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# Wildflowers as an Alternative for Landfill Revegetation in Spotsylvania County, VA

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ABSTRACT

As landfills become widespread and conspicuous components of the landscape, communities are increasingly trying to make them an asset rather than a liability. Ecological, financial, regulatory, and social concerns influence the choice of plants for revegetating landfills. In Spotsylvania County, part of the closed landfill was seeded with wildflowers to create a more aesthetically pleasing landscape than the standard revegetation mixture currently used. This study compared vegetative cover and species richness and composition in areas seeded with the wildflower and standard mixtures. Over a period of 2 years, 15 of the 19 species of wildflowers and all 9 species of the standard mixture became established. Cumulative species richness was higher in wildflower plots, whereas the number of species observed on individual sampling dates was similar in plots seeded with both mixtures due to the number of colonizing species in all plots. Vegetative cover did not differ significantly in areas seeded with the two mixtures. This study shows that, by using a range of criteria including erosion control, cost, and aesthetic and ecological value, a number of native and naturalized wildflower species compare favorably with species commonly used for landfill revegetation.

## INTRODUCTION

Landfilling is a common means of disposing of household nonhazardous waste. As growth in the human population has resulted in the generation of increasing amounts of solid waste, city and county governments are confronted more often with the escalating costs of landfill construction, operation, and closure. Municipal landfills pose numerous environmental and social problems. Byproducts of anaerobic decomposition in landfills can contaminate surrounding soil and water supplies if not properly contained and monitored (Booth and Vagt, 1990; Flower et al., 1981). The anaerobic decomposition processes in landfills generate offensive odors while a landfill is in operation and afterwards, and trash from the landfill may blow offsite despite efforts to keep material in place. The environmental contamination, the odors, and misplaced trash affect people living near landfills, and property values in the area often decrease as a result. Optimally, landfills should be located out of public view; however, today, the appropriate geological and hydrological parameters necessary to site landfills are usually located near population centers. Consequently, community officials are attempting to make landfills assets rather than visual or environmental liabilities.

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Research on landfill processes has focused on the effects of landfill leachate and gases on plants used to revegetate landfills. This research has evolved because, when a landfill is closed, it must be capped with an appropriate soil or geotextile membrane liner and seeded with fast growing vegetation to stabilize the liner (Figure 1). Most of the literature concerning landfill revegetation suggests that a mixture of quick growing annual and perennial grasses and perennial legumes be used to stabilize soil (Ettala et al., 1988; Gilman et al., 1985). Recommended plants are all hybrid, non-native species that have been particularly effective in suppressing colonizing woody species on roadside embankments and surface mined sites (Luken, 1987; Wade, 1989); in Virginia, commonly used species include *Festuca arundinacea* (Kentucky-31 tall fescue), *Lespedeza cuneata* (sericea lespedeza), and *Coronilla varia* (crown vetch) (see Table 1 for a complete list). The standard revegetation species succeed within a few years to a monoculture of *C. varia* or *L. cuneata*, which provide little wildlife value.

The municipal landfill (Chancellorsville Landfill) located in Spotsylvania County in central Virginia is an illustration of an innovative solution to the multiple constraints of landfill closure. The director of public works was confronted with the task of creating an attractive landscape on a 3.8 ha (9.4 acre) landfill. The landfill was in operation from the mid-1970s until its closure in 1992. Secondary roads now encircle the landfill, and the northwestern portion of the landfill site is less than a kilometer from residential housing. In addition, old railroad tracks that have been designated as part of the statewide "Rails to Trails" project run alongside the landfill. In an effort to create a more aesthetically pleasing landscape, the Board of Supervisors of Spotsylvania County approved money to plant wildflowers over part of the landfill. As the operator was concerned whether wildflowers would provide sufficient cover to retain the soil and maintain the integrity of the cap liner, he chose a shallow slope to seed as a trial study. The steeper slopes were seeded with a standard revegetation mixture.

The objectives of the present study were to compare vegetative cover and species richness and composition over time in each mixture type. In combination with a cost analysis, these data serve to determine if the wildflower seed mixture is a viable alternative to the standard revegetation mixture.

## MATERIALS AND METHODS

The Chancellorsville Landfill is a 3.8 ha (9.4 acre) nonhazardous solid waste disposal area near Fredericksburg, Virginia (N 38° 16.3', E 77° 32.7'). The landfill was closed in April 1992 using the capping design illustrated in Figure 1. The soil used in the capping layer was excavated when the landfill was constructed. Seeding of the capped landfill was completed in July 1992. Areas with 3:1 (33%) slopes were seeded with a standard revegetation mixture. The southwestern-facing portion of the landfill with a 4:1 (25%) slope was seeded with a "Northeastern" mixture of wildflowers prepared by Applewood Seed Company. This seed mixture was comprised predominantly of species native and naturalized to Virginia. We define native as species present in Virginia prior to European colonization. The term naturalized refers to species that, while not native to Virginia, are a well-established component of the flora and do not aggressively compete with native species. Scientific and common names for all species are listed in Table 1 (hereafter, species are referred to by their scientific names only). Both mixtures were hydroseeded by spraying a mixture of seeds, paper mulch, N:P:K fertilizer, and water.

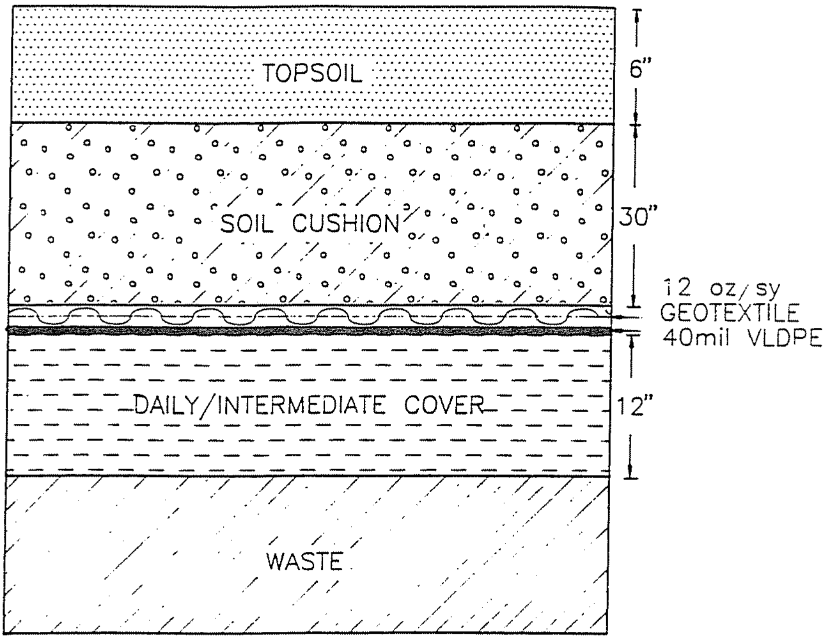


FIGURE 1. Soil cap design used at the Chancellorsville Landfill (courtesy of Draper Aden and Associates).

The hydroseed tank was not rinsed before the wildflower mixture was added, and parts of the area sprayed with the wildflower mixture included residual seeds from the standard revegetation mixture. The standard revegetation mixture was seeded at a density of 12 kg (~26 lbs) per acre, and the wildflower mixture was seeded at a density of 9 kg (~20 lbs) per acre. The difference in seeding rates was due to the higher cost of the wildflower mixture. No straw cover or additional irrigation was provided.

The southwestern aspect was chosen for study because both mixtures were represented. Four 80 m (~248 ft) transects, separated by 10 m (~31 ft), were established along the length of the same hillface. Two transects each were located in areas revegetated with the wildflower mixture (4:1 slope) and the standard mixture (3:1 slope). Eight permanent markers were placed at 10-m intervals along each transect for surveys. The total percent cover and percent cover of individual species were recorded in 1 $m^2$ ($9ft^2$) plots at each marker three times between April and September in both 1993 and 1994. Cover was estimated by the amount of area a plant shaded within the sampling unit. Plants were identified using specimens from the Virginia Polytechnic Institute and State University (Virginia Tech) Herbarium.

Species richness and cover were compared using t-tests, considering the 16 plots of each seeding mixture as replicates. Repeated measures analysis of variance was used to determine if the main effects of time and mixture type or the related interaction was significant across both pairs of transects. Repeated measures testing was required because the same experimental unit was repeatedly sampled over time (Meredith and Stehman, 1991). Throughout, results in which $p < 0.05$ are reported as significant.

TABLE 1. Plant species inventory at the Chancellorsville Landfill in 1993 and 1994. Values are the number of survey plots in which each species was observed in each year. Values are from a total of 16 plots for the standard and wildflower species and from a total of 32 plots for colonizing species, since most of these species were observed in plots seeded with each of the mixtures. P indicates that the species was not observed in study plots but was observed elsewhere on the landfill.

| LATIN NAME | COMMON NAME | No. of plots 1993 | No. of plots 1994 |
|---|---|---|---|
| STANDARD MIXTURE TRANSECTS (16 plots total) | | | |
| *Agrostis alba* | Red top | 0 | 1 |
| *Coronilla varia* | Crown vetch | 4 | 8 |
| *Festuca arundinacea* | Kentucky-31 fescue | 16 | 9 |
| *Lespedeza cuneata* | Sericea lespedeza | 4 | 11 |
| *L. stipulacea* | Korean lespedeza | 9 | 11 |
| *Lolium multiflorum* | Annual rye | 1 | 0 |
| *L. perenne* | Perennial rye | 16 | 13 |
| *Secale cereale* | Abruzzi rye | 1 | 0 |
| *Setaria italica* | German foxtail millet | 6 | 0 |
| NORTHEASTERN MIXTURE TRANSECTS (16 plots) | | | |
| *Aquilegia canadensis* | Eastern columbine | 0 | 0 |
| *Aster novae-angliae* | New England aster | 4 | 1 |
| *Bouteluoua gracilis* | Buffalo grass | 7 | 14 |
| *Centaurea cyanus* | Cornflower | 3 | 0 |
| *Cheiranthus allonii* | Wallflower | 3 | 0 |
| *Chrysanthemum maximum* | Shasta daisy | 8 | 1 |
| *Coreopsis lanceolata* | Lance-leaved coreopsis | 16 | 16 |
| *Dianthus barbatus* | Sweet William pink | 14 | 14 |
| *Digitalis purpurea* | Foxglove | P | 0 |
| *Echinacea purpurea* | Purple coneflower | P | P |
| *Gypsophila elegans* | Baby's breath | 4 | 0 |
| *Hesperis matronalis* | Dame's rocket | 0 | 10 |
| *Linaria maroccana* | Spurred snapdragon | 0 | 0 |
| *Linum grandiflorum rubrum* | Scarlet flax | 0 | 0 |
| *Lupinus perennis* | Perennial lupine | P | 0 |
| *Oenothora missourensis* | Dwarf evening primrose | P | P |
| *Papaver rhoeas* | Poppy | 0 | 0 |
| *Rudbeckia hirta* | Black-eyed Susan | 10 | 6 |
| *Silene armeria* | Catchfly | 1 | 1 |
| COLONIZING SPECIES* (32 plots) | | | |
| *Ambrosia artemisiifolia* | Ragweed | 24 | 18 |
| *Bidens polylepis* | Beggar tick | 13 | 0 |
| *Cassia nictitans* | Wild sensitive plant | 3 | 2 |
| *Dactylon* sp. | Crab grass | 12 | 9 |
| *Holcus lanatus* | Velvet grass | 1 | 1 |
| *Hypericum perforatum* | St. John's wort | 1 | 2 |
| *Medicago sativa* | Alfalfa | 4 | 3 |
| *Phleum pratense* | Timothy | 2 | 2 |
| *Rosa multiflora* | Multifloral rose | 4 | 4 |
| *Rumex acetosella* | Sheep sorrel | 2 | 2 |
| *R. obtusifolius* | Sorrel | 2 | 2 |
| *Solidago* spp. | Goldenrod | 0 | 2 |
| *Trifolium arvense* | Rabbit's foot clover | 4 | 4 |

*Colonizing species include all species that were not seeded on the landfill. They comprise a mixture of native, naturalized, and non-native species.

TABLE 2. Soil nutrients. Values are in mg/kg and are means ± 1 SE. N = 3 samples per transect.

| Transect | pH | P | K | $NO_3$-N | Ca | Mg | SS |
|---|---|---|---|---|---|---|---|
| Standard 1 | 6.8 ± 0.3 | 6.0 ± 2.7 | 63.0 ± 31.0 | 3.7 ± 1.2 | 592 ± 97 | 77.3 ± 8.6 | 55.3 ± 15.0 |
| Standard 2 | 6.4 ± 0.3 | 3.7 ± 1.2 | 55.7 ± 11.0 | 3.7 ± 1.2 | 492 ± 87 | 70.3 ± 4.6 | 46.7 ± 7.5 |
| Wildflower 1 | 6.9 ± 0.4 | 13.3 ± 6.1 | 55.7 ± 14.0 | 3.7 ± 1.2 | 1036 ± 148 | 98.3 ± 9.5 | 93.7 ± 14.0 |
| Wildflower 2 | 6.6 ± 0.3 | 6.3 ± 3.2 | 56.7 ± 17.0 | 4.3 ± 1.2 | 788 ± 363 | 86.0 ± 25.0 | 64.0 ± 23.0 |

Soil samples were collected in 1994 from the upper 8 cm (3.1 in.) of the soil cap at three randomly located points of each of the four transects to provide baseline information for the vegetation data collected. Samples were analyzed for pH and macronutrients (P, K, $NO_3$-N, Ca, Mg, SS) at the Virginia Tech Soil Testing Laboratory. Soil nutrient data were pooled for each transect, and the mean values were compared within and between seed mixture types using t-tests.

## RESULTS

Levels of all soil nutrients on the landfill were within ranges acceptable for growth (Table 2), although the level of nitrate nitrogen was low, 3-5 mg/kg (Brady, 1990). None of the measured nutrient levels differed significantly between paired transects nor between mixture type for any nutrient, suggesting that the soil nutrients were relatively homogeneous across the study area. Although Ca and soluble salts averaged higher levels in the wildflower plots, the differences were not statistically significant due to high variance.

Plant species observed in 1993 and 1994 in the survey plots are listed in Table 1. Eleven of the 19 wildflower species seeded were recorded on survey plots. Four additional species, including *Digitalis purpurea*, *Echinacea purpurea*, *Lupinus perennis* and *Oenothora speciosa*, were observed on the landfill but not in the survey plots. Only four of the wildflower species seeded, *Aquilegia canadensis*, *Linaria maroccana*, *Linum grandiflorum rubrum* and *Papaver rhoeas*, were not observed on the landfill. Two wildflower species, *Coreopsis lanceolata* and *Dianthus barbatus*, appeared at the highest frequency both years, being found on 16 and 14 plots, respectively. Five species, including *Centaurea cyanus*, *Cheiranthus allonii*, *Digitalis purpurea*, *Gypsophila elegans*, and *Lupinus perennis*, were observed in the first but not the second year of the study. All nine of the standard mixture species seeded were observed in survey plots in both years. *Festuca arundinacea* and *Lolium perenne* were the dominant species. Three species, *Agrostis alba*, *Lolium multiflorum*, and *Secale cereale*, were only observed in one plot in one year.

A total of 17 and 20 species (including both seeded and naturally colonizing species) was observed during the 2-year study period on the two wildflower transects, while 16 and 15 species were observed on the two standard mixture transects. Nine species naturally colonized in areas seeded with the wildflower mixture, and 11 species naturally colonized areas seeded with the standard mixture. The most common colonizing species was *Ambrosia artemisiifolia*. Most other colonizing species were widespread, non-native species.

On individual sample dates, species richness was slightly higher in the plots planted with the wildflower mixture, but it was significantly higher only in April 1994.

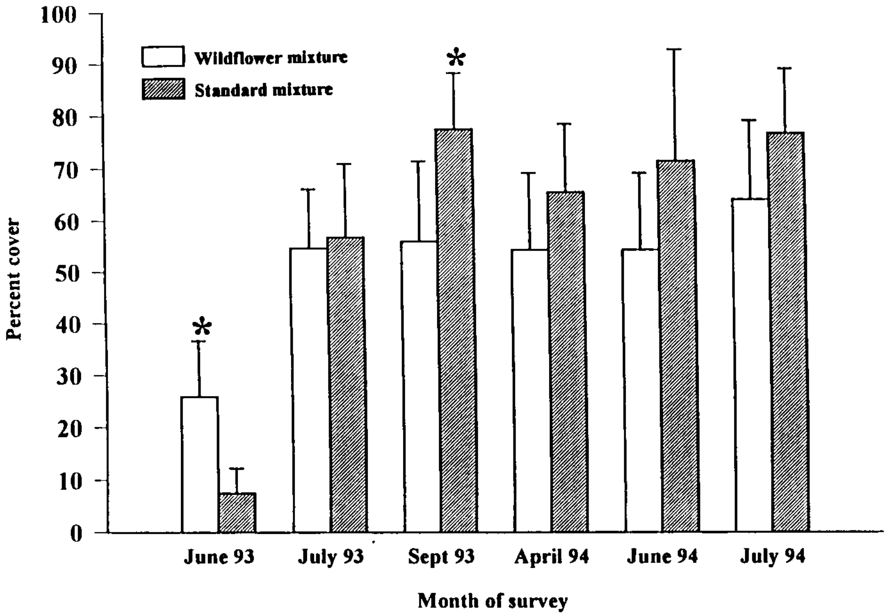


FIGURE 2. Average plant species richness on individual sampling dates for wildflower and standard mixture plots. N = 16 for each mixture. (*Means are significantly different at the p = 0.05 level using a t-test.)

Average species richness was highest in June 1993 in both mixtures (nine species) and declined in July and September (Figure 2). In 1994, species richness in the areas planted with the wildflower mixture increased from the previous September, but never recovered to the same level as the number recorded in June 1993. The number of species in plots planted with the standard revegetation mixture increased after an initial drop between June and July 1993. At the end of the survey, species richness was nearly the same in areas seeded, as a number of wildflower species were no longer present.

Total cover in the two areas ranged from 7.5-100% during the study; cover values were lowest at the initiation of the study. Cover was slightly higher in the plots planted with the standard revegetation mixture throughout the survey period (Figure 3), but it was only significantly higher than the wildflower mixture in June and September 1993. Cover of individual plots seeded with the standard mixture was sometimes the same or lower than that of the wildflower mixture plots, as there was high variability in vegetative cover in areas seeded with both mixtures. Cover for the areas seeded with the wildflower mixture remained at approximately the same level throughout the study, rising slightly in July 1994. The wildflower mixture cover increased with time during the two growing seasons. The standard revegetation mixture increased in the middle of the first growing season and decreased toward the end of the second growing season (Figure 3). Cover of naturally colonizing species ranged from 0-80% and increased overall during the 2 years of the study. Cover of naturally colonizing species was highly variable between plots seeded with the same mixture and was not significantly different in wildflower and standard mixture plots.

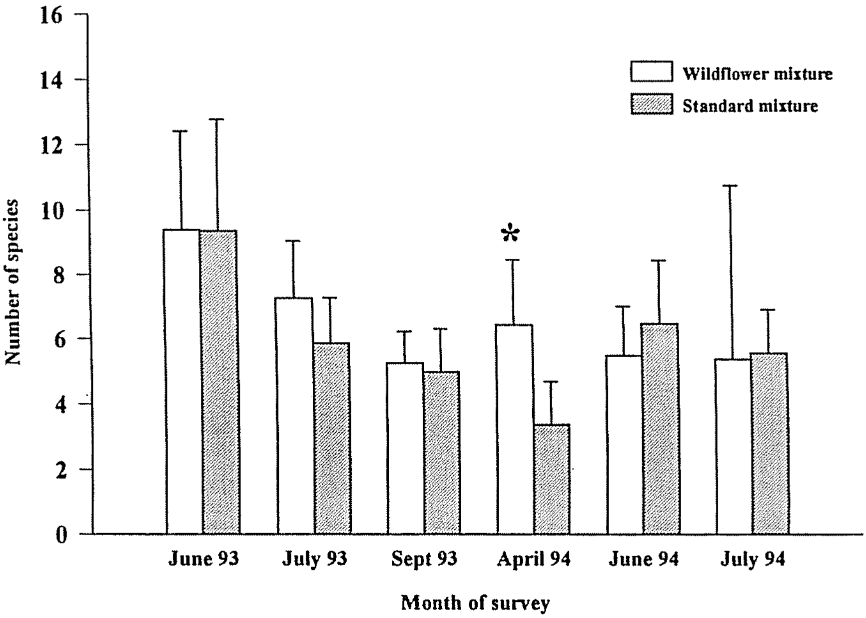


FIGURE 3. Average plant cover on individual sampling dates for wildflower and standard mixture plots. N = 16 for each mixture. (*Means are significantly different at the p = 0.05 level using a t-test.)

The total cost of the wildflower mixture seeded at 9 kg (~20 lb) per ha and of the standard mixture seeded at 12 kg (~26 lb) per ha was $1235.00 ($500.00/acre) each. The cost per hectare of the four absent wildflower species was $247.00 ($100.00/acre), 20% of the total cost of the wildflower mixture. The cost of the two dominant species of the wildflower mixture, *Coreopsis lanceolata* and *Dianthus barbatus*, was $89.00/ha ($36.00/acre), only 7% of the total cost of the mixture.

## DISCUSSION

Communities such as those in Spotsylvania County, VA, are increasingly recognizing the benefits of revegetating landfills with native and naturalized species. Use of wildflowers for landfill revegetation is currently limited by concerns about their low establishment rates and the high cost of purchasing these seeds. This study has demonstrated that several wildflower species seeded at the Chancellorsville Landfill constitute viable alternatives to the non-native species currently used. Despite suboptimal growing conditions present at this site, performance of the wildflowers did not differ significantly from the standard mixture species with regard to erosion control, aesthetic value, ecological value, and cost.

Many landfill operators are hesitant to use native and naturalized species because of fear of increased erosion. Using aboveground cover as an indication of erosion control, the wildflower mixture compared favorably with the standard mixture. At only one of six sampling dates was cover significantly higher in standard mixture plots, despite the fact that the standard mixture was seeded at a higher rate. Most importantly, the landfill operator was satisfied with the cover provided by the wildflower mixture during the course of the study. As state solid waste management guidelines do not specify an adequate quantity of vegetative cover for different slopes, the landfill operator must decide what is an acceptable amount. It is doubtful that cover alone is an accurate indicator of soil retention on slopes (Torbert and Burger, 1992). However, visual examination of aboveground cover is the most common method of determining whether an area is stabilized. Results of this study do not guarantee that either plant mixture will stabilize the cap without substantial soil loss; the results only indicate that the wildflower mixture is comparable to the standard mixture for aboveground cover over the 2 years of the study.

Cost is commonly the overriding criterion in choosing a revegetation protocol. A major reason for seeding aggressive, non-native species in disturbed areas is that they are often less expensive than native and naturalized species. If seeding rates had been equivalent in this project, the wildflower mixture would have been only 20% more expensive than the standard mixture. This difference in cost could be easily reduced by removing a few of the species that did not establish well on the site and replacing them with appropriate species. It is important to note that these costs are estimates; seed prices may vary greatly with company and year. Regardless, it appears that wildflowers are an economically viable revegetation alternative in the southeastern United States.

While difficult to quantify, aesthetic value is an important factor in the public's acceptance of disturbed areas such as landfills. Based on observations by the landfill operators and scientists, the sections seeded with wildflowers were more visually pleasing. By the end of the survey, the color display in the wildflower section was dominated by the yellows of *Bidens* spp., *Coreopsis lanceolata*, and *Rudbeckia hirta*. For the operator, the areas seeded with wildflowers contrasted favorably with the standard mixture areas and the surrounding meadow. If the standard revegetation mixture had provided an adequate view from the outset, then the landfill operator would not have invested time, money, and resources in trying an alternative mixture.

As with aesthetic value, quantification of the ecological value of plants is difficult and largely subjective. Unfortunately, regulations do not consider floristic composition as a factor in selecting revegetation covers. Species richness overall was slightly higher on plots seeded with the wildflower mixture, which is not surprising since more wildflower species were seeded. On individual sampling dates, species richness was similar in plots seeded with both wildflower and standard mixtures. This result is largely due to the high number of colonizing species occurring on both aspects, and also to the fact that most of the grasses in the standard mixture are present throughout the growing seasons while a number of the wildflower species have shorter growing seasons. For example, *Dianthus barbatus* flowers in June and rapidly senesces, while *Ambrosia artemisiifolia* grows slowly over the season until it flowers in August.

It is important to consider not only number of species but also the species composition. More of the wildflower species are either native or naturalized to the region, which suggests that they would provide more value to wildlife. For example, research on reclaimed coal surface mines in the southeastern United States has shown that animals are more commonly associated with native, naturally colonizing species than non-native, planted species on reclaimed mine sites (Brenner et al. 1984; Holl 1994). Research on landfills suggests that using wildflowers and compatible grasses provides a stable source of seeds for consumption by birds and insects (Davis, 1989; Robinson and Handel, 1993; Smith, 1993).

Naturally colonizing species constituted an important component of the vegetation in areas seeded with both mixtures. Naturally colonizing species ranged from species native to the area (e.g., *Ambrosia artemisiifolia*) to aggressive non-native species (e.g., *Rosa multiflora*). Non-native species can be beneficial or disastrous, depending upon their aggressiveness. Species such as *Dactylon* sp. commonly outcompete native species and form monocultures over large areas. Despite the reputation of the standard revegetation mixture to better resist colonization of aggressive weeds, the number of colonizing species (predominantly non-native) and percent cover of these species were similar in wildflower and standard mixture plots.

If left unmanaged, the wildflowers that were seeded would eventually be succeeded by woody vegetation. However, the Spotsylvania Landfill, as in many landfills in Virginia, is mowed towards the end of the growing season to prevent the establishment of woody vegetation. Legislation prohibits woody species on landfills, due to fear of the roots of woody species penetrating the landfill liner. This restriction is one of the reasons the landfill operator chose to use wildflowers to increase the vegetative diversity on the landfill. Mowing also serves to enhance growth of the wildflowers in the following year.

While the majority of wildflower species became established, a few of the seeded species were not observed on the landfill. *Centaurea cyanus*, *Echinacea purpurea*, and *Silene armeria*, which have shown high establishment rates on other disturbed sites (Sabre, 1994), were recorded in low numbers at the Spotsylvania landfill. *Papaver rhoeas*, a popular species used for roadside wildflower plantings throughout Virginia and the United States, was never observed on the landfill. The low establishment or absence of these species at the Chancellorsville Landfill may be due to the combined factors of time of seeding (July), variable germination densities, and quality of seed stock. These results highlight the importance of doing greenhouse germination studies and small-scale test plots prior to landfill seeding. Screening tests serve to identify species that have low germination or survival rates; this screening reduces the cost of the seeding mixture. Field test plots are important to identify site-specific differences in establishment rates.

Interpretation of these results should be considered in the context of three problems with the experimental design that were beyond the control of the researchers. First, as discussed previously, standard and wildflower seeds were mixed in the hydroseeder, which complicated comparing the two mixtures. Fortunately, standard revegetation species were rarely observed along the two wildflower transects, suggesting that the seed contamination was minimal. Second, the landfill seeding was done in July rather than at the normal time, spring or fall. While establishment rates may have been lower due to lack of rainfall and elevated soil temperatures, both mixtures were seeded at the same time, allowing for comparisons between mixtures. Finally, results may have been confounded by the fact that the two mixtures were seeded on different slopes. While some plant species may be affected by 8-10 degree differences in slope, most of the species used are adapted to a range of stressful conditions. Therefore, the effect of slope differences was likely minimal.

The results of this and other studies (e.g., Sabre, 1994) highlight the importance of beginning relevant planning and research at least 3-10 years before closure of a landfill to reduce costs of soil amendments, to locate appropriate vegetation types, and to reduce the risk of erosion as a result of inadequate seeding densities or dead seed at closure. For example, New York City has spent thousands of dollars annually at the Fresh Kills Landfill, the largest in the world at 1265 ha (3000 acres), to determine how the landfill might best serve the community when it closes in 20-30 years (Robinson and Handel, 1993). While the expenses of analyzing soil nutrients and establishing plots to test revegetation protocols increase the cost of restoration efforts over the short term, they will result in increased chances of success and reduced costs over the long term. In addition, it is important to include long-term monitoring as an integral component of any revegetation effort. The large turnover of species observed in the 2 years of this study demonstrates the need to monitor revegetation projects for a number of years in order to judge success and correct any problems that may arise.

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