Research article

Testing prescribed burning to shift an agronomic grass community to a diverse native plant community

Brandon Williams [*], Wendy Gardner, Jay Prakash Singh, Lauchlan Fraser

Thompson Rivers University, 805 TRU Way, Kamloops British Columbia, Canada, V2C 0C8

A B S T R A C T

Prescribed burning can be an effective land management tool. Here, we study changes in plant diversity and composition following experimental fire disturbance in microcosm units extracted from a twenty-five-year-old historically reclaimed grassland located at Highland Valley Copper mine in British Columbia (B.C.), Canada. Experimental microcosm units were dominated by agronomic grass species *Elymus lanceolatus, Thinopyrum intermedium* and *Bromus inermis*. The disturbance treatment was fire intensity, represented by three levels (light, moderate, and heavy), replicated six times per treatment. Fire intensity was controlled by modifying the weight of dried litter applied to each microcosm unit (50 g,150 g, 200g), along with the time each grass turf was burned (10 s, 15 s, 20 s). One day after the fire treatment was applied, microcosm units were seeded with a native species mix consisting of six grassland species common to southern B.C. to examine effectiveness of plant establishment postburn. Disturbance treatments resulted in higher overall alpha diversity, richness, evenness, and beta diversity. Plant community changes included colonization of seeded native forbs, grasses, and legumes in response to disturbance. Aboveground net primary productivity (ANPP) was net neutral within the light and moderate burning disturbance treatments but resulted in increased ANPP with heavy disturbance. Litter mass reduced plant diversity and ANPP, indicating that litter was a major factor in plant community dynamics. These results suggest disturbance by burning leads to short term positive plant community response towards increasing diversity of semi-arid grasslands, and aids in shifting plant communities to higher diversity composed of an increase in native plant species. Our results also suggest that without active management the gains observed in native species establishment might quickly be out shadowed and restricted by the previously dominant agronomic plant community.

1. Introduction

Fire is a natural ecological disturbance, but due to its heterogenous and environmentally specific behavior as fire intensity relates to fire severity, the effects on plant communities has not been well quantified (Duff et al., 2017). As fire drives plant community succession following its natural disturbance, this influences the evolution of numerous plant species and plant communities while acting as a mechanism to sustain structure, diversity and productivity of fire dependent ecosystems (Moritz et al., 2014). In grasslands, plant communities are primarily influenced by a combination of biotic and abiotic factors including fire, grazing, climate, soils and topography (Collins and Calabrese, 2012). Fire influences many ecological components within an ecosystem, including increasing the availability of resources such as light, as well as a short-term increase in nitrogen availability and nutrient cycling

(Swanson et al., 2011). This in turn can modify relationships among species and change dominance in a community due to species specific responses to changes in these variables (Ghermandi et al., 2004; Collins and Calabrese, 2012; Augustine et al., 2014).

Patterns of plant diversity are largely dependent on interactions between frequencies of disturbance and above-ground biomass of the vegetation (Pekin et al., 2012). In highly productive sites, biomass and litter accumulation that is left in a state without disturbance or some form of reduction may ultimately restrict above ground net primary productivity (ANPP), species richness, and favor tall-statured, long-lived species and reduced functional diversity in life form (Foster and Gross, 1998; Peco et al., 2012). Reduction in plant diversity can largely be attributed to biomass accumulation in the understory, sequestering limiting nutrients and restricting light availability to the environment below, resulting in competitive exclusion from tall, long-lived species

(Grime, 1973; Pekin et al., 2012). Similarly with highly productive grasslands a disturbance such as fire is an important determinant in increasing richness of grasses and forbs for the community through reducing competitive exclusion, evidenced by a >50% reduction in grass species richness in the absence of disturbance (Fynn et al., 2004). As agronomic dominant grasslands without a disturbance regime can spread rapidly and reduce the cover of native plants by initiating growth earlier than native species and forming a thick thatch and root mat layer through rhizomatous spread, fire can play a role in allowing new entrants into the plant community (Kral et al., 2018). Fire plays a significant role in plant community composition and structuring grassland ecosystems. Postburn conditions often favor establishment of new species through various abiotic ecosystem changes such as: decreased soil moisture, removal of accumulated litter and subsequent release of nutrients immobilized within the dead plant tissue, increased solar radiation to the ground, and allowing a period of reduced competition (Brockway et al., 2002; Scheintaub et al., 2009; Pekin et al., 2012).

Despite the ecological benefits and outcomes of prescribed fire, its application in ecological restoration is rarely utilized (McKenna et al., 2019) but its efficacy as a management tool is rapidly changing and often times is used to manage rangelands and fuel loads in fire prone ecosystems (Taylor, 2003; Penman et al., 2011). Fire managers and ecologists use burning in Canadian national parks to reduce fire risk or reintroduce disturbance to an ecosystem for management purposes (Scheintaub et al., 2009; Sutherland, 2019). There is a lack of research however, on how fire intensity on a controlled scale may affect plant and soil community responses. For the purposes of this research, fire intensity refers to the energy released through various phases of a fire (amount of fuel consumed and energy released), and fire severity refers to ecosystem impacts from fire defined in this case as the loss or change of organic matter that results in observable change (Keeley, 2009).

Grasslands are strongly tied to abiotic ecosystem drivers like fire to produce feedbacks on soil and plant properties which are moderated through fire intensity (amount of fuel consumed and energy released) (Reinhart et al., 2016; Werner et al., 2021). Prescribed burns are referred to and utilized frequently in the literature to reduce fuel loads (Fernandes and Botelho, 2003), however, the matter of characterizing or manipulating the intensity and its resultant effects on ecosystems is poorly documented (Reinhart et al., 2016). Timing of prescribed fire is often manipulated to change the fire intensity by targeting seasonal windows opposed to quantifying fuel loads in a detailed manner as we have completed in this study. The timing and seasons of burning is a large factor that can result in variable responses to the plant community based upon the conditions that may alter fire intensity. Generally speaking for grassland ecosystems that are high elevation and associated with high moisture levels in the spring, prescribed fires that are completed at this time result in wetter conditions, lower fuel combustion and lower intensity and resulting severity on the landscape whereas summer or fall burning offer higher intensity burns due to accumulation of biomass from the season, drier fuels, and greater combustion as a result (Reinhart et al., 2016; Wang et al., 2021).

The purpose of this research was to determine the relative effect that fire disturbance and fire intensity has on a twenty-five-year-old historically reclaimed plant community by manipulating fuel load and intensity in a controlled manner to shift an agronomic grassland plant community to a native plant community. We also examine the ability of a six-species plant mixture, to establish in postburn conditions. The goal of burning paired with seeding was proposed as an aid to shift an undesirable plant community dominated by largely fast growing, agronomic grass species (*Elymus trachycaulus, Bromus inermis, & Thinopyrum intermedium*) to a native plant community more typical of local and highly diverse grasslands. The six plant species selected for our experiment were *Castilleja miniata* (common red paintbrush), *Gaillardia aristata* (brown-eyed susan), *Festuca campestris* (rough fescue), *Festuca saximontana* (rocky mountain fescue), *Oxytropis campestris* (field locoweed) and *Lupinus arcticus* (arctic lupine). We chose these species for a number

of reasons: (1) To examine functional group responses to disturbance (2) They represent common species found within B.C.'s upper grassland communities (3) They align with the desired end land use reclamation goal objectives set out by Teck Highland Valley Copper and Indigenous project partners (Nlaka'pamux nation), and (4) They are expected to tolerate site conditions including high elevations up to 1500 m and, neutral to slightly alkaline soils, while also holding characteristics of drought tolerance and ease of establishment (Dobb and Burton, 2013).

A mesocosm, microcosm or excised community aims to mimic a natural system and extracting ecologically relevant information while providing a simplified model for complex disturbances within particular ecosystems (Fraser and Keddy, 1997). We used a microcosm approach in this experiment in an attempt to control fuel loads and intensity to a higher degree possible than is achievable in field scale trials. The experimental design focused on a gap in literature surrounding plant community response to fire intensity and severity effects for semi-arid grasslands in reclamation prescriptions.

2. Materials & methods

2.1. Microcosm unit extraction site

Microcosm experimental units were extracted in August of 2019 when plants were within summer dormancy, from the Historic Highmont Tailings Storage Facility (TSF), located approximately 5 km west of Logan Lake, British Columbia (B.C.) within Highland Valley Copper Mine (HVC; UTM Z10; 647739E, 5588766N, elevation 1500m).

Highmont Tailings is located within the Montane Spruce MSxk2 (very dry, cool) biogeoclimatic zone (Government of British Columbia Ministry of Forests, 1991). This location is characterized by cold winters and moderately short, warm summers. The mean annual temperature is 3–4.5 °C and mean annual precipitation ranges from 380 to 900 mm (Mahony et al., 2024).

The history of reclamation of Highmont TSF represents 32 years of reclamation work and was initiated in 1989 on soils derived from milling wastes (Majak et al., 2004). Notable reclamation efforts include a series of seeding trials in 2008 (35 kg/ha) paired with biosolid application (200 dt/ha) to aid in establishing vegetative cover onto unamended mine tailings. The selected seeds represent various introduced, long-lived, sod-forming wheat grasses often utilized for agronomic purposes due to their hardiness and ability to grow in nutrient limited, and water limited environments. These species represent the prior planned agricultural uses of cattle grazing and hay production.

The plant community in the study area represents a low diversity, patchy landscape that is primarily composed of a few dominant, and highly productive agronomic grasses (*Elymus lanceolatus, Thinopyrum intermedium* and *Bromus inermis*) that make up the majority of the plant community. Additional species include a low abundance of forbs (*Achillea millefolium & Sisymbrium altissimum*). The updated land use plan for Highmont Tailings now places more focus on increasing native biodiversity and shifting the site trajectory towards desired species that represent locally native bunchgrasses, forbs, and legumes more indicative of an undisturbed and diverse native grassland.

2.2. Microcosms

The indoor microcosms used to test the effects of fire intensity on the plant community were extracted as in-tact 'grass-turf' units and placed into 102-L HDX Tough Storage Bins™. All microcosm units were then transported back to the Thompson Rivers University (TRU) Research Greenhouse. The experiment was conducted under controlled conditions operated by Argus™ control systems (natural and artificial light: day/night 18h/6h; temperature: day/night 21 °C; humidity: 50–60%) (Antonelli et al., 2021).

The bins and turf sizes were selected to obtain an approximate area of 0.25 m^2 (Bin dimensions: L0.56 m by W0.46m by H0.38 m) for

vegetation analysis purposes and to ensure each grass turf contained intact root systems and soil profile. The soil profile within each microcosm contained an A-horizon layer ranging from approximately 2 - 3 cm, with the subsequent layer representing fine textured mine-tailings. Each microcosm container had a total of fifteen 1 cm diameter drainage holes, in addition to landscape fabric that was placed on the bottom to stop the release of fine textured tailings during watering events.

The microcosms were free draining to allow for natural soil moisture profiles and watered as needed. Plants were monitored daily for signs of stress and wilting within the greenhouse. Microcosms were watered approximately three times a week during winter months and every second day during summer months.

2.3. Experimental design

The experiment was established in the Summer of 2019 and treatments were applied in January 2020 and ran for 227 days (approximately seven months). The experimental design was a randomized complete block design with a single factor (disturbance treatment), with four levels (control, light, moderate, and heavy) and six replicates per level, for a total of twenty four individual experimental microcosm units. Each experimental unit including the control was hand-seeded with a custom native seed mix at a rate of 200 seeds/sp./microcosm unit after disturbance treatment (~4658 seeds/m^2 or ~ 1200 seeds/microcosm unit). All seeds were purchased from commercial sources. Treatments were randomly assigned to each block and microcosm unit.

2.4. Fire treatment & fire intensity

This study applied controlled fire to microcosm units at three levels of fire intensity. Fire intensity treatments were modified through amending the weight of dried litter (50 g, 150 g, and 200 g respective from light to heavy burn intensity) applied to each microcosm unit, along with modifying the time (10 s, 15 s, and 20 s respective from light to heavy burn intensity) each grass turf was burned with a cast iron head, propane torch (Tiger Torch™ Model No. 95-B). Litter material that was placed on each microcosm unit was sourced from the units themselves. Litter material was composed of all surface litter which includes dead plant parts including leaves, flowers, stems, fruits, seeds in addition to litter material scraped from the top of the soil (Buzhdygan et al., 2020).

The cast iron head was held at the same height (30 cm) above each unit and a 'S' type motion was used for torching each unit. Gas pressure and flame intensity remained constant throughout the process and was regulated using the controls on the propane torch. Preliminary trials modifying the weight of dried litter and time of burn were conducted to establish burn intensity before the formal experiment was initiated.

Fire intensity was semi-quantitatively recorded within each microcosm unit using self-constructed metal pyrometers utilizing Omega laq paints of varying melting points, placed in each microcosm beneath the fuel before burning (Omega Engineering, Stamford, CT, USA) (Wragg et al., 2018). A total of 15 paints with melting points spanning 107–510 °C were applied. Each pyrometer was analyzed after burn treatment and results were collected by a single observer. Temperature sensitive paints were determined to reach their specified target when a sharp drip was observed indicating melting, in addition to the loss of the original color and a shift from matte to glossy finish after treatment was applied (Omega Engineering, Stamford, CT, USA). Pyrometer melt point and observer calibration occurred by placing samples in a muffle furnace for 1 min at increasing temperatures, validating melt points across the range of temperatures. Pyrometer values consistently yielded heavy burn treatments reaching 343 °C, moderate at 302 °C, and low at 246 °C.

2.5. Seed selection, preparation & seeding rate

A total of two native grasses, two native forbs, and two native legumes were selected for seed application in the microcosm experiment. Within each of these three functional groups an early and mid or late successional species was selected based on their expected level of tolerance to site conditions including neutral to slightly alkaline soils, elevation range (1500 m), drought tolerance, and ease of establishment (Dobb and Burton, 2013). The native species also represent common species found within B.C.'s grassland communities, in addition to aligning with target species within the end land use goal of the mine.

Prior to the application of the hard coated legume species onto each microcosm unit, seeds were scarified using sandpaper and water soaked for 5 h. *Castilleja miniata* seeds were also cold stratified for 30 days by being placed on moist filter paper and placed in the laboratory fridge (Baskin and Baskin, 1998; Kimura and Islam, 2012; Luna, 2005). All seeds were then placed into an envelope packet along with 25 mg of sand to help achieve even dispersal when broadcasting the seed after treatments were applied.

Prior to sowing seeds, a germination trial was completed to determine the pure live seed (PLS) rate that was being applied to the units. Results from the germination trial resulted in a PLS rate of approximately 1873 PLS/m^2. This seeding rate represents the upper limit that has been established at 1400 PLS/m^2 (Barr et al., 2017) and 750–1500 PLS/m^2 for degraded grasslands to optimize richness and diversity (Burton et al., 2006a,b). Germination data from *Castilleja miniata* was excluded from the PLS calculation due to lack of any germination.

2.6. Vegetation assessment & harvesting

Plant communities were sampled in each microcosm unit by visual estimation prior to burning, using absolute canopy cover estimation of cover percentage (Gagnon et al., 2021). Microcosm units, approximated a 0.5 m by 0.5 m quadrat due to the size of the microcosm bins being 0.56 m by 0.46 m. Prior to treatment application baseline data for above ground net primary productivity (ANPP) were collected. All microcosms, except control, were harvested to quantify above-ground biomass and litter. After burn trials were completed, microcosms were then allowed to grow for seven months, after which above-ground biomass and litter were collected. The plants were harvested as close to the soil surface as possible and separated by species to quantify ANPP. Litter was collected after ANPP was collected by scraping dead material off the soil surface. All plant material was oven-dried for approximately 48h at 65 °C and weighed to a constant weight to determine dry matter biomass separated by above ground biomass and litter.

Vegetation community assessment via absolute canopy cover estimation was completed prior to disturbance and prior to final harvest (seven-months postburn). Species richness was considered the number of unique species present in each grass turf at the time of sampling. Plant community dynamics of evenness and dominance were calculated respectively using the Shannon-Weiner index which accounts for richness and evenness, and the Simpson index which is sensitive to dominance (Morris et al., 2014).

2.7. Statistical analysis

All statistical analyses and figures were produced using R for Statistical Computing (R Core Team, 2021). In all cases, significance was defined by p < 0.05. Data were analyzed using mixed effect modelling using the 'lmer' function from the package "lme4". For all analyses completed, the random effect was the specific microcosm from which the measurements were performed. Fixed effects for all models were extracted through running an analysis of variance (ANOVA) on the selected model. Benjamini-Hochberg (BH) post hoc analyses were performed on all models using the "emmeans" package to generate estimated marginal means (Benjamini and Hochberg, 1995). All linear mixed effects models used were first checked to meet the assumptions of normally distributed residuals, and homogeneity of variance. Transformations of data were used when data did not meet the above

assumptions.

Plant cover data from each microcosm unit was first analyzed descriptively by examining species richness, Shannon-Weiner and Simpson diversity indices using the 'vegan' package in R for statistical computing.

Data normalization was completed on ANPP data to meet the assumptions of normality. Seven months postburn data for each microcosm was normalized against its within block paired control by dividing the ANPP weight at seven months postburn to the ANPP weight of the control.

A permutational multivariate analysis of variance (PERMANOVA) analyzing Bray-Curtis dissimilarity was used to assess community-level divergence between treatments and timing. Pairwise Bray-Curtis dissimilarity between plot (mesocosm) pairs within a group (treatment or timing) was calculated independently and became a unique observation. The 'adonis' function in the 'vegan' package in R was used to complete this analysis. Species assemblages were normalized first using the Hellinger method. Bray-Curtis dissimilarity distances were then extracted in R to produce a boxplot to display dissimilarities between factors and examine post-hoc comparisons. This method allowed for pairwise comparison post-hoc analysis to be completed to determine the pairings of significant differences.

3. Results

Disturbance impacted all alpha diversity metrics (Fig. 1., A-C). Comparisons of burn treatments when examining Shannon and Simpsons diversity to the control resulted in a significant increase in diversity within the light, and moderate burn intensity treatments (Fig. 1., A & B). A similar trend was observed such that species richness increased across light and moderate burn treatments when compared to the control (Fig. 1., C).

The response of the plant community to disturbance treatment and timing was further investigated with a permutational multivariate analysis of variance which revealed that community composition based on Bray-Curtis dissimilarities was different among treatments ($p < 0.001$, Fig. 2.).

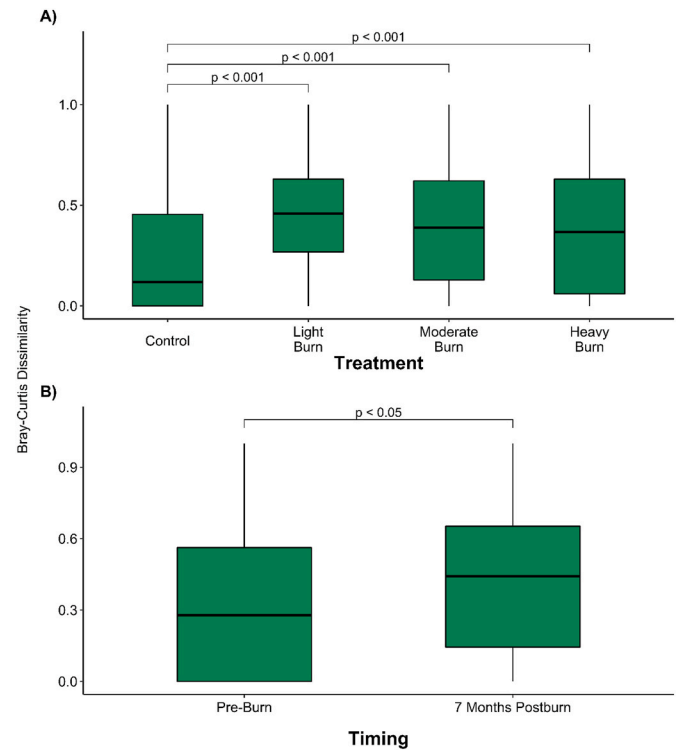Generally, all disturbance treatments and timing appear to have

Fig. 2. Extracted Bray-Curtis Dissimilarity plotted by A) Burn Treatment (seven months postburn) and B) Timing (Pre-burn and seven months postburn). All pairwise comparisons were conducted in A-B and p values were adjusted with Benjamini-Hochberg false detection rate (fdr) corrections.

resulted in a significant shift in the community composition ($p < 0.001$, Fig. 2A.). Plant community response to timing based on Bray-Curtis dissimilarities was also found to be significant ($p < 0.001$, Fig. 2B.).

Plant percent cover of agronomic grass between pre-burn and seven months postburn resulted in an increase (Fig. 3. A, $p < 0.05$), along with
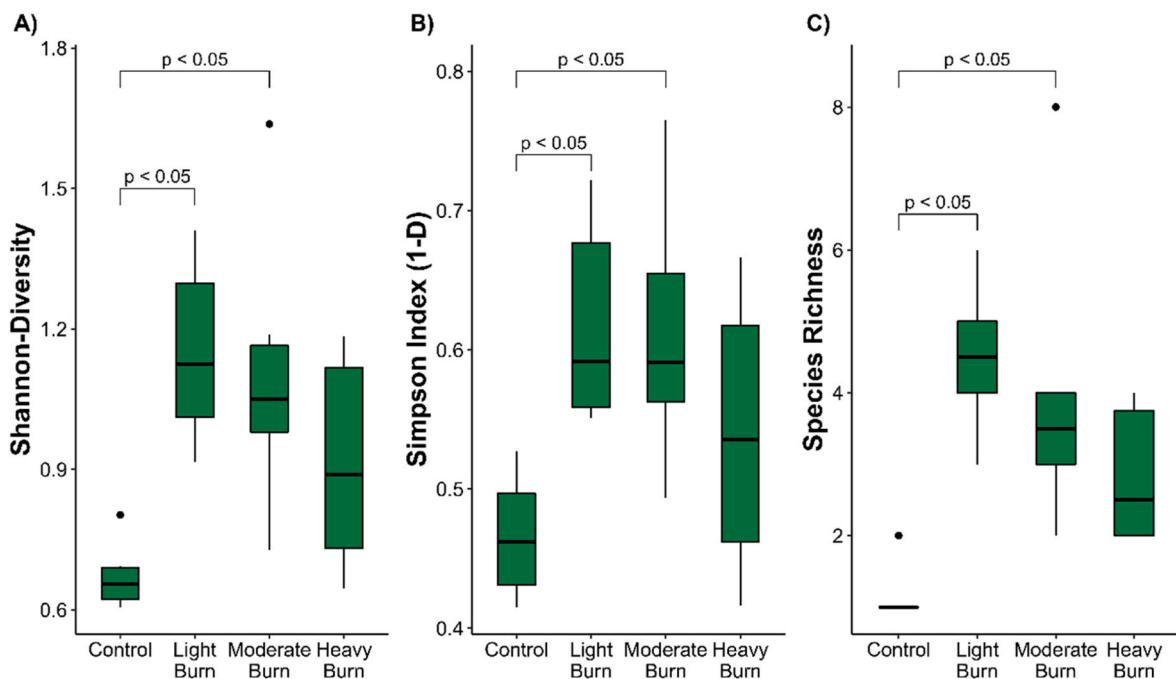
Fig. 1. Shannon-Diversity, Simpson Index (1-D), and Species Richness as an effect of burning and seeding treatments (n = 6 for all treatments) at seven months postburn (A–C). All pairwise comparisons were conducted in A-C and p values were adjusted with Benjamini-Hochberg false detection rate (fdr) corrections.
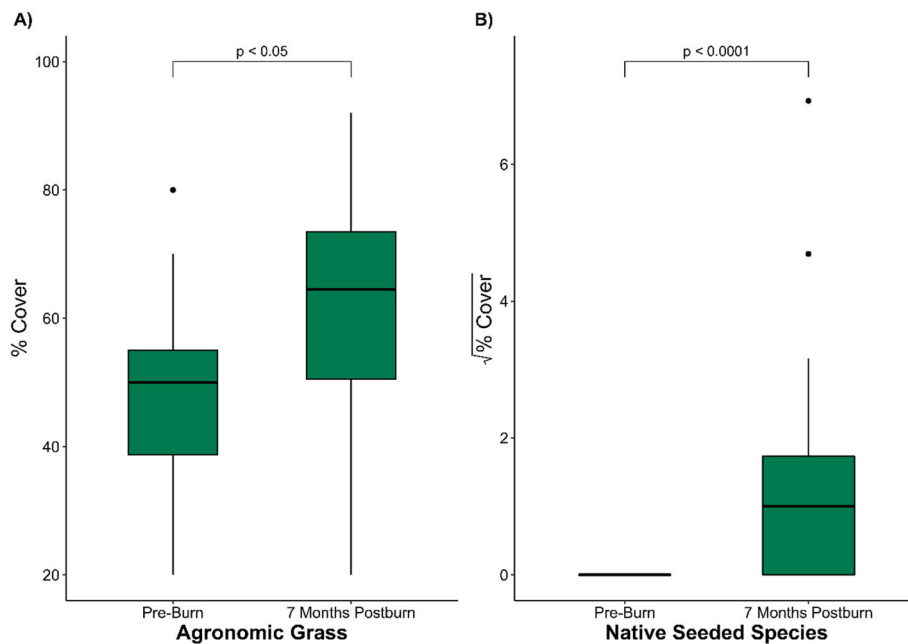
Fig. 3. Percent cover of agronomic grasses and native seeded species prior to burning and seven months postburn (n = 24 within each group). Seeded species were sown onto experimental units after burning was completed and the native mix is comprised of six unique species (*Festuca campestris, Festuca saximontana, Gaillardia aristata, Castilleja miniata, Oxytropis campestris, Lupinus arcticus*). All pairwise comparisons were conducted in A-B and p values were adjusted with Benjamini-Hochberg false detection rate (fdr) corrections.

total cover of seeded native species (p < 0.0001).

As burn treatment intensity increased from light to heavy significant increases in ANPP occurred (p < 0.01) suggesting a change in the plant community productivity with higher burn intensity. Burn treatments also resulted in reduced litter mass in comparison to preburn litter levels (p < 0.001).

4. Discussion

4.1. Impacts of disturbance on richness, evenness & diversity

Disturbance treatments, regardless of burn intensity resulted in an increase in species richness, evenness, and diversity. Light and moderate burn intensities resulted in similar increases in diversity metrics while heavy burning resulted in the lowest response across treatments. Furthermore, it appears as though the light and moderate burn intensity were not fully distinguishable from one another such that a similar response was observed within each treatment.

The moderate and light intensity response found within this experiment is comparable to the generally accepted "humped-back-model", which states the greatest diversity occurs in the moderate or middle range of a physical gradient (Grime, 1973; Fraser et al., 2015). A similar result was also found within the field in more recent work by Ashouri et al., (2016); Heydari et al., (2017) whereby maximum values for richness corresponded to sites with moderate stress that were characterized from high to low based on fire disturbance and grazing intensity.

Although our data supports increases in native species cover post-burn across all treatments (Fig. 1), regrowth from the previous agronomic grass community (Fig. 3) and resulting litter deposition as displayed in Fig. 4 is expected to be a significant factor reducing the overall success of seeded native species in postburn conditions. This limiting type response has been described in other research where previously dominant agronomic rhizomatous grasses post disturbance began to expand both above and belowground rapidly This expansion began depositing a layer of litter on the ground surface and growth outcompeted new seedlings for space and resources, effectively stalling successional progress (Facelli and Pickett, 1991; Scheintaub et al.,
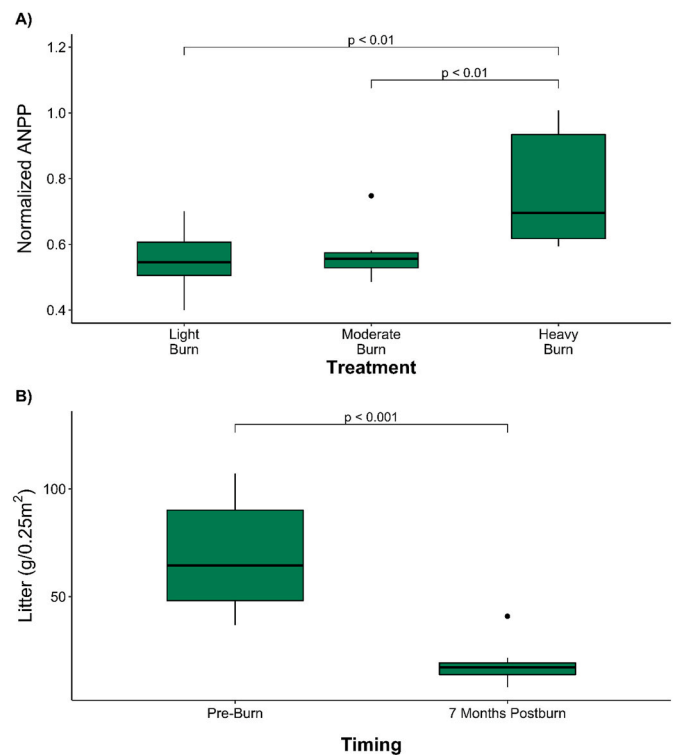

Fig. 4. A) Aboveground net primary productivity (ANPP) by burn treatment. Data was normalized against each factors paired control (n = 6 within each group). B) Litter levels prior to burning (n Pre-Burn = 24) and seven months postburn (n = 24).

2009). A similar response was found by Kirkman et al. (2014) whereby dominance of a rhizomatous grass was thought to be a factor of facilitating community dominance after prescribed burning. Early successional species that were able to withstand competition, contributed

significantly more to the increase in biodiversity over time. Although competition was not directly measured, observationally this result aligns with the postburn stages and benefits of postburn conditions. The first stage represents a 'race to occupy the area' when there is little competition for resources (light, water, space, etc.). Secondly, as growth continues resources become progressively more important, the challenge becomes 'the effort to maintain space' and compete (Ghermandi et al., 2004; Scheintaub et al., 2009).

The impacts of disturbance treatments and timing were also analyzed for Bray Curtis dissimilarity (beta diversity) on the plant community. Both timing and disturbance treatment resulted in significant changes to the plant community. This divergence is likely due to the similar composition of well-established non desirable grass species across experimental units, being contrasted by the later established native species that responded differently to disturbance treatments and other environmental gradients (Matthews and Spyreas, 2010). When examining beta diversity over the experimental period with respect to timing, we find significant community convergence away from the preburn community likely due to the increased number of new native species over time from seeding and new ruderal species appearing due to fire disturbance (Fig. 2B.).

4.2. Impacts of disturbance on aboveground net primary productivity

The impact of disturbance on ANPP was found to remain negative to neutral with respect to the light disturbance, while productivity appeared to increase as intensity increased to heavy burning. The light – moderate disturbance fire observations remains consistent with investigation of productivity effects of fire on Mediterranean type grasslands (Hervey, 1949; Henry et al., 2006) and more recent work completed within a semi-arid shortgrass steppe (Scheintaub et al., 2009). The net neutral to negative response to productivity may be more of an effect of timing of the burn with respect to whether the grass species are physiologically active or dormant. Scheintaub et al. (2009) found that the consumption of live tissue may have negatively impacted plants more than dormant season fire.

4.3. Plant cover and plant functional group response to disturbance and litter dynamics

Disturbance treatments by burning resulted in a significant response among the plant community resulting in increased cover in both the previously established agronomic plant community and the seeded species sown after burning treatment was applied. In all experimental units the former species found in preburn observations were observed seven-months postburn. The community shift seven-months postburn was still largely dominated by agronomic grasses but also resulted in the establishment of opportunistic ruderal herbs and native seeded species that benefitted from the fire disturbance event. This response is consistent with an appearance of a 'fugitive' community after disturbances which colonize early from the seedbank, which in this case was represented by ruderal herb species (Ghermandi et al., 2004).

The increase in cover for agronomic grass species remains consistent with similar studies that have shown burning to increase cover in tall grass species (Towne and Owensby, 1984; Peterson and Reich, 2008; Kirkman et al., 2014). This increase in cover of agronomic grass species is likely a factor of rhizomatous spread. This spread and increase in cover can facilitate continued dominance and exclusion of other species due to their strong ability to increase in size via vegetative spread, while occupying the canopy increases its competitive advantage to native bunchgrass species (Peterson and Reich, 2008; Gough et al., 2012). Seeded native species were able to establish on postburn conditions and may become outcompeted in time if the community is not managed for litter and biomass accumulation (Collins and Calabrese, 2012).

A relationship between diversity and litter was found such that plant community diversity was maximized when litter was removed by disturbance (Figs. 1 and 4B.). This response can be attributed by site productivity overall, in addition to the species found within the environment that contribute to litter deposition as described in previous sections. Litter alters the physical environment potentially acting as a mechanical interface barrier for seeds and the soil in addition to the chemical and abiotic environment directly and indirectly through release of nutrients in breakdown, intercepting light, shading seeds and seedlings, and reducing soil temperature (Facelli and Pickett, 1991; Scheintaub et al., 2009). The realization of litter acting as a mechanical barrier to seeding and success of germination was confirmed through examination of the community through analysis of control units (Fig. 1.) as virtually no native species established within the units, opposed to be seeded at exactly the same rate as other microcosm units. Further to this, with continued dominance of agronomic species in all burn treatment microcosms rhizomatous spread by the agronomic grass species appears to be a significant factor in facilitating continued dominance within the community and limiting other species establishment through competitive exclusion of the resources listed above (Kirkman et al., 2014). This result remains consistent with other studies that have found when accumulated litter in tallgrass prairie is not periodically removed (every 4–20 years) by grazing or fire disturbance, productivity, and plant diversity decline (Collins and Calabrese, 2012).

5. Conclusion

The results of this study show potential diversity enhancements at a small time scale towards a diversity shift in the plant community composition from an agronomic grass dominated grassland community towards a native species composed grassland. Disturbance by burning, followed up with seeding had a significant influence on plant community response whereby burning intensity resulted in agreement with the humped back model and allowed native species to colonize and establish as observed only within disturbed treatments. A major driver for the increase in diversity was driven by reducing limiting factors imposed on the plant community (i.e., litter as a mechanical barrier) by the intensive agronomic species that dominate the plant community whereby fire as a disturbance was able to alleviate this residual pressure on the plant community. The limitations of this study are confounded by the microcosm settings that were controlled in a greenhouse setting in addition to the short time scale in which we anticipate future competitive exclusion of native species to occur if active management of these grasslands is not pursued. Future studies should work towards greater data resolution with respect to the quantitative data associated with fire intensity to further investigate these factors as they relate to the plant community. Additionally, longer term field scale studies should be implemented to examine these results at a greater time scale and under natural conditions. Management considerations to increase plant diversity to this intensive agronomic dominated landscape should consider a disturbance regime that burns or cuts biomass and litter from sites in early spring and once again in the late fall post flowering to aid in producing favorable conditions for seedlings to germinate.

CRediT authorship contribution statement

Brandon Williams: Writing – review & editing, Writing – original draft, Methodology, Formal analysis. **Wendy Gardner:** Writing – review & editing. **Jay Prakash Singh:** Writing – review & editing, Formal analysis. **Lauchlan Fraser:** Writing – review & editing, Supervision, Resources, Funding acquisition.

Chair in Ecosystem Reclamation.

Data availability

Data will be made available on request.

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