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Urban Green Spaces Restoration Using Native Forbs, Site Preparation and Soil Amendments—A Case Study

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Abstract: Restoration of urban green spaces with native flora is especially important for promoting various ecosystem services. Although there have been years of research on land reclamation, ecological restoration and plant establishment, there is a lack of knowledge on how to reintegrate the native ecological component, specifically forb species in urban green spaces. We evaluated the restoration potential of 24 native forbs using different site preparation (herbicide, tillage, herbicide with tillage and control) and soil amendment (100% compost, 50% compost with 50% topsoil, 20% compost with 80% topsoil and control) treatments in a recreational park in Edmonton, Alberta, Canada. Soil texture and nutrients generally increased with increased compost application rate; some declined within a year, others increased. Based on survival and growth analysis, the forb species with the highest potential for use in urban green spaces were *Penstemon procerus*, *Fragaria virginiana*, *Heuchera cylindrica*, *Agastache foeniculum*, *Antennaria microphylla*, *Mentha arvensis* and *Geum aleppicum*. Native forb species response was more prominent with soil amendment than site preparation. Treatments with greater amounts of compost had greater survival, growth, species richness, cover and noxious weed cover than control treatments. This study suggests amendment of soil with compost can positively influence forb species restoration in urban green spaces; under some conditions site preparation may be required.

Keywords: compost; ecological restoration; herbicide; plant community; tillage; urban ecology

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1. Introduction

In the past, urban sustainability efforts mostly focused on engineered buildings, road networks and parks [1], while only modest attention was given to the green spaces that intermingle with urban structures [2,3]. Building a sustainable society in urban areas with appropriate management of green spaces (gardens and parks) is necessary [4–6] as they provide various environmental, economic and quality-of-life benefits [7]. Environmental benefits include increased biodiversity and wildlife use, soil stabilization, improved ground water recharge, windbreaks for snow capture and dust reduction, reduction in atmospheric greenhouse gases and cleaner air [3,5,8,9]. Economic benefits include significant reductions in maintenance costs such as mowing, irrigation and herbicide use. Quality-of-life benefits include landscape beautification, increased green and shady areas for recreation, increased community awareness of environmental issues and noise reduction by mature plantings [10,11].

To beautify urban gardens and parks, non-native garden flora is frequently planted, the most common pathway for alien species introductions worldwide [12,13]. In Europe, over 80,000 plant taxa are found in botanical gardens; 783 of these are alien species that have been introduced from other parts of the world and can be found in city parks and recreation areas [14]. Many of these invaders can easily escape and establish outside of their planted areas without human assistance and become problematic for native biodiversity [12,15]. Eradication of these alien species is difficult and expensive, thus preventing them by planting native species of regional provenance in urban areas may be a good management option. A successful native species restoration strategy in urban green areas can significantly reduce city management costs, promote preservation of local species, restore environmental services and encourage more community members to embrace native species as a desirable strategy to follow [3,16]. Therefore, cities such as Edmonton proposed to transform urban habitats into habitats suitable for native plants found in the area [17].

Restoration with native species can prevent new alien species invasions, reduce soil compaction and increase soil organic matter and microbial activity [5,18,19]. Compacted soils can restrict root growth, which can limit successful plant establishment and long-term development [20]. Restoration with native species can reduce soil compaction through root expansion, increased biological activity and frost heave, consequently increasing infiltration and percolation [16,21]. Naturalized sites retain leaf litter and woody debris, which decompose, adding organic material which can increase plant available soil water [22]. Planting native forbs (wildflowers) in addition to trees and shrubs is a relatively new approach in landscape architecture that is gaining momentum among urban planners and landscapers and is recommended in many studies [5,23–25]. Adding native forbs for restoration of urban green spaces promotes native biodiversity and creates attractive flowering vegetation for recreational enjoyment and education [25]. Although there are considerable possibilities for native forbs to be used in urban green space restoration, scientific research on methods for using native forbs is scarce. The huge variety of forbs complicates their use due to lack of knowledge about them as individual species in urban green space restoration. Current species selection is usually based on visual appearance and plant material availability. However, successful restoration requires use of plants that are competitive, hardy and resilient in a highly competitive urban area with non-native species that are often present in urban green spaces [17]. Native forb response to urban conditions and best introduction techniques thus need to be better understood. The objective of our study was to assess the effects of site preparation and soil amendment on the survival and growth of 24 native forb species and on plant community development. The outcome of this study helps us to predict which combinations of plant species, soil preparation techniques and amendments have the greatest potential for urban green space restoration and provides the ground for further detailed study in urban restoration and green space management.

2. Materials and Methods

2.1. Study Area and Experimental Design

The study was conducted in a prominent recreational park in the City of Edmonton, Alberta, Canada (53°34′19″ N and 113°31′10″ W). Mean annual temperature is 4.2 °C, mean growing season temperature from May to October is 13.0 °C and winter temperature from November to April is −4.6 °C. Mean annual precipitation is 348 mm, with 284 mm of rain from June to October [26]. The area is flat with a gentle slope to the southwest. Immediately surrounding the roundabout is asphalt, then buildings, small canopy trees and open lawn areas. Traffic conditions are moderately high for vehicles near the roundabout; pedestrian traffic is mostly concentrated on walking paths.

2.2. Experimental Design and Treatments

The experiment used a complete randomized design with four replicates 50 m from each other. Each experimental plot was 10 m × 10 m, divided into sixteen 2.5 m × 2.5 m subplots, covering an area of 6.25 m^2 each (Figure A1). Site preparation treatments were randomly assigned vertically, and amendment treatments were applied randomly horizontally to the experimental plot (10 m × 10 m). Thus, there were 4 site preparation treatments × 4 amendment treatments × 4 replicates for a total of 64 plots. Plots were approximately 50 m from any roads and 10 m from all walking paths to reduce the traffic effect. There were 30 cm buffer zones between the subplots to reduce the potential neighbor effects.

Four site preparations and four soil amendment treatments were applied in the study area. Four site preparation techniques were soil tillage, foliar herbicide application, tillage plus herbicide and no site preparation (control) to remove existing vegetation, which consisted of lawn grass and some common annual weeds. Soil was tilled in June to a 15 cm depth with a rear tined, hydraulic drive, rototiller; first in one direction, then crossed perpendicularly. Glyphosate foliar herbicide Transorb™ was applied as a 1% solution (540 g/L glyphosate) 2 weeks prior to site tillage. Glyphosate has been predominantly used for controlling weeds in North America due to its effectiveness, non-selective nature, little or no soil residue and relatively low cost. Therefore, to control the competitive weeds, the practice of herbicide use prior to revegetation with native species is common in North American urban areas for reducing competition, although its use was questioned by many international agencies due to its toxicity and environmental safety. Some alternatives to glyphosate such as other chemicals Diquat (Reward™), pelargonic acid (Scythe™), glufosinate (Finale™); manual removal, fire, steam, hot foam and weeding were recommended for different jurisdictions and countries.

Four soil amendment treatments were 100% compost, 50% topsoil with 50% compost, 80% topsoil with 20% compost and a control (0% compost with 0% topsoil). Compost was 20% wood chips and 80% compost by volume, a standard mix used by the City of Edmonton. Topsoil was Ah horizon from development on previous agricultural land and clay loam to clay to silty clay loam in texture. Topsoil and compost were mixed in their treatment proportions, then applied using a mini steer loader. Amendment mixes were added to the surface of each subplot and spread by hand with shovels to a 15 cm deep layer.

2.3. Planting and Plot Management

Twenty-four native forb species from 12 families were selected for urban green space restoration recommended by the City of Edmonton. Forbs species were small with a shallow root system and selection was based on the visual appearance (flower color, shape and longevity), availability, geographic distribution (species that are adapted within the same geographic location) and growing conditions (water stress tolerant, frequent disturbance tolerant and ability to grow in a wide range of soil types) [17] (Table 1). All planting stock was procured from the City of Edmonton nursery and planted on July 8 and 9. In each treatment unit (subplot), one plant of each of the 24 forbs was planted with equal spacing. In total, 1536 plants (4 site preparation × 4 amendment × 4 replicates × 24 plants) were planted in the study area. Plants were watered 24 to 48 h after planting; then every 2 to 3 days for the next two weeks, twice per week for the next four weeks, then once per week until the end of the growing season. Manual weeding was conducted within 2 m from the edge of research plots as a weed control buffer zone.

2.4. Vegetation Assessments

Plant survival assessments were conducted in August and October of 2014, and June and August of 2015. Live and dead planted forbs were counted. In June and August 2015, planted forb-species spread was measured for each seedling. Diameter of forbs from tip to tip was determined with a tape measure. For species with cluster growth habits, the tape was placed on the farthest tip of one individual then pulled to the tip of the farthest individual of the cluster. Forbs were considered clusters when several of the same species were fewer than 5 cm apart with no vegetation between them. Other than planted forbs, vegetation cover was assessed in August 2014 and 2015, in three randomly located 1 m × 0.1 m quadrats inside each treatment. In total, 192 quadrats (4 site preparation × 4 amendment × 4 replication × 3 quadrat) were established and ocularly assessed for percent of live vegetation, bare ground, litter and other (rocks, trash and feces) cover. Total number of sample plots was considered adequate as species numbers reached a plateau for all treatment plots (Figure A2). Live vegetation was assessed on an individual species basis for both planted and naturally occurring species. Plant identification and nomenclature followed Moss [27].

Table 1. Planted native forb species.

Common Name	Scientific Name	Family
Black-eyed Susan	*Rudbeckia hirta* L.	Asteraceae
Dotted blazing star	*Liatris liguliststylis* A. Nels. K. Schum.	Asteraceae
Hairy false golden aster	*Heterotheca villosa* Pursh Shinners	Asteraceae
Little-leaf pussytoes	*Antennaria microphylla* Rydb.	Asteraceae
Prairie sagewort	*Artemisia frigida* Willd	Asteraceae
White prairie aster	*Symphyotrichum falcatum* Lindl. G.L. Nesom	Asteraceae
Harebell	*Campanula rotundifolia* L.	Campanulaceae
Bunchberry	*Cornus canadensis* L.	Cornaceae
Giant hyssop	*Agastache foeniculum* Pursh ktze.	Lamiaceae
Wild mint	*Mentha arvensis* L.	Lamiaceae
Prairie onion	*Allium textile* A. Nels. and J. F. Macbr.	Liliaceae
Yellow buckwheat	*Eriogonum flavum* Nutt.	Polygonaceae
Canada anemone	*Anemone canadensis* L.	Ranunculaceae
Long-fruited anemone	*Anemone cylindrica* Gray	Ranunculaceae
Prairie crocus	*Pulsatilla patens* L.	Ranunculaceae
Tall larkspur	*Delphinium elatum* L.	Ranunculaceae
Veiny meadow	*Thalictrum venulosum* Trel.	Ranunculaceae
Prairie cinquefoil	*Potentilla arguta* Pursh	Rosaceae
Three-flowered avens	*Geum aleppicum* Jacq.	Rosaceae
Wild strawberry	*Fragaria virginiana* Dcne.	Rosaceae
Northern bedstraw	*Galium boreale* L.	Rubiaceae
Round-leaved alumroot	*Heuchera cylindrica* Douglas ex Hook.	Saxifragaceae
Slender penstemon	*Penstemon procerus* Dougl. Ex Graham	Scrophulariaceae
Early blue violet	*Viola adunca* Sm.	Violaceae

2.5. Soils Sampling and Analyses

Soils were sampled in July of each study year from the plots to determine original soil conditions and changes with amendment treatments. One sample from each amended treatment in each plot was collected using 15 cm augers (total 16 soil samples). Collected samples were stored in ziploc plastic bags and sent to a commercial laboratory for analysis. Chloride in saturated paste was determined colorimetrically by auto-analyzer [28]. Inorganic and organic carbon were determined by carbon dioxide loss [29] and total carbon by combustion methods [30]. Cation exchange capacity was determined through ammonium acetate extraction [31]; ammonium by potassium chloride extraction; nitrate nitrogen colorimetrically in calcium chloride solution [32]; total nitrogen by combustion [33]; available phosphorus and potassium by modified Kelowna process [34]; sodium adsorption ratio, calcium, magnesium, sodium, potassium and sulfate in saturated paste by inductively coupled plasma; electrical conductivity and pH by meters [35]. Soil particles (sand, silt and clay) were determined by pipette method after removal of organic matter and carbonate [36].

2.6. Statistical Analyses

All statistical analyses were conducted using R version 4.0.3 [37] and significance level for analysis was $\alpha = 0.05$. In most cases, data from the last monitoring date of year 2 were statistically analyzed to evaluate overall performance of species at the end of the experiment. Chi-square analysis was used to identify effects of site preparation and soil amendment treatments on species survival. In a classical ecological experiment, replication of the treatments is prerequisite to test the hypothesis [38]. According to Oksanen [39] experiments, unreplicated or low-replicated treatments may also be the only or best option when (i) gross effects of treatments are anticipated, (ii) the experiment is conducted appropriately at large scales, (iii) only a rough estimate of effect is required and (iv) if the cost of replication is high. We conducted a study with low replication for individual species as the goal was to determine a rough estimate of effect for developing a foundation for future in-depth work, while minimizing the cost and labor requirements. Due to small numbers per species, statistical analysis was conducted on species grouped by family. Chi-square criteria were applied to groups and analyses were conducted only if assumptions were met (<20% of expected frequencies <5). Soil preparation and amendment effects were analyzed per species with one-way analysis of variance (ANOVA). Shapiro-Wilk test was used to determine normality of distribution and Levene's test for homogeneity of variance assessments. For significant factors, an HSD Tukey's test was applied for pairwise comparison. All statistical analyses were conducted using package 'stats' version 4.2.0 [37].

3. Results

3.1. Forb Survival Response to Treatments

Regardless of site preparation and soil treatment, top surviving and performing forbs species were *Penstemon procerus* (96.9%), *Fragaria virginiana* (95.3%), *Agastache foeniculum* (92.2%), *Antennaria microphylla* (92.1%), *Heuchera cylindrica* (89.1%), *Geum aleppicum* (89.0%) and *Mentha arvenses* (89.6%) at the end of the two-year experiment (Figure 1a,b). Survival was generally high at the first monitoring in August of year one then decreased with time, with fewer than 35% of the plants surviving by the end of the experiment for *Cornus canadensis* (0%), *Anemone cylindrica* (20.3%), *Pulsatilla patens* (21.8%), *Eriogonum flavum* (23.4%), *Allium textile* (29.7%), *Viola adunca* (34.4%) and *Liatris ligulistylis* (35.9%) (Figure 1a,b). *Cornus canadensis* was the only species that did not survive by the end of year two.

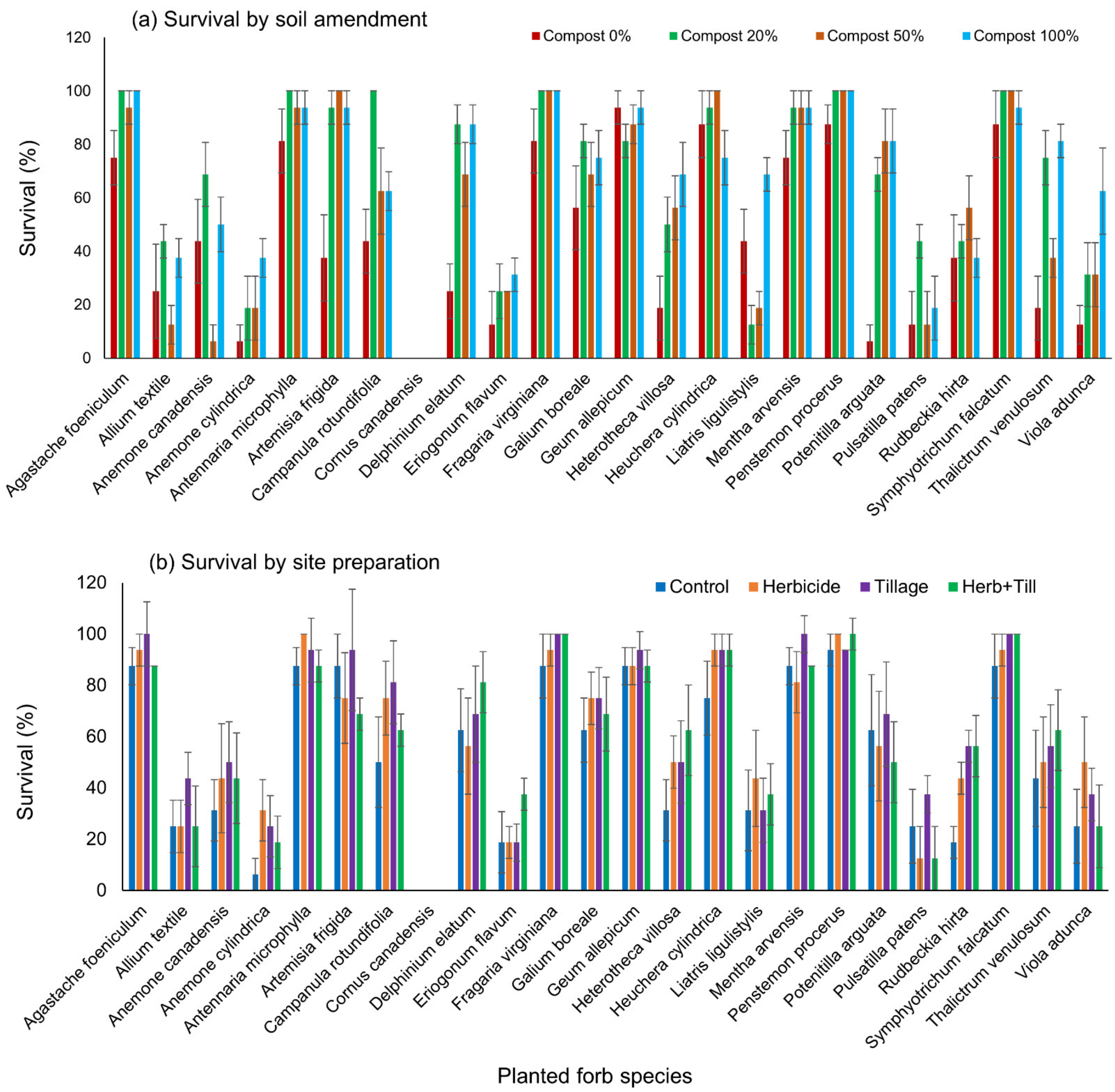

Figure 1. Mean (±SE) survival percent of planted forb by species at the end of monitoring dates in relation to (**a**) soil amendment and (**b**) site preparation. Herb + Till = Herbicide with tillage.

When species were analyzed grouped by family, a significant effect of soil amendment treatment on survival was found for Asteraceae, Ranunculaceae out of 12 families (Figure 2). Forb survival was significantly the lowest in compost 0% (unamended) for Asteraceae and the greatest in compost 100% (Figure 2). For Ranunculaceae, survival was significantly lower in compost 0% and compost 20%. Site preparation and interactions with amendment treatments did not significantly affect family survival.

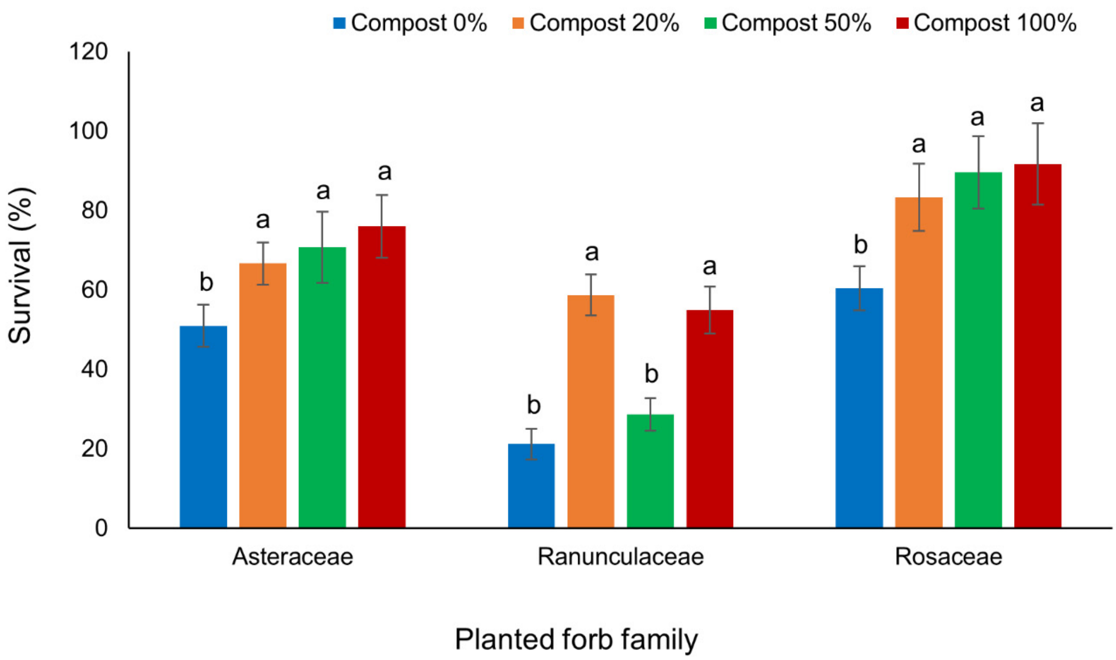

Figure 2. Mean (±SE) survival percent grouped by family and soil amendment. Different letters within species indicate significance differences at $\alpha = 0.05$.

3.2. Spread of Planted Forb Species

Spread of *Thalictrum venulosum* responded significantly ($p = 0.008$) to site preparation treatment; rate of spread was significantly higher with herbicide alone (25 cm) than herbicide–tillage together (14.8 cm) and tillage alone (12.9 cm), and statistically similar to untreated (19.4 cm) (data not shown). Soil amendment had a significant effect on spread for 9 of the 24 evaluated forb species (Table 2). *Fragaria virginiana*, *Penstemon procerus*, *Delphinium elatum*, *Symphyotrichum falcatum*, *Heuchera cylindrical*, *Antennaria microphylla*, *Rudbeckia hirta*, *Geum aleppicum* and *Mentha arvensis* had significantly greater spread in compost 100% than with no compost and more variable responses with the other two compost treatments (Table 2). The rate of spread was 6 to 128 cm across compost treatments, whereas in no compost 15 species had <10 cm spread (Table 2).

Table 2. Mean (±SE) spread (cm) by planted forb species in response to soil amendment treatments in year 2. Different letters within rows denote significant differences among treatments for species at α = 0.05.

Species	Compost 0%	Compost 20%	Compost 50%	Compost 100%
Agastache foeniculum	11.4 (1.2)	72.0 (4.3)	46.5 (3.4)	68.8 (7.2)
Allium textile	6.5 (0.9)	9.6 (1.9)	7.5 (0.5)	8.2 (2.3)
Anemone canadensis	8.7 (1.0)	16.2 (1.1)	17.0 (NA)	24.3 (1.4)
Anemone cylindrica	5.0 (NA)	11.7 (2.5)	9.7 (1.9)	18.7 (1.8)
Antennaria microphylla	20.7 (1.8) b	27.3 (2.3) ab	21.6 (1.1) b	30.7 (2.4) a
Artemisia frigida	16.2 (1.9)	128.0 (3.9)	118.7 (6.7)	99.2 (10.8)
Campanula rotundifolia	7.4 (0.7)	25.4 (3.7)	15.8 (1.7)	26.4 (2.9)
Delphinium elatum	5.3 (0.3) b	16.4 (1.8) a	16.4 (1.1) a	21.0 (1.9) a
Eriogonum flavum	8.5 (0.9)	14.0 (1.2)	9.0 (0.2)	12.4 (0.6)
Fragaria virginiana	9.5 (0.8) b	18.0 (1.7) a	16.6 (1.0) a	19.0 (1.2) a
Galium boreale	8.8 (1.1)	24.2 (2.6)	19.9 (1.0)	21.3 (2.6)
Geum aleppicum	12.1 (1.0) b	22.5 (1.7) a	18.1 (1.2) ab	21.0 (2.1) a
Heterotheca villosa	16.3 (2.1)	37.6 (5.5)	21.6 (3.3)	38.6 (4.9)
Heuchera cylindrica	9.4 (0.6) b	24.0 (1.2) a	19.8 (1.8) a	23.6 (1.6) a
Liatris ligulistylis	9.6 (1.0)	13.5 (0.5)	10.0 (1.6)	14.3 (0.9)
Mentha arvensis	9.7 (2.2) b	67.5 (10.3) a	39.1 (6.0) ab	52.2 (7.8) a
Penstemon procerus	18.9 (1.8) c	47.1 (2.7) a	33.3 (3.4) b	49.8 (2.5) a
Potentilla arguta	5.0 (NA)	25.7 (1.7)	22.6 (1.4)	30.2 (2.2)
Pulsatilla patens	2.5 (0.2)	8.1 (0.7)	6.0 (1.1)	10.0 (0.9)
Rudbeckia hirta	21.7 (2.7) b	39.1 (3.9) ab	38.4 (2.9) ab	46.8 (4.1) a
Symphyotrichum falcatum	21.8 (2.5) b	55.3 (4.6) a	60.1 (4.4) a	62.7 (5.6) a
Thalictrum venulosum	7.3 (1.3)	19.8 (2.2)	13.8 (2.9)	19.7 (1.3)
Viola adunca	7.5 (0.2)	11.2 (1.3)	10.6 (2.4)	12.6 (1.4)

3.3. Species Cover, Composition and Richness

Other than planted forbs, cover by plant categories followed similar trends for most soil preparation and amendment treatments, with a few exceptions (Figure 3). The untreated control, herbicide and tillage together and tillage only treatments had greater cover of native species, and the herbicide–tillage together treatment had greater bare ground than other treatments (Figure 3). Planted forb-species cover was significantly higher in compost treatments than in compost 0% at the end of year two.

A total of 28 plant species other than the planted forbs were identified across the plots (Table A1). There were 9 native, 15 non-native, 3 noxious (*Cirsium arvense* (L.) Scop. (Canada thistle), *Sonchus arvensis* L. (perennial sow thistle), *Tripleurospermum perforatum* (Mérat) M. Lainz (scentless chamomile)) and one prohibited noxious (*Potentilla recta* L. (sulphur cinquefoil)) species. Among the non-native species, *Festuca rubra* L. (creeping red fescue), *Polygonum convolvulus* L. (wild buckwheat) and *Taraxacum officinale* F.H. Wigg. (common dandelion) were the most common species. *Festuca rubra* and *Taraxacum officinale* were found on all site preparation treatments with compost 0% and *Polygonum convolvulus* was found on all site preparation treatments with compost 20%. The noxious species *Cirsium arvense* was found on almost 50% of the plots, being more frequent in the compost 100% treatment. Species richness excluding planted forbs differed with soil amendment but not site preparation treatments. Compost 0% had significantly greater overall species richness (R: 8.6; $p < 0.001$), native (R: 4; $p < 0.021$) and non-native (R: 3.5; $p < 0.045$) species richness than all soil amendments.

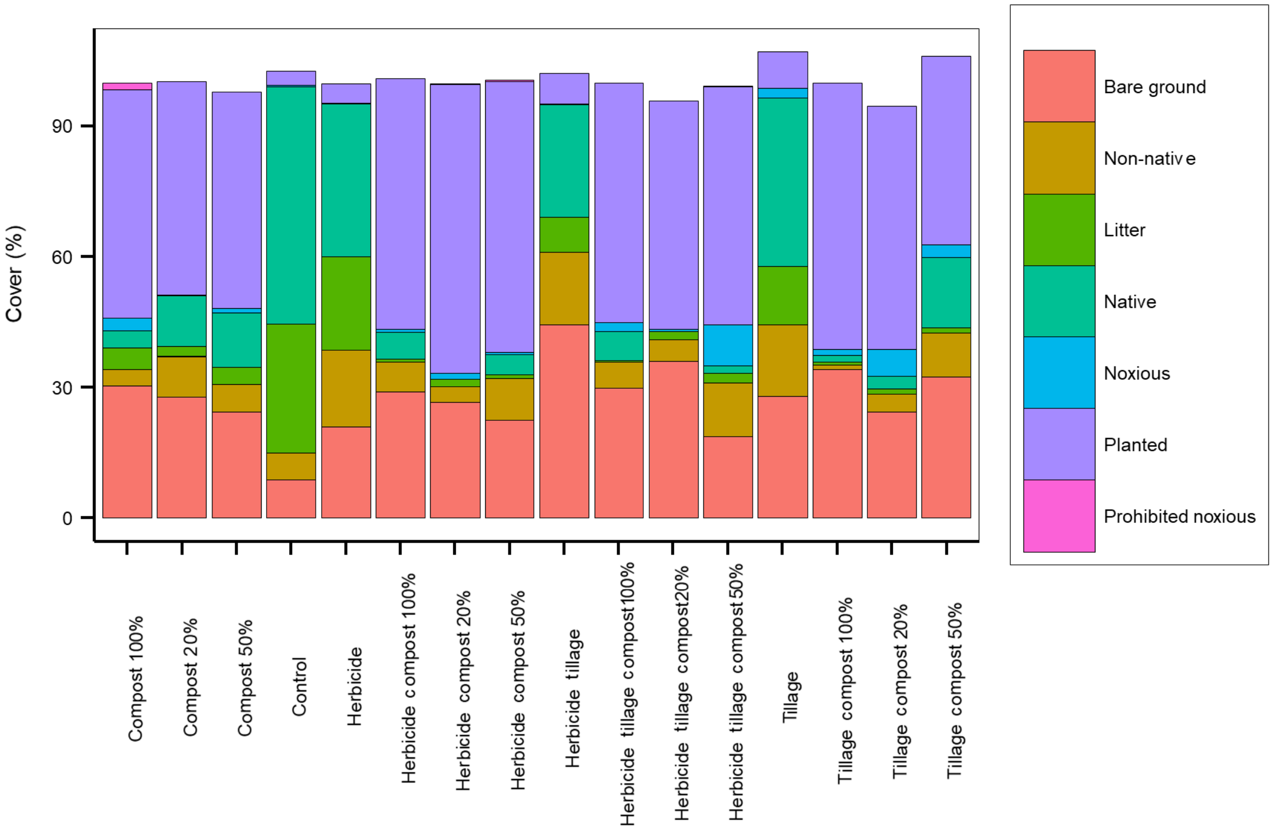

Figure 3. Percent cover by category for site preparation and soil amendment treatments.

3.4. Soil Response to Treatments

Most soil properties did not differ with year and soil amendment treatments. Soil nutrients generally increased with compost application: some declined slightly (total nitrogen, nitrate, total carbon, total organic carbon, ammonium, phosphorus, copper and zinc) and some increased slightly (sodium adsorption ratio, calcium, potassium, sodium and sulphate) within a year, being the highest and steadiest in both years with 100% compost (Table 3). Soil pH was acidic and increased with 100% compost (mean 5.7). Sodium adsorption ratio was very low across all amendment treatments (mean 0.5).

Table 3. Mean (±SE) soil properties by soil amendment treatments. Different letters indicate significant differences among amendment treatments in individual years at α = 0.05. EC = Electrical Conductivity, CEC = Cation Exchange Capacity, SAR = Sodium Adsorption Ratio and TOC = Total Organic Carbon.

Properties	Compost 0%		Compost 20%		Compost 50%		Compost 100%	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
pH	6.5 (0.1)	6.9 (0.1)	6.2 (0.2)	6.3 (0.1)	6.0 (0.1)	6.2 (0.1)	5.8 (0.1)	5.7 (0.1)
EC (dS m^{-1})	1.1 (0.1) c	1.2 (0.1) y	2.8 (0.3) b	2.2 (0.3) x	3.2 (0.3) a	2.0 (0.4) x	5.6 (0.6) a	2.1 (0.4) x
CEC (meq 100 g^{-1})	33.8 (1.5) b	35.7 (5.2) z	39.8 (4.0) b	41.5 (5.0) yz	43.1 (5.9) b	52.6 (4.7) y	61.6 (4.2) a	71.8 (5.2) x
SAR	0.7 (0.1)	1.0 (0.1)	0.4 (0.0)	0.5 (0.1)	0.4 (0.0)	0.5 (0.0)	0.3 (0.1)	0.3 (0.0)
Sodium (mg L^{-1})	26.4 (2.8)	56.4 (4.9) y	31.0 (4.8)	41.7 (6.2) xy	34.0 (6.2)	35.6 (8.5) x	28.3 (12)	22.5 (3.1) x
Total Carbon (%)	4.3 (0.4) c	3.4 (0.3) y	5.6 (1.7) c	5.1 (0.5) y	9.4 (1.6) b	6.9 (1.2) y	23.2.3 (2.5) a	20.86 (1.9) x
Total Nitrogen (%)	0.3 (0.0) c	0.3 (0.0) y	0.5 (0.1) c	0.5 (0.1) y	1.4 (0.1) b	0.6 (0.1) y	6.4 (0.8) a	1.5 (0.1) x
TOC (%)	4.3 (0.4) c	3.2 (0.3) y	5.2 (0.7) c	5.1 (0.5) y	8.3 (0.3) b	6.5 (1.2) y	22.5 (2.3) a	20.7 (1.4) x
Ammonium (mg L^{-1})	4.3 (1.8) c	2.3 (0.9) y	8.8 (3.5) bc	2.6 (0.3) y	17.4 (5.1) b	14.9 (4.6) x	70.4 (14.2) a	23.7 (6.4) x
Nitrate (mg L^{-1})	19.9 (3.3) b	2.9 (0.9) z	117.0 (23.2) a	56.4 (9.1) y	104.0 (15.8) a	55.1 (8.0) y	139.8 (22.3) a	91.6 (9.0) x
Phosphate (mg L^{-1})	29.9 (6.1) c	8.2 (1.8) z	251.0 (65.2) b	212.0 (41.2) y	470.2 (82.4)b	412.0 (79.5) y	2580.7 (179.3) a	1550.0 (154.2) x
Potassium (mg L^{-1})	176.5 (37.4) c	121.3 (23.8) z	231.0 (19.9) c	186.3 (14.1) y	330.7 (29.0) b	290.0 (62.3) y	1100.0 (58.6) a	1050.8 (100.8) x
Sulfate (mg L^{-1})	44.1 (2.2) c	82.1 (3.8) z	154.0 (23.6) b	129.4 (23.9) y	231.5 (32.4) ab	178.8 (31.1) y	372.7 (85.7) a	274.1 (61.1) x
Calcium (mg L^{-1})	111.4 (13.5) b	170.0 (15.8) y	340.1 (53.1) a	379.7 (48.2) x	396.8 (75.7) 4	328.0 (61.0) x	306.5 (45.4) a	299.8 (63.3) x
Chloride (mg L^{-1})	30.5 (3.8)	36.5 (4.3)	25.6 (5.0)	30.8 (5.7)	26.2 (7.7)	34.5 (4.9)	24.1 (6.5)	20.0 (3.1)
Copper (mg L^{-1})	16.6 (0.5) c	0.9 (0.1) z	44.0 (3.5) b	2.9 (0.4) y	55.5 (5.9) b	5.1 (1.9) y	308.0 (5.9) a	40.6 (2.7) x
Magnesium (mg L^{-1})	27.0 (4.2) c	39.5 (8.6) y	77.6 (15.1) b	89.7 (14.8) x	108.6 (21.4) a	91.5 (19.2) x	126.4 (19.4) a	114.0 (22.2) x

4. Discussion

Native forb species planted in green areas and exposed to urban disturbance and restoration treatments behaved quite differently. The limited impact of site preparation treatments in our study supports the results of Buonopane et al. [40] who found no differences in vegetation cover, germinant density or species richness between herbicide and non-herbicide plots in any group, including noxious weeds. Amendment with compost was a useful treatment for forb survival and spread in our study, similar to other studies that found a positive relationship between compost and forb survival [41,42]. Marrs and Gough [41] found floristic composition of wildflower meadows was controlled by soil fertility. Bretzel et al. [42] reported that the wildflower diversity index was related to cation exchange capacity and carbon–nitrogen ratio.

Native forbs used in our experiment were small with a shallow root system, and when planted in the upper 15 cm of soil that had been structurally altered and amended with compost, they had a new growing medium. Even small changes in nutrients in amended substrates may have impacted tiny plants at a vulnerable time when they needed nutrition. However, soil preparation and amendment application combinations were expected to influence soil water dynamics, indirectly determining stress and winterizing conditions. Site preparation techniques can alter soil water availability in the soil profile, and strategic plant treatments can increase revegetation success [43].

Although soil amendments resulted in a greater proportion of desired planted species cover, it exposed the site to invasion by non-native, noxious and prohibited noxious weed species. This finding is consistent with Skrindo and Pedersen [44], who found using topsoil as an amendment to restore a roadside in Norway increased vegetation cover from one year to the next for species such as *Cirsium arvense*. The loss of ecological memory in urban settings is thought to facilitate the establishment of alien or non-native invasive or weed species in recently disturbed urban environments, as these species have very high seed output, phenotypic and germination plasticity, adaptations for short- and long-distance dispersal, small seed size and high seed longevity [12,45]. Thus, these species are often difficult to control in newly naturalized landscapes, where they can quickly dominate and outcompete desired species [45]. Without management intervention such as native seeding, common seed bank species, especially exotic and noxious plants, may exclude or inhibit desirable later successional species until resources are made available by their damage or death [46].

Weed management in our study played a key role in assemblage of plant communities. Targeted hand weeding benefitted planted forbs, especially in amended plots where forbs grew larger. Weed management is a necessary tool to build plant communities rather than simply for containment and eradication of undesired species. Plant community weed management opens the possibility of using competitive native species to shift the plant community to a more desirable state and reduce weed management in the long term. Weed control can be complex for native forbs as they tend to be more sensitive to chemical control than other species [47]. There are few selective herbicides targeted to weeds that do not also kill the native forbs. Manually weeding the sites is an efficient but time-consuming practice and requires good plant identification skills. This type of manual weeding would need to be implemented early in the restoration program and continue at least beyond two years.

Due to the elevated level of exposure of the research site, it appeared that using native forbs was a great way to raise ecological awareness and involvement of the local community in citizen science [4,24,48]. People are often interested in wildflowers when they are in urban green spaces which opens up the possibility to integrate common citizens in maintenance and weed management strategies associated with naturalization, potentially reducing costs and creating a common goal among the community members [25,49]. Native forbs constitute part of our natural heritage and should be protected and preserved. This experiment confirmed that native forb species remain resilient in their endemic environments.

Human landscape modifications may provide opportunity for evolutionary adjustment, for growth, maturation and adaptation to new conditions.

Findings from this two-year study provide documented insight on how site preparation and soil amendment techniques can be used to improve the success of restoration with a relatively large number of native forb species. The outcomes of this study can provide a foundation for future work, including longer-term seedling establishment.

5. Conclusions

Soil amendment with compost was more influential than site preparation treatments for restoration of forb species in an urban green area as it had a direct positive impact on survival and growth of planted forbs. Treatments with greater amounts of compost had greater survival, growth, species richness, cover and noxious weed cover than control treatments. Soil amendment had a concurrent negative impact by increasing noxious weeds. Although site preparation treatments had little influence on survival of planted forbs, they could provide more benefits when combined with appropriate weed management that controls competition from baseline vegetation. Of 24 forb species, *Penstemon procerus*, *Fragaria virginiana*, *Heuchera cylindrica*, *Agastache foeniculum*, *Antennaria microphyla*, *Mentha arvensis* and *Geum aleppicum* showed the greatest potential for establishment under the management approach used in this study. These species are highly recommended for future use in restoration for the City of Edmonton and similar urban centers. *Cornus canadensis*, *Pulsatilla patens* and *Liatris ligulistylis* are not recommended for use due to their poor performance. Allium textile, *Eriogonum flavum*, *Viola adunca*, *Potentilla arguta*, *Heterotheca villosa*, *Anemone cylindrica*, *Rudbeckia hirta*, *Thalictrum venulosum* and *Anemone canadensis* need further study but may have potential for use in urban restoration programs. Since the results of this investigation are based on low replication, we recommend that urban planners and practitioners use our results but do so with caution as they may be site specific.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

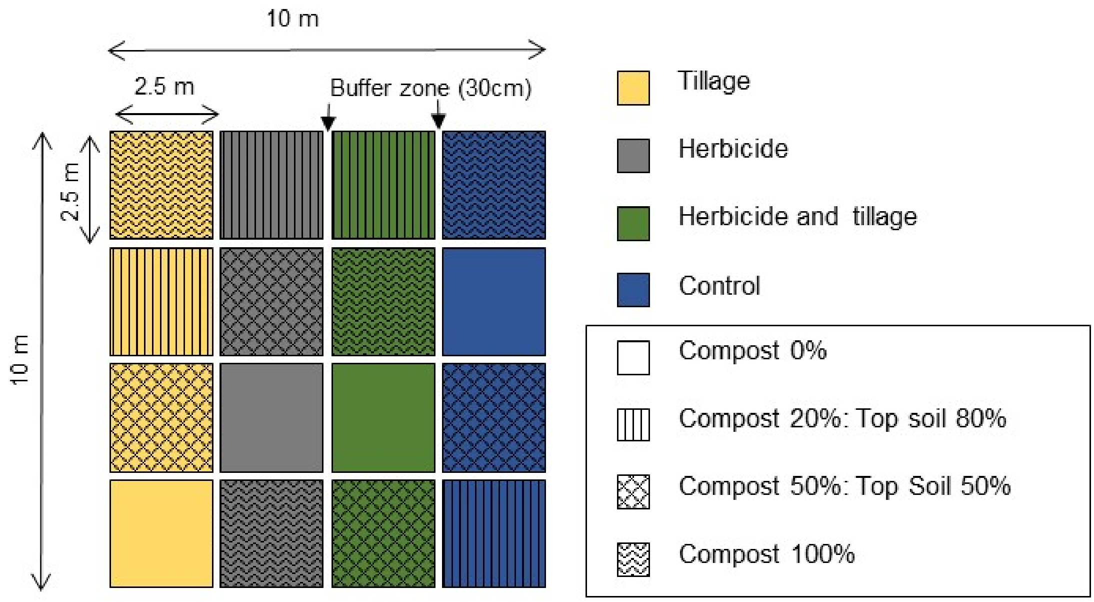

Figure A1. Plot design and soil preparation treatments (colored boxes) randomly applied in columns. Amendment treatments (patterns) randomly distributed within columns.

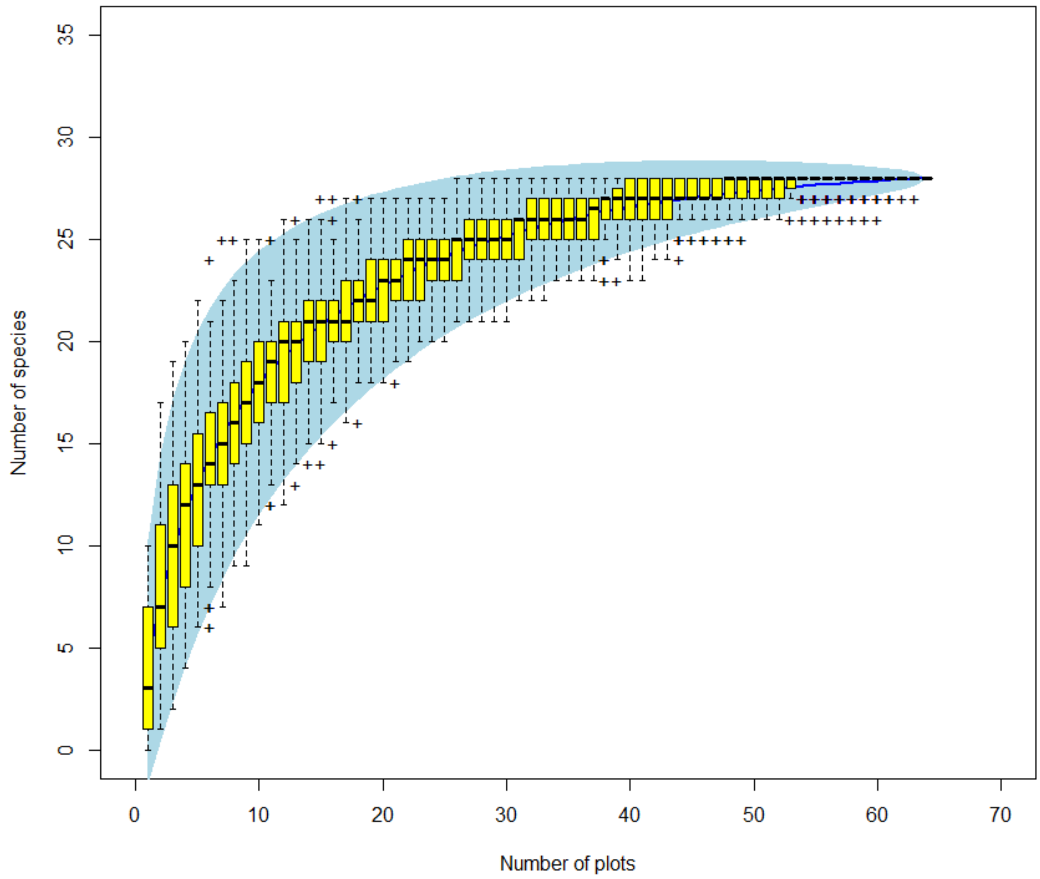

Figure A2. Species accumulation curves in reclamation well sites showing number of species (mean ± SD) versus number of plots.

Table A1. List of species found in the study site.

Plant Category	Common Name	Botanical Name
Native	Milkvetch	*Astragalus* L.
	Plains rough fescue	*Festuca hallii* (Vasey) Piper
	Mountain fescue	*Festuca saximontana* Rydb.
	Foxtail barley	*Hordeum jubatum* L.
	Western wheatgrass	*Pascopyrum smithii* (Rydb.) Á. Löve
	Alpine bluegrass	*Poa alpina* L.
	Wood bluegrass	*Poa nemoralis* L. subsp. interior (Rydb.) W.A. Weber
	Bluebunch wheatgrass	*Pseudoroegneria spicata* (Pursh) Á. Löve
	Prairie thermopsis	*Thermopsis rhombifolia* (Nutt. ex Pursh) Nutt. Ex Richardson
Non Native	Common oat	*Avena sativa* L.
	Smooth brome	*Bromus inermis* Leyss.
	Lamb's quarters	*Chenopodium album* L.
	Quackgrass	*Elymus repens* (L.) Gould
	Creeping red fescue	*Festuca rubra* L.
	Yellow sweet clover	*Melilotus officinalis* (L.) Lam.
	White man's foot	*Plantago major* L.
	Kentucky bluegrass	*Poa pratensis* L.
	Wild buckwheat	*Polygonum convolvulus* L.
	Prickly sow-thistle	*Sonchus asper* (L.) Hill
	Chickweed	*Stellaria media* (L.) Vill.
	Common dandelion	*Taraxacum officinale* F.H. Wigg.
	Alaska clover	*Trifolium hybridum* L.
	White clover	*Trifolium repens* L
	Rapeseed	*Brassica napus* L.
Noxious	Canada thistle	*Cirsium arvense* (L.) Scop.
	Perennial sow thistle	*Sonchus arvensis* L.
	Scentless chamomile	*Tripleurospermum perforatum* (Mérat) M. Lainz
Prohibited Noxious	Slphur cinquefoil	*Potentilla recta* L.

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