Impacts of Bale Grazing on Herbage Production, Forage Quality and Soil Health in South-central North Dakota

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This project examines the effect of winter hay bale-grazing on subsequent years' herbage production and nutritional quality six and 18 months after treatment. Parameters measured included herbage production, nutritional quality, soil nutrient content, cow body condition and system costs.

Summary

The effect of bale grazing on grass production six months and 18 months after treatment varied, based on ranch site location, from our demonstration trials conducted in 2015 through 2017. The overriding variables that appear to affect grass production are distance between bales and stocking rate intensity (density and duration of time).

Grass production was greater on the bale-grazed treatment, compared with the control treatment (no bales on site) 15 feet from the bale center; however, no difference was found within the zone 0 to 10 feet from the bale center six months after treatment. However, grass production was greater on the bale-grazed treatment, compare with control 0, 5 and 10 feet from bale center 18 months after treatment.

Bale grazing enhanced grass crude protein and phosphorus content six months after treatment from bale center out to 10 feet. Although bale grazing did not enhance total grass biomass production from within the 0- to 10-feet zone from the bale center, it increased grass crude protein content within this zone. Bale grazing increased grass phosphorus content within the 0- to 5-feet zone of the bale center.

Soil nitrates, phosphorus and potassium at the 0- to 6-inch soil profile increased on the bale-grazed treatment at all distances from the bale edge six to nine months after treatment with no increase on the control sites. The percentage of organic matter at the same soil depth increased up to 1.4-fold at the bale-grazed sites, compared with the control sites.

Our field trials demonstrated that the added urine, feces and hay waste within the 10-feet zone of the bale center did not impact grass production (no benefits or negative effects) six months after treatment; however, it did increase grass production 18 months after treatment.

Grass nutritional content was improved within the 10-feet zone of the bale center six months after treatment, enhancing forage quality. Herbage within the 5-feet zone of the bale center also had enhanced phosphorus content, a direct result from the added urine and feces. This additional phosphorus is beneficial in meeting the requirements of grazing livestock, as well as removing excess phosphorus from the soil. Soil nutrient parameters were enhanced significantly at the bale-grazed sites at the 0- to 6-inch soil profile from bale edge out to 12.5 feet, when compared with the control.

Introduction

Bale grazing is the practice of allowing livestock access to hay bales in a hayfield or improved pasture to reduce labor and feed delivery costs (Lardner et al., 2008). Livestock growers in the northern Great Plains practicing this technique also are interested in improving soil health and forage production through manure distribution while maintaining adequate livestock performance. Recently published data have shown a positive relationship between bale grazing and nitrogen capture, as well as forage growth (Jungnitsch et al., 2010; Kelln et al., 2012); however, local producer concerns in our region prompted the need for further applied research.

This project was conducted on four ranches in North Dakota to examine winter hay bale-grazing effects on subsequent years' herbage production and nutritional quality six and 18 months after treatment. Parameters measured included herbage production, nutritional quality, soil nutrient content, cow body condition and system costs.

Because bale grazing introduces higher nitrogen and phosphorus into a system, bale grazing on native pastures is not recommended. Therefore, this project was conducted on improved pastures planted to domesticated cool-season grasses. Herbage production, nutritional quality and soil nutrient content are presented in this report.

Methods and Design

Four ranches were selected on different ecological sites - claypan, thin loamy, loamy and shallow gravel - from south-central North Dakota. Sites consisted of improved, cool-season grass pastures/ hay. Three of the sites had not been bale grazed.

Four bales of similar hay type were selected randomly per ranch to represent bale grazing (BG) treatment in September 2015. Bale grazing on all sites occurred from January through March 2016. Four control sites without bales (C) were selected systematically on the same soil series, slope and plant community directly outside the bale-grazed area and sampled using the same protocol as the bale-graze sites (See Figures 1 and 2).

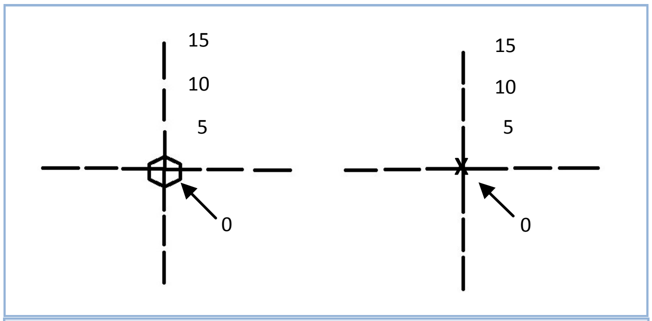

Figure 1. Example of collection locations from bale center and control center, 5, 10 and 15 feet from center for herbage production and soil nutrient content.

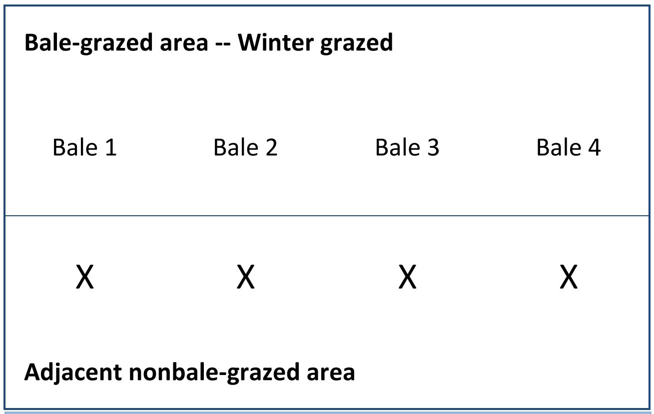

Figure 2. Example of bale-grazed study area showing a smooth brome grass pasture split into bale grazing treatment and the parallel nonbale grazing treatment (control), with "X" representing a corresponding sample location.

Herbage production was collected during peak production for cool-season grasses in North Dakota and before summer grazing occurred. Vegetation was clipped for biomass in late June or early July at four distance points (0, 5, 10, 15 feet) along each cardinal direction (16 total plots) from the bale center after cattle had grazed the bales in 2016 (Figure 1).

Grasses and forbs were separated and composited by plant form from all cardinal directions per bale distance point (four composited samples per bale distance). Hay residue was sampled at the same points and similarly composited to determine waste post-grazing, and to test for a possible relationship with herbage regrowth and quality.

Herbage samples were weighed, oven-dried at 65° C for 72 hours and reweighed for moisture content. Wet chemistry nutritional analysis on the grass component was conducted at the North Dakota State University Animal Science Nutrition Laboratory. Analysis included crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), ash, calcium (Ca), magnesium (Mg) and phosphorus (P).

Soil samples were collected pre-treatment in September 2015, and 12 and 24 months later in 2016 and 2017. Soil cores were collected at 0 to 6-inch depths from the same four bale treatment sites and four bale control sites that were used for herbage production. Soil parameters collected included penetrometer (compaction), electrical conductivity, Haney soil health calculation, nitrate, phosphorus, potassium, pH and organic matter.

Results and Discussion

Herbage Production

We found no difference ($P > 0.1$) in total grass biomass production among samples from the bale center, and 5 and 10 feet from the bale center on hay/pastureland that was bale grazed or on similar control hay/pastureland sites six months after treatment. However, bale grazing enhanced ($P \leq 0.1$) grass production 15 feet from the bale center (Table 1). In contrast to six months after treatment, grass production was greater at the bale center, and 5 and 10 feet from the bale center, compared with 15 feet from the bale center and the control hay/pasture sites 18 months after treatment (Table 1).

Table 1. Grass production at the bale's center, and 5, 10 and 15 feet from bale center on winter-grazed bales versus no winter grazing six months after treatment (collected late June/ early July at peak production) in south-central and central North Dakota in 2016 and 2017.

Treatment	Bale center	5 ft. from center	10 ft. from center	15 ft. from center
	lb/acre grass in 2016[1]			
Bale grazed	5,274[a]	5,320[a]	4,613[a]	8,604[b]
Control	5,358[a]	5,823[a]	5,888[a]	6,160[a]
	lb/acre grass in 2017[1]			
Bale grazed	3,114[a]	2,611[a]	2,413[ab]	1,848[b]
Control	1,553[b]	1,405[b]	1,383[b]	1,154[b]

[1] Grass production by treatment and distances from bale within years with the same letter (a, b) are not significantly different ($P > 0.1$).

When bales were placed close together (less than 15 feet), as seen at the Napoleon study site, the bale-grazed site produced from 21 to 172 percent less grass production, depending on distance from the bale, than the control site six months after treatment. However, 18 months after treatment, the bale-grazed site produced 37 to 73 percent greater grass production, with the percentage increase greatest at the furthest distance from bale (Table 2).

Because of the close bale spacing, manure and waste are naturally more prominent, as seen in the high residue levels, negatively impacting grass production the first year following treatment but

Table 2. Grass production and hay residue remaining six months after treatment at different distances from the bale when bales were grazed in early winter (January-March) in south-central North Dakota in 2016.

Location	Bale distance average (ft.)	Parameter	Bale center	5 ft. from center	10 ft. from center	15 ft. from center
			lb/acre in 2016			
Tuttle	25 to 30	Residue from bale	28.5	16.0	7.1	NC[1]
		Bale-grazed production	2,860	3,620	5,083	NC
		Control production	3,103	3,740	6,779	NC
			lb/acre in 2017			
		Bale-grazed production	1,766	2,485	1,992	1,558
		Control production	958	1,575	1,456	1,467
			lb/acre in 2016			
Wing	10 to 50[2]	Residue from bale	18.7	36.5	44.6	14.2
		Bale-grazed production	9,196	10,749	3,202	9,604
		Control production	5,695	8,423	5,789	6,125
			lb/acre in 2016			
Napoleon	15	Residue from bale	87.2	140.6	79.2	71.2
		Bale-grazed production	5,587	3,366	2,727	7,199
		Control production	8,775	7,865	7,432	8,679
			lb/acre in 2017			
		Bale-grazed production	3,379	2,569	3,029	2,422
		Control production	2,466	1,736	1,918	1,400
			lb/acre in 2016			
Fort Rice	50	Residue from bale	69.0	71.2	9.8	11.6
		Bale-grazed production	3,454	3,544	7,440	9,009
		Control production	3,859	3,264	3,551	3,677
			lb/acre in 2017			
		Bale-grazed production	4,196	2,779	2,269	1,563
		Control production	1,232	880	752	538

[1] NC = Not collected

[2] Spread unevenly throughout the field

positively impacting production the second year following treatment (Table 2). Plus, stock density may have been lower than recommended, leaving a high level of residue on the ground the first year following treatment, especially within 5 feet of the bale.

When bales were placed 50 feet apart at the Fort Rice study site, bale grazing had no effect on grass production up to 5 feet away from the bale center within six months of treatment (Table 2). However, bale grazing increased grass production by 109 to 145 percent at 10 and 15 feet from the bale center, respectively. At 18 months after treatment, the bale-grazed sites produced 190 to 241 percent more grass production, with the greatest increase closest to the bale.

This open spacing pattern reduces selection; more evenly distributes cattle and leaves fewer residues if cattle are forced to clean up the hay. This spacing causes higher levels of residue close to the bales but distributes manure more evenly away from the bales, helping explain the bale grazing's positive effect on grass production.

When the bales were placed 25 to 30 feet apart at the Tuttle study site, we found no difference between the bale-grazed sites and control sites six months after treatment (Table 2). Herbage production 10 feet away from the bale showed trends toward higher herbage production on the bale-grazed site, but without data from the 15-foot location, we were unable to determine if this production trend would continue to increase. At 18 months after treatment, bale grazing increased grass production by 6 to 84 percent, with the greatest increase closest to the bale (similar to the Fort Rice study site).

The Wing study site was the only location to show increased herbage production from bale grazing within the first 5 feet around the bale, with an increase of 28 to 61 percent. This site also showed a reduction in herbage production at 10 feet from the bale, that area with the greatest level of residue on the ground (Table 2). However, where residue was low, as seen at 15 feet away from the bale, the bale-grazing site had an increased herbage production of 56 percent.

This study site had bales spread irregularly, ranging from 10 to 50 feet. This uneven distribution of bales may have created uneven feeding patterns and increased the pecking order, creating these positive and negative impacts due to bale grazing within the same unit. No data were collected 18 months after treatment due to cattle grazing the site in May and June.

Forage Quality

Our demonstration trials exhibited that bale grazing increases ($P \leq 0.1$) crude protein content of the grass portion of the vegetation six months after treatment (late June/early July) at the bale center out to 10 feet (Table 3). Grass crude protein content was greater ($P \leq 0.1$) than the control at the bale center, and 5 and 10 feet from the bale but not ($P > 0.1$) at 15 feet from the bale center.

These findings indicate that benefits from bale grazing occur throughout the zone within 10 feet of the bales. This benefit is a result of added nitrogen from urine and fecal material, concentrated within this 10-feet zone.

Table 3. Grass quality parameters at the bale center, and 5, 10 and 15 feet from the bale center on winter-grazed bales versus no winter grazing in south-central and central North Dakota in 2016 six months after treatment (collected late June/early July at peak production).

Treatment	Bale center	5 ft. from center	10 ft. from center	15 ft. from center
	Crude protein (%) content[1]			
Bale grazed	17.2^{ax}	17.3^{ax}	15.9^{ax}	13.0^{bx}
Control	9.8^{ay}	9.8^{ay}	10.2^{ay}	10.9^{ax}
	Phosphorus (%) content[1]			
Bale grazed	0.30^{ax}	0.30^{ax}	0.27^{ax}	0.27^{ax}
Control	0.23^{ay}	0.23^{ay}	0.22^{ax}	0.24^{ax}
	Calcium (%) content[2]			
Bale grazed	0.48	0.44	0.41	0.38
Control	0.41	0.42	0.39	0.39
	Neutral detergent fiber (%) content[2]			
Bale grazed	61.7	60.9	62.4	64.4
Control	64.2	64.4	63.7	64.1
	Acid detergent fiber (%) content[2]			
Bale grazed	34.2	33.4	33.7	35.2
Control	33.9	34.7	33.7	34.1

[1] Nutritional parameters by treatment and distances from bale with the same letter (a, b) within row (treatment) are not significantly different ($P > 0.1$), and with same letter (x, y) within columns (between treatments) are not significantly different ($P > 0.1$).

[2] No differences ($P > 0.1$) were found among treatments or distances.

Grass phosphorus content was not ($P > 0.1$) different among bale treatment distances or control distances (Table 3). However, the bale-grazing treatment increased ($P \leq 0.1$) grass phosphorus content when compared with the control at the bale center and 5 feet from the bale center six months after treatment (Table 3).

No differences ($P > 0.1$) in neutral detergent fiber (NDF), acid detergent fiber (ADF) or calcium content of the grass component were found between the bale-grazed and control sites six months after treatment (Table 3). Within our demonstration trials, bale grazing had no effect on NDF, ADF or calcium content within the 15-feet zone six months after treatment.

Soil Nutrient Content

Nitrates (NO_3-N) increased 4.4- to 7.6-fold, depending on distance from bale edge, on the bale-grazed treatment six to nine months after treatment at the 0- to 6-inch soil profile; however, they declined to similar pre-treatment levels 18 to 21 months after treatment (Table 4). In contrast, NO_3N declined each year, with a total reduction of 70 percent 18 to 21 months after treatment on the control at the same soil depth.

Phosphorus (P) increased 2- to 2.4-fold, depending on distance from bale edge, on the bale-grazed treatment six to nine months after treatment, maintaining a similar reduction 18 to 21 months after treatment at the 0- to 6-inch soil profile (Table 4). In contrast, P was similar between the post-treatment six to nine months after treatment and increased 26 percent 18 to 21 months after treatment on the control at the same soil depth.

Potassium (K) increased 2.4- to 3.1-fold, depending on distance from bale edge, on the bale-grazed treatment six to nine months after treatment, maintaining a similar reduction 18 to 21 months after treatment at the 0- to 6-inch soil profile (Table 4). Potassium increased six to nine months after treatment and 18 to 21 months after treatment.

The percentage of organic matter increased 1.3- and 1.4-fold six to nine months after treatment at the bale edge (2.5 feet from center), and 5 and 10 feet from the bale edge; respectively (Table 5). However, organic matter returned to the pre-treatment levels 18 to 21 months after treatment. Organic matter on the control site was similar across all three years of the study.

The pH level declined from 7.6 and 7.5 pre-treatment for all distances from the bale edge and control, respectively, to 7.2 and 6.8 at 18 to 21 months after treatment for all distances from the bale edge and control; respectively (Table 5). Although electrical conductivity (EC) increased at all distances from the bale edge when comparing pre-treatment to six to nine months post-

Table 4. Soil nutrient parameters at the bale edge, and 7.5 and 12.5 feet from bale center, and the control in the 0- to 6-inch profile on winter-grazed bales pre- and post-treatment in south-central and central North Dakota in 2015 (pre-treatment), 2016 (six to nine months post-treatment) and 2017 (18 to 21 months post-treatment).

Distance from bale edge	NO_3-N (lbs/ac)			Phosphorus (ppm)			Potassium (ppm)		
	2015	2016	2017	2015	2016	2017	2015	2016	2017
Bale edge (2.5 ft. from center)	11.4	74.0	21.0	11.3	30.0	23.9	366.7	888.9	875.9
7.5 feet from center	12.2	92.2	26.1	8.9	22.8	26.8	336.6	1,047.5	912.3
12.5 feet from center	14.8	65.6	21.9	10.1	20.7	24.8	334.5	1,007.3	881.3
Control (no bale grazing)	29.6	18.4	8.9	9.7	9.9	12.2	292.4	408.7	252.4

Table 5. Soil nutrient parameters at the bale edge, and 7.5 and 12.5 feet from bale center, and the control in the 0- to 6-inch profile on winter-grazed bales pre- and post-treatment in south-central and central North Dakota in 2015 (pre-treatment), 2016 (six to nine months post-treatment) and 2017 (18 to 21 months post-treatment).

Distance from bale edge	Organic matter (%)			pH			EC (mmhos/cm)		
	2015	2016	2017	2015	2016	2017	2015	2016	2017
Bale edge (2.5 ft. from center)	3.9	5.2	3.8	7.6	7.0	7.2	0.31	0.44	0.29
7.5 feet from center	3.9	4.9	4.2	7.6	7.0	7.2	0.35	0.48	0.31
12.5 feet from center	4.1	5.6	4.1	7.6	7.1	7.2	0.32	0.41	0.29
Control (no bale grazing)	4.2	4.6	3.8	7.5	6.9	6.8	0.29	0.19	0.19

treatment, the levels returned to pre-treatment levels 18 to 21 months after treatment (Table 5). The increased EC observed in 2016 likely would have little adverse effect on forage production.

The Haney soil health calculation increased at all distances from the bale edge and on the control from 2015 to 2016 (Table 6). The Haney soil health declined to pre-treatment levels for all distances from the bale edge and control 18 to 21 months after treatment. Because the control had a similar positive, and negative, trend, compared with the bale-grazing treatment, the increase and decrease occurred due to environment or climatic effects and not due to the bale-grazing treatment during our sampling period.

Table 6. Haney soil health calculation, pH and electrical conductivity (EC) at the bale edge, and 5 and 10 feet from bale center, and the control in the 0- to 6-inch profile on winter-grazed bales pre- and post-treatment in south-central and central North Dakota in 2015 (pre-treatment), 2016 (six to nine months post-treatment) and 2017 (18 to 21 months post-treatment).

Distance from bale center	Haney soil health calculation (range: 1 to 50+)		
	2015	2016	2017
Center	19.7	38.8	18.6
5 feet from center	19.4	37.0	18.2
10 feet from center	19.2	35.7	18.0
Control (no bale grazing)	20.5	34.6	15.5

Conclusion

The effects of bale grazing on herbage production varied by ranch location; however, the distance between bales was the variable with the most impact on production. Residue and manure appeared to be a limiting factor affecting forage production where bales were spaced at 15 feet or less.

The open spacing pattern of bales at 40 to 50 feet apart appeared to better distribute cattle and minimize hay residue. Bale grazing positively affected crude protein and phosphorus content of grass growth during the growing season following the bale-grazing treatment; however, bale-grazing treatment had no effect on acid detergent fiber, neutral detergent fiber or calcium content.

Bale grazing increased soil nitrate, phosphorus and potassium levels, irrelevant of distance from bale edge the first growing season after treatment. However, soil nitrate reduced to pre-treatment levels during the second growing season. Interestingly, the phosphorus and potassium increase was sustained during the second growing season after treatment.

Bale grazing did not change pH or improve the Haney soil health calculation during the first or second growing season following treatment. Although EC increased in the first growing season after the bale grazing treatment, the EC levels declined to pre-treatment levels in the second growing after treatment.

This project has provided insight on the impacts of bale grazing on herbage production, forage quality and soil nutrient composition when studying different scales of bale distribution and stocking densities. Bale grazing appears to be a late-season grazing strategy that creates opportunity to increase forage production and quality, enhance some soil nutrients, and eliminate the labor and fuel associated with hauling manure and feeding cattle in a feed lot.

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