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Incorporating sheep into dryland grain production systems II. Impact on changes in biomass and weed density

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Abstract

Weed control in fallow management to conserve soil moisture and nutrients is the largest variable cost to dryland grain production. Our objective was to compare burning, grazing, tilling, trampling and clipping wheat stubble fields on changes in total aboveground biomass and weed density. Treatments were evaluated in three experiments using a randomized complete block design for each experiment with four replications at each site. Contrasts statements were used to make pre-planned comparisons. For experiment 1, treatments were fall tilled, fall grazed, spring grazed, fall and spring combined (Fall/Spr) grazed, and an untreated control. For grazing treatments, five mature ewes were confined with electric fence to 111 m^2 plot for 24 h for fall and spring resulting in a stocking rate of 452 sheep day/ha. For Fall/Spr the stocking rate was 904 sheep day/ha. For experiment 2, treatments were fall grazed, fall burned, fall tilled, and an untreated control. In experiment 3, treatments were fall trampling by sheep, spring trampling by sheep, fall and spring combined (Fall/Spr) trampling by sheep, stubble hand clipped to a height of 4.5 cm, and an untreated control. Trampling treatments were applied at the same stocking rates as grazing treatments but sheep were muzzled to prevent intake. Data were collected in the fall, prior to treatment imposition, and spring, after treatments had been removed. Post treatment biomass and weed density were greater ($P < 0.05$) in either control or tilled plots when compared to grazed plots. Post treatment biomass and weed density were greater ($P < 0.01$) for control than burned plots. Post treatment biomass, weed density, and percent change in these variables, did not differ ($P > 0.08$) between burned and tilled, and burned and grazed treatments. These results indicate the potential for using grazing sheep as a component in fallow management to reduce biomass and control weeds.

Keywords: Fallow management; Weed control; Sheep grazing; Tillage; Burning; Trampling

1. Introduction

Fallow management is the single most important cultural dryland cropping practice in the semiarid regions of the western U.S. (Greb, 1981) and Northern Great Plains. In the fallow system a field is deliberately left non-cropped to conserve sufficient soil water to reduce the risk of crop failure when the next crop is planted. This type of fallow management usually includes at least one winter and one full crop season (Greb, 1981), and for the winter wheat-summer fallow rotation in Montana, fields are fallow for 14 months of each 24-month period. Fallow management is the highest variable cost in small grain production in Montana (Johnson et al., 1997). One

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of the greatest challenges for fallow management is the prevention of weed growth without increasing soil erosion (Fenster, 1997) or soil bulk density (Canillas and Salokhe, 2001).

Sheep have been used on rangeland to manage tansy ragwort (*Senecio jacobaea*; Sharrow and Mosher, 1982), leafy spurge (*Euphorbia esula*; Olson and Wallander, 1998) and spotted knapweed (*Centaurea maculosa*; Olson et al., 1997). In addition, sheep and goats have been used in developing countries to graze stubble for centuries (Owen and Kategile, 1984). Weeds typically found in summer fallow fields in the northern Great Plains can include the annuals volunteer wheat (*Triticum aestivum*), green foxtail (*Setaria viridis*), Russian thistle (*Salsola iberica*), and kochia (*Kochia scoparia*), species that can have high nutritive value for ruminant livestock (Moyer and Hironaka, 1993).

The previous article in this series documented that sheep grazing can reduce wheat stem sawfly overwintering larval numbers (Hatfield et al., 2007a). However, the use of sheep to control weeds on fallow ground has not been investigated in cereal production systems in the Northern Great Plains. Our objective was to compare burning, grazing, tilling, trampling and clipping wheat stubble fields for potential changes in total aboveground biomass and weed density.

2. Material and methods

Experiments were conducted in conjunction with two other studies published in this series (Hatfield et al., 2007a,b). In this paper, we present the effects of sheep grazing and other management strategies on change in aboveground biomass and weed density in fallow fields in the Northern Great Plains. The experiments were conducted at eight sites on four farms over 2 years. The experimental design was a complete randomized block design, replicated four times at each site. Individual plots were 9 m × 12.3 m and were the experimental unit.

Plots were sampled to determine total above ground biomass and weed density prior to treatment imposition in the fall (September and October) and following completion of treatment imposition in the spring (May). For biomass, three 0.1 m^2 sub-samples, consisting of all live and dead aboveground vegetative matter, were taken from each plot. Sub-samples were composited, labeled and returned to a laboratory where they were dried at 50 °C for 48 h and weighed. The response variables were ending plant biomass and percent change in plant biomass calculated as (ending mean/beginning mean) × 100.

Weed density was determined only in the 1st year of the trial due to severe drought and an absence of weeds in the 2nd year. Three sub-samples were taken per plot as previously described for biomass sampling. For the determination of weed density, all weeds within each of three 0.10 m^2 rings were counted. Response variables were ending weed density and percent change in density, calculated as (ending treatment mean/beginning treatment mean) × 100.

A complete description of site, soils, precipitation, each of the three experiments, and statistical analysis are presented in Hatfield et al., 2007a). Briefly, in experiment 1, treatments were fall tilled, fall grazed, spring grazed, fall and spring combined (Fall/Spr) grazed, and an untreated control. For grazing treatments, five mature ewes were confined with electric fence to 111 m^2 plot for 24 h for fall and spring resulting in a stocking rate of 452 sheep day/ha. For Fall/Spr the stocking rate was 904 sheep day/ha. For experiment 2, treatments were fall grazed, fall burned, fall tilled, and an untreated control. In experiment 3, treatments were fall trampling by sheep, spring trampling by sheep, fall and spring combined (Fall/Spr) trampling by sheep, stubble hand clipped to a height of 4.5 cm, and an untreated control. Trampling treatments were applied at the same stocking rates as grazing treatments but sheep were muzzled to prevent intake.

The study was conducted over a two-year period at four locations per year. Locations were different each year. The model included effects of site, treatment, and site by treatment interaction and the contrast statements described in Hatfield et al. (2007a). The appropriate variable (i.e., biomass for biomass analysis and weed density for weed analysis) at the beginning of each experiment was tested in each model as a covariable and included when it was a significant ($P \leq 0.05$) source of variation.

3. Results and discussion

3.1. Experiment 1

Site by treatment interactions were not detected ($P < 0.08$) for post treatment and percent change in aboveground biomass and weed density, therefore main effects of treatment are presented. Post treatment biomass and weed density were greater ($P < 0.01$) in control than grazed (fall, spring, and Fall/Spr) plots. This difference was also reflected in percent change in biomass and weed density (Table 1). Post treatment biomass and weed density were greater ($P < 0.05$) in tilled than grazed (fall, spring, and Fall/Spr) plots. However, percent change in weed density did not differ ($P = 0.19$)

Table 1
Experiment 1: post treatment biomass[a] (g/1.0 m^2) and weed density[a] (#/m^2) and percent change in biomass and weed density in control[b], tilled[c], fall, spring, and fall + spring (Fall/Spr)[d] grazed plots at eight sites[e] in Montana

	Control	Tilled	Grazed			S.E.	Control vs. grazed *P* value	Tilled vs. grazed *P* value	Fall vs. spring *P* value	Fall and spring vs. Fall/Spr *P* value
			Fall	Spring	Fall/Spr					
Biomass										
Post treatment (g/1.0 m^2)	367	199	187	165	103	15.4	0.01	0.01	0.71	0.01
Change (%)	−1	−19	−20	−22	−28	2.7	0.01	0.03	0.32	0.01
Weed										
Post treatment (#/m^2	849	76	78	20	0	16.3	0.01	0.04	0.87	0.64
Change (%)	291	−67	−68	−89	−99	11.2	0.01	0.19	0.47	0.51

[a] Site × treatment interactions were not detected (*P* 0.08).
[b] Untreated control.
[c] Shallow tillage (20 cm) was conducted within 72 h of fall grazing.
[d] Sheep grazed 111 m^2plots for 24 h (Fall/Spr = 48 h); fall and spring grazed at 452 sheep day/ha, Fall/Spr grazed at 904 sheep day/ha.
[e] Sites located in Toole, Pondera, and Stillwater counties, only four sites used for weed data.

between tilled and grazed plots. Post treatment biomass, weed density, and percent change in these variables did not differ ($P > 0.32$) between fall and spring grazed plots. Although post treatment biomass was greater ($P = 0.01$) in fall and spring grazed plots than Fall/Spr grazed plots, post treatment weed density and percent change in weed density did not differ ($P > 0.51$) between Fall/Spr and the mean of fall and spring grazed plots (Table 1).

Grazing was better than tillage in reducing biomass. Tillage is used by producers for several reasons, including (1) improving soil tilt, (2) managing weeds, and (3) incorporating plant residue and organic matter into the soil (Schjønning and Rasmussen, 2000). However, mechanical turnover of the top 20–25 cm layer of soil is costly, requiring substantial energy inputs. Tillage brings new weed seeds to the upper soil layers, increasing germination rate. Additionally, tillage kills soil fauna active in the decomposition of organic matter (Schjønning and Rasmussen, 2000). Grazing, on the other hand could be managed to achieve a specific amount of weed and stubble removal. An observation from this study was that sheep first consumed young green weedy material before consuming winter wheat stubble. With the potential to time grazing to match new, active weed growth and remove animals before excessive stubble consumption occurs, managed sheep grazing could be an effective tool to manage both crop residues and weeds while maintaining adequate ground cover to prevent soil erosion.

Weed infestations are most severe when crop competition is reduced by poor stands, drought, inadequate fertility, and/or late growth (Schillinger and Young, 2000). Poor wheat stands caused primarily by drought occurred during our study. Grazing was equal to or better than tillage for reducing weeds. Mulholland et al. (1976) evaluated cereal stubble for sheep production. They suggested cereal stubble that contained some green plant material offered an acceptable grazing resource for wethers and dry ewes at a stocking rate of 4.25 sheep/ha for 11 weeks (330 sheep day/ha). Thomas et al. (1990) found that when sheep grazed weedy barley stubble in Montana at a stocking rate of 10 sheep/ha for 6 weeks (420 sheep day/ha), the stubble was capable of supporting economic lamb production. The stocking rate for our study was 452 sheep day/ha for the fall and spring grazed treatments, similar to that used by Thomas et al. (1990). Although both of these studies were focused on sheep production rather than sheep as a tool in fallow management, they indicate the importance of green material (i.e., weeds) in stubble grazing. Given the similar stocking rates, we conclude that effective weed control by grazing sheep is within the realm of reasonable stocking rates on grain stubble used for sheep production.

3.2. Experiment 2

Site by treatment interactions were not detected ($P > 0.09$) for post treatment and percent change in biomass and post treatment weed density, therefore results are presented as the main of effect of treatment. A site by treatment interaction was detected ($P = 0.01$) for percent change in weed density. Therefore results are presented by treatment within site (Table 2).

Post treatment biomass and weed density were greater ($P < 0.01$) for control than burned plots. These differences were also reflected in percent change in biomass and weed density. Post treatment biomass, weed den-

Table 2
Eperiment 2: post treatment biomass[a] (g/1.0 m^2 and weed density[a] (#/m^2) and percent change in biomass[a] and weed density[b] in control[c], tilled[d], burned[e] and fall, grazed[f] plots at six sites[g] in Montana

	Control	Tilled	Burned	Grazed	S.E.	Burned vs. control *P* value	Burned vs. tilled *P* value	Burned vs. Grazed *P* value
Biomass								
Post treatment (g/1.0 m^2)	350	182	171	177	20	0.01	0.71	0.84
Change (%)	10	−46	−39	−49	7	0.01	0.49	0.34
Weed								
Post treatment (#/1.0 m^2)	825	70	33	98	23	0.01	0.34	0.11
Change (%)								
Site 3	394	−67	−88	−75	19	0.01	0.44	0.63
Site 4	192	−79	−89	−55	13	0.01	0.60	0.08

[a] Site × treatment interactions were not detected ($P > 0.09$).
[b] Site × treatment interaction were detected ($P = 0.01$).
[c] Untreated control.
[d] Shallow tillage (20 cm) was conducted within 72 h of fall grazing.
[e] Burning was conducted within 72 h of fall grazing.
[f] Sheep grazed 111 m^2 plots for 24 h in the fall = 452 sheep day/ha.
[g] Sites located in Toole and Pondera counties, only two sites used for weed data.

sity, and percent change in these variables, did not differ ($P > 0.08$) between burned and tilled, and burned and grazed treatments (Table 2).

Due to high soil erosion potential in Montana (NRCS, 1997) management systems that are capable of meeting targeted, specific soil residue cover amounts are important. The NRCS recommends minimum plant residue cover of 25–30% on clay loam soils to protect these soils from wind and water erosion. The guidelines for these contracts are in the Federal Register: 2 April, 1998 (volume 63, number 63) proposed rules, pages 16142–16148. In our study, fall grazed appeared equal to fall burned in their impact on biomass reduction. Although the protocol of our study required a set graz-

Table 3
Experiment 3: interaction[a] of site[e] by treatment for post treatment biomass (g/1.0 m^2) and percent change in biomass and weed density (#/1.0 m^2) and percent change in weed density at one site in control[b], clipped[c], fall, spring, and fall + spring (Fall/Spr) trampled[d] plots at sites in Montana

	Control	Clipped	Trampled			S.E.	Control vs. trampled *P* value	Clipped vs. trampled *P* value	Fall vs. spring *P* value	Fall and spring vs. Fall/Spr *P* value
			Fall	Spring	Fall/Spr					
Biomass										
Post treatment (g/1.0 m^2)										
4	512	252	467	381	378	56	0.15	0.03	0.29	0.48
8	403	323	166	204	114	55	0.01	0.02	0.64	0.29
Change (%)										
4	−7	−58	−14	−31	−34	9	0.07	0.01	0.21	0.32
8	105	69	−15	8	−43	26	0.01	0.01	0.56	0.21
Weed										
Post treatment (#/1.0 m^2)	800	750	675	825	713	67	0.43	0.87	0.13	0.65
Change (%)	192	251	160	237	186	60	0.97	0.42	0.38	0.87

[a] Site × treatment interactions were significant ($P < 0.02$).
[b] Untreated control.
[c] Entire plot was clipped in the fall to a 4.5 cm stubble height; conducted within 72 h of fall trampling treatments.
[d] All sheep were muzzled while occupying a 111 m^2 plots for 24 h (Fall/Spr = 48 h); fall and spring = 452 sheep day/ha, Fall/Spr = 904 sheep day/ha.
[e] Sites located in Pondera and Toole counties, for weed data only one site located Pondera county.

ing time and duration, we speculate that grazing can be more compatible with NRCS regulations than burning because of opportunities through manipulating intensity and duration of grazing to regulate the amount of biomass removed. We also speculate that under managed grazing, grazing young, green weeds when they are most attractive to sheep, and potentially most susceptible to damage via excessive grazing pressure, sheep can become an important tool in fallow management.

3.3. Experiment 3

Site by treatment interactions were detected ($P < 0.02$) for post treatment biomass and percent change in biomass, therefore results are presented by treatment within site (Table 3).

Post treatment biomass was greater ($P = 0.01$) for control than trampled (fal, spring, and Fal/Spr) at Site 8, but did not differ ($P = 0.15$) at Site 4 (Table 3). Percent change in biomass tended to differed ($P < 0.07$) between control and trampled treatments, with the decrease in biomass being greater for trampled than control at Site 4 and an increase in biomass in control compared to a decrease in biomass in trampled plots at Site 8. Post treatment biomass and percent change in biomass did not differ ($P > 0.21$) between fall and spring trampled and Fall/Spr trampled plots (Table 3). Differences were not detected ($P > 0.13$) for post treatment biomass or percent change in weed density for experiment 3 (Table 3).

4. Conclusions

Weed control in summer fallow is essential for conserving soil moisture and nutrients. Historically, tillage has been the principal method of weed control in summer fallow in the Northern Great Plains, but sufficient soil residue cover must be maintained to prevent soil erosion due to wind or water action. Chemical fallow is rapidly replacing mechanical fallow, but it is even more costly than mechanical fallow (tillage). Sheep grazing resulted in similar decreases in aboveground biomass compared to conservation tillage, which typically can provide sufficient residues to protect the soil resource. Both tillage and sheep grazing resulted in decreased biomass compared to untreated controls. Grazing reduced weed density similar to tillage. Both management practices decreased weed density compared to untreated controls. The decrease in weed density and aboveground biomass was greater with increased stocking rate and multiply season grazing. Sheep grazing has the potential to be an effective means of fallow management without compromising soil residue cover for erosion prevention. However, additional research is necessary for determination of optimum stocking rates and grazing intensity for weed management in fallow systems.

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