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USING LAMBS TO CONTROL WEEDS
IN COTTON

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## ABSTRACT

With both conventional and organic cotton operations, producers face numerous issues with weed infestations. A potentially new method of weed control is biological control of weeds utilizing sheep. This study utilized weaned lambs (n=23) that were randomly assigned into three treatment groups: “averted,” “familiar,” and “naïve.” The lambs were placed in 1 x 1.5 m pens for the conditioning phase of the study. The averted group was fully averted to cotton utilizing lithium chloride. The familiar group was exposed and fed cotton for nine days to increase the amount of exposure to cotton, and the naïve group was not exposed to cotton prior to the field study. Each treatment group was assigned three plots that contained cotton and weeds to graze on a 6-day, nonconsecutive period. Regardless of treatment, lambs typically avoided cotton. However, the familiar treatment did consume more cotton than the averted group. Lambs typically selected grass and forbs, while foraging on a cotton field. Selection of cotton was not correlated with selection of herbaceous weeds ($r^2 = 0.02$). After the grazing trial was completed, weed density measurements were taken and compared among the treatment plots that were grazed and ungrazed. Regardless of the method of conditioning, lambs reduced weed cover when compared to ungrazed plots.

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## INTRODUCTION

A common definition of a weed is “any plant that is growing out of place” (Krohmann et al. 2006). Weeds, in a crop land setting, utilize water and essential nutrients needed to produce crops such as cotton (*Gossypium* spp.). Some common methods of weed control can include either chemical or mechanical control. Particularly in large scale production systems, the most optimal weed control is often through the utilization of broad-spectrum herbicides such as glyphosate. Modern sprayer technologies utilizing broad spectrum herbicides, can ultimately reduce labor and operating costs. Unfortunately, since the release of Roundup-Ready cultivars of soybeans, corn, and cotton the resistance of glyphosate in weeds has developed, and reduced weed control efficacy (Bain et al. 2017). Because of increased resistance to glyphosate in weeds, many cotton producers have reverted to mechanical methods of control such as cultivation and the individual hoeing of weeds. While these methods can be effective in controlling weeds, each requires additional labor and costs. In addition, cultivation results in the loss of soil moisture through evaporation and leads to a greater risk of soil erosion. Another potential method of weed control is biological control using livestock herbivory. Unfortunately, there is little information on using livestock herbivory to control weeds in cotton.

There are two main types of crop production systems: organic and conventional production systems. Organic cotton production systems must utilize a non-transgenic variety of cottonseed. Furthermore, organic production systems do not utilize synthetic fertilizers and herbicides. Conversely, conventional cotton production systems, often relying on transgenic cultivars, can use herbicides and synthetic fertilizers. Livestock herbivory would provide another method of weed control for organic systems, where herbicides for weed control are either not an option or declining in efficacy. For conventional cotton production systems, the biological

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control of weeds may also serve as another alternative to reduce the pressure of herbicide resistant weed species and potentially further reduce costs for weed control. Trials with ewes provided control of some weeds (Stewart et al., unpublished data). Unfortunately, the ewes also consumed cotton in year two of the study. This study examined methods to reduce cotton intake while utilizing sheep to control weeds. Three approaches that were examined include: (1) limiting familiarity with cotton, and (2) implementing a conditioned taste aversion to cotton (3) increasing the familiarity of cotton prior to the field study.

## OBJECTIVES

This study assessed the likelihood of reducing cotton intake by lambs when lambs are implemented for weed control. This study assessed the selection of weeds and cotton by (1) lambs familiar with common weed species but unfamiliar with cotton, (2) lambs averted to cotton, and (3) lambs familiar with common weeds and cotton.

## REVIEW OF LITERATURE

### The Chemical Resistance of Glyphosate

The release of Roundup Ready varieties of corn, soybeans, and cotton has allowed producers to control a wide variety of weeds in croplands at a reduced labor cost. Glyphosate, the active ingredient in Roundup™, is a broad-spectrum herbicide that controls both broadleaf and grass species of weeds. Over time, resistance to glyphosate has developed because of repeated use (Krohman et al. 2006). According to the International Herbicide-Resistant Weed Database, there are currently 273 species of weeds that show signs of herbicide resistance globally (IH-RWD 2025). Because of glyphosate resistance, many cotton producers are beginning to resort to alternative methods of weed control that typically involve increased labor such as, the cultivation of weeds and the individual hoeing of weeds. In Texas, some of the most herbicide resistant weeds include careless weed (*Palmer Amaranth),* perennial ryegrass (*Lolium perenne)*, barnyard grass (*Echinochloa crus-galli)*, kochia (*Kochia scoparium)*, Johnsongrass (*Sorghum halepense)*, and tall or common water hemp (*Amaranthus tuberculatus)* (McGinty et al. 2016). A high density of weeds can reduce the fiber quality of cotton, thereby decreasing the monetary value of the crop. Regardless of density, weeds compete against agricultural crops for sunlight, soil nutrients, and soil moisture, therefore reducing the overall yield.

### Forming Taste Aversions in Prior Studies

The propensity to acquire learned taste aversions because of unpleasant experiences with foods represents a potent defense mechanism against poisoning and affects food preferences (Berstein et al. 1999). Taste aversion conditioning relies on the elements of avoidance learning. A non-toxic compound (lithium chloride) is used to induce nausea and the formation of a conditioned taste aversion (Garcia and Koelling 1966). Dosage rates of 150 – 200 mg/kg BW typically result in avoidance of foods consumed prior to dosing (Thorhallsdottir et al. 1987; du Toit et al. 1991). Because LiCl has a salient flavor, (Provenza and Burritt 1991), concluded that the administration of LiCl should be administered directly to the rumen using a bolus and bolus gun so that nausea from LiCl is associated with the flavor of foods recently consumed and not the flavor of LiCl. The administration of LiCl will result in a decrease in the intake of feedstuffs. Flavors of foods paired with nausea induced by administering LiCl, results in the avoidance of foods. Conditioned taste aversions have been used to reduce intake of other plants. Dosing with LiCl was used to reduce intake of giant fennel (*Ferula communis*); lambs avoided giant fennel for 31 days after the first administration of LiCl, (Egber et al. 1998). Similarly, Ralphs et al. (1998) found that a single dose of LiCl was effective in creating and maintaining a total aversion to alfalfa pellets. Lithium chloride has also been used to create aversions to locoweed (Ralphs et al. 1997), pine needles (Pfister 2000), mountain mahogany (Burritt and Provenza 1989), leafy spurge (Kronberg et al. 1993), and larkspur (Lane et al. 1990). For this study, a conditioned taste aversion will be created in lambs to reduce the intake of cotton.

**Intake of Chemically Defended Plants**

Intake of several weed species is limited by secondary compounds (Olsen 1999). These include several weeds common in this region of Texas: silverleaf nightshade (*Solanum elaegnifolium)*, Carolina horse needle (*Solanum carolinense*), kochia (*Kochia scoparia)*, Russian thistle (*Salsola iberica)*, and devil’s claw (*Harpagophytum procumbens)*. The secondary compounds that are present in chemically defended plants can cause a wide variety of adverse symptoms, such as nausea, impairment of digestion, or assimilation, thus reducing the nutritional benefits of ingesting a plant (Lambdon and Hassall 2001). However, chemically defended weeds are often included in the diet of ruminants because the most nutritious plants within a rangeland setting are often grazed at varying intake levels. For example, cattle consume Tall Larkspur (*Delphinium exaltatum*) and limit ingestion of toxins below a threshold (Pfister et al. 1997). Likewise, some plants may be avoided by one class of livestock and consumed by another (Olsen 1999). For example, sheep readily consume spotted knapweed, (*Centaurea stoebe*) but limit intake below toxic levels, while cattle typically avoid the plant because of aversive postingestive feedback cattle experience after consuming the plant (Olsen et al. 1997).

**Gossypol In Cotton**

Cotton (*Gossypium* spp.*)* contains a phenolic compound produced by pigment glands in the stems, leaves, seeds, and flower buds (Gadelha et al. 2014). Gossypol is a secondary compound produced by the plant to protect itself from insects and pathogens (Stipanovic et al. 2006). High levels of intake of gossypol can lead to respiratory distress, impaired body weight gain, apathy, death (Gadelha et al. 2014). However, gossypol toxicity is more common in monogastric animals because ruminants can tolerate higher levels of gossypol in the diet because of rumen microbial degradation (Stipanovic et al. 2006).

**Exposure and Intake**

In a rangeland setting, ruminants focus on familiar plants and avoid novel plants. Ruminants are instinctively neophobic to novel foods as it serves as a survival mechanism for avoiding the over-consumption of toxic plants (Launchbaugh et al. 1997). In a rangeland setting, ruminants select familiar foods that are high in nutritional value and low in concentrations of secondary compounds. Additionally, ruminants also learn how to select and avoid certain plant species through social facilitation with a social model. Social models can either be the ruminant’s dam or peers in social grazing, during its juvenile stage of life (Thorhallsdottir et al. 1990).

Ultimately, the selection or avoidance of plants is dictated by the feedback mechanisms that follow the animal ingests a certain plant (Thorhallsdottir et al. 1990).

Despite being neophobic to novel foods, ruminants will sample new foods cautiously. This allows ruminants to identify nutritious and toxic foods in a search to meet nutritional requirements while avoiding toxicosis (Provenza 1995). Essentially, ruminants change their preferences for foods caused by a postingestive feedback that occurs automatically every time food is ingested, and the kind and amount of feedback is a function of the match between the food's chemical characteristics and its ability to meet an animal's current demands for nutrients (Provenza et al. 1994).

## METHODS

Upland cotton was planted on a 4-ha plot on the Angelo State University Management, Instruction and Research (MIR) Center, San Angelo, Texas. The test plot was cultivated to eliminate the pre-existing weeds and to provide a seed bed for the cotton to be planted. The cotton was planted on May 31, 2024. The variety used was Phytogen 480 W3FE. The target population planting rate of cotton was 86,450 seeds per ha. After the plot was planted, there was no disturbance to the plot until September, due to the drought conditions that resulted in poor cotton growth and poor weed establishment. Beginning on July 22$^{nd}$, the cotton was irrigated bi-weekly to allow for optimum growing conditions for both the cotton and weeds.

13 Rambouillet and 10 Suffolk ewe lambs that were 7 months of age were utilized in the study. All twenty-three lambs were randomly assigned to treatments. Three treatments were used in the study. The treatments include (1) lambs averted to cotton “averted group”(2) non-averted lambs that are familiar with cotton “familiar group”, and (3) non-averted lambs with no familiarity with cotton “naïve group” (control). All treatments were exposed to weeds prior to the field study. Prior to the conditioning phase, all lambs were housed on a crop field for 14 days that contains the target weed species. This allowed all lambs, regardless of treatment, to be familiar with the weed species that will be common in the cotton plots.

The plot was fenced off via hot wire fence. The plot was subdivided into 12 separate subplots. Three plots were ungrazed to serve as the control plots. Three plots were assigned to the “averted group,” three plots were assigned to the “familiar group,” and three plots were assigned to the “naïve group.” Each of the 12 subplots were 92.80 square meters.

During the conditioning phase, all lambs were placed in individual pens (1 m by 1.5 m) and fed a basal ration (2.5% BW) to meet maintenance requirements (Table 1). The nutrient content of the basal ration is listed in (Table 2).

Table 1. ASU Ram-20 Basal Ration

| Ingredients | % in Ration (As-Fed) |
| --- | --- |
| Cottonseed Hulls | 27.5 |
| Rolled Corn | 33.0 |
| Alfalfa Pellets | 33.0 |
| ASU- Premix Mineral | 2.5 |
| Molasses | 4.0 |

Table 1. Nutrient Content of ASU Ram-20 Basal Ration

| Ingredients | % D.M. | % Protein | % TDN | % CF | % ADF | % NDF |
| --- | --- | --- | --- | --- | --- | --- |
| Cotton Seed Hulls | 91.0 | 8.1 | 34.6 | 45.6 | 65.3 | 79.3 |
| Corn | 89.1 | 9.1 | 88.1 | 2.3 | 3.6 | 9.95 |
| Alfalfa Pellets | 90.0 | 17.0 | 52.6 | 26.2 | 34.0 | 45.0 |
| Molasses | 73.1 | 8.8 | 72.0 | 3.6 | 0.4 | 0.8 |

All 23 lambs were given a seven-day adjustment period to adapt to the housing in individual pens. Once the conditioning phase began on August 13$^{th}$, the seven "familiar" lambs were fed cotton daily for nine days. The eight averted lambs were fed cotton for nine days and dosed with LiCl (150 mg/kg BW) when intake of cotton remained 100 percent for a two-day period. If the intake of cotton was above zero percent after being dosed with LiCl, the lamb was re-dosed the following day to form a taste aversion. Cotton was fed for nine days and intake was monitored daily. Eight "naïve" lambs only received their basal ration daily. Fresh water and trace minerals were provided *ad libitum.* A basal ration of Ram-20 was offered at 2.5% BW to all lambs daily regardless of treatment during the conditioning phase to meet maintenance requirements of the lambs (NRC 2007).

The grazing portion of the trial began on September 16$^{th}$ and continued for six days. While foraging on cotton plots, bite counts by plant species were recorded for individual animals. Each animal within a treatment was observed for 30 minutes of foraging. After each treatment was grazed for 30 minutes, the lambs were placed in a pen and fed Ram-20 at 2.5% BW once a day to maintain the energy demands of the lambs. At the end of the grazing trial, line transects were measured to determine the percentage of weed cover on the ungrazed (control) and grazed plots.

Data were analyzed using repeated measures analysis of variance with treatment (familiar, naïve, averted) as the main effect and day as the repeated measure. Lambs nested within treatments served as replications for intake of cotton during conditioning and while foraging on cotton/weed stands. Differences in weed cover at the conclusion of the study were determined by analysis of variance with treatment as the main effect and plots serving as replications. Means were separated using Tukey's protected LSD when ($P \leq 0.05$). Data were analyzed using the statistical package JMP (SAS 2001).

# RESULTS

## Exposure and Aversion to Cotton

After day 3, intake of cotton decreased (Fig. 1). From day 5 through day 8 the intake of cotton remained approximately 15%. This was largely a function of some of the lambs decreasing intake but continuing to consume some cotton. Those individuals were re-dosed with LiCl at the same rate until intake was zero for all individuals.  The last lamb was averted to cotton on day 8.

Seven of the 15 lambs were randomly allocated to Familiar treatment. These were also fed fresh cotton daily. Intake increased daily until day 5 of exposure (Fig. 1). Thereafter, lambs consumed all of the cotton offered each day. Lambs in the naïve treatment were not exposed to cotton during this phase of the study.

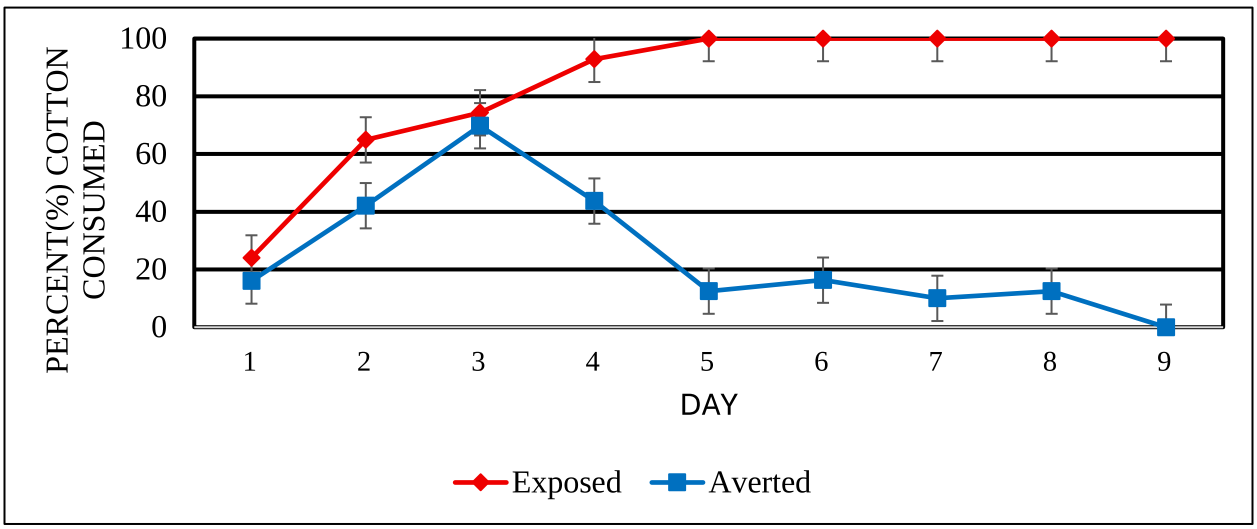


Figure 1. Percent of cotton consumed (intake) during the conditioning phase of this study. “Averted” lambs were dosed with LiCl on day 3 of the study to create an aversion to cotton. “Familiar” lambs were not dosed.

**Individual Day Cotton Bite Analysis**

The number of bites of cotton was low for all treatments. Averted lambs took fewer bites of cotton. Conversely, familiar lambs selected cotton more frequently than averted lambs (Fig. 2). The number of bites of cotton taken by naïve lambs was similar to familiar and averted lambs. Selection of cotton also differed by day (Fig. 3). All lambs, regardless of treatment, selected more bites of cotton on day 1 and 4 of the study.

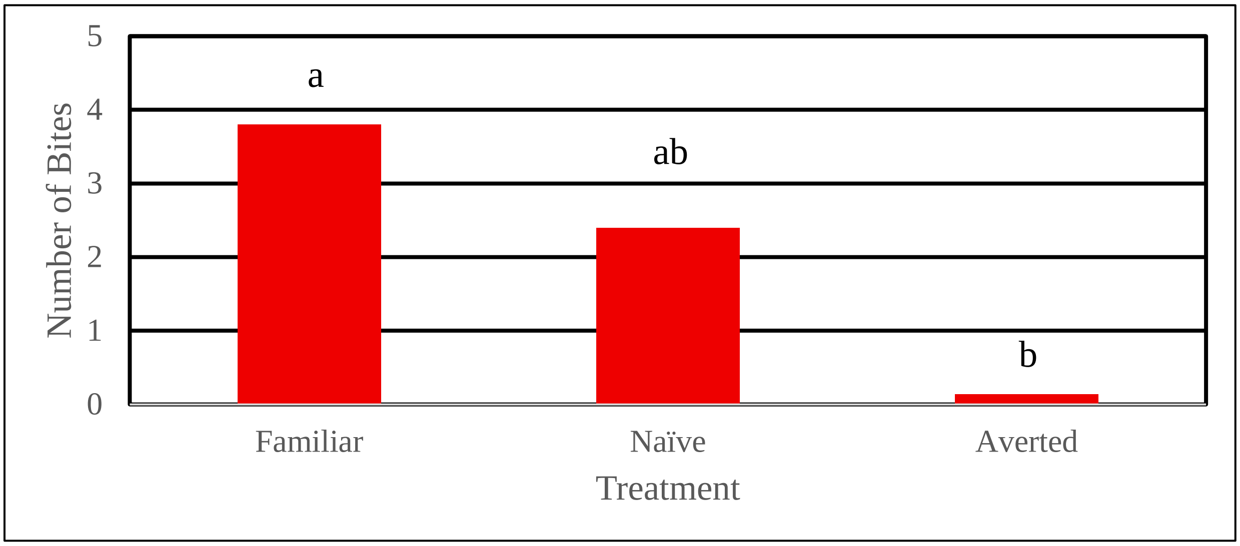


Figure 2. The mean number of bites of cotton consumed across in each treatment (familiar, naïve, averted) measured per grazing period throughout the six-day trial.

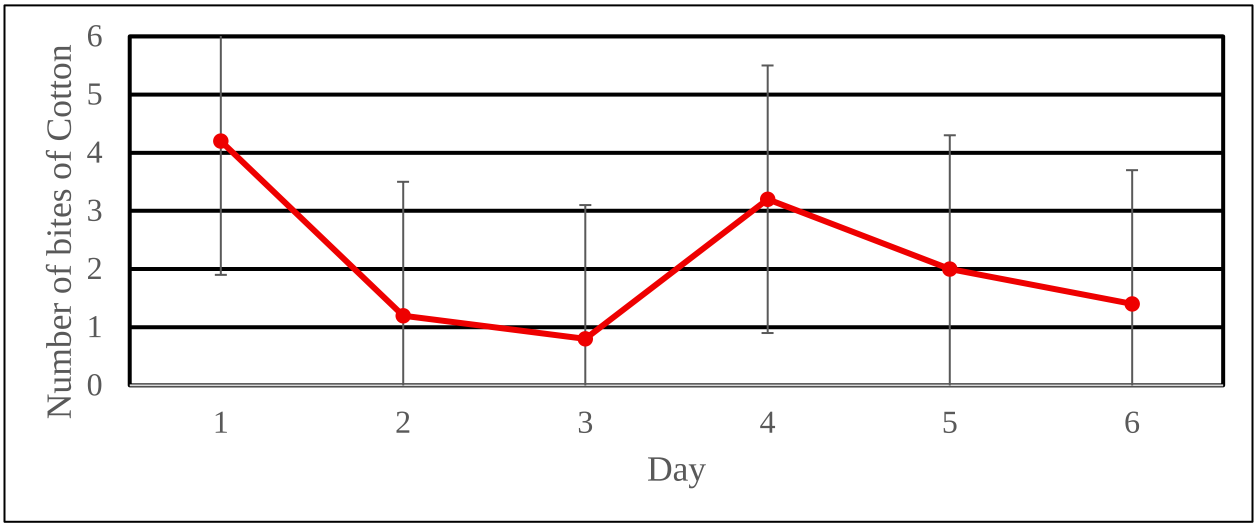


Figure 3. The mean number of bites of cotton consumed across of all treatments by lambs over six days of grazing cotton plots.

The treatment by day interaction also differed for both selection of herbaceous weeds and cotton (Figs. 4A and 4B). Regardless of treatment, lambs typically selected herbaceous weeds (grasses and forbs) and avoided cotton (Figs 4A and 4B). The mean number of bites of cotton varied across six-day trial (treatment by day interaction differed) (Fig. 4B). When cotton was selected, familiar lambs selected cotton more frequently than averted lambs. Throughout the 6-day grazing trial, the selection of cotton for lambs averted to cotton remained near zero. On day 1, both naïve and familiar lambs consumed cotton. Selection of cotton decreased on day 2 and 3 followed by an increase on day 4. Selection of cotton declined after day 4 for both familiar and naïve lambs. Selection of cotton was not correlated with selection of herbaceous weeds ($r^2$ = 0.02).

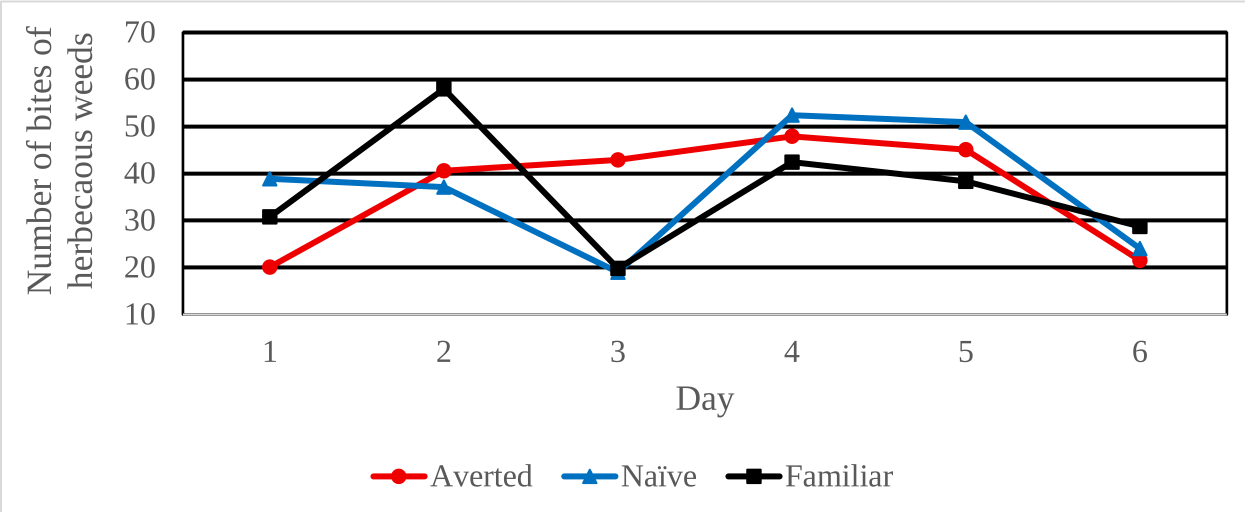


Figure 4A. The number of bites of herbaceous weeds (grasses and forbs) consumed over six days for grazing on cotton plots

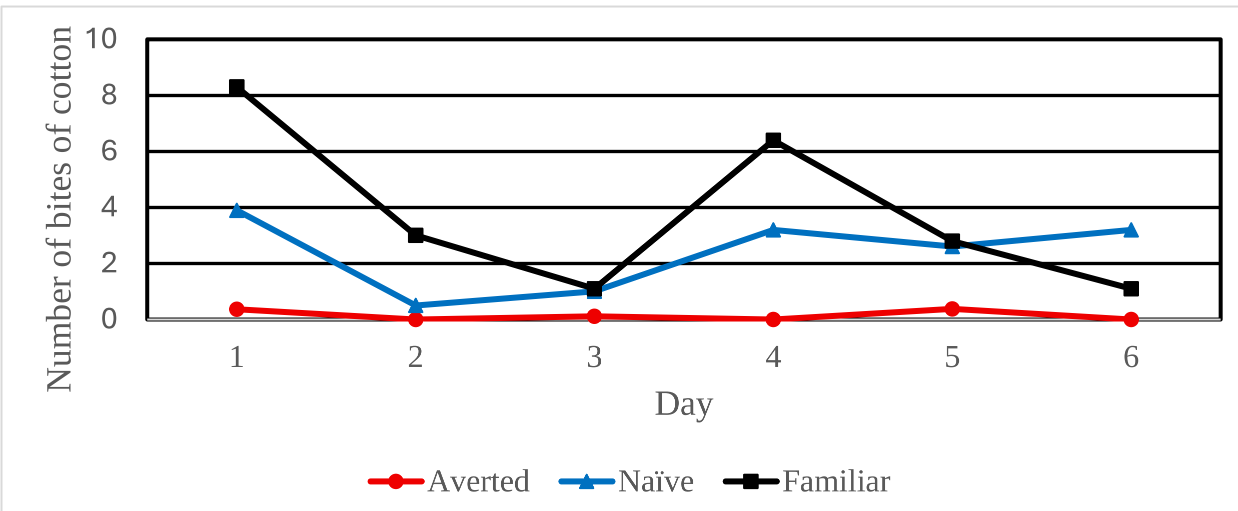


Figure 4B. The number of bites of cotton consumed over six days for grazing on cotton plots.

**Weed Cover**

After the grazing trial was completed nine of the grazed plots and three of the non-grazed plots (control) were measured for percent weed cover. After six days of grazing the plots the three treatment plots had similar cover of herbaceous weeds averaging 55 percent to 60 percent weed cover (Fig. 5). The ungrazed control plots averaged 87.9 percent in weed cover.

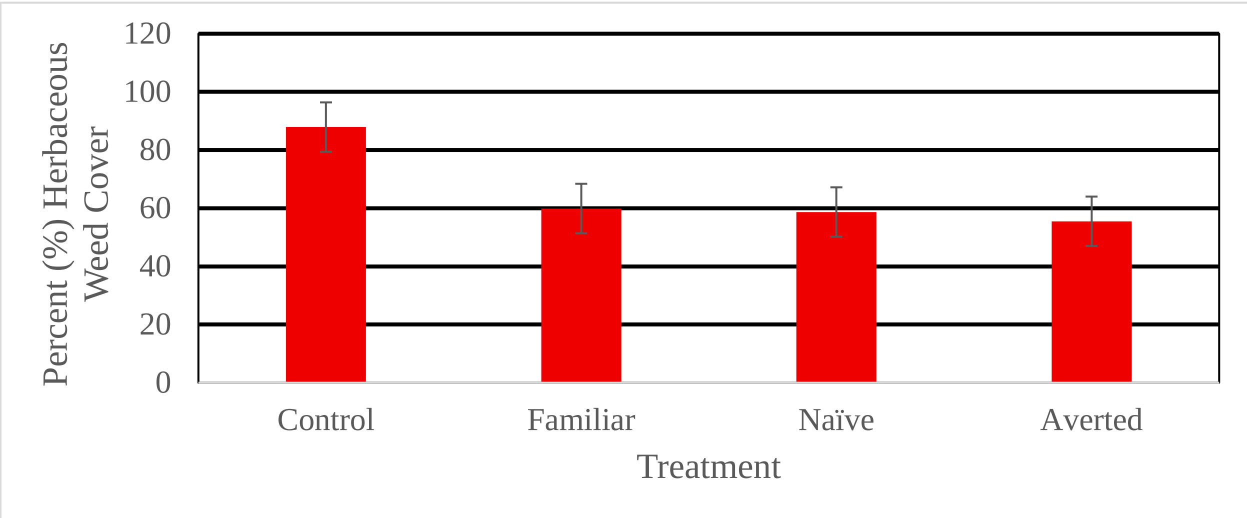


Figure 5. The average percent (%) cover of herbaceous weed cover within the "control," "familiar," "naïve," and "averted" treatment plots measured after the grazing trial.

Each grazing exposure (familiar, naïve, averted lambs) was compared to the control using orthogonal contrasts for herbaceous weed cover. When compared to ungrazed plots, lambs reduced weed cover regardless of treatment (Fig. 6).

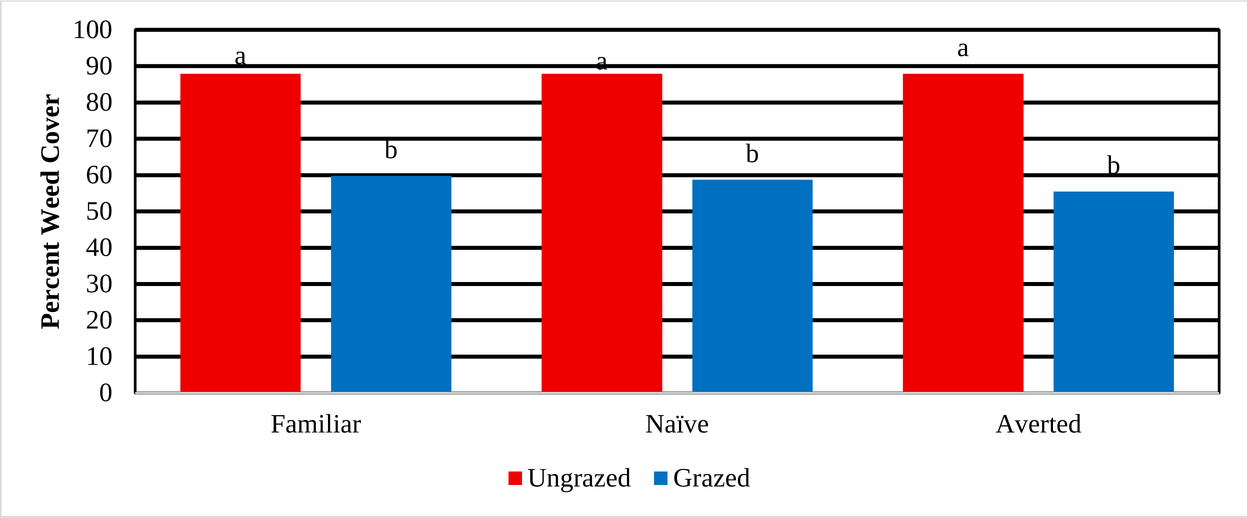


Figure 6. Orthogonal contrasts of herbaceous weed cover percentage comparing the ungrazed (control) plots to the grazed “familiar,” “naïve,” and “averted” test plots.

# DISCUSSION

## Exposure and Aversion to Cotton

Just like humans, livestock are neophobic and avoid novel foods (Provenza 1995). Figure 1 suggests for both the averted and familiar groups of lambs that cotton intake was minimal during the first and second days during the conditioning phase of this study. However, after being exposed and experiencing positive postingestive feedback apparently from nutrient release, the lambs consumed all of the cotton offered for the remainder of the trial. At the levels fed during the conditioning phase, cotton does not appear to be aversive, even though the plant contains the toxic compound gossypol. However, when lambs familiar with cotton were released in plots containing herbaceous weeds and cotton, lambs preferred weeds and took few bites of cotton. Conditioned food aversions occur when intake of secondary compounds, like gossypol, reaches levels sufficient to cause nausea and avoidance thereafter. The levels fed during the conditioning phase may not have been high enough to cause nausea. Unfortunately, gossypol levels were not measured in this study. More importantly, aversive postingestive feedback, while suspected, has not been reported from gossypol levels.

While gossypol is produced in glands throughout the plant, the highest concentration occurs in the cottonseed (Gadelha et al. 2014). Cotton leaves were collected from plants and fed during the conditioning phase and may not have contained sufficient gossypol to induce avoidance. Gossypol levels vary among varieties of cotton; Upland cotton used in this study is typically higher in gossypol than Pima varieties (Romano and Scheffler 2008). However, most toxicity issues reported are the result of feeding cottonseed or cottonseed byproducts (Mena et al. 2001). Ruminants can tolerate higher levels of gossypol in the diet because of rumen microbial degradation of the toxin than non-ruminants. Gossypol levels are typically lower in leaves than in seeds, stems or taproots (Stipanovic et al. 2006). Lambs used in this study may have avoided toxicity by primarily consuming leaves and through rumen degradation. Once lambs were grazing in cotton plots, intake levels may have been high enough to result in aversive postingestive feedback and a reduction in intake as noted after day 4 for lambs familiar with cotton.

The results from the conditioning phase of this study suggest that once lambs experienced aversive postingestive feedback, induced by dosing with LiCl, lambs avoided cotton (du Toit et al. 1991). Animals are both biologically and metabolically different and often vary in response to the same dose rate. A single dose of LiCl (150 mg/kg BW) was sufficient to cause an aversion to cotton with most of the lambs. However, some required two doses at the same rate to form an aversion (du Toit et al. 1991). By the end of the conditioning phase of the study, all lambs dosed with LiCl avoided cotton. Lambs continued to avoid cotton once released on cotton plots, with the number of bites of cotton remaining near zero.

**The Biological Control of Weeds and Herbivory of Cotton**

Throughout the six-day grazing portion of the trial, all the treatments of lambs reduced the cover of weeds by an average of 29.6 percent (Fig. 6). The averted group selected for the least amount of cotton, near zero bites. Naïve lambs typically avoided selecting cotton as well. While lambs familiar with cotton consumed more total bites of the plant, intake remained low. Overall, the results of the study suggest that weaned lambs can be a tool to biologically control weeds, while minimizing the selection and grazing of cotton. In a previous study, ewes were placed on cotton plots over two consecutive growing seasons. During the first year, ewes typically avoided cotton, selecting primarily herbaceous weeds. However, when released on cotton plots during the second year, ewes readily consumed cotton (Stewart et al. unpublished data). Based on the results of this study and the work by Stewart et al. (2024), it appears that the lack of familiarity with cotton and possibly creating an aversion to the plant is necessary to reduce cotton intake.

In prior studies, ruminants have been used to reduce weed cover and invasive species on rangelands. Goats have been used to control salt cedar (*Tamariz spp.)* (Aquirre et al. 2025). In addition, goats consumed Juniper (*Juniperus* sp.*)* and created browse lines and reduced cover of juniper (Dietz et al. 2010). Leafy Spurge, a noxious weed that prevails in the northern region of the United States, has been controlled both biologically and chemically. Multiple grazing trials that have been conducted at the U.S. Sheep Experiment Station utilizing sheep and goats to graze leafy spurge have resulted in an average 70% utilization rate in spurge infested pastures (Walker and Kronburg 1994).

## IMPLICATIONS AND FUTURE REASEARCH

The results of this study suggest that lambs will reduce the amount of weed cover in cotton plots. However, the frequency of exposure of cotton to sheep that have not been averted may result in an increase of cotton intake in sheep. The utilization of weaned lambs aged 7 months has proven that regardless of treatment the number of bites of cotton was minimal. However, (Stewart 2024). suggests that mature ewes that are exposed to cotton over two growing seasons will actively select for cotton. Future efforts should determine the amount of exposure to cotton that could potentially result in intake sufficient to reduce cotton yield.

The timing of grazing cotton can negatively affect cotton plants. Cotton plants are the most susceptible to thrips at the 4-5 leaf stage resulting in the reduction of cotton density (Francis 2016). Current thinking is that the flowering stage, when boll development is occurring, is the most critical stage, since the resources that the plant requires increase exponentially and the plant is therefore much more susceptible to environmental stress and poor management (Kerby et al. 2010). Additionally, as the cotton plant reaches maturity the levels of gossypol will increase, therefore reducing the palatability of cotton (Stipanovic et. al. 2006). Overall, ruminant animals, such as sheep, can serve as an effective tool to reduce the amount of weed cover in a cropland setting. However, further research needs to be conducted to fully understand the different variables of using livestock to graze weeds that may affect the yield of cotton. Areas of future research should include grazing weeds during different stages of cotton growth and comparing the yield of cotton to determine the time of herbivory to find the optimal time of grazing that minimizes yield loss when compared to plots that utilize the mechanical control of weeds.

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## VITA

Colbin Briley grew up on a farm in Borden County that raised cotton, wheat, and cattle. He graduated from Borden County High School in 2020. He began pursuing a higher education in the Fall of 2020 at Angelo State University. Colbin graduated in May of 2023 with a Bachelor of Science in Animal Science and a Minor in Range Management. Colbin began to pursue a Master of Animal Science in the Fall of 2023 at Angelo State University. Throughout Colbin's tenure at Angelo State University, he was a student worker in February of 2022 and became the Shelley New Show Cattle Coordinator/Assistant Ranch Manger at the Management Instruction and Research Center in December of 2023.