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Native and Dryland Pasture Seed Mixes Impact Revegetation 12 Years after Pipeline Construction in Southern Alberta

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Abstract: Activities associated with agriculture, grazing, and the energy industry have altered large tracts of native rangeland in North America. Pipelining causes intense local disturbance by removal of vegetation and alterations to soil horizons. Following a disturbance, reclamation is required to return the land to equivalent land capability. Revegetation is usually by seeding native and/or agronomic (non-native, dominant) species. This study investigated the long-term effects of native and dryland pasture (91% non-native species) seed mixes, grazing, and right-of-way (RoW) treatments on revegetation of native rangeland in southeastern Alberta. Native seed mixes were more successful at enhancing seeded vegetation cover than dryland pasture seed mixes. Grazing had a significant impact only on the survival of non-native grasses. The seed mix did not significantly affect total, native, non-native, annual, or perennial forb cover. Total forb cover was significantly higher on the trench with the dryland pasture seed mix than all other RoW treatments (storage, work). This long-term study suggests that native seed mixes can result in successful revegetation of reclamation following pipeline construction.

Keywords: grazing; rangeland; reclamation; right of way; seed mix

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1. Introduction

Due to the growing human population and economic demand, activities associated with agriculture, grazing, the energy industry (oil and gas pipelines, well sites, power lines), and mining for natural resources have significantly increased in the last century, altering large tracts of native rangeland in North America [1–4]. Over the past few decades, demand for pipelines has increased rapidly relative to other methods (rail, highway) of transporting natural resources, due to its greater volume capacity, higher security, and lower energy costs [5,6]. As of 2021, there were over 7 million km of pipeline in 124 countries, with Canada having 13.5% of total pipeline length [7]. The province of Alberta has over 445,000 km of pipelines, with a significant portion constructed in rangeland [8]. The growing demand for pipelines can lead to intense disturbances by increasing habitat fragmentation and pressures on biological diversity [9,10], posing substantial challenges to conservation and management of native grassland ecosystems [2,11–13].

Prior to 1997, pipeline construction in Alberta required a right-of way (RoW) of 15–30 m in width from which topsoil and subsoil were stripped to accommodate the pipeline trench and construction equipment. Stripped topsoil and subsoil were stockpiled for the duration of construction which was usually less than one month [14]. Pipeline construction activities such as topsoil and subsoil mixing, trenching, welding, and vehicular traffic can alter soil properties including electrical conductivity, pH, salinity, soil water content, texture, and temperature on the RoW [2,14]. During construction on native rangelands, vegetation and topsoil are usually removed, facilitating the introduction and potential spread of non-native and invasive plant species. These species can form monocultures, resulting in landscape fragmentation and altered wildlife habitat through loss of species important for food and shelter [2,5,6,15], and can persist for at least 40 years on the RoW [14]. Therefore, reclamation of native grasslands is critical to maintaining their existence and providing their ecosystem services [16,17]. Typically, reclamation converts disturbed sites to former or other useful purposes, and restoration attempts to return the site to pre-disturbance structure and function [17]. The success of reclamation needs to be assessed in long-term monitoring studies [18,19].

Reclamation involves management of numerous ecosystem components and interactions to achieve specific goals [2], with revegetation one of the important components. Revegetation is usually undertaken by seeding native and/or agronomic (non-native, dominant, mostly forage crops introduced from Europe and Eurasia in the 19th century during European settlement) species. Early reclamation of native rangelands after oil and gas activities focused on revegetation with rapidly growing agronomic species because of their ability to colonize quickly, reduce erosion, and make the area aesthetically pleasing [20–22]. Current technical guides and published literature typically focus on seeding native species since agronomic species can become dominant monocultures, reducing native species abundance and diversity on the site and surrounding landscape [22]; however, there is little published work comparing the two types of species. Native species are more adapted to poor soil conditions and require fewer management inputs than agronomic species [22–24]. Studies on impacts of agronomic species on plant community development indicate they can dominate even if they constitute a small portion of the seed mix, especially with high soil nutrient status [25]. If the objective is to restore a native plant community, planting non-native species to provide rapid cover on a pipeline may not be conducive to long-term egress of native species [26].

Current knowledge of ecosystems and regulatory requirements has changed revegetation goals, with a desire not only to protect the soil, but to reclaim the disturbed area to pre-disturbance conditions [13,27–30]. In Alberta, Canada, oil and gas pipeline disturbed sites must be reclaimed to equivalent land capability according to Alberta government regulatory requirements [31]. Equivalent land capability means that "the ability of the land to support various land uses after conservation and reclamation are similar to the ability that existed prior to an activity being conducted on the land, but that the individual land uses will not necessarily be identical" [32–34]. With these objectives, came the demand for more native species in seed mixes, including wheatgrasses. Wheatgrass cultivars are expected to reestablish pre-disturbance communities in a timely manner, are available in large quantities, relatively inexpensive, and establish rapidly [22]. However, wheatgrasses can produce highly competitive monocultures which could inhibit establishment of other naturally occurring species [33–35]. Therefore, adding other species with wheatgrasses in the seed mix may enhance reaching reclamation targets.

Cattle grazing can be a tool in reclamation and maintenance of grassland ecosystems as it can influence ecosystem structure, function, composition of surface litter, hydrologic, and soil properties [29,36–41]. Hence, the presence of grazing animals can influence grassland plant diversity by inhibiting growth of competitive species and favoring stress tolerant or grazing adapted plants [42,43]. The regular disturbance caused by grazing animals can therefore shape plant communities independent of dispersal in both restored and remnant grasslands by removing biomass through their selective diet, although ~80% of nutrients are returned to the soil [43,44]. However, the impact of cattle grazing on vegetation has yielded inconsistent results, with some studies showing vegetation cover can increase with grazing [45,46] and others showing a decrease or no effect [47,48]. As a dominant land-use practice on grassland, grazing may have the potential to influence revegetation success by affecting the soil seed bank [49], thus documentation of grazing impacts on reclamation is needed. When considering revegetation efforts on large rangelands, it is important to determine whether grazers utilize plant communities resulting from different seed mixes differently.

Questions are still unanswered as to whether native species are more effective than non-native species for reclamation, particularly long term. The long-term effects of pipeline disturbances on susceptible dry mixed grass prairie require investigation to protect and conserve integrity of these grassland communities, particularly how seed mixes alter revegetation on a disturbed site. The objective of this study was to determine whether two seed mixes (native, dryland pasture) impacted pipeline revegetation in the native rangeland of a dry mixed grass ecoregion after 12 years. The study addressed seed mix, grazing, and pipeline RoW treatments.

2. Materials and Methods

2.1. Study Area Description

The study sites were located in dry mixed grass ecoregions of southern Alberta. Temperature means were 15.9 °C in summer and −11.5 °C in winter; mean precipitation was 338 mm [50]. Soils are predominantly Brown Solods with occurrences of Brown Solodized Solonetz and Solonetzic Brown and Orthic Brown Chernozems. Alkaline soils are common, with occurrences of saline soils. Soil organic matter was 1.0 to 3.7%. Parent material was fine to coarse loamy till, moderately to well drained. The area was dominated by *Bouteloua—Stipa* (blue grama grass-needle grass) species prior to disturbance.

2.2. Treatments and Experimental Design

Two study sites (site 1 = 50°21′53″ N, 112°14′38″ W and Site 2 = 50°22′19″ N, 112°15′20″ W) were located on a 39 km long natural gas transmission pipeline (diameter 40 cm) (Figure 1). The RoW was 18 m wide, with trench, storage, and work areas each 2 m wide. During construction, the RoW was stripped of topsoil (~0.15 m) which was stockpiled separately for a month on the work side, to retain the plant propagule bank. Subsoil (0.16 to 2.0 m) was removed and stockpiled on the storage side of the RoW. The trench was excavated, the pipe placed in the center 2 m, and covered with a minimum 1.2 m of subsoil, then stockpiled topsoil was replaced on the surface of the entire RoW. Size of work (for vehicles, equipment, and foot traffic) and storage (for equipment) areas varied by site to accommodate travel lanes and grade requirements for a safe work surface and soil storage. Pipeline construction and reclamation occurred during winter and spring 1986. Soil physical and chemical properties were loam to clay loam texture, moderate well to well drained, with pH 6.7 to 7.4, topsoil organic matter 2.1 to 3.7%, and gravimetric water content 15.1 to 17.6%. The entire RoW was seeded immediately after construction with a rangeland drill with 15 cm spacing at approximately 8 kg·ha^{-1}. Seed mixes were either native grassland or dryland pasture (Table 1).

Table 1. Native and dryland pasture seed mixes used for reclamation. * indicates non-native species.

Species	Common Name	Variety	% By Weight
Native Seed Mix			
Elymus lanceolatus (Scribn. & J.G.Sm.) *Gould*	Northern wheatgrass	Elbee	25
Pascopyrum smithii (Rydb.) Á. Löve	Western wheatgrass	Walsh	25
Elymus trachycaulus (Link) Gould ex Shinners	Slender wheatgrass	Revenue	17
Poa compressa L.	Canada bluegrass	Ruebens	8
Puccinellia nuttalliana (Schult.) Hitchc.	Alkali grass	Nuttall's	25
Dryland Pasture Seed Mix			
Thinopyrum obtusiflorum (DC.) Banfi *	Tall wheatgrass	Orbit	7
Agropyron cristatum (L.) Gaertn. *	Crested wheatgrass	Parkway	3
Elymus lanceolatus ssp. riparius (Scribn. & J.G. Sm.) Barkworth	Streambank wheatgrass	Sodar	6
Elymus trachycaulus (Link) Gould ex Shinners	Slender wheatgrass	Revenue	3
Agropyron trichophorum (Link) K.Richt. *	Pubescent wheatgrass	Greenleaf	6
Leymus angustus (Trin.) Pilg. *	Altai wild rye	Prairieland	12
Psathyrostachys juncea (Fisch.) Nevski *	Russian wild rye	Swift	3
Astragalus cicer L. *	Cicer milk vetch	Oxley	17
Medicago sativa L. *	Alfalfa	Rambler	12
Onobrychis viciifolia Scop. *	Sanfoin	Common	33

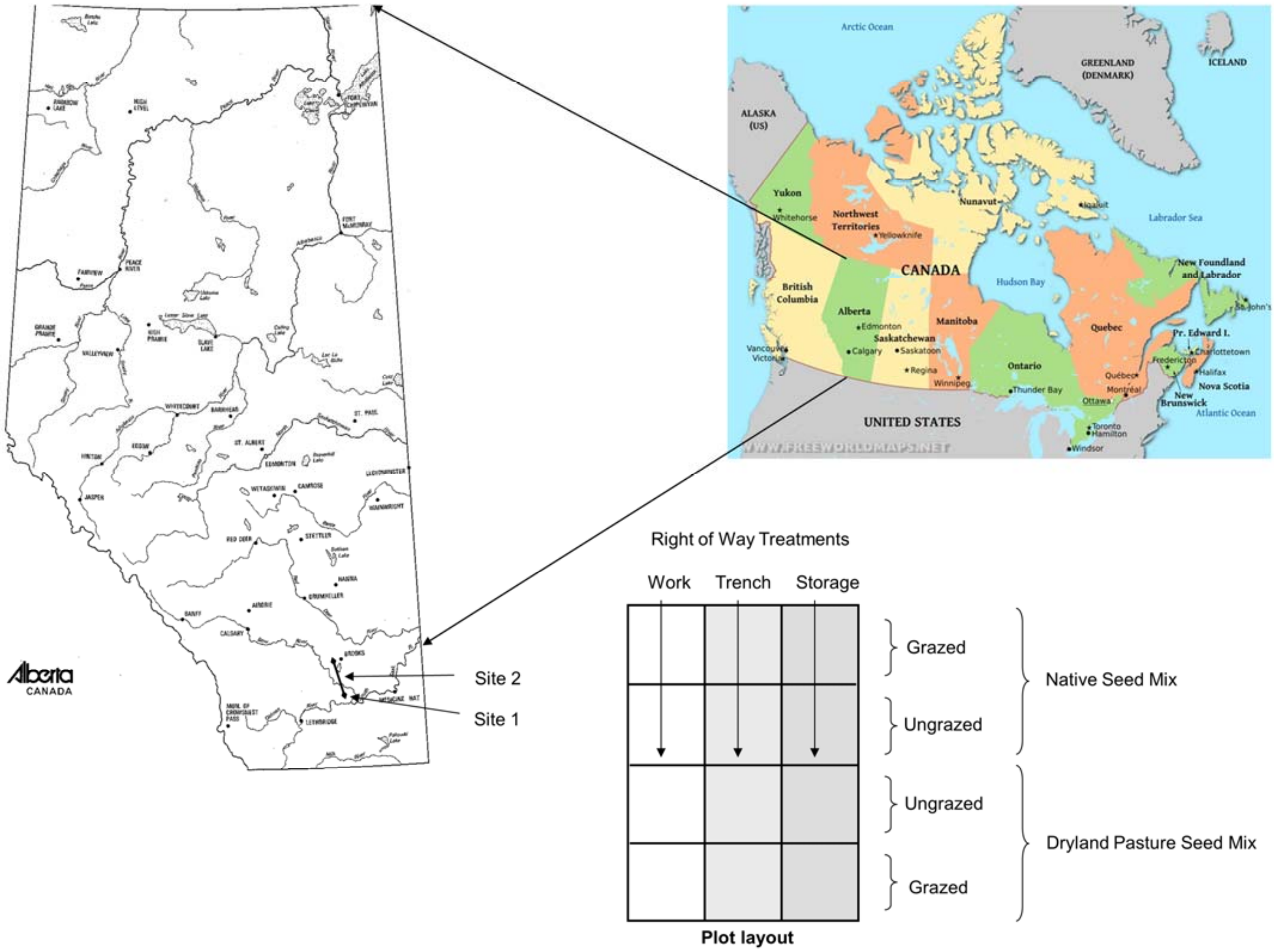

Figure 1. Location of study sites with plot layout.

At each site, a fence was constructed after seeding and prior to cattle grazing to determine grazing effect; with half of each seed mix treatment fenced to exclude grazing. The size of each seed treatment plot was approximately 100 m along the pipeline RoW, with 15 m buffers between seeded treatments. The unfenced portion of each treatment was grazed in summer between June and July until visual utilization approached 50% on each treatment. The experimental design was a split-block, split-plot, with 3 RoW (work, trench, storage) treatments in strips of plots running through the block in one direction, along the length (or axis) of the pipe; 2 seed mix treatments (native grassland, dryland pasture) were applied to strips of plots perpendicular to RoW strips, and divided into 2 grazing treatments (grazed, ungrazed) (Figure 1, Table 1). The study was a 3 × 2 × 2 factorial experiment where each plot was subjected to one of three RoW treatments, one of two seed mix treatments, and one of two grazing treatments.

2.3. Field Measurements

Plant species composition in each treatment was assessed on 30 m long line transects, parallel with the RoW, each with 30 randomly located permanent quadrats (1.0 × 0.10 m, 0.10 m^2). In years 3, 4, 5, and 6 vegetation was assessed as cover classes (1 = present to 0.5% cover, 2 = 2.5, 3 = 15, 4 = 37.5, 5 = 62.5, 6 = 85, 7 = 97.5). Vegetation data from Years 3 to 6 were converted from cover class to midpoint, with the 30 midpoints on each transect averaged per species for each plot. Midpoints for each species were added to determine total percent vegetation cover for each plot. Relative cover for each plant species was calculated as midpoint cover divided by total cover as total cover varied from below 50 to over 140%. In Year 12, vegetation cover was assessed on 10 quadrats. All assessments were conducted during peak growing season between late July and early August. In each quadrat ground cover was assessed ocularly as vegetation or live plant (excluding little club moss), little club moss (*Selaginella densa* Rydb.), lichen, litter (including manure), bare ground, and rock. All plant names were according to Moss [51].

2.4. Statistical Analyses

All data were analyzed using a mixed effects analysis of variance (ANOVA) to determine differences between the main effects of vegetation, bare ground, and litter cover. In ANOVA, grazing treatments (grazed, ungrazed), RoW treatments (trench, work, storage) and seed mixes (native, dryland pasture) were used as fixed factors and each block (each site treated as a block) was used as a random factor. Due to the split-block design a separate randomization was used in each block. The categories tested for vegetation cover were seeded species, native and non-native rhizomatous grass, total forbs, non-native forbs, and annual forbs. Due to irregular sample size, separate ANOVAs for each year were conducted using quadrats data. If the ANOVA results indicated significant differences ($\alpha = 0.10$) among the main effects, Scheffe's test for multiple comparisons was conducted to determine treatment differences. The significance level of a study is the Type I error probability, which is usually set at 5%. The sample size in our study was small due to time and monetary constraints. Thus it was reasonable to use a 10% significance level [52], a widely adopted practice in many studies, e.g., [53–55]. Multiple comparison p values were reported. Data were checked for outliers, normality, and equality of variances prior to statistical analyses, and square root transformations were conducted when required to meet the normality assumption. SAS version 6.12 (IBM Corporation, Armonk, NY, USA) was used for all statistical analyses.

3. Results and Discussion

3.1. Seeded and Non-Seeded Grass Cover

Vegetation cover was significantly greater with the native mix than the dryland pasture mix throughout all assessment times. By 12 years after reclamation, vegetation cover with the native seed mix (44.9%) was more than double that with the dryland pasture mix (21.8%) (Figure 2). This was consistent with Soulodre et al. [30] who concluded that seeding with a diverse native seed mix could be effective for mixed prairie reclamation. According to Soulodre et al. [30] native seed mix had greater biomass, cover, richness, diversity, perennial species, and less bare ground than agronomic or non-native dominant seed mixes. Kiehl et al. [56] found seeding with native species could speed up vegetation recovery in calcareous grassland restoration projects in Germany. Soulodre et al. [29] found seeding with a native seed mix could be an alternative approach for mixed prairie reclamation in the absence of an adjacent native prairie seed source. However, after six years, cover with the native mix began to decline and that of the dryland pasture mix began to increase, suggesting that with time they might converge.

For individual seed mixes, no differences were found between grazed and ungrazed treatments over time, except for vegetation cover of grazed and ungrazed treatments in Year 12 with the dryland pasture mix (Table 2). In Year 12, ungrazed dryland pasture mix led to a significant increase in total vegetation cover (Table 2) due to greater cover of non-native species (Figure 3). Overall grazed and ungrazed treatments showed irregular trends over time, although grazing was beneficial for the native seed mix. According to Bullock et al. [57] grazing intensity and timing of grazing are known to influence species responses to grazing. Pykälä [58] found that plant species might respond differently to grazing regarding changes in cover and density.

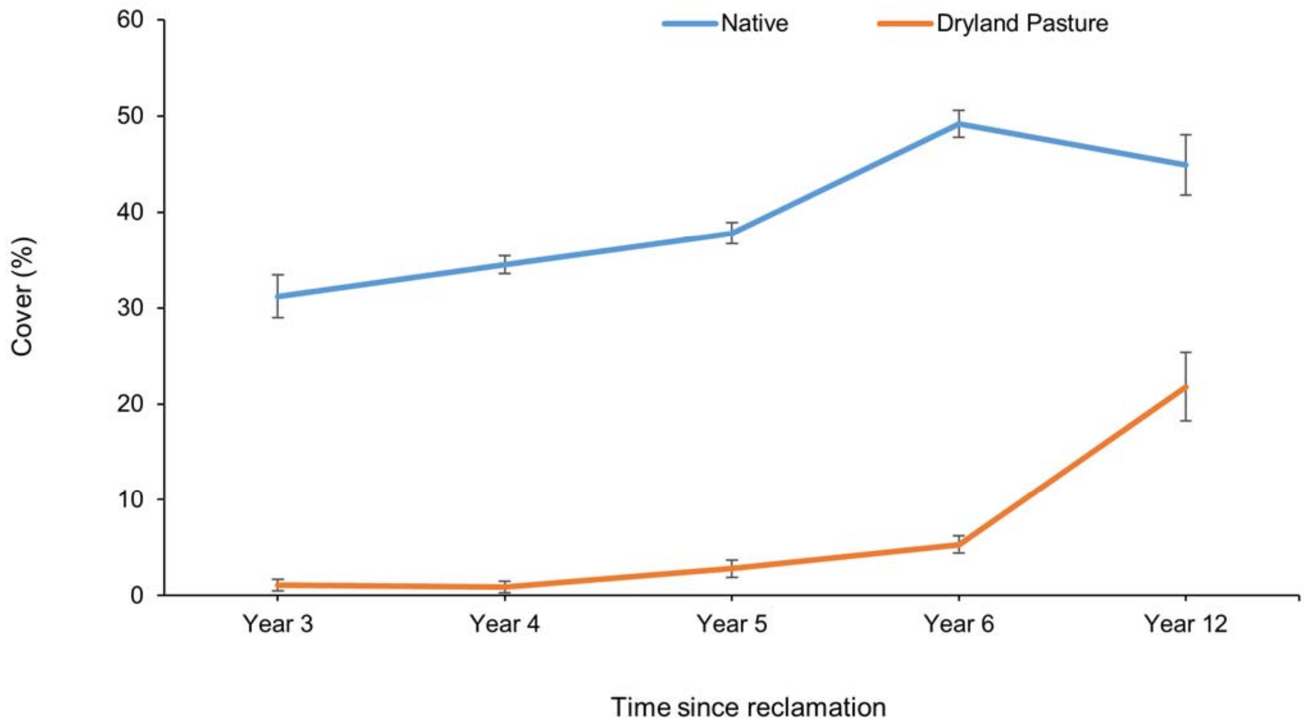

Figure 2. Mean (±SE) percent cover of seeded species by seed mix.

Table 2. Mean (±SE) percent cover of seeded species by grazing treatment.

Time since Reclamation	Native Seed Mix		Dryland Pasture Seed Mix	
	Grazed	Ungrazed	Grazed	Ungrazed
Year 3	30.0(3.4)	32.3(3.2)	0.2(0.0)	2.1(0.5)
Year 4	34.5(0.3)	34.5(0.8)	0.3(0.1)	1.6(0.2)
Year 5	32.4(1.7)	41.7(1.3)	1.0(0.1)	4.7(0.5)
Year 6	43.3(0.8)	55.0(2.0)	1.9(0.3)	8.7(1.3)
Year 12	48.7(4.2)	41.0(5.0)	3.2(0.6)	40.5(5.2)

Grazing had a significant impact on non-native grasses only with the dryland pasture mix in Years 5 ($p < 0.001$), 6 ($p = 0.075$), and 12 ($p < 0.001$). In the first 4 years, cover of non-native species increased slowly whether grazed (0 to 0.4%) or ungrazed (0 to 3.7%); however, from Years 6 to 12 non-native species increased from 9 to 37% in ungrazed treatments (Figure 3). This increase in cover was due to the non-native species *Agropyron cristatum*, a large agronomic species that can establish aggressively if not managed properly [59,60]. It matures early and becomes coarse and unpalatable as it matures; leaves and stems have a high content of structural components and can dominate established communities from natural encroachment or broadcast seeding without soil disturbance [61]. *Agropyron cristatum* starts to grow early in the spring, allowing it to take advantage of early nutrient fluxes before the warm season (C4) native species [62]. There was visual evidence of *Agropyron cristatum* invasion of RoW.

Recovery of native prairie depends on the ability of the plant community to resist invasion by undesirable species and allow movement of desirable species. After 12 years, the native mix did not have increased non-native grasses (0.6%), indicating invasion of non-native grasses into native seeded areas is not a concern. The dryland pasture mix which contained 91% non-native species had only 20% non-native species cover after 12 years (Figure 3). Native grasses had greater cover with both seed mixes (native 77.2% vs. dryland pasture mix 51.2%), indicating an equal ability of both mixes to have desirable species move into the community.

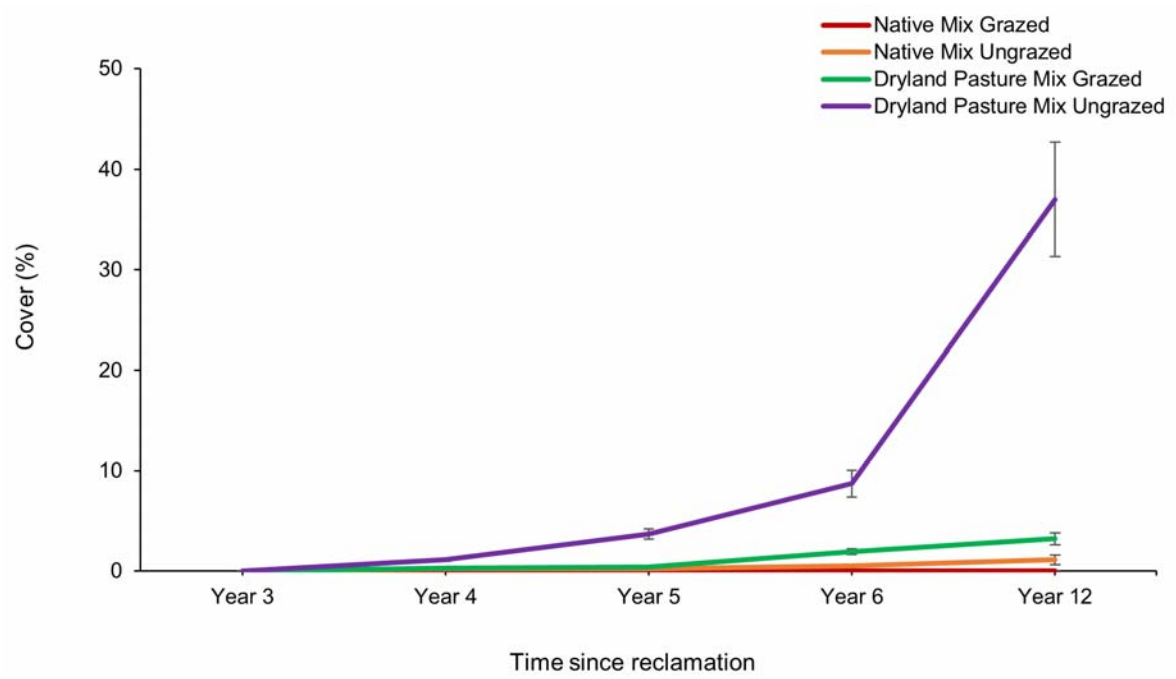

Figure 3. Mean (±SE) percent cover of non-native grass by seed mix and grazing treatment.

Significant differences were found between native and non-native grass cover and interactions between seed mix and RoW treatment (Figure 4). Although stockpiled topsoil was spread evenly over the RoW, native grass cover remained lower in the trench of the dryland pasture treatment than in storage and work treatments (Figure 4). Due to disturbance severity in the trench treatment, there were fewer surviving propagules than in the storage or work treatments, which is supported by other studies [2]. Establishment of native species on the trench was dependent on the species seeded. For non-native grasses, both mixes had a similar cover on storage and work treatments, although the trench of the dryland pasture mix had significantly greater cover of non-native grasses than that of the native seed mix.

Agropyron cristatum started to invade 3 years after reclamation, and by Year 12 contributed almost 40% of cover (data not shown). Increased *Agropyron cristatum* would have increased competition for other species, thus an inverse relationship between native and non-native species on trenches was found for both seed mixes. *Agropyron cristatum* invasion can affect several processes in native grasslands including aboveground vegetation that competes for light, and may have an advantage over native species because of its tall stature and relatively high standing biomass [63,64]. Heidinga and Wilson [65] found *Agropyron cristatum* invasion could reduce 35% total cover of native grassland species. Other studies found invasion of *Agropyron cristatum* was a primary cause of local plant and animal extirpation [66], and has led to local losses of more species than has recent climate change [67]. Vaness and Wilson [64] reported that *Agropyron cristatum* has potential to dominate a large proportion of remaining native grasslands if left unmanaged, but grazing can greatly decrease its abundance even though established populations may not be eliminated. Based on our study it can be concluded that using a native seed mix with cattle grazing would be the best strategy for reclamation success if non-native *Agropyron cristatum* dominates the sites.

Seeded wheatgrasses did well with both seed mixes; slender (*Elymus trachycaulus*), crested (*Agropyron cristatum*), northern (*Elymus lanceolatus*), and western (*Pascopyrum smithii*) wheatgrasses all remained in the plant community into Year 12. The wheatgrass performance in our study supports other research on seed mix establishment for rangelands [21,68,69]. Northern and western wheatgrasses were dominant species (native seed mix 31% in Year 3, 44% in Year 12; dryland pasture seed mix 19% in Year 3, 23% in Year 12). While these two species were part of the native seed mix, it is unlikely all cover is due to seeding as they were not present in the dryland pasture mix. Presence of these species may be due to survival and establishment of propagules or species success at moving in from adjacent undisturbed prairie.

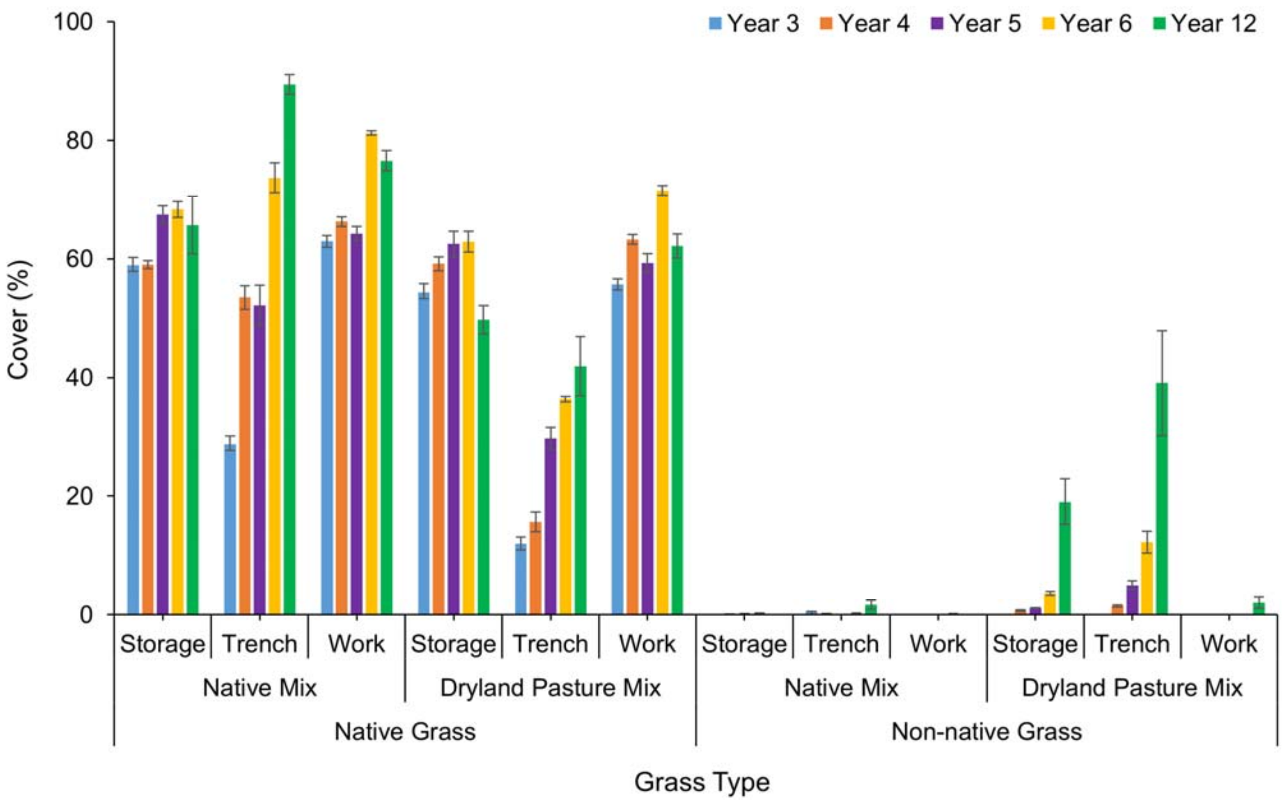

Figure 4. Mean (±) percent cover of native and non-native grass by seed mix and RoW treatments.

Wheatgrasses are strongly rhizomatous and produce highly germinable seeds, leading to their rapid establishment and cover following disturbance [30,70–72]. Slender wheatgrass, which is a reportedly short-lived species, still had 21% cover on the trench with native seed mix 12 years after seeding. These results are reflected in other research by Lamb (1998) [73] where grasses (creeping red fescue (*Festuca rubra* L.), orchard grass (*Dactylis glomerata* L.), and timothy (*Phleum pratense* L.)) that were thought to be short lived due to environmental conditions were still present 10 years after seeding. The success of the native seeded species, even when accounting for residual propagules, was contrary to previous work [13,74]. Pelech [21] found that two years after planting, non-native seed mixes were more successful at establishing cover than native seed mixes in Aspen parkland. The difference was likely a result of growing conditions and adaptability of species planted.

3.2. Forb Species Cover

The seed mixes did not significantly affect total, native, non-native, annual, or perennial forb cover over the years of the study (Figure 5). The results support other research which indicated seed mix had no effect on the early forb plant community [35,36,44,68,69,75]. In most cases annual and perennial forb cover were high at the beginning of the study, declined steadily, and by Year 12 were lowest with both seed mixes (Figure 5). After 12 years, perennial forb cover was slightly greater in native mix than dryland pasture mix. When we compared the proportion of annual and perennial forbs, annuals contributed substantially to total cover in the first few years after disturbance, but by Year 12 they contributed less than 1%. Perennials contributed over 75% of total forb cover early in the study, increasing to approximately 100% by Year 12, although overall perennial cover decreased (Figure 5).

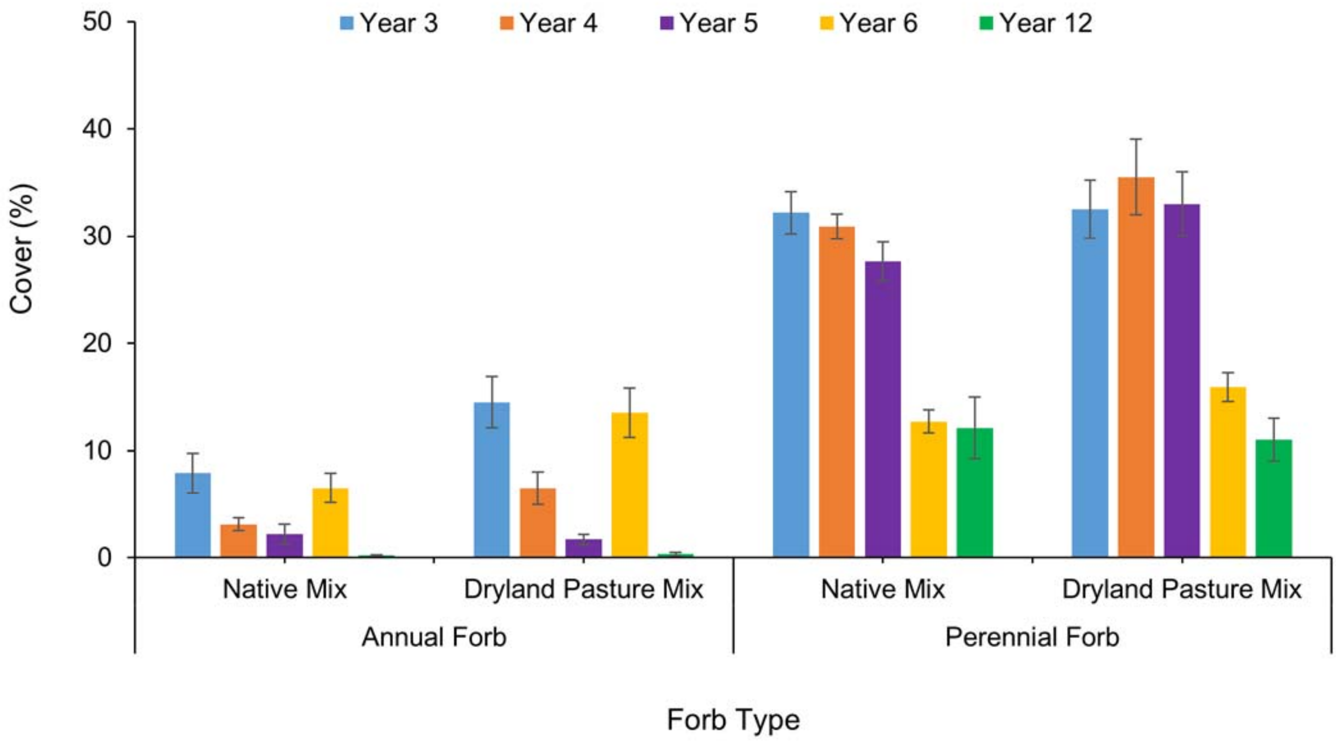

Figure 5. Mean (±SE) percent cover of total annual and perennial forbs (native + non-native) by seed mix.

Total forb cover was significantly greater on the trench than all other treatments for both seed mixes and started to decrease with time (Figure 6). A similar pattern has been observed in other grassland and forest reclamation studies [12,13,30,76,77]. Large numbers of forbs are often present in disturbed landscapes because of their secondary succession role, where they can be more efficient than grasses in using environmental resources such as nutrients, water, and sunlight [28,76]. Many forbs are not palatable, giving them an advantage in grazing environments.

Disturbed and fragmented ecosystems with a slow recovery rate are most susceptible to invasion by non-native species which can alter dynamic processes and recovery toward pre-disturbance states [78,79]. Although from Years 5 to 6, non-native forb cover sharply increased on the trench for both dryland pasture mix (4.3 to 33%) and native mix (2.4 to 17%) treatments; in Year 12 non-native cover again decreased dramatically in both seed mixes, increasing in the storage treatment for the native seed mix (Figure 6). The increase in non-native forbs from Years 5 to 6 was due to increases or decreases of non-native annuals (blue bur (*Lappula* sp. Moench) and lamb's quarters (*Chenopodium album* L.)) (Figure 6). This might be due to well-timed precipitation which sharply increased Lappula Moench and Chenopodium album on the sites. According to Naeth [47] a well-timed rainfall can cause a flush of annuals and enhance annual forb growth. Other research indicates annuals are often the first to establish after disturbance [2,13,30]. Pasture sage (*Artemisia frigida* Willd.) was the dominant perennial in the first few years. Other pipeline work in the mixed grass prairie listed pasture sage as an early dominant perennial [80].

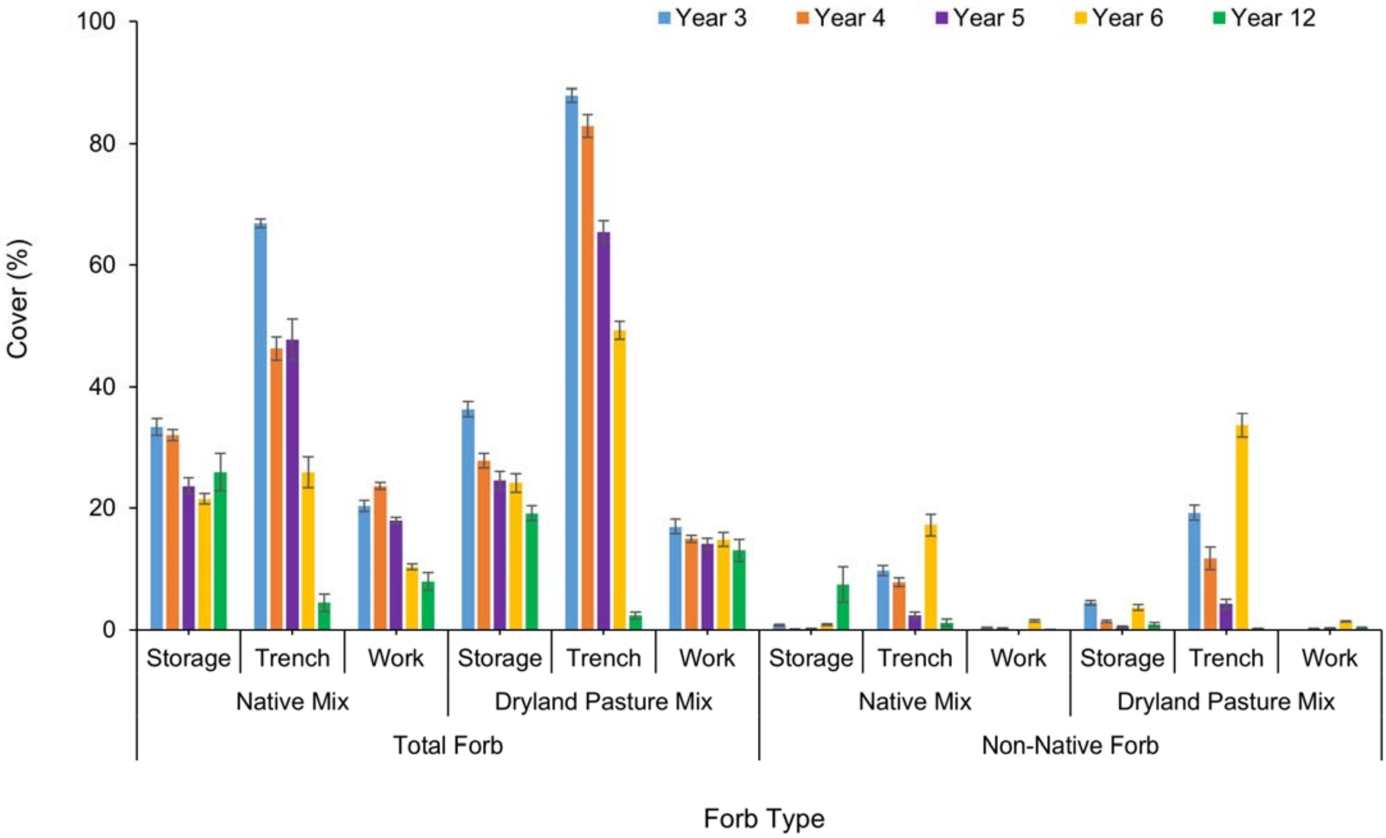

Figure 6. Mean (±SE) percent cover of total and non-native forb by seed mix and RoW treatments.

3.3. Bare Ground, Litter, and Little Club Moss Cover

Seed mix did not affect bare ground and litter cover, although bare ground decreased and litter cover increased with time with both seed mixes. In the storage treatment the dryland pasture seed mix had higher bare ground (34.8%) than trench and work treatments; whereas with the native seed mix all RoW treatments were <15% (Figure 7). The greatest litter cover was found on the trench treatment and lowest on the storage treatment, irrespective of seed mixes (Figure 7). Our study supports other grassland reclamation studies of this region [2,13,21,32,80]. Grazing decreases accumulated litter in some cases [48] but increases it in others [29,80].

According to Naeth [80] litter increases or decreases are directly linked with the timing of grazing. Late in the growing season, plants on disturbances are mature and less palatable so they are likely to be trampled or avoided, especially if they are annual weeds. Soulodre [29] found that although June and July grazing transitioned live vegetation into litter cover through trampling, bare ground still increased, even in highly productive wheatgrass swards. Litter increases soil aggregation and aggregate stability, decreases raindrop impact, runoff, erosion, and soil surface evaporation [81], provides habitats for organisms, and retains nutrients [82]. Greater bare ground in the storage treatment of the dryland pasture seed mix (34.8%) can be a concern for soil erosion. According to Weltz et al. [83], a threshold of 25 to 50% bare ground is often considered the level at which serious soil erosion could occur. Large amounts of bare ground on the trench treatment might be the result of scalping during construction [2,14] and overuse by cattle [49]. It is well established that soil disturbance during trench construction can alter soil physical and chemical properties [2,14]. Naeth et al. [49] found grazing increased bare ground and decreased litter and live cover on reclaimed mixed prairie pipeline sites.

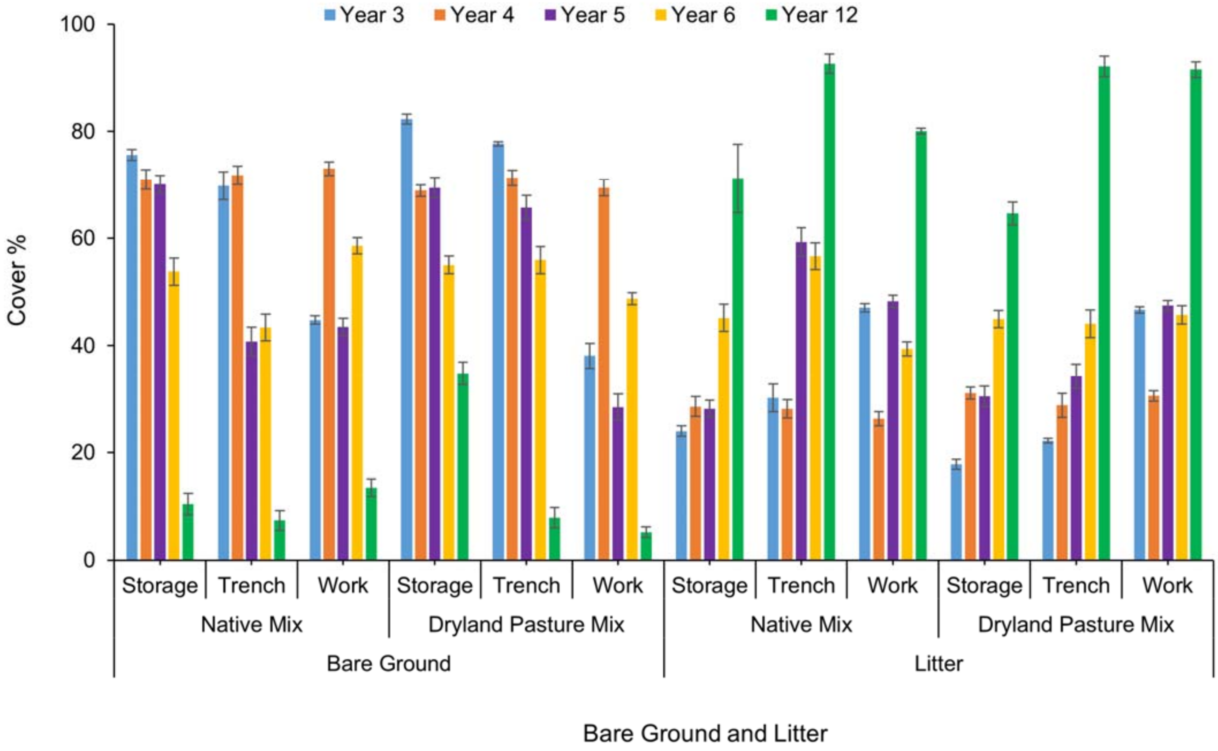

Figure 7. Mean (±SE) percent bare ground and litter cover by seed mix and RoW treatments.

Little club moss (*Selaginella densa*) cover, an indicator keystone species for grassland, increases with grazing pressure. However, over the 12 years of the study that trend was not evident with either seed mix (Figure 8a). In previous pipeline studies, little club moss was absent in fescue and mixed grass prairie for up to 32 years [12,80]. Little club moss was nearly absent on the trench, whereas work treatments had greater cover, followed by the storage treatment (Figure 8a). Irrespective of seed mixes, the absence of little club moss on the trench might be due to its greater disturbance from excavation than the other two RoW treatments, although conditions for its re-establishment are still unknown. Both seed mixes responded differently to grazing treatments; ungrazed (4.0%) with native seed mix and grazed (2.1%) with dryland pasture had greatest cover (Figure 8b). However, re-establishment of little club moss following disturbance on storage and work treatments may indicate some successional progress.

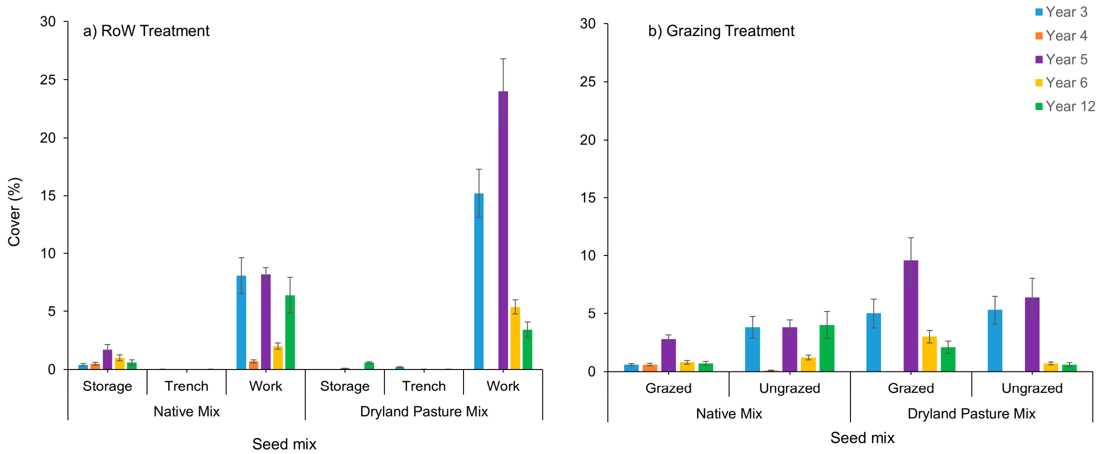

Figure 8. Mean (±SE) percent cover of little club moss (*Selaginella densa*) by RoW and seed mix treatments.

4. Conclusions

During pipeline reclamation of a native grassland, seeding with a native species mix led to greater vegetation cover than seeding with a dryland pasture mix. Grazing had a significant impact on cover of non-native grasses with the ungrazed treatment having greater cover than the grazed over time. The trench RoW treatment had a greater total forb cover up to Year 6, which sharply declined to its lowest in Year 12 relative to storage and work treatments. This study showed perennial forbs dominated over annuals throughout the 12-year period of the study. Reclamation to equivalent land capability on native grasslands can be best achieved with seeding of native plant species relative to a dryland pasture mix.

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