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Can Sheep Control Invasive Forbs Without Compromising Efforts to Restore Native Plants?

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ABSTRACT

Domestic sheep *(Ovis aries)* are increasingly being used to control non-native invasive plants in areas where restoration is a management goal. However, the efficacy of sheep grazing depends on both its potential for controlling undesirable plants and its ability to promote natives. To date, few studies have investigated impacts of sheep grazing on native forb recovery in North American grasslands. We assessed the impact of sheep on forbs by measuring the number of stems grazed before and after sheep foraged in western Montana, United States. Sheep grazed a higher percentage of non-native than native forbs (70% vs. 23%, respectively), and number of stems grazed was six times higher for non-natives than natives (48 vs. 5, respectively). Sheep preferentially selected the non-native forbs sulphur cinquefoil and yellow salsify over leafy spurge ($fi = 2.075$; $fi = 0.969$; $fi = 0.969$, respectively), as well as the native forbs white prairie aster ($fi = 1.090$) and blanketflower ($fi = 1.000$). Selection of native forbs was positively correlated with their pregrazing abundance and increased over the grazing period. Our findings indicate that when using sheep to control invasive forbs, appropriate timing and monitoring of grazing are critical for reducing nontarget impacts to native vegetation.

Introduction

Conservation grazing has the potential to rehabilitate plant communities and is increasingly being used as a management strategy in disturbed grasslands (Landgraff et al., 1984; Bangsund et al., 2001). To date, however, studies investigating effects of sheep grazing have focused primarily on invasive plant control (e.g., Landgraff et al., 1984; Olson and Lacey, 1994) rather than ecosystem recovery (but see Gibson et al., 1987; Norton and Young, 2016). Although there are a limited number of investigations on effects on native plant communities, they are restricted in taxonomic and geographic scope. Effects are better documented for grasses (e.g., McIntyre and Lavorel, 1994; Landsberg et al., 2002) than forbs and for Europe, South America, and Australia (Hellström et al., 2003; Cingolani et al., 2005; Evju et al., 2009; Mavromihalis et al., 2013) than North America.

The response of native plants to grazing is known to be variable, with some species increasing in abundance or size (e.g., Gibson et al., 1987; Hellström et al., 2003; Evju et al., 2009) and others declining (e.g., McIntyre and Lavorel, 1994; Landsberg et al., 2002; Austrheim et al., 2008). Plant traits may be an important predictor of response, but previous investigations of the relationship between traits and sheep grazing preferences have not found consistent patterns: Some investigators report that sheep select shorter over taller forbs (Cingolani et al., 2005), whereas others report that sheep avoid short stature species (Diaz et al., 2001; Evju et al., 2009). Similarly, some investigators report that sheep prefer nutrient-rich foods over low-quality options (Villalba and Provenza, 1999), while others report nutrient quality does not have an effect (Schwartz and Ellis, 1981). Additional studies, therefore, are needed to tease apart variation and provide species-level information. Toward that end, we investigated 1) whether sheep preferentially grazed native or non-native forbs, 2) whether pregrazing cover of native or non-native forbs affected their rate of consumption, 3) which forb species (native and non-native) were susceptible to grazing, and 4) whether grazing pressure (% stems grazed) on forbs varied during the grazing season.

Methods

This study was conducted in an intermountain grassland near Missoula, Montana (46.5217° N, 113.5750° W) at 1150 − 1250 m elevation with 35 − 45% slopes, Bigarm gravelly loam soil (NRCS, 2017), 35 cm average annual precipitation (NOAA, 2017), an average annual temperature of 45.9°F, and seasonal temperatures ranging from 47°F to 86°F in June − July (NOAA, 2017). Dominant native grasses include bluebunch wheatgrass *(Pseudoroegneria spicata* [Pursh] A. Love), Sandberg bluegrass (*Poa secunda* J. Prsel.), prairie Junegrass (*Koeleria macrantha*

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[Ledeb.] Schult.), and Idaho fescue (*Festuca idahoensis* Elmer). Common native forbs include white prairie aster (*Aster falcatus* [Lindl.] G.L. Nesom), milkvetch (*Astragalus* L.), hairy false goldenaster (*Heterotheca villosa* [Pursh] Shinners), silky lupine (*Lupinus sericeus* Pursh), common yarrow (*Achillea millefolium* L.), blanketflower (*Gaillardia aristata* Pursh), prairie sagewort (*Artemisia frigida* Willd.), and wavyleaf thistle (*Cirsium undulatum* [Nutt.] Spreng.). The most common non-native forbs are leafy spurge, sulphur cinquefoil (*Potentilla recta* L.), and yellow salsify (*Tragopogon dubius* Scop.). In 2010, approximately 400 sheep and five goats were allowed to roam and forage. Because 99% of grazing animals were sheep, hereafter, we refer to grazing as "sheep grazing."

Field Measurements

In May 2010, before sheep grazing, we randomly selected 55 2-m-diameter circular plots in a mixed native/non-native plant community. All plots contained a comparable mix of native and non-native species; no single species occurred at > 65% cover; and all of the common species used for analyses (see later) were present on ≥ 50% plots. Plots with total cover of leafy spurge >50% were rejected. Within each plot, we measured percent cover of forbs and density of forb stems by species within one randomly selected quarter of the circular plot (hereafter subplot). Nomenclature follows USDA, Natural Resources Conservation Service (2015).

Pregrazing and Control Plots

Sheep grazed an adjacent area heavily infested with leafy spurge for 3 weeks before introduction into the study area. After this conditioning period, 50 plots were available for grazing for 5 weeks (9 June to 19 July 2010); the remaining five controls were protected from grazing by a 1.3-m-high 5 000-volt electric fence.

Grazing Period Assessments

After sheep grazed for 1 week, we estimated percent forb stems grazed within each plot. Subsequent estimates were conducted on a random subset of subplots (including controls) on a weekly basis. At week 6, grazed and ungrazed forb stems were recounted in the same subplot where initial stem density was measured. Due to early desiccation, some less common native forbs were not resampled; these species all occurred at < 15% pretreatment frequency and accounted for < 12% of total stems (Table 1).

Analyses

Before statistical analyses, variables were assessed for normality. When distributions were non-normal, non-parametric tests were used. Analyses were conducted using SPSS 15.0 (SPSS Inc., 2009). We considered $\alpha < 0.05$ as significant and $0.05 - 0.10$ as marginally significant.

Assessing Background-Level Changes

To address whether sheep preferentially grazed native versus non-native forbs, we first assessed background changes (i.e., changes not due to grazing) in percent stems grazed and stem density. This was done by testing for differences between pre-and-post grazing assessments for each response variable (stem density and percent stems

Table 1
Scientific and common names of perennial forbs[1] (ordered according to selection index) on study plots, their origin (native or non-native),[1] functional traits,[2] post-treatment status (grazed or ungrazed), preference,[3] proportion of stems within each species grazed (for species occurring on >15% of the study plots), and frequency pretreatment (% of plots where present).

Species	Origin	Functional traits *height, leaves phenology*	Status	Selection index $fi = \sigma i/\mu i$	Mean % grazed σi	Frequency (%) μi
Potentilla recta, L., Sulphur cinquefoil	Non-native	Tall, tender late flowering	Grazed	2.075	83	40
Aster falcatus, Lindl., White prairie aster	Native	Tall, tough late flowering	Grazed	1.09	60	55
Gaillardia aristata, Pursh, Blanket flower	Native	Tall, tender early flowering	Grazed	1.000	17	17
Tragopogon dubius, Scop., Yellow salsify	Non-native	Tall, tender early flowering	Grazed	0.969	31	32
Euphorbia esula, L., Leafy spurge	Non-native	Tall, tender early flowering	Grazed	0.872	68	78
Astragalus, L., Milkvetch	Native	Short, tender late flowering	Grazed	0.588	10	17
Lupinus sericeus, Pursh., Silky lupine	Native	Tall, tender early flowering	Grazed	0.520	13	25
Achillea millefolium, L., Common yarrow	Native	Tall, tender early flowering	Grazed	0.400	10	25
Heterotheca villosa, (Pursh), Shinners Hairy false goldenaster	Native	Short, tough late flowering	Ungrazed	–	–	63
Cirsium undulatum, (Nutt.) Spreng., Wavyleaf thistle	Native	Short, tough late flowering	Ungrazed	–	–	17
Artemisia frigida, Willd., Prairie sagewort	Native	Tall, tough late flowering	Ungrazed	–	–	13
Taraxacum officinale, F.H. Wigg, Common dandelion	Non-native	Short, tender early flowering	Grazed	–	<1	13
Species	Origin	Functional traits	Status	Selection index[2] $fi = \sigma i/\mu i$	Mean % grazed σi	Frequency (%) μi
Erigeron pumilus, Nutt., Shaggy fleabane	Native	Tall, tender early flowering	Grazed		<1	7
Delphinium bicolor, Nutt., Little larkspur	Native	Short, tough early flowering	Ungrazed	–	–	5
Lomatium, Raf., Desert parsley	Native	Short, tender late flowering	Grazed	–	<1	4
Plantago patagonica, Jacq., Woolly plantain	Native	Short, tender late flowering	Ungrazed	–	–	3
Centaurea stoebe, L., Spotted knapweed	Non-native	Short, tough late flowering	Grazed	–	<1	3
Linaria dalmatica, (L.), Mill. Dalmatian toadflax	Non-native	Tall, tender late flowering	Grazed	–	<1	2
Sisymbrium altissimum, Tall tumble mustard	Non-native	Tall, tender early flowering	Grazed	–	<1	2
Antennaria rosea, Rosy pussytoes	Native	Short, tender early flowering	Ungrazed	–	–	1
Arabis holboellii, Hornem., Holboell's rockcress	Native	Short, tough early flowering	Ungrazed	–	–	1
Helianthus annuus, L., Common sunflower	Native	Short, tough late flowering	Ungrazed	–	–	1
Monarda fistulosa, L., Wild bergamot	Native	Short, tough late flowering	Ungrazed	–	–	1
Penstemon Schmidel, Beardtongue	Native	Short, tough late flowering	Ungrazed	–	–	1
Cirsium vulgare, (Savi) Ten., Bull thistle	Non-native	Tall, tough late flowering	Ungrazed	–	–	1

[1] Nomenclature and origin: USDA PLANTS Database.
[2] Functional traits: tall ≥ 30 cm, short ≤ 30 cm; tender = easily bruised, tough = leathery or waxy.
[3] Forage selectivity index: Manly et al. (2002).

grazed for native and non-native forbs) in control plots using Wilcoxon signed rank tests ($n = 5$), with separate tests for each variable.

Tests for Direct Effects

We assessed whether sheep grazed more native forbs than expected by calculating (for each subplot) the percentage of 1) total forb stems that were native and 2) total native stems grazed pre-and-post-treatment for plots in which sheep were allowed to graze. We then tested for differences between these percentages using a Student's *t*-test ($n = 50$; grazed plots only) (Ott and Longnecker, 2010). We performed similar analyses to test for differences between percentage of total forb stems that were non-native and percentage of total non-native stems grazed.

We also tested for differences in number of stems grazed and change (pre-to-post-treatment) in percent stems grazed between native and non-native forbs. For change in percent stems grazed, we first calculated percent stems grazed for each group before and after treatment and then calculated changes between the two measurement periods in each case. We tested for differences in response (separate tests for each response variable) between native and non-native forbs using Kruskal-Wallis tests ($n = 50$; grazed plots only). We used Spearman rank correlations ($n = 50$) (Ott and Longnecker, 2010) to assess relationships between each response variable and pretreatment percent cover of native or non-native forbs.

To assess whether sheep selected certain forbs, we calculated the proportion of individuals of each species grazed (oi) given the proportion of plots in which they occurred (μi) relative to the total number of occurrences of all species in all plots. We then calculated forage selectivity ($fi = oi/\mu i$) (Manly et al., 2002) for each species occurring on >15% of plots. Finally, temporal trends in percent stems grazed were assessed graphically for common forbs.

Results

Plots averaged 82 forb stems m^{-2}, with lower pretreatment stem density for natives than non-natives (23 m^{-2} vs. 59 m^{-2}, respectively). We found evidence of grazing on 14 (seven native and seven non-native) of 25 common (≥15% pretreatment frequency) forbs (Table 1). Fifteen less common (<15% pretreatment frequency) forbs were also observed on study plots; of these, 2 of 10 native and 4 out of 5 non-natives were grazed (see Table 1).

In control plots, we found <0.01% of stems grazed pretreatment and only 0.01% post treatment; there was no difference between pretreatment and post-treatment measurements of percent stems grazed for total native ($z = 0.00$, $P = 1.0$, df = 4) or non-native ($z = 0.00$, $P = 1.0$, df = 4) forbs. Additionally, no differences were detected between pregrazing and postgrazing measurements of stem density for total native ($z = -0.67$, $P = 0.5$, df = 4) or non-native ($z = -0.14$, $P = 0.9$, df = 4) forbs. Since we did not detect differences between pretreatment and post-treatment measurements in the ungrazed controls, observed changes in grazed plots indicate effects of grazing.

In grazed plots, 81.7% of all stems were grazed. The percent of native stems that were grazed was lower than their proportional abundance (20.6% vs. 42.7%, respectively; t = 4.97, $P > 0.001$, df = 49; Fig. 1). Although sheep grazed more non-natives than expected (79.4% of stems grazed were non-native; only 57.3% of all stems were non-native), the difference was only marginally significant (t = 1.58, $P = 0.060$, df = 49; see Fig. 1). Compared with native forbs, more non-natives forb stems were grazed ($z = -2.54$, $P = 0.011$, df = 49; see Fig. 1), and there was a greater change in percent stems grazed ($z = -4.18$, $P = < 0.001$, df = 49; see Fig. 1).

Pretreatment cover of *native forbs* was significantly related to grazing patterns. We found positive significant correlations between the number of *native* stems grazed and pretreatment percent cover of *native* forbs ($r_s = 0.311$, $P = 0.03$) and *non-native* stems grazed and pretreatment cover of *native* forbs ($r_s = 0.55$, $P = < 0.001$). For our other measure of response, change in percent stems grazed, we found no significant correlations between changes in native or non-native stems grazed and pretreatment cover of *native* forbs.

Conversely, pretreatment cover of *non-native forbs* was not related to grazing patterns. Change in percent *native* stems grazed was marginally negatively correlated with pretreatment percent cover of *non-native* forbs ($r_s = -0.27$, $P = 0.1$); change in percent of *non-native* stems grazed was not correlated with pretreatment percent cover of *non-native* forbs. There was no relationship between pretreatment cover of non-native forbs and either change in number of stems grazed or change in percent stems grazed for either natives or non-natives.

Of the 10 common forbs (occurring on >15% of plots), 5 were preferentially selected by sheep ($fi = oi/\mu i$, $fi > 1$, Table 1) including two natives, white prairie aster ($fi = 1.090$) and blanket flower ($fi = 1.000$), and three non-natives, sulphur cinquefoil ($fi = 2.075$), salsify ($fi = 0.969$), and leafy spurge ($fi = 0.872$). Of the 15 less common forbs, we observed sheep grazing on 2 out of 10 natives (20%) and 4 out of 5 non-natives (80%) (see Table 1). In grazed plots, trends in percent stems grazed over time varied by species (Fig. 2). For leafy spurge and sulphur cinquefoil, percent stems grazed increased until week 2 and then remained constant through week 4 (see Fig. 2). For white prairie aster, percent stems grazed increased during week 1 and 2 and then declined in week 3 and increased again during the fourth and final week of the grazing period. Although <10% of blanketflower and milkvetch stems were grazed through week 2, both were grazed more frequently during the remainder of the grazing period (see Fig. 2). Silky lupine and yarrow were grazed infrequently (see Fig. 2).

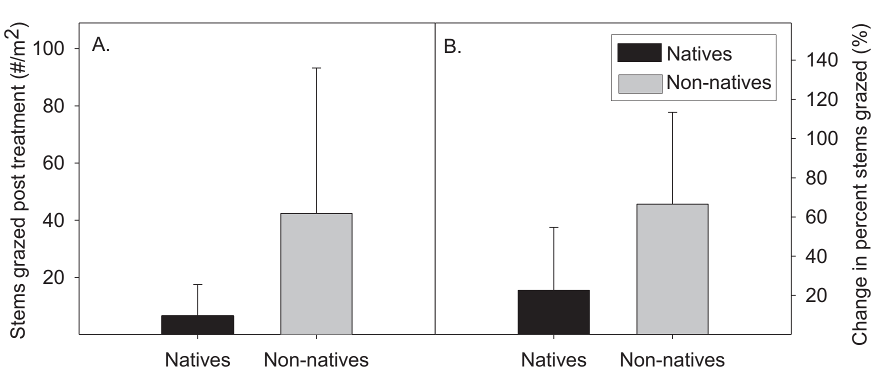

Figure 1. Mean (± 1 standard error) number of stems grazed post-treatment **(A)** and mean change in percent stems grazed pretreatment versus post treatment (**B**) for native *(black bars)* and non-native *(gray bars)* forbs.

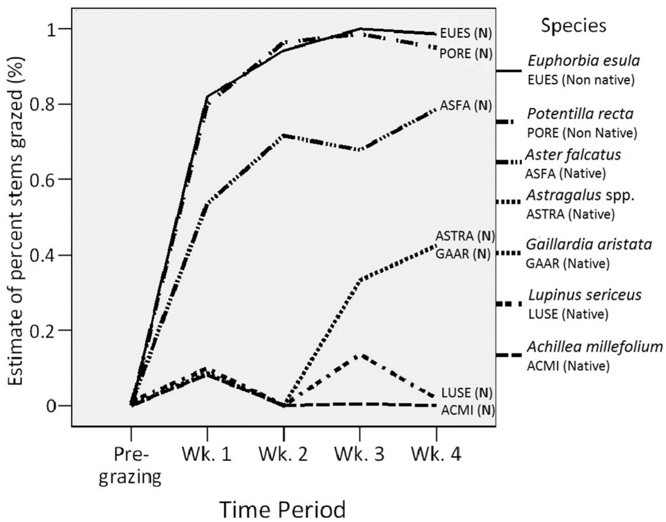

Figure 2. Trend (pregrazing to wk 4 of grazing) in estimated percent stems grazed for common forbs that were grazed: *Euphorbia esula* (leafy spurge), *Potentilla recta* (sulphur cinquefoil), *Aster falcatus* (white prairie aster), *Astragalus* spp. (milkvetch), *Gaillardia aristata* (blanket flower), *Lupinus sericeus* (silky lupine), and *Achillea millefolium* (yarrow). *Gaillardia aristata* and *Astragalus* spp. have the same trace style because they follow the same trajectory. *Tragopogon dubius* (salsify) is not shown because it occurred infrequently on selected plots.

Discussion

Sheep dietary preferences are an important consideration for managed grazing programs. Despite our small sample size, we found that sheep preferred non-native over native forbs but increased consumption of natives as the availability of non-natives decreased. Preferred forage species had some consistent traits: seven of eight preferred species were tall in stature (the exception was milk vetch) and had tender, nonwaxy leaves (the exception was white prairie aster). These results are consistent with Evju et al. (2009) and Diaz et al. (2001) but contrast with Cingolani et al. (2005), who found sheep preferred short species with tough leaves. The two most preferred species, sulphur cinquefoil and white prairie aster, both flowered late in the grazing period, consistent with Hellström et al. (2003), who found that sheep preferred late-flowering species.

Our findings suggest that sheep may be effective at controlling a wider array of non-natives than previously thought. Although impacts of grazing are well documented for certain non-natives, such as leafy spurge (e.g., Landgraff et al., 1984; Olson and Lacey, 1994), less is known about other invasive forbs. In our study, sheep selected sulphur cinquefoil over all other non-native forbs but also consumed yellow salsify, common dandelion, spotted knapweed, Dalmatian toadflax, and tall tumble mustard.

Duration of grazing influenced sheep foraging choices over the study period. Grazing of non-native forbs, primarily leafy spurge and sulphur cinquefoil, peaked by the third week of grazing when most available forage from these two species had been grazed. Grazing on two natives, blanketflower and milkvetch, increased only at the end of the grazing period, suggesting that an even shorter grazing period would mitigate impacts.

Management Implications

Given that sheep grazing is increasingly incorporated into weed control programs, it is important to consider best practices for restoring native plant communities while controlling the spread of non-native plants. In areas where native plant establishment is an objective, grazing prescriptions should be based on the relative abundance of both invasive and native forbs. Active monitoring throughout the grazing period and short duration grazing (4 − 8 week) is recommended to ensure animals are moved once target weed removal levels are reached and before damage occurs to native forbs. At our study site, this sweet spot between target and nontarget effects was reached 3 weeks after grazing started. Lastly, to improve the effectiveness of using sheep for restoration, there is a need for information on species-specific effects on native forbs. Toward that end, managers who use sheep for restoration should aim to document effects and share findings.

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References

Austrheim, G., Mysterud, A., Pederson, B., Halvorsen, R., Hassel, K., Evju, M., 2008. Large-scale experimental effects of three levels of sheep densities on an alpine ecosystem. Oikos 7 (6), 837–846.

Bangsund, D.A., Nudell, D.J., Sell, R.S., Leistritz, F.L., 2001. Economic analysis of using sheep to control *E. esula*. Journal of Range Management 54 (4), 322–329.

Cingolani, A.M., Posse, G., Collantes, M.B., 2005. Plant functional traits, herbivore selectivity and response to sheep grazing in Patagonian steppe grasslands. Journal of Applied Ecology 42 (1), 50–59.

Diaz, S., Noy-Meir, I., Cabido, M., 2001. Can grazing response of herbaceous plants be predicted from simple vegetative traits? Journal of Applied Ecology 38 (3), 497–503.

Evju, M., Austrheim, G., Halvorsen, R., Mysterud, A., 2009. Grazing responses in herbs in relation to herbivore selectivity and plant traits in an alpine ecosystem. Oecologia 161 (1), 77–85.

Gibson, C.W.D., Watt, T.A., Brown, V.K., 1987. The use of sheep grazing to recreate species-rich grassland from abandoned arable land. Biological Conservation 42 (3), 165–183.

Hellström, K., Huhta, A., Rautio, P., Tuomi, J., Oksanen, J., Laine, K., 2003. Use of sheep grazing in the restoration of semi-natural meadows in northern Finland. Applied Vegetation Science 6 (1), 45–52.

Landgraff, B.K., Fay, P.K., Havstad, K.M., 1984. Utilization of *E. esula* (*Euphorbia esula*) by sheep. Weed Science 32 (3), 348–352.

Landsberg, J., James, C.D., Maconochie, J., Nicholls, A.O., Stol, J., Tynan, R., 2002. Scale related effects of grazing on native plant communities in an arid rangeland region of South Australia. Journal of Applied Ecology 39 (3), 427–444.

Manly, B.F., McDonald, L., Thomas, D., McDonald, L., Erickson, W.P., 2002. Resource selection by animals: statistical design and analysis for field studies. Kluwer Academic Publishers, Dordrecht, The Netherlands 222 p.

Mavromihalis, J.A., Dorrough, J., Clark, S.G., Turner, V., Moxham, C., 2013. Manipulating livestock grazing to enhance native plant diversity and cover in native grasslands. The Rangeland Journal 35 (1), 95–108.

McIntyre, S., Lavorel, S., 1994. Predicting richness of native, rare and exotic plants in response to habitat and disturbance variables across a variegated landscape. Conservation Biology 8 (2), 521–531.

NOAA, 2017. National Climatic Data Center [online]. National Oceanic and Atmospheric Administration (Producer), Silver Springs, MD, USA Available at:. http://www.ncdc.noaa.gov/oa/ncdc.html, Accessed date: 10 May 2017.

Norton, D.A., Young, L.M., 2016. Effects of sheep grazing exclusion on alpine tall tussock grasslands. New Zealand Journal of Ecology 40 (1), 179–185.

NRCS, 2017. Web Soil Survey [online]. US Department of Agriculture, Natural Resources Conservation Service (Producer). Available at:. https://websoilsurvey.sc.egov.usda.gov/, Accessed date: 10 August 2017.

Olson, B.E., Lacey, J.R., 1994. Sheep: a method for controlling rangeland weeds. Sheep Research Journal (Special Issue), 105–112.

Ott, R.L., Longnecker, M., 2010. An introduction to statistical methods and data analysis. 6th ed. Brooks and Cole, Belmont, CA, USA 1273 p.

Schwartz, C.C., Ellis, J.E., 1981. Feeding ecology and niche separation in some native and domestic ungulates on the shortgrass prairie. Journal of Applied Ecology 18 (2), 343–353.

SPSS Inc. Released 2009. SPSS Statistics for Windows, version 15.0 [computer software]. Chicago, IL, USA: SPSS Inc.

USDA, Natural Resources Conservation Service, 2015. The PLANTS database [online]. National Plant Data Team, Greensboro, NC, USA Available at:. http://plants.usda.gov, Accessed date: 10 May 2017.

Villalba, J.J., Provenza, F.D., 1999. Effects of food structure and nutritional quality and animal nutritional state on intake behavior and food preferences of sheep. Applied Animal Behavior Science 63 (2), 145–163.