SHEEP GRAZING EFFECT ON DRYLAND SOIL CARBON AND NITROGEN IN THE WHEAT-FALLOW SYSTEM

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ABSTRACT

Weed control by sheep grazing during fallow periods in the dryland wheat-fallow system may influence soil C and N levels. The effects of fallow management for weed control and soil water conservation [sheep grazing (grazing), herbicide application (chemical), and tillage (mechanical)] and cropping sequence [continuous spring wheat (CSW), spring wheat-fallow (SW-F), and winter wheat-fallow (WW-F)] on wheat biomass (stems + leaves) yield and soil organic C (SOC) and total N (STN) at the 0-120 cm depth was evaluated from 2004 to 2008 in western Montana. Annualized wheat biomass yield was greater in CSW than in SW-F and WW-F from 2004 to 2006 but varied among fallow management practices from 2004 to 2008. In 2008, SOC at 10-30, 30-60, 90-120, and 0-120 cm was greater in the mechanical than in the chemical or grazing treatment in CSW. In SW-F, SOC at 10-30, 30-60, and 0-120 cm was greater in the chemical than in the mechanical or grazing treatment. Similarly, STN at 0-5 cm was greater in the chemical and mechanical than in the grazing treatment but at 30-60 cm was greater in the grazing than in the chemical treatment in CSW. Reduced amount of wheat residue returned to the soil due to consumption by sheep during grazing probably reduced SOC and STN at the surface and subsurface layers compared with tillage and herbicide application. For sustaining wheat yields and soil organic matter, reduced tillage with continuous cropping and less intensive sheep grazing may be needed to increase the amount of residue returned to the soil.

INTRODUCTION

Sheep grazing during fallow periods in the dryland wheat-fallow system is often used to control weeds and pests, reduce feed cost, and increase nutrient cycling in the northern Great Plains (Johnson et al., 1997; Entz et al., 2002). Tillage and herbicide application are also used to control weeds during fallow but they are expensive, resulting in some of the highest variable costs for small grain production in Montana (Johnson et al., 1997). Sheep grazing can enrich soil nutrients, improve soil quality, and increase crop yields by returning animal feces and urine to the soil (Tracy and Zhang, 2008; Maughan et al., 2009). Goosey et al. (2005) and Hatfield et al. (2007a, 2007c) reported that sheep grazing controlled weeds and insects, such as wheat stem saw fly [*Cephus cinctus* Norton (Hymenoptera: Cephidae)] compared with nongrazed, tilled, or burned treatments. Some of disadvantages of using these practices, however, are the exposure of soil to erosion due to tillage and increased risk of contamination of herbicides in soil, water, and human and animal health (Fenster, 1997).

Little is known about the effect of sheep grazing on dryland crop biomass and soil C and N levels compared with tillage or herbicide application to control weeds in wheat-fallow and continuous wheat systems. Our objective was to evaluate the effects of fallow management for weed control [sheep grazing (grazing), herbicide application (chemical), and tillage (mechanical)] and cropping systems (CSW, SW-F, and WW-F) on dryland wheat biomass from 2004 to 2008 and SOC and STN levels at the 0-120 cm depth in 2008 in western Montana.

MATERIALS AND METHODS

The experiment was conducted from 2004 to 2008 at the Fort Ellis Research and Extension Center, Montana State University, Bozeman, MT. Treatments consisted of three fallow management practices for weed control and soil water conservation (grazing, chemical, and mechanical) as the main-plot and three cropping sequences (CSW, SW-F, WW-F) as the split-plot treatment arranged in a randomized complete block with three replications. The grazing treatment consisted of grazing with a group of western white-faced sheep at a stocking rate of 29 to 153 sheep day ha^{-1} during fallow periods in fenced plots. Sheep grazed on weeds and wheat residue after grain harvest during 3 out of 8 mo of fallow period in CSW to 10 out of 20 mo in SW-F. Grazing ended when about 47 kg ha^{-1} or less of wheat residue and weeds remained in the plot. The chemical treatment consisted of applying herbicides and the mechanical treatment consisted of tilling the plots during fallow with Flexicoil harrow to a depth 15 cm, two three times a year. Each phase of the cropping sequence was present in each year. The split plot size was 91.4 m by 15.2 m.

From 2004 to 2008, N fertilizer was applied to spring and winter wheat at 200 kg N ha^{-1} in CSW and W-W-F and at 250 kg N ha^{-1} in SW-F. Because of greater soil P and K levels (61.2 and 41.6 mg P kg^{-1} and 424 and 296 mg K kg^{-1} at 0-15 and 15-30 cm depths, respectively) in 2004, no P and K fertilizers were applied. Spring wheat was planted at 90 kg ha^{-1} in late April-early May and winter wheat at 73 kg ha^{-1} in late September-early October using a double disc opener with a row spacing of 30 cm. Growing season broadleaf weeds were controlled with selective post-emergence herbicides. In late August-early September, two days before grain harvest, total wheat yield containing stems, leaves, and grains were harvested from two 0.5 m^2 quadrats. These were oven-dried at 60^oC for 2-3 days and dry matter yield was determined after weighing. Grain yields for spring and winter wheat (at 12 to 13% moisture content) were determined from an area of 1389 m^2 using a combine harvester in each year. Biomass (stems + leaves) yield was determined after deducting grain yield from total yield. After grain harvest, wheat residue containing stems and leaves were returned to the soil, except in 2004 when straw from non-grazed plots was removed. All cropped plots were tilled with a tandem disk in the late fall following harvest.

In October 2008, soil samples were collected from the 0-120 cm depth from five places within the plot using a hydraulic probe (5 cm i.d.), separated into 0-5, 5-10, 10-30, 30-60, 60-90, and 90-120 cm increments, and composited by depth. Samples were air-dried, ground, and sieved to 2-mm for determining SOC and STN concentrations by using high combustion C and N analyzer (LECO, St. Joseph, MI) after treating the soil with or without 5% H_2SO_3 to remove inorganic C. An additional undisturbed soil core (5 cm i.d.) was also collected from these depths to determine bulk density by dividing the mass of the oven-dried soil at 105^oC by the volume of the core. Because of the nonsignificant effects of treatments and interactions, bulk density values of 1.20, 1.34, 1.61, 1.61, 1.53, and 1.46 Mg m^{-3} at 0-5, 5-10, 10-30, 30-60, 60-90, and 90-120 cm, respectively, were used to convert concentrations (g kg^{-1}) of C and N to contents (Mg ha^{-1}).

Data were analyzed using the MIXED procedure of SAS (Littell, et al., 1996). Fallow management was considered as the main plot variable and fixed effect, cropping sequence as the split-plot variable and another fixed effect, and year as the repeated measure variable. Random variables were replication and replication × fallow management. Means were separated by using the least square means test when treatments and interactions were significant (Littell et al., 1996). Statistical significance was evaluated at $P \leq 0.05$, unless otherwise stated.

RESULTS AND DISCUSSION

Because of the similarity between wheat grain and biomass yields as influenced by treatments, only biomass yield will be reported. Annualized biomass yield was greater in CSW than in SW-F and WW-F from 2004 to 2006 (Fig. 1). In 2007 and 2008, biomass yield was greater in CSW than in SW-F. Biomass yield was lower in the mechanical than in grazing treatment in 2004 but was greater in the mechanical than in the chemical treatment in 2006 and 2008.

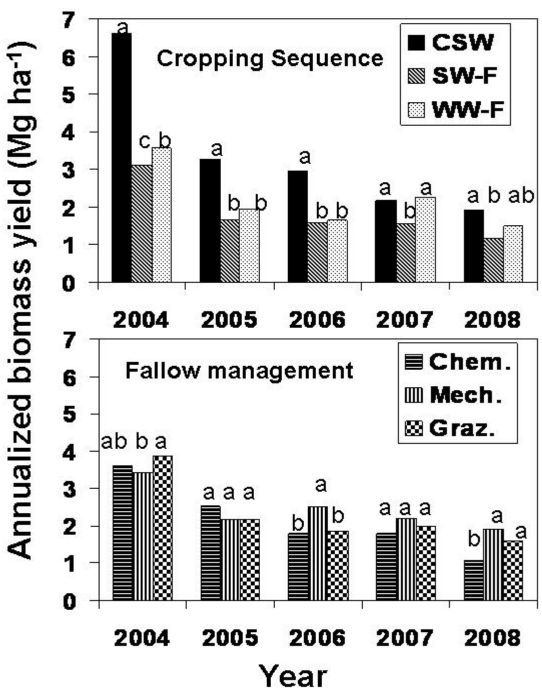

Fig. 1. Effects of cropping sequence and fallow management on annualized wheat biomass yield from 2002 to 2008. Bars followed by different letters at the top are significantly different at $P \leq 0.05$ by the least square means test.

The SOC at 10-30, 30-60, 90-120, and 0-120 cm was greater in the mechanical than in the chemical or grazing treatment in CSW (Table 1). In SW-F, SOC at 10-30, 30-60, and 0-120 cm was greater in the chemical than in mechanical or grazing treatment. In WW-F, SOC at 10-30 cm was greater in the chemical than in grazing treatment. The STN at 0-5 cm was greater in the chemical or mechanical than in the grazing treatment but at 30-60 cm was greater in the grazing than in the chemical treatment (Table 2). Treatments did not significantly affect STN in the whole soil profile (0-120 cm).

Table 1. Effects of cropping sequence and fallow management practice on soil organic C (SOC) content at the 0- to 120-cm depth in 2008.

		SOC content						
Cropping sequence†	Fallow management‡	0-5 cm	5-10 cm	10-30 cm	30-60 cm	60-90 cm	90-120 cm	0-120 cm
		--------------------------------Mg C ha^{-1}	-------------------------------					
CSW	Chem.	18.2	18.4	60.0	32.8	30.3	23.3	183.0
	Mech.	18.5	18.4	62.7	41.5	37.7	43.6	222.4
	Graz.	16.6	18.6	55.4	39.9	30.0	30.8	191.2
SW-F	Chem.	17.5	19.4	63.2	42.0	34.6	35.6	212.3
	Mech.	16.6	16.7	55.1	33.8	34.0	34.9	191.2
	Graz.	17.1	17.1	53.1	36.2	31.8	28.1	183.4
WW-F	Chem.	19.2	19.6	62.0	39.1	31.5	28.3	199.7
	Mech.	16.8	17.2	56.9	38.7	35.8	32.4	197.7
	Graz.	17.0	17.5	54.2	32.1	31.8	35.3	187.8
LSD (0.05)		NS§	NS	5.5	7.7	NS	8.9	28.0

† Cropping sequence are CSW, continuous spring wheat; SW-F, spring wheat-fallow; and WW-F, winter wheat-fallow.
‡ Fallow management practices are Chem., chemical where weeds controlled with herbicides; Graz., grazing where weeds were controlled with sheep grazing; and Mech., mechanical where weeds were controlled with tillage.
§ Not significant.

The greater annualized wheat biomass yield in CSW than in SW-F and WW-F from 2004 to 2006 was probably due to continuous cropping. Absence of crops during fallow probably reduced annualized biomass in SW-F and WW-F. This is similar to that reported by various researchers in dryland cropping systems in the northern Great Plains (Aase and Pikul, 1995; Lenssen et al., 2007; Sainju et al., 2009). Similarly, greater biomass yield in the mechanical than in the chemical and grazing treatments from 2006 to 2008 was probably a result of increased root growth due to tillage. Greater biomass yield in 2004 than in other years was probably due to higher precipitation (363 mm annual precipitation in 2004 compared with 320 to 350 mm in other years).

The greater SOC content at 10-120 cm in the mechanical than in the chemical treatment in CSW (Table 1) was probably a result of residue incorporation to a greater depth due to tillage, since the mechanical treatment had greater tillage frequency for weed control than the chemical treatment. Tillage increases SOC in subsoil layers compared with no-tillage due to residue incorporation at greater depths (Franzluebebrs and Stuedemann, 2008). In contrast, greater SOC content at 10-60 cm in the chemical than in the mechanical treatment in SW-F could be due to greater root growth in the subsoil layers, since the mulch effect of the residue accumulated at the soil surface during fallow in the chemical treatment can conserve soil water and promote root growth of the succeeding crop (Merrill et al., 1996). Lower SOC content at 0-120 cm in the grazing than in the chemical or mechanical treatment in CSW and SW-F suggests that grazing reduced SOC by removing crop residue, a result of consumption of residue by sheep. A similar trend in STN at 0-5 cm occurred in CSW (Table 2). Although part of residue C and N were returned to the soil through sheep feces and urines, they may not be enough to alter C and N levels in the soil. It may be possible that most of the wheat residue was used by sheep to increase live weight. The finding was in contrast to that observed by Hatfield et al. (2007b) who reported that SOC was not different among sheep-grazed, non-grazed, and tilled treatments in dryland cropping systems in northwestern Montana. The variations in the duration of the experiment and soil and climatic conditions among locations may have varying effects on crop biomass production and SOC and STN storage and mineralization, since Hatfield et al. (2007b) conducted experiment for 2 yr compared with 5 yr in this study. The reasons for greater STN at 30-60 cm in the grazing than in chemical treatment were not known.

Table 2. Effects of cropping sequence and fallow management practice on soil total N (STN) content at the 0- to 120-cm depth in 2008.

		STN content						
Cropping sequence†	Fallow management‡	0-5 cm	5-10 cm	10-30 Cm	30-60 cm	60-90 cm	90-120 cm	0-120 cm
		---------------------------------Mg N ha^{-1}-------------------------------						
CSW	Chem.	1.73	1.89	6.48	4.66	3.38	2.86	21.00
	Mech.	1.72	1.78	6.24	5.29	3.64	3.26	21.93
	Graz.	1.19	1.92	7.12	6.59	4.10	3.28	24.20
SW-F	Chem.	1.51	1.90	6.66	5.24	3.84	2.82	21.97
	Mech.	1.49	1.73	5.61	4.56	3.39	2.69	19.47
	Graz.	1.75	1.74	6.14	5.36	3.73	2.69	21.40
WW-F	Chem.	1.84	1.89	6.30	4.97	3.53	2.70	21.23
	Mech.	1.62	1.71	5.88	5.15	3.28	2.64	20.27
	Graz.	1.66	1.73	5.73	4.83	3.74	3.00	20.60
LSD (0.05)		0.44	NS§	NS	1.34	NS	NS	NS

† Cropping sequence are CSW, continuous spring wheat; SW-F, spring wheat-fallow; and WW-F, winter wheat-fallow.

‡ Fallow management practices are Chem., chemical where weeds controlled with herbicides; Graz., grazing where weeds were controlled with sheep grazing; and Mech., mechanical where weeds were controlled with tillage.

§ Not significant.

SUMMARY

Sheep grazing during fallow periods reduced SOC and STN contents compared with tillage and herbicide application for weed control in dryland wheat-fallow systems in the northern Great Plain. The effect was noticeable more in CSW than in SW-F and WW-F. Consumption of wheat residue by sheep during grazing probably reduced SOC and STN. Reduced tillage with continuous cropping and less intensive sheep grazing that increase the amount of wheat residue returned to the soil may be needed to sustain dryland wheat yields and soil organic matter.

REFERENCES

Aase, J.K., and J.L. Pikul, Jr. 1995. Crop and soil response to long-term tillage practices in the northern Great Plains. Agron. J. 87:652-656.

Entz, M.H., V.S. Baron, P.M. Carr, D.W.Meyer, S.R. Smith, Jr., and W.P. McCaughey. 2002. Potential of forages to diversify cropping systems in the Northern Great Plains. Agron. J. 94:240-250.

Fenster, C.R. 1997. Conservation tillage in the northern Great Plains. J. Soil Water Conserv. 32:37-42.

Franzluebbers, A.J., and J.A. Stuedemann. 2008. Early response of soil organic fractions to tillage and integrated crop-livestock production. Soil Sci. Soc. Am. J. 72:613-625.

Goosey, H.B., P.G. Hatfield, A.W. Lenssen, S.L. Blodgett, and R.W. Kott. 2005. The potential role of sheep in dryland grain production systems. Agric. Ecosys. Environ. 111:349-353.

Hatfield, P.G., S.L. Blodgett, T.M. Spezzano, H.B. Goosey, A.W. Lenssen, R.W. Kott, and C.B. Marlow. 2007a. Incorporating sheep into dryland grain production systems. I. Impact on overwintering larval populations of wheat stem sawfly, *Cephus cinctus* Norton (Hymenoptera: Cephidae). Small Rumin. Res. 67:209-215.

Hatfield, P.G., H.B. Goosey, T.M. Spezzano, S.L. Blodgett, A.W. Lenssen, and R.W. Kott. 2007b. Incorporating sheep into dryland grain production systems. III. Impact on changes in soil bulk density and soil nutrient profiles. Small Rumin. Res. 67:222-232.

Hatfield, P.G., A.W. Lenssen, T.M. Spezzano, S.L. Blodgett, H.B. Goosey, R.W. Kott, and C.B. Marlow. 2007c. Incorporating sheep into dryland grain production systems. II. Impact on changes in biomass and weed density. Small Rumin. Res. 67:216-221.

Johnson, J.B., W.E. Zidack, S.M. Capalbo, J.M. Antle, and D.F. Webb. 1997. Pests, pesticide use, and pesticide costs on larger central and eastern Montana farms with annually-planted dryland crops. Spec. Rep. 23. Dep. Agric. Econ., Montana State Univ., Bozeman, MT.

Lenssen, A.W., G.D. Johnson, and G.R. Carlson. 2007. Cropping sequence and tillage system influences annual crop production and water use in semiarid Montana. Field Crops Res. 100:32-43.

Littell, R.C., G.A. Milliken, W.W. Stroup, and R.D. Wolfinger. 1996. SAS system for mixed models. SAS Inst. Inc., Cary, NC.

Maughan, M.W., J.P.C. Flores, I. Anghinoni, G. Bollero, F.G. Fernandez, and B.G. Tracy. 2009. Soil quality and corn yield under crop-livestock integration in Illinois. Agron. J. 101:1503-1510.

Merrill, S.D., A.L. Black, and A. Bauer. 1996. Conservation tillage affects root growth of dryland spring wheat under drought. Soil Sci. Soc. Am. J. 60:575-583.

Sainju, U.M., A.W. Lenssen, T. Caesar-TonThat, and R.G. Evans. 2009. Dryland crop yields and soil organic matter as influenced by long-term tillage and cropping sequence. Agron. J. 101:243-251.

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