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# Effects of Nitrogen and Phosphorus Fertilizer and Topsoil Amendment on Native Plant Cover in Roadside Revegetation Projects

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**Abstract**

Establishing vegetation on roadsides following construction can be challenging, especially for relatively slow growing native species. Topsoil is generally removed during construction, and the surface soil following construction ("cut-slope soils") is often compacted and low in nutrients, providing poor growing conditions for vegetation. Nebraska Department of Transportation (NDOT) protocols have historically called for nitrogen (N) and phosphorus (P) fertilization when planting roadside vegetation following construction, but these recommendations were developed for cool-season grass plantings and most current plantings use slower-establishing, native warm-season grasses that may benefit less than expected from current planting protocols. We evaluated the effects of nitrogen and phosphorus fertilization, and also topsoil amendment, on the foliar cover of seeded and non-seeded species planted into two postconstruction roadside sites in eastern Nebraska. We also examined soil movement to determine how planting protocols and plant growth may affect erosion potential. Three years after planting, we found no consistent effects of N or P fertilization on foliar cover. Plots receiving topsoil amendment had 14% greater cover of warm-season grasses, 10% greater total foliar cover, and 4–13% lower bare ground (depending on site) than plots without topsoil. None of the treatments consistently affected soil movement. We recommend that NDOT change their protocols to remove N and P fertilization and focus on stockpiling and spreading topsoil following construction.

**Keywords:** Roadside seeding, Warm-season grasses, Fertilization, Nitrogen, Phosphorus, Topsoil

## Introduction

Seeding roadsides with native species is common in many states. The Nebraska Department of Transportation (NDOT) uses primarily native species because their deep root structures provide better anchorage, soil erosion prevention, and drought tolerance than common exotic species once established (Nebraska Department of Transportation 2017). However, NDOT's fertilization specifications remain geared toward its historic seeding mixture dominated by exotic cool-season grasses (e.g., smooth bromegrass, *Bromus inermis*) with relatively few native warm-season grasses and forbs, and updated fertilizer recommendations geared towards native species are needed.

Establishing stands of relatively slow growing native vegetation after construction can be challenging because of low nutrient levels and compaction of roadside soils. The Roadside Revegetation Guide (Steinfeld et al. 2007) published by the US Department of Transportation lists considerations for maximizing the success of roadside plantings nationwide, including water, soil characteristics, nutrient availability, and surface and slope stability. In Nebraska, primary concerns include water availability, nutrient availability, weed control, and selecting appropriate species for erosion control (Nebraska Department of Transportation 2017). Water availability is addressed by restricting planting to months of suitable growing conditions, and by adding a layer of straw or hay mulch after planting to help slow water movement and reduce evaporation (Nebraska Department of Transportation 2017). Fertilization of roadside plantings is commonly recommended to promote growth of fast-growing grasses, and standard protocols call for nitrogen (N) and phosphorus (P) fertilizer application at the time of planting unless planting into salvaged topsoil or supplementing nutrient levels with composted yard waste (Nebraska Department of Transportation 2017). However, native plant establishment has not been consistent under these protocols, and it is unclear if fertilization is beneficial to the relatively slow growing native species under these conditions. This had led to questions of how beneficial (or not) the standard fertilizer protocols are to roadside plantings of native species (Wienhold 2008, Research Statement of Need, NDOT internal document) and concern about the costs of fertilizer that may not be benefitting the plantings.

In contrast to NDOT guidelines, many native warm-season grass planting guidelines call for no N fertilization at planting (Anderson 2007; Barnhart 1996). Nitrogen fertilizer application may assist the establishment of introduced cool-season grasses (Rehm 1990), and N fertilization at planting may be detrimental to native warm-season perennial grass plantings because it favors fast growing weeds that compete with seeded species (Anderson 2007; Claassen and Marler 1998; McLendon and Redente 1992). The competition slows stand establishment and may cause stand failure if planted perennial species are suppressed. Also, perennials grown at higher N levels may have decreased rooting depths (Claassen and Marler 1998) and potentially greater sensitivity to water stress than those grown at lower N levels. In contrast, P fertilization is considered to be of value for perennial grass plantings because it is reported to encourage rapid root development (Hill et al. 2006). However, literature has reported varied responses of grasses to P fertilization (Black 1968; Sullivan and Daiber 1974) and restoration guidelines for warm-season grass and wildflower-dominated prairies do not provide fertilization recommendations for establishment (e.g., Packard and Mutel 1997). As a result of these uncertainties, this project evaluated the effect of using N and P fertilizer at the time of seeding to increase foliar cover at stand maturity.

An alternative to using fertilizer to restore soil fertility and enhance plant growth currently being considered by the NDOT is removing and stockpiling topsoil and replacing it on the soil surface after construction is completed (Claassen and Zasoski 1994). The application of stockpiled topsoil restores nutrients and soil microbes that assist with plant growth, nutrient uptake, and water holding capacity (Hargis and Redente 1984). Although this practice is widespread (and often required) for mining operations, its use has been infrequent following road construction. Stockpiling topsoil adds substantial expense and requires a location for storage of topsoil while construction is in progress.

## Objective

Our objectives were to evaluate the interacting effects of N fertilization, P fertilization, and topsoil amendment on the establishment of mature stands perennial native vegetation on standard post-construction roadside soils (cut-slope soils) in Nebraska. We expected greater cover of seeded species on roadsides receiving topsoil amendment prior to seeding. We hypothesized that cover of weedy species would increase in response to N fertilization and that establishment of seeded species would not be affected by N or P fertilization. In addition, we examined the impact these factors had on soil erosion for the first 3 years after seeding, and expected that any factor leading to decreased plant cover would increase erosion.

## Methods

### Study Site and Treatment Application

This research was conducted on two roadsides along Highway 66 in eastern Nebraska that had been seeded in September 2005 immediately after road construction was completed. As was standard practice, topsoil was not salvaged and the recommended seeding mixture of native grasses and forbs was drilled into the remaining cut-slope soils. The resulting stands of native perennial vegetation were thinner than desired and the roadsides served as good sites for our study. The Strategic Air Command (SAC) site was 4.5 km east of Ashland, Nebraska on Highway 66 and the Ashland site was 0.3 km east of Ashland, Nebraska on Highway 66. These sites included cut slopes with 3:1 backslopes and sufficient length and width to accommodate study plots. Sites had similar soil conditions within site and crop fields occurred on the boundaries. Immediately prior to application of treatments, the sites were repeatedly disked to turn under the aboveground vegetation and to prepare a seedbed. By NDOT request, the planting dates were staggered. The SAC site was disked and treatments applied in November 2009. The Ashland site was initiated using the same protocols in June 2010. Sites received ambient rainfall.

The experimental design at each site was a randomized complete block with three replications; each replications was 110 m long and 8 m wide running along the contour of the backslope. The treatment design was a split-split-plot design with topsoil amendment as the whole plot factor, nitrogen fertilization as the split plot factor,

**Table 1.** Pre-treatment cut-slope soil and topsoil properties

| | Ashland cut-slope soil May 2010 | | Ashland topsoil | SAC cut-slope soil November 2009 | | SAC topsoil |
|---|---|---|---|---|---|---|
| | 0–7.5 cm | 7.5–15.0 cm | | 0–7.5 cm | 7.5–15.0 cm | |
| Bulk Density (g/cm3) | 1.3 | – | 1.3 | – | | |
| Soil organic matter (%) | 2.3 | 1.9 | 2.4 | 1.3 | 1.1 | 2.3 |
| Nitrate nitrogen (ppm) | 2.7 | 2.5 | 9.2 | 2.0 | 1.6 | 11.9 |
| Phosphorus (ppm) | 11 | 6.7 | 38.2 | 13 | 13 | 30 |
| Potassium (ppm) | 191 | 151 | 244 | 303 | 271 | 160 |
| Cation exchange capacity | 16.6 | 15.4 | 21.8 | 20.5 | 19.7 | 18.4 |

and phosphorus fertilization as the split-split-plot factor. Whole plots (55 m long) were randomly assigned to either post-construction roadside soils (cut-slope soils) or topsoil addition. Cut-slope soil plots were similar to those of typical post-construction plantings, and the surface was primarily comprised of subsoil that was exposed after cutting into existing slopes and shaping by the project contractor. Topsoil addition plots received 10–15 cm of topsoil spread on top of cut-slope soils. The topsoil was purchased from a local construction company and the presence of soybean residue in the soil suggested a cropfield origin. The topsoil used in this study was not high quality but tended to have higher organic matter, nitrate, and phosphorus than the cut-slope soils (Table 1). After the whole plots had been established, the entire plot area was seeded with NDOT Type A complex seeding mixture (Table 2) using a Brillion landscape seeder. The NDOT Type A complex seeding mix is comprised of mostly native grass and forb species with seed produced in Nebraska or adjoining states. This seeding mix has been tested and found appropriate for seeding backslopes in this region (Schacht and Soper 2012).

Following seeding, each whole plot was divided into thirds (18 m split-plots) and assigned randomly to one of the three rates of N fertilization. Nitrogen rates included no N addition (0 kg N/ha), the standard NDOT application rate of 40 kg N/ha, and an intermediate rate of N fertilization (20 kg N/ha). The intermediate rate was included because establishment of warm-season grasses may respond favorably to low levels of N fertilizer (Anderson 2007). Nitrogen was applied by hand in the form of 0, 44, or 88 kg/ha urea.

Each of the nitrogen-fertilized split-plots was divided into three equal-size split-split-plots (6 m) and one of three P application rates (0, 22, or 44 kg P/ha) was assigned randomly to each of these three split-split-plots (“plots”). The three levels of P fertilization included no P addition (0 kg P/ha), the standard NDOT application rate of 44 kg P/ha, and an intermediate rate of P addition (22 kg P/ha). As with the N, the intermediate rate of P was included because grasses may respond to this lower rate of P fertilization. Phosphorus was applied by hand in the form of 0, 51.5, or 103 kg/ha $P_2O_5$.

Following seeding and fertilization, all plots were covered with prairie hay and crimped using a straw crimper as is the common practice on roadside plantings.

Pre-Treatment: Cut-Slope Soil and Topsoil Characteristics

Twelve vertical undisturbed soil cores (1.6 cm diameter × 15 cm deep) were taken from throughout each whole plot before disking and divided into 2 depths: 0–7.5 cm and 7.5–15 cm. Samples were composited by whole plot and analyzed by AgSource Harris Lab (Lincoln, NE) for pH, organic matter content, N, P, potassium, and cation exchange capacity. In addition, random samples were collected from each load of topsoil delivered to the sites and tested. Bulk density for pre-treatment soil was determined collecting three soil cores (5 cm diameter × 10 cm depth) from random locations within each whole plot. Pretreatment soil data were used to determine the characteristics of the cut-slope soils. Ashland had higher soil organic matter and N than SAC, and SAC had higher P, potassium, and cation exchange capacity than Ashland (Table 1). Differences were consistent across the two depths. We expected the topsoil to be better quality than cutslope soils in all aspects of soil fertility tested, but this was only partially true. Ashland topsoil was consistently higher quality than Ashland cut-slope soil (Table 1), but topsoil at SAC did not entirely meet soil quality expectations. SAC topsoil had greater N, P, and soil organic matter than SAC cut-slope soils, but the topsoil had less potassium and cation exchange capacity than the cut-slope soil (Table 1).

Soil bulk density was similar between Ashland and SAC sites, averaging 1.3 $g/cm_3$, which is within a typical range for cultivated clay and silt loam soils (Brady and Weil 1999) and below a threshold that would lead to restricted root growth (USDA Natural Resources Conservation Service 2008).

**Table 2.** Type A complex seeding mixture used in research plots

| Type "A" | Minimum physical purity (%) | Application rate (lbs PLS/acre)[a] |
|---|---|---|
| Virginia wildrye—NE, IA | 85 | 6 |
| Canada wildrye—Mandan | 85 | 4 |
| Slender wheatgrass | 85 | 4 |
| Intermediate wheatgrass—Slate, Oahe, Mandan | 85 | 4 |
| Western wheatgrass—Flintlock, Barton | 85 | 4 |
| Switchgrass—Pathfinder, Blackwell, Trailblazer | 90 | 1.5 |
| Indiangrass—Oto, NE-54, Holt | 75 | 3 |
| Big bluestem—Pawnee, Roundtree | 60 | 3 |
| Sideoats grama—Butte, Trailway, El Reno | 75 | 3 |
| Little bluestem—Aldous, Blaze, Camper | 60 | 2 |
| Illinois bundleflower—inoculated | 90 | 0.5 |
| Purple prairie clover—inoculated, Kaneb | 90 | 0.5 |
| Upright prairie coneflower (*Ratibida columnifera*) | 90 | 0.5 |
| Mexican red hat (*Ratibida columnifera*, red) | 90 | 0.75 |
| New England aster (*Aster novae-angliae*) | 90 | 0.1 |
| Indian blanket (*Gaillardia pulchella*) | 90 | 1 |
| Black-eyed Susan (*Rudbeckia hirta*) | 90 | 0.5 |
| Black samson (*Echinacea angustifolia*) | 90 | 0.25 |
| Oats/Wheat[b] | 90 | 10 |

a. Approved mechanical drill application rate in pounds of pure live seed (PLS) per acre
b. Wheat in the fall
All seed shall be origin Nebraska, adjoining states, or as specified.

### Data Collection

We used a 20 × 50-cm frame to estimate percent ground cover and percent foliar cover at 10 randomly-selected sampling points per plot in August 2012. Cover was estimated to the nearest 5% for major plant functional groups: cool-season grass (planted or volunteer native perennials), warm-season grass (planted or volunteer native perennials), forbs (planted or volunteer native perennials), weedy grasses (non-planted annual grasses, non-planted exotic perennial grasses, and other undesirable grasses), and weedy forbs (non-planted annual forbs and other undesirable forbs). Areas of the frame not covered by foliar cover were recorded as ground cover (percent bare ground or litter), so foliar cover plus ground cover for each plot equaled 100%.

Within 24 h of seeding, ten erosion pins were installed in each plot at regular intervals to estimate soil movement (Haigh 1977). Our erosion pins were metal rods 45 cm in length that were pushed into the ground so that the top of the rod was 20 cm above the soil surface. Measurements from the top of the rod to the soil surface were taken annually in June and September after planting and were used to determine soil loss or accumulation. The pins were reset at 20 cm each time measurements were taken. We described soil movement within three time periods: date of seeding to September 2010 (period 1), September 2010–2011 (period 2), and September 2011–2012 (period 3). We defined the difference in soil height from the beginning to the end of each time period as the change in soil height.

### Data Analysis

Data were analyzed as a split-split plot design using PROC GLIMMIX in SAS (SAS 9.3, Cary, NC 2012) to assess the impact of site, soil, N, and P, and their interactions on the foliar cover of each functional group and total foliar cover. Random terms were included in the cover analysis to properly distribute the degrees of freedom, ultimately defining the denominator degrees of freedom for the whole plot as 4, for the split-plot as 16, and for the split-split-plot as 48. The same analysis was used to analyze soil movement responses, except a time period factor was added.

## Results

### Cover

Across sites, soils, and fertilizer treatments, there were no differences in foliar cover found for cool-season grasses, forbs, weedy forbs, or weedy grass cover. All significant

**Table 3.** Summary of significant cover responses to site and treatments

| | | Warm-season grass | Total foliar cover | Bare ground | Litter |
|---|---|---|---|---|---|
| Overall Average | | 51.7% | 62.5% | 12.7% | 24.8% |
| Site | Ashland | Site x N | Site x N | Site x soil | 19.0% |
| | SAC | interaction* | interaction* | interaction* | 30.6%*** |
| Soil | Topsoil | 58.6%* | 67.7%** | Site x soil | NSD |
| | Cut-slope soil | 44.7% | 57.3% | interaction* | |
| N | 0 kg N/ha | Site x N | Site x N | NSD | NSD |
| | 20 kg N/ha | interaction* | interaction* | | |
| | 40 kg N/ha | | | | |

*, **, and *** indicate significant differences between factors at $P \le 0.05$, $P \le 0.01$, and $P \le 0.001$, respectively
There were no significant responses of cover to *P* levels and no significant responses to any treatment by cool-season grass, forbs, weedy grass, or weedy forbs

results (warm-season grass, total foliar cover, percent bare ground, and litter cover, and soil movement) are summarized in Table 3 and Figs. 1 and 2.

Cover at both sites was strongly dominated by warm-season grasses, litter, and bare ground (Fig. 3). Total foliar cover (62.5%) did not differ between sites (Table 3), but we found site differences on the cover of litter, warm-season grasses, and percent bare ground. Litter was greater at SAC than at Ashland (30.6% vs. 19.0%, $P < 0.001$). There were site x N interactions for warm-season grass cover and total foliar cover ($P = 0.013$ and $P = 0.037$, respectively). Warm-season grass cover was greater at Ashland than at SAC at the 0 and 40 kg N/ha levels ($P = 0.019$ and $P <$ 0. 001, respectively, Fig. 1a). Total foliar cover was greater at SAC than at Ashland at the 20 kg N/ha level only ($P = 0.032$, Fig. 1b).

Percent bare ground was involved in a site x soil interaction ($P = 0.018$, Fig. 1c). Ashland had greater bare ground than SAC in both cut-slope soil and topsoil plots ($P = 0.003$ and $P = 0.021$, respectively), and percent bare ground was greater in the cut-slope soil plots than in topsoil plots at both sites. However, the topsoil application at Ashland resulting in a greater decrease in percent bare ground (24.7% vs. 13.4%, $P = 0.001$) than topsoil use at SAC (8.6% vs. 3.9%, $P = 0.020$).

Soil type had an effect on warm-season grass cover and total foliar. Topsoil plots had greater warm-season grass cover (58.6 vs. 44.7%, respectively, $P = 0.026$) and greater total foliar cover (67.7% vs. 57.3%, respectively, $P = 0.003$) than cut-slope soil plots.

Warm-season grass cover and total foliar cover were the only variables with a significant response to N fertilization, and both were part of site x N level interactions. (Figs. 1a, b). At SAC, N at the 20 kg N/ha rate resulted in greater warm-season grass cover than at the 40 kg N/ha rate ($P = 0.014$, Fig. 1a). At Ashland, N at the 40 kg/ha rate resulted in greater total foliar cover than at the 20 kg N/ha level ($P = 0.046$, Fig. 1b). There were no other significant effects of N fertilization.

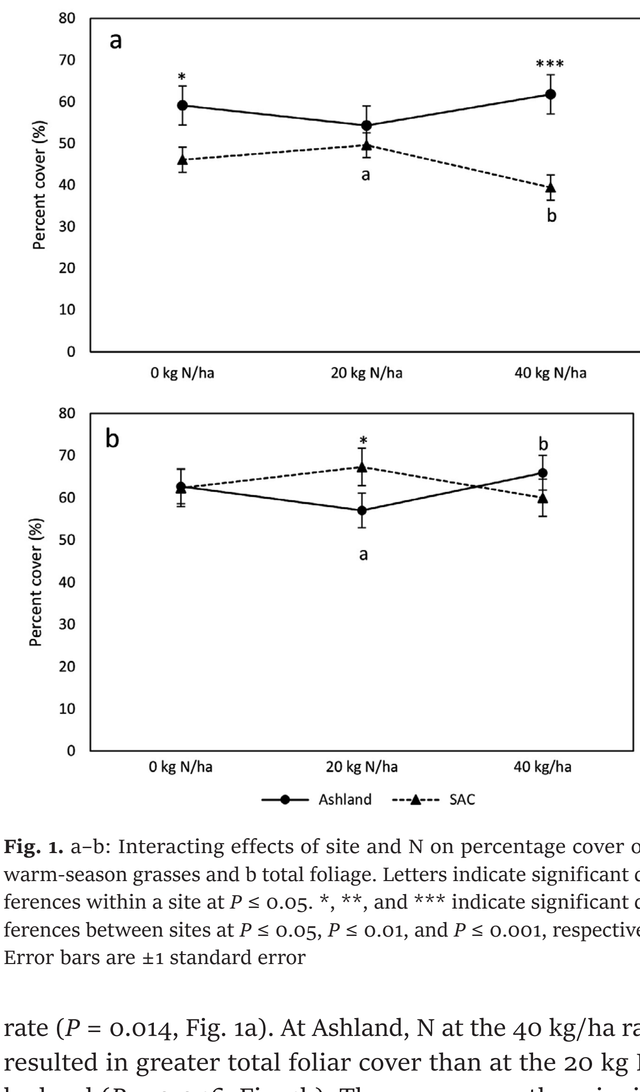


**Fig. 1.** a–b: Interacting effects of site and N on percentage cover of a warm-season grasses and b total foliage. Letters indicate significant differences within a site at $P \le 0.05$. *, **, and *** indicate significant differences between sites at $P \le 0.05$, $P \le 0.01$, and $P \le 0.001$, respectively. Error bars are ±1 standard error

There were no significant effects of P fertilization on foliar cover.

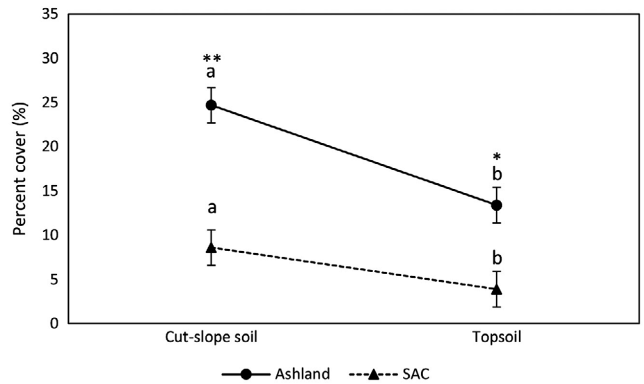


**Fig. 2.** Interacting effects of site and soil type on bare ground cover. Letters indicate significant differences within a site at $P \le 0.05$. *, **, and *** indicate significant differences between sites at $P \le 0.05$, $P \le 0.01$, and $P \le 0.001$, respectively. Error bars are ±1 standard error

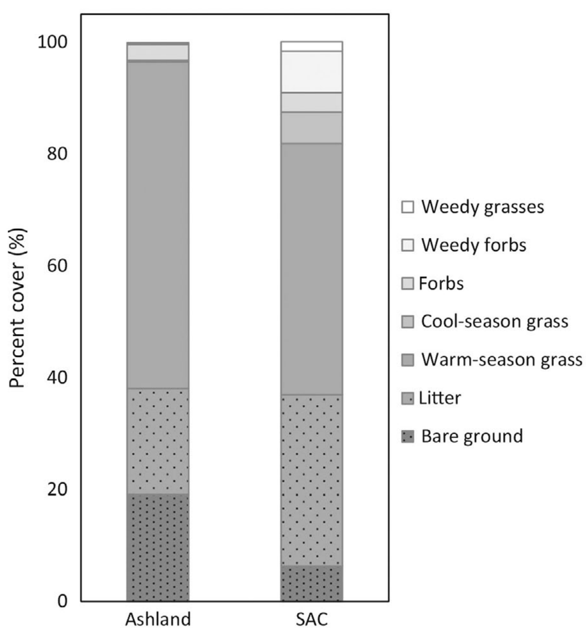


**Fig. 3.** Percent cover by plant functional group at SAC and Ashland sites

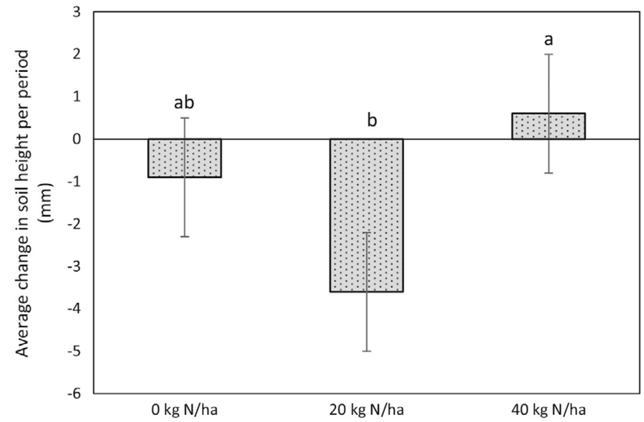


**Fig. 4.** Soil movement (mm) in response to N fertilization. Different letters indicate significant differences in soil movement by N fertilization level at $P \le 0.05$. Error bars are ±1 standard error

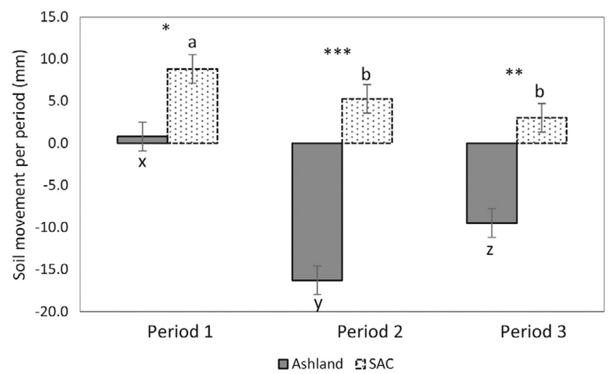


**Fig. 5.** Change in soil movement by site and time period. Within a site, different letters indicate significant differences ($P \le 0.05$) in soil movement by time period. *, **, and *** indicate significant differences between sites at $P \le 0.05$, $P \le 0.01$, and $P \le 0.001$, respectively. Error bars are ±1 standard error

Soil Movement

We found no effect of phosphorus or soil type on soil movement, but there was an effect of nitrogen fertilization overall ($P = 0.039$, Fig. 4). Across the three time periods, plots receiving 40 kg N/ha accumulated an total of 0.6 mm of soil per year while plots receiving 20 kg N/ha lost 3.6 mm of soil per year ($P = 0.039$, Fig. 4). There were no differences in the rate of soil movement between plots receiving 0 kg N/ha (−0.9 mm) and plots receiving added nitrogen.

There was a significant site x time period interaction ($P$=0.001, Fig. 5). Soil movement at SAC was different from Ashland in all 3 years. SAC accumulated soil in each of the three periods, but the accumulation rate generally decreased over time. SAC soil accumulation in Period 1 (8.8mm) was greater than soil accumulation in Period 2 (5.3 mm, $P$=0.046) and Period 3 (3.0mm, $P$=0.005) but soil accumulation did not differ statistically between Period 2 and 3. In contrast, Ashland soil movement changed over time. Ashland accumulated soil in Period 1 (0.8mm), but lost soil in Period 2 (−16.3 mm, $P < 0.001$ vs. year 1) and Period 3 (−9.5mm, $P$=0.001 vs. year 1, $P$=0.002 vs. year 2).

## Discussion

Roadsides of newly constructed or renovated highways are harsh environments for the establishment of perennial vegetation. Soil compaction, lack of existing cover, steep slopes, and low nutrient level availability following topsoil removal create challenges for the early germination and growth of seeded species. In addition, native species are often relatively slow to establish, and many guidelines for native species recommend periodic mowing during the first year or two after seeding to help control weed pressure while native plants are young (Packard and Mutel

1997; Williams et al. 2007). Although this is not part of the NDOT protocols, it highlights the relatively slow early growth rates of many native plants.

We tested the effectiveness of fertilizer and topsoil addition on facilitating the development of perennial plant cover 3 years after seeding, and on reducing soil erosion during the first 3 years after planting, in order to develop recommendations to promote future seeding success under these conditions. We expected topsoil addition to increase the cover of seeded species, and our results supported this hypothesis. Plots that received topsoil had greater warm-season grass cover, total foliar cover, and reduced percent bare ground relative to cut-slope soil plots. Despite higher nutrient levels than cut-slope soils, topsoil addition had no effect on seeded forbs and did not result in an increase in weedy species cover. Other studies have found higher concentrations of weedy species in areas treated with topsoil than in a variety of alternative substrates, including mine spoils (Huxtable et al. 2005) and serpentine subsoils (Koide and Mooney 1987). However, these studies used topsoil that had been stockpiled, not crop field topsoil as was used in our study. Crop field soil may have fewer weed seeds than these examples of stockpiled soil because of the active weed management that takes place. In contrast, most studies that focus on stockpiled topsoils use stockpiles that are in place for multiple years, allowing multiple generations of weedy growth to produce a substantial weed seed abundance in the soil. We expect that stockpiled topsoil in roadside construction settings would have relatively low weed seed abundances because the soils were recently covered by perennial vegetation and only held in stockpiles for a relatively short amount of time (usually less than 1 year).

We expected N fertilization to result in greater cover of weedy species and have no benefit to perennial species. Instead, although nitrogen fertilization had no benefit to perennial species, it also had no effect on cover of weedy species. Although other studies have found N fertilization to increase weedy plant cover (Berg 1995; Blumenthal et al. 2005; Gillen et al. 1987), we had relatively low cover of weedy grasses and forbs overall. The recently exposed cutslope soils may have had a limited seed bank, and any weedy species that occurred may have declined in the 3 years since planting as the seeded species became mature. Nitrogen fertilization has frequently been shown to increase biomass in warm-season grass, but these studies generally include multiple fertilizer applications in the years following planting instead of a one-time fertilization at the time of planting (Berg 1995; Gillen and Berg 1998; Heggenstaller et al. 2009; Rehm et al. 1972). NDOT practices usually only apply fertilizer at the time of planting, but N fertilizer applied in the year(s) following planting may be a more effective way to increase cover.

Phosphorus fertilization, as expected, did not affect foliar cover. As with N, this is in contrast with studies that have found P fertilization to increase biomass in previously established native grasses (Black 1968; Rehm 1990), although the response was not universal (Black 1968; Muir et al. 2001; Sullivan and Daiber 1974).

Despite impacts on total and warm-season grass cover, the factor with the strongest and most consistent impact on soil movement was site, with Ashland generally losing soil and SAC generally gaining soil. This may be the result of differences in the amount of bare ground and litter between sites. SAC averaged 6.5% bare ground and 31% litter while Ashland averaged 19% bare ground and 19% litter (Fig. 3). The greater litter cover and lower percent bare ground at SAC likely reduced potential for both wind and water erosion relative to Ashland, and may have contributed to capturing sediment from outside the plot areas despite the higher warm-season grass cover at SAC. The results suggest that the most important factor in soil movement after these plantings was increasing litter and decreasing the amount of bare ground.

One of the key differences in both foliar cover and soil movement was site, but understanding the reasons for these differences presents challenges. SAC was planted in November 2009 while Ashland was planted in June 2010 and Ashland cut-slope soils were higher quality than SAC soils in most metrics tested (Table 1). However, Ashland also had greater percent bare ground and soil loss, which is directly in contrast with what might be expected with greater warm-season grass cover at this site. In contrast, SAC had greater litter cover and lower soil quality.

Cover of perennial plant species (relative to preconstruction vegetation) is the standard metric by which roadside plantings are evaluated. Of the factors tested, only topsoil addition shows promise in increasing perennial plant cover based on our increased total foliar cover (from 57.3 to 67.7%) and decreased bare soil (from 16.6 to 8.7%). Overall, we found minimal justification for fertilizing warm-season grass and forb plantings with nitrogen or phosphorus.

It is likely that roadside construction projects would prefer to stockpile topsoil rather than acquiring topsoil amendments from another source because of the associated costs. On this project, the acquired topsoil was likely of crop field origin (based on soybean residue observed in the soil), and cultivated topsoil is well known to be lower in soil organic matter (SOM) than uncultivated soils (Burke et al. 1995). Others recent studies have found soil organic matter on established roadside slopes in Eastern Nebraska to range from 2.8 to 5.5%, averaging 4.3% overall (unpublished data). These soils are comparable to soil that would be stockpiled when a construction project occurs on previously well-vegetated roadsides in this region.

Our cropland topsoil averaged 2.3% SOM, suggesting that if stockpiled topsoil from the construction site is used, soil quality may well be higher than that which was used in this project, potentially leading to even greater benefits.

Overall, our results suggest no benefit in stand establishment or erosion reduction with use of nitrogen or phosphorus fertilizer. Instead, seeding into topsoil resulted in 14% greater cover of warm-season grasses and half the amount of bare ground than seeding into cut-slope soils, suggesting that the use of topsoil amendments following roadside construction can result in greater cover of desirable perennial plants in the years after planting.

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