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Short Communication

Forage productivity is resilient to timing of post-wildfire defoliation in mixed-grass Prairie

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Abstract

Post-fire rangeland management recommends rest from grazing to allow forage regrowth and litter accumulation. In the first year after wildfire in the mixed-grass Prairie, we examined forage and litter mass responses to variable timing of defoliation in burned and non-burned areas. Total forage biomass did not differ between burned and non-burned areas by the second growing season. The July defoliation in both burned and non-burned areas reduced total forage biomass. Litter mass was decreased by wildfire and was further reduced by all defoliation treatments.

Key words: mixed-grass prairie, grassland wildfire, rangeland management

Résumé

La gestion des grands parcours brûlés préconise d'attendre que les espèces fourragères aient repoussé et qu'assez de litière se soit accumulée avant qu'on reprenne la paissance. L'année qui a suivi le ravage de prairies à mélange de graminées par un feu incontrôlé, les auteurs ont examiné la variation de la biomasse des plantes fourragères et de la litière consécutivement à une défoliation de durée variable aux endroits dévastés par le feu et à ceux qui ne l'avaient pas été. La biomasse des plantes fourragères était identique aux deux endroits dès la deuxième période végétative. Toutefois, la défoliation de juillet réduit leur biomasse totale, que le site ait été ou pas ravagé par le feu. Un feu incontrôlé réduit la masse de la litière, que les traitements de défoliation, quels qu'ils soient, diminuent encore plus. [Traduit par la Rédaction]

Mots-clés : prairie à mélange de graminées, feu incontrôlé de prairie, gestion des grands parcours

Introduction

The Great Plains of North America formed through a disturbance regime of drought, fire, and herbivory (Fuhlendorf et al. 2009). While fire is natural, it results in a short-term reduction in livestock forage. Grazing management that promotes post-fire forage regrowth is integral to sustain livestock operations. Timing of post-fire grazing is important because defoliation at the wrong time can reduce forage growth and availability, regardless of fire presence (Bailey et al. 2010). Additionally, litter (dead plant material) is removed by fire but contributes positively to moisture conservation and the maintenance of long-term forage growth (Willms et al. 1986). To inform rangeland managers and policy makers of optimal grazing management options following grassland fire, we assessed the impact of variable timing of defoliation in the first year following wildfire in the mixed-grass Prairie of western Canada.

Post-fire grazing may prolong recovery periods by reducing forage productivity below that which fire induces alone; therefore, it is generally recommended to avoid grazing grasslands following fire. In Alberta, Canada, the provincial recommendation is to rest burned areas for 1 year following fire (Government of Alberta 2018), while on some public lands in the United States there is a required rest period of 2 years (Bureau of Land Management 2007).

The length of time required for grassland forage productivity to recover following fire is variable and can take several years (Erichsen-Arychuk et al. 2002), and is further subject to environmental conditions and ongoing grazing influences. In particular, above-normal precipitation following fire can lead to more rapid recovery of forage productivity on burned areas (Wright and Bailey 1982). Furthermore, cattle and wildlife prefer burned grasslands due to increased forage quality (Dufek et al. 2014), which could result in overgrazing.

In contrast, other studies have suggested that only 1 year of post-fire rest is needed, if at all, because defoliation did not compound the negative effects of fire on forage growth (Vermiere et al. 2014; Gates et al. 2017). However, litter mass lost from burning accumulated more slowly when grazed (Vermiere et al. 2014), which could decrease forage productivity as litter is known to support forage growth (Willms et al. 1986). On the other hand, too much litter can reduce plant productivity and species diversity (Bailey et al. 2010) and grazing and fire can aid nutrient cycling in these dry systems where litter decomposition is otherwise slow (Brockway et al. 2002). Consequently, appropriate post-fire rest periods may be required to enable litter layer recovery and maintain long-term forage productivity.

We experimentally evaluated defoliation timing during the first year after wildfire to improve our understanding of grassland forage responses to post-fire defoliation and determine appropriate management recommendations. The objective of this study was to assess the effects of defoliation timing on burned and non-burned grassland forage productivity in the mixed-grass Prairie following fall wildfire.

Methods

Study sites

On 17 October 2017, wildfire burned a region of the mixed-grass Prairie in southeastern Alberta and southwestern Saskatchewan, Canada. Dry conditions and winds up to 120 km/h contributed to rapid fire spread (Government of Alberta 2020). Vegetation within the study region is primarily composed of cool season grasses, such as needle-and-thread (*Hesperostipa comata* (Trin. & Rupr.) Barkworth), western wheatgrass (*Pascopyrum smithii* (Rydb.) Barkworth & D.R. Dewey), and northern wheatgrass (*Elymus lanceolatus* (Scribn. & Smith) Gould), with some warm season grasses such as blue grama (*Bouteloua gracilis* (Kunth) Lag. ex Griffiths). Soils in the region are predominately Orthic Brown Chernozems (Natural Regions Committee 2006). The historical fire frequency in the Northern Great Plains is estimated at 5 to 10 years (Wright and Bailey 1982). In recent history, affected pastures were grazed by cattle rotationally (spring, summer, or fall) or continuously through the growing season. The average stocking rate was 0.69 AUM/ha, which is near the sustainable stocking rate in this area (Natural Regions Committee 2006). Stocking rates ranged from 0.24 to 1.29 AUM/ha (rancher personal communications, October 2021).

Long-term average annual precipitation (1961–2020), from the three closest Alberta Agriculture and Forestry weather stations (Acadia Valley, Schuler, and Social Plains) was 317.3 mm (Government of Alberta 2020). Annual precipitation during the field experiment was 278.5 mm in 2018 and 259.8 mm in 2019.

Experimental design

Following wildfire, defoliation timing of adjacent burned and non-burned grassland was evaluated. Sites were selected along the fire perimeter where the same ecological site was present and where the wildfire boundary was not impacted by natural features (i.e., hills or wetlands). Within eight pastures, 13 sites were located to create a paired burned/non-burned sampling design. Cattle were prevented from grazing study areas using temporary fencing or range cages ($\sim$1 m^2 in size).

We conducted a small plot experiment controlling defoliation timing in 2018, the first post-wildfire growing season. At each site, four 1 m^2 quadrats were established in each of the burned and non-burned subplots and randomly assigned one of the four one-time defoliation treatments: early June (1st–3rd June), late June (26th–28th June), July (10th–20th July), and non-clipped control. Quadrats were hand-clipped to 2 cm above the soil surface to standardize the intensity of defoliation within each plot. The central 50 $\times$ 50 cm (0.25 m^2) quadrat area was used for data collection, which created a 25 cm treated buffer to reduce edge effects. Vegetation clipped from the buffer area was removed from quadrats. In 2019, all quadrats were hand-clipped to 2 cm at peak biomass (10th–20th July) to assess forage response from wildfire and the defoliation treatments. Harvested vegetation was collected and sorted into grasses, forbs, or shrubs. Shrubs were uncommon (<1% of biomass) and not included in analysis. In 2018, litter was not collected, while in 2019, litter was hand raked from the central quadrat prior to clipping. All samples were dried at 55 °C to stable mass and weighed. Clipping by hand was used as a substitute for livestock grazing; however, a 2 cm stubble height is representative of a high intensity grazing event and is not recommended in these grasslands. Collection of samples was done in accordance with all applicable laws and regulations. Temporary field authorization was required to conduct fieldwork on public lands in Alberta (TFA 203 594 and TFA 185 830).

Statistical analysis

We used a mixed effects model to test the responses of total, grass and forb biomass, and litter mass collected in 2019, to the effects of 2017 wildfire (burn/non-burn) and the four one-time defoliation treatments applied in 2018. A split-plot design with defoliation time nested within wildfire treatment, and wildfire nested within site, was used to examine the effects of defoliation and wildfire on forage and litter quantity. For all analyses, wildfire and defoliation time were included as fixed effects, with site as a random effect. Both fire and defoliation are expected to reduce forage biomass and litter mass, so our analyses focused on the interaction of wildfire $\times$ defoliation, and we followed all significant effects with a Tukey honest significant difference (HSD) test. Response variables were transformed when necessary to achieve normality and homogeneity of variance; total and grass biomass were log (x + 1) transformed, while forb biomass and litter mass were log (2x + 1) transformed. The significance of all ANOVA and Tukey HSD tests was assessed at alpha = 0.05. Statistical analyses were conducted in R (version 4.1.1).

Results and discussion

Our experiment showed that forage productivity was not affected by the wildfire and defoliation timing interaction at peak forage biomass in 2019, the second growing season after wildfire (Table 1), which indicates that forage in this mixed-grass Prairie was relatively resilient to defoliation follow-

Table 1. Results of mixed model testing effects of a 2017 fall wildfire and defoliation timing (non-clipped control, early June, late June, and July) during the 2018 growing season on 2019 forage response of total biomass, grass biomass, forb biomass, and litter mass.

Variable	df	*F*	*p*
		2019	
Total biomass			
Burn	1	0.099	0.75
Defoliation time	3	10.5	**<0.001**
Burn × defoliation time	3	0.32	0.81
Grass biomass			
Burn	1	0.42	0.52
Defoliation time	3	8.47	**<0.001**
Burn × defoliation time	3	0.51	0.67
Forb biomass			
Burn	1	0.74	0.39
Defoliation time	3	2.63	0.056
Burn × defoliation time	3	0.31	0.82
Litter mass			
Burn	1	46.2	**<0.001**
Defoliation time	3	32.8	**<0.001**
Burn × defoliation time	3	2.40	0.073

Note: p values < 0.05 are indicated in bold font.

ing wildfire. Further, by 2019, burned and non-burned treatments did not differ in total, grass, or forb biomass (Table 1, Fig. 1). Similar results of rapid recovery have been found in the mixed-grass Prairie of North Dakota, where defoliation did not impact post-fire wildfire recovery (Gates et al. 2017). Wheatgrass species, which dominated our study sites, are considered as resistant to fire because they have less flammable litter at plant bases and regrow from rhizomes (Wright and Bailey 1982). The lack of a significant interaction between wildfire and defoliation during years with below average precipitation demonstrates that long periods of post-fire rest may not be necessary for forage recovery in the mixed-grass Prairie.

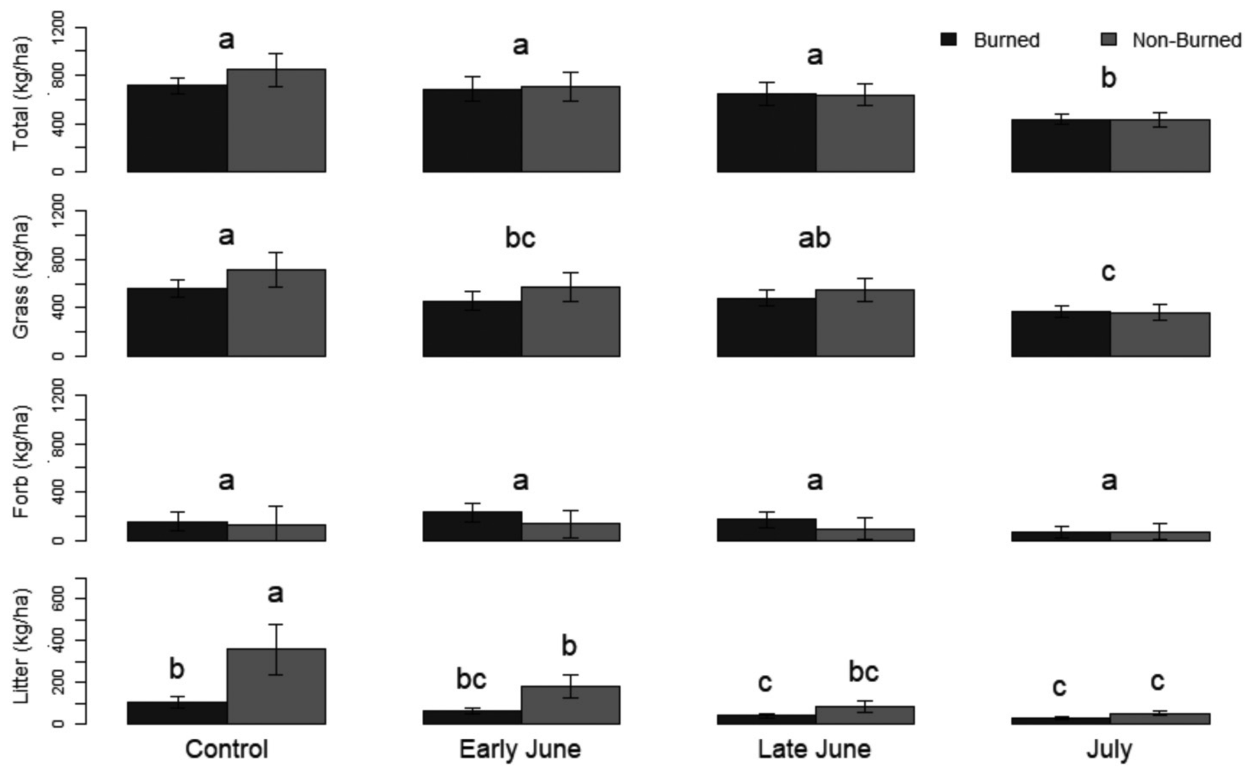
Despite this, the timing of post-fire defoliation affected peak forage biomass in 2019 (Table 1). Total biomass was lowest when defoliated in July 2018, while the non-clipped control and June defoliations were equivalent (Fig. 1). Grass biomass was also the lowest following July defoliation, and greatest in the control, with June defoliations intermediate (Fig. 1). Forb biomass was not significantly affected by defoliation timing, but it was lowest following July defoliation (Fig. 1). These results indicate that intense defoliation (2 cm stubble height) at peak biomass, in July, can decrease plant vigour and associated forage growth in the mixed-grass Prairie. This may be a concern because our July defoliation treatment coincided with the recommended grazing period for native grasses in this region; however, early season grazing is not recommended for native grasslands in moisture limited environments because plants are susceptible to overgrazing (Bailey et al. 2010). Notably, defoliation effects in our study were assessed through a fixed defoliation height (2 cm) and the relative stress imposed on plants at various times may not have been equivalent. Less biomass was removed from plants defoliated in June compared to July, which may impose less relative impact on subsequent regrowth (Bogen et al. 2003). Additionally, clipping by hand is not a direct substitute for livestock grazing and caution should be exercised when extrapolating these results to grazing livestock. Animals can affect vegetation through other effects including defoliation frequency and intensity, forage selectivity, grazing season, and trampling. However, a recent comparison of grazing and mowing (similar to clipping) concluded that the difference in effect sizes between these treatments remains small (Tälle et al. 2016). Although our July defoliation reduced subsequent forage productivity, more biomass was removed at this time relative to the earlier defoliation treatments.

Litter mass was reduced by both the wildfire and defoliation treatments, and further affected by a marginal (p = 0.073) wildfire × defoliation interaction (Table 1). To preclude a type 2 error, we conducted a post hoc comparison on the interaction. In the absence of defoliation (non-clipped control), litter on burned subplots was 71% lower than in the non-burned, while defoliation further reduced litter mass (Fig. 1). Additionally, later defoliation reduced litter to a greater extent in the second year. The inhibitory effect of defoliation on litter accumulation is an important post-fire management consideration for producers. Litter is beneficial for mixed-grass Prairie forage productivity (Willms et al. 1986), and litter loss may be particularly detrimental when water is limiting, such as during drought.

Summary

By the second year after this mixed-grass Prairie wildfire, our experiment showed total forage productivity did not differ between burned and non-burned areas, while July defoliation reduced total forage biomass, which could be explained by defoliation removing more biomass in July compared to earlier defoliation periods. Defoliation earlier in the year (June) had no effect on total forage biomass, which suggests that rest following wildfire may not be necessary even with below-average rainfall; however, these plots had more within-season recovery time and forage availability, as well as plant regrowth potential must be considered following burn events. Importantly, the height of defoliation (2 cm stubble height) used in this experiment is considered extreme and not recommended in these grasslands, but likely contributed to the slow litter accumulation and highlights the resilience of plant growth in this experiment. Furthermore, our study did not quantify the direct impacts of selective livestock grazing. Our results imply that heavy grazing use has a greater negative impact on plant productivity and litter than fire. The more critical finding of our study may be the additional reduction in litter mass with defoliation after wildfire. As litter can increase forage productivity by enhancing soil moisture, post-fire management should allow litter to ac-

Fig. 1. Total, grass, forb, and litter mass kg/ha (mean ± SE) collected in July 2019, following the 2018 defoliation treatment in burned and non-burned mixed-grass Prairie. There was no difference between burned and non-burned subplots for any live forage response (Table 1), therefore the letters compare only the timing of defoliation. Litter mass showed a difference between burned and non-burned treatments, and letters compare the whole interaction (Note: to illustrate differences between treatments, the litter mass scale is different than total, grass, or forb). Bars sharing the same letters do not differ (Tukey HSD test, $p < 0.05$).



cumulate for the long-term maintenance and sustainability of forage resources. However, this may need to be weighed against the management of fire risk created by greater litter amounts.

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Author contributions

The authors responsibilities were as follows—BKB, EWB, and CNC designed the research, and wrote and edited the manuscript; BKB and CNC analyzed data; BKB conducted the research and was responsible for the final manuscript content; BKB, EWB, and CNC read and approved the final manuscript.

Competing interests

The authors declare there are no competing interests.

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References

Bailey, A.W., McCartney, D., and Schellenberg, M.P. 2010. Management of Canadian Prairie Rangeland. Agriculture and Agri-Food Canada, Cat. No. A52-178/2010E.

Bogen, A.D., Bork, E.W., and Willms, W.D. 2003. Defoliation impacts on *Festuca campestris* (Rydb.) plants exposed to wildfire. J. Range Manage. **59**: 375–381.doi: 10.2307/4004042

Brockway, D.G., Gatewood, R.G., and Paris, R.B. 2002. Restoring fire as an ecological process in shortgrass prairie ecosystems: initial effects of prescribed burning during the dormant and growing seasons. J. Environ. Manage. **65**: 135–152.doi: 10.1006/jema.2002.0540PMID: 12197076

Bureau of Land Management. 2007. H-1742-1 burned area emergency stabilization and rehabilitation handbook. Department of the Interior, Washington, DC, USA.

Dufek, N.A., Vermiere, L.T., Waterman, R.C., and Ganguli, A.C. 2014. Fire and nitrogen addition increase forage quality of *Aristida purpurea*. Rangel. Ecol. Manag. **67**: 298–306.doi: 10.2111/REM-D-13-00057.1

Erichsen-Arychuk, C., Bork, E.W., and Bailey, A.W. 2002. Northern dry mixed prairie responses to summer wildfire and drought. J. Range Manage. **55**: 164–170.doi: 10.2307/4003352

Fuhlendorf, S.D., Engle, D.M., Kerby, J., and Hamilton, R. 2009. Pyric-herbivory: rewilding landscapes through the recoupling of fire and grazing. Conserv. Biol. **23**: 588–598.doi: 10.1111/j.1523-1739.2008.01139.xPMID: 19183203

Gates, E.A., Vermiere, L.T., Marlow, C.B., and Waterman, R.C. 2017. Fire and season of postfire defoliation effects on biomass, composition, and cover in mixed-grass prairie. Rangel. Ecol. Manag. **70**: 430–436.doi: 10.1016/j.rama.2017.01.009

Government of Alberta. 2018. Post-fire assessment protocol for rangelands. In press.

Government of Alberta. 2020. Current and historical Alberta weather station data viewer. Available from https://acis.alberta.ca/weather-data-viewer.jsp. [Accessed December, 2020].

Natural Regions Committee. 2006. Natural regions and subregions of Alberta. Compiled byDowning, D.J., and Pettapiece, W.W. Government of Alberta. Pub. No. T/852.

Tälle, M., Deák, B., Poschlod, P., Valkó, O., Westerberg, L., and Milberg, P. 2016. Grazing vs. mowing: a meta-analysis of biodiversity benefits for grassland management. Agric. Ecosyst. Environ. **222**: 200–212.doi: 10.1016/j.agee.2016.02.008

Vermiere, L.T., Crowder, J.L., and Wester, D.B. 2014. Semiarid rangeland is resilient to summer fire and postfire grazing utilization. Rangel. Ecol. Manag. **67**: 52–60.doi: 10.2111/REM-D-13-00007.1

Willms, W.D., Smoliak, S., and Bailey, A.W. 1986. Herbage production following litter removal on Alberta native grasslands. J. Range Manage., **39**: 536–540.doi: 10.2307/3898766

Wright, H.A., and Bailey, A.W. 1982. Fire ecology: United States and Southern Canada. John Wiley and Sons, Inc., Toronto, ON. pp. 501.