herbicide	5	31 a
Interactions		
Contol Fertilized	0	0 c
Control Unfertilized	0	0 c
Seed Fertilized	6	3 bc
Seed Unfertilized	0	0 c
Mow Fertilized	0	5 bc
Mow Unfertilized	5	10 b
Till Fertilized	5	25 a
Till Unfertilized	13	36 a
Herbicide Fertilized	5	31 a
Herbicide Unfertilized	5	31 a

*No significant differences were found for the September 2003 survey.

[1]Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

Mowed plots close behind at 32% and 30%, respectively (Table 21). For Fall established plots at Elkins, Herbicide treated plots and unfertilized Tilled plots had significantly higher seeded native cover compared to all other treatment combinations (Table 18). Fall established fertilized Tilled plots also had significantly lower seeded native cover (1% versus 16%).

Table 21. Seeded native cover of Spring plantings at Elkins with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Elkins	Elkins
	Sep-03	Sep-04
Fertilizer	---------%---------	
Fertilized	6 a*	25 a
Unfertilized	9 a	22 a
Disturbance		
Control	0 a	0 a
Seed	2 a	12 c
Mow	5 a	30 b
Till	16 b	43 d
Herbicide	13 b	32 b
Interactions		
Contol Fertilized	0 b	0 d
Control Unfertilized	0 b	0 d
Seed Fertilized	1 b	13 c
Seed Unfertilized	3 b	11 c
Mow Fertilized	2 b	32 ab
Mow Unfertilized	8 ab	28 b
Till Fertilized	16 a	45 a
Till Unfertilized	16 a	42 ab
Herbicide Fertilized	10 a	35 ab
Herbicide Unfertilized	16 a	30 ab

*Treatments within main effects (fertilizer, disturbance, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

Individual Species Response

Individual species response to the treatments applied was also evaluated for the seeded species as well as five of the most commonly occurring non-seeded species (Tall fescue, Red fescue, Crownvetch, Birdsfoot Trefoil, and Clover (*Trifolium* spp.)). Although American Vetch was seeded, no plants were seen; therefore it was removed from this analysis. Fertilizer did not significantly influence individual cover of the species tested, but treatment did significantly influence cover (Table 22). For the seeded natives, Herbicide treated and Tilled plots significantly increased their cover. Herbicide increased the cover of Brown-eyed Susan and

Table 22. Individual species response to fertilizer, disturbance, and fertilizer-disturbance interactions.

Treatment	Little Bluestem	Switchgrass	Partridge Pea	Ox-eye Sunflower	Brown-eyed Susan	Tall fescue	Red fescue	Crownvetch	Birdsfoot Trefoil	Clover
Fertilizer	------------------	------------------	------------------	------------------	-----%-----	------------------	------------------	------------------	------------------	
Fertilized	3 a*	1 a	1 a	0 a	2 a	11 a	20 a	14 a	2 a	1 a
Unfertilized	3 a	1 a	1 a	0 a	2 a	10 a	18 a	13 a	2 a	1 a
Disturbance										
Control	0 a	0 a	0 c	0 a	0 a	10 b	26 a	19 a	3 b	2 a
Seed	1 a	0 a	1 b	0 a	0 a	12 b	25 a	16 a	4 a	2 a
Mow	2 b	0 a	2 b	0 a	1 a	17 a	24 a	15 a	2 b	2 a
Till	6 b	2 b	3 a	0 a	3 b	12 b	13 b	9 b	1 b	0 b
Herbicide	5 b	2 b	1 b	1 b	6 c	1 c	8 c	10 b	1 b	1 b
Interactions										
Contol Fertilized	0 d	0 a	0 a	0 a	0 a	8 c	29 a	18 a	4 ab	1 a
Control Unfertilized	0 d	0 a	0 a	0 a	0 a	11 bc	23 a	19 a	2 b	2 a
Seed Fertilized	1 c	0 a	0 a	0 a	0 a	12 b	22a	19 a	3 ab	3 a
Seed Unfertilized	1 c	0 a	1 a	0 a	0 a	11 bc	28 a	12 a	5 a	2 a
Mow Fertilized	1 c	0 a	2 a	0 a	1 a	21 a	25 a	15 a	0 c	1 a
Mow Unfertilized	2 c	0 a	2 a	0 a	1 a	13 b	22 a	15 a	3 ab	2 a
Till Fertilized	5 a	2 a	3 a	0 a	3 a	11 bc	13 b	10 a	1 b	0 a
Till Unfertilized	6 a	3 a	3 a	0 a	3 a	12 b	13 b	7 a	1 b	0 a
Herbicide Fertilized	5 a	2 a	1 a	1 a	5 a	1 d	11 bc	9 a	1 b	1 a
Herbicide Unfertilized	4 a	2 a	1 a	1 a	7 a	0 d	6 c	10 a	1 b	0 a

*Treatments within main effects (fertilizer, disturbance, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

Ox-Eye Sunflower significantly when compared to tilling, but tilling significantly increased cover of Partridge Pea when compared to herbicide treatment. No significant difference was found between tilling and herbicide treatments for Little Bluestem and Switchgrass. Partridge Pea was the only seeded species to have had its cover increased by the Mowing treatment.

The inverse was found to be true for the non-seeded species. Herbicide and tilling decreased the cover of all the non-seeded species tested. Tall fescue was the only non-seeded species to have its cover increased by one of the disturbance treatments (Mow = 17%, Control = 10%).

Summary

Site had a significant effect on total cover; the Elkins site had the lowest total percent cover and Weston the highest. Fertilizer was also found to significantly increase total cover at this site. This is most likely due to the newness of the site. Even though the site had been seeded previously, very little ground cover had established before this project began.

Disturbance also had a significant effect on total cover. The Control, Mowed, and Seeded plots had the highest averages, while the Herbicide treated and Tilled plots had the lowest. This is to be expected, as the herbicide used, Glyphosate, is a non-selective, foliar applied, symplastically translocated herbicide. Therefore, all vegetation within the herbicide treated plots was destroyed. Tilling also destroyed most of the plants located within the plots. Plants subsequently found in these plots were either from seeds in the soil seed bank, wind deposited seeds, or those seeded for this study.

Ground cover contributed by the seeded natives was minimal at all sites in 2003 but significantly higher in 2004. In 2003, seeded native cover was greatest at 16% in Tilled and Herbicide treated plots at Elkins, while in 2004 it was 30-45% in the same plots. Fertilizer had no significant effect on seeded native cover; however, disturbance did have a significant effect. While having the lowest total cover averages, the Tilled and Herbicide treated plots had the highest cover contributed by the seeded natives. These plots had the competing vegetation removed, allowing the seeded natives to germinate and become established before other species invaded.

While Site did not have a significant effect on cover contributed by the seeded natives, it should be noted that Elkins had the most seeded native cover. This site had much less plant cover prior to plot establishment compared to Buckhannon and Weston, and the seeded natives were better able to become established with a lack of competing vegetation.

The results of this portion of the study partially concur with previous studies, which are a bit contradictory themselves. Thompson et al.'s (2001) finding that early on (after two years) native species establishment is better promoted by disturbance is similar to the findings of this study. However, Leishman and Thomson (2005) found physical disturbance had no effect on survival and growth of either native or non-native species, but fertility did increase survival and growth of non-natives. This also concurs with the results of this study as it was found that fertilizer did increase total cover, which was primarily composed of non-native species.

4.3. Objective 3

This objective involved the determination of soil properties at each of the six sites to assess the effect of soils on plant establishment. Soil pH ranged from 5.1 to 7.1 (Table 23). Electrical conductivity (EC), which serves as a measure of soluble salts in the soil, is an important measurement for roadside soils due to the application of de-icing salts in the winter. In West Virginia, bottom ash, which contains many trace elements and salts, from local power plants is used as a major de-icing material on highways. These salts can build up in the soil and negatively affect plant establishment and growth. All sites had low electrical conductivities except the Elkins site, which was almost 10 times higher than the other sites surveyed. The Elkins site is young and on grade with the road. Since the sampling locations at that site are approximately 10 meters from the road it is not believed that the higher salt content is a product of de-icing salts and/or bottom ash applications, but rather from the weathering and release of ions contained in the rocks that were used to build the road. The Elkins site is highly compacted and contained large amounts of shale rock fragments in the soil. Because of this, it is believed that leaching has not been sufficient yet to remove these ions from the soils. Over the next couple of years, as weathering and subsequent leaching occurs, the salts should be washed from the soil profile resulting in lower electrical conductivities.

Cation exchange capacity (CEC) and base saturation (BS) were moderate across most sites, and higher CECs were found to be correlated with higher total plant covers. Parkersburg and Weston CEC values were two times more, at 19.2 and 19.7 cmol/kg, than Baker and Hazelton

CECs at 7.9 and 8.7 cmol/kg, respectively. Base saturation ranged from 39% to 100% and was similar for three of the six sites. While having one of the highest CECs, Parkersburg had the lowest base saturation and this is due to much of the original native topsoil being replaced on this site, which contained higher clay contents and was more acidic. Of the extractable bases, Na and K were similar for all sites, while Ca and Mg varied considerably among the different sites. Calcium ranged from 2.4 cmol/kg to 18.2 cmol/kg, and Mg ranged from 0.2 cmol/kg to 1.6 cmol/kg. Elkins and Weston had the highest Ca concentrations and Baker had the lowest. Parkersburg and Weston had the highest Mg concentrations and Hazelton the lowest.

All sites had substantial soil organic matter, and soil organic matter was significantly correlated with total plant cover. The Weston and Buckhannon sites had the highest amount of organic matter (>6%). This most likely reflects the age and productivity of these sites as they are the oldest and therefore have had more time to accumulate organic matter. Values obtained for total carbon correlated with soil organic matter. The Weston and Buckhannon sites had the highest total carbon concentrations and Baker the lowest. Total carbon showed a trend to increase total plant cover, while total percent nitrogen tended to increase seeded native plant cover. The Elkins site had a higher nitrogen concentration (0.22 %) compared to the other sites (three times higher than Weston and seven times higher than Baker, Hazelton, Parkersburg, and Buckhannon) and this correlates to a significantly higher seeded native plant cover (10% versus 0-3%). The higher nitrogen concentrations at this site could relate to the lack of total cover (fewer plants available to remove nitrogen from soil) and to the lack of leaching as evidenced by the increased EC. Phosphorus concentrations were low at all sites. The Baker and Parkersburg sites had concentrations three times higher than the other sites. Copper and manganese concentrations were sufficient for plant growth at all sites. Zinc concentrations ranged from 2.2 to 12.5 mg/L and were significantly correlated to total plant cover but not to seeded native cover.

Total bulk density (Table 24) was variable across sites, ranging from 1.2 to 1.9 g/cm^3. Higher bulk densities were significantly correlated to decreased total cover but no correlation was found between bulk density and seeded native cover. Adjusted bulk density (<2mm) was similar across all sites. A negative trend was seen between rock fragment content and total plant cover, while a positive trend was seen for seeded native cover and rock fragments. A substantial amount of rock fragments occurred at all sites except Parkersburg, which contained only 2% by volume. The Elkins and Baker sites had the highest amount of rock fragments with 47 and 41%,

Table 23. Chemical properties of the upper 10 cm of soil (< 2mm fraction) found on six roadside sites in West Virginia.

Site	pH	EC (dS/m)	OM (%)	CEC (cmol/kg)	Extractable Bases ($cmol_c$/kg) Ca	Mg	Na	K	Base Saturation (%)	Total C (%)	Total N (%)	Total S (%)	P (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Mn (mg/kg)
Baker	6.5	0.15	1.7	7.9	2.4	1.0	0.05	0.37	50	0.6	0.0	0.1	24.3	2.2	2.2	174.4
Elkins	6.5	1.64	2.0	11.9*	18.2*	0.6	0.05	0.27	100*	1.0	0.2	0.1	5.9	3.3	2.2	58.2
Hazelton	6.1	0.16	2.7	8.7	4.0	0.2	0.06	0.35	55	0.9	0.0	0.1	8.4	5.8	1.2	124.2
Parkersburg	5.1	0.14	2.9	19.2	5.3	1.4	0.06	0.45	39	1.0	0.0	0.1	24.5	8.0	2.4	26.0
Buckhannon	5.7	0.15	6.0	12.2	4.6	0.9	0.07	0.41	51	3.0	0.0	0.2	3.9	12.5	3.0	94.5
Weston	7.1	0.30	6.4	19.7	14.1	1.6	0.08	0.37	83	2.9	0.1	0.2	1.2	6.7	8.2	75.5

*Soil contained excess calcium salts.

Table 24. Physical properties of the upper 10 cm of soil found on 6 roadside sites in West Virginia.

Site	Texture	WRD (cm/cm)	Bulk Density (g/cm3)	Bulk Density < 2mm (g/cm3)	Rock Fragments (%/Volume)
Baker	Sandy Loam	0.07	1.8	1.3	41
Elkins	Clay Loam	0.08	1.9	1.2	47
Hazelton	Loam	0.14	1.6	1.3	21
Parkersburg	Clay Loam	0.15	1.2	1.2	2
Buckhannon	Loam	0.16	1.5	1.1	22
Weston	Silt Loam	0.15	1.5	1.2	22

Table 25. Correlation table showing r-values.

Correlation Parameters	Total Cover	Seeded Native Cover
pH	-0.41	0.35
EC	-0.26	0.54
OM	0.83*	0.09
CEC	0.89*	0.20
Ca	0.37	0.60
Mg	0.54	0.03
Na	0.66	0.03
K	0.77	-0.20
Base Saturation	-0.26	0.54
Total C	0.71	0.43
Total N	0.09	0.71
Total S	0.09	0.60
P	-0.09	-0.60
Zn	0.83*	0.03
Cu	0.60	0.31
Mn	-0.66	-0.26
WRD	0.83*	0.03
Bulk Density	-0.93*	0.35
Bulk Density <2mm	-0.66	-0.43
Rock Fragments	-0.71	0.71

*Significant at p=0.05.

respectively. Water retention difference (WRD) was found to be significantly correlated to total plant cover but not to seeded native cover. At both the Elkins and Baker sites, the WRD was half that of the other four sites. Elkins and Baker are two of the youngest sites and therefore substantial weathering of rock material had not occurred. This would account for the higher rock fragment content as well as the higher bulk densities, lower water retention differences, and lower organic matter values at these sites compared to the older sites. Table 25 illustrates the r-values from the correlation analysis.

Summary

Few of the soil properties measured were significantly correlated to total cover (OM, CEC, WRD, zinc and total bulk density only) and none were significantly correlated to the seeded native cover. Some of the younger sites had lower total covers and corresponding soil physical properties that would be expected to impede plant establishment and growth (i.e. high bulk densities, high rock fragment content, low organic matter). However, the seeded natives were not as inhibited by these poor soil conditions. Elkins had the highest bulk density and rock fragment content (1.9 g/cm^3 and 47%, respectively) and one of the lowest water retention differences (0.08 cm/cm) and yet had the highest seeded native cover (10%). The five other sites had similar and much lower seeded native covers (≤3%), yet had soil properties considered better for plant establishment. This lack of seeded natives is most likely due to the amount of total cover on these sites competing for resources and impeding native establishment, rather than a soil physical or chemical problem.

5. Conclusions

Introduced and invasive species have been recognized as potential threats to natural plant communities. Many such plant species are introduced along roadways, which then can spread to adjacent fields and forests. The West Virginia Division of Highways is required to develop seeding mixtures comprised of native plants for revegetating highway corridors and thereby to reduce the potential for introduction of non-native species along roads. Therefore, the objectives of this project were to identify native plants suitable for seeding on highway sites, to develop methods to aid in the establishment of these species, and to correlate native species establishment to soil physical and chemical properties. Fertilizer was not found to increase the cover of the seeded natives, but disturbance by tilling or herbicide did increase the seeded native cover. However, the seeded natives did not contribute any significant cover until the second and third growing season.

The data indicates that natives cannot be seeded into established stands and become an important contributor of ground cover during the first two years after seeding. Instead, some action must be taken to remove the competing vegetation to allow the slower growing natives to become established. Significant cover of the seeded natives primarily occurred on sites with little established vegetation (Baker and Elkins), and in plots that had the majority of their cover removed or killed by tilling and herbicide. The exception is the Parkersburg site, which in spite of its inadvertent hydro-seeding, had high levels of native cover. This supports the idea that bare ground and a lack of competition is required for native establishment, because it was in areas of inadequate hydro-seeding (which translates into less total cover and more bare ground) that the natives were found. The seeding and fertilizer rates used in this study could have been higher, and were increased for Objective 2. This adjustment resulted in a noticeable difference in the rate at which the natives established (lower rates took an extra year to obtain similar native cover). This indicates that further research could be done to determine the optimal seeding and fertilizer rates.

6. Recommendations

Establishment of native plants on a freshly disturbed or newly constructed site would be the easiest and most cost effective method to assure native species development. A soil test should be performed to determine the lime requirement, and then after construction seed, mulch, and lime should be hydro-seeded across the site. No fertilizer should be used as the results of this study found that fertilizer only increased the growth of the more aggressive species. Seeds should be obtained from a known source with high germination and purity. Based on the results of this study, plants recommended for seeding are Big Bluestem, Little Bluestem, Switchgrass, Indiangrass, Partridge Pea, and Brown-eyed Susan. Few of the other natives seeded were found in any of the plots. Their slow growing nature may indicate the need for a temporary ground cover, such as an annual grass like Annual ryegrass, for site stabilization until the natives have a chance to become established and expand their coverage. If there is little concern for esthetics, grasses could be seeded alone to potentially increase cost-effectiveness (flowering plants tend to be more costly).

Establishment of natives on sites with existing vegetation will be difficult, labor intensive, and expensive. It would require the destruction and/or removal (partial or complete) of the vegetation from the site. This could be done by tilling, spraying herbicide, or an herbicide-tilling combination. The combined usage of herbicide and tilling would probably yield the best results, but is very time consuming and therefore not cost-effective enough to be feasible. In fact, because of the extra time and manpower needed, establishing natives on vegetated sites may not be cost-effective at all or at least in a very limited way. One option to overcome this obstacle may be to develop a program for native grasses or forbs similar to the West Virginia Wildflower program. The disturbance of a strip or plot of land through tilling or herbicide along a roadside can be done, and then seeding in a combination of native species will increase the native species composition and allow invasion by other native species. Blocks of native vegetation can form islands from which propagules could disperse and invade into neighboring areas or as the existing vegetation declines. This process may take several years, but would certainly cut down on cost.

7. <u>Literature Cited</u>

Ahern, J., C. Niedner, and A. Barker. 1992. Roadside wildflower meadows: summary of benefits and guidelines to successful establishment and management. Transportation Research Record 1334: 46-53.

Bamert Seed. 2005. Partridge Pea. 9 May 2005. < http://www.bamertseed.com/descriptions/partridge_pea.htm>.

Barton, S., G. Schwetz, and R. Darke. 2002. Enhancing Delaware highways: a roadside vegetation management study. Land and Water May/June 2002: 26-30.

Boreal Forest. 2005. Vicia Americana. 9 May 2005. < http://www.borealforest.org/herbs/herb39.htm>.

Buckner, R. C. 1985. The Fescues. p. 233-240. *In* M. E. Heath et al. (ed.) Forages: The science of grassland agriculture. 4th ed. Iowa State Univ. Press, Ames.

Executive Order 13112: Invasive Species. 1999. Federal Register. Vol. 64, No. 25, Presidential Documents. Signed by W. J. Clinton. Washington, DC.

Executive Order 13148: Greening the Government through Leadership in Environmental Management. Federal Register. Vol. 65, No. 81, Presidential Documents. Signed by W. J. Clinton. Washington, DC.

Connecticut Botanical Society. 2005. Connecticut Wildflowers: Wild Senna. < http://www.ct-botanical-society.org/galleries/sennahebe.html>.

Corley, W.L. 1995. Enhancement of native wildflowers for roadside beautification. Georgia Department of Transportation Report No. FHWA-GA-95-9206. University of Georgia, Athens, GA.

Daniels, W.L. and D.F. Amos. 1981. Mapping, characterization and genesis of mine soils on a reclamation research area in Wise County, Virginia. p. 261-275. *In* 1981 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation, Univ. of Kentucky, Lexington, KY.

Daniels, W.L. and D.F. Amos. 1982. Chemical characteristics of some southwest Virginia minesoils. p. 377-380. *In* 1982 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation, Univ. of Kentucky, Lexington, KY.

Daniels, W.L. and C.E. Zipper. 1997. Creation and management of productive mine soils. *In* Reclamation Guidelines for Surface Mined Land in Southwest Virginia. Publication 460-120. Virginia Cooperative Extension, Blacksburg, VA.

Daubenmire, R. 1968. Plant Communities: A Textbook of Plant Synecology. Harper and Row, New York, NY.

Ernst Conservation Seed. 2005. 28 April, 2005 <http://www.ernstseed.com/>.

Facemire, L.R., J.J. Gula, and T.E. Long (eds.). 2000. West Virginia Division of Highways Standard Specifications, Roads and Bridges. West Virginia Division of Highways, Charleston, WV.

Fiedler, R. R., Schaefer, M. J., and Jaskaniec, M.E. 1990. Roadside Vegetation Management Policy. Division of Highways and Transportation Services, Madison, WI.

Gartley, Karen L. 1995. Recommended soluble salts tests. p. 70-75. *In* Recommended Soil Testing Procedures for the Northeastern US. 2nd Ed. Northeastern Regional Publication #497.

Grossman, R.B. and T.G. Reinsch. 2002. Bulk density and linear extensibility. p. 201-228. *In* J.H. Dane and G.C. Topp (eds.) Methods of Soil Analysis Part 4-Physical Methods. SSSA, Madison, WI.

Hall, K.E., J.R. George, and R.R. Riedl. 1982. Herbage Dry Matter Yields of Switchgrass, Big Bluestem, and Indiangrass with N Fertilization. Agronomy Journal 74: 47-51.

Harper, B.L. 1988. Return of the natives to Minnesota roadsides. *In* 67th Annual Meeting of the Transportation Research Board, Paper No. 870410, January 11-14, 1988, Washington, DC.

Harrington, J.A. 1991. Survey of Landscape Use of Native Vegetation on Midwest Highway Rights-of-Way. Transportation Research Record 1326: 19-30.

Hintz, R.L., K.R. Harmoney, K.J. Moore, J.R. George, and E.C. Brummer. 1998. Establishment of Switchgrass and Big Bluestem in Corn with Atrazine. Agronomy Journal 90: 591-596.

Hsu, F.H., C.J. Nelson, and A.G. Matches. 1985. Temperature Effects on Germination of Perennial Warm-Season Forage Grasses. Crop Science 25: 215-220.

Hsu, F.H. and C.J. Nelson. 1986. Planting Date Effects on Germination of Perennial Warm-Season Forage Grasses. I. Field Emergence. Agronomy Journal 78: 33-38.

Illinois Wildflowers. 2005. Early Goldenrod. 9 May 2005. < http://www.illinoiswildflowers.info/prairie/plantx/er_goldenrodx.htm>.

Illinois Wildflowers. 2005b. Partridge Pea. 9 May 2005. < http://www.illinoiswildflowers.info/prairie/plantx/part_peax.htm>.

Johnson, C.D. and J. Skousen. 1995. Minesoil Properties of 15 Abandoned Mine Land Sites in West Virginia. Journal of Environmental Quality 24(4): 635-643.

Lake, J.C. and M.R. Leishman. 2004. Invasion Success of Exotic Plants in Natural Ecosystems: The Role of Disturbance, Plant Attributes, and Freedom from Herbivores. Biological Conservation 117: 215-226.

Leishman, M.R. and V. P. Thomson. 2004. Experimental Evidence for the Effects of Additional Water, Nutrients, and Physical Disturbance on Invasive Plants in Low Fertility Hawkesbury Sandstone Soils, Sydney, Australia. Journal of Ecology 93: 38-49.

Mehlich, A. 1984. Mehlich 3 Soil Test Extractant: A Modification of Mehlich 2 Extractant. Communications in Soil Science and Plant Analysis 15(12): 1409-1416.

Missouri Botanical Garden. 2005. Asclepias tuberosa. 9 May 2005. < http://www.mobot.org/gardeninghelp/plantfinder/Plant.asp?code=B490>.

Missouri Botanical Garden. 2005b. Heliopsis helianthoides. 9 May 2005. < http://www.mobot.org/gardeninghelp/plantfinder/Plant.asp?code=G520>.

Missouri Botanical Garden. 2005c. Penstemon canescens. 9 May 2005. < http://www.mobot.org/gardeninghelp/plantfinder/Plant.asp?code=A254>.

Morrison, D.G. 1981. Use of prairie vegetation on disturbed sites. Transportation Research Record 822:10-17.

Nature Conservancy. 2003. Invasive Species Initiative. 19 Dec 2003. <http://nature.org/initiatives/invasivespecies/index.html>.

Nelson, D.W. and L.E. Sommers. 1996. Total carbon, organic carbon, and organic matter. p. 961-1010. *In* D.L. Sparks (ed.) Methods of Soil Analysis Part 3-Chemical Methods. SSSA, Madison, WI.

North Creek Nurseries. 2005. Rudbeckia triloba. 9 May 2005. < http://www.northcreeknurseries.com/Plants/Rudbeckia%20triloba.htm>.

Prairie Nursery. 2005. Ox-eye Sunflower. 9 May 2005. < http://www.prairienursery.com/SpeciesASP/hhpage.asp>.

Richardson, E.C. and E.G. Diseker. 1962. Fertilized Native Plants Promise Quick and Cheap Roadbank Protection. Soil Conservation 69: 68-69.

Riewe, M.E. and C.L. Mondart, Jr. 1985. The Ryegrasses. p. 241-246. *In* M. E. Heath et al. (ed.) Forages: The science of grassland agriculture. 4th ed. Iowa State Univ. Press, Ames.

SAS Institute. 2001. SAS Software v. 8.2. SAS Institute, Cary, N.C.

Skousen, J., and Fortney, R. 2003. Native species establishment on highway corridors in West Virginia. *In* 2003 National Meeting of the American Society of Mining and Reclaimation, Billings, MT, June 3-6, 2003. ASMR., Lexington, KY.

Smart, A.J and L.E. Moser. 1997. Morphological Development of Switchgrass as Affected by Planting Date. Agronomy Journal 89: 958-962.

Soil Survey Staff. 1996. Soil Survey Laboratory Method Manual. Soil Survey Investigations Report No. 42. Version 3.0. USDA Natural Resources Conservation Service. National Soil Survey center. Lincoln, Nebraska.

Strausbaugh, P.D., and E.L. Core. 1977. Flora of West Virginia. Seneca Books, Inc., Grantsville, WV.

Swan, C., Cripps, R., Coorts, and B. Byler. 1993. Landscaping with native plants and wildflowers on Tennessee Interstates. Tennessee Department of Transportation Report TN-RES1004, June 1993, Nashville, TN.

Thompson, K., J.G. Hodgson, J.P. Grime, and M.J. Burke. 2001. Plant Traits and Temporal Scale: Evidence from a 5-year Invasion Experiment Using Native Species. Ecology 89: 1054-1060.

Thomson, V.P. and M.R. Leishman. 2004. Survival of Native Plants of Hawkesbury Sandstone Communities with Additional Nutrients: Effects of Plant Age and Habitat. Australian Journal of Botany 52: 141-147.

Thurman, N.C. and J.C. Sencindiver. 1986. Properties, Classification, and Interpretations of Minesoils at Two Sites in West Virginia. Soil Science Society of America Journal 50: 181-185.

UC IPM On-Line. 2005. The UC Guide to Healthy Lawns. 9 May 2005. < http://www.ipm.ucdavis.edu/TOOLS/TURF/TURFSPECIES/redfes.html>

Vassey, T.L., J.R. George, and R.E. Mullen. 1985. Early-, Mid-, and Late-Spring Establishment of Switchgrass at Several Seeding Rates. Agronomy Journal 77: 253-257.

Voigt, P. W. and R. S. MacLauchlan. 1985. Native and other western grasses. p. 177-187. *In* M. E. Heath et al. (ed.) Forages: The science of grassland agriculture. 4th ed. Iowa State Univ. Press, Ames.

Weed Alert. 2005. Birdsfoot Trefoil. 9 May 2005. < http://www.weedalert.com/weed_pages/wa_birdsfoot_trefoil.htm>.

Wisconsin Department of Natural Resources. 2005. Invasive Species. 9 May 2005. < http://www.dnr.state.wi.us/org/land/er/invasive/factsheets/crown.htm>.

8. Appendix - Data Tables

Table 26. Total plant cover of Spring plantings at Baker with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Baker	Baker	Baker
	Jun-02	Jun-03	Jun-04
Fertilizer	-------------%-------------		
Fertilized	32 a*	59 a	73 a
Unfertilized	20 b	51 a	63 a
Seed Mix			
DOH	41 a	80 a	83 a
DOH-Native	32 a	81 a	82 a
½ DOH-Native	32 a	73a	82 a
Native	15 b	19 b	48 b
Control	11 b	23 b	44 b
Interactions			
DOH Fertilized	50 a	83 a	81 a
DOH Unfertilized	32 b	76 a	85 a
DOH-Native Fertilized	38 ab	81 a	86 a
DOH-Native Unfertilized	26 bc	80 a	77 a
½ DOH-Native Fertilized	38 ab	87 a	88 a
½ DOH-Native Unfertilized	26 bc	58 b	76 a
Native Fertilized	18 cd	17 c	59 b
Native Unfertilized	12 cd	20 c	37 b
Control Fertilized	15 cd	24 c	50 b
Control Unfertilized	6 d	21 c	38 b

*Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

Table 27. Total plant cover of Fall plantings at Baker with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Baker	Baker
	Jun-03	Jun-04
Fertilizer	-------------%-------------	
Fertilized	21 a*	69 a
Unfertilized	17 a	61 a
Seed Mix		
DOH	13 b	75 a
DOH-Native	29 a	75 a
½ DOH-Native	14 b	73 a
Native	23 a	55 b
Control	17 ab	47 b
Interactions		
DOH Fertilized	14 bc	78 a
DOH Unfertilized	11 bc	72 ab
DOH-Native Fertilized	28 a	75 ab
DOH-Native Unfertilized	29 a	75 ab
½ DOH-Native Fertilized	17 abc	77 a
½ DOH-Native Unfertilized	10 c	69 ab
Native Fertilized	19 abc	60 b
Native Unfertilized	27 ab	50 c
Control Fertilized	26 ab	53 c
Control Unfertilized	7 c	40 c

*Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

Table 28. Total plant cover of Spring plantings at Hazelton with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Hazelton	Hazelton	Hazelton
	Jun-02	Jun-03	Jun-04
Fertilizer	-------------%-------------		
Fertilized	48 a*	60 a	79 a
Unfertilized	39 a	58 a	75 a
Seed Mix			
DOH	35 a	71 a	76 a
DOH-Native	51 a	77 a	68 a
½ DOH-Native	50 a	50 b	80 a
Native	35 a	50 b	83 a
Control	47 a	49 b	79 a
Interactions			
DOH Fertilized	44 bc	72 ab	68 b
DOH Unfertilized	26 c	69 ab	84 a
DOH-Native Fertilized	63 a	77 a	79 a
DOH-Native Unfertilized	38 c	77 a	56 b
½ DOH-Native Fertilized	50 ab	46 cd	77 a
½ DOH-Native Unfertilized	50 ab	54 cd	83 a
Native Fertilized	38 c	57 bc	84 a
Native Unfertilized	32 c	43 d	82 a
Control Fertilized	44 bc	50 cd	85 a
Control Unfertilized	50 ab	47 cd	72 ab

*Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

Table 29. Total plant cover of Fall plantings at Hazelton with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Hazelton Jun-03	Hazelton Jun-04
Fertilizer	---------%---------	
Fertilized	57 a*	87[1]
Unfertilized	49 a	85
Seed Mix		
DOH	50 a	86
DOH-Native	50 a	84
½ DOH-Native	59 a	87
Native	52 a	89
Control	56 a	84
Interactions		
DOH Fertilized	68 a	84
DOH Unfertilized	32 e	89
DOH-Native Fertilized	52 bcd	83
DOH-Native Unfertilized	47 d	86
½ DOH-Native Fertilized	57 bc	88
½ DOH-Native Unfertilized	60 b	86
Native Fertilized	49 cd	91
Native Unfertilized	55 bcd	87
Control Fertilized	59 b	90
Control Unfertilized	52 bcd	78

*Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

[1]No significant differences were found for the June 2004 survey.

Table 30. Total plant cover of Spring plantings at Parkersburg with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Parkersburg Jun-02	Parkersburg Jun-03	Parkersburg Jun-04
Fertilizer		-------------%-------------	
Fertilized	91[1]	77 a*	82 a
Unfertilized	87	76 a	79 a
Seed Mix			
DOH	89	64 a	75 a
DOH-Native	90	71 ab	77 a
½ DOH-Native	89	87 b	85 a
Native	86	80 ab	84 a
Control	93	82 b	82 a
Interactions			
DOH Fertilized	91	60 a	84 a
DOH Unfertilized	86	68 a	66 b
DOH-Native Fertilized	94	75 ab	76 ab
DOH-Native Unfertilized	86	66 a	77 a
½ DOH-Native Fertilized	86	86 b	87 a
½ DOH-Native Unfertilized	91	88 b	83 a
Native Fertilized	91	77 ab	82 a
Native Unfertilized	80	82 ab	86 a
Control Fertilized	94	87 b	83 a
Control Unfertilized	91	76 ab	81 a

*Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

[1]No significant differences were found for the June 2002 survey.

Table 31. Seeded native cover of Spring plantings at Baker with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Baker Jun-02	Baker Jun-03	Baker Jun-04
Fertilizer	-------------%-------------		
Fertilized	1*	0	4 a[1]
Unfertilized	1	0	4 a
Seed Mix			
DOH	0	0	0 b
DOH-Native	2	0	0 b
½ DOH-Native	3	0	0 b
Native	3	2	21 a
Control	0	0	0 b
Interactions			
DOH Fertilized	0	0	0 b
DOH Unfertilized	0	0	0 b
DOH-Native Fertilized	1	0	0 b
DOH-Native Unfertilized	2	0	0 b
½ DOH-Native Fertilized	3	0	0 b
½ DOH-Native Unfertilized	2	0	0 b
Native Fertilized	3	2	22 a
Native Unfertilized	2	1	20 a
Control Fertilized	0	0	0 b
Control Unfertilized	0	0	0 b

*No significant differences were found for the June 2002 and 2003 surveys.

[1]Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

Table 32. Seeded native cover of Fall plantings at Baker with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Baker Jun-03	Baker Jun-04
Fertilizer	------%------	
Fertilized	0*	4 a[1]
Unfertilized	0	7 a
Seed Mix		
DOH	0	0 b
DOH-Native	0	3 b
½ DOH-Native	0	10 a
Native	0	14 a
Control	0	0 b
Interactions		
DOH Fertilized	0	0 b
DOH Unfertilized	0	0 b
DOH-Native Fertilized	0	0 b
DOH-Native Unfertilized	0	5 b
½ DOH-Native Fertilized	0	5 b
½ DOH-Native Unfertilized	0	14 a
Native Fertilized	0	13 a
Native Unfertilized	0	14 a
Control Fertilized	0	0 b
Control Unfertilized	0	0 b

*No significant differences were found for the June 2003 survey.

[1]Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

Table 33. Seeded native cover of Spring plantings at Hazelton with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Hazelton	Hazelton	Hazelton
	Jun-02	Jun-03	Jun-04
Fertilizer	-------------%-------------		
Fertilized	0*	0	0
Unfertilized	0	0	1
Seed Mix			
DOH	0	0	0
DOH-Native	0	0	2
½ DOH-Native	0	0	0
Native	0	1	0
Control	0	0	0
Interactions			
DOH Fertilized	0	0	0
DOH Unfertilized	0	0	0
DOH-Native Fertilized	0	0	0
DOH-Native Unfertilized	0	0	4
½ DOH-Native Fertilized	0	0	0
½ DOH-Native Unfertilized	0	0	0
Native Fertilized	0	0	0
Native Unfertilized	0	1	0
Control Fertilized	0	0	0
Control Unfertilized	0	0	0

*No significant differences were found.

Table 34. Seeded native cover of Fall plantings at Hazelton with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Hazelton Jun-03	Hazelton Jun-04
Fertilizer	---------%---------	
Fertilized	0*	0
Unfertilized	0	0
Seed Mix		
DOH	0	0
DOH-Native	0	0
½ DOH-Native	0	0
Native	0	0
Control	0	0
Interactions		
DOH Fertilized	0	0
DOH Unfertilized	0	0
DOH-Native Fertilized	0	1
DOH-Native Unfertilized	0	0
½ DOH-Native Fertilized	0	0
½ DOH-Native Unfertilized	0	0
Native Fertilized	0	0
Native Unfertilized	0	0
Control Fertilized	0	0
Control Unfertilized	0	0

*No significant differences were found.

Table 35. Seeded native cover of Spring plantings at Parkersburg with and without fertilizer, seeded with various mixtures, and treatment combinations.

Treatment	Parkersburg Jun-02	Parkersburg Jun-03	Parkersburg Jun-04
Fertilizer		-------------%-------------	
Fertilized	0*	0	3 a[1]
Unfertilized	0	1	7 b
Seed Mix			
DOH	0	0	0 c
DOH-Native	0	0	5 b
½ DOH-Native	1	1	8 b
Native	1	2	13 a
Control	0	0	0 c
Interactions			
DOH Fertilized	0	0	0 c
DOH Unfertilized	0	0	0 c
DOH-Native Fertilized	0	0	5 b
DOH-Native Unfertilized	0	0	5 b
½ DOH-Native Fertilized	0	0	1 c
½ DOH-Native Unfertilized	1	1	14 a
Native Fertilized	0	0	9 b
Native Unfertilized	1	3	17 a
Control Fertilized	0	0	0 c
Control Unfertilized	0	0	0 c

*No significant differences were found for the June 2002 and 2003 surveys.
[1]Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

Table 36. Total plant cover of Spring plantings at Weston with and without fertilizer, under various disturbance regimes, and treatment combinations.

Treatment	Weston Jun-03	Weston Jun-04
Fertilizer	---------%---------	
Fertilized	67 a*	81[1]
Unfertilized	71 a	82
Disturbance		
Control	93 a	85
Seed	87 a	81
Mow	91 a	85
Till	50 b	80
Herbicide	26 c	77
Interactions		
Contol Fertilized	90 a	79
Control Unfertilized	96 a	91
Seed Fertilized	84 a	82
Seed Unfertilized	89 a	80
Mow Fertilized	94 a	86
Mow Unfertilized	88 a	83
Till Fertilized	43 b	77
Till Unfertilized	56 b	82
Herbicide Fertilized	24 c	79
Herbicide Unfertilized	28 c	75

*Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

[1]No significant differences were found for the June 2004 survey.

Table 37. Total plant cover of Spring plantings at Buckhannon with and without fertilizer, under various disturbance regimes, and treatment combinations.

Treatment	Buckhannon	Buckhannon
	Jun-03	Jun-04
Fertilizer	---------%---------	
Fertilized	59 a*	66 a
Unfertilized	50 a	63 a
Disturbance		
Control	83 a	74 a
Seed	78 a	74 a
Mow	64 b	76 a
Till	25 c	45 b
Herbicide	23 c	56 b
Interactions		
Contol Fertilized	88 a	79 a
Control Unfertilized	78 a	68 a
Seed Fertilized	77 a	65 a
Seed Unfertilized	79 a	82 a
Mow Fertilized	79 a	79 a
Mow Unfertilized	49 b	72 a
Till Fertilized	28 c	46 b
Till Unfertilized	22 c	43 b
Herbicide Fertilized	25 c	62 ab
Herbicide Unfertilized	20 c	49 b

*Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

Table 38. Total plant cover of Spring plantings at Elkins with and without fertilizer, under various disturbance regimes, and treatment combinations.

Treatment	Elkins	Elkins
	Jun-03	Jun-04
Fertilizer	---------%---------	
Fertilized	57 a*	47[1]
Unfertilized	36 b	48
Disturbance		
Control	56 a	44
Seed	61 a	48
Mow	62 a	52
Till	32 b	49
Herbicide	24 b	46
Interactions		
Contol Fertilized	65 ab	40
Control Unfertilized	47 b	47
Seed Fertilized	74 a	43
Seed Unfertilized	47 b	53
Mow Fertilized	79 a	50
Mow Unfertilized	44 b	53
Till Fertilized	37 b	51
Till Unfertilized	26 b	46
Herbicide Fertilized	29 b	50
Herbicide Unfertilized	18 b	41

*Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

[1]No significant differences were found for the June 2004 survey.

Table 39. Seeded native cover of Spring plantings at Weston with and without fertilizer, under various disturbance regimes, and treatment combinations.

Treatment	Weston Jun-03	Weston Jun-04
Fertilizer	---------%---------	
Fertilized	2[1]	5 a*
Unfertilized	2	6 a
Disturbance		
Control	0	0 b
Seed	1	0 b
Mow	0	0 b
Till	8	11 a
Herbicide	3	19 a
Interactions		
Contol Fertilized	0	0 b
Control Unfertilized	0	0 b
Seed Fertilized	0	0 b
Seed Unfertilized	1	0 b
Mow Fertilized	0	0 b
Mow Unfertilized	0	0 b
Till Fertilized	8	13 a
Till Unfertilized	7	9 a
Herbicide Fertilized	4	14 a
Herbicide Unfertilized	2	23 a

[1]No significant differences were found for the June 2003 survey.

*Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

Table 40. Seeded native cover of Spring plantings at Buckhannon with and without fertilizer, under various disturbance regimes, and treatment combinations.

Treatment	Buckhannon	Buckhannon
	Jun-03	Jun-04
Fertilizer	---------%---------	
Fertilized	1[1]	5 a*
Unfertilized	1	7 a
Disturbance		
Control	0	0 b
Seed	1	1 b
Mow	1	2 b
Till	1	14 a
Herbicide	2	14 a
Interactions		
Contol Fertilized	0	0 b
Control Unfertilized	0	0 b
Seed Fertilized	1	1 b
Seed Unfertilized	0	0 b
Mow Fertilized	0	1 b
Mow Unfertilized	1	2 b
Till Fertilized	0	10 a
Till Unfertilized	2	18 a
Herbicide Fertilized	2	14 a
Herbicide Unfertilized	1	13 a

[1]No significant differences were found for the June 2003 survey.

*Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).

Table 41. Seeded native cover of Spring plantings at Elkins with and without fertilizer, under various disturbance regimes, and treatment combinations.

Treatment	Elkins Jun-03	Elkins Jun-04
Fertilizer	---------%---------	
Fertilized	5[1]	14 a*
Unfertilized	7	19 a
Disturbance		
Control	0	0 c
Seed	4	8 b
Mow	7	11 b
Till	13	36 a
Herbicide	8	29 a
Interactions		
Contol Fertilized	0	0 c
Control Unfertilized	0	0 c
Seed Fertilized	2	5 b
Seed Unfertilized	6	10 b
Mow Fertilized	2	10 b
Mow Unfertilized	11	11 b
Till Fertilized	14	29 a
Till Unfertilized	11	42 a
Herbicide Fertilized	8	25 a
Herbicide Unfertilized	8	33 a

[1]No significant differences were found for the June 2003 survey.

*Treatments within main effects (fertilizer, seed mix, or interactions) and within columns (sites) with the same letter are not significantly different (p=0.05).