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Abstract

In dryland farming areas of Montana, annual precipitation is not sufficient for annual planting of cereal grains. Instead, a crop–summer fallow farming system is used to conserve soil moisture and increase available nitrogen for subsequent crop growth. Managing this summer fallow, either by mechanical means or with herbicides, is the highest variable cost associated with dryland grain production in Montana. Wheat stem sawfly, *Cephus cinctus* (Hymenoptera: Cephidae) is the most damaging insect pest to Montana's US\$ 1 billion per year grain industry. Weed management is the largest variable cost associated with dryland grain production and summer fallow management. Six fields, located on four commercial Montana grain operations, were grazed by sheep and goats from October 2002 to May 2003 to determine the impact grazing has on *C. cinctus* populations, weed and volunteer cereal growth, soil compaction, and gravimetric water concentrations. Percent *C. cinctus* larval mortality and percent reduction of weed biomass was greater in grazed compared to non-grazed areas ($P \leq 0.01$). No differences in soil bulk density or gravimetric water concentrations were found between treatments ($P > 0.11$). Grazing fallow with sheep and goats appears to successfully improve *C. cinctus* and weed management in grain production systems without impacting soil compaction.

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1. Introduction

In dryland farming areas of Montana annual precipitation is not sufficient for annual harvest of small grains. Current methods of fallow management are primarily mechanical tillage and spraying with

herbicides (i.e., chemical fallow). Although these methods are effective, they are expensive, making fallow management the highest variable cost in dryland grain production.

1.1. Wheat stem sawfly

The wheat stem sawfly, *Cephus cinctus* Norton (Hymenoptera: Cephidae) overwinters in post harvest

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wheat stubble and is considered the most destructive pest to Montana's US\$ 1 billion per year grain industry (Blodgett et al., 1996). Current methods of *C. cinctus* management include tillage (Weiss et al., 1987; Goosey, 1999), swathing (Goosey, 1999), insecticides (Holmes and Hurtig, 1952; Blodgett et al., 1996), stubble burning (Farstad, 1944; Goosey, 1999), delayed planting (Morrill and Kushnak, 1999), biological control (Morrill et al., 1998; Runyon et al., 2002), and resistant cultivars (Bruckner et al., 1997). All of these methods are either ineffective, erratic, or, at best, marginal in their effectiveness.

The potential use of sheep grazing for management of pest insect populations, namely the alfalfa weevil, *Hypera postica* Gyllenhal, has been investigated in several U.S. states. Dowdy et al. (1992) reported a 67% reduction in alfalfa weevil eggs and 25% reduction in spring alfalfa weevil larval numbers in grazed compared to non-grazed plots in Oklahoma. Goosey et al. (2004) reported sheep grazing reduced alfalfa weevil adult and larval numbers by 35–100%, depending on study year and sampling date, in grazed compared to non-grazed alfalfa.

Research in Montana demonstrated positive results using sheep grazing to reduce overwintering *C. cinctus* larval populations (Hatfield et al., 1999). Hatfield et al. (1999) reported *C. cinctus* mortality in grazed plots ranged from 46 to 87% above that recorded in controls and speculated that sheep trampling (hoof action) was responsible for much of *C. cinctus* larval mortality.

1.2. Biomass (weeds and stubble)

In the Northern Great Plains, approximately 6 million ha of farmland are rotated into summer fallow annually with herbicides used for weed control on the majority of ha (Stewart, 1988). Sheep grazing has been used to control weed populations on rangelands (Walker et al., 1992; Olsen and Lacey, 1994).

1.3. Soil bulk density and moisture

Soil compaction is a reduction in volume of a given mass of soil (Canillas and Salokhe, 2001) and is commonly estimated with soil bulk density. The problems associated with increasing soil bulk density in agricultural lands are soil hardness, reduced yields,

irregular plant growth, pooling of rainfall on the soil surface due to insufficient drainage, reduced hydraulic conductivity, and reduced water use efficiency (Canillas and Salokhe, 2001; Radford et al., 2001). Worrell et al. (1992) recorded cattle grazing in wheat fields at a stocking rate of 5.3 head/ha from November to January increased soil bulk density compared to a non-grazed control.

The objective of this study was to determine the impact of grazing cereal grain stubble with sheep on overwintering wheat stem sawfly larval populations, stubble and weed biomass, and soil bulk density on a field scale, commercial cereal grain operation level.

2. Materials and methods

This study was conducted at six different sites across Montana (Table 1) from October 2002 to May 2003. At each site, three blocks containing each treatment (grazed and non-grazed) were established. All sites were established on cereal grain stubble in small grains/fallow cropping systems. Three non-grazed plots (9.1 m × 12.2 m) were randomly located within each experimental field. Three grazed (9.1 m × 12.2 m) plots were established, in the same field, 6.1 m north of each non-grazed enclosure. Each non-grazed and paired grazed plot constituted a block. Sheep stocking rates and field sizes ranged from 70 to 285 sheep d/ha and 11.4–113 ha, respectively (Table 1). Non-grazed enclosures were fenced in August–September 2002 prior to introducing sheep or goats. Nitrogen application rates ranged between 67.2 and 86.2 kg/ha at all six sites prior to crop seeding. Insecticides were not applied at any site within the calendar year prior to this research being conducted. *C. cinctus* larvae were only found infesting fields at sites five and six. Therefore, *C. cinctus* results are only presented for these sites. All pre-treatment samples were taken in September, prior to imposition of grazing while all post-treatment samples were taken in May after grazing had ceased but prior to *C. cinctus* emergence at sites 5 and 6.

2.1. Wheat stem sawfly

Three samples were taken from each plot, both pre- and post-treatment. A sample consisted of all stubble

Table 1

Location, previous crop, cultivar, grazing dates, field size, stocking rate, and grazing animals for six research sites in Montana, 2002 and 2003

Site	Location	Stubble species/cultivar	Grazing dates (2002)	Field size (ha)	Stocking rate (sheep d/ha)	Numbers and type of animal
1	Gallatin Co.	Barley/Gallatin	31 August–18 September	17.8	84	79 Smut wethers
			9–22 October		125	171 Ram lambs ^a
2	Gallatin Co.	Barley/Gallatin	31 August–18 September	11.4	285	171 Ram lambs ^a
			20 October–1 November		180	171 Ram lambs ^a
			29 April–10 May 2003		84	80 Mature rams ^a
3	Stillwater Co.	Spring wheat/McNeal	30 November–4 December	81	89	980 Ewes and 455 yearling lambs ^a
4	Stillwater Co.	Winter wheat/Quantum	15–17 November	54	73	980 Ewes and 330 lambs ^a
5	Choteau Co.	Winter wheat/Rocky	15 November–15 December	41	146	200 Ewes ^a
6	Toole Co.	Winter wheat/Rocky	25 November–25 January	113	70 ^b	130 Nannies ^c

^a Targhee sheep.^b Goat d/ha.^c Borer goat.

material, including plant crowns, from a 0.46 m length of stubble row. Samples were labeled and returned to the laboratory where *C. cinctus* cut stems were identified and dissected to determine if they contained viable *C. cinctus* larvae. The percent reduction (i.e., % mortality) of overwintering *C. cinctus* larvae was calculated from these data.

2.2. Biomass (weeds and stubble)

Three samples were taken from each plot, both pre- and post-treatment. Each sample consisted of all above ground biomass within a 0.1 m² quadrat. Biomass was separated into wheat stubble and weeds, which were bagged separately. Samples were returned to the laboratory, dried at 50 °C for 48 h, and weighed to determine dry matter.

2.3. Soil bulk density and moisture

Three soil bulk density samples were taken from each plot, both pre- and post-treatment. Each sample consisted of all soil from a 91 cm³ compaction core sampler. Samples were returned to the laboratory at Montana State University, dried at 105 °C for 48 h and weighed to determine soil bulk density. Additionally, three soil moisture samples were taken per plot, in May after grazing had ceased, using the compaction core sampler. Extracted soils were immediately placed in air-tight, plastic bags, and returned to the laboratory. Samples (soils and bags) were weighed to determine wet weight, then dried at 105 °C for 48 h and weighed

again to determine dry weight. Gravimetric water content was calculated from these data in accordance with Gardner (1986).

2.3.1. Statistical analyses

The experimental design was a randomized complete block with three replicates at each site. The overall model included the effects of site, treatment, and site by treatment interaction. Pre-fall biomass was included as a *C. cinctus* co-variable to weight data to reflect differences between site available forage and the impact this may have on grazing effectiveness. The GLM procedure of SAS (SAS Institute Inc., 1989) was used to compute least squared means for treatment effects.

3. Results and discussion

Site by treatment interactions were not detected ($P > 0.12$) for any variable tested therefore data were combined and analyses were recalculated including only the effects of treatment across sites. Pre-fall biomass did not contribute significantly ($P > 0.25$), as a co-variable, to the original *C. cinctus* model and was therefore eliminated from further analyses.

3.1. Wheat stem sawfly

Numbers of pre-treatment *C. cinctus* larvae did not differ ($P = 0.18$, S.E. = 1.4) between grazed (14.9 larvae/m) and non-grazed (17.6 larvae/m) plots. Percent

C. cinctus larval reduction (i.e., % mortality) was greater ($P = 0.01$, S.E. = 2.6) in grazed (28.1%) compared to non-grazed (16.4%) plots.

These results are similar to those of Hatfield et al. (1999) who reported *C. cinctus* larval mortalities ranged from 46 to 87% in sheep grazed plots with stocking rates of 400 and 800 sheep d/ha. However, the mean *C. cinctus* mortality in this study (28%) was 39–68% lower than values recorded by Hatfield et al. (1999). This difference is believed to be a function of stocking rates. Stocking rates in this study, at sites 5 (146 sheep d/ha) and 6 (70 goat d/ha) were 57–91% lower than stocking rates of Hatfield et al. (1999) indicating that *C. cinctus* larval mortality, as a response to sheep grazing, could be dependent on stocking rate.

3.2. Biomass (weeds and stubble)

Pre-treatment stubble and weed biomass did not differ ($P > 0.29$) between treatments (Table 2). Reduction in and stubble biomass did not differ ($P = 0.08$) between treatments, however, reduction in weed biomass was greater ($P < 0.01$) in grazed, compared to non-grazed, plots (Table 2).

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. 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 weathers and dry ewes at a stocking rate of 4.25 sheep/ha for 11 weeks (330 sheep d/ha). Thomas et al. (1990) recorded that when sheep grazed weedy barley stubble in Montana at a stocking rate of 10 sheep/ha for 6 weeks (420

sheep d/ha), the stubble was capable of supporting economic lamb production. The stocking rates in this study ranged from 70 to 549 sheep d/ha which are comparable to, or less than, those used by Thomas et al. (1990) and Mulholland et al. (1976).

3.3. Soil bulk density and moisture

Pre-treatment soil bulk density, percent reduction in soil bulk density and post-treatment gravimetric moisture did not differ ($P > 0.11$) between treatments (Table 2). Crop production in cultivated clay loam soils is best when soil bulk density ranges from 0.9 to 1.5 t/m³ (Chancellor, 1977). The mean bulk density of sheep grazed plots, 1.35 t/m³, was within the normal range of production for cultivated clay loam soils, and not a single site had bulk density outside the optimal range.

These data concur with Drewry et al. (1999) who recorded high intensity (1800 sheep d/ha) grazing imposed no lasting detrimental effects on soil bulk density. Murphy et al. (1995) reported that soil bulk density was 81% greater in cattle compared to sheep grazed plots with similar stocking rates of approximately 80 animal units/ha. The difference between cattle and sheep grazing on soil compaction may be due to differences in hoof shape and animal weight, and the resulting static pressure. Sheep tend to have a more pointed hoof and exert less force per surface hoof area than cattle. However, for most livestock grazing, impact on soil compaction is typically limited, unless soils were recently tilled or very wet (Greenwood and McKenzie, 2001). However, as with any placement of grazing livestock on a natural or cultivated site, sound grazing management, including timing, duration, and intensity are important in proper sustainable management (Greenwood and McKenzie, 2001).

Table 2

Plot biomass and soil bulk density in sheep grazed and non-grazed plots from six sites in Montana

Treatment	Pre-treatment stubble (kg/ha)	Stubble reduction (%)	Pre-treatment weeds (kg/ha)	Weed reduction (%)	Pre-treatment bulk density (mg/m ³)	Bulk density reduction (%)	Post-treatment gravimetric moisture (%)
Grazed	1797	36.0	571	47.5	1.37	1.19	11.5
Non-grazed	1870	26.8	485	7.8	1.36	2.07	10.5
S.E.	142	3.9	57	6.7	2.2	1.7	0.4
P-value	0.72	0.08	0.29	<0.01	0.87	0.73	0.11

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