IMPACTS OF GOAT BROWSING ON SALT CEDAR STANDS IN WEST TEXAS

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TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

ABSTRACT

The objectives were to measure goat performance and preference of saltcedar (SC) in a pasture setting as well as SC response to browsing. Sixteen Boer-cross goats were conditioned to SC in individual pens for 16 days. SC and basal diet intake was recorded during conditioning, as well as goat weights throughout the study. Ten goats were then placed in 20’X40’ pens situated in dense SC stands, three plots per treatment. Treatment 1 consisted of plots grazed once; Treatment 2 consisted of plots grazed twice, after sufficient re-growth was observed on the SC plants. Additionally, 18 SC seedlings were defoliated by hand and measured for height and mass. SC intake increased over time in the conditioning and field trials. Goat weight did not change. SC cover decreased following treatment but did not differ between treatments. Mortality did not occur in any seedlings but height and aboveground mass were reduced by defoliation.

INTRODUCTION

Tamarix ramosissima Ledeb., or salt cedar, is a phreatophytic shrub native to China that was introduced into the U. S. in the 1920's for erosion control (Di Tomaso 1998). It invades western riparian areas and negatively impacts hydrologic function in stream systems, impacts local soil characteristics and, subsequently, impairs productivity and biodiversity of riparian areas (Di Tomaso 1998). This has resulted in a loss of wildlife habitat and rangeland production capacity (Belzer 2005; Di Tomaso 1998). Traditional control methods such as prescribed fire, mechanical removal and herbicide application have proven expensive compared to other brush control projects and have had varied success (Lovich et al 1994; Taylor and McDaniel 1998; Belzer 2005). Because of the high cost of these control methods and the environmental risk they impose, land managers are investigating biological control as an alternative.

Biological control of *Tamarix* spp. has historically been limited to salt cedar beetles, which have proven to be effective in many cases but have also demonstrated important limitations (Hudgeons et al. 2007). For example, salt cedar beetles are often incompatible with chemical control and fire, and colonies can be difficult to establish (Moran et al. 2009).

Recently, several studies have indicated sufficient nutrient content and palatability of *Tamarix* as forage for ruminants, especially goats (Munoz 2007; Garcia 2011; Knight 2012). Goats have been shown to readily consume salt cedar in individual pens and increase intake as the amount of basal ration is reduced (Knight 2012). Crude protein levels in *T. ramosissima* fed during Knight's trials ranged from 16-20% while total digestible nutrients (TDN) ranged from 67-69%. Collectively, these results suggest that salt cedar is both

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Rangeland Ecology and Management

palatable and nutritious. Unfortunately, no data exist on salt cedar intake in free-choice pasture conditions. Likewise, there is no evidence of the impact of goat browsing on salt cedar vigor and survival.

OBJECTIVES

The objectives of this study were to:

1. Determine rate of selection of *Tamarix* forage in a pasture setting using goats conditioned to salt cedar
2. Determine the rate of *Tamarix* plant reduction in cover and mortality under grazing pressure

LITERATURE REVIEW

Control Methods

Historically, *Tamarix* spp. have shown variable response to herbicides, almost always necessitating re-treatment (Hart et al. 2005). Several invasive *Tamarix* species are susceptible to chemical control, especially Imazapyr® (Hart et al. 2005), but this method is costly and can cause environmental damage (Moran et al. 2009). For example Imazapyr® is a broad spectrum herbicide that may kill or damage other plant species.

Salt cedar beetles (*Diorhabda* Weise sp.) have been released in the U.S. as a biological control method, with varying success of establishment (Pattison et al. 2011). The northern salt cedar beetle (*Diorhabda carinulata* Desbrochers) has established colonies in northwest sites, while three other species (larger salt cedar beetle, Mediterranean salt cedar beetle, and the subtropical salt cedar beetle) successfully established colonies in southwest sites.

Salt cedar beetles can defoliate plants very effectively, and are host-specific. Moran et al. (2009) treated *Tamarix* stands successfully with beetles in Big Spring, TX, and recorded a high level of defoliation of salt cedar stands, sometimes twice annually. However, at a different Texas site, the authors noted struggling beetle populations, and attributed this to limited regrowth of salt cedar stands following defoliation and their lack of ability to support beetle populations effectively. In most cases, successful beetle programs include control of salt cedar stands rather than eradication. Complete eradication of salt cedar stands by the salt cedar beetle is unlikely because even after years of exposure to beetles, plant mortality often did not occur (Pattison et al. 2011).

Potential role of goats as a biological control

Results of studies in west TX have demonstrated the potential for goats as a biological control of *T. ramosissima*. Goats exhibited high consumption of *Tamarix* in a pen setting (Knight 2012), as well as adequate performance under a *Tamarix* diet (Munoz 2007; Knight 2012). Nutrient analysis of *T. ramosissima* on the west TX study site revealed high crude protein content and low intake-limiting factors, highlighting its potential as a palatable and nutritious feed source (Knight 2012). These findings are consistent with results of a previous study (Garcia 2011) that found no significant effect of protein supplementation on intake of *T. ramosissima* with goats.

Use of halophytes as feed source

Salt tolerant plants, or halophytes, have been used as a forage source in their native environments for centuries (Masters et al. 2007; El Shaer 2010). Many halophytes can be a valuable feed source especially because they offer relatively high nutrient value during drought conditions or dry seasons (El Shaer 2010). For instance, *Atriplex* sp. (saltbush) are widely used in many parts of the world as a valuable feed source because they are high in crude protein (Norman et al. 2004; Abu-Zanat and Tabbaa 2006; Norman et al. 2010). Nomadic herders graze camels and goats on *T. nilotica* in Egypt (Badri and Hamed 2000) and camels graze *T. ramosissima* in the Taklamakan desert in Western China (Vonlanthen et al. 2011). *Tamarix* nutrition and palatability varies seasonally and by location, which could impact the feasibility of using grazing as a control method.

Nutrient variation throughout the season

Tamarix leaves typically senesce under cold temperatures and re-grow when spring temperatures are high enough (Pattison et al. 2011). Percent nitrogen and % phosphorus in

Tamarix leaves decrease as the growing season progresses (Gonzalez et al. 2010). Arndt et al. (2004) recorded variation in salt concentration by season in *T. ramosissima* leaves in China, with high sugar (alcohol pinitol) concentrations corresponding with the higher concentrations of salts. These sugars act as an osmotic adjustment mechanism in the leaf tissues.

Site specific nutrient variation

Salt cedar accumulates salts in its leaf tissue and excretes them onto the leaf and stem surface, depositing crystals. The concentrations of salts in the leaves as well as the amount of salt excreted on the leaf surface depend on site-specific soil properties (El-Beheiry and El-Kady 1998). Gonzalez et al. (2010) reported higher nutrient variability within several species of *Tamarix* growing on different sites central Spain, than when compared against *Populus* (cottonwood) trees of the same sites. El-Beheiry and El-Kady (1998) reported higher nutrient variation between different stands of the same species of *Tamarix* in Egypt than between *T. nilotica* and *T. aphylla* from the same site. Salt cedar's capacity for nutrient variation between sites may affect palatability and might impose challenges for its use a feed source.

Crude protein

Many halophytes including *Tamarix* sp. and *Atriplex* sp. contain relatively high levels of crude protein (El Shaer 2010; Badri and Hamed 2000; Knight 2012); however, crude protein levels reported in the literature may misrepresent actual protein value depending on the amount of non-protein nitrogen included in the measurements (Masters et al. 2007). Non-protein nitrogen could constitute up to 50% of these data (El Shaer 2010). Non-protein nitrogen can become bio-available if consumed with adequate metabolisable energy (Masters et al. 2007; Norman et al. 2004; El Shaer 2010). Therefore, a feed source with high metabolisable energy may be necessary for complete utilization of the nitrogen available in halophyte forages (El Shaer 2010). A mixed diet of grasses, legumes, shrubs, and forbs could also enhance intake of halophytes due to differing carbohydrate, fiber, nitrogen and mineral compositions (El Shaer 2010). Unfortunately, dense stands of *Tamarix* are typically characterized as monocultures with little availability of other classes of forages.

Tamarix ramosissima **response to defoliation**

T. ramosissima can show a negative response to repeated grazing pressure, including reduced vigor and regrowth, reduced seedling survival, reduced reproduction, and in some cases mortality with consecutive seasons of defoliation (Vonlanthen et al. 2011; Hudgeons 2007). Vonlanthen et al. (2011) noticed decreased survival of planted *T. ramosissima* seedlings and vegetative fragments under the presence of grazing animals (camels, goats, sheep and donkeys) in the Taklamakan Desert of China.

While beetle colonies have been shown to completely defoliate *T. ramosissima* stands, the trees can re-grow leaves within weeks (Hudgeons et al. 2007; Pattison et al. 2011). Repeated defoliation, however, has been shown to reduce plant carbohydrate reserves (which are necessary for regrowth of leaf tissues) and could reduce plant longevity (Hudgeons et al. 2007).

Hudgeons et al. (2007) studied the reductions in non-structural carbohydrate reserves following beetle defoliation of *T. ramosissima* stands in TX and NV as an indicator of plant health. The reduction in starch reserves was greatest after one year of defoliation, somewhat less after the second year, and not significant after the third and fourth year of defoliation. The authors reported an estimated 40% death rate of trees defoliated for four consecutive years, reduced re-growth after a single year of defoliation, and reduced ability for seed production, especially since the trees were defoliated completely before they were reproductively active. In a Big Springs, TX study, Moran et al. (2009) noticed complete defoliation of *T. ramosissima* trees in 60 ha of study site, twice annually in some cases. *Tamarix* trees exhibited less regrowth each subsequent year of defoliation, with 25% mortality within 3 years.

Repeated herbivory can reduce root growth, which can affect plant water intake and, subsequently, drought tolerance (Pattison et al. 2011). However, the initial effects of herbivory on plant water status can be a temporary increase in water status as a result of an increase in root to shoot ratios (Pattison et al. 2011). In central NV, Pattison et al. (2011) recorded an initial increase in water status in *T. ramosissima* trees exposed to beetle defoliation, but reduced stem growth in trees following two years of beetle defoliation. After four years of defoliation, the authors found reduced water status in *Tamarix* trees, possibly because of reduced root growth. These results suggest that repeated grazing by goats could be sufficient to induce mortality in *Tamarix* stands, or reduce plant vigor enough to increase the efficacy of other control methods.

METHODS

Goat Conditioning

Sixteen recently weaned (approximately 90 days old, 29.4 ± 1.5 kg) female Boer-cross goats were placed in individual pens (1 X 1.5 m) and fed salt cedar for 16 days. Salt cedar was offered each day (1300) for 30 min with refusals weighed to estimate intake. At 1400, goats were offered a basal diet at 2.5% BW (Table 1) to meet maintenance requirements (NRC 2007). Refusals of the basal diet were also weighed after 30 min to estimate intake. Goats also had *ad libitum* access to fresh water and trace mineral blocks. Goats were weighed prior to their placement in pens and at the end of the 16-day feeding trial. Ten goats with the highest intake of salt cedar following the conditioning trial were selected to graze treatment plots.

Treatment Plots

Six 20’ X 40’ plots, three for each treatment, were constructed in dense salt cedar stands in the dry lake basin at O.C. Fisher Reservoir, San Angelo, TX. The salt cedar plants were estimated to be roughly two years old, having emerged since the reservoir water receded in 2010. Pens were constructed using welded wire panels supported by t-posts. Percent canopy cover of salt cedar, grasses, forbs, and other shrubs was estimated using the line transect method (Bonham 1989) within each plot prior to and after each grazing period. Additionally, the plots were photographed before and after each treatment.

Treatment 1 consisted of plots grazed once in the growing season. Six goats were used in this treatment. Treatment 2 consisted of plots grazed twice, after sufficient new growth was observed on the salt cedar plants. Plots were grazed for three days until all salt

Table 1. Ingredient and nutrient content of the basal diet. Data reported herein was on an as fed basis.

Ingredient	Percent (%) in the Feed
Sorghum grain	45.0
Cottonseed meal	10.0
Soybean hulls	22.5
Alfalfa pellets (dehydrated)	17.0
Cane molasses	3.5
Premix[1]	2.0
Nutrient Content	
Crude protein	14.8
Digestible protein	10.0
Digestible energy (Mcal/kg)	2.8
Crude fiber	14.1
TDN	63.0

[1]Premix includes: Lasalocid, calcium, salt, manganese, zinc, selenium, copper, Vitamins A, D, and E.

cedar plants were completely defoliated. Each treatment was replicated by establishing three plots per treatment. Additionally, three control plots were established adjacent to the treatment plots the same stand of salt cedar.

Goats were released each morning and allowed to remain on the plots for 10 hrs. Bite counts were recorded for individual goats for 10 min intervals to estimate diet selection. Each 10 min interval was repeated until all goats had been observed.

After each feeding bout, all goats were housed together. The basal diet was offered at 2.5% BW per day to meet maintenance requirements. A calcium/phosphorus mineral supplement along with fresh water was offered *ad libitum* as well.

Hand Defoliation

In addition to the goat browsing trials, individual salt cedar plants were defoliated by hand to mimic goat browsing, and monitored for plant vigor and regrowth. Fifteen live salt cedar plants were transplanted to pots and transferred to a greenhouse where they were maintained under optimal growing conditions. Treatments consisted of eight seedlings defoliated by hand and seven seedlings left undisturbed as a control. They were measured for height, and then clipped to the nearest woody stem, removing all leaves and green stems. They were monitored for re-growth, and re-measured and clipped repeatedly in this manner for a total of three clippings. After re-growth was observed following the third treatment, all plants were harvested and dried in an oven. Aboveground mass and belowground mass of treatment seedlings were weighed and compared to control seedlings.

In addition to the seedlings in the greenhouse, 20 salt cedar seedlings growing naturally in the study area were marked and measured for height. Ten seedlings were defoliated by hand and 10 were left as a control. All seedlings were re-measured prior to each treatment. The defoliated seedlings were monitored for re-growth, and re-clipped when sufficient re-growth was observed, for a total of three defoliations.

Data was analyzed using repeated measures analysis of variance with treatments serving as the main effect, goats nested in treatments as the random effect, and day of observation as the repeated measure. Means were separated using Tukey's LSD when $P \leq 0.05$. Data was analyzed using the statistical package JMP® (SAS 2007).

RESULTS

The goats readily consumed salt cedar in the conditioning trial. Mean intake increased from 1.3 g · kg^{-1} BW on day one of the conditioning phase to 11.2 g · kg^{-1} BW by the end of the trial (Fig. 1). Intake of the basal diet increased throughout the conditioning trial as well (Fig. 2). There was no change ($P > 0.05$) in mean goat weight throughout the conditioning trial. Initial goat weights were 29.4±1.5 kg versus 27.0±1.5 kg after the trial.

All goats used in the field trials readily consumed salt cedar when foraging in plots. Goat weights did not change significantly ($P > 0.05$) during the field treatments. Initial goat weights were 27.9±1.4 kg, versus 33.2±2.3 during Treatment 1 and 32.7±1.8 kg during Treatment 2. Mean salt cedar bite counts increased from day 1 to day 3 across pens in each treatment, while grass bite counts decreased (Table 2). There were no differences in bite counts for any forage type between treatments ($P > 0.05$).

Vegetative cover was evaluated by comparing the mean value of the plots before treatment versus after treatment, between treatments, and treated plots versus control plots. Plant species present in the plots included salt cedar (*T. ramosissima*), willow baccharis (*Baccharis salicina* Torr. @ Gray), Bermuda grass (*Cynodon dactylon* (L.) Pers.), Texas grass (*Vaseyochloa multinervosa* (Vasey) Hitchc.), and several forbs present in trace amounts. Goats reduced cover of both salt cedar and grass. Salt cedar cover was significantly reduced in all treatment plots immediately after goat browsing. However, there were no differences ($P > 0.05$) in cover of salt cedar or grass between Treatment 1 and Treatment 2. The treatment by time interactions were significant, suggesting the goats reduced salt cedar cover by a greater value during Treatment 2 than during Treatment 1. Mean salt cedar cover

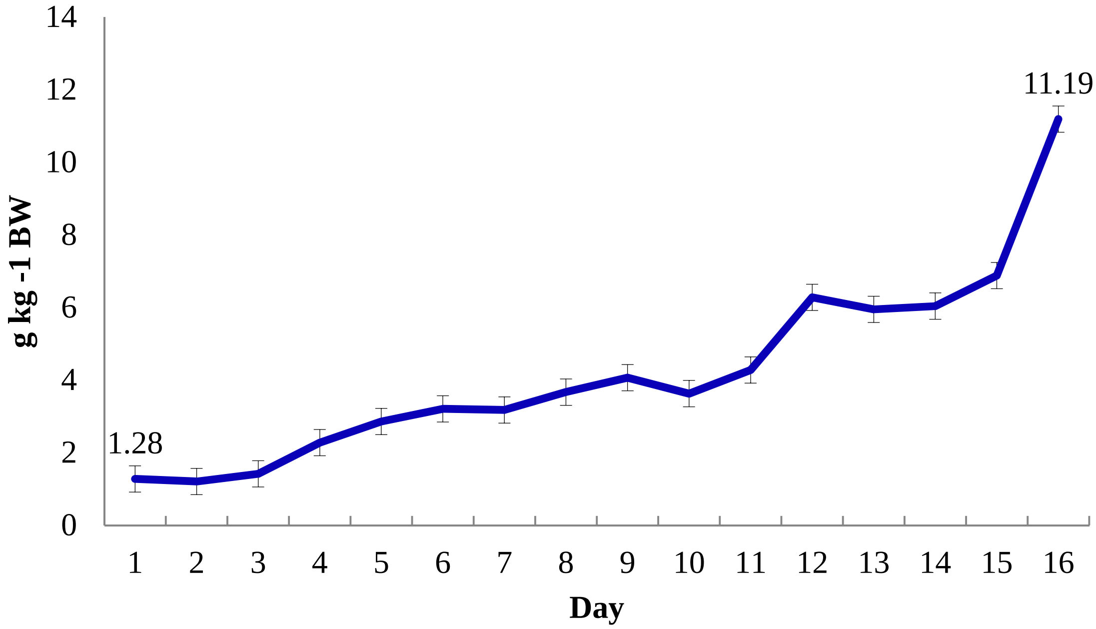

Figure 1. Mean salt cedar intake increased (P < 0.05) during the conditioning trial. Goats were fed individually for 16 days.

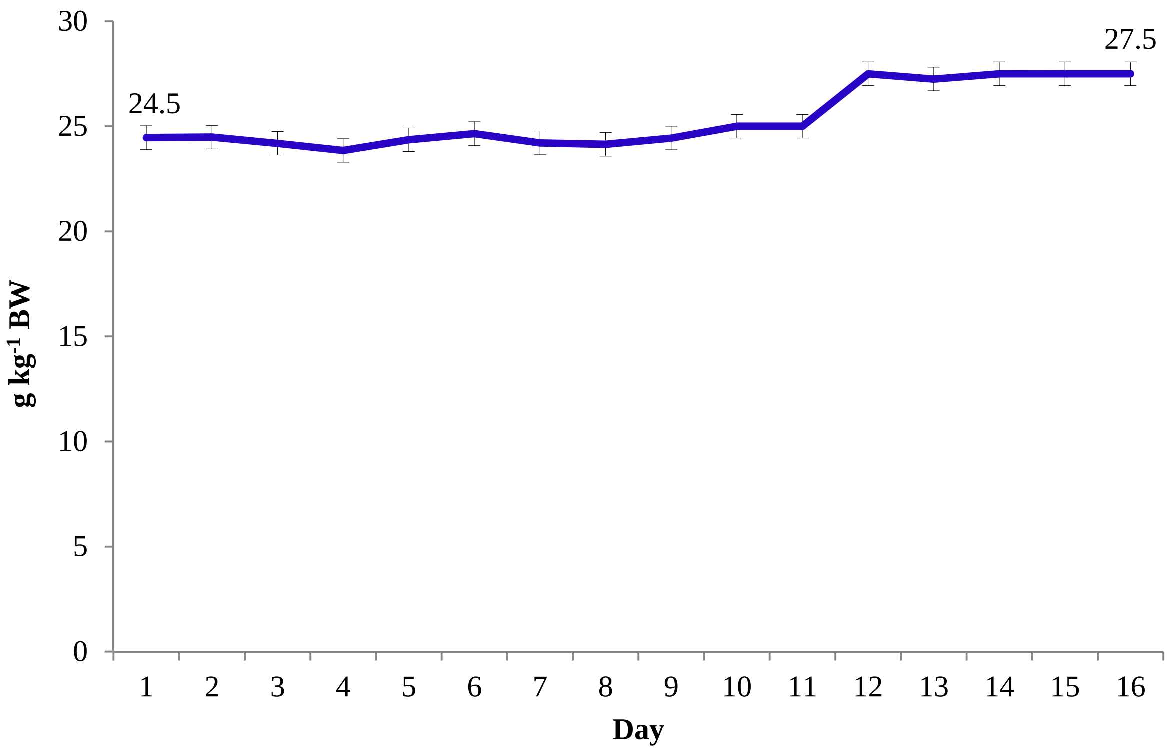

Figure 2. Mean intake of basal diet increased ($P < 0.05$) during the conditioning trial. Goats were fed individually for 16 days.

Table 2. Mean bite counts by forage type as a percentage of total intake. Data were pooled across treatments.

	Day		
	1	**2**	**3**
Salt cedar	56.0±4.6^{a}	73.4±4.6^{b}	86.5±6.2^{b}
Grass	34.7±4.1^{a}	22.2±4.1^{ab}	13.7±5.5^{b}
Forbs	4.8±0.9^{a}	0.0±0.9^{b}	0.2±1.3^{b}

$^{a\text{-}b}$Means within rows with different superscript differ ($P < 0.05$).

was less in browsed plots after the treatment than in the control plots (Table 3). Percentage mean grass cover was significantly reduced in the treatment plots immediately after treatment, from 5.5±1.4 to 1.0±1.6. Cover of forbs was not altered significantly.

Mortality was not observed in any hand defoliated seedlings in the greenhouse or in the field. All greenhouse and field seedlings readily re-sprouted after defoliation. Seedling height differed between defoliated and non-defoliated plants. Defoliated plants were shorter and had less above ground mass. Root mass did not differ ($P > 0.05$) between greenhouse treatment seedlings and non-treatment seedlings, but above-ground mass was lower in the treatment seedlings (Table 4).

Table 3. Salt cedar cover (%) before and after goat browsing.

Treatment	**Before**	**After**
1	26.7 ± 3.6^{a}	17.0 ± 4.4^{b}
2	30.8 ± 3.6^{a}	11.6 ± 3.6^{b}
1 and 2 Average	--------	12.7 ± 4.4^{c}
Control	37.6 ± 3.3^{d}	--------

$^{a-b}$Means with different superscript differ ($P < 0.05$).
$^{c-d}$Means with different superscript differ ($P < 0.05$).

Table 4. Greenhouse seedling weight before and after hand defoliation. Plants were maintained in pots in a greenhouse and watered daily.

	Treatment	
	Defoliated	**Control**
Aboveground mass (g)	3.3±1.9[a]	16.4±2.0[b]
Root mass (g)	2.9±1.2[a]	5.8±1.2[a]

[a-b]Means within rows with different superscript differ ($P < 0.05$).

DISCUSSION

The goats consumed salt cedar for a total of 42 days. The lack of change in goat weight in either the conditioning trial or the field trials attests to the nutritional value of salt cedar as a forage species. These observations support the nutritional analysis and intake patterns observed by Knight (2012).

Although salt cedar preference (bite counts) was measured instead of intake in the field, the goats readily selected salt cedar shrubs and defoliated them heavily (Table 2). Goats drastically reduced the cover of salt cedar immediately after the treatment, indicating that they consumed a large quantity of salt cedar forage. The treatment by time effect revealed by the ANOVA test is attributed to the goats learning to become more effective browsers of the shrubs. In Treatment 1, the goats were observed to browse only as high as they could reach, while in Treatment 2 the goats would bend tall plants over to defoliate the parts beyond their reach. During Treatment 2 goats were observed stripping bark, breaking and eating twigs, and digging up roots. It is also possible that the goats could have adapted physiologically to an intake limiting factor present in the salt cedar foliage (Distel and Provenza 1991) that allowed them to consume more as the trials went on. Consumption of salt cedar in field trials was not attributed to shortage of alternative feed since the goats continued to receive a full maintenance ration.

A conditioning trial appears key to increasing intake of salt cedar (Fig. 1). During the first few days of conditioning, the goats ate little salt cedar (around 1.3 $g \cdot kg^{-1}$ BW), before increasing intake (Fig. 1). However, by the end of the conditioning trial, they consumed much larger (11.2 $g \cdot kg^{-1}$) amounts of salt cedar. Because of the low intake during the first few days of the trial, it appears that salt cedar intake would be similarly low in a pasture situation. It remains unclear what intake limiting factor prevents goats from eating salt cedar without conditioning. During the first few days of the conditioning trial, goats appeared to be familiarizing themselves to a novel food, in anticipation of a positive or negative feedback after ingestion (Provenza 1995). Because intake continued to increase, aversive postingestive feedback from consuming salt cedar seems unlikely. Distel and Provenza (1991) found that exposing goats to blackbrush (*Coleogyne ramosissima* Torr.) early in life increased their consumption of that shrub later in life. Morphological and physiological adaptions to the toxins in blackbrush were likely a result of that early exposure, and allowed the exposed goats to consume and possibly detoxify higher quantities of blackbrush. Similar observations were made by Munoz (2007) and Knight (2012). In this study, the continued increase in intake could have resulted from similar adaptations.

Salt is the most obvious possible intake-limiting factor in salt cedar. High salt intake affects different species of ruminants differently. High salt intake increases water intake and urine output of sheep while reducing feed intake and growth rate (Hamilton and Webster 1987; Assad and El-Sherif 2002; Badri and Hamed 2000). Abu-Zanat and Tabbaa (2006) fed saltbush (*Atriplex* sp.) to sheep in Jordan and mentioned increased water intake and influences on rumen physiology and metabolism due to the high salt content of the forage. Goats, however, have a higher tolerance for salt in the diet, second to camels (Masters et al. 2007). High salt intake did not affect water consumption in pygmy goats, but decreased feed intake and thus the ratio of feed: water (Rossi et al. 1998). In this study, however, neither water intake nor feed intake seemed to be affected (Fig. 2) by the apparent high salt content of salt cedar forage. Moreover, Knight (2012) did not find water consumption to increase as salt cedar intake increased in goats. Apparently, the high water content (67.8%) accounted for any additional water intake requirements from consuming salt cedar (Knight 2012).

Other intake-limiting factors such as flavonoids may be present in salt cedar as well, but the amounts of secondary compounds and their level of toxicity in *T. ramosissima* are not well studied. Badri and Hamed (2000) reported large amounts of flavenoids and trace amounts of steroids and terpenoids in *T. nilotica*, but did not mention these secondary compounds to have an effect on palatability or forage value. They reported flavenoids to have a function in protecting plants from microbial disease, rather than protection against herbivory. Thus, further research is necessary to determine the presence and amounts of secondary compounds in *T. ramossisima* and their effect on ruminant digestion. Given that goats readily selected and consumed salt cedar in this study and others suggests that any secondary compounds in salt cedar are not limiting intake.

On day one of the grazing trials, the mean percentage of bites of salt cedar for all goats was 56.0±4.6, versus that of grass (34.7±4.1). Because bite counts were taken as soon as the goats were released into the pen, all classes of forage were available at the time. For that reason, the bite counts on day one could approximate the proportion of salt cedar versus grass in their diet in a free-range condition. At those proportions of intake, salt cedar appears to be favored forage. The cover of grass and other forage was lower in the plots compared to salt cedar (grass was 5.5%, forbs were negligible; compared to 28.8% salt cedar cover), but they were available to all goats during the bite count observations. Goats chose salt cedar over grass or forbs even when other classes of forage were available to them.

Salt cedar appears to be an extremely resilient shrub, able to tolerate repeated defoliations and trauma to bark, twigs and roots. Browsed salt cedar plots re-grew to within 92.0% of their initial cover, within an average of 36 days. Plots browsed twice re-grew to within 97.2% of their cover within an average of 45 days. A seven-inch rainfall following the treatments possibly contributed to the re-growth of the salt cedar stand. Shelly Simmons, Assistant District Forester for the Colorado State Forest Service, and Dr. Daniel Bean, Research Entomologist for the Colorado Department of Agriculture, maintain that combination of stressors, such as drought and repeated defoliation, may increase mortality of salt cedar plants faster than defoliation alone (personal communication). Researchers using beetles as biological control have reported that it takes a minimum of three defoliations to kill salt cedar, and have seen plants defoliated as many as nine times before mortality occurred (Daniel Bean, personal communication).

Salt cedar management might not necessitate whole-stand mortality. Reduced biomass and reduced reproductive capacity can decrease colonization and reduce salt cedar's competitive ability (Daniel Bean, personal communication). There are a handful of weed control contractors that specialize in using goats to control salt cedar. Ruth Richards from Big Horn County Weed and Pest (WY) reports favorable results for using goats to increase access to thick salt cedar stands and to decrease the amount of herbicide necessary in a follow up treatment (personal communication). Tartowski and Darren (2005) gathered data on a NM study with 400-630 goats browsing salt cedar stands along the Rio Grande. They reported aggressive salt cedar consumption, biomass removal and goat weight gain throughout the study. Goats were particularly effective as a follow up treatment to previous mechanical removal treatments, where they reduced the density of re-sprouts. Ralph Spreen, a Ballinger, TX rancher, continuously grazed 20 Boer goats in a 300 acre pasture adjacent to the receding O.H. Ivie Lake. He noticed mortality of salt cedar seedlings in the pasture, while adjacent pastures not subject to goat browsing were taken over by salt cedar within several years (personal communication). Collectively, these experiences suggest high potential for the use of goats as a tool for salt cedar control.

IMPLICATIONS

Tamarix ramossisima offers adequate nutrition and palatability to be used as forage for goats. There is potential for biological control of salt cedar with goats since performance requirements are met on a salt cedar diet. Conditioning appears key to increasing consumption of salt cedar. At this point, it is unclear whether repeated browsing will cause salt cedar plant mortality, and a longer-term study will be necessary to gain this understanding. However, biological control of salt cedar with goats remains a viable option especially if used in combination with other control methods. The low cost and lower environmental impact of goat browsing enhances its value in comparison with traditional control methods.

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