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Impacts of winter hay feeding on pasture soils and plants

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ABSTRACT

In temperate regions, feeding livestock year round on pasture is usually limited by weather conditions and livestock must be fed hay, or other stored feeds, at least part of the year when pasture forage runs out. On many farms, hay must be fed during winter and hay feeding is typically confined to pastures that are sacrificed for this purpose. The concentrated use of pasture during winter hay feeding could negatively impact subsequent forage production from soil compaction and possibly create water quality degradation from manure runoff. In 2008, we initiated a field experiment to address how winter hay feeding on pasture might have affected forage and soil variables in VA, USA. Variables were compared between 12 paired pastures each with and without hay feeding sites. Forage accumulation, forage mass, nutritive value and plant species composition along with soil penetration resistance, soil respiration and soil nutrient concentrations were monitored for 2 years. The presence of winter hay feeding sites in pastures had neutral to positive effects on forage productivity and forage nutritive value. Hay feeding pastures were not weedier than control pastures as we predicted, and they did contain more white clover through the grazing season ($P < 0.05$), which may have benefited forage production and nutritive value. As expected, soils from winter hay feeding pastures were more compacted compared with pastures without winter use. Soil compaction did not negatively affect forage production or soil respiration, however. By the end of this study, soil P, K and organic matter concentrations were 59%, 55% and 10% higher, respectively, in hay feeding pastures compared with control pastures. Our findings suggest that well-managed hay feeding in winter could benefit pasture forage production. Moreover, strategic placement of hay feeding sites around farm could be used as a management tool to improve land productivity though nutrient inputs and introduction of legumes into pasture.

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1. Introduction

Grazing animals play a major role in the recycling and distribution of nutrients within pasture (Haynes and Williams, 1993). It is well documented that soil in areas of livestock concentration associated with water, shade or feeding sites accumulate nutrients from manure and urine depositions (West et al., 1989; Mathews et al., 1994; Franzluebbers et al., 2000). Areas of concentrated animal use also can become compacted and denuded of vegetation so nutrient and/or pathogen losses to the environment may be expected (Sharpley et al., 1987; Mawdsley et al., 1995; Hubbard et al., 2004; Owens and Shipitalo, 2009). The uneven distribution of soil nutrients also has important implications for pasture fertility as areas far from animal concentration areas could become increasingly nutrient limited over time. In low input pasture systems, management of livestock to distribute nutrients more equally across pasture could be an important management method that can be used to help sustain high forage production without reliance on external fertilizer inputs.

In temperate regions, feeding livestock year round on pasture is usually limited by weather conditions and livestock must be fed hay, or other stored feeds, at least part of the year when pasture forage runs out. This time frame usually corresponds with winter, but may apply to summertime if drought conditions become severe. Compared with other livestock concentration areas, feeding sites, in particular, have major effects on pasture soils because of the additional nutrients deposited as manure and feed wastes (Sigua and Coleman, 2006). In fact, Sanderson et al. (2010) found that feeding areas accounted for more disturbed pasture area than other concentration areas associated with water, gates and shade sources. In winter, when soils are frequently wet, hay feeding areas can become heavily disturbed and compacted from trampling by livestock. When many livestock are confined to feeding areas for long durations, the buildup of manure on compacted soils also may contribute to water quality problems if soil nutrients, sediments and fecal pathogens are washed into surface waters from heavy rain or snow melt (Warren et al., 1986; Owens and Shipitalo, 2009; Boyer and Kuczynska, 2010). Other problems can arise from trampling

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and soil disturbance that may create focal points for weed invasion (Renne and Tracy, 2007) or from hay and manure wastes that provide habitat for serious insect pests like the stable fly *Stomoxys calcitrans* (L.) that afflict cattle (Broce, 2005).

Although most impacts associated with concentrated feeding sites are assumed to be negative, this may not always be the case. For example, some studies have shown that soil compaction from livestock trampling may be short-lived, and that recovery to pre-grazed condition can occur in as little as 30 days (Drewry et al., 2004; Drewry, 2006; Cournane et al., 2011). Moreover, if managed properly, nutrient inputs from livestock waste and feed could be used to build soil organic matter and overall fertility. Given the environmental importance and ubiquitous presence of feeding sites on livestock farms, more information on their impacts would be useful to ensure they are managed to limit negative effects in pasture soils and forage. In 2008, we initiated a field experiment to address this issue in VA, USA. Our specific objectives were to evaluate how winter hay feeding would affect: (1) plant variables that included forage mass and accumulation, forage nutritive value, and sward species composition, and (2) soil variables that included penetration resistance as a proxy for soil compaction, soil respiration, and nutrient concentrations. A secondary objective sought to estimate the nutrient import into pasture from hay and manure recycling during the winter feeding phase. We hypothesized that hay feeding sites would reduce forage availability and soil respiration due to soil compaction and increase weediness because of greater soil disturbance. We expected that the high manure and urine inputs in hay feeding sites would increase soil P and K concentrations, but we did not expect to detect significant differences in organic matter within the time frame of this study.

2. Material and methods

2.1. Study site

The experiment was carried out at Virginia Tech Shenandoah Valley Agricultural Research and Extension Center (Steeles Tavern VA; 37°55′55″). Soils at the site were Frederick-Christian silt loams, fine, mixed, semiactive, mesic Typic Paleudults. Climate is considered temperate with mean air temperature of 17 °C ranging from 4.7 °C in January to a high of 28.5 °C in July. Precipitation at the site predominately falls as rain with an annual mean of 987 mm and peaking between May and September (Southeast Climate Center, 2010). The experiment presented in this paper was part of a larger grazing study that began in 2008 to evaluate different grazing systems used to produce pasture-raised beef. The study involved rotational grazing of cow-calf pairs from April to September on tall fescue (*Festuca arundinacea* Schreb.) based pasture. Cow-calf pairs ($n = 7$ or 8 per group) were assigned to one of 12 grazing systems that each had 8 or 9 pastures (mean pasture area 0.8 ha). After weaning, cows then grazed a subset of pastures that had been stockpiled for winter grazing. The winter grazing on stockpiled tall fescue usually lasted from November to January. From January to mid-April, cows were fed hay and one pasture in each of the 12 grazing systems was designated for this purpose. The 7 or 8 cows assigned to each grazing system were confined to the designated hay feeding pasture and allowed access to hay placed in open top, round bale feeders. In addition to hay, cows could also graze residual grass biomass within the pasture. Winter stocking rates in hay feeding pastures averaged 9 animal units (AU)/ha, where 1 animal unit is equivalent to 454 kg. The same 12 hay feeding pastures were used starting in winter 2008, 2009 and 2010. Except for winter overseeding of red and white clover in 2009, the pastures received no external inputs during the course of this study.

This study used a paired plot approach to evaluate effects from hay feeding on pasture variables. Each hay feeding pasture ($n = 12$) was paired with an adjacent pasture that had no hay feeding area. Areas under and within the immediate vicinity of hay rings (within 2 m) were excluded from sampling. These heavily impacted areas accounted for about 5% of the pasture area and were denuded of vegetation from the high amount of hay waste that covered the soils. No comparable area could be sampled in the control pastures so areas directly under hay feeding rings were not sampled.

2.2. Forage variables

Mean herbage mass, herbage accumulation, and forage nutritive value were measured 2009 and 2010 in hay feeding (HF) and control pastures with no hay feeding (NHF). Herbage mass was estimated once a month from April through November. Forage was harvested within a 0.75 m × 3.5 m strip using a forage harvester (Swift Forage Harvester, Swift Current SK, Canada) attached to a tractor. The harvester was equipped with a balance that allowed us to weigh the samples in the field. From that sample, a subsample was taken and dried in an air forced oven (60 °C), for at least 48 h. After that, samples were weighed and the dry matter content was calculated. The dried samples were then sent to the Ruminant Nutrition Laboratory at Virginia Tech University for forage nutritive value analysis of crude protein (CP), neutral digestible fiber (NDF) and acid digestible fiber (ADF) using standard methods (Goering and Soest, 1970; Perkin Elmer, 1999; AOAC, 2000).

Forage accumulation was measured using three wire cages (1.2 m × 1.2 m) established in each pasture to exclude cattle. Forage was allowed to accumulate in exclosures from April to July and then harvested within a 0.5 m × 0.5 m quadrat. Samples were dried in an air forced oven (60 °C), for at least 48 h and weighed. Nutritive value analysis was not done on the herbage accumulation samples.

Plant species composition was accessed in October 2009, April and November 2010. Evaluations were made in 10 random locations in each plot using a 0.5 m × 1.0 m quadrat. Percent ground cover was estimated for the following species: tall fescue (*F. arundinacea* Schreb), blue grass (*Poa pratensis L.*), orchardgrass (*Dactylis glomerata L.*), white clover (*Trifolium repens L.*), and red clover (*Trifolium pratense L.*). Additional species were grouped together and classified as weeds.

2.3. Soil variables

Soil variables measured in the paired pastures included soil nutrient concentration, soil respiration and penetration resistance as a proxy for soil compaction. Soil nutrient concentrations had been monitored in all pastures within the larger grazing system experiment since 2007. We used these samples from the respective paired pastures to evaluate changes in soil nutrient concentrations since 2007 (pre hay feeding). Soil samples for nutrient concentration analysis were taken each year from 2007 until 2010. Eight samples, 20 cm deep, were taken per pasture with a soil probe (2.5 cm diameter). Subsamples were mixed in a bucket to obtain a composited sample. Soil samples then were analyzed for pH, available P and K, and exchangeable Ca, and Mg at the Virginia Tech Soil Testing Laboratory. Water pH was analyzed using a TPS Pty Ltd., model WP-80D, Dual pH–mV and temp. meter. Phosphorus, K, Mg and Ca concentrations were analyzed using an ICP-AES (Inductively Coupled Plasma – Atomic Emission Spectrometer) from a Mehlich 1, 0.05 N HCl in 0.025 N H_2SO_4 extracting solution. In 2010, soil organic matter content was evaluated using a modified Walkley–Black method.

Measurements of soil respiration began in late April 2009. To measure respiration, PVC rings (20 cm diameter and 12 cm height), were inserted into the soil (3–4 cm deep) within cattle exclosures