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Short communication

Seasonal change in nutrient composition of spotted knapweed and preference by sheep

Amy C. Ganguli^{a,*}, Michael B. Hale^{b,1}, Karen L. Launchbaugh^c^a School of Natural Resource Sciences, North Dakota State University, 1402 Albrecht Blvd., Fargo, ND 58102, USA^b Bunchgrass Enterprises LLC, Joseph, OR 97846, USA^c Rangeland Ecology and Management Department, University of Idaho, Moscow, ID 83844, USA

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ABSTRACT

Spotted knapweed (*Centaurea stoebe* ssp. *micranthos*) is one of the most troublesome rangeland weeds in western North America. As part of a larger investigation evaluating the use of targeted sheep grazing to control spotted knapweed, we examined sheep preference and forage quality of dried spotted knapweed in different phenological stages. We collected spotted knapweed for preference evaluation trials from a sagebrush steppe community near Dubois, Idaho throughout the 1999 growing season and analyzed the plants for nutritional quality. Preference for spotted knapweed was evaluated in a cafeteria trial, where we offered 12 ewes dried and chopped spotted knapweed in rosette, bolting, and flowering/seedset phenological stages. Nutritional value of spotted knapweed was highest in early phenological stages and declined with phenological development. Sheep readily consumed spotted knapweed in all phenological stages; however, rosette and bolting knapweed were generally selected over the flowering/seedset knapweed. Spotted knapweed consumption was related to crude protein, and neutral detergent fiber content of spotted knapweed, yet consumption was not related to cnicin content, a suspected feeding deterrent. This study suggests knapweed is acceptable forage that has adequate nutritional value during the growing season to sustain wild and domestic ungulates.

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1. Introduction

Invasion by introduced plant species is one of the greatest contemporary ecological and economic threats facing North America. Overgrazing by livestock is one mechanism that has been implicated in the spread of noxious weeds (DiTomaso, 2000), however, carefully managed sheep and goat grazing can successfully control rangeland weeds like

leafy spurge (*Euphorbia esula*) (Walker et al., 1994; Olson and Lacey, 1994; Lym, 2005). The effectiveness of using small ruminants for leafy spurge control has stimulated considerable interest in using livestock grazing as a tool for weed control (Frost and Launchbaugh, 2003; Launchbaugh et al., 2006; DiTomaso et al., 2008; Ralphs and Banks, 2009).

Carefully managed grazing could be employed in the battle against weeds if the time of grazing and stocking rate necessary for control were known for specific weeds. In addition, the animal production consequences of employing grazing for weed control must also be elucidated to assess if targeted grazing is an economically viable weed management tool. Several rangeland weeds have been identified as adequate forage resources (Frost et al., 2008), but low-quality weeds, such as mature knapweed (*Centaurea* spp.) or rush skeletonweed (*Chondrilla juncea*), will

* Corresponding author. Tel.: +1 701 231 5828.

E-mail addresses: amyganguli@gmail.com, amy.ganguli@ndsu.edu (A.C. Ganguli), halem@eoni.com (M.B. Hale), klaunchb@uidaho.edu (K.L. Launchbaugh).¹ At the time of research, Ganguli was research associate and Hale was graduate research assistant, Rangeland Ecology and Management Department, University of Idaho, Moscow, ID 83844, USA.

undoubtedly result in production losses if grazed in high amounts (Laca et al., 2001; Frost et al., 2008).

Spotted knapweed (*Centaurea stoebe* ssp. *micranthos*) was selected for this research because it is of ecological concern throughout North American rangelands. Spotted knapweed displaces native plant communities, degrades wildlife habitat (Wright and Kelsey, 1997), alters soil biogeochemistry (LeJeune and Seastedt, 2001), and can result in increased soil erosion (Lacey et al., 1989). Sheep are known to readily graze spotted knapweed (Olson et al., 1997; Thrift et al., 2008), and are considered the most effective livestock species for control of many herbaceous forbs (Olson and Lacey, 1994). However, spotted knapweed contains cnicin (Kelsey and Locken, 1987), a sesquiterpene lactone that is thought to reduce forage palatability and deter grazing (Olson and Kelsey, 1997). Therefore, we examined the nutritional value, cnicin content, and palatability of spotted knapweed for domestic sheep in different phenological stages to assess the feasibility of developing targeted grazing strategies for spotted knapweed management.

2. Materials and methods

We collected spotted knapweed in three phenological stages (rosette, bolting, and flowering/seedset) in 1999 from sagebrush steppe communities near the USDA-ARS U.S. Sheep Experiment Station, in southeastern Idaho (112° 11'W, 44° 14'N). We dried spotted knapweed foliage at 50 °C in a forced air oven, chopped with a flail mill to <4 cm long, and stored it in a cool, dry, dark place until the forage preference test was conducted in July 2000.

We examined knapweed preference with 12 mature whiteface, Columbia-Rambouillet cross, non-lactating range ewes (72–83 kg). Sheep were housed in individual pens (1.25 m × 2 m), with shade and *ad libitum* access to water. The preference trial lasted 9 days and included three phases: knapweed conditioning, protocol conditioning, and preference testing. A 5-day knapweed-conditioning phase familiarized animals with each knapweed phenological stage. Sheep were offered 200 g alfalfa pellets twice daily (at 06:30 and 18:30 h) and 30 min after each offering sheep received 90 g of dried spotted knapweed of a single phenological stage. To meet daily basal requirements, sheep were also offered alfalfa pellets at 08:30 and 20:30 h to total 20 g/kg body weight.

The protocol-conditioning phase familiarized animals with the cafeteria-style preference test by conducting four trials over 2 days. To reduce hunger and enhance selectivity among diets offered, we fed sheep 200 g alfalfa pellets twice daily. Within 30 min of receiving alfalfa pellets, we simultaneously offered 100 g each of three types of chopped hay (oat, grass, and alfalfa). Feeds were offered in containers set in a row, and removed when about 90% of one feed was consumed. The conditioning phase of the preference trial demonstrated that ewes were sufficiently discriminating between the diets offered ($P < 0.05$), with highest preference consistently expressed for alfalfa.

Following the protocol-conditioning phases we conducted four spotted knapweed preference trials over 2 days

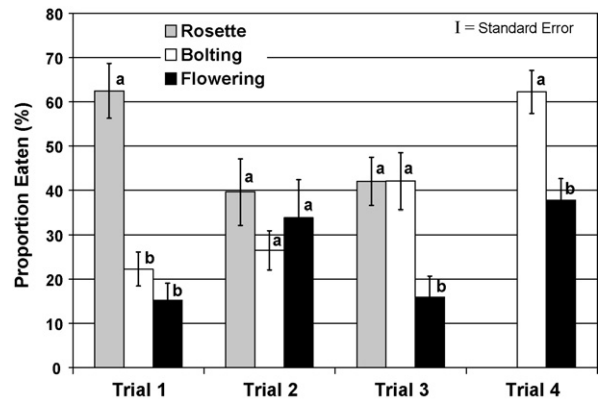


Fig. 1. Sheep preference among three phenological stages of spotted knapweed expressed as a percent of total intake for each sheep ($N = 12$). Research was conducted in a cafeteria trial with dried plant material. Values with similar superscript are not statistically different ($\alpha < 0.05$).

to determine sheep preference among three phenological stages of spotted knapweed. We conducted the spotted knapweed preference trials identical to the protocol-conditioning trials. However, we offered 90 g of chopped knapweed in the rosette, bolting, and flowering/seedset phenological stages. In the 4th preference trial we had insufficient rosette foliage to conduct a three-way preference test, thus we were only able to conduct a paired preference test between bolting and flowering/seedset spotted knapweed.

We analyzed the spotted knapweed diets used in the preference trial for neutral detergent fiber (NDF), crude protein (CP), and cnicin. We determined NDF with a filter bag technique that used sodium sulfite and alpha-amylase (ANKOM, 2006), CP by Dumas combustion analysis on a Carlo Erba NA Series 2 analyzer (AOAC, 1997), and cnicin with high performance liquid chromatography using a C18 column (Luna 4.6 mm × 250 mm by Phenomenex) on a Waters Breeze HPLC system with UV detection (Olson and Kelsey, 1997).

Preference was assessed as the intake of each knapweed phenological stage, expressed as a percent of total knapweed eaten by each sheep and evaluated in a repeated measures analysis of variance (Steel et al., 1997) with phenological stage as the between animal effect and test number as the repeated measure (SAS Version 8.1 software; SAS, 2000). Significant treatment by test number interactions were analyzed with a Duncan's multiple-range test (Duncan, 1955). The association between the proportion of spotted knapweed eaten and knapweed diet quality (CP, NDF, and cnicin) was determined with correlation analysis (SAS Version 8.1 software; SAS, 2000).

3. Results

Sheep readily consumed spotted knapweed in all phenological stages, although they did not exhibit a clear preference for any single phenological stage in its dry and chopped form ($P < 0.05$; Fig. 1). Sheep did, however, generally select rosette and bolting spotted knapweed over flowering/seedset material (Fig. 1). The rosette phenologi-

cal stage of spotted knapweed used in the preference trial was higher in crude protein ($19.5 \pm 0.3\%$) than the bolting or flowering/seedset stages, which were $11.6 \pm 0.5\%$ and $11.3 \pm 0.2\%$ respectively ($P < 0.05$). Fiber (NDF) was different in each phenological stage ($P < 0.05$) with lowest levels occurring in rosettes ($24.9 \pm 1.1\%$) followed by bolting ($29.2 \pm 0.3\%$) and flowering/seedset knapweed material ($40.4 \pm 0.1\%$). Cnicin was highest ($P < 0.05$) in spotted knapweed rosettes ($0.47 \pm 0.01\%$), followed by bolting ($0.36 \pm 0.04\%$) and flowering/seedset ($0.28 \pm 0.02\%$) knapweed material, which were not different from each other ($P < 0.05$).

Sheep selection of spotted knapweed was related to CP ($r = 0.72$; $P < 0.05$) and NDF ($r = 0.71$; $P < 0.05$). That is, sheep selected spotted knapweed with higher levels of CP and lower levels of NDF. Despite differences in cnicin content, sheep diet selection was not related to cnicin concentration ($P = 0.14$).

4. Discussion

Sheep readily consumed spotted knapweed in all phenological stages suggesting that it is acceptable to sheep throughout the growing season. Sheep generally preferred knapweed in the rosette or bolting phenological stage, and expressed less preference for plants in the flowering/seedset stage, although this preference was variable. Field investigations have revealed that the timing of grazing and the relative abundance of spotted knapweed can influence patterns of spotted knapweed and associated non-target species consumption (Thrift et al., 2008). Our study indicates that spotted knapweed may provide high quality forage for sheep in the first part of the season before flowering and seed production. The relatively low fiber and high crude protein content of knapweed early in the growing season agrees with the results of other researchers (Kelsey and Mihalovich, 1987; Olson and Kelsey, 1997) and suggests that there is no nutritional reason to restrict animal's consumption of spotted knapweed prior to flowering and seed production.

Cnicin is an allelochemical in several *Centaurea* species and has been speculated to reduce spotted knapweed palatability (Kelsey and Mihalovich, 1987; Olson and Kelsey, 1997; Wright and Kelsey, 1997). Although cnicin has a bitter taste, at least to humans, it does not necessarily result in reduced palatability to sheep. Sheep like other herbivores do not consistently avoid bitter flavors, nor do sheep form stronger aversions to bitter than sweet flavors (Nolte et al., 1994). Furthermore, herbivores can form strong preferences for bitter tasting compounds if their consumption is associated with nutrient or energy enhancement (Launchbaugh, 1996).

Considerable interest has been generated for developing prescriptions for using livestock in targeted grazing programs to control undesirable plant species while maintaining healthy plant communities (Frost and Launchbaugh, 2003; Launchbaugh et al., 2006; DiTomaso et al., 2008). Development of targeted grazing prescriptions requires integrating information, such as this study provides, with controlled field study that identifies the grazing timing and intensity required to have greatest negative impact to the

target species and least impact to desirable plant species (Frost and Launchbaugh, 2003).

5. Conclusion

Nutritional composition of spotted knapweed before flowering and acceptance of spotted knapweed by sheep suggest that there are opportunities to develop targeted grazing programs for spotted knapweed control that can also be complimentary with sheep production goals. Furthermore, sheep will apparently consume spotted knapweed in different phenological stages throughout the growing season. This creates the potential to use sheep in targeted grazing programs specifying the season of grazing that causes greatest negative impact to spotted knapweed and minimizes negative impact on associated plant communities (Frost and Launchbaugh, 2003). Our results coupled with those of others (e.g., Thrift et al., 2008) warrant controlled field investigation to identify the best timing and intensity of grazing necessary to reduce spread and impact of spotted knapweed while maintaining healthy rangeland ecosystems.

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