Improving Pasture Productivity and Persistence by Renovating or Rejuvenating

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Abstract
Forages make up a large part of the feed requirements of beef cattle, and grazing remains the most economical form of feed delivery. However, several years after pasture establishment, forage productivity and longevity usually decline. Maintaining productive forage stands in the long term becomes a major challenge that beef producers face. A 3-yr on-farm study was conducted to determine the comparative effects of several pasture rejuvenation methods, such as spraying of herbicides to control weeds and brush, Spray herbicide + direct seed in spring (RSS), forage seeding methods, fertilizer application (FERT), and pasture rest as well as aeration/spiking in fall (AF) and aeration/spiking in spring (AS) on forage dry matter (DM) yield and forage quality. Breaking & reseeding (B&R), which is a grassland renovation method, was compared to these four pasture rejuvenation methods. A no treatment method (control) was included for comparison. Three years after treatments were implemented, pasture rejuvenation methods did significantly affect ($P<0.05$) grass botanical composition but did not significantly influence ($P>0.05$) total DM yield and legume botanical composition. The only method that involved land cultivation and reseeding (B&R) showed higher total input costs than other methods. Overall, RSS as well as AS, AF and FERT had greater 2-year total forage production, revenue and returns, and profit over control than the other treatment methods.

Introduction
Years after establishment, the productivity, quality and longevity of pastures usually declines as a result of reduced plant stand vigor and loss of productive forage species. This is mostly a consequence of seasonal drought, pests, weeds, brush invasion and overgrazing in pastures. Controlling weeds and brush in pastures will restore pasture health and productivity, and improve and sustain forage quality (Bradley and Kendig, 2004). Rejuvenation can be a pasture management strategy for rapid improvement of existing and/or depleted forage stand/pasture that can bring new vigor or usefulness to a pasture and thereby restore it to its original state. Breaking and reseeding old forage stands is the traditional method of pasture rejuvenation, but this can be a complex and costly challenge, as well as time consuming for producers (Omokanye et al., 2018). The high costs associated with the traditional method has encouraged livestock producers to search for alternative strategies and technologies for improving and sustaining pastures. In western Canada, several methods of rejuvenation have been investigated for the purpose of increasing pasture and livestock production and these include: grazing management during growing season), bale grazing during winter season, fertilizer application, direct seeding of legumes into an existing pasture and pasture resting (Durunna et al., 2015; Jungnitsch et al., 2011; Kemp et al. 2000; Khatiwada, 2018; Lardner et al., 2000; Omokanye et al., 2018). However, most of these studies have only examined a few methods at a time. The objective of this study was to investigate several methods of pasture rejuvenation at the same time to enable a proper assessment of different methods on-farm.

Methods and Study Site
From 2016 to 2018, an on-farm study was conducted at Oyen (51°21′N, 110°28′W; 770 m), Alberta Canada. The initial (before treatments) surface soil (0-15 cm) characteristics showed a pH of 6.4, an organic matter of 1.4% and an electrical conductivity of 0.16 dS/m. Soil texture was sandy loam. The soil group/natural sub-region is brown chernozemics/dry mixed grass. The site has a subarctic climate (also called boreal climate), which is characterized by long, usually very cold winters, and short, cool to mild summers. The pasture had been established for over 15 years before the study and consisted of tame hayland: [mainly: bromegrasses (*Bromus biebersteinii*), alfalfa (*Medicago sativa*) and June grass (*Koeleria macrantha*), Frobes: Dandelion (*Taraxacum officinale*), Yarrow (*Achillea millefolium*).

The treatments were arranged in a randomized complete block design with 3 replications. The following 10 pasture rejuvenation methods were investigated:

1. Check (control): No treatment was done.
2. Summer rest (REST): Pasture rest in 2016 only.
3. Broadcast seed + aerate/spike in spring (BSAS): Seeded at 12.35 kg/ha on June 21, 2016
4. Broadcast seed + aerate/spike in fall (BSAF): Seeded at 12.35 kg/ha on October 27, 2016
5. Aerate/spike in fall (AF): October 27, 2016.
6. Aerate/spike in spring (AS): June 22, 2016
7. Spray Grazon™ herbicide + seed in spring (GRSEED): Sprayed Grazon™ at 3.7 L/ha on June 8, 2016 and seeded at 12.35 kg/ha on June 22, 2018
8. Fertilizer application (FERT), kg/ha: Broadcast 112 lb/ha N on June 20, 2016
9. Spray herbicide + direct seed in spring (RSS): Sprayed Roundup at 4.9 L/ha on June 8, 2016 and seeded forage at 12.35 kg/ha on June 21, 2018.
10. Complete renovation method (B & R): Double disced and rototilled June 13, 2016. Rototilled again June 20 and seeded forage mixture at 12.35 kg/ha on June 22, 2016

Plot size was 30 m x 30 m (0.09 ha). The forage seed mixture used consisted of 40% coated MB-A meadow bromegrass (*Bromus riparius*), 16% AC Grazeland alfalfa (*Medicago sativa*), 8% Dahurian wildrye grass (*Elymus dahuricus*), 7% slender wheatgrass (*Elymus trachycaulus*), 15% Kirk crested wheatgrass (*Agropyron cristatum*) and 15% Duramax tall fescue (*Festuca arundi nacea*). Direct seeding was done with a custom seed drill, 1.4 m in width with 0.28 m row spacing center to center paired rows 0.08 m apart and broadcast seeding was done with a Frontier, 3-point hitch mounted spinner spreader.

Forage botanical composition (% grass and % legume) and forage dry matter yield were determined from a target area within a plot on done on July 6, 2016; July 11, 2017 and July 13, 2018. The forage quality parameters (% DM bases) were determined in a commercial laboratory (A&L Canada Laboratories Inc.) using standard laboratory procedures for wet chemistry and near infrared reflectance spectroscopy (or NIRS).

Direct input costs and output revenue (forage DM yield multiply by hay price) were used to determine returns/ha. Hay price used was CAD $180/t of forage DM yield. Marginal returns was calculated as: revenue minus total input costs. Profit/loss over control was calculated as: marginal returns for a particular treatment minus marginal returns for control. Capital items including land costs and paid capital interest were not used for the partial budget analysis in this study.

For the data analysis (GenStat statistical package (2009, 12thEdition), where ANOVA indicated significant treatment effects, the means were separated by the least significant difference (LSD) at the 0.05 probability level. Significant differences in the text refer to $P<0.05$.

Results and Discussion

Botanical Composition and Forage Yield

In both 2017 and 2018, GRSEED recorded the highest amount of grasses than other methods (Table 1). In 2017, RSS, AF and BSAF showed significantly higher % legume than other methods. In 2018, BSAS showed some slight improvement in the amount of legumes present in the forage stands over the respective previous years.

In the year following treatments (2017), forage DM yield appeared to be far lower for AF and BSAS than their respective previous year forage DM yields (2016) (Table 9). In 2017, the control had significantly ($P<0.05$) higher yield than all pasture rejuvenation methods investigated.

In the present study, no methods seemed to have any significant effects on total forge production than control. In 2018, the total rainfall from April-September was 164.8, 77.9 and 92.3 mm lower than 2016, 2017 and long-term average respectively. April-September of 2016-2018 appeared to be warmer than long-term average maximum temperatures, but April-September were much colder than long-term minimum temperatures (data not provided). The differences in weather observed particularly in 2017 and 2018 were thought to be responsible for the lack of any significant effect on forage production. The high sand component of the soil at study site would have compounded the effect of low precipitation due to the low water holding capacity of sand.

Though weather was thought to have contributed to the lack of any significant forage DM yield improvement in the present study, other earlier reports have shown that some of the methods investigated here did not greatly improve pasture production as well. For instance, Lardner et al. (2000) found that aeration reduced forage DM yield at two sites, but had no effect at three other sites in the year following treatment. The effect of spiking showed only slightly greater increases in forage DM yield over the control in years 1 and 2, across all sites. Malhi et al. (2000) indicated that mechanical aeration was not consistently beneficial for pasture rejuvenation. The effects of applied dry fertilizer may only last for 2-3 years (Omokanye et al., 2018, b; Lardner et al 2000). Omokanye et al. (2018) did not observe significant improvements in forage DM yield following resting a pasture for a year.

Table 1. Forage dry matter (DM) yields and forage botanical composition from 2016-2018 for different methods.

Method	Forage DM yield (kg ha^{-1})			Forage composition (%)					
				2016		2017		2018	
	2016	2017	2018	Grass	Legume	Grass	Legume	Grass	Legume
Control	3345^{d†}	3574^{a}	3248^{a}	54.9^{f}	45.1^{d}	76.6^{h}	23.4^{bc}	73.2^{b}	26.8^{a}
AF	3936^{b}	2503^{e}	3572^{a}	47.3^{h}	52.7^{b}	66.5^{j}	33.5^{a}	66.9^{bcd}	33.1^{a}
AS	2669^{g}	2115^{j}	3564^{a}	51.7^{g}	48.3^{c}	78.2^{g}	21.8^{c}	67.1^{bcd}	32.8^{a}
B&R	NA‡	1798^{k}	3440^{a}	NA	NA	81.9^{e}	18.1^{cd}	72.5^{bc}	27.5^{a}
BSAF	5733^{a}	2317^{h}	3327^{a}	86.2^{a}	13.8^{i}	65.4^{k}	34.6^{a}	59.5^{cd}	40.4^{a}
BSAS	1413^{i}	1762^{l}	3327^{a}	62.7^{c}	37.3^{g}	79.8^{f}	20.2^{c}	62.7^{bcd}	37.3^{a}
FERT	2754^{f}	2585^{c}	3049^{a}	62.1^{d}	37.9^{f}	84.9^{c}	15.1^{d}	63.4^{bcd}	36.6^{a}
GRSEED	NA	2584^{d}	2716^{a}	NA	NA	100^{a}		100.0^{a}	
REST	2789^{e}	2430^{f}	3351^{a}	45.1^{i}	54.9^{a}	72.8^{i}	27.2^{b}	56.9^{d}	43.0^{a}
RSS	NA	2416^{f}	3770^{a}	NA	NA	61.8l	38.2^{a}	72.4^{bc}	27.6^{a}

‡NA, not available because treatments had been sprayed out before forage harvest.
† Means within a particular column followed by different superscripts differ significantly (P<0.05).

Forage Nutritive value

Of the several forage nutritive value parameters measured, only forage crude protein (CP) and Mg were significantly affected (P<0.05) by pasture rejuvenation methods investigated. In 2018, REST had significantly higher forage CP (except for AS) than other methods. The control was mostly in the bottom 2 for forage CP (data not provided). In 2018, BSAF showed significantly higher forage Mg content than other pasture methods (except for AS, BSAS and FERT). REST had the lowest forage Mg content (data not provided).

Partial budget analysis

For both production years combined (2nd and 3rd years after treatments), total forage production varied from 5084 kg ha^{-1} for BSAS to 6815 kg ha^{-1} for control (Table 2). The revenue was highest for control (CAD $1232/ha). Most of the methods had > CAD $1000/ha in revenue. The 2 methods that involved land cultivation and reseeding (B&R) had higher total costs than other methods. Both AF and AS had the least total costs with only CAD $20/ha. The returns were generally positive for all methods with the control recording the highest of CAD $1232/ha, while B&R had the lowest with CAD $593/ha. Apart from the control, only 3 of the actual treatment methods (AF, AS and REST) had a returns > CAD $1000/ha. The profit over control for each method were all negative. The greatest loss was B&R, followed by GRSEED, BSAS and BSAF in that order with > CAD $400/ha in loss. The lack of any profits from any methods over control was because control consistently produced comparable forage DM yield in 2017 and 2018 with methods investigated. In addition to the comparable forage DM yield, the control did not incur any input costs, so it had a higher marginal returns over the combined 2 years of forage production. Again, the weather during the study period, particularly in 2017 and 2018, was thought to be responsible for the non-apparent effects of investigated methods.

Conclusions

A good pasture is critical to beef cattle production systems, but maintaining productive forage stands years after pasture establishment is a major challenge that beef producers face in Alberta, Canada. Instead of replacing a pasture, rejuvenation can be a pasture management strategy that can bring new vigor or usefulness to a pasture and thereby restoring it to its original state. Three years after treatments, pasture rejuvenation methods did significantly affect the amount of grasses in total forage production but did not significantly influence total DM yield and amount of legumes in the total forage production. The 4 methods which had aeration reduced forage production in the year following the aeration treatments. Weather condition was thought to be responsible for the different forage yield pattern following aeration. The only method that involved land cultivation and reseeding (B&R) had higher total costs than other methods. The returns were generally positive for all methods with the control recording the highest (CAD $1232/ha), while B&R had the lowest with CAD $593/ha.

Table 2. Summary of economic comparisons of pasture rejuvenation methods for 2 years' forage production combined (2017 & 2018).

Method	Total DM yield (kg ha^{-1})	Revenue	Total costs	Marginal returns $/2 years/ha	Profit/Loss over control
Control	6815	1232		1232	
AF	6069	1098	20	1078	-154
AS	5674	1026	20	1006	-226
B&R	5233	946	353	593	-639
BSAF	5639	1020	210	810	-422
BSAS	5084	919	210	710	-522
FERT	5629	1018	173	845	-387
GRSEED	5295	958	271	687	-545
REST	5775	1044		1044	-188
RSS	6180	1118	236	882	-350

Note: This is only a simple cost analysis and is not intended as an in depth study of the cost of production. CAD $1=US $0.76.

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