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# ESTABLISHING NATIVE PLANTS ON NEWLY-CONSTRUCTED AND OLDER-RECLAIMED SITES ALONG WEST VIRGINIA HIGHWAYS

J.G. SKOUSEN<sup>\*,†</sup> AND C.L. VENABLE<sup>‡</sup>

Division of Plant and Soil Sciences, West Virginia University, Morgantown, WV 26506-6108, USA

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## ABSTRACT

Many state highway departments in the USA must use native plants for revegetating roadsides. We conducted two field studies in West Virginia to assess native plant establishment under two different conditions. On newly-constructed sites, native species were seeded alone or combined with non-native species. On older roadsides, native species were seeded in disturbed existing vegetation. In the first study, we used four seed mixtures comprised of seeds of native and non-native species, and two N-P-K fertilizer treatments at three newly-constructed sites. Native, warm-season grasses were slow to establish and only contributed 25 per cent cover in some plots after three years. Indiangrass (Sorghastrum nutans [L.] Nash), big bluestem (Andropogon gerardii Vitman), Brown-Eyed Susan (Rudbeckia triloba L.), and wild senna (Cassia hebecarpa Fernald) were the only seeded native species found. Fertilizer at 150 kg ha<sup>-1</sup> of 10-20-10 showed little influence on increasing plant cover. In the second study, we disturbed three different-aged established stands of vegetation composed of tall fescue (Festuca arundinacea Screb.) and crownvetch (Coronilla varia L.) by mowing, herbicide, or tillage, and native plants were seeded with and without fertilizer. Native cover was <10 per cent in all plots during the first year, but greatly increased by the second year to as much as 45 per cent in tilled plots, indicating that disturbance was necessary for natives to become important contributors within 2 years. Only switchgrass (Panicum virgatum L.), little bluestem (Andropogon scoparius Vitman), partridge pea (Chamaecrista fasciculate Michx.), and Brown-Eyed Susan were observed in plots. Fertilizer at  $300 \text{ kg} \text{ ha}^{-1}$  of 10-20-10 did not increase native plant cover on these sites. Based on our results, introducing or increasing the cover of native species along roadsides requires (1) reducing competition from non-native species, and (2) longer time periods for these slower-establishing species to be observed. Copyright © 2008 John Wiley & Sons, Ltd.

KEY WORDS: highway rehabilitation; native grasses; native forbs; reclamation; revegetation; roadside planting; USA

#### INTRODUCTION

Construction of four-lane highways began in the late-1950s in many parts of the eastern USA, and these highways continue to be built today. Roadside soils are often generated from blasted geologic material, composed of unweathered rock fragments with little to no soil fines. Because of this coarse texture and unweathered condition, many roadside soils contain little organic matter and microorganism activity, lack available plant nutrients and water, have poor soil structure, and therefore are often hard to revegetate (Booze-Daniels *et al.*, 2000).

An important component of highway construction is effective sediment and erosion control immediately after construction, which is facilitated by seeding fast-growing vegetation. Nearly all species currently used for both temporary and permanent stabilization in the eastern USA are non-native because they are effective in stabilizing disturbed sites with poor soil conditions, readily accessible in large quantities, inexpensive, and known to have excellent germination and establishment characteristics (USDA, 1993). Typical species used for highway seeding

<sup>\*</sup> Correspondence to: J.G. Skousen, 1106 Agricultural Sci. Bldg., West Virginia University, Morgantown, WV 26506-6108, USA.

E-mail: jskousen@wvu.edu

<sup>&</sup>lt;sup>†</sup>Professor of Soil Science and Reclamation Specialist.

<sup>&</sup>lt;sup>‡</sup>Graduate Research Assistant.

in many parts of the northeastern USA are tall fescue (*Festuca arundinaceum* (Schreb.), red fescue (*Festuca rubra* L.), annual ryegrass (*Lolium multiflorum* Lam.), weeping lovegrass (*Eragrostis curvula* [Schrad.] Nees), birdsfoot trefoil (*Lotus corniculatus* L.), and crownvetch (*C. varia* L.) (West Virginia Division of Highways, 2000). These non-natives, especially when fertilized, form an almost complete ground cover within a few months that limits erosion and makes the site look lush and green.

Federal regulations require limiting the spread of invasive species and promoting the establishment of native species along highways (Boyce, 2002). However, native species tend to establish slower and provide less ground cover, and seeds of natives are generally less available in large quantities compared to non-natives (Harrington, 1991). Further, native species are often unsuitable for conventional seeding techniques, such as hydro-seeding.

Many states have established native plants on roadsides, but most of the work involves native forbs (wildflowers) (Morrison, 1981; Rinard, 1986; Harper, 1988; Ahern *et al.*, 1992; Schutt and Teal, 1994; Barton *et al.*, 2002). Byler *et al.* (1993) found wildflowers worked well for vegetating roadsides in Tennessee as long as tillage was used to produce a suitable seed bed, and Corley (1995) tested 32 wildflower species in Georgia with good success. A greater variety of native species (beyond roadside flowers) needs to be tested, and less-destructive techniques rather than complete tillage and seedbed preparation should be studied to establish native plants along roads.

The objectives of this research were to: (1) assess the degree of establishment and growth of native species seeded with and without non-native species on newly-constructed highway sites and (2) evaluate native species establishment with three disturbance techniques (tillage, herbicide, or mowing) in older, established stands of non-native vegetation.

## SITE DESCRIPTIONS AND METHODS

## New Site Study

We selected three newly-constructed highway sites in West Virginia (Figure 1) for this seeding experiment. The first site is located along a new section of Appalachian Corridor H near Baker, WV, in the Eastern Ridge and Valley Province. Soils at the site have sandy loam textures with 1.7 per cent organic matter, bulk density of  $1.8 \text{ g cm}^{-3}$  with 41 per cent rock fragments, and pH of 6.5 (Table I). The second site is located on I-79 near Hazelton, WV, in the Allegheny Mountain Province. The soils at Hazelton are loams with 2.7 per cent organic matter, bulk density of  $1.5 \text{ g cm}^{-3}$  with 21 per cent rock fragments, and pH of 6.1. The third site is near the intersection of I-77 and US Route 50 in Parkersburg, WV, in the Western Hill Province. The native topsoil was replaced at Parkersburg so the soils are clay loams with 2.9 per cent organic matter, bulk density of  $1.2 \text{ g cm}^{-3}$  with only 2 per cent rock fragments, and pH of 5.1.

On each site, an area of about  $800 \text{ m}^2$  along the roadway was selected for plot establishment. Treatments consisted of a factorial arrangement of five seed mixtures (four seed mixtures as defined in Table II and a no-seeding control) and two rates of fertilizer. Each treatment combination was replicated four times in a completely randomized design. Plots measured 2 m by 2 m (4 m<sup>2</sup>), with a 1 m buffer between plots, and the plots were arranged in four rows with 10 plots each for a total of 40 plots per site. The Division of Highways (DOH) seed mix was comprised of non-native, cool-season species typically used for seeding along highways. The native species we chose for seeding occur naturally throughout the northeastern USA, have erosion control potential, have aesthetic or wildlife value, and can be purchased from seed suppliers (USDA, 1993; Fortney *et al.*, 2002). Native warm-season grasses were particularly emphasized in our mixes because of their large size and aesthetic value. Native seeds were purchased from Ernst Conservation Seeds of Meadville, PA, and seeds adapted to northern West Virginia were selected for our seeding projects.

We established the plots in April 2002 by tilling the entire  $800 \text{ m}^2$  area to a depth of 5 cm with a garden tiller to lightly disturb the soil prior to seeding. Fertilizer and PLS recommended seed rates (Table II) were spread by hand based on WVDOH recommendations (WVDOH, 2000). The fertilizer (10-20-10 NPK) was applied at a rate of 0 or  $150 \text{ kg ha}^{-1}$ . Straw mulch was spread over all plots at a rate of  $1500 \text{ kg ha}^{-1}$  to obtain about 80 per cent coverage. In September of the ensuing 3 years, we determined plant cover by species in four, randomly selected  $1/4 \text{ m}^2$  sub-plots



Figure 1. Location of study sites in West Virginia. The sites for the New Site Study were Parkersburg, Hazelton, and Baker, while the sites for the Established Site Study were located at Weston, Buckhannon, and Elkins.

within each 4 m<sup>2</sup> plot. Total plant and individual species cover was recorded into one of 6 plant cover classes (0=0 per cent, 1=1-5 per cent, 2=5-25 per cent, 3=26-50 per cent, 4=51-75 per cent, 5=76-95 per cent, 6=95=100 per cent) and the midpoint of the class range was used for averaging plant cover within plots (Daubenmire, 1968). Analysis of variance was performed on each site for each year, and differences at  $p \le 0.05$  were considered significant (SAS Institute, 2001). Plant cover averages among treatments (fertilizer and seed mix) were separated by the Least Significant Difference (LSD) test.

planting													-	
Table I.	Chemical	properties	of the upper	10 cm of	f soil (	$<2\mathrm{mm}$	fraction)	found	on six	roadside	sites in	West	Virginia	before

Site	pН	EC	ОМ	Ca	Extracta Mg	ble bases Na	S K	С	N	S	Р	Zn	Cu
		$(dSm^{-1})$	(%)		(cmo	c kg <sup>-1</sup> )			(%)		(1	mg kg <sup>-1</sup> )	)
Baker	6.5	0.15	1.7	2.4	1.0	0.05	0.37	0.6	0.0	0.1	19.6	2.2	2.2
Hazelton	6.1	0.16	2.7	4.0	0.2	0.06	0.35	0.9	0.0	0.1	10.4	5.8	1.2
Parkersburg	5.1	0.14	2.9	5.3	1.4	0.06	0.45	1.0	0.0	0.1	14.5	8.0	2.4
Elkins	6.5	1.64	2.0	10.2	0.6	0.05	0.27	1.0	0.2	0.1	8.9	3.3	2.2
Buckhannon	5.7	0.15	6.0	4.6	0.9	0.07	0.41	3.0	0.0	0.2	3.9	12.5	3.0
Weston	7.1	0.30	6.4	14.1	1.6	0.08	0.37	2.9	0.1	0.2	4.2	6.7	8.2

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			Seed mixtures	
Seeded species	DOH <sup>1</sup>	Native	DOH-native	<sup>1</sup> / <sub>2</sub> DOH-native
		(PLS s	eeding rate, kg ha <sup>-1</sup> )	
Tall fescue (F. arundinacea Screb.)	5		5	2.5
Red fescue (F. rubra L.)	5		5	2.5
Annual ryegrass (L. multiflorum Lam.)	2		2	1
Birdsfoot trefoil (L. corniculatus L.)	3		3	1.5
Indiangrass (S. nutans (L.) Nash)		2	2	2
Big bluestem (A. gerardii Vitman)		2	2	2
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 (R. triloba L.)		0.25	0.25	0.25
Gray beardtongue (Penstemon canescens Britton)		0.25	0.25	0.25
Wild senna (C. hebecarpa Fernald)		2	2	2
Total seeding rate	15	7.25	22.25	14.75

Table II. Seeded species and seeding rates of four seed mixtures used in the New Site Study at Baker, Hazelton, and Parkerburg, West Virginia

<sup>1</sup>Abbreviation for Division of Highway seed mix.

## Established Site Study

We chose three sites along US Route 33 in West Virginia (Figure 1). The first highway site is located 8 km east of Weston, WV, on the bench of a cut slope, and the road was built in 1976 (27-years-old). Soils at Weston are clay loams with 6.4 per cent organic matter, bulk density of  $1.5 \text{ g cm}^{-3}$  with 22 per cent rock fragments, and pH of 7.1 (Table I). The second site is located 10 km east of Buckhannon, WV, on the bench of a fill area constructed in 1986 (17-years-old). Soils at Buckhannon are loams with 6.0 per cent organic matter, bulk density of  $1.5 \text{ g cm}^{-3}$  with 25 per cent rock fragments, and pH of 5.7. The third site is located 3 km north of Elkins, WV, in a fill area and constructed in 2003 (1-year-old). Elkins soils are silt loams with 2 per cent organic matter, bulk density of  $1.9 \text{ g cm}^{-3}$  with 47 per cent rock fragments, and pH of 6.5. All three sites had a complete cover of tall fescue, orchardgrass (*Dactylis glomerata* L.), crownvetch, and birdsfoot trefoil.

An area of  $800 \text{ m}^2$  was chosen on each of these sites. Treatments consisted of a factorial arrangement of five disturbance/seeding regimes by two fertilizer rates. We replicated the treatments four times in a completely randomized design. The disturbance-seeding treatment combinations were: (1) mowing and seed, (2) tillage and seed, (3) herbicide and seed, (4) no disturbance and seed, and (5) no disturbance and no seed (Table III). Fertilizer was applied at either 0 or  $300 \text{ kg ha}^{-1}$  of 10-20-10 NPK fertilizer. The rate of fertilization used in this study was double that used in the New Site study because we observed no fertilizer effect on plants in the New Site Study

Table III. Seeded species and seeding rates used in the Established Site Study at Weston, Buckhannon, and Elkins, West Virginia

Seeded species	PLS Seeding Rate $(kg ha^{-1})$
Switchgrass ( <i>P. virgatum</i> L.)	5
Little bluestem (A. scoparius Vitman)	5
Partridge pea (C. fasciculate Michx.)	5
American Vetch (Vicea Americana Muhl.)	2
Ox-eye sunflower (Heliopsis helianthoides (L.) Sweet)	2
Brown-Eyed Susan (R. triloba L.)	2
Total Seeding Rate	21

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during the first year. Treatments were randomly assigned to plots measuring  $2 \text{ m by } 2 \text{ m } (4 \text{ m}^2)$  with a 1 m buffer between plots.

We established these plots in April 2003. Mowing was done with a weed eater to a height of 2–3 cm. Tillage was accomplished by hand with pick-mattocks to a depth of 10 cm. Glyphosate herbicide was applied at recommended rates  $(3.4 \text{ kg} \text{ acid equivalent ha}^{-1})$  2 weeks before seeding. A total of 21 kg ha<sup>-1</sup> of PLS seed was applied on seeded plots. Plant cover by species was determined in September 2003 (1st year) and 2004 (2nd year) as described above. Analysis of variance tests were performed on each site for each year, and  $p \le 0.05$  were considered statistically significant (SAS Institute, 2001). Plant cover means among treatments (fertilizer and disturbance/seeding) were separated by the LSD test.

## RESULTS

## New Site Study

Fertilizer did not significantly increase total plant cover (Table IV). We thought some increase in plant cover would be realized with fertilization. However, the rate we used at  $150 \text{ kg ha}^{-1}$  of 10-20-10 was low compared to the amounts used by highway departments (usually from 600 to  $1000 \text{ kg ha}^{-1}$  of 10-20-10). Because these sites were newly-constructed, sufficient amounts of nutrients may have resided in the soils (P and K were relatively high and N was low on these three sites, Table I) and the small amount of fertilizer we added resulted in little change in plant cover.

Total plant cover (which included all seeded and volunteer species) among seeding treatments was significantly different only at Baker, and not at Hazelton or Parkersburg (Table IV). After one growing season, the average plant cover was 28 per cent at Baker, and this increased to 68 per cent after three growing seasons (Table IV). Second-year data is not presented because it was similar to first-year data. The DOH and DOH-Native plots had higher total cover than unseeded control plots. By the third year, total cover for native and unseeded control plots was the same, suggesting that the native plant seeding had little impact.

At Hazelton, average total cover increased from 64 per cent after one growing season (1st year) to 93 per cent after three growing seasons (3rd year), and we found no significant differences in total cover among seed mixtures or fertilizer treatments during the 3-year study.

At Parkersburg, total cover was similar across all treatments during the study, but this was due to DOH crews inadvertently hydro-seeding the entire site a few months after the plots were established. The crews hydro-seeded

Treatment	Ba	ker	Haz	elton	Parker 1st year (% 98 a 98 a 98 a 98 a 98 a 98 a 98 a 98 a 98 a 98 a	rsburg	
	1st year	3rd year	1st year	3rd year	1st year	3rd year	
Fertilizer	(%)		(4	%)	(%)		
Fertilized	30 a*	73 a	67 a	92 a	98 a	96 a	
Unfertilized	26 a	63 a	60 a	94 a	98 a	96 a	
Seed Mix							
DOH	38 a	83 a	65 a	96 a	98 a	94 a	
DOH-native	35 a	81 a	71 a	92 a	98 a	96 a	
<sup>1</sup> / <sub>2</sub> DOH-native	29 ab	82 a	65 a	92 a	98 a	97 a	
Native	23 ab	48 b	59 a	91 a	98 a	98 a	
Control	15 b	44 b	56 a	92 a	98 a	98 a	
Average total plant cover	28	68	64	93	98	96	

Table IV. Total plant cover at Baker, Hazelton, and Parkersburg after the first and third growing seasons in response to fertilizer and seed mixtures

\*Values within treatments (fertilizer and seed mix) and within columns (site and date) with the same letter are not significantly different ( $p \le 0.05$ ) using ANOVA and the LSD test.

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Treatment	Ba	ıker	Haz	elton	Parke	Parkersburg	
	1st year	3rd year	1st year	3rd year	1st year	3rd year	
Fertilizer	("	%)	(4	%)	("	%)	
Fertilized	0	6 a*	0	0	0	9 a	
Unfertilized	0	4 a	0	0	0	13 a	
Seed mix							
DOH	0	0 b	0	0	0	0 c	
DOH-native	0	0 b	0	0	0	11 b	
<sup>1</sup> / <sub>2</sub> DOH-native	0	1 b	0	0	0	20 a	
Native	0	24 a	0	0	0	25 a	
Control	0	0 b	0	0	0	0 c	
Average native species cover	0	5	0	0	0	11	

Table V. Native species cover at Baker, Hazelton, and Parkersburg after the first and third growing seasons in response to fertilizer and seed mixtures

\*Values within treatments (fertilizer and seed mix) and within columns (sites) with the same letter are not significantly different ( $p \le 0.05$ ) using ANOVA and the LSD test.

the DOH mix at triple the rates shown in Table II, along with  $600 \text{ kg ha}^{-1}$  of 10-20-10 fertilizer. Because of this, plant cover in all plots was nearly 100 per cent and obviously no differences were found for plant cover among treatments. While this site was compromised in relation to the other two sites, the hydro-seeding did not stop seeded natives from establishing, which is discussed later.

Cover by seeded natives was nearly zero at all sites until after the third growing season (Table V). Native plots at Baker and Parkersburg had the highest seeded native cover at about 25 per cent. Native-fertilized plots at Baker had significantly higher native plant cover (29 per cent) than corresponding Native-unfertilized plots (19 per cent), while the cover in fertilized and unfertilized Native plots at Parkersburg were not significantly different (23 and 28 per cent, respectively) (data for treatment combinations are not shown). Hazelton had almost no native cover in any plot. From our results on Baker and Hazelton, fertilization had no effect on non-native or native species cover. This could again be related to the low rate of fertilizer application. Parkersburg had heavy fertilization in all plots due to the hydro-seeding.

In spite of the hydro-seeding and heavy ground cover by non-native species, Parkersburg still had relatively high native cover in all plots where these native species were seeded. This was the only site where 20 to 25 cm of topsoil was replaced on the surface, and this topsoil could have enhanced native species establishment since native species were found in all native-seeded plots. However, Baker with no topsoil had similarly high native species cover in native plots, so we cannot examine whether topsoil aided native species establishment or not.

Indiangrass, big bluestem, Brown-Eyed Susan, and wild senna were the only seeded native species that contributed cover on our sites. The other species (goldenrod, butterfly weed, and beardtongue) were not observed in our plots during the 3-year study.

In summary, the low rate of fertilizer we used had no effect on total plant or native species cover. We observed native species after three growing seasons at Baker and Parkersburg, but very little at Hazelton. The DOH species established and grew well in the first growing season, while the native species did not. By the 3rd year, the natives increased their cover to about 25 per cent in some treatments on two of the sites.

# Established Site Study

At the  $300 \text{ kg ha}^{-1}$  rate, application of fertilizer increased total plant cover only at Elkins (Table VI). Average total plant cover, which included cover by seeded native, non-native, and volunteer species, increased as the age of the site increased from 63 per cent for the 1-year-old site to 87 per cent for the 27-year-old site (Table VI). Total plant cover was higher in Control, No Disturb, Mow, and Till plots than Herbicide plots at Elkins and Weston. Till and Herbicide plots had significantly lower cover at Buckhannon than other treatments.

Treatment	Elkins 2nd year	Buckhannon 2nd year	Weston 2nd year
Fertilizer	(%)	(%)	(%)
Fertilized	67 a	76 a	84 a
Unfertilized	57 b	75 a	90 a
Disturbance			
Control	66 a	84 a	88 a
No disturb	67 a	89 a	84 ab
Mow	70 a	88 a	93 a
Till	62 a	57 b	89 a
Herbicide	44 b	57 b	79 b
Total plant cover	62	76	87

Table VI. Total plant cover after two growing seasons at Elkins (1-year-old), Buckhannon (17-years-old), and Weston (27-years-old) in response to fertilizer and disturbance

Values within treatments (fertilizer and disturbance) and within columns (sites) with the same letter are not significantly different ( $p \le 0.05$ ) using ANOVA and the LSD test.

At Elkins, seeded native cover was <10 per cent in plots during the first year (first year data not shown), but grew to as much as 43 per cent in Tilled plots after 2 years (Table VII). Cover of seeded natives was <1 per cent at Buckhannon and Weston during the first year (data not shown), but increased to more than 30 per cent cover in some treatments after the second growing season. While generally having low total plant cover, the Till and Herbicide plots at all three sites consistently had the highest seeded native cover (13 to 43 per cent). In general, as total plant cover decreased, seeded native cover increased. We found that fertilizer even at the heavier rate did not affect seeded native cover at any site.

We also evaluated individual species response to the treatments for four of the prominent seeded natives as well as four of the non-native species that existed on the site before disturbance. Fertilizer did not influence any of the individual species' cover, but disturbance did (Table VIII). Herbicide increased the cover of Brown-Eyed Susan over tillage, which was greater than other treatments. Tillage and herbicide increased the cover of little bluestem and switchgrass over the other treatments. The inverse was found for the non-seeded species, except for tall fescue, which was reduced only by herbicide.

In summary, average total plant cover was highest in Control, Mow, and No Disturb plots with lower plant cover in Herbicide and Till plots. Native cover was highest in Herbicide and Till plots. Elkins had much less plant cover

Treatment	Elkins 2nd year	Buckhannon 2nd year	Weston 2nd year
Fertilizer	(%)	(%)	(%)
Fertilized	25 a	$13 a^{1}$	$9 a^1$
Unfertilized	22 a	15 a	10 a
Disturbance			
Control	0 d	0 b	0 c
No disturb	12 c	1 b	1 c
Mow	30 b	8 b	1 c
Till	43 a	31 a	13 b
Herbicide	32 b	31 a	33 a
Average seeded native cover	24	14	10

Table VII. Seeded native cover after two growing seasons at Elkins, Buckhannon, and Weston in response to fertilizer and disturbance

Values within treatments (fertilizer and disturbance) and within columns (sites) with the same letter are not significantly different ( $p \le 0.05$ ) using ANOVA and the LSD test.

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Treatment	Little bluestem	Switchgras	s Partridge pea	e Brown-Ey Susan	ed	Tall fescue	Red fescue	Crownvetch	Birdsfoot trefoil
Fertilizer		(%)	(%)	(%)	(%)	(9	6)	(%)	(%)
Fertilized	3 a*	1 a	1 a	2 a		31 a	20 a	14 a	2 a
Unfertilized	3 a	1 a	1 a	2 a		30 a	18 a	13 a	2 a
Disturbance									
Control	0 b	0 b	0 a	0 c		30 a	26 a	19 a	3 ab
No disturb	1 b	0 b	1 a	0 c		32 a	25 a	16 a	4 a
Mow	2 b	0 b	2 a	1 c		32 a	24 a	15 a	2 ab
Till	6 a	2 a	3 a	3 b		32 a	13 b	9 b	1 b
Herbicide	5 a	2 a	1 a	6 a		20 b	8 c	10 b	1 b

Table VIII. Average cover of individual species (including native and non-native species) after two growing seasons at Elkins, Buckhannon, and Weston in response to fertilizer and disturbance

These cover values for each species were averaged across all three sites at the end of the second year.

\*Values within treatments (fertilizer and disturbance) and within columns (species) with the same letter are not significantly different ( $p \le 0.05$ ) using ANOVA and the LSD test.

prior to plot establishment (only 1-year-old) compared to Buckhannon and Weston (17- and 27-years-old, respectively), and seeded natives were generally higher in all disturbed plots at Elkins. Fertilizer did not affect cover of non-native or native species even at the heavier rate of  $300 \text{ kg ha}^{-1}$ . These data indicate that natives can be seeded into established stands, but only if disturbed, and become an important contributor to ground cover by the second growing season after seeding. Partial or complete removal of established vegetation is necessary to allow the development of the slower-growing natives.

## DISCUSSION

Seeding newly-constructed sites is probably the easiest and most cost-effective method for introducing native plants, however the establishment of these species may be slow. On new sites, like Baker, seeded non-native species will generally out-perform native species and provide more cover immediately after seeding, but native species will establish slowly and contribute noticeably to the total plant cover after a few years. At Parkersburg where the topsoil was replaced and the site was heavily seeded with non-native, aggressive species, we were surprised that some of the seeded natives established and grew anyway and contributed up to 25 per cent cover after three growing seasons. This finding illustrates that the aggressive, cool-season, non-native species did not preclude native species establishment and development. It is possible that the topsoil may have provided some advantage to native species should have also received similar benefits from topsoil. Therefore on new sites, the slower-establishing nature of native plants suggests the need for a temporary ground cover for erosion control, such as an annual or biennial, until the natives become established and expand their coverage during the second and third growing seasons. Only big bluestem, little bluestem, switchgrass, Indiangrass, partridge pea, and Brown-Eyed Susan were found in our plots, so these are the only seeded native plants we can recommend for seeding at this time.

We emphasized the use of warm-season grasses in our native seed mixtures because our highway department was particularly interested in aesthetic, tall grasses along roadsides. Had we included cool-season, native grasses in our mixtures (like wildrye (*Elymus spp.*) or brome (*Bromus spp.*) grasses), we probably would have seen quicker establishment of these species than the later-successional, slower-establishing, warm-season grasses (Darris, 2003). As demonstrated in our study, the warm-season grasses did indeed require more time for establishment before significantly contributing to ground cover.

At sites with existing vegetation, we found that native plant establishment required disturbing the vegetation, and better establishment occurred with more vegetation removed through herbicide or tillage (see also Thompson *et al.*,

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2001). Mowing of existing vegetation did not disrupt or reduce competition sufficiently for native plants. The process of conversion from a non-native stand to a prominently native stand with herbicide or tillage is expensive and labor intensive for most state highway agencies. Because of this, seeding natives on sites with established vegetation should only be done where the established stand is already declining and open spaces are increasing. Continued monitoring of our native species plantings for several more years will give us additional information on the rise and spread of these species.

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