INTAKE OF SALT CEDAR BY TWO DIFFERENT BREEDS OF SHEEP

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ABSTRACT

Salt cedar encroachment is of great concern in the western portion of the United States. Control attempts have been made with leaf beetles and herbicides in the past, but none yet have been found to be completely successful. The goal of this experiment was to determine if two breeds of sheep would consume salt cedar. Twelve Rambouillet and twelve Suffolks, along with ten Boer goats were penned for approximately one month and fed a basal ration for maintenance and growth, along with fresh salt cedar. Salt cedar intake was measured daily and body weights were taken approximately every week. Initially, intake was low, but after 2 days, consumption levels consistently increased. There was no difference between breeds of sheep, but sheep did eat more salt cedar than goats. Other than the first weigh period, animal weights consistently increased throughout the experiment.

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INTRODUCTION

Salt cedar (*Tamarix* spp.), an introduced halophyte, has had a detrimental impact on riparian zones across the western portion of the country. Since its arrival in the 19th century, salt cedar has taken dominance over most native plants within its realm, primarily dominating riparian zones and flood plains (Shafroth et al. 2005). Once salt cedar becomes established, rapid encroachment is inevitable. Salt cedar out-competes native species, causing dense monocultures resulting in a reduction of biodiversity and degradation of stream flow. Attempts to control salt cedar have been made, but none yet have been found to be entirely feasible.

Salt cedar is native to Eurasia, but was brought over by settlers and intended for ornamental purposes. From here, it escaped cultivation and made it to riparian areas and lake basins. The spread of salt cedar was the result of multiple factors. Settlers planted salt cedar to serve as wind breaks, shade for livestock, and to help battle erosion in arid and semiarid areas. Around the 1870's, salt cedar was believed to have escaped cultivation, and by the 1930's had become a serious issue along lake shores (Brotherson and Winkel 1986). It was not until around this time that salt cedar was finally noticed flourishing along riparian areas, diminishing native species along the way and having noticeable impacts on water flow. It is estimated that salt cedar has already replaced native species in 470,000-650,000 ha of riparian floodplain habitat in 23 states (Zavaleta 2000). Along with causing disturbances in biodiversity, salt cedar has been shown to cause issues with stream flow in rivers and streams. Dense thickets cause a decline in natural erosion to take place, narrowing flood

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plains and increasing flood occurrence with less rainfall (Blackburn et al. 1982).

Efforts to remove salt cedar populations have been successful for limited time periods, until re-establishment takes place. Mechanical and chemical removal methods can be somewhat effective, but at high cost. In New Mexico, costs ranged from $750-$1300/ha (Taylor and McDaniel 1998). These methods must be regularly implemented in order to maintain control of an area due to rapid reproductive rates. High costs and labor intensity make this method difficult to sustain. Even after removal has been performed, a return of native vegetation is necessary to bring value back to the land and prevent erosion.

In 2001, the salt cedar leaf beetle (*Diorhabda elongata*) was released in 6 states in an attempt to control salt cedar (Dudley and DeLoach 2004). Leaf beetles do consume the plant, but their effects on plants in nature do not cause mortality, only defoliation (Dudley and DeLoach 2004). Although mortality is not common from leaf beetle predation, it can be used as a method to slow intrusion. In addition, beetle populations are often difficult to establish in some locations because of ambient conditions. In addition to beetles, goats have been used as a biological control agent for salt cedar. This study explored using sheep as a potential biological control agent for salt cedar.

This objective was addressed by determining the forage value of *Tamarix* for sheep. Intake and performance (weight change) by two different breeds were measured at different levels of salt cedar in the diet. In addition, this study determined if sheep would consume a similar amount of salt cedar as goats.

OBJECTIVES

The objectives of this experiment were to determine if two breeds of sheep would readily consume salt cedar. By determining if sheep will readily consume salt cedar, a new method of control and or use of *Tamarix* may be applied to produce biological as well as financial benefits.

LITERATURE REVIEW

Nurserymen were recorded selling salt cedar for ornamental purposes as early as 1823 in New York (Horton 1964). By the latter part of the nineteenth century, records indicate that the USDA had multiple species of salt cedar planted in their arboretum (Horton 1964). It was not long after that salt cedar had made its way into the western half of the country, establishing itself along rivers and lakes, only to dominate native vegetation, cause a loss of biodiversity, and alter natural stream flow systems. Some of the first populations of salt cedar were probably established during periods of large annual floods followed by years with much lower peak flow (Birken and Cooper 2006). These flood events followed by years of recessed water levels caused a widespread dispersal of salt cedar seeds along riverbeds, only to germinate and repeat the process year after year. Today, it is estimated that salt cedar infests roughly 650,000 ha in North America alone (Zavaleta. 2000).

Invasive capabilities of salt cedar make it an extremely challenging species. The plant produces an estimated average of 100 seeds per square inch in dense stands (Warren and Turner 1975). In the same experiment, 47 seedlings were recorded growing in a one square inch sample plot (Warren and Turner 1975). Chen et al. (2010), demonstrated that *Tamarix* populations respond significantly better than native populations after flooding. Surface water-overflowing caused substantial rises in salt cedar by raising surface moisture, resulting in increased seed germination and plant growth. Flooding also plays an important role in seed dispersal as the seeds float on the surface of water. This characteristic combined with wind patterns drifts seeds in non-flowing bodies of water as well. Mature salt cedar plants are able to survive complete submergence for as long as 70 days, and only partial submergence for even longer periods (Warren and Turner 1975).

When annual floods do not take place and rainfall is a rare event, salt cedar continues to surpass native plants. In a study focusing on drought tolerances in southern Nevada, *Tamarix* showed to be the most tolerant when compared to numerous native phreatophytes by utilizing slow growth rates and higher leaf area per unit of sapwood (Cleverly et al. 1997). This allows salt cedar to withstand long periods of drought better than most native species by utilizing limited water more effectively.

Over the past century, factors such as increasing numbers of manmade dams have caused annual flooding to cease, resulting in a decrease in soil moisture and an increase in saline concentrations at the soil surface (Carter and Nippert 2012). These shifts in surface soil salinity along riparian areas have caused a transformation in plant communities from native species to *Tamarix* due to higher salt tolerances. *Tamarix* has been known to survive salt concentrations three times higher than native cottonwoods and willows and therefore is better capable of establishing communities in these high saline settings (Glenn and Nagler 2005). Not only does *Tamarix* thrive in saline-rich soils, but, after absorbing salt from the soil, it is transferred to glands on the surface of the leaf and then deposited under the canopy of the plant, further reducing competition (Di Tomaso 1998). These salt concentrations vary with location depending on the available nutrient levels within the soil (Berry 1970).

Although floodplains make up a small percentage of aquatic and terrestrial landscape, the control of salt cedar on these locations is of utmost importance because they support high levels of environmental heterogeneity and biological diversity (Birken and Cooper 2006). Infestation of salt cedar in riparian areas results in biological loss by depleting native plant species and the associated wildlife (Dudley and DeLoach 2004). Numerous bird species are found foraging in salt cedar thickets, but in lower numbers and with less diversity when compared to native stands (Dudley and DeLoach 2004, Ellis 1995). One reason for the lack of avian diversity in salt cedar stands is due to the fact that there is a lack of insects to consume. Greater insect diversity and abundance is found among native stands, whereas salt cedar tends to be limited to insects, such as cicadas and European honey bees (Di Tomaso 1998, Glenn and Nagler 2005).

Increased *Tamarix* densities along streambeds reduce natural erosion patterns causing channels to narrow, flow rates to rise, and an increase in the frequency of flooding (Di Tomaso 1998, Glenn and Nagler 2005). Along with changing flow regimes in rivers and streams, *Tamarix* stands affect aquatic life as well. A study in Nevada focusing on effects of *Tamarix* on aquatic life indicated that excessive stream shading by salt cedar caused a reduction of algae growth, resulting in several native fish populations to decrease (Kennedy et al. 2005).

Water consumption rates are also a topic of concern regarding *Tamarix* encroachment. Several undocumented reports have estimated water usage by salt cedar in excess of 700 L/day. When comparing transpiration rates of *Tamarix* to sympatric native phreatophytes, Sala et al. (1996) demonstrated that salt cedar rates were no greater than the native species. Owens and Moore (2007) stated that a realistic estimate of the maximum daily water use by a *Tamarix* tree to be 121L. Although water use rates per tree were no greater than native species, the higher density of salt cedar stands may have a substantial effect on water table levels compared to native species (Cleverly et al. 1997).

Some of the first attempts to control salt cedar were with mechanical methods, primarily chaining followed by repeated mowing (Taylor and McDaniel 1998). This technique has little effect on salt cedar stands because of its ability to reproduce from buried root crowns with sufficient moisture. Improvements to this technique include raking the surface material, as well as root crowns into a pile and burning. This technique has shown high mortality rates of 97-99% but at costs ranging from $1500-$1700/ha (Taylor and McDaniel 1998). Chemical control is a successful method depending on mixture rates, time of year, and age of stands. Imazapyr alone or in combination with glyphosate have shown to have success rates of 90% and higher (Duncan and McDaniel 1998). Due to the high densities and ability for salt cedar to reproduce from root crowns, this method is most successful when applied aerially and in multiple treatments (Duncan and McDaniel 1998). Other attempts to eradicate older salt cedar stands have been performed using surface placement of the herbicide Spike 20P followed up with controlled burns. Data from these experiments show that when using higher quantities (5x manufactures recommended rate) of the herbicide followed by fire eight months later mortality rates reached 94% (Stevens and Walker 1998). Although successful kill rates were accomplished, the method requires large quantities of costly herbicide followed by prescribed fires. In the same experiment, test plots were subjected to bark removal or stem pruning followed by herbicide application. Results from these attempts varied from 59-95% kill rates depending on herbicide used and stem treatment (Stevens and Walker 1998). Basal and stump spray methods using numerous herbicides show to be somewhat effective on smaller trunk sizes, but due to vastness of salt cedar stands shows to be unpractical for large scale control (Hughes 1965).

Experiments using biological methods, such as leaf beetles and ruminant animals, have been the latest attempts to find a feasible control method for salt cedar. In 2001, the salt cedar leaf beetle (*Diorhabda elongata*) was released in six states in an attempt to control large stands of salt cedar (Dudley and DeLoach 2004). Although the leaf beetle is successful at defoliating *Tamarix* species, long term success has not yet been established due to the ability of *Tamarix* to re-foliate its branches only weeks after defoliation (Hudgeons et al. 2007). Compared to its native range, the leaf beetle is subjected to shorter day lengths in most of North America, which causes a decline in reproduction and survivability (DeLoach et al. 2003). It was also observed that areas with strong ant populations as well as certain bird species were found preying on the leaf beetle, further reducing its success rates (DeLoach et al. 2003). Although extensive research has been performed on leaf beetle effects in riparian ecosystems the long term impacts of its introduction cannot be determined. In June of 2010, the USDA issued a moratorium on the interstate transportation of the leaf beetle in response to concerns about its potential effects on habitats (Paxton et al. 2011). Rapid dispersal of leaf beetles to non-native areas without extensive ecological understandings could result in complex biological concerns.

MATERIALS AND METHODS

Twenty-four freshly weaned female lambs averaging 36 ± 1.4 kg were penned at the Angelo State University (ASU) Management Instruction and Research (MIR) Center in San Angelo, Texas. Of the 24 lambs, 12 were of the Rambouillet breed and the other 12 Suffolks. A control group of 10 freshly weaned female Boer goats averaging 28 ± 1.8 kg were used as well. Boer goats were used as the control group in conjunction with other on-going research. Each animal was individually penned in 1.5 x 1 m research pen with *ad libitum* access to water and trace mineral. Both treatment and control groups were given a 2.5% BW basal diet of RAM 20 (Table 1) to meet requirements for maintenance and growth (NRC 2007). The RAM 20 diet is commonly used on the ASU MIR Center to meet or exceed dietary requirements of both sheep and goats, depending on the level fed. After a five day pen adjustment period, the individuals from each breed/species were offered salt cedar once a day for 30 minutes, and on day 14, offerings were increased to three times a day. The 5 d adjustment period took place prior to the experiment to allow the animals to acclimate to their pen settings and basal diet. Body weights were taken approximately every 7 d. All research protocols were approved by the ASU Institutional Animal Care and Use Committee (IACUC).

At 0800 each morning, any RAM 20 refusals from the previous day were collected and weights recorded. At 0830 on day 1, 50 g of salt cedar was offered to each animal for 30 minutes. Any refusals were taken up and recorded at 0900. Following the salt cedar, the basal ration was offered for the remainder of the day. Animals that exhibited zero refusals of salt cedar for that day were offered an additional 25 g the following day.

Table 1. Ingredient and nutrient content of the ration used to meet maintenance requirements. 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 (dehy)	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, Vitamin A, D, and E

Following day 14 of the experiment, Rambouillet and Suffolk lambs were offered salt cedar at 0800, 1200, and 1700, to simulate realistic feeding bouts in ruminant animals throughout a day. Refusals were measured and recorded 30 min after each offering of salt cedar. Basal rations remained at 2.5% BW per day for each individual animal.

The salt cedar used in the experiment was harvested at the Angelo State University MIR Center along the receding shorelines of O.C. Fisher Reservoir. Salt cedar leaves were hand-stripped, composited, and placed in large contractor trash bags. Salt cedar not used that day was stored in a large walk-in cooler at 4°C until needed. Collections were stored no more than 4 d before being used to ensure freshness and palatability.

Salt cedar intake data as well as body weight gains were analyzed using repeated measures analysis of variance. Intake data was converted and analyzed on a $g \cdot kg^{-1}$ BW basis to account for variations in body size. Breed served as the main effect and day as the repeated measure. Individual animals were nested within treatments and served as replications. Means were separated using Tukey's LSD Test when $P \leq 0.05$. Statistical analysis was performed on the JMP Statistical Software Package (SAS 2007).

RESULTS

Salt cedar intake was similar between both breeds of sheep (Table 2). Both Rambouillet and Suffolk breeds consumed more ($P<0.05$) salt cedar than goats. Sheep readily consumed salt cedar and increased intake daily (Figure 1). On d 1 of the experiment, animals were hesitant to consume the 50 g of salt cedar offered. Following the first exposure to salt cedar, consumption levels increased steadily throughout the length of the experiment. By the end of the first trial, salt cedar consumption by Rambouillet sheep averaged 5.1 $g \cdot kg^{-1}$ BW, Suffolks averaged 5.6 $g \cdot kg^{-1}$ BW, and goats averaged 6.4 $g \cdot kg^{-1}$ BW. Throughout the experiment, sheep and goats consumed all of the basal rations offered each day.

Weight fluctuated among both breeds of sheep as well as goats but differed among feeding trials. Average body weights of the animals decreased when animals received salt cedar once a day along with the basal ration (Figure 2). Once salt cedar was fed three times a day, body weights began increasing and increased throughout the remainder of the study. Weight changes between Rambouillet and Suffolk breeds were not different ($P>0.05$).

When salt cedar was fed three times a day, intake increased from 17.4 $g \cdot kg^{-1}$ BW to 26.5 $g \cdot kg^{-1}$ BW across the 13 d of feeding (Figure 3). On d 1 of the second feeding period, sheep readily consumed most of the salt cedar offered. The following two days, intake levels decreased slightly, but returned to increasing levels until the end of the study (Figure 3). The breed x day interaction was similar ($P>0.05$). During the thrice daily feedings, no significant ($P>0.05$) differences were found from the a.m., noon, or p.m. feedings (Table 3).

Table 2. Average intake (g · kg^{-1} BW) of salt cedar and the basal ration when salt cedar was fed once a day

	Intake	
Breed/Species	Salt cedar	Basal
Rambouillet	3.2 ± 0.2	25.8 ± 0.3
Suffolk	3.4 ± 0.2	25.8 ± 0.3
Goat	2.4 ± 0.2	24.4 ± 0.3

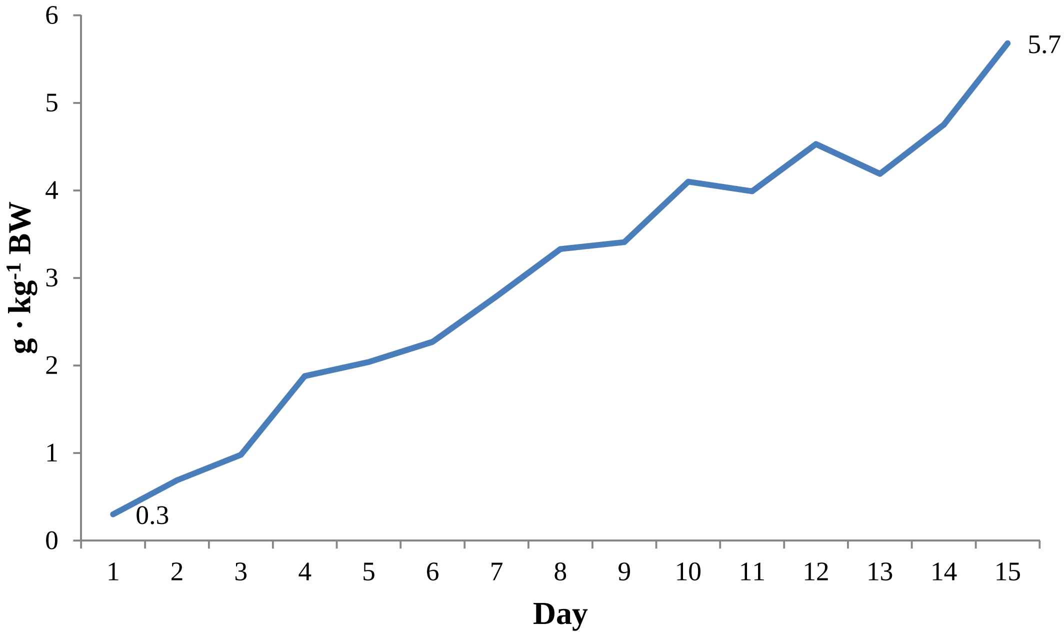

Figure 1. Average salt cedar intake (g · kg^{-1} BW) for sheep during single day feeding period.

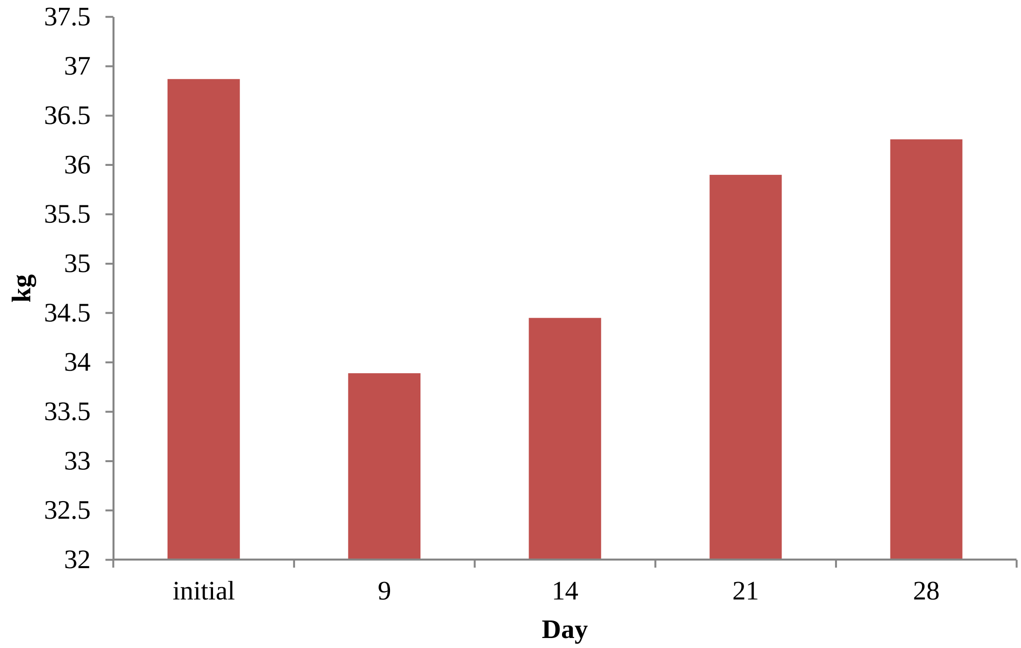

Figure 2. Average body weight (kg) of animals across the entire experiment.

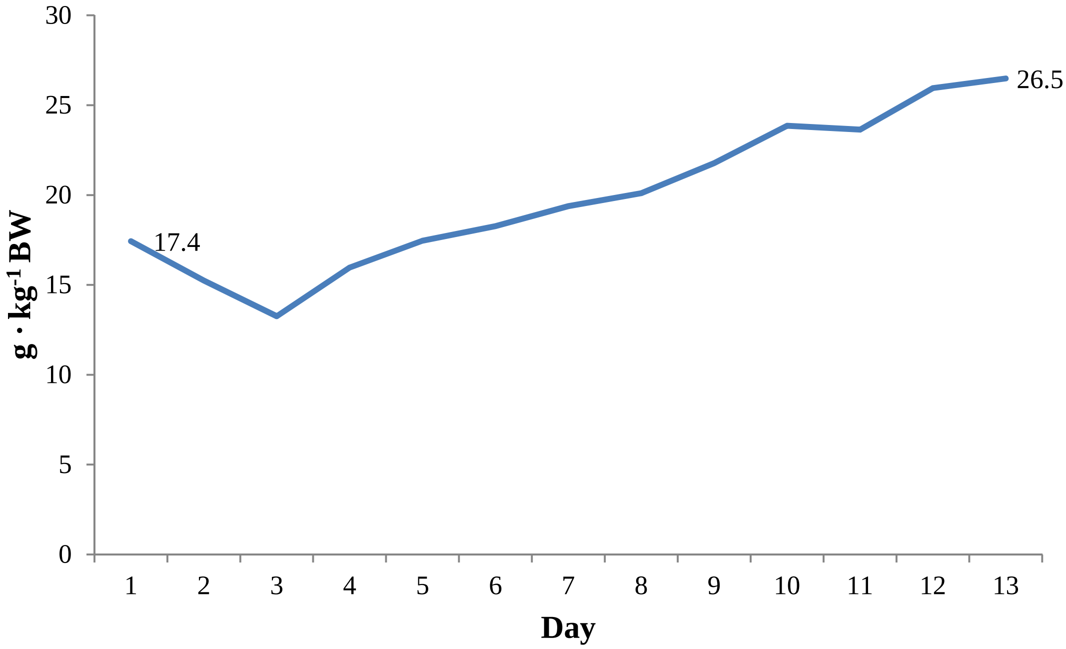

Figure 3. Average daily salt cedar intake (g · kg^{-1} BW) for sheep during three times a day feedings

Table 3. Average salt cedar intake (g · kg^{-1} BW) when salt cedar was fed three times a day.

	Time		
Breed	A.M.	NOON	P.M.
Rambouillet	6.5 ± 0.4	6.2 ± 0.4	6.3 ± 0.4
Suffolk	6.8 ± 0.4	6.9 ± 0.4	7.0 ± 0.4

DISCUSSION

Based on the results of this study, it appears sheep will consume salt cedar at levels similar to those reported for goats (Munoz 2007; Garcia 2011; Knight 2012). Sheep actually consumed more salt cedar than goats in the first trial of the study. Salt cedar does not appear to cause aversive postingestive feedback or adversely affect production (i.e., weight gain). In addition, salt cedar is apparently relatively high in nutrient quality. Knight (2012) reported that CP ranged from 16-19.6% while TDN ranged from 67.5-69.4%. Given the results of this study and others, both sheep and goats should consume salt cedar on a pasture setting and potentially reduce the amount of salt cedar cover. Unfortunately, it is not known if sheep and goat browsing will result in a long-term reduction in salt cedar cover. Defoliation by leaf beetles slows encroachment, but a long-term control method has not been successfully established.

On d 1 Sheep were hesitant to consume the first 50 g of salt cedar offered. Following this initial exposure, intake steadily increased throughout the study. Ruminants are typically hesitant to consume novel foods and increase intake slowly (Provenza 1995). Animals will typically continue to increase intake until reaching satiation or experiencing aversive postingestive feedback (Provenza et al 1994).

By the end of the second week of single day feedings, sheep were consuming all of the salt cedar offered. The amount offered during each feeding bout was beginning to exceed the capacity of the feeding troughs used in this study. Both sheep and goats lost weight during this feeding period. It was then decided that feedings would increase to three times daily, to more closely imitate normal feeding bouts in animals.

On day 2, of the thrice daily feeding bouts, intake declined. Thereafter, salt cedar intake increased throughout the duration of the trial. By the end of the second week of feeding three times a day, intake levels were still increasing steadily. Harvesting of the salt cedar had reached a point in which collecting enough for the thrice daily feedings had become an issue. Consequently, the study was stopped at this point. Based on the results observed, it appeared that salt cedar intake would continue to increase as the amount offered increased. This observation also suggests that sheep could potentially survive and remain productive on a 100% salt cedar diet. The observation is also supported by other concurrent research that has illustrated that goats perform well while foraging on salt cedar dominated pasture (Rogers, unpubl. data)

Body weight varied across feeding periods. Following the initial weigh period, average body weight decreased. During the remaining weigh periods all animals gained weight, including the initial weight lost during the first period. Body weight continued to increase throughout the remainder of the study. Apparently, sheep and goats were able to meet their nutritional requirements by consuming salt cedar throughout the day. Conversely, feeding salt cedar once a day along with the basal ration apparently did not meet maintenance requirements; resulting in weight loss.

Even though the basal ration was fed at levels reportedly adequate to meet maintenance requirements; both sheep and goats consumed salt cedar throughout the study. Satiety is food specific, resulting in animals continuing to eat when alternative foods are offered (Parson et al. 1994; Newman et al. 1992; Provenza 1995). When a variety of foods are available, intake typically increases and animals gain more weight (Provenza et al. 1995).

If sheep and goats are placed on monocultures of salt cedar, alternative food sources (i.e.; supplementation) may be required to promote weight gain.

Water consumption levels were not recorded during this study. However, in previous studies with goats, salt cedar intake did not cause increased water consumption even though salt cedar is relatively high in sodium (Knight 2012). More recently, field observations have suggested that goats consume very little water while consuming salt cedar apparently due to the high moisture content in the plant (Knight 2012, Rogers, unpubl. data).

There were no differences in intake of salt cedar between the Rambouillet and Suffolk breeds used in this study. Depending on the desire of landowners, either breed could be used as a biological control mechanism for salt cedar control.

The use of sheep and goats to browse salt cedar could serve great importance in situations where leaf beetle populations cannot be established or where population numbers remain low. Furthermore, using livestock as a biological control method would still produce a product (kids, lambs, wool) that could be sold as a commodity.

IMPLICATIONS

Incorporating salt cedar into the sheep diet can be successfully accomplished by preconditioning. Nutritional value of salt cedar is relatively high and sheep will gain weight by consuming it. This data infers that salt cedar consumption can occur on pasture. Future research should be done with sheep in salt cedar monocultures to determine if they will reduce density and/or slow encroachment. Hair sheep breeds should also be considered for future research due to the increasing population of this breed in the West Central Texas area.

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