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Feeding Shinoak to Meat Goats Improves Four-wing Saltbush and Total Intake

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ABSTRACT

Herbivores consume a variety of foods that contain toxins in order to increase food intake, but typically avoid over ingestion of any single toxic food. Four-wing saltbush (*Atriplex canescens*) and shinoak (*Quercus havardii*) are two shrubs common to the southwestern United States that are consumed by ruminants, but intake is limited to avoid toxicity. Four-wing saltbush contains saponins while shinoak contains tannins. Saponins and tannins may chelate in the digestive tract of ruminants which would reduce the toxicity of both. We compared intake of four-wing saltbush and shinoak singly and together to determine if feeding both shrubs increased overall intake or intake of either shrub. In addition, alfalfa hay (saponin-containing plant) was fed with shinoak to determine if intake of shinoak would increase when alfalfa was fed. The study used 39 freshly weaned Boer-cross goats. Each was individually penned and then randomly assigned to 1 of 5 treatments. Eight were fed four-wing saltbush, eight were fed shinoak, eight were fed both, eight were fed shinoak and alfalfa, and seven were fed a basal ration for two weeks. Goats preferred shinoak to four-wing saltbush when each was fed alone. When both were offered simultaneously, goats ate more four-wing saltbush than when it was fed alone. Total intake was also increased when both shrubs were fed and when alfalfa was fed with shinoak. Feeding four-wing saltbush or alfalfa did not affect shinoak intake. Serum levels indicative of toxicosis were similar among treatments. Tannins and saponins may chelate in the digestive tract of ruminants when they are consumed simultaneously thereby increasing overall intake and decreasing the likelihood of experiencing toxicity.
KEY WORDS: intake, chelation, rangelands, food aversions, toxins

INTRODUCTION

Herbivores may consume a variety of foods that contain different toxins to increase nutrient intake and to avoid toxicosis (Freeland and Janzen 1974; Westoby 1978; Provenza 1995). A varied diet should enhance an animal's ability to meet its nutritional needs when foraging on

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plants with secondary compounds provided the toxins have different physiologic effects, are detoxified by independent metabolic pathways, and do not interact with each other to become more toxic (Freeland and Janzen 1974; Burritt and Provenza 2000). While ruminants typically avoid over ingestion of toxic plants, complete avoidance of toxic plants in arid regions may result in nutritional deficiencies.

Tannins and saponins are among the more common classes of phytochemicals used as defenses by plants (Cheeke 1998). While both toxins can limit intake in animals, each affects the animal differently. Tannins can bind up nutrients that are consumed making them unavailable for digestion, which affects enzymatic and microbial activity mainly in the rumen and intestine. The reduction in substrate, microbial and enzymatic activity reduces levels of volatile fatty acids in the rumen (Makkar et al., 1995). Reduced volatile fatty acid levels lower food quality and palatability. Saponins are triterpenoid glycosides that can cause aversive postingestive feedback, anorexia, gastroenteritis, diarrhea, and kidney failure in ruminants (Cheeke 1998). They may also have the effect of being powerful surfactants and hemolytic agents (Scheline 1991). Herbivores may be able to overcome the toxic effects of tannins and saponins by simultaneously consuming both because tannins and saponins may chelate in the intestinal tract thereby reducing the aversive effect of both compounds (Freeland et al., 1985).

Four-wing saltbush (*Atriplex canescens*) and shinoak (*Quercus havardii*) are common throughout the southwestern United States. Four-wing saltbush contains saponins while shinoak contains tannins. A study was designed to determine the complementary and physiologic effects of tannins and saponins as they relate to intake, weight gain, and serum level when they are fed singly and together. Both of these plants have a relatively high nutritive value, even though they both contain toxins. Given their widespread distribution throughout the southwestern United States, they have potential importance as forage for browsing ruminants. It is difficult though to determine how these two toxins may react with each other because little information is available on diet selection when both shrubs are available. The purpose of this study was to quantify differences in intake related to the ingestion of tannins and saponins fed singly compared to being fed in conjunction with each other. We hypothesized that feeding tannin- and saponin-containing plants simultaneously would increase intake of both.

MATERIALS AND METHODS

This study was conducted during the summer and fall of 2003 at Angelo State University's Management, Instruction, and Research (MIR) Center, San Angelo, TX (31E N; 100E W). Intake along with serum metabolite levels were monitored throughout. Research objectives for this study were addressed by placing goats in individual pens and feeding tannin- and saponin-containing plants. In addition to receiving shrubs, all goats received a basal diet (2% BW) to meet maintenance requirements (NRC 1981) (Table 1). Fresh water was provided *ad libitum* to all goats during testing in individual pens.

Table 1. Ingredients and nutrient content of ration fed to goats to meet maintenance requirements.

Ingredient	**Percent in the Diet**
Alfalfa	17
Corn Grain	45
Cottonseed meal	10
Soybean hulls	22.5
Cane molasses	3
Premix	2.5
Nutrient	
Crude protein	14.4
Crude fiber	13.7
Digestible energy	2.8 Mcal/kg
TDN	62.7

Shinoak leaves were collected on the Coleman Ranch in Colorado City, TX in July 2003 and then transported to the Angelo State University's MIR Center where they were air-dried and stored until feeding. Four-wing saltbush leaves were collected on established plots located on the Angelo State University MIR Center. Both four-wing saltbush and shinoak leaves were stored separately throughout both trials in similar environmental conditions.

A pretrial was conducted to quantify levels of *ad libitum* intake of four-wing saltbush and shinoak. Levels were established by individually penning 14 castrated male Boer-cross goats (0=45 kg). Seven were fed four-wing saltbush and seven were fed shinoak. All goats received a basal diet (2% BW) to meet maintenance requirements (Table 1).

Once *ad libitum* intake levels were established, 39 different freshly weaned mixed sexed (average weight 45 kg) Boer-cross goats were placed in individual pens after weaning. Eight were fed shinoak, eight fed four-wing saltbush, eight fed both, eight were fed shinoak and alfalfa, and seven were fed only the basal ration for 14 days. Each food item (shinoak, four-wing saltbush, alfalfa) were fed for 1 hr daily for 14 days. Initially, 50 g of each was fed to each goat. If goats consumed all that was offered, the amount fed was increased daily to the point of refusal. Intake was monitored daily.

Serum metabolite levels were monitored every 72 hrs to assess liver and tissue damage from toxicosis. Blood samples were collected via jugular venipuncture, centrifuged, frozen, and transported to the Texas A&M University Medical Diagnostic Lab for analysis. Changes in serum metabolite levels are often indicative of toxicosis (Cornelius 1989, Calhoun et al., 1981). Serum metabolites measured included serum aspartate transaminase (AST), gamma glutamyltransferase (GGT), blood urea nitrogen (BUN), and creatinine (CREAT). Increases in serum metabolite levels, particularly GGT and AST levels, are indicative of liver damage while increases in creatinine are indicative of kidney damage. In addition, any weight changes were determined at the end of the trial.

Differences between treatments for intake, serum metabolite levels, and weight change were assessed using repeated measures analysis of variance with individual goats as replications nested within treatments and day of observation as the repeated measure (Hicks 1993). Differences among means were determined using the LSD test when $P<0.05$ (Gomez and Gomez 1984). The statistical package JMP was used for all analyses (SAS 2007).

RESULTS

Goats readily consumed shinoak and four-wing saltbush when each was fed alone; however, intake differed between the two species. Goats consumed more shinoak than four-wing saltbush (91.0 g vs 60.0 g SEM=5.3) on a daily basis. The diet by day interaction also differed (Fig. 1). Intake was similar for days 1 through 6; however, on day 7, goats consumed more of the shinoak daily every day thereafter. Four-wing saltbush intake varied between treatments. Goats that were offered four-wing saltbush and shinoak consumed more four-wing saltbush than goats that were offered four-wing saltbush alone (Table 2). Intake for goats also varied by treatment and day (Fig. 2). Intake of both diets varied daily; however, goats ate more four-wing saltbush on most days when they were also fed both shinoak.

Shinoak intake was similar for goats receiving shinoak alone, shinoak and four-wing saltbush, or shinoak and alfalfa (Table 2). However, the treatment by day interaction differed (Fig. 3). Goats typically consumed more shinoak when it was fed with four-wing saltbush than when it was fed alone or with alfalfa.

Total intake varied between treatments (Table 2) and across days of feeding (Fig 4). Total intake was higher for goats that were offered shinoak with four-wing saltbush or shinoak with alfalfa compared to feeding either shrub alone. Total intake was lower for the control group (basal ration only) when compared to inclusion of a shrub or alfalfa in the diet.

Serum metabolite levels of gamma glutamytransferase (GGT), serum aspartate transaminase (AST), and creatinine were similar among treatments (Table 3). The treatment by day interaction was not significant for any of the serum metabolites measured. Weight change was similar among treatments (Table 4).

Table 2. Average intake of four-wing saltbush, shinoak, and total intake for treatments fed food items singly or in combination.

Treatment	Four-wing	Shinoak	Total
Four-wing	24.8[b]	--	524.8[b]
Shinoak	--	38.6	538.6[b]
Four-wing +Shinoak	36.6[a]	44	580.6[a]
Alfalfa + Shinoak	--	36.6	582.7[a]
Control	--	--	500[c]

[a-c]Means within columns with different superscripts differ ($P<0.05$)

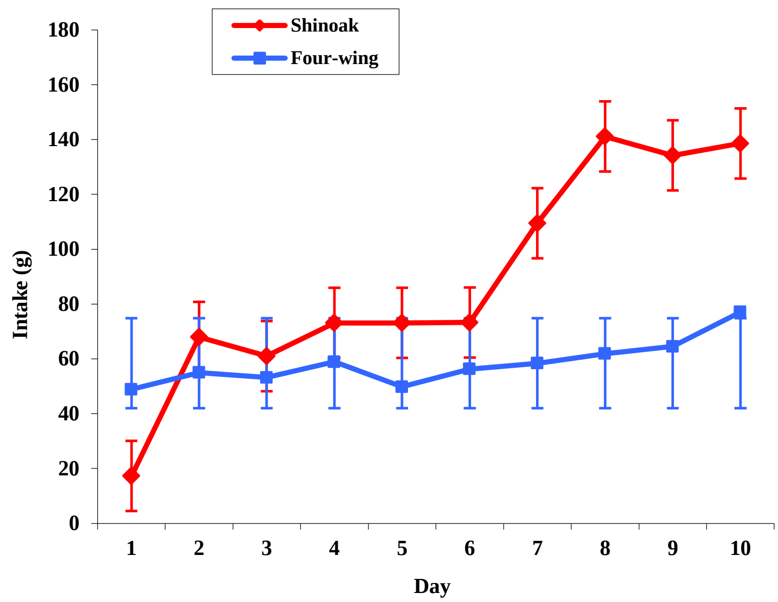

Figure 1. Intake of shinoak and four-wing saltbush when each was fed separately during the pre-trial

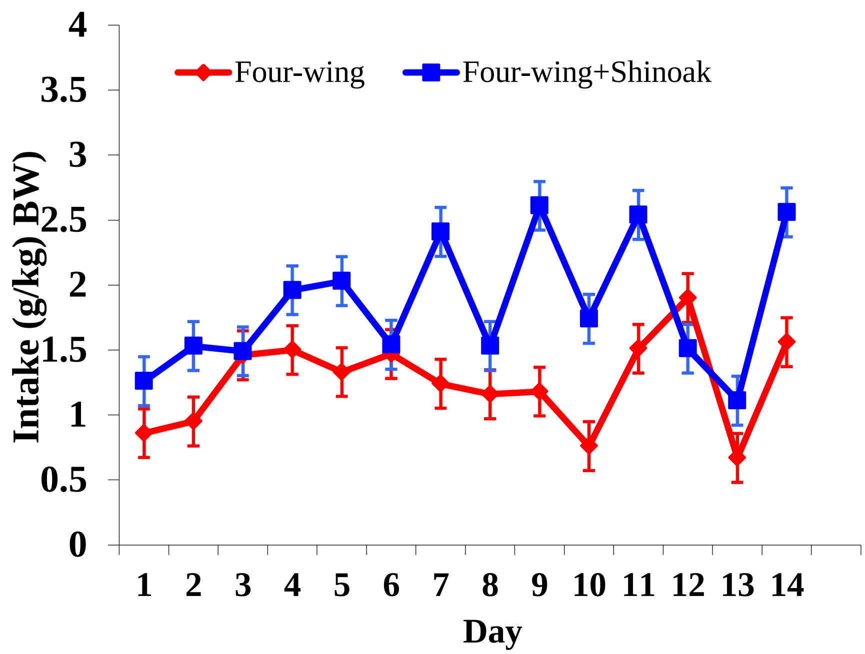

Figure 2. Intake of four-wing saltbush when it was fed singly versus when it was fed with shinoak

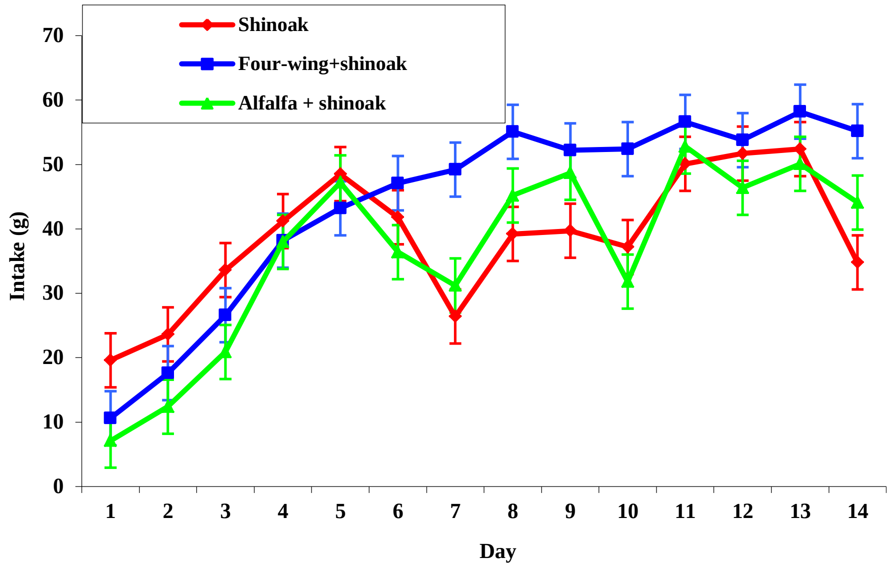

Figure 3. Intake of shinoak when it was fed singly, with four-wing saltbush, or with alfalfa hay

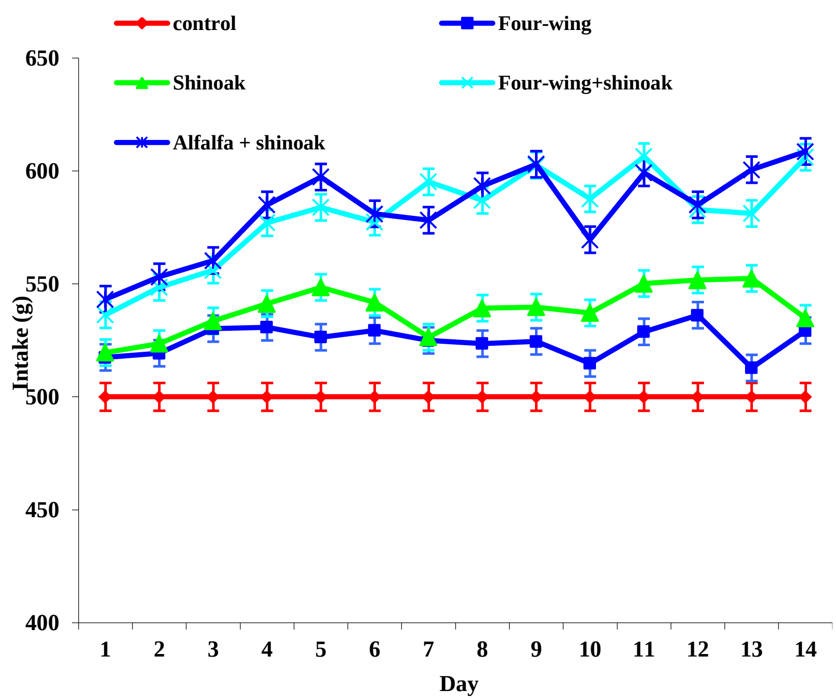

Figure 4. Total intake between treatments on a daily basis. Each treatment was fed a basal diet (2% BW) and either four-wing saltbush, shinoak, both, shinoak with alfalfa hay or neither shrub

Table 3.Serum metabolite levels for treatments fed different combinations of a basal diet with four-wing saltbush, shinoak, and alfalfa. Samples were collected on days 0, 4, 8, 12 and 16 of the study. Serum levels on day 0 were used as a covariate to account for variation among individual goats.

	Serum Metabolite Levels		
Treatment	**Creatinine**	**AST**	**GGT**
Four-wing	0.76∀0.05	46.9∀3.1	51.7∀1.8
Shinoak	0.74∀0.05	49.1∀2.8	47.0∀1.6
Four-wing + Shinoak	0.74∀0.05	51.8∀2.9	48.0∀1.7
Alfalfa + Shinoak	0.78∀0.05	49.0∀2.9	47.0∀1.7
Control	0.80∀0.05	48.4∀3.1	51.8∀1.8
Normal range	0.4-1.2	32-152	<319

Table 4. Weight change for treatments fed different combinations of a basal diet with four-wing saltbush, shinoak, and alfalfa. Weights were recorded at the beginning and end of the study.

	Weight (kg)		
Treatment	**Initial**	**Ending**	**SEM**
Four-wing	44.8	43.2	3.5
Shinoak	39.5	37.6	3.5
Four-wing + Shinoak	44.9	43.2	3.5
Alfalfa + Shinoak	45.8	43.9	3.5
Control	46.6	44.1	3.8

DISCUSSION

Shinoak was apparently less aversive than four-wing saltbush during this study. Four-wing saltbush is sometimes planted as forage for livestock and wildlife in central and western Texas. It is also found growing on native southwestern rangelands and is considered a nutritious, preferred browse plant (Marquart et al., 1992). Conversely, shinoak is considered a problematic species, out-competing other browse plants and herbaceous forage on many southwestern rangelands. Data from this study illustrates that shinoak may be preferred over four-wing saltbush.

When feeding both shrubs, intake increased for four-wing saltbush but not for shinoak. However, shinoak intake remained high throughout the study for goats fed shinoak singly, with four-wing saltbush, or with alfalfa. Shinoak was collected during July (approximately 45 days after bud break). Tannin levels are high in new growth during bud break in the spring and decrease thereafter (Villena and Pfister 1990). Shinoak, because of decreased tannin levels, may not have been aversive to goats in this study. Nevertheless, tannins do not disappear during summer months. It is reasonable to assume that shinoak contained some level of tannins during this study (Villena and Pfister 1990).

The increase in four-wing saltbush intake confirms the hypothesis that the saponins in four-wing saltbush and tannins in shinoak may have chelated in the small intestine of goats. Conversely, the lack of difference in shinoak intake does not support the hypothesis. The hypothesis of this study was that feeding both four-wing saltbush and shinoak would increase intake of each because of chelation of toxins. Given the different patterns of intake when comparing the two shrubs, we cannot confirm nor reject the hypothesis. However, other studies do offer some support for chelation of tannins and saponins. Saponins in small grains (e.g., wheat) often cause bloat in cattle grazing in the High Plains region of Texas. Recent research suggests that inclusion of therapeutic levels of condensed tannins in the diet reduce the number of bloat incidences from saponin ingestion (Bill Pinchak, pers. comm.).

When goats were offered alfalfa (saponin-containing plant), shinoak intake did not improve. The hypothesis of this study was that inclusion of alfalfa in the diet would increase intake of shinoak was not confirmed. If tannin levels would have been higher in shinoak, results may have been different in both trials. Future studies should feed shinoak leaves collected soon after budbreak.

Serum metabolite levels were similar among treatments and remained within the range for healthy goats (Table 3). Weight change was also similar among treatments (Table 4). It does not appear that goats experienced any physiological damage from consumption of four-wing saltbush or shinoak (Cheeke 1998, Vermeire and Wester 2001).

Goats consumed four-wing saltbush throughout the trial when it was fed singly and with shinoak despite the fact that it apparently caused aversive post-ingestive feedback. Ruminants typically consume more forage when fed a variety of foods that differ in nutrients and toxins than when a single food if fed (Provenza 1996, Wang and Provenza 1996, Provenza et al., 2003). The maintenance ration used in this study (Table 1) was formulated to meet maintenance requirements for growing goats. Goats could have met their nutritional requirements by avoiding four-wing saltbush or shinoak. Nevertheless, they always ate some four-wing saltbush or shinoak. This study and others (Provenza et al.,1996, Wang and Provenza 1996) have illustrated that ruminants will consume more when a variety of foods varying in nutrients and toxins are available.

Tannin and saponin levels were not measured in this study. Even though absolute levels of each were not known, it can be assumed that four-wing saltbush contained saponins that caused aversive post-ingestive feedback as evident from the lower levels of intake of four-wing saltbush. Palatability is a complex process that integrates the taste, odor, and texture of foods with post-ingestive feedback (Provenza 1995). As intake of toxins that result in aversive post-ingestive feedback increase, palatability decreases. Thus, reduced intake of four-wing saltbush illustrates that it remained aversive, apparently from saponin levels within the plant.

Goats in this study may have relied on other physiological mechanisms to circumvent toxicosis. Many foreign compounds (i.e., toxins) are bio-transformed by chemical reactions to reduce toxicity (Nebbia 2001). Most toxins are absorbed as lipid soluble substances are then metabolized in the body to water soluble metabolites that can then be excreted in the urine (Cheeke 1998). Thus, goats may have been able to detoxify the tannins in shinoak which resulted in higher intake.

Diet quality affects ruminants' ability to detoxify some toxic plants. Energy and nitrogen are required to maintain rumen microbial populations in the rumen and liver function that are involved in the breakdown on toxic substances (Bidlack et al., 1986, Illius and Jessop 1995). Protein supplementation improved redberry juniper (*Juniperus pinchottii*) intake over energy intake, apparently because of improved rumen and liver efficiency (Taylor et al., 1997). Recent research has also illustrated that feeding protein sources high in escape proteins improved consumption of redberry juniper more than supplements with highly soluble protein sources (George et al., 2008). Similarly, supplementation with protein sources high in sulfur-containing amino acids improved the livers ability to detoxify hymenoxon, the toxic substance in bitterweed (*Hymenoxys odorata*) (Ueckert and Calhoun 1988, Calhoun et al., 1989). In some cases, energy supplementation has also improved intake of poisonous shrubs. Intake of big sagebrush (*Artemisia tridentata*) was improved when lambs received supplemental barley (Banner et al. 2000, Burritt et al., 2000).

All treatments received the same nutritious basal diet. Any benefit in terms of supplying nutrients from the basal diet should have been the same given they were all fed the same basal diet and ate the same amount. It is possible that shinoak provided some essential nutrients used to detoxify saponins. Oaks are typically high in condensed tannins which form complexes with proteins reducing their degradation in the rumen (Cheeke 1998). If some amino acids escaped rumen metabolism, they could have been absorbed in the small intestine and improved metabolism of toxins in the liver.

IMPLICATIONS

Ruminants that have the opportunity to utilize a diverse array of forage are better able to meet their nutritional needs on rangelands. By managing for increased levels of plant diversity, producers are able to increase intake and utilize more of the forage that is present on their land. With a varied diet, ruminants will be more likely to meet their nutritional needs much more efficiently. Increased intake will, in turn lead, to an increase in performance. Likewise, supplementation costs should be lower because of greater nutrient intake from a varied diet.

Usually when shrubs are planted or re-established to improve browse quality for livestock and wildlife, a single species, like four-wing saltbush, is planted. Land managers should consider planting a variety of shrubs to improve nutrient quality and limit the likelihood of over-ingestion of toxic plants. Arguably, all foods are toxic. Over-ingestion of any forage can result in internal malaise. Providing a variety of forages will limit the opportunity for plant-induced toxicity in livestock.

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Effects of Tasco-14 Supplementation on Growth and Fertility Traits in Young Male Boer Goats Experiencing Heat Stress

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ABSTRACT

The current study examined effects of supplementation of Tasco-14 (seaweed, kelp extract) on growth and fertility in young male goats experiencing heat stress. Twenty young Boer males (27.8 ± 1.5 kg) were grouped randomly into 1 of 4 dry-lot pens and maintained on a free choice high-energy diet. Goats received either supplementation of Tasco-14 (35 g/week, oral) or no supplementation (control) for an 84-day period, during which weekly average high temperatures ranged from 32.1-38.2 °C. Data were collected for scrotal growth, average daily gain (ADG), final live-animal ribeye area (REA), bi-weekly rectal temperature, final sperm cell concentration, and final sperm motility score. No differences (*P* > 0.05) were observed between supplemented and control males for scrotal circumference growth, REA, or ADG. Rectal temperature was greater (*P* = 0.010) in males receiving Tasco-14 than in controls. Although no difference (*P* = 0.232) was observed between treatments for sperm motility score, sperm cell concentration was greater (*P* = 0.036) in supplemented males than in controls. Thus, sperm cell motility was unaffected and sperm cell concentration was improved by supplementation of Tasco-14 in growing males experiencing heat stress, despite marginally increased body temperature.

KEY WORDS: heat stress, kelp extract, seaweed extract, tasco-14

INTRODUCTION

Heat stress is a major limiting factor of goat production in Texas. Increased ambient temperature adversely impacts both physical performance (McDaniel and Parker, 2004) and reproductive capacity (Rockett et al., 2001). Increased respiratory frequency (Allen et al., 2001) and metabolism (Valko et al., 2004) that often characterize heat stress can increase levels of free radical compounds, resulting in decreased sperm quality and production (Volger et al., 1991). Supplementation of products rich in antioxidants during periods of heat stress has been shown to improve fertility (Breezezinska-Slebodzinska et al., 1995; Leonard et al., 2001; Evans et al., 2002). One such product is kelp extract (Galipalli et al., 2004a) which contains two important

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antioxidants: α-tocopherol and glutathione. The objective of this study was to determine effects of Tasco-14 (a kelp extract) on growth and fertility traits of young Boer males experiencing heat stress.

MATERIALS AND METHODS

Experimental Procedure. Twenty young male Boer goats (27.7 ± 1.5 kg, approximately 100 days of age and 21 days after weaning) produced at Angelo State University were used in the present study. Goats were stratified by size and confined in one of four dry-lot pens at the Angelo State University Management, Instruction, and Research Center on May 26. After an 11-day adjustment period, all goats were fed a free access high-energy diet (Table 1) for 84 days. Ten randomly selected goats were supplemented with Tasco-14 (Acadian Agritech, Dartmouth, Nova Scotia; Table 2) seaweed (kelp) extract (35 g/week, oral) for the duration of the 84-day feeding period. Each week, ten-gram doses of extract were administered on Monday and Wednesday, and 15-g doses were given on Friday. Extract was administered orally from a 100-g squeeze-tube to the back of the tongue. Body weights were recorded on days 0, 28, 56, and 84, rectal temperature was measured on days 8, 22, 36, and 50, and scrotal circumference was measured on days 0 and 84. Final ribeye area measurements were conducted on the live animal using an ALOKA 500 (ALOKA, Inc., Wallingford, CT) ultrasound machine. On day 84, a sperm sample was collected from each goat via electroejaculation and sperm motility score (1 = extreme movement; 7 = no movement) was assigned and sperm cell concentration was determined via hemacytometer. Maximum ambient temperature (Figure 1) for the region averaged 35.9, 36.1, and 36.2 °C for June, July, and August, respectively.

Statistical Analysis. Weight and rectal temperature were analyzed as a split plot using the mixed procedure of SAS (SAS Institute, Inc., Cary, NC) with repeated measures function. Treatment was in the main plot and the sub plot included day of measurement and treatment by day interaction. Scrotal circumference growth, REA, sperm motility score, and sperm cell concentration were analyzed as completely randomized designs. Due to variance, a Wilcoxon rank test was performed using the nonparametric one-way procedure of SAS. Goat was the experimental unit.

Table 1. Analysis (as fed) of ad libitum experimental diet (as fed)

Ingredient	Amount
Crude protein, %	16.00
Crude fat, %	2.50
Crude fiber, %	17.00
Ca, %	1.00
P, %	0.30
K, %	1.00
NaCl, %	1.25
Cu, ppm	25.00
Se, ppm	0.30
Vitamin A, IU/kg	4545.45
Vitamin E, IU/kg	9.09
Monensin, IU/kg	4.55

Table 2. Nutrient analysis (as fed) of Tasco-14 supplemented to young male Boer goats experiencing heat stress.

Nutrient	Amount	Nutrient	Amount
Dry Matter, %	88	Chloride, % (max)	3.5
Crude Protein, % (min)	4	Magnesium, % (min)	0.6
Crude Fiber, %	6	Phosphorus, % (min)	0.1
Crude Fat, % (min)	2.5	Potassium, % (min)	1.5
Carbohydrates, %	52	Sodium, % (max)	3.5
Ash, % (max)	23	Sulfur, % (min)	1.8
Aluminum, ppm (max)	120	Chromium, ppm	1
Barium, ppm (max)	15	Cobalt, ppm	< 1.0
Beryllium, ppm	< 1.0	Copper, ppm (max)	2
Boron, ppm (min)	80	Iodine, ppm (min)	650
Cadmium, ppm (min)	< 1.0	Manganese, ppm (min)	25
Lead, ppm	< 1.0	Selenium, ppm	< 1.0
Mercury, ppm	< 1.0	Zinc, ppm (min)	20
Molybdenum, ppm	< 1.0	Vitamin A, IU/kg[1]	259
Vanadium, ppm (max)	5	Vitamin D3, IU/kg[1]	1,404.00
Calcium, % (min)	1.2	Vitamin E, IU/kg[1]	3.6

[1] As determined by SDK Laboratories, Hutchinson, KS.

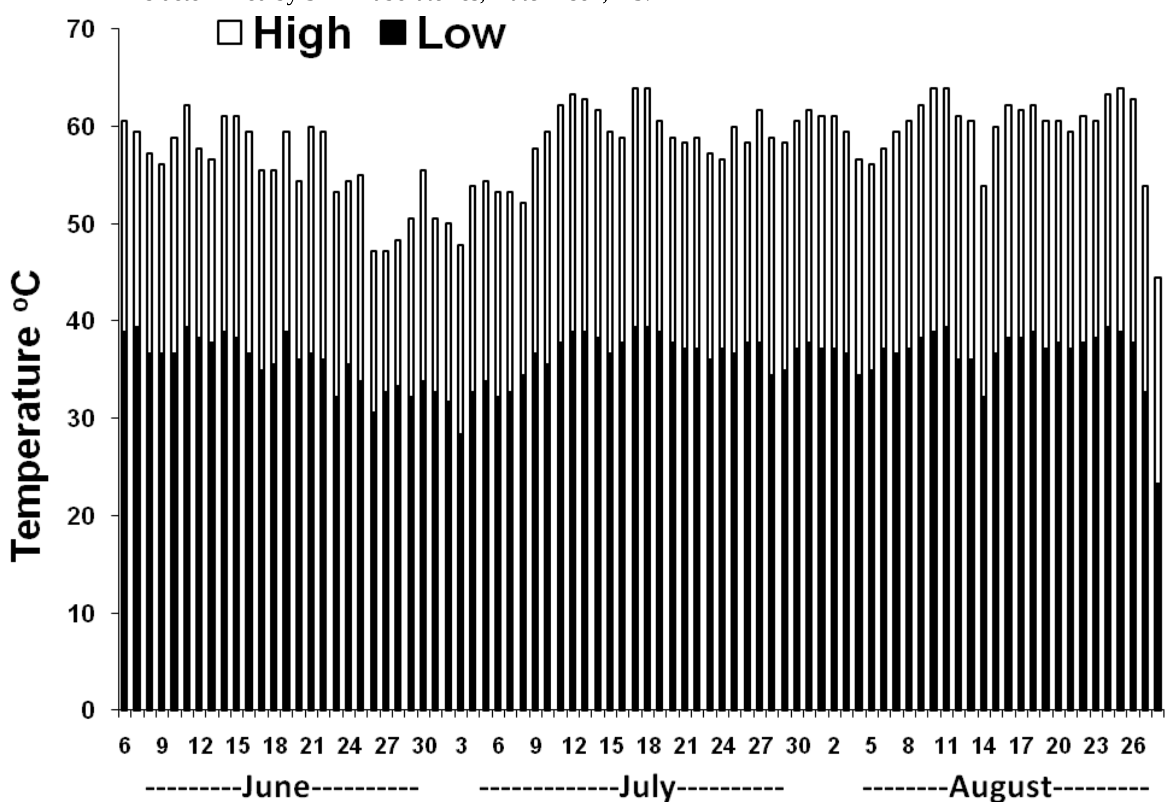

Figure 1. Daily maximum and minimum ambient temperatures (°C) for San Angelo, TX over the 84-day feeding period.

RESULTS AND DISCUSSION

No treatment by day interaction was observed (*P* = 0.742) for body weight over the 84-day experimental period. Body weight (Figure 3) did not differ (*P* = 0.964) between goats receiving Tasco-14 supplementation and controls, but did increase (*P* < 0.001) with day, as expected, suggesting that supplementation of Tasco-14 to goats under the current conditions does not alter weight gain. These data contradict previous findings by Leupp et al., (2005), in which Tasco-14 increased digestibility of poor quality roughage and allowed supplemented animals to more efficiently use available forage and, consequently, exhibit greater rates of gain. This effect may not have been observed in the present study due to the use of a high energy diet.

Ribeye area (Table 3) measured at the conclusion of the 84-day experimental period did not differ (*P* = 0.515) between supplemented and control groups. Although Ventura and Castañón (1997) found that protein availability was improved by supplementing seaweed extract, goats in the current study received adequate amounts of dietary protein. Scrotal circumference growth was not different (*P* = 0.111) among treated goats and control counterparts. However, variance between animals within treatment groups was large, and greater replication may have been warranted.

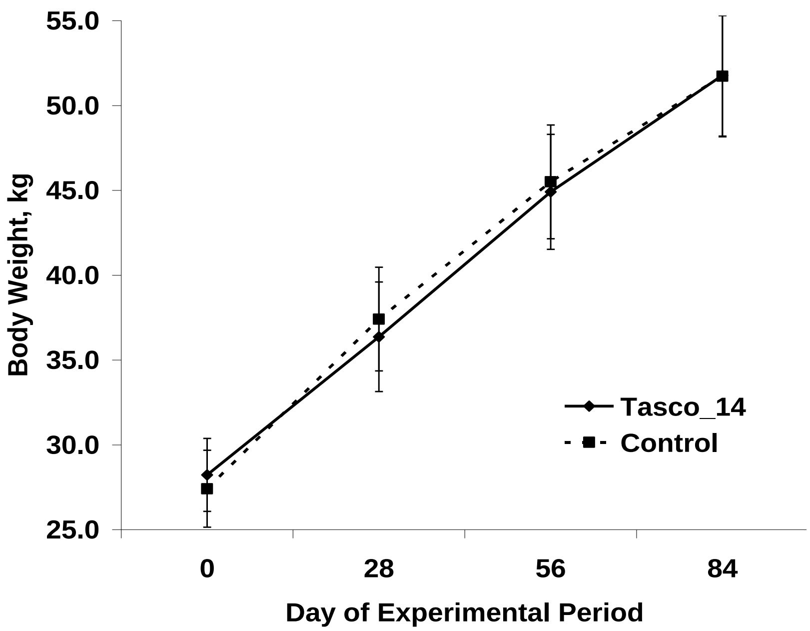

Figure 3. Average body weight (kg) of young male Boer goats supplemented with Tasco -14 (35 g/week) for 84 days while experiencing heat stress. No treatment by day interaction was found (*P* = 0.742). Overall treatment means did not differ (*P* = 0.964)

Sperm motility score did not differ (*P* = 0.399) among goats administered Tasco-14 and controls. However, the supplemented group appeared to exhibit more consistency, with 80 % of the animals scoring in the top quarter of the scale, compared to 50 % of controls. This study does not support previous research that found high levels of antioxidants in seaweed extract reduce damage to sperm cells and increase sperm motility (Brezezinsha-Slebodzinska et al., 1995;

Galipalli et al., 2004a; Galipalli et al., 2004b). Sperm cell concentration was greater (*P* = 0.036) in goats supplemented with Tasco-14 compared to controls. Average concentration for both groups were above the 2 to 3 billion cells/mL average reported by Coffey et al., (2004), although some control animals fell well below this average value. These data indicate supplementation of kelp extract increases sperm cell concentration in goats experiencing heat stress.

Data indicate supplementation of Tasco-14 improves sperm cell concentration in young Boer goats experiencing heat stress. Although rectal temperature (Figure 2) was increased by Tasco-14 supplementation, this phenomenon did not appear to adversely affect growth traits. Supplementation of seaweed extract during periods of elevated ambient temperature may provide improved breeding opportunities. However, more research is needed to clarify effects of Tasco-14 on scrotal circumference and growth traits.

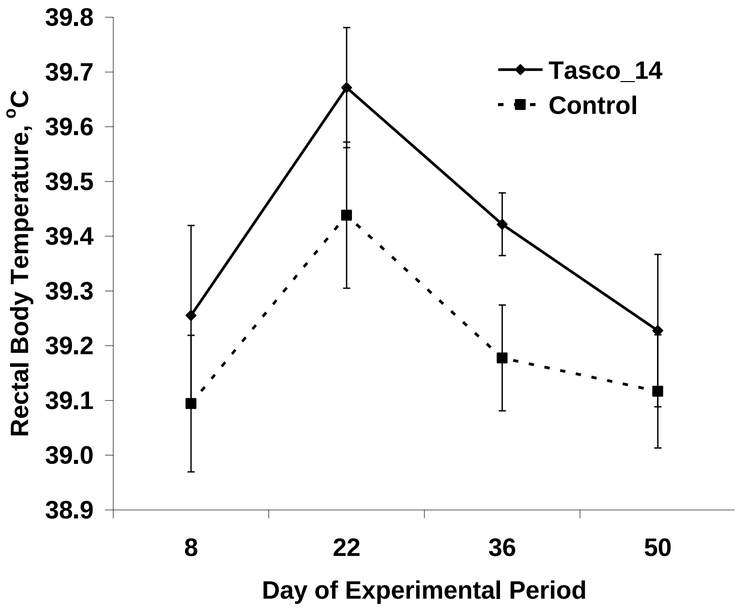

Figure 2. Average rectal temperature (°C) of young male Boer goats supplemented with Tasco -14 (35 g/week) for and 84-day period while experiencing heat stress. No treatment by day interaction was found (*P* = 0.947). Overall treatment means differ (*P* = 0.010)

Table 3. Ribeye area, scrotal circumference growth, sperm motility score, and sperm cell concentration in young male Boer goats supplemented with Tasco -14 (35 g/week) for and 84-day period while experiencing heat stress.

Item	Treatment			
	Control	Tasco-14	SE[1]	*P*-value
Ribeye area, cm^2	5.0	5.1	0.1	0.515
Scrotal circumference growth, cm	7.6	9.9	1.3	0.111
Sperm motility score[2]	2.7	1.8	0.6	0.399
Sperm cell concentration, x 10^9/mL	3.0	4.2	0.5	0.036

[1]Standard error (n = 10).
[2]1 = extreme movement; 7 = no movement.

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Survivability of Bovine Derived *Escherichia Coli* Subjected to Temperatures Typical of Summer in Texas

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ABSTRACT

Dairy manure and wastewater is often stored in lagoons and applied to fields during summer months. The objective of this study was to determine the affect of moderate durations of typical Texas summer temperatures on the survivability of *E. coli* in dairy manure. Manure samples were collected from two dairy operations and assigned to one of three temperature treatments, 73 °F, 95 °F, or 111 °F. Manure samples were analyzed for *E. coli* on d 10 and d 21. By d 10, reductions of 0.79 and 5.01 log units of *E. coli* occurred in manure samples stored at 95°F and 111 °F, respectively. Survivability of *E. coli* populations at d 10 varied by farm for samples stored at 73 °F. All samples showed significant reductions in *E. coli* populations after 21 d. On d 21, *E. coli* bacteria in manure stored at 111 °F were undetectable, and *E. coli* concentrations averaged 0.63 and 3.87 log CFU/g for the 95 °F and 73 °F treatments, respectively. Survivability of bovine derived *E. coli* was reduced by temperatures that are typical of summer in Texas. Application of manure to agriculture land in Texas during periods of high environmental temperatures may facilitate a quicker decline in *E. coli* concentrations.

KEY WORDS: *Escherichia coli*, dairy, manure, temperature

Escherichia coli are a type of bacteria well adapted for survival in natural environments. These bacteria are naturally widely distributed in soils and bodies of water throughout the world and are commonly found in the intestines of animals and humans. There are concerns that toxic strains of *E. coli* from livestock manure could move into surface or groundwater and pose risks to human health.

Reports have shown that elevated temperatures decrease the concentrations of *E. coli*. A composting study reported by Hess et al. (2004) found that temperatures as low as 104 ºF reduced the numbers of *E. coli* 0157:H7. Similar temperatures have also been shown to eliminate all strains of *E. coli* bacteria during the process of aerobic digestion (Michel et al., 2005).

Escherichia coli populations do not multiply rapidly under cool temperatures. Temperatures of 46.4 ºF have been shown to initially foster the growth of certain *E. coli* strains,

[c]The authors would like to express their thanks to the Texas Animal Nutrition Council for their assistance in funding this study

but cause them to decline in subsequent days. Temperatures of 39.2 ºF have been shown to reduce, but not eliminate, the growth of *E. coli* (Francis and O'Beirne 2001). Furthermore, *E. coli* has the ability to reproduce exponentially as an initial response to exposure to temperatures between 73 ºF and 77 ºF (Fujioka and Byappanahlli 1998).

Previous reports have indicated that *E. coli* and total coliform counts from handling and land application of manure were lower when manure was applied under cooler temperatures, which is generally any time of the year other than mid-summer (Miller, 2006). In contrast, a study by Sharples et al. (2004) found that manure applied in June resulted in greater survival rates of *E. coli* as opposed to manure applied in August.

In Texas, dairy waste is often stored in lagoons and applied to fields during the summer months. Summer air temperatures in Texas can easily exceed 100 ºF. Due to the high temperatures that are common during the summer, *E. coli* concentrations of manure may decline more rapidly than would be expected in a more moderate climate. The objective of this study was to determine the affect of moderate durations of typical Texas summer temperatures on the survivability of *E. coli* in dairy manure.

MATERIALS AND METHODS

Manure samples for this study were collected from 2 different dairy operations, P and F. The dairy operations used different management styles and feeding practices. Dairy P was a 150 cow dry-lot dairy that utilized a total mixed ration with a feeding lane, and dairy F was a 90 cow grazing-based dairy that fed supplemental grain inside the milking parlor and fed some supplemental silage. The manure was taken from the milking parlor holding pens at each dairy. Manure was manually scraped from each milking parlor holding pen within 2 h of completion of the morning milking.

Treatments. Manure collected from each dairy was thoroughly mixed and divided into nine 24 qt. plastic containers. The containers from both dairy F and dairy P were then separated into three groups of three replicates each. Each group of replicates from the two dairies was assigned to one of three temperature treatments. The control treatment was set at a "room temperature" of 73 °F. The second treatment was stored at 95 °F, and the third treatment was subjected to a greater temperature of 111 °F. Manure samples were stored at their respective assigned treatments within 3 h of collection.

Containers for each replicate were 24 qt. plastic storage boxes with loose fitting lids to allow for venting of gases. Room temperature replicates were stored in an air-conditioned laboratory, and medium and high temperature replicates were stored in large, electric temperature-controlled incubators. Individual containers were stored at the same temperature throughout the study.

Sample Collection. Sub-samples from each container were collected on d 10 and d 21 of the study. Six samples, three composite samples from each dairy, were analyzed after the initial manure collection to determine *E. coli* levels at the initiation of the trial period and to test for the presence of *E. coli* O157: H7.

Manure samples were cooled to 39 °F immediately after collection and shipped the same day to insure that samples were analyzed within 24 h of collection. Samples were analyzed for *E. coli* using 3M Petrifilm™ by Midwest Labs in Omaha, Nebraska. A composite sample from each dairy was analyzed at the end of the study to determine the nutrient content of the manure.

Statistical Analyses. The study was arranged in 2x3 factorial design with repeated measures. Numbers of *E. coli* were measured in colony forming units (CFU)/g. These populations were transformed using logarithms to achieve normal distributions. The data were analyzed using the Proc Mixed procedure of SAS with an unstructured covariance structure (SAS Institute, 1996). The repeated statement was included to analyze the differences over time. Differences were declared significant when $P < 0.05$, as determined by the least squares means test. Statistical analysis of bacteria populations is reported in logarithmic form.

RESULTS

Initial physical characteristics of the manure from the two dairy operations appeared to differ at the time of collection. Manure from dairy F appeared to be dryer, more fibrous, and had visible signs of whole grain sorghum in the manure. Manure from dairy P appeared to have a greater moisture content, possibly due to the sprinkler system that was in use in the cattle holding pen for cow cooling at dairy P. Moisture and nutrient analysis of the manure samples at the end of the study are shown in Table 1. Average concentrations of *E. coli* at the start of the study were 370,000 CFU/g for dairy F and 156,666 CFU/g for dairy P.

The initial manure samples from dairies F and P were analyzed for the presence of *E. coli* O157:H7. The results of the hemorrhagic *E. coli* O157:H7 tests were negative for both dairies.

Table 1. Moisture and nutrient composition of manure samples from dairy F and dairy P.

Parameter	Dairy P2	Dairy F
Total Solids, %	21.0	22.1
	---------------DM Basis------------	
Ash, %	23.05	18.55
Total Nitrogen, %	3.48	4.34
Ammonium Nitrogen, %	1.00	0.77
Organic Nitrogen, %	2.48	3.57
Phosphorus, %	1.33	1.13
Potassium, %	3.43	4.52
pH	7.6	6.5

The differences between the treatments at each sampling date for dairy F and dairy P are shown in Tables 2 and 3, respectively. On d 10, *E. coli* concentrations in the manure from dairy F stored at 95 ºF were significantly less than *E. coli* concentrations in the manure stored at 73 °F. However, *E. coli* concentrations in the manure stored at 73 °F from dairy F actually increased as compared to concentrations at the start of the study, whereas there was a slight decrease in *E. coli* concentrations for the 73 °F treatment on d 10 for dairy P.

Table 2. Concentrations of *E. coli* (log CFU/gram) of manure samples at dairy F.

	Treatment		
Day[*]	73 ºF	95 ºF	111 ºF
0	5.53	5.53	5.53
10	6.28[a]	4.89[b]	ND[c]
21	3.87[a]	0.63[a]	ND[b]

[*]Differing superscripts within row indicate significant differences ($P < 0.05$).
ND – Not detectable

Table 3. Concentrations of *E. coli* (log CFU/gram) of manure samples at dairy P.

	Treatment		
Day*	73 ºF	95 ºF	111 ºF
0	5.14	5.14	5.14
10	4.61[a]	4.21[a]	0.51[b]
21	3.51[a]	ND[b]	ND[b]

*Differing superscripts within row indicate significant differences ($P < 0.05$).
ND – Not detectable

In this study, *E. coli* concentrations of manure stored at 111 °F declined significantly more quickly than manure stored at either 73 °F or 95 °F. By d 10, *E. coli* was only detectible in one replicate from dairy P, and the concentration in that sample was only found to be 33 CFU/g. At d 21, *E. coli* was not detectible in any of the samples stored at 111 °F. In contrast, *E. coli* was still present in all of the manure samples stored at 73 °F. However, even the samples stored at 73 °F showed a significant decline in the concentrations of *E. coli* over the 21 d period (Figure 1).

DISCUSSION

The lower concentrations of *E. coli* in manure at dairy P were partially accounted for by the difference in moisture concentration between the two farms. The differences in the manure nutrient, moisture, and bacteria concentrations were most likely a result of the different management styles of the two dairy operations, as dietary feed ingredients, housing, and animal management varied between the two dairy operations. Overall, the *E. coli* concentrations in the fresh manure samples were lower than expected, as Mawdsley et al., (1995) reported *E. coli* concentrations greater than 1 billion CFU of *E. coli*/g of wet feces. The varying moisture or nutrient content of the manure from the two dairies may have played a roll in the greater sustained growth of *E. coli* in the manure from dairy F stored at 73 °F.

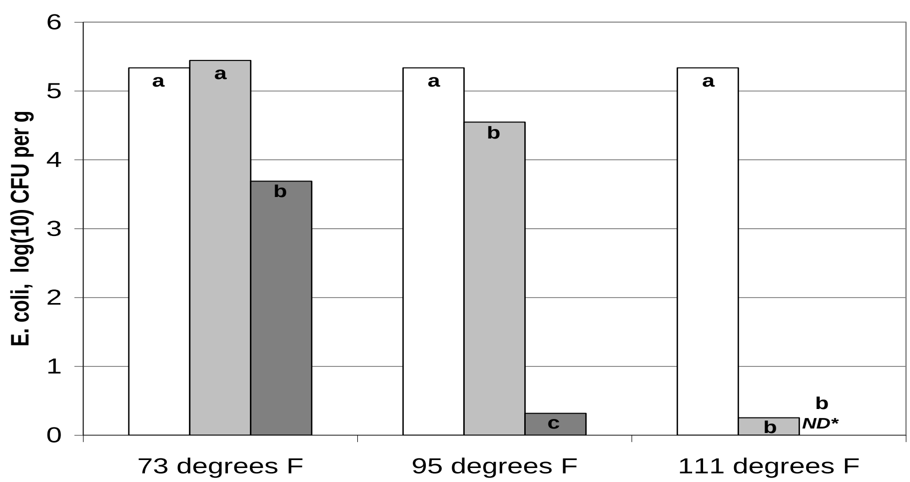

Figure 1. Concentrations of *E. coli* in dairy manure on day 0, at day 10, and day 21 when held at various temperatures. Day of Sampling: (□) 0, ( ) 10, and ( ) 21.
*ND - *E. coli* were not detectable (ND) at day 21.
[abc]Bars with different letters at a given temperature indicate significance at $P < 0.05$.

With increased time and/or increased heat, the survivability of *E. coli* decreased significantly in this study. When the temperature of the manure was held at 111 ºF, *E. coli* concentrations in manure declined quickly and were not detectible in most of the manure samples within 10 d. The decline in *E. coli* at 73 ºF occurred without exposure to solar radiation or drying affects that would be expected in a natural environment. When the storage temperature of manure increased, the mortality rate of *E. coli* increased significantly.

Escherichia coli O157:H7 is the strain implicated in most human health concerns. In this study, the presence of *E. coli* O157:H7 was not detected in the manure samples. According to Vinten et al., (2002), *E. coli* O157 appears to be equal to or more susceptible to environmental stress than generic *E. coli* and less likely to be present in runoff from land where agriculture slurry may be applied.

The Environmental Protections Agency uses generic *E. coli* bacteria as the criteria to determine when the levels of fecal contamination in surface waters need to be addressed, regardless of the strain of *E. coli* present. Animal derived *E. coli* survivability is dependent on the environment in which it must reside. This study concludes that elevated temperatures, similar to temperatures common to Texas and other Southern States during the summer months, will create conditions which increase the mortality rate of *E. coli* bacteria found in dairy manure.

Recommendations for manure management practices concerning the timing of the application of dairy manure to cropland or pasture in Texas may need to be revisited. In Texas or other areas with hot climates where *E. coli* is a concern, application of manure when ambient temperatures are at the greatest may be a management practice that facilitates reductions in *E. coli* concentrations. Recommendations for manure application during high temperatures are in contrast to past studies (Miller et al., 2004) that imply cooler temperatures will reduce the rate of *E. coli* multiplication. Elevated air temperatures, along with solar radiation (LeJeune et al., 2001; Berney et al., 2006), may reduce *E. coli* populations in manure, thereby reducing the amount of viable *E. coli* that could be transported to nearby water sources. The results of this study indicate recommendations for manure application should be based on the climate of the application location.

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Evaluation of Commercial Aerial Imagery to Assess Variability of Height and Yield in Cotton (*Gossypium hirsutum* L.) Fields

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ABSTRACT

Variable rate application of products can be applied based on the identification of vigor zones in cotton fields. Companies exist which acquire imagery, create vigor zones, and provide application maps for products based on the vigor zones. The accuracy of using commercially obtained vigor zones in semi-arid cotton growing areas, such as the southern High Plains of Texas was investigated, and compared with the value obtained by digitized soil maps, that are obtained at no charge by the Soil Survey Geographic Data Base of the USDA Natural Resources Service. Commercial aerial imagery was taken of nine cotton fields (six in 2006 and three other fields in 2007) by Wilbur-Ellis, using AgFleet version 3.0 in 2006 and by In Time Inc. in 2007. Vigor maps based on three zones were created by these companies and used to test whether the zones accurately represented differences in plant height in nine fields, and yield in five fields. Soil maps were overlaid over the imaged fields, and plant height and yield were compared among the different soil types. In general, yield differences were not adequately predicted by height differences in the fields. Vigor maps did adequately represent yield differences in 3 of 5 fields. Soil maps were related to yield differences in 3 of 5 fields. However, it was not intuitive which soils would be more productive based on their properties. There were several instances where soils with a shallow petrocalcic horizon yielded higher than areas of deep, calcium free soils. The use of commercially available imaging to identify vigor zones was successful in some fields, but in a number of situations it was not reliable. Producers should evaluate the technology on a case-by-case basis before using recommendations based on imagery for variable rate applications. Plant height was not necessarily a reliable method to identify vigor zones, so the use of a yield monitor may be the best method of identifying consistent management zones.

KEY WORDS: imagery, precision agriculture, variable-rate application

INTRODUCTION

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Variability in cotton growth can occur due to soil physical characteristics, soil chemical differences, and biotic factors. Variable rate application of agricultural products can be utilized if differences in fields are consistent over years (Guo and Maas, 2005), or if variability can be measured timely during the season through remote sensing. Imagery can be used to calculate a vegetation index which can represent plant vigor. One of the most commonly used vegetation indices is called the normalized difference vegetation index (NDVI) which is calculated by light reflected at the (near-infrared wavelength – red wavelength) / (near-infrared wavelength + red wavelength) (Tucker, 1979). The near infrared wavelength is approximately 700 to 900 nm, and the red wavelength is approximately 600 to 700 nm. This vegetation index has been correlated with cotton yield (Jayroe et al., 2005; Plant et al., 2000). There are commercial enterprises which collect imagery, transform them with NDVI, and sell them to producers for crop management (www.gointime.com).

Variable rate applications are conducted with almost all farm inputs including seed density (Shanahan et al., 2004), nitrogen and phosphorus rates (Bronson et al., 2003; Bronson et al., 2005), plant growth regulators (Lewis et al., 2002; Nelson et al., 2005), nematicides (Wheeler et al., 1999), and harvest aids (Nelson et al., 2005). Producers using some of these inputs in a variable rate system can take advantage of in-season remote sensing imagery.

In cotton, the connection between aerial imagery and commercial variable rate applications was primarily developed in Mississippi, with a project under the NASA Ag 20/20 program. At that time, it was difficult for producers to obtain a commercial product that both obtained imagery and assisted them with application maps. The company In Time (www.gointime.com) was created as a result of the collaborative efforts of this project (www.gointime.com/about_history.jsp). Over the years there have been some large companies that have also tried to tie-in remote sensing services with variable rate applications (Wilbur-Ellis and John Deere). There are also some consultants who offer imagery plus the ability to create application maps as part of their consulting services. There were a number of on-farm experiments conducted in California, Louisiana, and Mississippi to demonstrate that multispectral remote sensing could be used to generate accurate plant growth maps, and these could be used to generate application maps (Bethel et al., 2003; Leonard et al., 2003; Lewis et al., 2002). However, the ability of companies to use imagery to create management zones related to plant vigor in the semiarid region of West Texas has not been demonstrated. This area produces deficit-irrigated cotton, that may develop into a much smaller plant as well as other differences related to the climate. The objectives of this project were to take commercially developed three-zone vigor maps, and relate them to plant height taken at a time appropriate for application of plant growth regulators; to relate yield to these three-zone vigor maps; and to relate yield and plant height to digitally available soil maps.

MATERIALS AND METHODS

In 2006, imagery represented as three vigor zones was obtained from Wilbur-Ellis (AgFleet version 3.0, a part of ZedX Inc., Bellefonte, PA) from six cotton fields on 17 July (Fig. 1). Soil maps were obtained for each field from the Soil Survey Geographic Data Base from the USDA Natural Resources Conservation Service and overlaid on the images (Fig. 1).

In 2007, imagery represented as seven vigor zones (called scout maps) was obtained from In Time Inc. (www.gointime.com) from three cotton fields on 16 July (Fig. 2 Byrd, Herr07, Watson). The scout maps were also transformed into application maps with three zones by In Time Inc. Soil maps were obtained for each field similarly as in 2006.

Plant height in 2006 was taken at these six sites between one and three times depending on the site. In 2006, plant height locations taken in early July were selected by representative sampling of soil types for all six fields. Plant height taken in late July (Clark and Saylor fields only) and August (Clark and HH fields only) were selected by representative sampling of vigor zones. In 2007, a relatively even spacing of locations or height measurement was made on all fields, and the same locations sampled three times for all three fields. At each location that plant height was measured, 10 consecutive plants were measured and the height was averaged for that point (in both years).

Yield maps were obtained with an AgriPlan yield monitor attached to the burr extractor of a John Deere 7445 cotton stripper, at two sites in 2006 (Clark on 17 Nov., and HH on 1 Nov.) and three sites in 2007 (Byrd on 24 Oct., Herr on 22 Oct., and Watson on 26 Oct). At each site, a minimum of six, six row areas were stripped and monitored for yield. Within each six row area, two rows were harvested at a time, so that a minimum of 18 2-row strips were obtained. Yield was collected at 1 sec intervals.

Aburto. This field consisted primarily of two soils, an Arch loam and Portales loam (0-1% slope), with 3% of the field in a Drake soil (1-3% slope) (Fig. 1). There were 10 locations per soil measured for height on 13 July, 2006 (30 total measurement points). These locations corresponded to nine, 10, and five measurements in the high, medium, and low vigor groups, respectively.

BAM. This field consisted primarily (91%) of an Amarillo loamy fine sand (0-1% slope, and 1-3% slope), with a small percentage of the field in three other soil types (Acuff loam, 1-3% slope; Arvana fine sandy loam, 0-1% slope; and Posey fine sandy loam, 1-3% slope) (Fig. 1). Plant height was measured in all five soils on 13 July, 2006 with the highest number of measurements (24) occurring in the Amarillo loamy fine sand with 1-3% slope. Plant height measurements were taken at 24, 25, and 20 locations in the high, medium, and low vigor groups, respectively.

Byrd. Plant height was taken on 12 July, 26 July, and 8 Aug in 2007. This field was predominantly a Portales loam (81%) with 0-1% slope, with an Acuff loam (0-1% slope) as the only other soil with at least 10% area (Fig. 2). There were 38 locations where plant height was measured, and there was at least 10 locations measured for height in each vigor group. Height measurements were predominantly located on the Portales loam (31 locations), with five locations on the Acuff loam, and one location each on the other two soils.

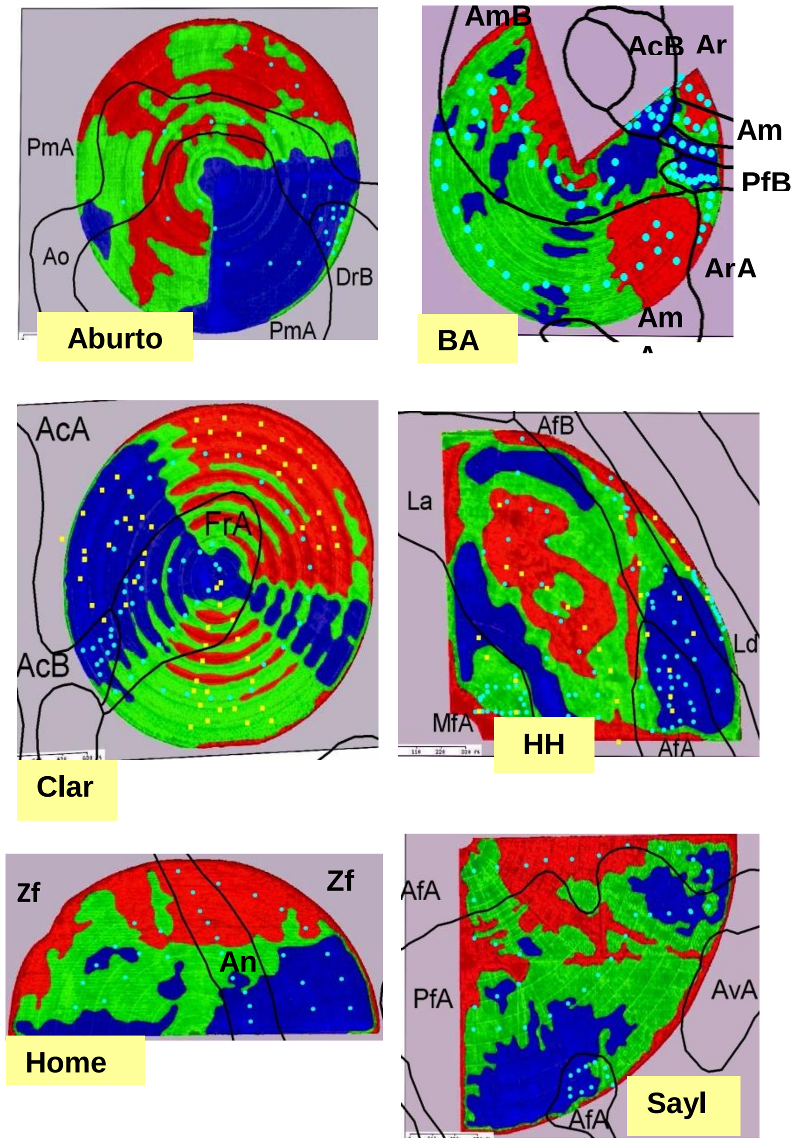

Figure 1. Vigor categories obtain from images taken on 17 July, 2006, which were group was colored green, and the lowest vigor group was red.

Soil classes included Arch loam (Ao), Drake soils with 1-3% slope (DrB), Portales loam with 0-1% slope (PmA), Acuff loam with 1-3% slope (AcB), Amarillo loamy fine sand with 0-1% slope (AmA), Amarillo loamy fine sandy with 1-3% slope (AmB), Arvana fine sandy loam with 0-1% slope (ArA), Posey fine sandy loam with 1-3% slope (PfB), Friona loam with 0-1% slope (FrA), Amarillo fine sandy loam with 0-1% slope (AfA), Amarillo fine sandy loam with 1-3% slope (AfB), Bippus clay loam with 0-2% slope (Ld), Likes-Arch complex that is hummocky (La), Mansker fine sandy loam with 0-1% slope (MfA), Arch fine sandy loam (An), Zita fine sandy loam with 0-1% slope (ZfA), and Midessa fine sandy loam with 0-1% slope (PfA)

Clark. Plant height was measured on 13 July, 19 July, and 10 Aug, 2006. An Acuff loam was the predominant soil (78%), with some variation in slope (0-1% versus 1-3%), and 22% of the field in a Friona loam with 0-1% slope (Fig.1). On the first sampling date, 20 locations were measured on each of the Acuff loam with 0-1% slope and the Friona loam, and nine locations on the Acuff loam with 1-3% slope. On the second sampling date, 32 samples were taken on the Acuff loam with 0-1% slope, and three samples on the Friona loam. On the third sampling date, 47 samples were taken on the Acuff loam with 0-1% slope, one sample on the Acuff loam with 1-3% slope, and 10 samples on the Friona loam. Plant height measurements were taken at a minimum of nine locations in each vigor group for all three sampling times.

HH. There were five soils in this field, an Amarillo fine sandy loam (0-1% and 1-3% slope), Bippus clay loam with 0-2% slope, a Likes-Arch complex that is hummocky, and a Mansker fine sandy loam with 0-1% slope (Fig. 1). Plant height measurements were taken on 7 July and 10 Aug, 2006. Plant height measurements ranged from 18 to 20 locations for each soil type on 7 July, and 5 to 10 locations for each soil type on 10 August. Locations measured for height within vigor groups ranged from 21 to 52 on 7 July, and 7 to 9 on 10 August.

Herr. There were primarily two soils in this field, an Arvana fine sandy loam with 0-1% slope (38% area) and a Mansker fine sandy loam with 0-1% slope (56% area) (Fig. 2). A small portion of the field had a Zita fine sandy loam with 0-1% slope. Plant height measurements were taken on 11 July, 26 July, and 9 Aug, 2007. At least 11 locations were sampled for plant height in the two main soil types at each of the measurement times. Sampling locations in the high, medium, and low vigor groups consisted of 7, 15, and14 for the first sampling time; 5, 10, and 13 for the second sampling time; and 12, 11, and 13 for the third sampling time, respectively.

Home60. There were two soils in this field, an Arch fine sandy loam (17% area) and a Zita fine sandy loam, with 0-1% slope (83% area) (Fig. 1). Plant height was measured on 13 July, 2006 at 30 locations (10 in the Arch and 20 in the Zita fine sandy loam soils). Plant height was measured at 9 to 11 locations in each of the vigor groupings.

Saylor. This field had primarily two soils, an Amarillo fine sandy loam with 0-1% slope (24% area), and a Midessa fine sandy loam with 0-1% slope (75% area) (Fig. 1). On 13 July, plant height was measured at 23 locations in the Amarillo fine sandy loam and 20 locations in the Midessa fine sandy loam, and on 19 July, plant height was measured at nine locations in the Amarillo fine sandy loam and at 24 locations in the Midessa fine sandy loam. On 13 July, plant height measurements were taken at 10, 17, and 7 locations in the high, medium, and low vigor groups. On 19 July, plant height measurements were taken at 10, 15, and 10 locations in the high, medium, and low vigor groups.

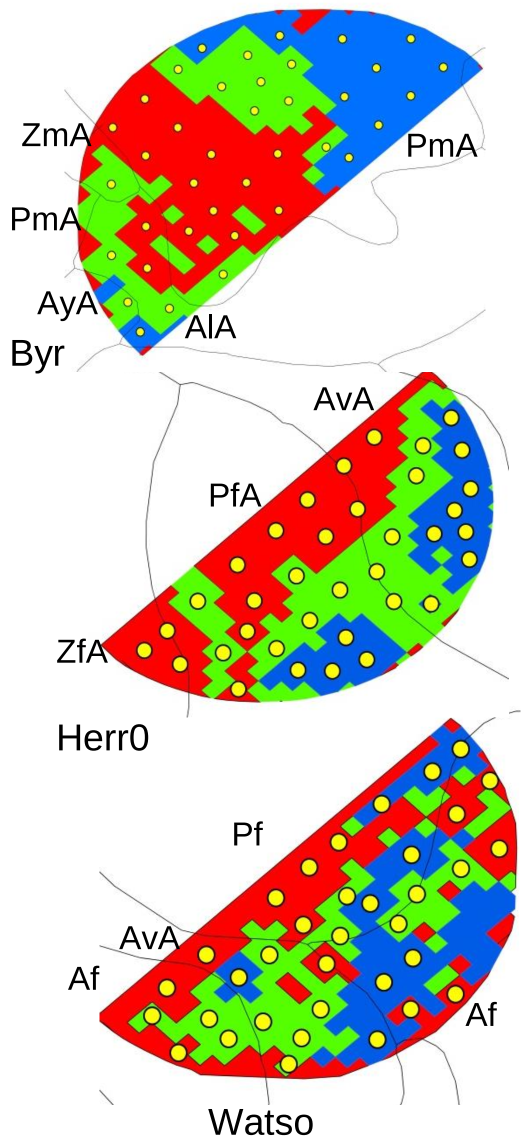

Figure 2. Vigor groups obtained from imagery taken on 16 July, 2007 and overlaid on soil maps.

The highest vigor group was colored blue, the intermediate vigor group was colored green, and the lowest vigor group was red. Soil classes included Acuff loam with 0-1% slope (AcA), Friona-Acuff loams with 0-1% slope (AyA), Portales loam with 0-1% slope (PmA), Zita loam with 0-1% slope (ZmA), Arvana fine sandy loam with 0-1% slope (AvA), Mansker fine sandy loam with 0-1% slope (MfA), Zita fine sandy loam with 0-1% slope (ZfA), Amarillo fine sandy loam with 0-1% slope, and Midessa fine sandy loam with 0-1% slope (PfA)

Watson. This field had three soil types, an Amarillo fine sandy loam with 0-1% slope (48% area), an Arvana fine sandy loam with 0-1% slope (22% area), and a Midessa fine sandy loam with 0-1% slope (30% area) (Fig. 2). Plant height measurements were taken on 11 and 26 July, and 9 August. Plant height measurements ranged from 9 to 17 locations for each of the soil types, and 12 to 13 locations for each vigor group at all measurement times.

Cochran's test of homogeneity was used to determine if variance was similar between vigor groupings, both on an individual field level and combined across all fields. Variances were not similar between vigor groupings at all levels tested (unequal number of samples, unequal variances). A T-test was used to compare vigor groupings to height and yield on all fields combined, and individual fields, and for vigor group comparisons from soil types within fields where all three vigor classifications were found for yield only. Comparisons between low versus moderate vigor, low versus high vigor and moderate versus high vigor were made, with $P \leq 0.05$.

RESULTS AND DISCUSSION

Plant Height Taken Close to Time of Images. In 2006, plant height was significantly different between vigor groupings across all six sites, with low, medium, and high vigor groupings averaging 37.6, 42.7, and 46.7 cm, respectively. In 2007, only the highest vigor grouping (27.7 cm) separated out from the other vigor groupings (24.4 and 25.1 for low and medium vigor groupings respectively). However, weather conditions were much cooler in 2007 compared to 2006, (Fig. 3) resulting in slower growth, shorter plants and smaller differences between fastest and slowest growing plants.

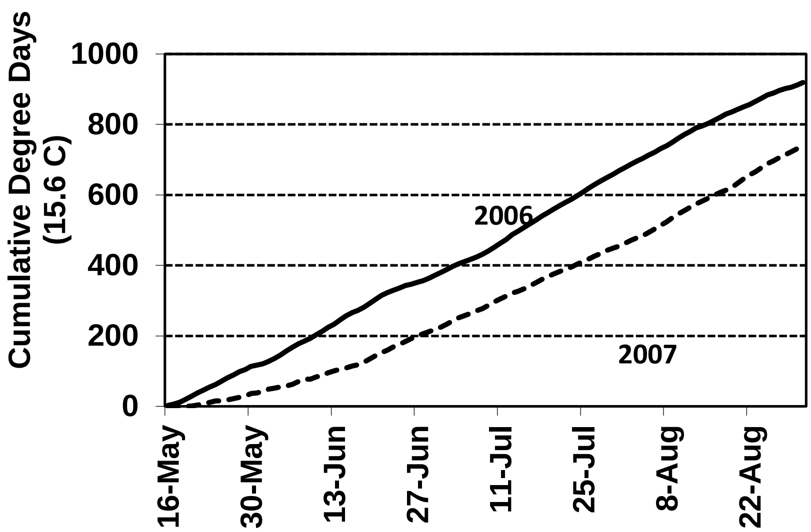

Figure 3. Degree days accumulated near the test locations during 2006 and 2007.

When comparing plant height for individual fields in 2006, all the sites but the Saylor field had at least some significant height differences between vigor groups with the tallest plants always associated with the better vigor groupings (Table 1). In 2007, the high vigor groupings had taller plants than the medium and low vigor groupings for the Byrd field (Table 1).

Relationship Between Imagery and Plant Height at Two to Five Weeks After Imagery Acquisition. In 2006 only two fields were monitored for plant height in late July and August, so these will be presented separately. At the Clark field, the high vigor grouping had significantly taller plants than the medium or low vigor grouping at all additional measurement times (Table 2). In the HH field, the high vigor grouping had significantly taller plants than the medium or low vigor grouping in August (Table 2). At the Saylor field, the high, medium and low vigor areas all had significantly different plant heights (Table 2).

In 2007, when the combined ratings for high, medium, and low vigor were examined for late July and mid August, the groupings were significantly different in each case, and positively related to vigor (47.0, 43.7, and 40.4 cm in late July, and 60.2, 56.9, and 51.8 cm in mid August, for high, medium, and low, respectively). For individual field vigor ratings in 2007, there were significant differences between plant height in the low and high vigor areas in late July and mid-August for all three fields (Table 2). However, in the Herr and Watson fields, the high and medium vigor areas had similar plant heights in late July. In mid-August, at the Herr field, the medium vigor area had taller plants than the high vigor area and at the Watson field, the medium and low vigor areas had similar plant height (Table 2). As time passed after imagery was taken, in general the vigor relationships, as defined by plant height, were accurate in most cases.

Relationship Between Vigor Groupings and Yield. In the combined analysis (five fields), yield was positively related to vigor grouping, with the low, medium, and high vigor grouping having significantly different ($P \leq 0.01$) yields (3777, 4174, and 4412 kg/ha, respectively). Yield in this case reflects the combination of lint, seed, and trash that was recorded by the yield monitor. For the individual field analysis, the Clark, HH, and Herr fields had yields that separated out into three significant groups that corresponded with the three vigor ratings (Table 3). The Byrd field separated into two groupings with the high and medium vigor grouping having similar and higher yields than the low vigor grouping (Table 3). The Watson field however was quite different than the other fields, where the low and medium vigor groupings had higher yields than the high vigor grouping (Table 3). Height measurements correlated fairly well with vigor groupings at this site, so it was surprising that the yields were poorer in the high vigor areas compared to other parts of the field.

Relationship Between Soil Types and Plant Height. Soils in this region are generally more productive when the calcic horizon is deeper. The $CaCO_3$ nodules that form in the calcic horizon are associated with poor root growth; however, they do not completely restrict root growth. There is also the existence of a petrocalcic horizon that can form in some soils, and this layer is so hard that it will almost completely restrict root growth. Soil series that have deep calcic horizons that were present in the test fields are Acuff (76-152 cm depth) and Amarillo (76 to 152 cm depth) (Soil Survey Staff, 2008). Soils that may have shallower calcic horizons include Zita (51 to 102 cm depth), Midessa (51 to 102 cm depth), Posey (30 to 58 cm depth), Mansker (15 to 51 cm depth), Arch (25 to 51 cm depth), Drake (25 to 102 cm depth), and Portales (13 to 38 cm depth) (Soil Survey Staff, 2008).

Table 1. Relationship between vigor grouping obtained by imagery[a] and plant height (cm) taken within one week of the imagery in 2006 and 2007.

		Vigor groupings		
Year	Field	Low	Medium	High
2006	Aburto	34.5 b[b]	37.1 ab	40.4 a
2006	Bam	34.8 c	37.3 b	41.4 a
2006	Clark	48.5 b	47.5 b	57.7 a
2006	HH	35.3 b	42.7 a	45.2 a
2006	Home60	28.7 b	38.6 a	37.6 a
2006	Saylor	50.8	52.3	52.1
2007	Byrd	22.1 b	22.4 b	25.1 a
2007	Herr	22.1	23.1	23.9
2007	Watson	30.0 ab	30.0 b	32.0 a

[a]Aerial imagery was obtained from Wilbur-Ellis (AgFleet version3.0, a part of ZedX Inc., Bellefonte, PA) on 17 July, 2006, and In Time Inc. (www.gointime.com) on 16 July in 2007. The vigor zone rating was determined from the company based entirely on their broad band, multispectral imagery.
[b]Different letters in a row indicate that means are significantly different based on a t-test at $P \leq 0.05$.

Table 2. The relationship between vigor groupings obtained from imagery[a] taken in mid July, and plant height (cm) taken in late July and mid August in 2006 and 2007.

		Plant height (late July)			Plant height (August)		
Year	Field	Low	Medium	High	Low	Medium	High
2006	Clark	51.6 b	46.7 b	67.3 a[b]	63.5 b	60.7 b	74.7 a
2006	HH				54.9 b	56.4 b	64.0 a
2006	Saylor	45.2 c	59.2 b	66.0 a			
2007	Byrd	38.1 c	40.6 b	45.5 a	49.0 c	54.6 b	61.7 a
2007	Herr	38.4 b	41.7 a	44.2 a	52.6 c	59.9 a	56.6 b
2007	Watson	45.2 b	47.8 ab	49.8 a	54.4 b	56.1 b	63.2 a

[a]Aerial imagery was obtained from Wilbur-Ellis (AgFleet version3.0, a part of ZedX Inc., Bellefonte, PA) on 17 July, 2006, and In Time Inc. (www.gointime.com) on 16 July in 2007. The vigor zone rating was determined from the company based entirely on their broad band, multispectral imagery.
[b]Different letters in a row and within a month indicate that means are significantly different based on a t-test at $P \leq 0.05$.

Soils in the test fields with the more impervious petrocalcic layer include Arvana (50 to 100 cm depth) and Friona (51 to 89 cm depth) (Soil Survey Staff, 2008). While $CaCO_3$ is not the only soil property involved with productivity of soils, it is an important one in this region. Soil moisture holding capacity, slopes, and location near to playa lake basins are also important properties.

Table 3. Relationship between vigor groupings obtained by imagery[a] and yield (kg/ha of seed + lint + trash) in five cotton fields.

		Vigor grouping		
Year	Field	Low	Medium	High
2006	Clark	4299 c	4696 b	4930 a[b]
2006	HH	4265 c	4598 b	5018 a
2007	Byrd	3601 b	3727 a	3730 a
2007	Herr	2420 c	3179 b	3335 a
2007	Watson	3632 a	3698 a	3530 b

[a]Aerial imagery was obtained from Wilbur-Ellis (AgFleet version3.0, a part of ZedX Inc., Bellefonte, PA) on 17 July, 2006, and In Time Inc. (www.gointime.com) on 16 July in 2007. The vigor zone rating was determined from the company based entirely on their broad band, multispectral imagery.
[b]Different letters in a row indicate that means are significantly different based on a t-test at $P \leq 0.05$.

There was no relationship between soil types and plant height in the Aburto, Byrd, Home60, and Watson fields (Table 4). In the Bam field at the first height evaluation, plants in the Acuff loam were taller than plants in the Amarillo loamy fine sand, Posey fine sandy loam and Arvana fine sandy loam (Table 4). At the Clark field and only during the evaluation in late July, plants in the Friona loam were taller than plants in the Acuff loam, which is surprising because the Acuff loam is considered much more productive than the Friona soil, which has a petrocalcic horizon. In the HH field during the first evaluation and in mid-August, plants in the Amarillo fine sandy loam with 0-1% slope were taller than plants in the Mansker fine sandy loam and Likes-Arch complex. Plants in the Bippus clay loam were initially similar in height to plants in the Amarillo fine sandy loam with 0-1% slope, but by August they averaged 8 cm shorter than plants in the Amarillo fine sandy loam. In the Herr field, plants were taller in the Arvana fine sandy loam compared with the Midessa fine sandy loam, but only when measured in late July, not in early July or August. In the Saylor field, plants were taller in the Midessa fine sandy loam compared with the Amarillo fine sandy loam in late July, but they were similar in height in early July. Overall, for a combination of 19 field/height measurement times, six had significantly different height measurements between soil types. When using imagery to compare height difference, 17 of the 19 field/height measurements had significant differences between vigor classes. So, plant height differences were captured more readily with imagery defined into vigor groupings than using soil types based on digitized soil maps. However, better vigor (taller plants) was not always associated with what would be predicted as the better soil type.

Relationship Among Soil Types, Yield, and Imagery. In the Byrd field, the highest yields were in the Zita loam (4144 kg/ha), followed by the Portales loam (3708 kg/ha), Acuff loam (3322 kg/ha), and Friona-Acuff loam soil (2974 kg/ha) (Table 5). These results were surprising because the Acuff loam would be considered a more productive soil for cotton than the Zita and Portales soils, which have a shallower calcic horizon. Within the Portales loam, which covered 81% of the field, the low vigor areas had lower yield (3611 kg/ha) than the medium (3751 kg/ha) or high vigor areas (3790 kg/ha) (Table 5). With imagery alone, the difference in average yield between the low and high vigor areas was 3.5%.

Table 4. Relationship between soil type[a] and plant height for nine fields.

			%	% Land	Plant height (cm) at		
Year	Field	Soil	Slope	area	Early July	Late July	August
2006	Aburto	Ah l		26	38		
2006	Aburto	Dr	1-3	3	38		
2006	Aburto	Pt l	0-1	71	38		
2006	Bam	Ac l	1-3	2	43 a[b]		
2006	Bam	Am lfs	0-1	47	38 b		
2006	Bam	Am lfs	1-3	44	38 b		
2006	Bam	Av fsl	0-1	<1	35 c		
2006	Bam	Po fsl	1-3	3	38 b		
2007	Byrd	Ac l	0-1	13	22	39	55
2007	Byrd	FA l	0-1	2			
2007	Byrd	Pt l	0-1	81	23	42	55
2007	Byrd	Z l	0-1	4			
2006	Clark	Ac l	0-1	75	50	55 b	66
2006	Clark	Ac l	1-3	3	54		
2006	Clark	F l	0-1	22	56	81 a	72
2006	HH	Am fsl	0-1	10	47 a		65 a
2006	HH	Am fsl	1-3	16	37 c		60 ab
2006	HH	B cl	0-2	5	46 ab		57 bc
2006	HH	LA		58	38 c		53 c
2006	HH	Ma fsl	0-1	11	41 b		58 b
2007	Herr	Av fsl	0-1	38	23	43 a	53
2007	Herr	Mi fsl	0-1	56	23	39 b	56
2007	Herr	Z fsl	0-1	6	23	39 ab	55
2006	Home60	Ah fsl		17	34		
2006	Home60	Z fsl	0-1	83	35		
2006	Saylor	Am fsl	0-1	24	51	48 b	
2006	Saylor	Mi fsl	0-1	75	53	60 a	
2007	Watson	Am fsl	0-1	48	31	48	56
2007	Watson	Av fsl	0-1	22	30	48	60
2007	Watson	Mi fsl	0-1	30	30	46	57

[a]Soil abbreviations were Ah = Arch, l=loam, Dr = Drake soils, Pt = Portales, Ac = Acuff, Am = Amarillo, lfs = loamy fine sand, Av = Arvana, fsl = fine sandy loam, Po = Posey, FA = Friona-Acuff, Z = Zita, F = Friona, B = Bippus, cl = clay loam, LA = Likes-Arch complex, hummocky, Ma = Mansker, Mi = Midessa.
[b]Different letters within a column and for the same field indicate that means are significantly different based on a t-test at $P \leq 0.05$.

With soil type, differences in average yield between the Zita loam and Friona-Acuff loam averaged 28.2%, though neither of these soils covered more than 4% of the field. The Portales loam (81% of the field) averaged 10.5% higher yield than the Acuff loam (13% of the field). No height differences were measured within these two soils. Plant height was not a good predictor of yield within this field. Variable rate management of this field might be more effective if soil types are utilized rather than vigor zones based on imagery.

With the Clark field, yield was similar for the Acuff loam with 0-1% slope (4663 kg/ha) and Friona loam (4640 kg/ha) compared with the Acuff loam with 1-3% slope (4030 kg/ha) (Table 5). Within both the Acuff loam with 0-1% slope and the Friona loam, yields separated well by vigor grouping (Table 5). The average difference in yield by soil type alone was 14% and image grouping differed by 13%, while differences when combining soil type and imagery vigor grouping were 10 to 14%. Management based on vigor groupings would allow for more variable rate applications than soil types, because 97% of the soils yielded similarly, yet within each soil type there was a range of yield. Plant height by soil type indicated large differences between the Acuff loam and Friona loam in late July, but no yield differences. Plant height was different based on vigor groupings, though still a poorer predictor of yield than vigor grouping. NDVI provided a good indicator of yield differences and could be used in a variable rate management program for this field. Soil type was not useful for variable rate management.

In the HH field, yield was different between soil types, with the highest yields associated with the Amarillo fine sandy loam (4838 and 4801 kg/ha for 0-1 and 1-3% slope), followed by the Bippus clay loam (4682 kg/ha), and with the lowest yields associated with the Likes-Arch and Mansker fine sandy loam soils (4573 and 4649 kg/ha, respectively). These differences are also what would be expected based on soil properties, where the Bippus soil does not have a calcic horizon, and the Amarillo soil has a very deep calcic horizon.

The Mansker and Arch soils can have very shallow calcic horizons. The maximum difference in yield between poorest and best yielding soil was 5.5%. Imagery combined with soil type did result in significant differences between vigor classes for all soil types (Table 5). The differences in yield within a soil type and between vigor classes ranged from approximately 11% for the Amarillo fine sandy loam with 0-1% slope and Bippus clay loam, to approximately 16% for the Amarillo fine sandy loam with 1-3% slope, Likes-Arch complex, and Mansker fine sandy loam. The average yield difference between low and high vigor groups was 15%. Vigor groupings based on imagery was a better predictor of yield differences than soil type. Plant height was a reasonable good predictor of yield in the different soil types as was plant height in image groupings to yield in image groupings.

Yields in the Herr field were highest in the Arvana fine sandy loam (3069 kg/ha), followed by the Midessa fine sandy loam (2922 kg/ha) and the Zita fine sandy loam (2076 kg/ha) had the lowest yields. The Arvana soil has a petrocalcic horizon, also referred to as an impervious calieche layer. However, the depth of the calieche layer may have been deep enough to allow for good root growth. The Zita fine sandy loam fell completely into the low vigor grouping. Within the Arvana fine sandy loam, yields were similar in the medium and high vigor group and better than the low vigor group. Within the Midessa fine sandy loam, yield was significantly and positively associated with vigor grouping. At this site more than any other in the test, there were large differences between soil types, where cotton in the Zita soil yielded 32% less than in the Arvana soil. Yield differences between low and high vigor groupings within a soil type differed by 27 to 35%. Height ratings based on soil types and vigor groupings were not particularly good predictors of yield differences. Vigor groupings alone or combined with soil types were useful in differentiating between high and low yielding areas of the field, and should be useful in a variable rate management system. However, because the differences in soils were not intuitive, based on their expected properties, it would be important to look at yield relationships over several years with a yield monitor, before using soil type for variable rate applications.

Table 5. Affect of soil type and vigor grouping[a] on yield for five cotton fields.

				Yield (lint + seed + trash) kg/ha			
			%	Image classification			
Year	Field	Soil[b]	Slope	Low	Medium	High	Average
2007	Byrd	Ac l	0-1	3261	3324	3452	3322 y
2007	Byrd	FA l	0-1		3362 a	2678 b	2974 z
2007	Byrd	Pt l	0-1	3611 b[c]	3752 a	3790 a	3708 x
2007	Byrd	Z l	0-1	3938 b	4475 a	3315 c	4144 w
2006	Clark	Ac l	0-1	4295 c	4726 b	5014 a	4663 y
2006	Clark	Ac l	3-Jan			4030	4030 z
2006	Clark	F l	0-1	4314 c	4606 b	4806 a	4640 y
2006	HH	Am fsl	0-1		4457 b	4979 a	4838 x
2006	HH	Am fsl	3-Jan	4202 c	4677 b	4973 a	4801 xy
2006	HH	B cl	0-2	4290 b	4787 a	4806 a	4682 yz
2006	HH	LA		4289 c	4538 b	5163 a	4573 z
2006	HH	Ma fsl	0-1	4072 b	4766 a	4832 a	4649 z
2007	Herr	Av fsl	0-1	2135 b	3217 a	3264 a	3069 x
2007	Herr	Mi fsl	0-1	2553 c	3153 b	3515 a	2922 y
2007	Herr	Z fsl	0-1	2076			2076 z
2007	Watson	Am fsl	0-1	3423 ab	3501 a	3328 b	3407 z
2007	Watson	Av fsl	0-1	3658 b	3962 a	4083 a	3893 x
2007	Watson	Mi fsl	0-1	3756	3724	3637	3718 y

[a]Aerial imagery was obtained from Wilbur-Ellis (AgFleet version3.0, a part of ZedX Inc., Bellefonte, PA) on 17 July, 2006, and In Time Inc. (www.gointime.com) on 16 July in 2007. The vigor zone rating was determined from the company based entirely on their broad band, multispectral imagery.
[b]Soil abbreviations were Ac = Acuff, l = loam, FA = Friona-Acuff, Pt = Portales, Z = Zita, F = Friona, Am = Amarillo, fsl = fine sandy loam, B = Bippus, cl = clay loam, LA = Likes-Arch complex, Ma = Mansker, Av = Arvana, Mi = Midessa.
[c]Different letters indicate that means are significantly different based on a t-test at $P \leq 0.05$. If the letters start with a, b, etc., then the comparisons are within a soil type for the three image classifications. If the letters end with z, then the comparisons are down a column and among the soil types that are present within a field.

Yields in the Herr field were highest in the Arvana fine sandy loam (3069 kg/ha), followed by the Midessa fine sandy loam (2922 kg/ha) and the Zita fine sandy loam (2076 kg/ha) had the lowest yields. The Arvana soil has a petrocalcic horizon, also referred to as an impervious calieche layer. However, the depth of the calieche layer may have been deep enough to allow for good root growth. The Zita fine sandy loam fell completely into the low vigor grouping. Within the Arvana fine sandy loam, yields were similar in the medium and high vigor group and better than the low vigor group. Within the Midessa fine sandy loam, yield was significantly and positively associated with vigor grouping. At this site more than any other in the test, there were large differences between soil types, where cotton in the Zita soil yielded 32% less than in the Arvana soil. Yield differences between low and high vigor groupings within a soil type differed by 27 to 35%. Height ratings based on soil types and vigor groupings were not particularly good predictors of yield differences. Vigor groupings alone or combined with soil types were useful in differentiating between high and low yielding areas of the field, and should be useful in a variable rate management system. However, because the differences in soils were not intuitive, based on their expected properties, it would be important to look at yield relationships over several years with a yield monitor, before using soil type for variable rate applications.

Yields in the Watson field were highest in the Arvana fine sandy loam (3893 kg/ha), followed by the Midessa fine sandy loam (3718 kg/ha), with the lowest yields associated with the Amarillo fine sandy loam (3407 kg/ha) (Table 5). It is unusual to have higher yields associated with an Arvana fine sandy loam than an Amarillo fine sandy loam, since the calcic horizon would be deep in the Amarillo soil. Amarillo soils are among the most productive for this growing region. Vigor groups at this site were misleading, with the highest vigor group having the lowest yield. When vigor group was examined within soil type, there was no relationship between vigor and yield in the Midessa fine sandy loam. However, the high and medium vigor groups associated with the Arvana fine sandy loam did have higher yields (4083 and 3962 kg/ha) than the low vigor group (3658 kg/ha). With the Amarillo fine sandy loam, the high vigor group had the lowest yield (3328 kg/ha), and the medium vigor group had the highest yield (3501 kg/ha) with the low vigor group intermediate (3423 kg/ha) (Table 5). These results are so unusual, that there may have been some other significant factor that occurred at this site, and affected the Amarillo soil more than the other soil types. Cotton in the different soils had up to 12.5% yield differences while yield associated with the vigor groups were misleading and only averaged a maximum difference of 4.5%. Imagery based vigor groups were not useful for management decisions at this site, though it is questionable whether soil differences would be consistent over years.

Imagery taken in mid-July was used to differentiate each field into three vigor classifications. At the time that this project began, the choice of how many zones a field should be broken into was dictated to the end user. However, In Time Inc. now offers a service that selects the appropriate number of zones based on the variability within the image, called Vari-Scout Plus™ (www.gointime.com/ProductsScout.jsp). This would address one of the problems identified in this project, namely that three vigor zones were not necessarily appropriate for each field. In general, vigor zones were more closely associated with yield differences than plant height. Soil types were associated with significant yield differences in the Byrd and Watson fields, while vigor zones based on imagery were better indicators of yield potential in the Clark and HH fields. In the Herr field there were significant yield differences using both vigor groupings and soil type. In the three sites where yield differences were significant and of large magnitude between soil types, there was poor agreement between what would be considered the best soils and the highest yields. In many of the sites, the soils that were deep and basically free of a calcic horizon, the yields were lower than in soils that had very shallow calcic horizons. This makes it difficult to use soil type without years of monitoring yield in different soils for each site. The vigor classifications did not require any prior knowledge of the field, but vigor grouping was not reliable across all the sites tested. Producers should evaluate the technology on a case-by-case basis before making variable rate applications. Plant height was not necessarily a reliable method to identify vigor zones, so the use of a yield monitor rather than imagery may be the best method of identifying consistent vigor zones that require variable rate applications.

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Inventory of Cotton Gin Trash on the Texas High Plains and Bio-Energy Feedstock Potentials

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ABSTRACT

With the increasing demand for bioenergy, agricultural products are being studied to determine their availability and feasibility for use as feedstock in bioenergy production. Availability is one of the most important factors in the feasibility of the use of any product for bioenergy production. Cotton gin trash is a potential feedstock for electricity or ethanol production. The objective of this study was to determine the availability of cotton gin trash in the Texas High Plains (THP) and to estimate the potential supply of bioenergy generated from cotton gin trash. County cotton production data was used to determine energy supply given fixed energy content for cotton gin trash. Thirty counties produced 64% of the total cotton production in Texas and 22% of United States' cotton production from 2001 to 2006 resulting in 994,736 tons of cotton gin trash produced annually. An average of 4.3 million mmBTUs of energy exists annually from gin trash in THP with an annual minimum of 2.5 million mmBTUs and maximum of 6.5 million mmBTUs. On average, cotton gin trash in the area could supply 12.5 million gallons of ethanol or 65,000 megawatt hours (MWe).

KEY WORDS: agricultural waste, bioenergy, energy, feedstock, gin trash

INTRODUCTION

Increases in prices for crude oil and natural gas, and concerns for the environment, have led to a call to reduce the United States' reliance on foreign energy. The increased importance and demand for biofuels can be seen in new policy development, especially the Energy Policy Act of 2005 (U. S. Environmental Protection Agency, 2007), which calls for the use of 7.5 billion gallons of ethanol and biodiesel by 2012 with some political calls for even more use of biofuels. To meet these goals, agriculture is being called upon to assist in the development of bioenergy.

Cotton gin trash is a byproduct of the cotton ginning process and consists of the dried burr of the cotton boll, stems, leaf fragments, and some short or damaged cotton fibers, all of which are high in cellulose. Although cotton gin trash has not been a popular feedstock for biofuel production as have grains for ethanol or switchgrass and wood byproducts for cellulosic fuels, it is abundant in the southern and southwestern region of the United States and in approximately 80 countries where cotton is a major cash crop. The use of cotton gin trash could help fill the increasing demand for bioenergy feedstock, thereby increasing its value by providing extra revenue to cotton gins and cotton growers as well as offer a means of disposal of the trash created during the ginning process.

The objective of this study was to determine the availability of cotton gin trash for the Texas High Plains (THP) and estimate the potential supply of energy that can be created.

LITERATURE REVIEW

Two studies reported on the fate of cotton gin trash. Cohen and Lansford (1992) determined that most cotton gin trash was disposed of by spreading on the land, composting, feeding to livestock, landfill disposal, incineration, conversion to energy, making pellets for fuel in heat stoves, building materials, and insulation. Incineration was a recommended method of disposal that controlled pink bollworm and generated energy for the gin until the practice was discontinued in 1975 by the Clean Air Act of 1970 (Hainze 1999). Castleberry and Elam (1998) conducted a survey of cotton gins in the Texas High and Low Plains and reported that 47.9% of cotton gin trash was used for livestock feed, 33.2% was spread on the land as a soil amendment, and 15.9% was composted. Gins that reported composting as a disposal method were concentrated within a 50 mile radius of southeastern Lubbock County where a composting operation was located. Average disposal cost of cotton gin trash was $1.44 per ton and a cotton bale produced 741 lbs. of gin trash from the ginning process.

The proceedings from the Symposium on Cotton Gin Trash Utilization Alternatives, held in Lubbock, Texas in April 1982, is a rich source of reports of early studies of biofuel uses for cotton gin trash. Avant (1982) reported that cotton gin trash had immediate potential as a boiler or combustion unit fuel for regional processing industries and utilities, and long term possibilities included methanol and ethanol production. A study of combustion and gasification of cotton gin trash, conducted by LePori, et al., (1982), determined that cotton gin trash collected at a gin has potential of supplying all the energy needed for the gin in stripper harvesting areas. Lacewell, et al., (1982) reported that each pound of trash could yield 7,000 BTUs. They determined that the major cotton producing counties of the THP produced a yearly average of 596,988 short tons of gin trash with a potential of 8,357,832 million BTUs from 1970 to 1974. Beck and Clements (1982) showed that ethanol production from cotton gin residue was both technically and economically feasible. It was also determined that gin residue varies widely from crop year to crop year. In their study, the Texas South Plains counties produced an annual average of approximately 900,000 tons of cotton gin residue. The conclusion of the study was that it was economically feasible to produce ethanol from cotton gin residue in large-scale plants. Additionally, the research demonstrated that 37.8 gallons of ethanol can be produced per ton of gin trash.

Sharma-Shivappa and Chen (2008) reviewed several studies of various conversion processes but concluded that continued studies must be conducted to improve process efficiency and economic efficiency for bioethanol production. Other processes for biofuel production include briquettes, pyrolysis, and anaerobic digestion. Two recent studies near the THP include Holt et al., (2004) in Lubbock, Texas which produced fuel pellets from gin trash and Macia-Corral, et al., (2005) in eastern New Mexico which produced methane gas from gin trash and dairy manure.

METHODS AND PROCEDURES

The study area is the 30 county region of the Texas High Plains shown in Figure 1 and consists of the counties of Andrews, Armstrong, Bailey, Borden, Briscoe, Castro, Cochran, Crosby, Dawson, Deaf Smith, Dickens, Floyd, Gaines, Garza ,Glasscock, Hale, Hall, Hockley, Howard, Lamb, Lubbock, Lynn, Martin, Midland, Motley, Parmer, Randall, Swisher, Terry, Yoakum. These counties represent 64% of the total cotton production in Texas and 22% of U.S cotton production from 2001 to 2006 (U.S. Department of Agriculture, 2007).

County cotton production data, from 2001 to 2006, was retrieved from USDA's National Agricultural Statistics Service (NASS) for the 30 counties listed above (U.S. Department of Agriculture, 2007).

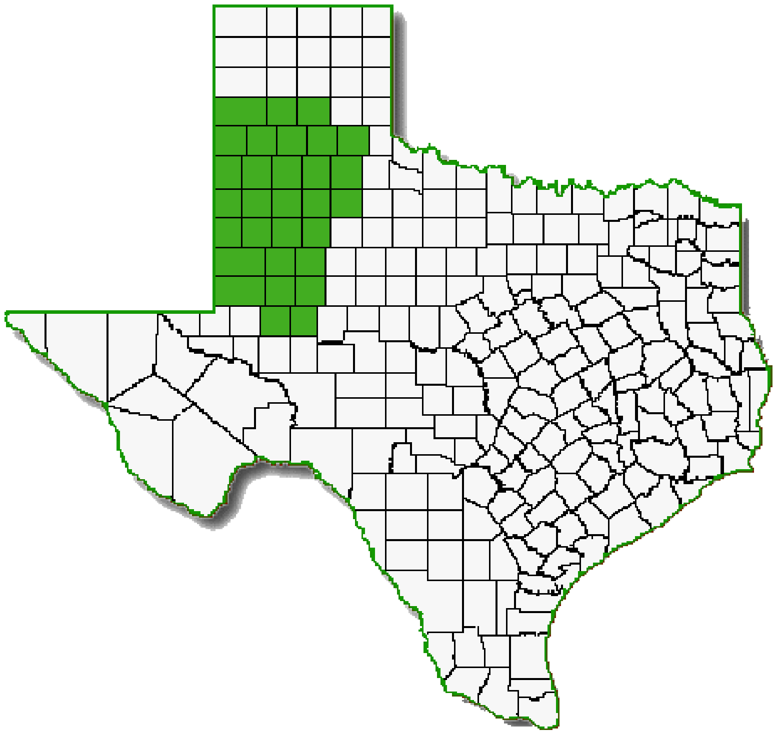

Figure 1. Cotton Gin Trash Study Area in Texas.

The cotton production data from these counties was used to determine the gin trash production based on lint and trash turnout percentages. Potential bioenergy production was estimated using the following function:

$$E = (CP / TO) * TR * BTU,$$

where E represents energy production in BTUs, CP represents cotton lint production in tons, TO represents the turnout percentage, TR represents the trash production as a percentage of seed cotton, and BTU represents the energy in BTU generated per ton of cotton gin trash. The cotton lint production in tons was calculated from the NASS reported production for each county in bales, assuming a 480 pound bale. The turnout percentage is the weight of lint as a percentage of the weight of seed cotton ginned and was estimated by Mitchell et al., (2007) to be 27.35% for recent cotton varieties. The trash percentage was estimated to be 29.75% (Mitchell et al., 2007). The amount of cotton gin trash per bale is lower than previously reported by Castleberry and Elam (1998) due to the increased use of burr extraction in harvesting and picker harvesting and the adoption of new varieties with higher lint yields per boll in the THP. The value for BTU generated per ton of cotton gin trash is 13.10 mmBTU/ton of gin trash (Curtis et al., 2003).

RESULTS

The 30 counties in the study area produced an annual average of 994,736 tons of cotton gin trash with a minimum of 606,156 tons and a maximum of 1,485,929 tons for the period from 2001 to 2006. Seven counties each produced an annual average of over 60,000 tons, comprising

39% of cotton gin trash for the study area, including Gaines, Hale, Hockley, Lamb, Lubbock, Lynn, and Terry. Hale County produced the highest yearly average cotton gin trash with 104,080 tons. Three counties produced an annual average between 40,000 and 60,000 tons, comprising 16% of cotton gin trash for the study area, including Crosby, Dawson, and Floyd counties. Six counties produced an annual average between 20,000 and 40,000 tons, comprising 19% of cotton gin trash for the study area, including Castro, Cochran, Martin, Swisher, Parmer, and Yoakum counties. These 16 counties that annually produced at least 20,000 tons of cotton gin trash produced 74.68% of the cotton gin trash in the study area. The counties with the highest cotton gin trash production in the study area are centered on the Southern High Plains of Texas, shown in Figure 2.

This study assumes that the demand for gin trash for use as livestock feed and for composting will remain constant and that the gin trash that is currently used for soil amendment will be used for energy production. According to Castleberry and Elam (1998), about one third of the gin trash from the THP is currently being used for soil amendment. Using one third of the total gin trash estimated to be produced, the counties in the study area can provide an average annual supply of energy of 4.3 million mmBTUs with an annual minimum of 2.6 million mmBTUs and maximum of 6.5 million mmBTUs for the 2001 to 2006 period. Each county's average, minimum and maximum energy supply is shown in Table 1. It is important to consider the maximum and minimum values, as the available feedstock will fluctuate with production conditions, especially weather related conditions.

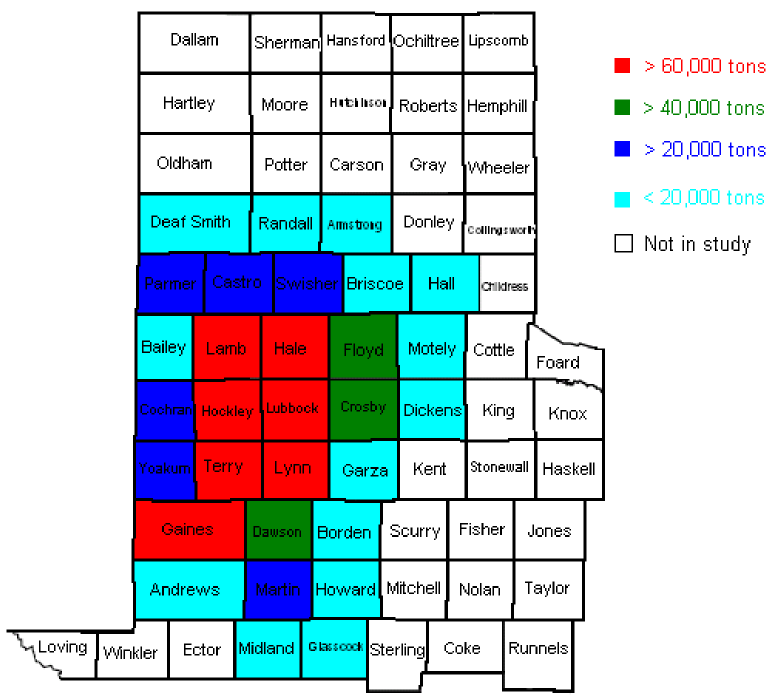

Figure 2. Yearly Average Tons of Cotton Gin Trash in 2001-2006 in THP.

The minimum, maximum and average energy values for each county are shown in Figure 3 with a tick mark representing the average.

The seven counties with an annual average of over 60,000 tons produced could supply 2.2 million mmBTUs of energy, while the ten counties producing over 40,000 tons of gin trash could supply 3.0 million mmBTUs.

If available gin trash in the study area was converted to ethanol using a conversion factor of 37.8 gallons of ethanol per ton of gin trash (Beck and Clements, 1982), 12.5 million gallons of ethanol would be supplied by cotton gin trash. If available gin trash in the study area was converted to electricity using a conversion factor of 1 MWe per ton of gin trash (Capareda 2009), 331 thousand MWe of electricity would be supplied by cotton gin trash.

Table 1. County Energy Supply in Gin Trash in 2001-2006.

County	5 yr Average Production (Bales)	Available gin trash [1] (short ton)	Average BTU (mmBTU)	Min BTU (mmBTU)	Max BTU (mmBTU)
Andrews	21,367	1,859	24,357	13,680	43,091
Armstrong	2,183	190	2,489	0	5,928
Bailey	69,267	6,028	78,961	13,908	127,676
Borden	16,400	1,427	18,695	4,218	40,925
Briscoe	29,667	2,582	33,819	18,809	46,852
Castro	141,617	12,323	161,438	97,695	199,038
Cochran	126,900	11,043	144,661	37,847	222,293
Crosby	207,450	18,052	236,485	112,856	377,328
Dawson	225,783	19,648	257,385	93,477	455,985
Deaf Smith	48,317	4,205	55,079	27,473	67,486
Dickens	16,433	1,430	18,733	9,120	30,323
Floyd	189,567	16,496	216,099	73,414	302,090
Gaines	314,717	27,387	358,765	216,593	525,523
Garza	34,800	3,028	39,671	18,239	81,507
Glasscock	69,250	6,026	78,942	39,899	170,995
Hale	398,683	34,693	454,484	213,857	584,801
Hall	67,083	5,838	76,473	36,479	127,676
Hockley	255,867	22,266	291,679	153,895	434,326
Howard	63,317	5,510	72,179	9,120	141,013
Lamb	272,400	23,704	310,526	107,043	387,018
Lubbock	282,550	24,588	322,097	166,435	532,363
Lynn	229,900	20,006	262,078	70,108	489,044
Martin	81,467	7,089	92,869	21,089	204,053
Midland	17,317	1,507	19,740	10,260	32,489
Motley	15,183	1,321	17,308	10,602	30,551
Parmer	142,967	12,441	162,977	42,635	217,961
Randall	3,533	307	4,028	2,508	5,130
Swisher	104,500	9,094	119,126	69,652	137,936
Terry	234,383	20,396	267,188	136,226	466,245
Yoakum	127,500	11,095	145,345	92,907	220,013
Total	3,810,367	331,579	4,343,679	2,646,881	6,488,558

[1] Available gin trash is one third of total gin trash produced and represents the amount of gin trash estimated to be used currently as soil amendment.

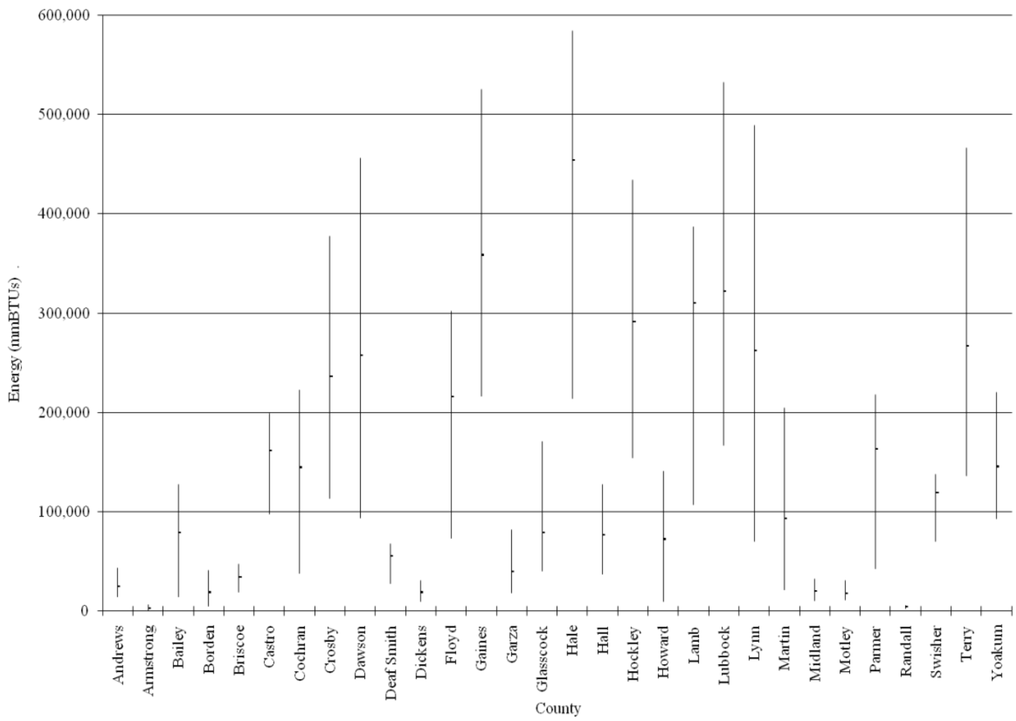

Figure 3. County Energy Supply in 2001-2006.

CONCLUSIONS

A large potential feedstock source exists for use in producing bioenergy centered around the cotton producing counties on the THP. One ton of trash converted into electricity would displace 1.31 mmBTUs in the energy market; while one ton of gin trash converted into ethanol would displace 76 mmBTUs. The use of this feedstock could help supply the call for greater bioenergy use and displace nonrenewable energy in the market while providing additional revenue for cotton gins and producers in the region.

Further study is warranted to determine the economic feasibility of the use of cotton gin trash as a feedstock for bioenergy production and the logistics that would be required to use cotton gin trash as a feedstock in bioenergy production. While the cost of producing energy products from cotton gin trash is important for investment decisions or development planning, that analysis was beyond the scope of this study. As technological processes become commercially viable, the costs of production and investment decisions can be more thoroughly analyzed.

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The Economic Impact of Boll Weevil Eradication in Texas

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ABSTRACT

Substantial progress has been made in eradicating the boll weevil from the majority of the cotton producing regions in Texas. While the full economic benefits will not be realized until eradication is achieved statewide, the cumulative economic benefits to growers from 1996 to 2007 are estimated to be over $1 billion.

KEY WORDS: boll weevil, cost-benefit ratio, net present value, economic impact

INTRODUCTION

Without a doubt, the boll weevil has been the most destructive insect pest of cotton in Texas and the United States. Efforts to eradicate this insect from the U.S. Cotton Belt began in 1978 with a small, 30,000 acre pilot program conducted in North Carolina. Eradication of the boll weevil rapidly progressed across other southeastern states, as well as western cotton producing states in the 1980's. Texas joined the national boll weevil eradication (hereafter, BWE) program in the mid-1990's, along with several states in the mid-south. To the south of Texas, Mexico has also implemented a BWE program that encompasses all areas that are contiguous with the United States border.

Due to the large cotton acreages involved in Texas, the state was divided into eradication zones. Presently there are sixteen zones (see figure 1) in Texas. New Mexico has one zone in the Texas BWE program, and two zones in Texas include acreage in New Mexico. Eradication zones in Texas include all but seven counties in the state. Since these seven counties are not cotton-producing counties, all cotton acreage in the state is in the BWE program. While not complete at this time, substantial progress has been made in eradicating the boll weevil from the majority of the state's cotton producing regions. This has increased the productivity of Texas cotton, allowed the industry to be more competitive economically, and ultimately reduced insecticide exposure to humans and the environment.

OBJECTIVES: This study focused on four main objectives: 1) estimate the change in net cash flow to cotton growers in Texas as a result of BWE, 2) conduct cost-benefit analysis for each eradication zone in the state, 3) estimate the annual statewide economic benefits to growers, and 4) estimate the economic impact of BWE in 2007 in terms of economic output and employment impacts.

REVIEW OF LITERATURE

Cost-benefit analysis methods have been applied to BWE proposals and also to actual BWE programs. In general, the purpose of these studies was to determine the net economic benefits of BWE to farmers and to society. Most of these published studies measuring the economic benefit of the BWE program can be classified as either before or after-the-fact studies (*ex post*).

The before-the-fact studies tend to rely on more assumptions, and have typically been more aggregate in scope. A national study by Taylor et al., (1983) evaluated the effects of alternative BWE proposals on cotton production. Given the *a priori* nature of the study, the researchers collected expected yield and cost impacts based on expert opinion through a Delphi method. These expected changes in gross returns and variable costs were applied in a general equilibrium simulation model of the U.S. agricultural crop industry. This approach generated price and supply effects for a number of crops and allowed calculation of conventional economic surplus measures. Taylor et al. demonstrated that several eradication scenarios resulted in a higher net social value product than the status quo scenario. However, BWE scenarios had a negative net impact on producer incomes due to lower cotton prices which more than offset the positive effect of higher cotton yields and lower production costs. The Taylor et al. study highlights the importance of the supply response of lower cotton prices due to increased production from BWE, and the resulting impacts on producer benefits.

In contrast to the Taylor et al. study, Szmedra et al., (1991) used crop simulation modeling to simulate BWE scenarios in the Mississippi Delta region. Applying stochastic dominance methods to these results, the authors concluded that BWE strategies were feasible and were preferred by risk adverse farmers compared to “low IPM” or “high IPM” levels without BWE. This study suggests that BWE programs would be supported by growers in areas like Mississippi, which they have been as well as across our present study area (Texas).

Extension economists in various states have conducted a number of unpublished *a priori* studies. For example, Robinson (1995) presented a before-the-fact study of BWE in the Texas Rolling Plains. While this study included cotton price effects, the effects were so small that they were outweighed by the expected savings in boll weevil spray cost. Similarly, Robinson and Vergara (1999) used expected savings in boll weevil yield losses and on-farm sprayings, net of any increase in insecticide costs, to show that BWE in the Mississippi Delta region was still a profitable investment using the net present value criterion. While these studies were *a priori*, similar methodology used for estimating yield savings and changes in boll weevil treatment costs associated with the BWE program was used in our study.

Abernathy et al., (1997), another *a priori* study conducted in the Texas High Plains, used an Agricultural Sector Model to estimate producer costs and revenues associated with boll weevil infested cotton. Based on annual yield losses, increases in insect control costs, and losses associated with acreage shifts to alternative crops from boll weevil infestation, farmer’s net incomes were reduced from $189 million to $47 million (a loss of $142 million). This study provides a more in-depth analysis of the economic costs resulting from boll weevil infestations in the Texas High Plains in the absence of an eradication program, and takes into account acreage shifting from cotton to other crops.

The published *ex post* studies have been on various regions of the U.S. Carlson et al., (1982) used cost-benefit analysis to evaluate the investment efficiency of the Southeastern BWE Program in Virginia and the Carolinas. The cost of the Southeastern BWE Program included federal, state, and private (i.e. farmer) expenditures to pay for the administration, labor, and material costs of the program. Program benefits were derived by comparing nine years of post-eradication yield and cost data with baseline data. In addition to yield and cost savings, the researchers noted positive changes in land values as a beneficial effect of BWE. Carlson et al. demonstrated positive net returns and a high internal rate of return for the Southeastern BWE program. The present study also used capital budgeting, but differed in scope from Carlson et al. by focusing on farm level, per acre impacts.

Tribble et al., (1999) conducted a farm-level decision analysis about BWE adoption in Georgia. The study focused on determining the extent to which the increase in planted cotton acreage was directly associated with BWE in the region. Tribble et al. used a Cooley-Prescott adaptive regression model to estimate pre-and post-BWE cotton acreage response. The results indicated that cotton acreage had become more inelastic to own and cross-price changes. As a result of the shift in acreage response and yield increases from eradication, average net producer benefits were estimated at $88.73 per acre. While the methodology and study area used in this study differ from our study, the Tribble et al. study is included in a comparison of results to previous studies found in the Results and Discussion section.

Ahouissoussi et al., (1993) used a survey of producers during a five-year (1986-1990) period to determine the economic viability of the BWE Program in Alabama, Florida, and Georgia. The research team used a comparison of discounted program benefits with discounted costs (private and full) for assessing the net benefits of the BWE program to producers. Results of the study indicated the program increased lint yields by 100 pounds per acre and found a 19 percent internal rate of return for producers over a ten-year period. This level of yield savings is comparable to the yield savings estimates
in the most recent years of our analysis.

Another regional *ex post* study of BWE, which included the Southern Rolling Plains of Texas (Johnson et al., 2001), found that in the seven years (1994-2000) it took to declare the boll weevil functionally eradicated, the costs exceeded the benefits in the first two years for a net loss to the producer before the benefits outweighed the costs (net gain) in each of the next five years. On the aggregate level for the entire zone at the end of the 7-year period, the benefits were estimated to be $1.45 for every $1.00 cost incurred by the producer. Given the similarity to our study in terms of study area and methodology, the Johnson et al., study provides interesting results for comparison purposes. It is included in a comparison of results to previous studies in the Results and Discussion section.

An *ex post* study by Carpio et. al., (2001) analyzed the economics of the cotton boll weevil control in the Texas High Plains. The study found that, at current cotton prices and insecticide costs, a typical farmer’s net revenues would increase by $56 per acre annually once the boll weevil had been completely eradicated.

This present study is important in part because the Texas BWE program has been implemented statewide, e.g. all cotton-producing counties are in the BWE program. Significant progress has been made towards eradication in all zones since the program was initiated. In 2009, there were no boll weevils caught in nine of the sixteen zones and 80% of the state’s cotton acreage was boll weevil-free. This study also uses input-output modeling to assess the broader economic implications, such as employment impacts and economic output, associated with boll weevil eradication in the farm and ginning sectors in Texas.

MATERIALS AND METHODS

The economic impact of the BWE Program was measured in terms of the change in net cash flow to cotton producers in 11 of the 16 boll weevil eradication zones in Texas (Figure 1). Zones 2, 13, 16, and 17 were excluded from this analysis because they just entered the program (2004 and 2005) and thus have not had enough time to realize any affects of eradication efforts. Zone 12 was excluded due to a unique situation where the primary pest was pink bollworm rather than boll weevil. Excluding this zone does not significantly affect the results due to the small number of cotton acres in this area (less than 1% of the state's cotton acres).

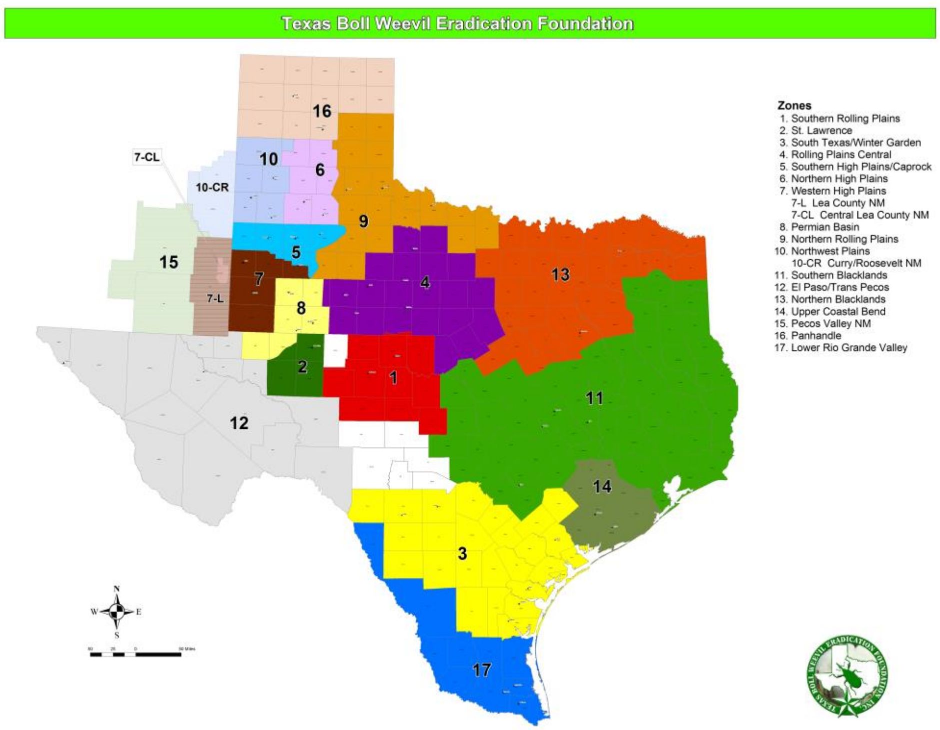

Figure 1. Texas Boll Weevil Eradication Zones.

This analysis expands on a BWE economic assessment by Robinson and Barham (2005). The analytical approach involved quantifying a multi-year average boll weevil treatment cost and yield loss for each zone prior to the start of the BWE program. This formed a baseline prior to the eradication program for each zone. To assess the economic changes relative to the baseline, for each eradication zone, the baseline was compared to post-BWE program annual boll weevil yield losses, boll weevil program assessment fees, other boll weevil treatment costs, and harvesting and ginning costs associated with the changes in production. Hereafter, the additional harvesting and ginning cost is referred to as "other cost changes."

Several data sets were used in the analysis. Secondary yield data consisted of county yield data collected by the USDA - National Agricultural Statistics Service for both irrigated and non-irrigated cotton (USDA-NASS) (Table 1). To estimate yield losses caused by boll weevils and insecticide costs for controlling boll weevils, annual yield loss and insecticide costs data from the

Beltwide Cotton Conference - Cotton Pest Loss Database (2006) were used. Historical BWE program assessments were obtained from the Texas Boll Weevil Eradication Foundation (Allen, 2007).

Table 1. Post BWE Average Yields for Zones 1 through 7 (lbs. lint per acre).

	TBWEF Zones					
	1	3	4	5	6	7
1996	372	353	288			
1997	392	492	396			
1998	375	407	339			
1999	280	810	240			421
2000	178	751	250			378
2001	248	627	257	342	579	391
2002	298	641	377	455	636	493
2003	310	783	327	371	643	491
2004	515	885	506	686	757	720
2005	538	744	547	650	811	803
2006	392	880	289	464	806	681
2007	722	915	760	749	1,002	787

Table 1. Post BWE Average Annual Yields, for Zones 8 through 14 (lbs. lint per acre) and the State Average Price (*continued*).

	TBWEF Zones					
	8	9	10	11	14	State Avg. Price*
1996	378			392	523	$0.66
1997	417			498	581	$0.60
1998	460			412	353	$0.56
1999	317	310	547	612	659	$0.52
2000	294	237	520	406	543	$0.52
2001	320	310	713	504	723	$0.52
2002	351	390	844	676	783	$0.52
2003	323	354	725	620	643	$0.58
2004	452	556	817	743	701	$0.52
2005	576	612	976	724	593	$0.52
2006	474	496	965	661	829	$0.52
2007	729	733	996	813	661	$0.52

* Higher of price or loan rate.

Using the data from the Beltwide Cotton Pest Loss Database, the mean boll weevil insecticide costs per acre over multiple years prior to the eradication program (Pre-BWE) were used to form a baseline for boll weevil (exclusively) insecticide costs (Table 2). The time frame contained in the average varies and was based on the year each zone entered the BWE program, the availability of data in the Beltwide Pest Loss Database, and the number of years each zone had been infested with boll weevils. For the years after each zone entered the eradication program, annual boll weevil insecticide costs were subtracted from the baseline, resulting in the change in boll weevil insecticide costs. Similarly, pre-BWE yield loss estimates were averaged to form a baseline for yield losses attributable to boll weevils (Table 2). The post-BWE average yield loss percentages were compared to the average pre-BWE yield loss percents to obtain an average annual savings in yield loss percentage, which were multiplied by the regional cotton yields, resulting in an estimate of the average annual yield savings (Johnson et al., 2001). The yield savings was valued at the state average cotton price, except for years when the average price was below the USDA cotton marketing loan rate ($0.52/lb). In these years, the yield savings was valued at the loan rate. Cotton seed was valued at the state's average cotton seed price each year.

Table 2. Average Pre-BWE Treatment Cost (per acre) and Yield Loss Percent.

	Average Treatment Cost Pre-BWE	Boll Weevil % Yield Loss Pre-BWE	Time Frame
Zone 1	$10.26	15.45%	(1986-1993)
Zone 3	$15.94	15.00%	(1986-1995)
Zone 4	$8.74	15.52%	(1986-1995)
Zone 5	$9.93	14.87%	(1994-2000)
Zone 6	$9.93	14.87%	(1994-2000)
Zone 7	$6.76	9.28%	(1994-1998)
Zone 8	$6.04	11.21%	(1991-1998)
Zone 9	$5.40	15.97%	(1986-1998)
Zone 10	$6.76	9.28%	(1994-1998)
Zone 11	$12.43	9.39%	(1990-2000)
Zone 14	$23.61	8.08%	(1992-2001)

After comparing preliminary loss estimates using the Beltwide Cotton Pest Lost Database versus subjective grower estimates, there were some notable differences in the results. In general, the yield impacts estimated with the published Beltwide Cotton Pest Lost Database were five to ten times smaller than results obtained by interviewing growers (Robinson and Barham, 2005). Upon consultation with the entomologists who made the original Beltwide estimates, they revisited their original boll weevil yield loss estimates. This resulted in increasing the yield loss estimates in wet years. Extension Entomologists revised some of the published Beltwide boll weevil yield loss percentages, increasing them in wet years by 25% for Zones 1, 4, 8, 9, and 11, 20% in Zones 5, 6, 7, and 10, and tripling the yield loss in Zones 3 and 14 (Fuchs et al., 2006).

One of the difficulties in assessing the yield impacts attributable to BWE is the almost simultaneous introduction of improved cotton varieties, including the Bt transgenic cotton varieties. Both BWE and the adoption of improved cotton varieties have resulted in increased yields, however, the impacts of improved varieties would not have been as significant without BWE.

Annual insecticide cost savings per acre, yield loss savings per acre, BWE assessments per acre, and other cost changes (e.g. the cost of harvesting and ginning additional production) per acre were used in calculating growers annual change in net cash flow per acre resulting from BWE, net present value of the cash flows, and cost-benefit ratios. Cost-benefit analysis followed standard methodology and was conducted for the period beginning with the year the eradication program began in each zone, through 2025 (Sassone and Schaffer, 1978). Since BWE takes many years to achieve, net present value (NPV) was used to facilitate the benefit-cost analysis. NPV is useful in investment analysis when dealing with cash flows over multiple years, and involves calculating the net present value at a single point in time of all cash inflows and outflows using a discount rate. In this fashion, the NPV criterion directly accounts for the timing and magnitude of the cash flows (Barry et al., 1983). In calculating NPV, a desired rate of return is often used as the discount rate.[f] A discount rate of 5% was used in this analysis based on the premise that Texas growers were financing the program with their own equity, and 5% would be a conservative, expected rate of return had the funds been put to an alternative use. Sensitivity analysis on the cost-benefit ratios was also conducted to evaluate the effects of higher discount rates.

Boll weevil yield loss estimates have declined since the eradication program, causing production to increase relative to the pre-BWE time frame and creating downward pressure on cotton prices. Given estimates of market conditions, the estimated price impacts were -\$0.003 per pound for 1996, -\$0.002 for 1997, -\$0.003 for 1998, and -\$0.002 for 2003.[2] Applying these price adjustments to cotton production statewide resulted in the following reductions in statewide net benefits: \$6.1 million (1996), \$5.9 million (1997), \$5.6 million (1998), and \$4.1 million (2003).

RESULTS and DISCUSSION

Using the acreage by zone, and the data and methods previously described, the change in total net cash flow was estimated for each zone from 1996 to 2007, and projected through 2025. An illustration of how net present value and cost-benefit ratios were calculated is shown in Table 3. A positive net present value and a cost-benefit ratio greater than one are both preferred, and are an indication of a good investment. Using the data for Zone 1, Southern Rolling Plains as an example, the table contains columns for grower assessment costs, other cost changes, boll weevil spray (treatment) cost savings, boll weevil yield savings, total costs, total benefits, and growers' net cash flow. Using the growers' net cash flow and a discount rate of 5%, the net present value for Zone 1 is estimated at \$357 per acre. Cost-benefit ratios for all eradication zones were calculated as the NPV of benefits divided by the NPV of costs for the period 1996-2025. For Zone 1, the cost-benefit ratio was estimated at 2.05 (\$699.15 divided by \$341.21); meaning there is \$2.05 in benefits for each dollar of costs incurred by growers. Price impact estimates were obtained from the Food and Agricultural Policy Research Institute at the University of Missouri (March 2007).

While the costs and benefits per acre vary by zone, some additional explanation of the costs and benefits for Zone 1 (Table 3) will be useful for understanding the costs and benefits for

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[f] The formula for calculating net present value is $\mathrm{NPV} = \sum_{j=1}^{n} \frac{values_j}{(1+rate)^j}$ where *n* is the number of cash flows in the list of values, *j* is the time period, *rate* is the rate of discount over the length of one period, and *values* is the present value of a given period.

all zones. Future BWE assessment fees (2007-2025) for all zones were provided by the Texas Boll Weevil Eradication program. These assessment fee estimates are constant from 2007 to 2025 within each zone, but are not the same for all zones. To be on the conservative side, a 3-year average of BW yield savings for 2005-2007 was used for future years. This convention is conservative because is assumes no increase in average cotton lint yields in future years. Annual boll weevil insecticide costs were subtracted from the baseline, resulting in the change in boll weevil spray (treatment) costs, labeled "BW Spray Cost Savings" in Table 3. For each zone, the annual BW Spray Cost Savings for the initial year through 2007 was adjusted for inflation using the NASS inflation index for agricultural chemicals (USDA:NASS, 1996-2007). For 2008 through 2025, an annual inflation rate of 2% was used for BW Spray Cost Savings and Other Cost Changes.

Table 3. Representative Farm-Level Cash Flow and Summary Investment Values From Boll Weevil Eradication and Selected Longer Season Management Practices for All Cotton in TBWEF Zone 1, Southern Rolling Plains (Nominal Dollars per Acre).

Year	Grower Assessment (a)	Other Cost Changes (b)	BW Spray Cost Savings (c)	BW Yield Savings (d)	Total Benefits (e)= (c+d)	Total Costs (f) = (a+ b)	Undiscounted Growers Net Cash Flow (g) = (e-f)
1996	$11.53	$9.12	$10.61	$35.19	$45.81	$20.65	$25.16
1997	$11.34	$10.06	$5.97	$35.55	$41.52	$21.40	$20.12
1998	$11.15	$9.85	$10.43	$32.51	$42.93	$21.00	$21.93
1999	$5.28	$7.35	$10.17	$22.50	$32.67	$12.63	$20.03
2000	$10.85	$4.68	$10.17	$14.30	$24.47	$15.53	$8.95
2001	$9.00	$6.51	$10.34	$19.93	$30.27	$15.51	$14.75
2002	$8.87	$7.83	$10.09	$23.94	$34.03	$16.70	$17.33
2003	$8.91	$8.14	$10.43	$27.64	$38.07	$17.05	$21.01
2004	$6.00	$14.32	$10.26	$41.38	$51.63	$20.32	$31.31
2005	$5.00	$15.79	$10.34	$43.23	$53.57	$20.79	$32.77
2006	$5.00	$11.81	$10.76	$31.50	$42.26	$16.81	$25.45
2007	$4.00	$21.75	$10.42	$58.01	$68.43	$25.75	$42.67
2008	$4.00	$22.19	$10.62	$44.24	$54.87	$26.19	$28.68
2009	$4.00	$22.63	$10.84	$44.24	$55.08	$26.63	$28.45
2010	$4.00	$23.09	$11.05	$44.24	$55.30	$27.09	$28.21
2011	$4.00	$23.55	$11.28	$44.24	$55.52	$27.55	$27.97
2012	$4.00	$24.02	$11.50	$44.24	$55.74	$28.02	$27.73
2013	$4.00	$24.50	$11.73	$44.24	$55.97	$28.50	$27.48
2014	$4.00	$24.99	$11.97	$44.24	$56.21	$28.99	$27.22

2015	$4.00	$25.49	$12.20	$44.24	$56.45	$29.49	$26.96
2016	$4.00	$26.00	$12.45	$44.24	$56.69	$30.00	$26.70
2017	$4.00	$26.52	$12.70	$44.24	$56.94	$30.52	$26.42
2018	$4.00	$27.05	$12.95	$44.24	$57.20	$31.05	$26.15
2019	$4.00	$27.59	$13.21	$44.24	$57.45	$31.59	$25.87
2020	$4.00	$28.14	$13.47	$44.24	$57.72	$32.14	$25.58
2021	$4.00	$28.70	$13.74	$44.24	$57.99	$32.70	$25.28
2022	$4.00	$29.28	$14.02	$44.24	$58.26	$33.28	$24.99
2023	$4.00	$29.86	$14.30	$44.24	$58.54	$33.86	$24.68
2024	$4.00	$30.46	$14.59	$44.24	$58.83	$34.46	$24.37
2025	$4.00	$31.07	$14.88	$44.24	$59.12	$35.07	$24.05
				Net Present Value	$699.15	$341.21	$357.94
						Cost-Benefit Ratio	2.05

The net present values for all eradication zones are presented on a per-acre basis for the 1996 – 2025 period in Table 4. The NPVs range from a low of $119 per acre in BWE Zone 11 to a high of $533 for BWE Zone 6. The reason for so much variation in the NPV's across the state is because of the differences in the level of productivity among the zones. Eradication of the boll weevil will generally lead to greater benefits in areas with higher productivity. This could include areas with ample irrigation or dry land areas that have benefitted from generous summer rains in recent years.

Table 4 also contains the cost-benefit ratios which range from a low of 1.28 in BWE zone 11 to a high of 2.14 in BWE zone 6. A cost-benefit ratio of 1.28 means that each dollar spent by growers results in estimated benefits of $1.28.

Table 4. Net Present Value and Cost-Benefit Ratio From the Texas Boll WeevilEradication Program (1996-2025).

TBWE Zones	NPV ($/Acre)[1]	Cost-Benefit Ratio
Zone 1	$357.94	2.05
Zone 3	$263.29	1.34
Zone 4	$316.56	1.91
Zone 5	$391.34	2.08
Zone 6	$533.80	2.14
Zone 7	$188.05	1.65
Zone 8	$221.02	1.78
Zone 9	$261.99	1.62
Zone 10	$296.12	1.95
Zone 11	$119.33	1.28
Zone 14	$285.25	1.68

[1.] Cost-benefit ratios are calculated as the NPV of benefits divided by the NPV of costs for the period 1996 – 2025, using a discount rate of 5%.

To evaluate the sensitivity of the cost-benefit ratios to the discount rate, additional analyses were conducted using higher discount rates of 7.5% and 10.0%. Using a discount rate of 7.5%, the cost-benefit ratios range from a low of 1.24 (Zone 11) to a high of 2.16 (Zone 6). With a discount rate of 10.0%, the cost-benefit ratios range from a low of 1.19 (Zone 11) to a high of 2.18 (Zone 6). Thus, the cost-benefit ratios are robust over this range of discount rates.

Table 5 summarizes the total land acreage enrolled in the Texas BWE program, annual total net benefits for all zones included in this study, annual net benefits per acre, and the cumulative benefits. Annual net benefits to growers are presented in 2007 (real) dollars, which is also the basis for the cumulative net benefits. Annual net benefits have increased as acreage in the eradication program has climbed from 1.4 million acres in 1996, to over 5 million acres in 2007. Annual net benefits to growers have increased from $19.4 million in 1996 to $232.2 million in 2007. The statewide cumulative net benefit (1996-2007) of the BWE program is an estimated $1.4 billion.

On a per acre basis, average annual net benefits to producers increased from $13.15 in 1996 to $46.15 in 2007 on a statewide basis. In comparison to previous studies, Carpio et al., (2001) found net benefits to Texas High Plains producers of $56 per acres after eradication was achieved. For the three eradication zones in the Texas High Plains area, our study found net benefits to producers in 2007 of $54 per acre for Zone 5, $71 per acre for Zone 6, and $30 per acre for Zone 7. These results are very comparable to the study by Carpio et al., which focused on the same study area. In a study of BWE in the South Rolling Plains area of Texas, Johnson et al., (2001) estimated a cost-benefit ratio of 1.45 for the period 1994-2000. This compares to an estimated cost-benefit ratio in our study of 2.05 for the South Rolling Plains (1996-2025). Tribble et al. found net producer benefits on average of $88.73 per acre (ranging from $54 to $116) in Georgia. Reasons for the higher benefits can be attributed to higher insecticide spray costs and yield losses associated with the boll weevil eradication in the study area.

Table 5. Statewide Summary of the Net Benefits to Cotton Producers of the Texas Boll Weevil Eradication Program.

Year	Total No. of Land Acres*	Annual Net Benefit Real Dollars (2007)	Annual Net Benefits Per Acre	Cumulative Net Benefit
1996	1,476,745	$19,419,668	$13.15	$19,419,668
1997	1,113,748	$18,422,515	$16.54	$37,842,183
1998	1,203,037	$30,952,377	$25.73	$68,794,561
1999	3,892,387	($44,641,014)	($11.47)	$24,153,546
2000	4,266,331	$81,030,115	$18.99	$105,183,661
2001	5,803,719	$133,880,149	$23.07	$239,063,811
2002	5,664,936	$152,275,230	$26.88	$391,339,041
2003	5,723,436	$173,038,040	$30.23	$564,377,081
2004	5,982,985	$222,431,130	$37.18	$786,808,211
2005	6,070,076	$219,337,363	$36.13	$1,006,145,574
2006	6,402,723	$198,785,546	$31.05	$1,204,931,120
2007	5,032,700	$232,250,380	$46.15	$1,437,181,500

*Source: Texas Boll Weevil Eradication Foundation (Allen, 2007).

For 2007, the IMPLAN input-output model was used to estimate the economic impact of the BWE program to both growers and cotton ginners.[g] IMPLAN is a widely used economic impact analysis model which uses economic data for each sector of the economy and can be used to estimate how a change in one sector affects economic output, employment, and value-added in other sectors of the economy that supply inputs to that sector. This analysis focused on the employment impacts, and economic output - a measure of gross sales (business activity) throughout the economy. There are numerous studies where the IMPLAN model was used in a variety of applications, including economic impact assessment of various issues relating to cotton production, farm policy, and natural resources. Flanders et al., (2006) used the IMPLAN model to evaluate the economic impact of the Georgia cotton industry on the U.S. economy. Their findings suggests the economic viability of the cotton industry is not only important for the agricultural sector, but for all major sectors of the economy. With concern over the future supply of water available for agricultural irrigation, Yates et al., (2009) used the IMPLAN model to evaluate the economic impact of irrigated crop production relative to dry land and limited irrigation crop production in the Texas High Plains region. The study estimated that a loss of agricultural water of this magnitude – though not likely – would result in a loss of $616 million in value added and 7,300 jobs. The future availability of water for agricultural use was also the topic of a study by Howitt et al., (2009). Their results indicate an estimated 21,000 jobs would be lost due to a reduction in water supplies in the Central Valley of California.

The estimated direct impact of the BWE program at the farm-level in 2007 was $232.2 million (Table 6). Economic impact analysis at the farm-level was based on the impacts of the spending of the improved income using household expenditure patterns within the IMPLAN system. An estimated $155.4 million of the increased income was available to be spent and represents the direct impact. The remaining amount that is not spent, $76.8 million, accounts for savings, taxes and interest paid to state and federal government, and purchases of goods outside the state and goods imported from outside the U.S.

The direct impact to the ginning sector was based on the estimated cost of ginning the additional production resulting from BWE. Valco et al., (2004) estimated the average variable cost for ginning at $24.87 per bale. Using this ginning cost estimate, the cost of ginning the additional production in 2007 (1.09 million bales) was $27.3 million and represents the direct impact of ginning.

Table 6 summarizes the farm-level and ginning impacts for 2007. Economic output resulting from expenditures associated with the improved farm-level income was an estimated $266 million, which helped support an additional 2,089 jobs. For the ginning sector, economic output was estimated at $36.4 million, which helped support an additional 186 jobs. Total economic output associated with improved cotton production resulting from BWE was an estimated $302 million, which helped support over 2,275 jobs, directly and indirectly, statewide.

[g] IMPLAN Professional Ver. 2.0, Minnesota IMPLAN Group (MIG), Inc., 2006. Stillwater, MN

Table 6. Economic Impact of Boll Weevil Eradication (2007).

	Direct Impact ($ millions)	Total Economic Output ($ millions)	Employment
Impacts Farm-Level	$155.40	$266.30	2,089
Impacts to Ginning Sector*	$22.10	$36.40	186
Total Farm-Level and Ginning Sector	$177.50	$302.70	2,275

*This is the impact associated with costs incurred by cotton gins in ginning the additional production.

CONCLUSION

The goal of this study was to assess the economic benefits of BWE in Texas now that the BWE program has achieved statewide participation. Acreage involved in the Texas BWE program has grown from 1.4 million in 1995 to over 5 million today. The growth and acceptance of BWE was a direct result of the strong public-private partnership that was formed. With the Texas BWE program now including all cotton production in the state, this study is unique in that economic benefits were assessed for the vast majority of the State's cotton production rather than the focus being limited to one or more eradication zones. It should be understood that while the study area is the entire state, the results reflect the economic benefits of BWE that have been achieved thus far. While the full economic benefits will not be realized until eradication is achieved statewide, economic benefits of over $1 billion have already been realized.

Production losses resulting from boll weevil damage have caused significant economic hardship on producers and local economies that are supported by cotton. The importance of reclaiming this lost production through BWE efforts is clear when evaluating the economic impacts associated with BWE. In 2007, BWE progress resulted in an estimated direct impact of $177.5 million which supported an additional 2,275 jobs in Texas.

Caveats to this analysis include having favorable summer moisture to realize BWE yield gains, and avoiding any serious damage associated with new pests in a post-BWE environment, e.g. Lygus or Creontiades bugs.

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Management of Palmer Amaranth (*Amaranthus palmeri*) in Second-Generation Glyphosate-Resistant Cotton

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ABSTRACT

Field experiments were conducted in 2005 and 2006 to evaluate glyphosate timings and use of residual herbicides to control Palmer amaranth (*Amaranthus palmeri* S. Wats.) in second-generation glyphosate-resistant cotton (*Gossypium hirsutum* L.). Glyphosate treatments based on timing were used, in addition to preplant incorporated and postemergence-topical residual herbicides, to determine effective Palmer amaranth management systems. In 2005, complete control (100%) of Palmer amaranth was achieved across all glyphosate postemergence-topical systems. Less than complete control (94 to 98%) was observed with postemergence-directed glyphosate-resistant systems either with or without trifluralin preplant incorporated compared to second-generation glyphosate-resistant postemergence-topical systems. In 2006, similar Palmer amaranth control (95 to 99%) was observed across all second-generation glyphosate-resistant systems following trifluralin preplant incorporated and no benefit was observed from pyrithiobac or *S*-metolachlor tank-mixed with glyphosate. When trifluralin was not used, pyrithiobac or *S*-metolachlor tank-mixed with glyphosate early postemergence-topical followed by glyphosate improved control compared to glyphosate alone. Delaying early-season glyphosate applications did not reduce cotton lint yield; however, when no glyphosate was used cotton yields were reduced.

KEY WORDS: *Amaranthus palmeri* S. Wats., glyphosate, *Gossypium hirsutum* L., palmer amaranth, residual herbicides, roundup ready flex cotton, weed management systems

Abbreviations: ASN, as-needed; DAT, days after treatment; EPOST, early postemergence-topical; fb, followed by; GR, glyphosate-resistant; MPOST, mid postemergence-topical; PDIR, postemergence-directed; POST, postemergence-topical; PPI, preplant incorporated.

INTRODUCTION

The introduction of glyphosate-resistant (GR) cotton cultivars in the late 1990's allowed producers to effectively control many weeds season-long (Goldmon et al., 1996; Welch et al., 1997). Glyphosate applications in first generation GR cotton are restricted to postemergence-topical (POST) through the four-leaf growth stage of cotton, and glyphosate applied after this stage must be postemergence-directed (PDIR) to reduce the risk of yield loss in first generation GR cotton (Light et al., 2003; Welch et al., 1997). Producers have been successful at controlling early-season weed flushes; however, season-long Palmer amaranth control in first generation GR cotton has been limited on the Texas Southern High Plains due to the small POST application window, weed size, semi-arid conditions, and repeated weed flushes during the growing season.

Second-generation GR cotton was introduced in 2006 and offers cotton cultivars with season-long tolerance to glyphosate POST. Additional benefits of second-generation GR cotton systems are convenience, production flexibility, economic feasibility and promotion of conservation tillage, all while obtaining superior weed control (Dill 2005). In 2008, 77% of the Texas High Plain's cotton acres were planted to second-generation GR cotton cultivars, which has increased from 13% in 2006 (Anonymous, 2009).

Second-generation GR systems also provide the ability to use other herbicide modes of action as needed for weed management or the management of resistant biotypes (Clewis et al., 2006a). Residual herbicides applied preplant incorporated (PPI) and preemergence are successful in managing early-season annual weeds such as Palmer amaranth (Keeling et al., 1997). Residual herbicides used in conjunction with glyphosate provide excellent weed control, high yields and at the same time reduce the number of glyphosate POST applications (Askew et al., 2002; Isgett et al., 1997; Keeling et al., 2006; Keeton and Murdock 1997).

The wide use and acceptance of this new technology suggests that there will be a continued increase in second-generation GR cotton production as producers seek more flexible application windows. Therefore, research was conducted to evaluate Palmer amaranth management in second-generation GR cotton with different glyphosate POST application timings in combination with PPI and POST residual herbicides.

MATERIALS AND METHODS

Field experiments were conducted in 2005 and 2006 at the Texas *Agri*LIFE Research and Extension Center near Lubbock. The soil type was an Acuff clay loam [Fine-loamy, mixed, thermic Aridic Paleustolls, (41% sand, 25% silt, 34% clay)] with <1% organic matter and pH of 7.6. Stoneville 4554 B2RF cotton was planted on 40 in. rows at a depth of 2 in. using a seeding rate of 15 lb/A. Planting dates were May 18, 2005 and May 8, 2006. During October and November of 2004, 8.9 in. of rainfall was received which benefited the 2005 crop. Little rainfall was received prior to planting in 2006. Rainfall received from April 1 to August 31 totaled 8.8 and 4.8 in. in 2005 and 2006, respectively, and an additional 6 in. of water by furrow irrigation was applied in 2005 and 12 in. in 2006.

Postemergence-topical (POST) and preplant incorporated (PPI) herbicide applications were made using a tractor-mounted compressed-air sprayer or a CO_2 pressurized backpack sprayer both calibrated to deliver 10 gal/A with TurboTeeJet 110015VS nozzles spaced at 20 in. Preplant herbicides were incorporated 2 to 3 in. immediately after application using a spring-tooth harrow.

Herbicides included trifluralin PPI at 0.75 lb ai/A, *S*-metolachlor at 1.0 lb ai/A tank-mixed with glyphosate early-postemergence (EPOST) or mid-postemergence (MPOST), pyrithiobac at 0.03 lb ai/A tank-mixed with glyphosate EPOST or MPOST, and glyphosate at 0.75 lb ae/A applied EPOST, MPOST and as-needed (ASN). A GR herbicide program was also evaluated consisting of glyphosate EPOST followed by postemergence-directed (PDIR) applications of glyphosate both at 0.75 lb/A.

Percent weed control was estimated 14 and 28 days after each glyphosate application followed by an end of season evaluation using a scale from 0 (no control) to 100% (complete control). Yield was determined by harvesting the middle two rows using a two row plot stripper on October 18, 2005 and October 20, 2006. Samples were collected from each plot for ginning to determine the percent turnout of cotton lint used to calculate lint yields.

The experiments were arranged in a randomized complete block design with three replications. Plots were four rows wide by 30 ft in length and a natural infestation of Palmer amaranth was present at approximately 1 plant/ft^2. Arcsine square root transformation was performed on Palmer amaranth control data but did not affect conclusions; therefore, non-transformed means are presented. Data were subjected to analysis of variance (SAS 9.1) and means were separated using Fisher's Protected LSD test at the 5% level of probability.

RESULTS AND DISCUSSION

A year by treatment interaction was observed; therefore, Palmer amaranth control data was analyzed by year. In 2005, early-season Palmer amaranth control 14 days after treatment (DAT) ranged from 95 to 100% (Table 1). Trifluralin preplant incorporated (PPI) controlled Palmer amaranth 96% while glyphosate applied early postemergence-topical (EPOST) achieved 100% control. Glyphosate systems applied mid postemergence-topical (MPOST) controlled Palmer amaranth 95 to 99%, with similar control achieved with glyphosate alone or glyphosate plus either *S*-metolachlor or pyrithiobac. At 28 DAT, Palmer amaranth was controlled 83% with trifluralin PPI alone. Control was similar between glyphosate applied either EPOST or MPOST and control ranged from 85 to 98%; however, there was a trend towards increased control with the use of *S*-metolachlor or pyrithiobac tank-mixed with glyphosate compared to glyphosate applied alone. At the end of the season (120 DAT), trifluralin PPI alone did not control Palmer amaranth at least 70% (Table 1).

After all second-generation GR systems received a sequential glyphosate application, complete Palmer amaranth control was achieved, corroborating similar results from Main et al. (2007). In those studies, Palmer amaranth control was nearly complete with any treatment containing multiple glyphosate applications. Less than complete Palmer amaranth control (98 and 94%) was observed with first generation GR systems comprised of glyphosate EPOST followed by (fb) glyphosate PDIR either with or without trifluralin PPI, respectively. In 2005, timely rainfall throughout the growing season allowed for optimum crop growth, reducing the amount of in-season irrigation needed, and subsequently less weed germination throughout the growing season. A glyphosate POST only system controlled Palmer amaranth 100%; therefore, no benefit from PPI or tank-mixed POST residual herbicides was observed.

In 2006, early-season Palmer amaranth control ranged from 92 to 100%, with trifluralin PPI controlling Palmer amaranth 82% (Table 1). Glyphosate following trifluralin PPI controlled Palmer amaranth 98 to 100%, with similar control for both EPOST and MPOST timings. When no PPI was used, Palmer amaranth control ranged from 92 to 98%, with a trend towards improved control when glyphosate applications were delayed from EPOST to MPOST. Culpepper and York (1999) found improved control of large crabgrass [*Digitaria sanguinalis* (L.) Scop.], when glyphosate applications were delayed in a weed management program with pendimethalin plus fluometuron. Tharp and Kells (1999) reported that control of many weed species improved by delaying herbicide applications in glufosinate- and glyphosate-resistant corn (*Zea mays* L.). Delaying glyphosate applications to MPOST allowed for more weed seeds to germinate before the application, and weed seed germination after the application was minimal due to dryer soil conditions. VanGessel et al. (2000) found that delaying glyphosate applications past the four-trifoliate stage in glyphosate-resistant soybean [*Glycine max* (L.) Merr.] provided inconsistent weed control.

Table 1. Palmer amaranth (*Amaranthus palmeri*) management in second-generation GR cotton systems in 2005 and 2006[a].

Weed management system[b]		Application timing[c]	2005 14DAT[d]	2005 28DAT	2005 120DAT	2006 14DAT	2006 28DAT	2006 120DAT
			--- % control ---					
trifluralin alone		PPI	96bc	83d	66d	82g	47h	30d
trifluralin fb	gly fb gly	EPOST	100a	91bcd	100a	98bc	94def	97ab
	gly+pyr fb gly	EPOST	100a	95abc	100a	100a	98abc	99a
	gly+*S*-met fb gly	EPOST	100a	98a	100a	100a	99ab	99a
	gly fb gly	MPOST	100a	92abcd	100a	99ab	99ab	96ab
	gly+pyr fb gly	MPOST	96bc	95abc	100a	100a	99ab	96ab
	gly+*S*-met fb gly	MPOST	99abc	97ab	100a	100a	98abc	95ab
	GR: gly fb gly	PDIR	99abc	94abcd	98b	100a	99ab	86c
no trifluralin	gly fb gly	EPOST	100a	85cd	100a	92f	75g	85c
	gly+pyr fb gly	EPOST	100a	95abcd	100a	98bc	89f	95ab
	gly+*S*-met fb gly	EPOST	100a	95abcd	100a	95e	91ef	92b
	gly fb gly	MPOST	97abc	88bcd	100a	97cd	100a	96ab
	gly+pyr fb gly	MPOST	98abc	94abcd	100a	97cd	99ab	94ab
	gly+*S*-met fb gly	MPOST	95c	93abcd	100a	97cd	100a	93b
	GR: gly fb gly	PDIR	98abc	88bcd	94c	100a	96cde	87c

[a] Abbreviations: DAT, days after treatment; EPOST, early-postemergence; fb, followed-by; gly, glyphosate; GR, glyphosate-resistant;
MPOST, mid-postemergence; PDIR, postemergence-directed; PPI, preplant incorporated; pyr, pyrithiobac; *S*-met, *S*-metolachlor.
[b] Herbicide rate = 0.75 lb ai/A, trifluralin; 0.75 lb ae/A, glyphosate; 0.03 lb ai/A, pyrithiobac; 1.0 lb ai/A, *S*-metolachlor.
[c] Application timings reflect the first glyphosate application. However, GR systems had an initial glyphosate application made EPOST followed by glyphosate PDIR. In 2006, two PDIR applications of glyphosate were needed.
[d] Evaluations reflect days after the first glyphosate application.

When evaluated 28 DAT, trifluralin PPI controlled Palmer amaranth 47%, whereas trifluralin fb glyphosate EPOST resulted in 94% control (Table 1). Pyrithiobac or *S*-metolachlor tank-mixed with glyphosate EPOST improved control to at least 98%. Glyphosate EPOST without a PPI controlled Palmer amaranth 75%, and the addition of pyrithiobac or *S*-metolachlor to glyphosate EPOST improved control to 89 and 91%, respectively. Similarly, Clewis et al. (2006b) found improved Palmer amaranth control when S-metolachlor was tank-mixed with glyphosate. Glyphosate MPOST controlled Palmer amaranth 98 to 100%; however, no benefit was observed from trifluralin PPI or tank-mixes of *S*-metolachlor or pyrithiobac with glyphosate MPOST. Askew and Wilcut (1999) reported that soil applied herbicides were not necessary in many studies when repeated glyphosate application were used in cotton. At the end of the season, trifluralin PPI controlled Palmer amaranth 30%. Similar control (95 to 99%) was observed across all glyphosate-based Roundup Ready Flex systems following trifluralin PPI, with no benefit from pyrithiobac or *S*-metolachlor tank-mixed with glyphosate. When no PPI was used, pyrithiobac or *S*-metolachlor tank-mixed with glyphosate EPOST fb glyphosate controlled Palmer amaranth 95 and 92%, respectively. Palmer amaranth control was controlled 85% following glyphosate EPOST fb glyphosate.

The GR systems comprised of glyphosate EPOST fb two PDIR glyphosate applications either with or without trifluralin PPI controlled Palmer amaranth 86 and 87%. Similar second-generation GR systems required fewer glyphosate applications throughout the growing season to achieve similar or greater Palmer amaranth control (85 and 97%). In 2006, four in-season furrow irrigations were needed, which resulted in continuous weed seed germination throughout the growing season (authors personal observations). Therefore, overall Palmer amaranth control was less effective in 2006 compared to the 2005 growing season.

. A year by treatment interaction was observed and data was analyzed by year. All glyphosate-based weed management systems produced greater yields than the trifluralin alone and non-treated control in both years; however, the benefit from the use of a residual herbicide with glyphosate was not always apparent. When glyphosate EPOST or MPOST followed trifluralin PPI, yield increased from 500 to up to 1035 lb/A (52% increase) in 2005 (Table 2). Delaying early-season glyphosate applications from EPOST to MPOST (seven days) did not reduce cotton lint yield. In 2006, lint produced in the trifluralin alone system was 223 lb/A, which was 76 to 78% less than the weed management systems that contained trifluralin followed by glyphosate alone applied EPOST (919 lb/A) or MPOST (1000 lb/A). Similar to 2005, no reductions in cotton lint yield was observed when early-season glyphosate applications were delayed from EPOST to MPOST (13 days) and the benefit of the residual herbicide with glyphosate was not always apparent Greater end of season weed control in the glyphosate-based weed management systems compared to the trifluralin alone systems was reflected in yield produced.

CONCLUSION

In one of two years, residual herbicides improved Palmer amaranth control in second-generation glyphosate-resistant cotton. In addition, residual herbicides are effective tools to reduce the risk of the development of glyphosate-resistant Palmer amaranth.

Table 2. Effects of Palmer amaranth control on second-generation GR cotton lint yield in 2005 and 2006[a].

Weed management system[b]	Application timing [c]		2005	2006
			-----------lb/A---------	
trifluralin				
	glyphosate fb glyphosate	EPOST	919 c-f [d]	910 b
	glyphosate+pyrithiobac fb glyphosate	EPOST	1,000 b-f	901 b
	glyphosate+*S*-metolachlor fb glyphosate	EPOST	982 b-f	1,214 a
	glyphosate fb glyphosate	MPOST	892 f	1,062 ab
	glyphosate+pyrithiobac fb glyphosate	MPOST	1,187 a	910 b
	glyphosate+*S*-metolachlor fb glyphosate	MPOST	1,026 bc	875 b
	GR: glyphosate fb glyphosate	PDIR	910 def	1,053 ab
no trifluralin				
	glyphosate fb glyphosate	EPOST	973 b-f	919 b
	glyphosate+pyrithiobac fb glyphosate	EPOST	1,017 bcd	1,071 ab
	glyphosate+*S*-metolachlor fb glyphosate	EPOST	1,008 b-e	1,080 ab
	glyphosate fb glyphosate	MPOST	1,035 b	1,000 ab
	glyphosate+pyrithiobac fb glyphosate	MPOST	1,000 b-f	1,116 ab
	glyphosate+*S*-metolachlor fb glyphosate	MPOST	1,071 b	1,053 ab
	GR: glyphosate fb glyphosate	PDIR	901 ef	1,089 ab
trifluralin alone		PPI	500 g	223 c
non-treated		NA	357 h	80 c .

[a] Abbreviations: EPOST, early-postemergence; fb, followed-by; GR, glyphosate-resistant; MPOST, mid-postemergence;
NA, not applicable; PDIR, postemergence-directed; PPI, preplant incorporated.

[b] Herbicide rate=0.75 lb ai/A, trifluralin; 0.75 lb ae/A, glyphosate; 0.03 lb ai/A, pyrithiobac; 1.0 lb ai/A, *S*-metolachlor.

[c] Application timings reflect the first glyphosate application. However, GR systems had an initial glyphosate application made EPOST followed by glyphosate PDIR. In 2006, two PDIR applications of glyphosate were needed.

[d] Yield means followed by the same lower case letter are not significantly different (P = 0.05) using Fisher's protected LSD.

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Redberry Juniper Consumption Does Not Adversely Affect Reproduction of Meat Goats

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ABSTRACT

Goat browsing can slow the encroachment of juniper (*Juniperus pinchottii* and *Juniperus asheii*) onto rangelands, but potential detrimental effects of monoterpenoids on reproduction are unknown. We determined whether redberry juniper consumption by pregnant goats caused abortions or reduced offspring neonatal viability. Pregnant Boer-cross nannies (n = 19) were randomly divided into four treatments, three treatments fed redberry juniper 1 h daily for 22 d during one of the three trimesters and a control group fed alfalfa pellets throughout gestation at 2% BW to meet maintenance requirements. In a pasture trial, pregnant nannies (n = 20) were placed on juniper dominated rangeland throughout gestation; juniper preference was monitored once monthly via bite count surveys and fecal NIR analysis. In both trials, birth date and weight, offspring number, sex, and vigor scores were recorded at parturition. Kids were weighed on days 14 and 28 postpartum. No abortions occurred as a result of redberry juniper consumption and no differences (P > 0.05) were observed in offspring number, vigor scores, or weight. Predicted juniper in goat diets on pasture was similar. Producers can use goats as a management tool for slowing juniper encroachment onto rangelands without causing abortions or reducing neonatal viability.

KEY WORDS: abortifacient, aversive feedback, *Juniperus*, monoterpenes

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INTRODUCTION

Redberry (*Juniperus pinchotii* Sudw.) and ashe (*Juniperus asheii* Buch.) juniper continue to invade rangelands and become a problematic plant for ranchers in west central Texas (Ansley et al., 1995; Smeins et al., 1997). These two species of juniper were originally limited to rocky outcrops and steep canyons; however, with the suppression of wildfires, the density and location of juniper has increased. Several methods including the use of herbicides (spraying), prescribed burning, and mechanical removal (grubbing, chaining, root plowing) are utilized to aid in the management of these unwanted species (Stueter and Wright 1983; Ueckert et al., 1994; Johnson et al., 1999). However, with rising fuel, labor, and herbicide costs, many ranchers are looking for alternative management strategies. Preliminary evidence reveals that goats can slow the encroachment of juniper onto rangelands by browsing seedlings and immature plants (Taylor and Fuhlendorf 2003; Taylor 2004).

Monoterpenoids, a class of terpenes containing two isoprene units, found in juniper are known to cause aversive postingestive feedback (Riddle et al., 1996; Pritz et al., 1997) thereby limiting intake. During winter months when alternative forage availability and nutrient quality is limited, juniper consumption can range from 22-29% of the diet (Campbell et al., 2007a). Juniper intake and corresponding vegetation management of juniper can be further increased by preconditioning goats in a pen situation at weaning (Dietz et al., 2010).

Although extensive research has gone into conditioning goats to consume juniper (Bisson et al., 2001; Ellis et al., 2005; Dunson et al., 2007), little research has investigated the potential detrimental effects of juniper on goat reproduction. Evergreen species can inflict embryonic damage, resulting in abortion and birth defects (Panter et al., 1992). Ingestion of ponderosa pine (*Pinus ponderosa* Laws.) causes abortions in cattle due to acetyl isocupressic acid (ICA) which is converted to isocupressic acid in the rumen (Gardner et al., 1998). Trace levels (< 2 %) of ICA are present in lodgepole pine (*Pinus contorta* Dougl. ex. Loud.), common juniper (*Juniperus communis* L.), and Rocky Mountain juniper (*Juniperus scopulorum* Sarg.) (Gardner et al., 1998). Juniperus species have also been suspected to cause abortions in livestock. For instance, Johnson et al. (1976) discovered that feeding one-seeded juniper (*Juniperus osteosperma* Torr.) to sheep in the second and early third trimester caused abortions.

In west central Texas, concentrations of monoterpenoids in juniper are highest in the winter and spring (Owens et al., 1998); this timeframe directly coincides with the kidding season of most goat producers in west Texas. Because many producers use goat browsing to manage juniper, the potential effects on reproduction must be examined. Accordingly, this study determined if juniper consumption by pregnant goats caused abortions or reduced neonatal viability, and if so, in what trimester.

MATERIALS AND METHODS

Pen Feeding Trial. Forty-six female Boer-cross goats (25 yearling and 21 mixed age) with an average weight of 54.1 kg (± 4.9) were exposed to Boer billies for 3 mo for natural breeding. Conception dates were determined using ultrasonographic imagery (Classic Medical, Palm Scan PSM-3.5-S) at two week intervals throughout the breeding season.

Once pregnancy was confirmed, goats were allocated into treatments based on date of conception. Treatment 1 consisted of nannies fed redberry juniper in the first trimester of pregnancy; Treatment 2 consisted of nannies fed redberry juniper during the second trimester of pregnancy, and Treatment 3 consisted of nannies fed redberry juniper during the third trimester of pregnancy. Treatment 4 nannies served as the control and were not fed juniper anytime during pregnancy. At two week intervals throughout gestation, ultrasonographic imagery was used to monitor fetal development and health. Less than optimum body condition scores for pregnancy maintenance in yearling nannies and intense heat during breeding resulted in low conception rates and ultimately a variation in the number of goats per treatment.

In June 2006, redberry juniper leaves were stripped from plants located on the Texas Agrilife Research Center, Sonora, TX and stored at 4°C until feeding. During the first trimester, 10 randomly selected, pregnant Boer-cross female goats (Treatment 1) were placed in individual pens and fed redberry juniper at 0800 hours *ad libitum* for 1 h daily for 22 d at the Angelo State University Management, Instruction, and Research (MIR) Center, San Angelo, TX (31° N; 100° W). Individual pens (1 m X 1.5 m) were elevated with expanded metal floors to allow for removal of excreta. All excreta were removed from beneath pens at weekly intervals. Procedures in Treatments 2 and 3 were conducted exactly as Treatment 1 during the second and third trimesters, with 8 and 5 pregnant nannies, respectively. The remaining 5 pregnant nannies (Treatment 4) were fed only alfalfa pellets at 2% BW throughout the feeding trial.

Nannies in Treatments 1-3 were fed 50 g (as fed basis) of redberry juniper on Day 1 of the feeding trial, and amount of juniper fed was increased to ad libitum levels based on intake of individual goats throughout the remainder of feeding. At the conclusion of feeding each day, refusals were collected and weighed. To meet daily maintenance and pregnancy requirements, all goats were fed alfalfa pellets at 2% BW each day following juniper feeding and throughout the remainder of the feeding trial (NRC, 1981). Pregnancy was verified using ultrasonographic imagery at two week intervals throughout gestation. All goats were given free access to a calcium/phosphorous mineral supplement with trace minerals and fresh water throughout pregnancy.

At the conclusion of the feeding trial and just prior to parturition, all pregnant nannies (Treatments 1-4) were placed in kidding pens located on the Angelo State University MIR Center. In order to avoid pregnancy toxemia, the nannies were placed on a balanced ration based on NRC requirements for late-term pregnancy (Table 1). Each nanny was monitored daily, and at parturition, data including birth date, number of offspring, birth weight, and offspring sex was collected. Vigor scores were also assigned during the first 8 h of life based on the following scale: 0 = dead; 1 = extremely weak, no attempt to get up or stand; 2 = struggles to get up, delay in nursing; 3 = slow to get up, slow to nurse; 4 = strong but slow to nurse; and 5 = strong, nurses rapidly. Body weights of kids were collected again on days 14 and 28 postpartum.

Pasture Trial. Twenty-five mixed age Boer-cross female goats were exposed to Boer billies for three months for natural mating. At two week intervals throughout the breeding season, pregnancy rate was evaluated using ultrasonographic imagery to determine approximate conception dates. At the conclusion of breeding, 20 pregnant nannies were transported to the Texas Agrilife Research Center, Sonora, TX (30° N; 100° W) and placed in a 16.2 ha pasture on juniper dominated (20.3% canopy cover) rangeland for four months (Dietz et al., 2010). All goats were given free access to a calcium/phosphorous mineral supplement with trace minerals and fresh water during the grazing portion of the study.

To monitor juniper preference, monthly bite count surveys were conducted. Each goat was observed individually for a period of 10 min once a month during optimum grazing times in the afternoon. During this time, bite frequency and bite type was identified and recorded as either herbaceous, juniper, or other browse. Fecal samples were also obtained from each goat to evaluate predicted juniper percentage in diets using the fecal near infrared reflectance spectroscopy (NIRS) procedure described by Walker et al. (2007). During each monthly observation period, nannies were scanned using ultrasonographic imagery to ensure pregnancy.

After four months on pasture, and just prior to parturition, the nannies were transported back to the Angelo State University MIR Center for kidding. In order to avoid pregnancy toxemia, the nannies were placed on a balanced ration based on NRC requirements for late-term pregnancy (Table 1). Each nanny was monitored daily, and at parturition data including birth date, number of offspring, birth weight, and offspring sex was collected. Vigor scores were also assigned during the first 8 h of life based on the previously mentioned scale. Body weights of kids were collected again on days 14 and 28 postpartum.

To quantify that adequate herbaceous forage was available for goats throughout the trial, clip samples were obtained during each monthly observation period. Ten 1/3 m^2 quadrats, randomly located throughout the pasture, were clipped and bagged by herbaceous species; samples were dried in a forced-air oven at 60°C for 48 h and weighed to determine dry matter forage availability.

Table 1. Ingredients and nutritional value of balanced feed ration fed to pregnant nannies immediately prior to kidding in both experiments.

Ingredients	Percent (%) of Diet DM[a]
Alfalfa, Dehydrated	56.9
Cane Molasses	2.8
Corn	37.9
Premix[b]	2.4
Avg. Daily Feed Intake Per Head	1.4 kg
Digestible Energy	3.0 Mcal/kg
Total Digestible Nutrients	68.90%
Crude Protein	15.50%

[a]All percentages based on 1 ton (909.1 kg).

[b]Angelo State University Premix: Lasalocid 1158 g/ton, Calcium 19.0%, Salt 19.0%, Magnesium 1.4%, Zinc 2095 mg/kg, Manganese 1015 mg/kg, Iodine 0.02 mg/kg, Copper 1.0 mg/kg, Selenium 3.9 mg/kg, Vitamin A 18,364 IU/kg, Vitamin D3 13,400 IU, Vitamin E 280 IU.

In order to evaluate juniper monoterpene concentration and composition, 50 grams of leaf and small stem tissue was collected by hand clipping from the apical portion of sprouts from each tree and immediately placed in liquid nitrogen to halt physiological activity and prevent volatilization. Leaf tissue was then stored at -50°C. Samples were randomly collected from three redberry and three ashe plants during each observation period.

In August 2007, 15 g of previously frozen leaf material from each plant was individually combined with 150 ml of distilled water in a modified Clevenger (1928) type distillation apparatus. Hexane (5 ml) was used as a solvent for the distillate in the condensation tube, and the distillation time period was eight hours to ensure maximum recovery of monoterpenes (Owens et al. 1998; Campbell et al., 2007b). Five microliters of tetradecane were added to condensate as an internal standard.

The chromatographic system consisted of a Clarus 500 GC (Perkin Elmer, Shelton, CT) equipped with an FID. The analytical column was a 30 m x 0.25 mm Rtx-5, 0.25 um (Restek, Bellefonte, PA). One microliter splitless injections (split time of 0.1 min) were made under the following conditions: the injection temperature was 200°C and the detector was 300°C. The initial oven temperature of 40°C was held for 0.5 min. The first oven ramp took the oven to 110°C at a rate of 5°C/min (0-min hold time). The final ramp of 20°C/min took the oven to its final temperature of 300°C (0-min hold time). The total run time was 23 min. The carrier gas was helium delivered at a constant 39 cm/s by employing electronic pressure control. The detector gasses were hydrogen (45.0 ml/min), and air (450 ml/min). Analytical procedure followed a modification of the procedure described in Kimball et al. (2004).

Detector responses were evaluated for each analyte over the range of 0.25-1.0 ug/ml. For each compound three hexane solutions with concentrations in the range of interest were injected into the GC in triplicate. Linear regression analyses were conducted and external standard calibrations were used by comparing detector responses of the analytes from the sample extracts to responses from commercially available standards (Acros Organics, NJ).

Intake data from the pen feeding trial was analyzed using repeated measures analysis of variance with goats (replications) nested within treatments (trimesters) and day of collection. Differences between treatments for birth weight, 14 d weight, and 28 d weight were analyzed using analysis of variance. Number of offspring born per nanny and sex were included in the analysis to determine their influence on weights of kids. Vigor scores and the average number of births were compared among treatments using a Chi-square test. For the pasture trial, bite count data, NIRS estimates of forage preference, and forage availability were compared among sampling dates using analysis of variance. Mean birth weight, 14 d weight, 28 d weight, number of births, and vigor scores were not analyzed in the pasture trial because of a lack of a treatment effect. Means were separated using Least Significant Difference when $P \leq 0.05$ in both experiments. Data were analyzed using the statistical package JMP (SAS, 2007).

RESULTS AND DISCUSSION

Pen Feeding Trial. During the breeding portion of this trial, intense heat and drought-like conditions reduced conception rates in mature nannies. Also, yearling nannies obtained for this study just prior to breeding were not in optimum body condition for breeding and pregnancy maintenance. Both of these factors resulted in a variation in number of nannies per treatment in the pen feeding trial. Of the 46 nannies exposed to billies, 28 nannies became pregnant and were divided into 4 treatments for the feeding trial. A combination of heat stress and yearling nannies' inability to maintain pregnancy resulted in early termination of pregnancy in 5 nannies in Treatment 1 and 4 nannies in Treatment 2 prior to feeding juniper. Therefore, 19 of the 46 exposed nannies gave birth to 34 kids resulting in a 74% kidding percentage. Overall kidding percentage in both trials suffered due to environmental conditions and was not caused by juniper consumption.

Average daily juniper intake was similar ($P = 0.09$) among treatments during the pen-feeding phase of this study. Nannies in Treatment 1 consumed 1.1 ±0.3 g kg^{-1} of juniper per day. Treatment 2 nannies consumed 0.6 ±0.3 g kg^{-1} of juniper per day, and nannies in Treatment 3 consumed 0.5 ±0.4 g $kg^{-1}$of juniper per day. Juniper intake during Treatment 1 gradually increased through d 13 of feeding followed by a repeated pattern of decreased and increased intake throughout the remainder of the trial (Fig. 1). Goats in Treatments 2 and 3 maintained similar patterns of consumption through d 20 when Treatment 2 began to decrease intake and Treatment 3 increased juniper intake. No significant differences were observed in the treatment by day interaction. Goats can be preconditioned in a pen-fed situation to consume higher levels of juniper once released onto pasture (Dietz et al., 2010). Avoidance occurs because of monoterpenoids contained in juniper associated with aversive postingestive feedback (Riddle et al., 1996; Pritz et al. 1997). Goats in the pen feeding trial, although offered juniper for a longer period of time (22 d), tended to consume less juniper than goats in previous studies.

Monoterpenoid levels tend to be higher in the winter and spring (Owens et al. 1998). However, seasonal rainfall variations can effect monoterpenoid concentrations (Riddle et al. 1996). Gas chromatograph analysis of redberry juniper fed to goats revealed higher concentrations of monoterpenes inversely correlated to intake than that of a study conducted by Dietz et al. (2009). The severity of the drought-like conditions which occurred during the summer feeding trial may have played a role in elevating monoterpenoid levels in the juniper resulting in reduced overall intake. Also, r^2 values for intake may have been arbitrarily higher than Dietz et al. (2009) because of low sample size in this study.

Birth weights, 14 d weights, and 28 d weights were similar ($P \geq 0.05$) among treatments (Table 2). The number of single and multiple births were also similar among treatments (Table 3). Number of kids born per nanny had no apparent effect ($P > 0.05$) on birth weight, 14 d weight, or 28 d weight. Also, vigor scores were similar among treatments (Table 3).

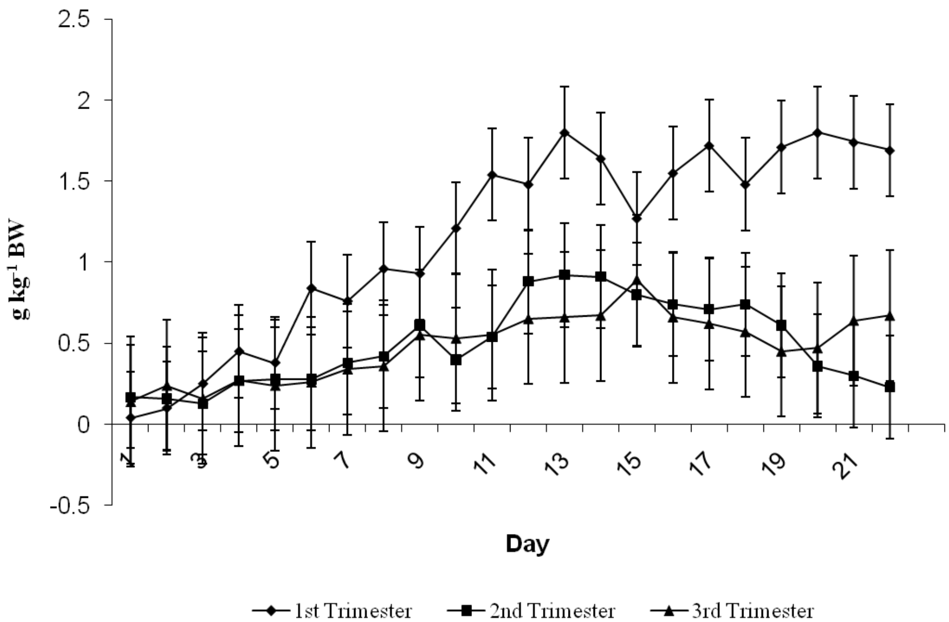

Figure 1. Redberry juniper intake for nannies throughout pregnancy.
*Average daily juniper intake for nannies fed redberry juniper *ad libitum* 1 hour daily for 22 d during each trimester of gestation in the pen feeding trial ($P = 0.09$).

Table 2. Birth weights (BW), 14 d weights (14W), and 28 d weights (28W) of all kids born to nannies in the pen feeding trial fed redberry juniper *ad libitum* 1 hour daily for 22 d during each trimester of gestation.

Trimester	Goats/Treatment	BW (kg)	SEM	14W (kg)	SEM	28W (kg)	SEM
1st	10	3.7	0.2	5.2	0.8	7.6	1.2
2nd	8	3.1	0.2	4.6	0.8	6.9	1.2
3rd	5	3.3	0.1	3.2	0.7	4.3	1.0
Control[a]	5	3.6	0.2	5.9	0.8	9.4	1.1

[a]Nannies in control received only alfalfa pellets at 2% BW throughout the feeding trial.

Pasture Trial. Goats were released onto pasture 20 July 2006, at a moderate stocking rate based on year-round grazing (1 animal unit year / 8.1 ha). Differences between goat forage preferences throughout gestation were observed and recorded (Table 4). During the August observation period, goats tended to prefer other shrubs (algerita, liveoak, persimmon, lotebush) over the other two forage classifications. Herbaceous forage was preferred during the September observation period, and juniper was the preferred forage class during the October observation. Herbaceous production during October increased as goat preference shifted from herbaceous forage to juniper.

Table 3. Number of kids born as singles, twins, or triplets and vigor scores of all nannies fed redberry juniper *ad libitum* 1 hour daily for 22 d during each trimester of gestation.

	Trimester			
Number born	1st	2nd	3rd	Control[a]
Single	0	0	1	1
Twins	6	4	0	10
Triplets	3	6	12	0
Vigor Score				
0	1	1	2	0
1	0	0	1	0
2	0	0	0	0
3	0	2	0	0
4	0	1	1	0
5	8	6	9	11

[a]Nannies in control received only alfalfa pellets at 2% BW throughout the feeding trial.

Table 4. Total herbaceous production (kg ha^{-1}) and preference of herbaceous vegetation, juniper, or other shrubs (percent of total bites) for pregnant nannies during 3 months of observation on juniper dominated rangeland.

	August	September	October	SEM
Herbaceous Production	1066.5	659.46	1459.2	309.04
Preference				
Herbaceous	6.8	53.7	33.9	1.2
Juniper	17.3	43.7	66.2	1.4
Other Shrubs	76.0	0.0	0.0	0.6

Average available herbaceous forage remained relatively constant throughout the trial with the exception of September where a decrease in kg ha^{-1} of forage produced was observed (Table 4). This decline may be a result of lack of significant rainfall along with greater preference for herbaceous forage over any other forage class during this time as noted during visual observation.

According to bite count estimates, juniper consumption steadily increased as the fall of the year approached. During gestation, monthly juniper samples were taken to evaluate monoterpene concentration and composition. Gas chromatograph analysis shows total monoterpene concentrations for both ashe and redberry juniper were highest during the July and August collection periods (Tables 5, 6). A significant difference was observed in sabinene/b-pinene, cymene, and terpeneol concentrations in ashe juniper and borneol, g terpinene, and terpinen4ol concentrations in redberry juniper over the four month collection period (Tables 5, 6). Juniper intake was inversely correlated to sabinene/b-pinene (r^2 = 0.96) concentrations in ashe juniper and a terpinolene (r^2 = 0.97), terpineol (r^2 = 0.99), and total monoterpene (r^2 = 0.96) concentrations in redberry juniper. Conversely, it was positively correlated to borneol (r^2 = 0.79) concentration in redberry juniper. Gas chromatograph analysis revealed lower levels of total monoterpene concentrations in ashe and redberry juniper during September and October. These results may explain increased juniper consumption and agree with the observation that lower monoterpene concentrations exist in juniper in west central Texas during the fall (Owens et al., 1998).

Fecal NIRS data obtained from samples collected revealed similar (P > 0.05) amounts of predicted juniper in goat diets between observation periods.

Table 5. Average monoterpene levels (mg oil g^{-1} leaf material) in ashe juniper collected during pasture trial.

Monoterpene	Month				
	July	August	September	October	SEM
alpha-pinene	0.20	0.17	0.14	0.14	0.03
Camphene	0.21	0.17	0.14	0.33	0.05
Sabinene/b-pinene	0.02	0.02	0.02	0.001	0.002
Myrcene	0.14	0.11	0.12	0.29	0.08
Cymene	0.13	0.17	0.10	0.07	0.02
Limonene	0.91	0.95	0.72	0.69	0.19
g terpinene	0.08	0.07	0.08	0.09	0.03
a terpinolene	0.07	0.07	0.07	0.07	0.02
Linalool	0.01	0.01	0.01	0.02	0.006
Fenchyl Alcohol	0.05	0.09	0.04	0.05	0.02
Camphor	5.32	5.86	4.73	3.67	0.85
a-citronellol	0.20	0.20	0.35	0.11	0.08
Borneol	0.40	0.46	0.25	0.12	0.09
Terpinen4ol	0.01	0.02	0.01	0.02	0.003
Terpineol	0.01	0.01	0.02	0.05	0.002
Carvone	0.06	0.07	0.05	0.03	0.01
Bornyl Acetate	1.88	1.70	1.64	1.24	0.36
Total	10.12	10.63	8.83	7.33	1.64

Twenty-five nannies were exposed to billies and 18 nannies gave birth to 34 kids resulting in a 136% kidding percentage. Data collected on birth weights, 14 d weights, and 28 d weights of all kids born to nannies in the pasture trial did not reveal any apparent differences. All weights were similar to those weights of kids in the pen feeding trial through the duration of the trial.

Based on the results from this study, monoterpenoids found in redberry and ashe juniper do not appear to have a negative effect on goat reproduction. No differences in neonatal vigor scores were observed in kids from any treatment group in either trial. Likewise, all kids from both trials, no matter how many siblings, maintained similar growth patterns based on birth, 14 d, and 28 d weights throughout the duration of the study. These results indicate that juniper intake does not inhibit offspring growth and development. Unlike results from Johnson et al. (1976) where abortions occurred in sheep fed juniper (1 lb of plant per day) via stomach pump in the second and third trimesters, no incidences of abortions or teratogenic effects (birth defects) were observed in this study. Goats may metabolize monoterpenes found in juniper better than sheep and are therefore able to avoid toxin-induced abortions.

Table 6. Average monoterpene levels (mg oil g^{-1} leaf material) in redberry juniper collected during pasture trial.

Monoterpene	Month				
	July	August	September	October	SEM
alpha-pinene	0.40	0.37	0.31	0.32	0.06
Camphene	0.08	0.10	0.09	0.11	0.02
Sabinene/b-pinene	3.98	3.32	2.77	2.80	0.70
Myrcene	1.00	0.95	0.76	0.81	0.14
Cymene	0.01	0.01	0.01	0.01	0.002
Limonene	0.92	0.98	0.79	0.74	0.13
g terpinene	1.08	0.95	0.75	0.62	0.09
a terpinolene	0.44	0.39	0.31	0.29	0.04
Linalool	0.04	0.03	0.03	0.04	0.01
Fenchyl Alcohol	0.03	0.03	0.03	0.03	0.0006
Camphor	1.24	1.35	1.29	1.21	0.23
a-citronellol	0.07	0.12	0.14	0.07	0.05
Borneol	0.01	0.03	0.03	0.05	0.005
Terpinen4ol	2.77	2.39	1.91	1.53	0.24
Terpineol	0.12	0.11	0.09	0.08	0.008
Citronellol	0.09	0.08	0.09	0.01	0.06
Bornyl Acetate	0.31	0.28	0.29	0.56	0.20
Total	12.58	11.48	9.70	9.26	1.51

CONCLUSION

Collectively, results of previous studies along with the results of this study indicate that goats should continue to be used as a cost-effective method of juniper management (Taylor and Fuhlendorf, 2003; Ellis et al., 2005; Dietz et al., 2010). Producers can implement strategies to increase juniper consumption by preconditioning yearling replacement nannies for 14 d at weaning along with concentrating the main breeding herd in juniper-dominated pastures without fear of a reduction in kidding percentage or lighter kid weaning weights.

Monoterpenoid concentrations in juniper are typically highest during the early spring and winter when most browse and herbaceous plants are dormant. This timeframe directly coincides with the breeding seasons of most goat ranchers in west central Texas. Concentrating goats into juniper-dominated pastures during this time period will increase browsing pressure on these plants and optimize potential management of juniper.

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Exclusion Fencing for Feral Hogs at White-tailed Deer Feeders

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ABSTRACT

Management programs aimed at white-tailed deer (*Odocoileus virginianus*) production often include the use of feeders, either to deliver supplemental feed or bait. However, much of the feed placed into deer feeders is consumed by non-target species, such as feral hogs (*Sus scrofa*). Our objectives were to compare three exclusion fence designs at deer feeders for their ability to restrict feral hog visitation and enable white-tailed deer visitation. Our high fence design consisted of 86 cm high graduated paneling. Our medium fence design consisted of 76 cm high, 10×10 cm paneling. Our low height design consisted of 51 cm high, 10×10 cm paneling. We placed deer feeders >1.5 km apart and monitored feeders with motion-sensing digital photography during the summer and winter. We compared the percent change in visitation index by fence design and season. We found feral hog percent change in visitation index varied by treatment, with our low fence design restricting feral hog visitation less than the medium and high fence designs. Given the cost of materials and the effectiveness of the exclusion fences, we recommend using an 86 cm high exclusion fence for feral hogs around deer feeders. However, we caution that our data and recommendations are from short-term seasonal trials.

KEY WORDS: boar, exclusion fencing, feeder, feral hog, *Sus scrofa*, white-tailed deer

INTRODUCTION

White-tailed deer (*Odocoileus virginianus*) and invasive feral hogs (*Sus scrofa*) coexist on millions of hectares throughout Texas (Adams et al., 2005). Management programs aimed at

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white-tailed deer production often include the use of feeders, either to deliver supplemental feed or bait (Webb et al., 2008). In fact, Texas landowners feed approximately 136 million kg of corn annually (R.N. Wilkins, Texas AgriLife Extension Service, unpublished data). However, much of the feed placed into deer feeders is consumed by non-target species (Lambert and Demarais 2001). Feral hogs and raccoons (*Procyon lotor*) are the primary non-target species causing damage through feed loss at deer feeders (Cooper and Ginnett 2000).

Biologists and land managers are seeking solutions to reduce damage at deer feeders by feral hogs (e.g., consuming feed, turning feeders over, and creating wallows at feeders). For example, biologists have determined that feral hog activity at deer feeders may be reduced by using feed types that are unpalatable to feral hogs as deer feed (Cooper 2006). Additionally, land managers often use fencing to exclude feral hogs from deer feeders (e.g., see Webb et al., 2008). However, little data exist regarding the effectiveness of different fence designs for feral hog exclusion at deer feeders. For example, both woven-wire (Hone and Atkinson 1983, Doupé et al., 2009) and electric (Reidy et al., 2008, Vidrih and Trdan 2008, Honda et al., 2009) fence designs have been found effective at reducing feral hog movements in various field applications, but have not been evaluated at a focal resource, such as deer feeders. Furthermore, the optimum height of exclusion fencing for deer feeders has not been determined.

Our objectives were to compare three exclusion fence designs at deer feeders for their ability to restrict feral hog visitation and enable white-tailed deer visitation during the summer and winter. Given previous reports that woven-wire fencing ≥80 cm restricted feral hog movement in captivity (Hone and Atkinson 1983), we hypothesized that our treatment 86 cm in height would restrict feral hog visitation to deer feeders. Furthermore, we hypothesized that white-tailed deer visitation to deer feeders would not be inhibited by our treatment fence designs because they were ≤86 cm in height (VerCauteren et al., 2006).

MATERIALS AND METHODS

We conducted our study during 2009 on the 3,157-ha Rob and Bessie Welder Wildlife Refuge (28°06'N, 97°22'W) in San Patricio County, which received an average of 79 cm of rainfall annually. The property was dominated by live oak (*Quercus virginiana*), honey mesquite (*Prosopis glandulosa*), and huisache (*Acacia farnesiana*). Primary non-target species at deer feeders were feral hogs, raccoons, and collared peccaries (*Pecari tajacu*). Feeding of deer and other wildlife did not occur on the property prior to our study. All animal use procedures were approved by the National Wildlife Research Center's Animal Care and Use Committee (Number QA-1702).

We evaluated three exclusion fence designs at deer feeders from 29 June–28 July (summer) and from 5 November–3 December (winter). Our fence designs used six 4.9-m livestock panels constructed into a 9.4 m diameter perimeter circle around deer feeders with the aid of 12 t-posts (Figure 1). Our high fence design consisted of 86 cm high graduated paneling (Feedlot Panel, Hog; Tractor Supply Company, Brentwood, Tennessee). Our medium fence design consisted of 152 cm high 10×10 cm paneling (Utility Panel, 5 ft × 16 ft; Tractor Supply Company, Brentwood, Tennessee) cut in half, yielding a 76 cm high exclusion fence. Our low height design consisted of the same 152 cm high 10×10 cm paneling cut into thirds, yielding a 51 cm high exclusion fence. We used 2.4 m high tripod deer feeders with a 102 kg capacity (R225 Pro VB Tripod Feeder Kit; American Hunter Outdoor Products, Grand Prairie, Texas) during our trials. Throughout our seasonal trials, we programmed deer feeders to release corn for 10 seconds daily at 0600 and 1700 hours.

Figure 1. Exclusion fencing using 6 1.9-m livestock panels constructed into 9.4 m diameter perimeter circle around deer feeders with the aid of 12 t-posts in San Patricio County, Texas during the summer (29 June–28 July) and winter (5 November–3 December) of 2009.

At the beginning of our summer and winter trials we identified locations with fresh signs of white-tailed deer and feral hog activity and from these we selected locations to place deer feeders (*n* = 6 per trial and *n* = 2 per treatment). For each trial we placed deer feeders >1.5 km apart and monitored feeders with motion-sensing digital photography (Silent Image Professional; Reconyx, LaCrosse, Wisconsin). We placed camera systems 5 m from deer feeders and programmed systems to "high sensitivity" to capture 5 digital images every 5 seconds at a 2-minute trip interval. We revisited deer feeders, checked camera systems, and downloaded digital images every 3 to 5 days. From day 1 to 14 of each trial we maintained and monitored deer feeders without construction of exclusion fencing, the before fence construction period. On day 15 of each trial, we used a random number generator to assign deer feeder locations to an exclusion fencing treatment (*n* = 2 for high, medium, and low treatments) and constructed exclusion fencing treatment. From day 15 to 28 of each trial, we maintained and monitored deer feeders with exclusion fencing treatments, the after fence construction period.

We determined species-specific visitation rates through examination of digital images. As an index to visitation, we recorded the maximum number of individuals consuming corn by species captured on any one image within any hour on a daily basis. We report these data as the maximum number of visits by species per hour. We calculated the percent change in visitation index before and after fence construction for each location by dividing the after index by the before index and multiplying by 100. Percent values were square root transformed prior to analysis (Steel and Torrie 1980). For each species, we used PROC ANOVA (SAS Institute, Inc., Cary, North Carolina) to compare the percent change in visitation index by fence design (high, medium, and low) and season (summer and winter) in a 2 × 3 factorial design (Littell et al., 2006). We reported means ± SE.

RESULTS AND DISCUSSION

We examined and recorded data from 111,769 digital images during our summer trial and 75,630 digital images during our winter trial. For feral hog percent change in visitation index, we found no interaction between fence design and season ($F_{2,11}$ = 0.54, P = 0.61) and no season effect ($F_{1,11}$ = 0.54, P = 0.49). However, feral hog percent change in visitation index varied by treatment ($F_{2,11}$ = 3.92, P = 0.08), with our low fence design (51 cm) restricting feral hog visitation to deer feeders less than the medium (76 cm) and high (86 cm) fence designs. In fact, after construction of the medium and high exclusion fencing treatments, no feral hogs gained access to the deer feeders (Figure 2). This was consistent with our hypothesis that our high exclusion fence would restrict feral hog visitation to deer feeders. For white-tailed deer percent change in visitation index, we found no interaction between fence design and season ($F_{2,11}$ = 0.08, P = 0.92) and no treatment effect ($F_{2,11}$ = 0.44, P = 0.66). This was consistent with our hypothesis that visitation by deer would not be inhibited by our exclusion fencing. After construction of the high, medium, and low exclusion fencing treatments, deer continued to gain access to the feeders (Figure 3). However, deer percent change in visitation index varied by season ($F_{1,11}$ = 6.89, P = 0.04), with a greater percent change in visitation index occurring during the summer (4 ± 23%) than winter (–74 ± 9%).

Our observation of greater deer visitation during the summer compared to the winter trial may be due to severe drought conditions observed during the summer. For example, from January–July 2009 our study site received only 28% of its average normal precipitation for the period (NOAA 2009) and available deer forage was reduced, which may have prompted deer to visit feeders at a greater rate. Near average normal monthly precipitation occurred from September–December 2009 on our study site, which increased available forage during our winter trial. Another explanation for this observation is that deer in our winter trial may have been more interested in breeding activities than foraging activities and visited feeders at a lesser rate. A final explanation is that during our winter trial heavy rainfall occurred after exclusion fence construction. This may have further reduced deer activity and visitation to feeders.

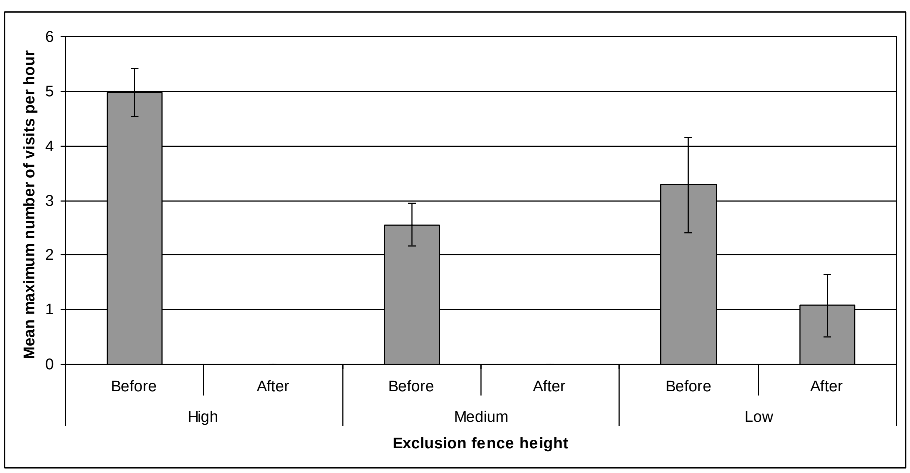

Figure 2. Mean (±SE) maximum number of visits by feral swine per hour 14 days before and 14 days after construction of exclusion fencing at high (86 cm, n = 4), medium (76 cm, n = 4), and low (51 cm, n = 4)

heights around deer feeders in San Patricio County, Texas during the summer (29 June–28 July) and winter (5 November–3 December) of 2009.

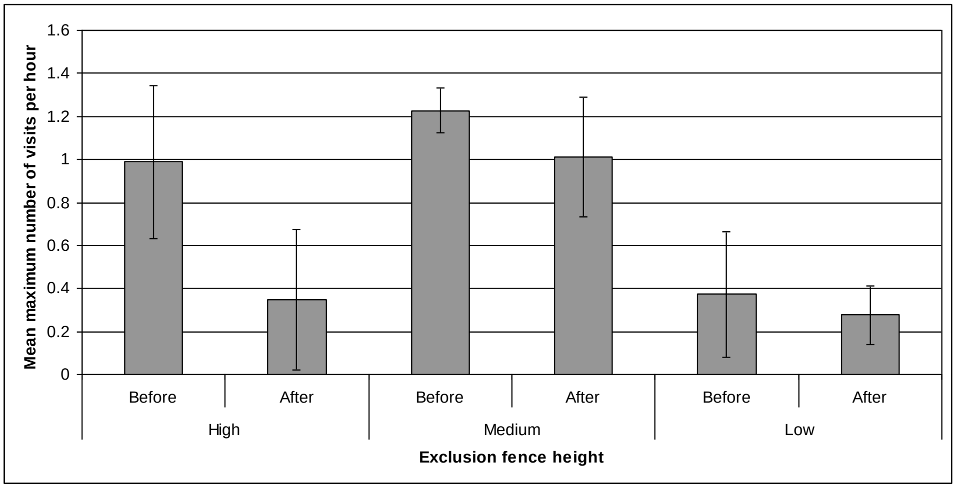

Figure 3. Mean (±SE) maximum number of visits by white-tailed deer per hour 14 days before and 14 days after construction of exclusion fencing at high (86 cm, *n* = 4), medium (76 cm, *n* = 4), and low (51 cm, *n* = 4) heights around deer feeders in San Patricio County, Texas during the summer (29 June–28 July) and winter (5 November–3 December) seasons of 2009.

Researchers from southern Texas have noted few fawns using deer feeders with feral hog exclusion fencing (VanBogelen et al., 2009). Our digital image data support this observation. During our summer trial we observed fawns with does, but on no occasion did they consume corn at feeders either before or after fence construction. During our winter trial fewer fawns were observed, perhaps due to mortality caused by the abovementioned drought conditions. Again, we did not observe these animals consuming corn at feeders before or after fence construction, even at our low exclusion fence locations. In addition to exclusion fencing restricting access of fawns to deer feeders, VanBogelen et al., (2009) suggest that social interactions with adult deer may also restrict fawns from visiting feeders. This explanation appears plausible given our observations.

Our data suggest that feral hog exclusion fencing at deer feeders should be >51 cm and that fencing 76 cm and 86 cm were equally effective at excluding feral hogs. Including t-posts and t-post clips, our high, medium, and low exclusion fence material costs were $190, $187, $142 per deer feeder, respectively. If managers cut t-posts in half, then these costs would be reduced. Additionally, our 3-person fence construction crews were able to build one exclusion fence in approximately 45 minutes and this was consistent among fence designs. Furthermore, preparation time was needed to cut the medium fence in half. As such, our medium fence cost slightly less than our high fence to construct, but this may depend on local supplies available, vendors, and markets. Given the cost of materials that we encountered and the effectiveness of the exclusion fences, we recommend using an 86 cm high exclusion fence for feral hogs around deer feeders. However, we caution that our data and recommendations are from short-term seasonal trials and may not apply to situations in which year round supplemental feeding is practiced. With time, over longer durations, and depending upon other available forages, feral hogs will likely challenge even the 86 cm high exclusion fencing. Additional study is needed to formulate management appropriate recommendations in these situations.

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Effects of Serum Levels of Copper and Zinc on Antibody Titers of Two Breeds of Stocker Calves Injected With *Leptospirosis sp.* Vaccine and Drenched With an Organic Mineral Supplement

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ABSTRACT

This study was conducted to determine the effects of serum levels of copper (Cu) and zinc (Zn) on antibody titers of stocker calves administered *Leptospirosis sp.* vaccine that were given a balanced oral mineral drench. A total of 111 head of stocker calves were injected with *Leptospirosis sp.* vaccine and blood samples were taken from each calf to determine initial serum levels of Cu and Zn. Calves were blocked according to breed (Limousin or Angus based crossbred) and sex (steers or heifers) and allotted to one of two treatments. Treatments were allotted and worked on Day 0 (D 0), treatment one (Trt.-1) received a balanced mineral drench containing chelated forms of Cu and Zn, while treatment two (Trt.-2) did not receive mineral drench and served as control. Blood was obtained via jugular venipuncture on D 14 and D 28 for determination of serum Cu, Zn and titer strength to *Leptospirosis.* Data analysis revealed no differences ($P>0.05$) in mineral levels between control and drench treated calves on D 14 or D28. Pooling calves on breed revealed a higher level ($P<0.05$) of serum Cu levels in Limousin calves, while crossbred calves had higher ($P<0.05$) circulating Zn levels. These results are indicative of previous trials showing substantial breed differences in mineral metabolism and also suggest that a short-term treatment of Zn and Cu will not positively affect a calf's ability to respond to Leptospirosis vaccines.

KEY WORDS: copper, zinc, Leptospirosis, antibody titer, cattle

INTRODUCTION

Factors including cost of vaccines and antibiotics, limited qualified labor, efficiency of gain and overall mortality rates impact management decisions made by cow/calf, stocker and feedyard producers. In an attempt to increase profitability, some producers utilize improved preventative health practices for their cattle marketing. The USDA (2000) defined "preconditioning" as procedures designed to improve an animals' likelihood of successfully adapting to the feedyard environment. Improving preconditioning practices to minimize inputs, health practices and death losses is a high priority for the feedyard industry. Feedyards have found an advantage in purchasing cattle that have undergone a recommended preconditioning regimen. The marketing of cattle through special preconditioned sales continues to increase. Preconditioning procedures may include better matching of rations to cattle requirements, improving formulation and availability of trace mineral mixes and reducing physical stress. Herd (1997) stated that maintenance, growth, lactation and animal health could not be maximized in a situation where minerals were not properly fed. It has also been shown that deficiencies in some minerals compromise immune function (Berger, 1996). An impact on the immune system and growth may be present, if trace minerals are available at less than optimum levels, long before overt deficiency signs such as hair coat and skeletal abnormalities are seen (Mortimer et al., 1999). These works by Mortimer et al. (1999) also indicated that the first biological activity affected by mineral deficiency is the immune system. Suttle and Jones (1989) referred to trace element deficiencies in farm livestock as endemic in many areas of the world. Two minerals that have documented links to immune status in cattle are Zn and Cu (Blezinger, 2000; Zinpro Corp., 2000). Therefore it was the objective of this study to determine if an oral mineral drench containing chelated Zn and Cu would increase circulating plasma levels of these minerals and have an affect on titer levels to *Leptospirosis sp.* vaccine and subsequent serum concentrations of Cu and Zn.

MATERIALS AND METHODS

This trial was conducted in Northeast Texas near the town of Windom during the fall of 2003. The pastures were at approximately 33.6º N latitude and 96º W longitudes with an elevation of approximately 770 ft above sea level. Soil type on both locations was a Houston Black Clay on a limestone base from surface to 30 + ft deep.

Purebred Limousin calves (n = 60; 30 male, 30 female) were in one location and Angus-based crossbred calves (n = 51, 30male, 21 female) were in another location that were approximately one mile apart. Calf initial weights ranged from 450 to 600 lbs. On October 18, Angus crossbred calves were weaned and placed on grass hay and fresh water until processing. Limousin cattle were weaned on October 19 and also placed on grass hay and fresh water until processing. On October 24 all calves were processed using similar handling facilities in a squeeze chute. The same crew of four men performed all processing. They used methods to attempt to minimize stress on calves and create a safe environment for calves and workers.. Penning and processing of the Angus crossbred calves began at 0700 h and concluded at 1000 h. Penning and processing of the Limousin calves began at 1100 h and concluded at approximately 1400 h. All calves were processed in accordance with Texas Cooperative Extension and the Lamar County Cattleman's Association in preparation for the Cattleman's Vac-45 preconditioned calf sale held in Paris, TX on November 25, 2003. All calves were dewormed with Ivomec Plus® (Merial Ltd., Iselin, NJ) as indicated on label recommendations at a rate of 1 ml per 100 lbs of body weight. Injections were given subcutaneously in the elbow pocket, just behind the shoulder. Ultrabac 7 / Somnubac®, Clostridial vaccine with *Hemophilus somnus*, (Pfizer Inc., New York, NY) was administered in a 5 ml dose, subcutaneously in the neck. Vira Shield 4® (Grand Labs., Larchwood, IA) and a 4 way respiratory vaccine for IBR, BVD, BRSV and PI-3 was administered in a 2 ml dose intramuscularly into the neck. Presponse HM®, a *Pasteurella hemolyticum* vaccine (Fort Dodge Labs., Fort Dodge, IA) was administered at 2 ml per head intramuscularly in the neck. All calves received Origin Lepto 5® vaccine, (Agropfarm, Grapevine, TX) at a rate of 2 ml per head intramuscularly in the neck. Origin Lepto 5® vaccine contains inactivated cultures of

Leprospirosis Pomona, *L. canicola*, *L. grippotyphosa*, *L. hardjo* and *L. icterohaemorragia*. These five *Leptospira* organisms are commonly known collectively as "Lepto."

Calves were blocked by sex and breed and assigned to the two treatments. One treatment (Trt. 1) received a Pull-Thru® cattle drench (Albion Laboratories Inc., Clearfield, UT) while the calves assigned to the control treatment (Trt. 2) did not receive the mineral drench. Guaranteed analysis of the Pull-Thru® cattle drench, which is used primarily as a mineral and vitamin supplement drench, was Mg 1.97%; K 1.97%; Cu 2.27%; Zn 2.27%; Se 0.02%; Mn 0.93%; Co 0.13% and Vitamin E 15,350 I U/ 45 kg (Albion Laboratories, Clearfield, UT). The Pull-Thru® drench was mixed by adding water to one packet containing 283.5 g of drench powder to create a 950 ml suspension. This resulting suspension was administered at the recommended level of 30 ml for calves 400 to 600 lb. The drench suspension was given orally using an oral hook connected to an automatic draw, pistol grip dosing gun. The dosing gun was connected to a bottle containing 950 ml of the drench suspension.

On D 0, prior to administration of the oral drench, two blood samples were taken via venipuncture from each calf. Blood was collected with a 10 ml Vacutainer glass test tube utilizing red topped tubes for later analysis of Cu and blue topped tubes containing samples for Zn analysis. Immediately following blood collection, tubes were placed on ice in a cooler and transported to the Texas A&M University-Commerce Nutrition Laboratory. Blood was centrifuged at 1600 RPM for 15 min. Serum was aspirated from each tube and placed into a sterile 10 ml test tube for shipping. Serum was packed with cool packs and shipped to the Texas A&M Veterinary Medical Diagnostic Laboratory, College Station, TX for analysis of serum Cu and Zn. Following processing all calves were placed on grass hay and pasture with ad libitum access to water.

On D 14 calves were revaccinated with Vira Shield 4® and Presponse HM®. Blood samples were taken and treated as previously described, but samples collected on D 14 were also analyzed for titers against all five serovars of Lepto given on D 0 as well as analysis for Cu and Zn. On D 28, blood samples were collected again as previously described and analyzed by Texas A&M Veterinary Medical Diagnostic Laboratory for Cu, Zn and the five serovars of Lepto given on D 0. Data were analyzed using analysis of variance generated by a statistics software package called Statview produced by SAS.

RESULTS AND DISCUSSION

Serum samples collected on D 0 were not analyzed for Zn levels due to extreme hemolysis, however, Cu analysis was performed at this collection date. Treatment with Pull-Thru® cattle drench had no effect ($P>0.05$) on Lepto titers (Table 1). There were no differences in the basal level of Cu on antibody titers for Lepto on any date, showing no response due to the mineral drench administered on D 0 (Table 2). These findings are consistent with Underwood and Suttle (1999), Spears and Kegley (2002) and Richardson (2002) who reported no response in serum Cu level to supplemental Cu being fed.

Table 1. Guaranteed Analysis of Pull-Thru® Cattle Drench (Albion Laboratories, Clearfield, UT)

Magnesium (Mg)…………………………………………..1.97%
Potassium (K)……………………………………………1.97%
Copper (CU)……………………………………………..2.27%
Zinc (ZN)………………………………………………...2.27%
Selenium (Se)……………………………………………0.02%
Manganese (MN)…………………………………………...0.93%
Cobalt (Co)………………………………………………0.13%
Vitamin E……………………………..minimum 15,350 IU/.45 kg

Ingredients: MAAC® Magnesium Amino Acid Chelate, Potassium Amino Acid Complex, MAAC® Copper Amino Acid Chelate, MAAC® Zinc Amino Acid Chelate, MAAC® Manganese Amino Acid Chelate, Cobalt Sulfate, Vitamin E Supplement (di-alpha tocopherol acetate), Sodium Selenite, Saccharine Sodium, Modified Starch, Silicon Dioxide, Molasses Flavoring and Dextrose.

Table 1. Effect of Pull-Thru® Cattle Drench on *Leptospirosis sp.* Titer Response in Growing Calves.

	L. pomona	*L. ictero*	*L canicola*	*L. grippo*	*L. hardjo*
Trt. 1*	4.31 ± .8	.86 ± .5	9.48 ± 1.0	.86 ± .5	32.3 ± 3.3
Trt. 2+	5.66 ± .9	3.77 ± 1.2	8.49 ± 1.1	1.89 ± 1.1	25.38 ± 3.1

*Received one 30 ml oral Pull-Thru® cattle drench on D 0
+Received no supplemental mineral treatment

However, other research has indicated that Cu supplementation resulted in variable immune responses depending on the class of immune cell being studied, as well as the source and concentration of the supplemental Cu (Dorton et al., 2003). Treatment with Pull-Thru® cattle drench had no effect on serum concentrations of Cu and Zn on either day 14 or day 28 (Table 2). This could possibly be attributed to the homeostatic functions metallothionein has on hepatic Cu and Zn storage (Bremner 1987; Richards 1989).

Table 2. Effect of Pull-Thru® Cattle Drench on Serum Cu and Zn Concentrations 14 and 28 Days Post-administration in Growing Calves.

	-----------------Cu ppm------------		----------------Zn ppm----------------	
	D 14	D 28	D 14	D 28
Trt 1*	0.86 ± .04	0.73 ± .03	0.87 ± .03	0.59 ± .02
Trt 2+	0.79 ± .04	0.69 ± .03	0.78 ± .03	0.59 ±.02

*Received one30 ml oral Pull-Thru® cattle drench on D 0
+Received no supplemental mineral treatment

Breed differences existed in this study with Limousin calves having a higher (P<0.05) serum Cu level across all collection dates than did Angus crossbred calves. There were no differences (P>0.05) between steers and heifers for any treatments and data was pooled. However, Angus crossbred calves had higher serum concentrations of Zn (P<0.05) across all collection dates (Table 3). In a similar study done by Mullis et al. (2003a), Simmental steers had lower serum and liver Cu concentrations than did their Angus counterparts. These data as well as an accompanying study suggest that Simmental cattle may have a higher Cu requirement than Angus (Mullis et al., 2003b). Other supporting data found that Angus calves whose dams were fed supplemental Cu exhibited higher serum concentrations than either Charolais or Simmental calves treated similarly (Ward et al., 1995). Cumulatively, these studies suggest a higher Cu requirement for Simmentals and/or inherently lower serum Cu levels when compared to Angus.

Table 3. Effect of Breed on Circulating Concentrations of Cu and Zn in Growing Calves During a 28 Day Period.

Breed	Cu ppm
Limousin[¥]	$0.78^{a} \pm .01$
Angus Cross[§]	$0.73^{b} \pm .01$

[¥]Registered purebred Limousin cattle

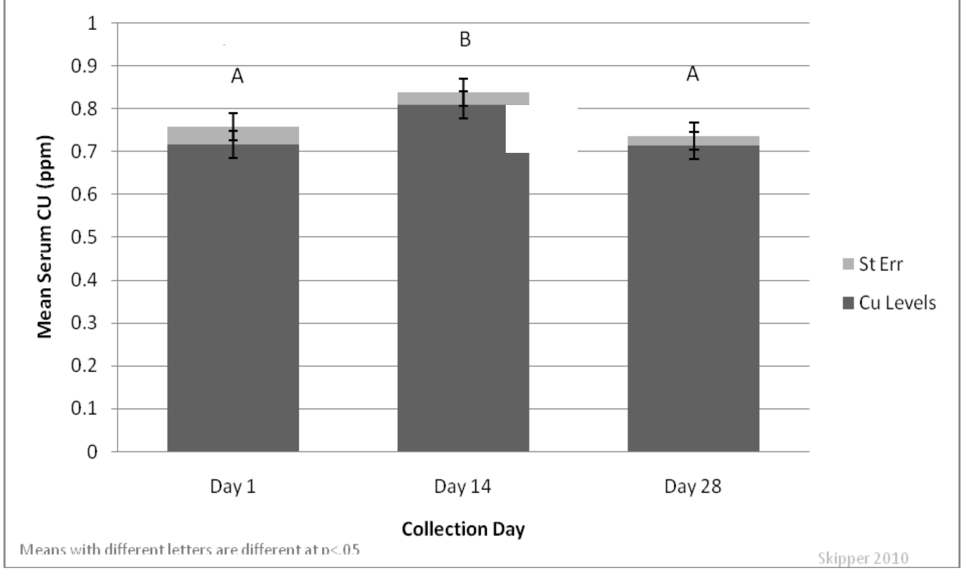
[§]Angus sired cattle with crossbred Dams

Means indicated with different letters are significant at ($P<0.05$)

Serum Cu concentrations on D 0 ranged from 0.10 ppm to 1.00 ppm with a mean of 0.72 ppm. On day 14 Cu levels ranged from 0.30 to 1.50 ppm with a mean of 0.71 ppm. Barr (2004) stated that cattle with serum Cu concentrations of less than 0.40 ppm are considered deficient. Marginal when serum levels are between 0.40 ppm and 0.60 ppm and optimum levels should be within a range of 0.80 ppm and 1.50 ppm. Based on these levels given by Barr (2004), initial Cu levels of calves on D 0 revealed that 19% were considered deficient, 47% fell in the marginal range and the remaining 34% were optimum. When calves were sampled on D 14, 5% of calves would be considered deficient, 24% had Cu levels which placed them in the marginal range, while the remaining 71% were optimum in serum Cu levels. Numbers changed at the D 28 collection, where it was found that only 1% of calves were deficient. However, the number of calves in the marginal range increased to 44%, with the remaining 55% of calves being within the optimum circulating Cu range. These data may indicate a continual reduction in the number of deficient calves from D 0 through D 28.

As shown in Figure 1 average serum Cu levels on D 14 were higher ($P<0.05$) than day 0, but returned to baseline levels on D 28. An increase in circulating levels of Cu on day 14 could have been the administration of the drench or this increase may be the result of cattle being subjected to processing stress on day 0, including vaccinations, blood sampling and handling. This explanation would concur with findings by Orr et al. (1990) who found that cattle stressed with infectious bovine rhinotracheitis virus or with market-transit showed increases in serum levels of Cu. Additional research has shown that stress was accompanied by a decrease in fecal and urinary excretion of Cu as compared to baseline levels in studies where stress was induced (Nockels et al., 1993). The return to near baseline levels may be attributed to the homeostatic functions the metallothionein has on storage of Cu and Zn indicated by Bremner (1987) and Richards (1989).

Figure 1. Serum Cu Concentrations of Stocker Calves Over Three Collection Dates



Although insufficient data exists in this trial as to the change in Zn from D 0 through the remaining two collections dates, Nockels et al. (1993) found urinary Zn excretion was lower during stress periods than in baseline. They suggested the decrease in feed consumption led to reduced urinary volume that increased metallothionein synthesis in the kidney which may have contributed to a negative Zn balance during the period of stress.

Levels of Zn and Cu in relation to immune response tend to be inconclusive. As Dorton et al. (1993) stated, these relationships tend to be related to immune cell type being studied as well as the source and concentration of supplements in the diet. These levels may be influenced by the relationship between Cu, Zn and the synthesis of metallothionein in the homeostatic binding and storage of both Cu and Zn. Breed differences and stress also seem to be major influencing factors in absorption, excretion and utilization of Cu and Zn.

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Observed Results and Possible Outcomes of Implementing a Veterinary Technology Program into High School Agriculture Departments in Texas

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ABSTRACT

As our nation strives to remain competitive in the global market, science and math curriculum have come to the forefront. Integrating science and math curriculum into high school agriculture courses allows students the opportunity to improve academically in all content areas. This study examined the current state of the veterinary technology program being taught in Texas high school agriculture departments, as well as determined the needs of those schools currently not teaching the program. The results of the study found that: 1) implementing the veterinary technology program increased enrollment of non-traditional and minority students in agriculture departments; 2) teachers agreed that science and math components of the veterinary technology program are important factors to consider when deciding to implement the program; 3) program faculty were most often the reason the program was implemented; and 4) teachers of the program were the primary curriculum developers. This study recommends agriculture teachers partner with the science and math departments to provide a rich science, technology, engineering, and math (STEM) content in their programs and that a mandatory curriculum training program be implemented for teachers teaching the veterinary technology program.

KEY WORDS: veterinary technology; science, technology, engineer, math (STEM) coalition; agricultural education

INTRODUCTION

As the national public school enrollment numbers increased from 1995 to 2005 by 9.5 percent while Texas' school enrollment numbers over the same ten year period, increased at an even faster rate, increasing by more than 20 percent (TEA, 2009; National Center for Education Statistics, 2007b). Not only did the number of students in Texas public schools increase, so did the diversity of the student population. African Americans, Hispanics, and other minorities have become the majority of the students enrolled in Texas public schools (*Policy Research*, 1998). However, these groups of students are still currently under-represented in high school agriculture programs (Talbert & Larke, 1995). Based on a review of the literature, minority students do not enroll in agriculture programs for a number of reasons. These reasons range from students viewing agriculture negatively due to misconceptions that agriculture deals only with the growing of crops, the lack of support from the guidance counselor, scheduling issues (Nichols & Nelson, 1993), and changing graduation requirements for the current student (Knight, 1987). Overcoming these perceived barriers held by minority students can prove to be difficult. One way to combat the problem is to possibly spark an interest by offering new, more modern courses in agriculture.

In 2006, 61.6% of all high school graduates in the United States continued on to institutions of higher education (NCHEMS, 2006). By 2008, this number had increased to 68.6% (Bureau of Labor Statistics, 2009). The remaining 31.4 - 38.4% of high school graduates, then, must be trained for some form of employment while enrolled in high school. . From 1997-98 to 2007-08, the enrollment rate of CTE courses rose by 92.1 percent (TEA, 2009). The National Research Council (1988) recommended the continued expansion and improvement of vocational agriculture courses to include more scientific and technical course material in order to provide stable employment opportunities to those students that do not continue on to institutions of higher education.

Much attention has been directed toward increasing students' class time in the areas of math and science (Stephenson, Warnick, & Tarpley, 2007). This increased attention toward math and science is due in part to the United States falling behind other nations academically in these areas (OECD, 2010). In order to rectify the situation, the STEM (science, technology, engineering, and mathematics) Coalition was formed in order to increase awareness of these four areas in Congress (STEM Coalition, 2010).

Many researchers argue the fact that more academics should be integrated into vocational courses and vocational competencies into academic courses. This push toward integrating academic and vocational competencies is not a new one; this integration has been supported and promoted dating as far back as 1918 (Balschweid, 2001; Nolan, 1918; Warnick, Thompson, & Gummer, 2004; National Commission on Excellence in Education, 1983; National Academy of Science, Committee on Agricultural Education in the Secondary Schools, 1988; Secretary's Commission on Achieving Necessary Skills, 1991). The Perkins Act, upon being passed, encouraged collaboration between academic and vocational teachers, increased integration among disciplines, and increased the amount of real-life learning experiences offered to students (Lankard, 1992; Stephenson, Warnick, & Tarpley, 2007). Science has been incorporated into agricultural education curriculum since the Hatch Act of 1887 was passed; however it was not until 1988 that the National Research Council pressed researchers to detail methods to assist educators as they modernized the curriculum to make it more science-based (Budke, 1991; Christian & Key, 1994; Hillison, 1996; Thompson & Balschweid, 2000; True, 1929; Vaughn, 1993).

Integration of science into agriculture curricula has been shown to increase student achievement rates in both the science and agriculture content areas (Chiasson & Burnett, 2001; Enderlin & Osborne, 1992; Enderlin, Petrea & Osborne, 1993; Roegge & Russell, 1990; Warnick, Thompson, & Gummer 2004; Whent & Leising, 1988; Thompson & Balschweid, 2000). Veterinary technology is a high science and modern technology program which can help remove the perceived barrier that agriculture is only studying the production of crops and livestock. This perceived barrier can prevent minority students from enrolling in agriculture courses (Knight, 1987).

The employment field of veterinary technology is considered to be a very stable field during times of economic recession; layoffs are not likely to occur due to the continual need for animal health care (Bureau of Labor Statistics, 2010). In 2008, the field of veterinary technology was projected to increase by 36 percent, a much higher rate than the average of all other occupations according to the Bureau of Labor Statistics (2010). According to the BLS, in 2008 79,600 people were employed as veterinary technicians. The BLS projects that by 2018, 108,100 people will be employed as veterinary technicians. Across the country, in May 2008, veterinary technologists earned a "median annual wage of $28,900" (BLS, 2010). Some technicians made significantly more, upwards of $41,490, and some made significantly less, around $19,770 (BLS, 2010).

The purpose of this study was two-fold: (1) to determine the current state of the veterinary technology program being taught in high school agriculture departments across Texas and (2) to determine the needs of those agriculture programs not currently teaching the veterinary technology program in the state.

METHODS

The target population of the study was comprised of high school agriculture teachers in the state of Texas. Agriculture teachers who are currently not offering the veterinary technology program was compiled from a list of 1,646 current high school agriculture teachers provided by the Texas Education Agency (TEA). A list of 143 current high school agriculture teachers who teach a veterinary technology program was also obtained from TEA. A random selection of 105 teachers teaching the veterinary technology program and 105 teachers not teaching the veterinary technology program were chosen to participate in the study. Due to firewall restrictions placed on teacher emails across the state, 105 of each group of teachers were reachable via email to participate in the study. The instrumentation for this study consisted of two questionnaires: one for agriculture programs with the veterinary technology program and one for agriculture programs without the veterinary technology program. The instrument included open and closed-ended questions, multiple choice questions, Likert-scale questions, and fill in the blank questions. The researcher developed the questionnaires based on a small pilot-test of agriculture teachers not included in the population for this study.

The data collection procedure used in this study was completed by emailing the randomly selected teachers a cover letter and link to the appropriate online survey hosted by SurveyMonkey.com. One week following the initial email, a reminder email was sent to those teachers that had not responded. The teachers completed the online survey and their answers were compiled into a spreadsheet by SurveyMonkey.com. The data was then downloaded from SurveyMonkey.com and imported into PASW 17.0 for analysis.

RESULTS AND DISCUSSION

The study consisted of three groups: agriculture departments with the veterinary technology program, agriculture departments without the veterinary technology program, and the veterinary technology program as its own entity. Three groups were utilized in the data analysis process to determine what, if any, significant results could be gleaned from comparing the agriculture departments with the veterinary technology program, the agriculture departments without veterinary technology program, and the veterinary technology program as its own entity. Demographic information was obtained for all three groups. As seen in Table 1, agriculture departments with the veterinary technology program were mostly female (M = 50.3%), while agriculture departments without the veterinary technology program were mostly male (M = 59.0%). The veterinary technology program consisted mostly of females (M = 59.4%).

Table 1. Gender Distribution of High School Students Enrolled.

Gender	Ag. w/ Vet. Tech	Ag. w/o Vet. Tech	Vet. Tech Only
	M	*M*	*M*
Males	49.7	59	40.6
Females	50.3	41	59.4

* All numbers appear in percentages.

Table 2 describes the ethnic break-down of each group; agriculture departments with the veterinary technology program consisted mainly of Caucasian (*M* = 58.5%), Hispanic (*M* = 29.2%), and African American (*M* = 10.0%) students. Agriculture departments without the veterinary technology program consisted mostly of Caucasian (*M* = 66.5%), other minority (*M* = 27.0%), and African American (*M* = 5.32%) students. The veterinary technology program consisted of Caucasian (*M* = 66.6%), Hispanic (*M* = 23.9%), and African American (*M* = 8.07%) students.

Table 2. Ethnicity Distribution of High School Students Enrolled.

Ethnicity	Ag. w/ Vet. Tech	Ag. w/o Vet. Tech	Vet. Tech Only
	M	*M*	*M*
Caucasian	58.5	66.5	66.6
African American	10	5.32	8.07
Hispanic	29.2	0	23.9
Asian	1.4	0.4	1
Native American	0.7	0.33	0.1
Pacific Islander	0.03	0.45	0.03
Other	0.17	27	0.3

* All numbers appear in percentages.

Out of 38 agriculture teachers who are currently teaching the veterinary technology program, 30 of them responded to the survey concerning their perceptions of the importance of the inclusion of science and math competencies (Table 3). The questions were based on a five point Likert scale with 1 being “strongly disagree” and 5 being “strongly agree.” With regard to the science component, the teachers currently teaching veterinary technology mostly agreed (*M* = 3.93) that it was an important factor when deciding to implement the program. When asked about the importance of the math component in the decision to implement the program, teachers currently teaching the program mostly agreed (*M* = 3.60) that this was an important factor to consider when deciding to implement the program.

Table 3. Importance Level of Science and Math in the Decision to Implement the Veterinary Technology Program.

Science and Math Component	*n*	*M*	*SD*
The science component of the veterinary technology program was an important factor in the decision to implement the program.	30	3.93	0.83
The math component of the veterinary technology program was an important factor in the decision to implement the program.	30	3.6	0.81

* Scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral/No Opinion, 4 = Agree, 5 = Strongly Agree

Thirty-eight teachers were asked why the program was implemented into their program and 32 responded (Table 4). Teachers currently teaching the program responded that it was mostly due to faculty request (*M* = 50.0%), student request (*M* = 36.8), and career and technology education director request (*M* = 23.7%). According to these teachers, college requirements (*M* = 81.6%), superintendent requested (*M* = 78.9%), and principal requested (*M* = 73.7%) were least related to the implementation of the veterinary technology program.

Table 4. Implementation Reasons of the Veterinary Technology Program.

Reason for Implementation	Yes		No	
	n	%	*n*	%
Student Request	14	36.8	18	47.4
Parental Request	5	13.2	27	71.1
Faculty Request	19	50	13	34.2
Principal Request	4	10.5	28	73.7
Career and Technology Director Request	9	23.7	23	60.5
Superintendent Request	2	5.3	30	78.9
College Requirements	1	2.6	31	81.6
Other (please specify)	5	13	27	71.1

Thirty-eight teachers were asked about enrollment characteristics of the veterinary technology program and 32 responded (Table 5). The teachers currently teaching the program tended to agree (*M* = 4.03) that their program had continued to grow since its implementation. These teachers were mostly in agreement (*M* = 3.63) that the veterinary technology program was implemented to increase enrollment of non-traditional students into the agriculture department. Finally, agriculture teachers currently teaching the program were in agreement (*M* = 3.97) that the veterinary technology program has increased the enrollment numbers for the agriculture department as a whole.

Table 5. Agriculture Teacher Perceptions of Recruitment and Enrollment Trends of the Veterinary Technology Program.

Recruitment Information	*n*	*M*	*SD*
Since its implementation, our veterinary technology program has continued to grow.	30	4.03	0.89
Our school implemented the veterinary technology course to recruit non-traditional students into the agriculture department.	30	3.63	1.06
The veterinary technology program increased enrollment in the agriculture department.	30	3.97	0.85

* Scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral/No Opinion, 4 = Agree, 5 = Strongly Agree

Thirty-eight teachers currently teaching veterinary technology were then asked a series of questions regarding how the program was implemented and information concerning the curriculum that is being used and 30 responded (Table 6). These teachers responded that they were neutral/no opinion (*M* = 3.03) when asked about their partnership with the science department at their school. Similar results (*M* = 2.90) were obtained when these teachers were asked about their partnership with the math department at their school. The curriculum information gained in the study showed that teachers currently teaching a veterinary technology program were neutral/no opinion (*M* = 3.27) regarding the availability of curriculum for the course. These teachers also tended to agree (*M* = 3.87) that the curriculum being used in the course was developed by the agriculture teacher in charge of the veterinary technology program. When asked about the facilities and materials used in the veterinary technology program, these teachers were neutral/no opinion for both areas (*M* = 3.17 and *M* = 3.23 respectively).

Table 6. Veterinary Technology Program Implementation and Curriculum Factors.

Implementation and Curriculum Factors	*n*	*M*	*SD*
The agriculture department has a strong partnership with the science department. (team teaching)	30	3.03	1.07
The agriculture department has a strong partnership with the math department. (team teaching)	30	2.9	0.99
The curriculum used in the veterinary technology program was readily available.	30	3.27	1.26
The curriculum used in the veterinary technology program was developed by the agriculture teacher in charge of the program.	30	3.87	1.01
The facilities available are adequate to teach the veterinary technology program.	30	3.17	1.51
The materials available are adequate to teach the veterinary technology program.	30	3.23	1.38

* Scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral/No Opinion, 4 = Agree, 5 = Strongly Agree

Table 7 summarizes the training received by the agriculture teacher in charge of the veterinary technology program in preparation to teach the program, as well as, the certification and continued training of the students enrolled in the program. Thirty-eight teachers were surveyed and 30 responded. The teachers were neutral/no opinion (*M* = 3.17) when asked if their program was certifying students as Certified Veterinary Assistants. On all three questions regarding the continued education of the students in the field of veterinary technology (employment, associates degree, and enrollment in veterinary school) the teachers were neutral/no opinion (*M* = 3.07; *M* = 2.93; *M* = 2.70). With regard to the training received by the teacher in preparation to teach the program (received training; training was helpful; training was easily found), the teachers were neutral/no opinion (*M* = 3.50; *M* = 3.43; *M* = 3.13) on all questions.

Table 7. Veterinary Technology Certification of Students and Training of Agriculture Teachers.

Certification and Training	*n*	*M*	*SD*
The veterinary technology program is certifying students as Certified Veterinary Assistants with the Texas Veterinary Medical Association.	30	3.17	1.26
The majority of students enrolled in the veterinary technology program go on to be employed by a veterinarian.	30	3.07	0.94
The majority of students enrolled in the veterinary technology program go on to enroll in/complete an associate's degree in veterinary technology.	30	2.93	0.94
The majority of students enrolled in the veterinary technology program go on to enroll in/complete veterinary school.	30	2.7	0.84
The agriculture teacher received training specifically for the veterinary technology program.	30	3.5	1.4
The agriculture teacher found the training for veterinary technology helpful.	30	3.43	1.04
Teacher training for the veterinary technology program was easily found and enrollment was simple.	30	3.13	1.33

* Scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral/No Opinion, 4 = Agree, 5 = Strongly Agree

Agriculture teachers who are not currently teaching the veterinary technology program were asked a series of questions about their perspective on the potential impact of the program (Table 8). When asked if the teacher thought adding the veterinary technology program would increase enrollment numbers of the agriculture department and non-traditional students, they were neutral/no opinion (*M* = 3.32; *M* = 3.35). Teachers agreed (*M* = 3.82; *M* = 3.76) that the math and science component of veterinary technology is an important factor in the decision to implement the program.

Teachers not currently teaching a veterinary technology program were also asked a series of questions to establish their school's need for such a program (Table 9). Most teachers not teaching the program agreed (*M* = 3.79) that their school was aware that the veterinary technology program existed. These teachers were neutral/no opinion regarding if their school has considered implementing this program or would be considered for future implementation (*M* = 3.03; *M* = 3.09). Teachers disagreed (*M* = 2.24) when asked if their school has offered the program previously. Teachers not teaching the program were neutral/no opinion when asked if more student interest or additional faculty would be necessary to implement the veterinary technology program (*M* = 3.35; *M* = 3.29). They agreed when asked if more funding or more facilities would be necessary to implement the program (*M* = 4.00; *M* = 3.91).

Table 8. Perspectives on the Impact of Implementing the Veterinary Technology Program.

Perspective	*n*	*M*	*SD*
The veterinary technology program would likely increase enrollment numbers of the agriculture department.	34	3.32	1.01
The veterinary technology program would likely increase enrollment numbers of non-traditional students in the agriculture departments.	34	3.35	1.01
The science component of the veterinary technology program would be an important factor to consider when implementing this program.	34	3.82	0.8
The math component of the veterinary technology program would be an important factor to consider when implementing this program.	34	3.76	0.78

* Scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral/No Opinion, 4 = Agree, 5 = Strongly Agree

Table 9. Agriculture Departments Without Veterinary Technology Needs Assessment.

Need	*n*	*M*	*SD*
Our school is aware of the veterinary technology program	34	3.79	0.95
Our school has considered implementing the veterinary technology program.	34	3.03	1.11
Our school has offered the veterinary technology program previously.	34	2.24	1.23
The veterinary technology program would be considered for future implementation.	34	3.09	0.99
Additional student interest would be needed to implement this program.	34	3.35	1.04
Additional funding would be needed to implement this program.	34	4	1.13
Additional faculty would be needed to implement this program.	34	3.29	1.29
Additional facilities would be needed to implement this program.	34	3.91	1.14

* Scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral/No Opinion, 4 = Agree, 5 = Strongly Agree

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was two-fold: (1) to determine the current state of the veterinary technology program being taught in high school agriculture departments across Texas and (2) to determine the needs of those agriculture programs not currently teaching the veterinary technology program in the state. The results of this study may be used to assist administrators, career and technology directors, and agriculture teachers in making a decision on whether or not to implement the veterinary technology program into their high school's agriculture department. The veterinary technology program has many positive attributes that should be considered when making such a decision.

This study found that the veterinary technology program is assisting in recruiting females and minorities into the agriculture department. The veterinary technology program is a more science-based program that allows females and minorities the opportunity to experience agriculture without having to study production agriculture, which, as found by Knight (1987), is one barrier to agriculture perceived by minority students. By adding the veterinary technology program to an existing agriculture department, one would be exposing a wider variety of students to the world of agriculture. In doing so, the FFA and agriculture departments alike would experience a growth in enrollment numbers. The agriculture teachers currently teaching the veterinary technology program agreed that implementing this program increased enrollment in the agriculture department (M = 3.97). Since both the FFA and agriculture departments are dependent on enrollment numbers for funding, the veterinary technology program would be a huge asset to these programs.

STEM content will play a role in many future course implementation decisions, regardless of department area, due to the emphasis being placed on such course information in Congress (STEM Coalition, 2010). The agriculture teachers currently teaching the veterinary technology program agreed that the science and math components of the veterinary technology program were important factors to consider when deciding to implement the program (M = 3.93; M = 3.60). Agriculture teachers not currently teaching the veterinary technology program agreed that the science and math components of the veterinary technology program would be important factors to consider when deciding to implement this program (M = 3.82; M = 3.76). Thus, conclusions can be drawn that curriculum which includes STEM content will be a determining factor for many schools in the decision to implement such a program.

Along with the emphasis on improving STEM proficiencies, the TAKS, **Texas Assessment of Knowledge and Skills,** tests have become the norms in high schools across TX to increase the accountability of individual schools and teachers. Thompson and Balshweid (2000) along with Roegge and Russell (1990) suggest that students will perform better academically when they are taught integrated science and agriculture course material. Increasing the students' performance in science will not only help the student succeed in their courses, but has the possibility to increase the students' performance on TAKS tests or other standardized tests. From the results of this study it is apparent that most agriculture teachers currently teaching the veterinary technology program do not have a strong partnership with either the science or math departments (M = 3.03; M = 2.90). In order for agriculture teachers to provide integrated courses with a rich STEM content, partnering between the agriculture department and the science and math departments is highly recommended by the researcher.

Teacher effects are the main influence on students' academic achievement rates (Wright, Horn, & Sanders, 1997). According to Wright et al,. (1997), the teacher's effect on student achievement rates was higher than any of the other factors studied in twenty out of thirty analyses. As the results of this study show, many of the agriculture teachers currently teaching the veterinary technology program agreed that they are the one responsible for developing the curriculum used in the course (M = 3.87). This is cause for concern with regard to the consistency with which the program is being taught. With multiple versions of the course being taught, each developed by the individual teacher in charge of the program, how can the teachers, students, parents, administration, or the state be certain that the students in these programs are learning the required material in a consistent manner across all programs? It is the recommendation of the researcher that a consistent framework for the curriculum be developed and implemented in this program to provide a more consistent delivery to the students enrolled in the program across TX.
One possible solution to the issue of inconsistent curriculum would be to require all agriculture teachers teaching the veterinary technology program to attend mandatory curriculum training for the course. At present, agriculture teachers currently teaching the veterinary technology program agreed (M = 3.50) that they received training specifically for the veterinary technology program. By requiring teachers to attend training for the veterinary technology program, a consistent framework for teaching the program could be distributed as well as guidelines for helping students to become certified as veterinary assistants.

A major goal of the veterinary technology program is to train and certify the students as Certified Veterinary Assistants. As evident from the results of this study, when asked if their program was certifying students, agriculture teachers were neutral/no opinion (M = 3.17). Agriculture teachers also responded similarly when asked if their veterinary technology students were continuing veterinary studies at institutions of higher education to gain an associates degree in veterinary science or enroll in veterinary school (*M* = 2.93; *M* = 2.70). It is recommended by the researcher that agriculture teachers concentrate on assisting their students in becoming Certified Veterinary Assistants. Increasing the rate of certification of the students enrolled will help to fulfill the goals of the program and provide those students with sufficient training to obtain stable employment regardless of their ambitions towards higher education. Increasing the rate of certification may also increase student matriculation into veterinary studies at institutions of higher education, whether it be an associates degree or veterinary school.

This study shows that the agriculture teachers teaching veterinary technology programs in high school agriculture departments agree that their programs have continued to grow since their implementation (*M* = 4.03). This could be due to demand/interest of the student population. As the economy has continued to make funding decision more difficult for school administrators, economically it makes sense to continue to fund a growing program. For agriculture teachers not currently teaching the veterinary technology program, teachers agreed that increased funding and more facilities were a definite need in order to implement this program (*M* = 4.00; *M* = 3.91). However, as seen through the results of this study, the benefits of implementing this program absolutely outweigh the increased funding and facilities requirements. This study shows that the veterinary technology program can increase the enrollment numbers of nontraditional students in the agriculture department, increase the enrollment number of minorities in the agriculture department, and can be integrated with science and math to meet STEM requirements. This program can also be given as science credit to be used towards student graduation requirements.

This study was directed toward Texas agriculture departments, thus generalizations should not be made beyond this population; however it does raise the question of similar issues existing in other states offering the veterinary technology program. Implementing science-based, technologically current programs into agriculture departments is needed to keep agriculture departments' enrollment numbers at sufficient levels. The study examined only a portion of the possible population; it may be beneficial to expand the survey population to all agriculture departments in Texas currently teaching the veterinary technology program to determine the extent to which the programs vary.

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Vitamin D_3 Supplementation to Goats Does Not Improve Loin Chop Tenderness and Color Stability

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ABSTRACT

This study evaluated the effect of vitamin D_3 (VITD) supplementation on the tenderness and retail color stability of loin chops from older goats. Twenty purebred Boer goats, approximately 90 days of age, were fed a 10% crude protein concentrate and hay ad libitum for 365 days. During the final 7 days of feeding, goats were supplemented with two levels of VITD (0 and 750,000 IU/hd/d vitamin D_3). Following harvesting and a 10 day aging period, loin chops were evaluated for tenderness by Warner-Bratzler shear force (WBS) and sensory panel. Loin chops were also evaluated for retail color stability for 5 days by a Minolta CR-410 colorimeter and a visual sensory panel. Loin chops from VITD supplemented goats yielded higher ($P < 0.05$) WBS values compared to loin chops from controls. Sensory panel tenderness scores for VITD chops were lower ($P < 0.05$) than for the control chops, indicating decreased tenderness due to supplementation. Treatment did not affect ($P > 0.05$) Minolta CR-410 a* values. Minolta CR-410 b* values and L* values were higher ($P < 0.05$) for VITD chops throughout the 5-day retail display period. Visual panel scores for surface discoloration and overall appearance indicated VITD chops showed more ($P < 0.05$) surface discoloration and were less ($P < 0.05$) preferred by day 2 of display. Supplementing VITD to goats before harvesting negatively affected both tenderness and shelf-life.

KEY WORDS: goat, vitamin d_3, tenderness, shelf-life

INTRODUCTION

Consumption of goat meat, one of the most consumed meats in the world, continues to increase in the United States (Chenault, 1996). In 1977, the USDA began maintaining statistics on number of goats slaughtered annually, finding 35,000 goats harvested that year. By 1994, the industry harvested 350,000 goats (Gipson, 2004). In 2006, the USDA reported that slaughter plants harvested approximately 572,000 goats, and the numbers continue to increase. Sherman (2007) reported that goat meat production increased dramatically from 1.29 million metric tons in 1970 to 3.76 million metric tons in 2001. The growing population of immigrants and ethnic groups entering and living in the United States, whose dietary preferences favor the consumption of goat meat, contributes to the increase in demand (Gipson, 2004). Goat meat also provides favorable nutritional quality, which also increases demand (Webb et al., 2005).

Compared to lamb/mutton of similar age groups, consumers accept goat meat in a similar fashion. However, goat meat does not acquire high degrees of tenderness postmortem (Schonfeldt et al., 1993). Compared to beef and lamb/mutton, tenderness values are lower (Pike et al., 1973). Several factors contribute to less tenderness associated with goat meat. Lack of fat cover predisposes goat carcasses to cold shortening when chilled too quickly (Webb et al., 2005). Some breeds, such as Boer goats, contain higher collagen content, increased fibrous residues (Schonfeldt et al., 1993), and a coarser texture, which also contribute to decreases in tenderness (Gaili and Aili, 1985).

Several studies with beef cattle reported that supplementing vitamin D_3 (VITD) several days before slaughter increased tenderness (Swanek et al., 1997; Montgomery et al., 2000). According to Karges et al. (1999), VITD improves tenderness in various muscles, especially in breeds of cattle that produce less tender meat. The calcium-activated tenderization process (CAT) by the two calpain proteases, μ-calpain and m-calpain, contribute to increased tenderness (Swanek et al., 1999). The objective of this study was to determine if VITD supplemented prior to harvest improves goat longissimus dorsi chop tenderness without adversely affecting retail shelf-life.

MATERIALS AND METHODS

Animal Management. The Sul Ross State University Institutional Animal Care and Use Committee approved the protocol for this study. Twenty purebred Boer goats (7 wether males and 13 females) were separated into two dietary treatment groups (n = 10/group). Treatments consisted of 0 (CON) and 750,000 IU/hd/d of Vitamin D_3 (VITD) for 7 days prior to harvesting. The level of VITD was chosen based on the results of Wiegand et al. (2001). We chose a level lower than these published results to prevent the possibility of VITD toxicity in the goats. Ten goats were born at the Sul Ross State University Animal Science Complex, and weaned at 3 months of age. The other ten goats were purchased from a purebred Boer goat producer (Woodward Trading Company, Bakersfield, TX) at approximately 3 months of age. Goats from each source were evenly stratified between treatment groups. To prevent mixing of treatment groups, each goat recieved a colored ear tag corresponding to the appropriate treatment group (Allflex USA Inc., Dallas, TX).

Both treatment groups were housed at the Sul Ross State University feed lot in pens containing dirt flooring, a shelter area, and a source of drinking water. During the pre-harvest period, goats in each study pen were fed alfalfa hay twice a day, and a 10% crude protein concentrate (Baeza Feeds, Marfa, TX) fed *ad libitum*. To ensure each group received the proper dosage of VITD, the vitamin was given via two 1 g boluses containing one-half gram of Rovamix D_3 500 (DSM Nutritional Products Inc., Fort Worth, TX) and one- half gram of ground corn.

Harvesting and Sample Collection. After the feeding and supplementation period, the goats were weighed and transported to a commercial slaughter facility, and harvested in accordance with the Humane Methods of Slaughter Act of 1978 (Clark's & Winford's Fine Quality Meat Company, Midland, TX). The age of these animals were approximately 455 days of age. Following an initial chill period at 35°F for 24 hours, carcasses were fabricated Hotel Style, based on Institutional Meat Purchase Specifications for fresh goat. The right loin was removed from each carcass, vacuum packaged, aged for 10 days, and frozen for use in the Warner-Bratzler shear force (WBS) evaluation and the trained sensory panel analysis. The left loin from each carcass also was vacuum packaged, aged and frozen for use in the instrumental color and visual panel analysis.

Shear Force Evaluation. Loins were thawed at 39°F for 24 hours. The longissimus dorsi from each loin was removed and cut into 1 inch chops. Chops were weighed to obtain a pre-cooked weight. A meat thermometer (Koch, Kansas City, MO) was placed in the geometric center of each chop to record internal temperatures during cooking. Using a Blodgett convection oven (The G. S. Blodgett Co., Burlington, VT) set at 325°F, chops were cooked to an internal temperature of 160°F, then allowed to cool to room temperature (AMSA, 1995). Post-cooked weight was recorded for each chop. Three half-inch cores from each chop were removed parallel to the muscle fiber orientation, and sheared perpendicular to the orientation of the muscle fiber using a Warner-Bratzler shear machine (The G-R Electric Mfg. Co., Manhattan, KS). The three shear force values for each chop were averaged to obtain a mean chop value for statistical analysis.

Sensory Panel. Chops used for the sensory panel evaluation were thawed and cooked according to the same procedures as WBS chops. After cooking, the longissimus dorsi of each chop was cut into 1cm x 1cm x 1cm cubes, kept warm in a water bath, and fed to a panel of thirty individuals. Sensory panelists included Sul Ross State University students and staff with little to no experience consuming goat meat. In two independent training sessions panelists were trained to evaluate samples for juiciness, tenderness, connective tissue amount, and goat flavor intensity. Panel members independently evaluated four randomly assigned cubes for juiciness (8 = extremely juicy; 1 = extremely dry), tenderness (8 = extremely tender; 1 = extremely tough), amount of connective tissue (8 = none; 1 = abundant), and goat flavor intensity (8 = extremely intense; 1 = extremely bland). Panelists cleansed their palettes with crackers and water between consuming each cube.

Instrumental Color Analysis. Loins used for instrumental color analysis were thawed for 24 hours and then boned to obtain the longissimus dorsi. Chops measuring 1 inch in thickness from the longissimus dorsi were placed on white Styrofoam trays (Instawares Inc., Kennesaw, GA), and over-wrapped with polyvinyl chloride film (oxygen transmission rate of 6,500 cc/m^2 for 24 hours at 0% relative humidity; Glad Products Company, Oakland, CA). To simulate actual retail conditions, packaged products were displayed in a retail coffin-case at 35ºF (Tyler Refrigeration, Niles, MI) and illuminated by fluorescent lamps emitting 4,100K (General Electric Company, Cleveland, OH). To avoid variability in light exposure, packages were rotated randomly in the display case daily. Using a Minolta CR-410 colorimeter (Minolta USA, Ramsey, NJ), objective color measurements were taken for L* (lightness), b* (yellowness), and a* (redness) once daily (at 4 p.m.) for a five days.

Consumer Visual Panel. During the five-day display period, panelists (n = 30; separate from sensory panelists) visually evaluated each chop for characterization of oxygenated pigment lean color (8 = extremely bright red; 1 = extremely dark red), fat color (5 = yellow; 1 = white), surface discoloration (7 = total discoloration [100%]; 1 = no discoloration [0%]), and color of the chop (7 = like very much; 1 = dislike very much). No scale exists to evaluate goat lean color, therefore scales for evaluating lamb and beef were used in this process (AMSA, 1991).

Statistical Analysis. This study was designed as a 2 x 2 randomized complete block design, with individual carcasses as the experimental unit. Warner-Bratzler shear force and Minolta colorimeter data were analyzed using the PROC MIXED procedure of SAS (SAS Inst. Inc., Cary, NC, 2002). Fixed factors included sex, treatment, and their interaction. In addition, display day and the appropriate interactions were also fixed factors in analyzing Minolta color data. Random factors included animal within treatment and goat birth place. Pair-wise comparisons between least square means of factor levels were computed using the PDIFF option of the LSMEANS statement. For ordinal scale data from the trained sensory panel and trained visual panel, the Wilcoxon rank-sum test for discrete data was used to detect differences between panel treatment preferences for tenderness and color stability.

RESULTS

Data from antemortem weight and WBS values indicated that treatment produced a significant (*P* < 0.05) effect (Table 1). Sex and the sex/treatment interaction did not (*P* > 0.05) produce a significant effect in antemortem weight and WBS values. Least square mean antemortem weight of VITD treated goats was significantly larger (*P* = 0.04) than the least square mean antemortem weight of CON goats. Data from postmortem weight showed that treatment tended (*P* < 0.10) to yield an effect, while sex and the sex/treatment interaction did not (*P* > 0.05) yield an effect. Goats from the VITD treatment tended (*P* = 0.08) to have heavier average postmortem weights when compared to CON treatment goats. Least square means for the two treatments showed VITD chops as significantly tougher (*P* = 0.02) than CON chops.

Juciness, tenderness, and connective tissue scores were significantly (*P* < 0.05) affected by VITD treatment, whereas sex and the sex/treatment interaction did not (*P* > 0.05) produce a significant effect (Table 1). Neither sex, treatment, nor their interaction affected flavor intensity (*P* > 0.05). Sensory panel scores demonstrated that panelists rated chops from CON goats as significantly (*P* < 0.05) more tender and juicy, and containing less connective tissue, than VITD chops. Panelists detected no difference (*P* = 0.36) in goat flavor intensity between the two treatments.

Minolta CR-410 colorimeter L*, a*, and b* scores were recorded over a 5-day display period (Table 2). Day of display significantly affected (*P* < 0.0001) Minolta a* values, while treatment or the display day/treatment interaction did not significantly affect (*P* > 0.05) a* values. Minolta a* values for both treatments declined (P < 0.05) as display day increased, indicating that chops became less red, but these values did not differ from one another on each day of display. Minolta b* values demonstrated a significant (*P* = 0.01) display day/treatment interaction.

Table 1. Mean Warner-Bratzler shear force and sensory panel scores of loin chops from goats fed a control or vitamin D_3 supplemented diet for 7 days prior to harvesting.

	Control[a]	Vitamin D_3[b]	SEM	*P* > *F*
Antemortem Weight, lb	107.6	126.7	8.5	0.04
Postmortem Weight, lb	54.9	64.1	4.5	0.08
Cook loss, %	19.7	25.6	1.9	0.11
Warner-Bratzler Shear Force, lb	9.8	11.8	0.6	0.02
Juiciness[c]	5.10	4.43	0.14	0.03
Tenderness[d]	5.70	4.50	0.18	<0.01
Connective Tissue[e]	5.80	5.13	0.20	0.05
Flavor Intensity[f]	4.20	4.33	0.10	0.36

[a] Three females and 7 males fed 10% CP concentrate and hay ad libitum
[b] Four females and 6 males fed 10% CP concentrate and hay ad libitum and supplemented 750,000 IU/d vitamin D_3
[c] 8=Extremely Juicy; 7=Very Juicy; 6=Moderately Juicy; 5=Slightly Juicy; 4=Slightly Dry; 3=Moderately Dry; 2=Very Dry; 1=Extremely Dry
[d] 8=Extremely Tender; 7=Very Tender; 6=Moderately Tender; 5=Slightly Tender; 4=Slightly Tough; 3=Moderately Tough; 2=Very Tough; 1=Extremely Tough
[e] 8=None; 7=Practically None; 6=Traces; 5=Slight; 4=Moderate; 3=Slightly Abundant; 2=Moderately Abundant; 1=Abundant
[f] 8=Extremely Intense; 7=Very Intense; 6=Moderately Intense; 5=Slightly Intense; 4=Slightly Bland; 3=Moderately Bland; 2=Very Bland; 1=Extremely Bland

Throughout the display period, VITD chops recorded greater least square mean b* values than did CON chops. Minolta L* values were significantly affected (*P* = 0.01) by treatment, tended to be affected (*P* = 0.06) by display day, and were not affected (*P* > 0.05) by the display day/treatment interaction. Throughout the display period, VITD chops L* values were greater than for CON chops, indicating VITD chops were lighter. While not significant, the L* values for both CON and VITD chops decreased on day two but increased each day afterward.

A panel visually evaluated lean color, fat color, surface discoloration, and overall color of chops each day during the display period. Lean color visual panel scores (Table 3) for VITD and CON chops declined from slightly bright red scores to moderately dark red scores over the 5-day display period. Mean lean color scores for VITD and CON chops did not differ (*P* > 0.05) on each day of the display period. Least squares means fat color scores (Table 3) for both treatment groups were white on day one, then changed to creamy white by day five. On each day of the display period, fat color scores for VITD and CON chops were similar (*P* > 0.05).

Surface discoloration scores (Table 4) for the two treatment groups did not differ (*P* > 0.05) on day one. Beginning on day two, panelists assigned higher (*P* < 0.05) discoloration scores to VITD chops. On day five, VITD chops received greater discoloration scores, and CON chops received slight discoloration scores. Overall preference scores (Table 4) did not differ (*P* > 0.05) between VITD and CON chops on days one or two, but thereafter consumers scored (*P* < 0.05) CON chops higher than VITD chops.

Table 2. Mean Minolta CR-410 a*, b*, and L* values from goats fed a control[1] or vitamin D_3[2] supplemented diet for 7 days prior to harvesting

Day	1	2	3	4	5
a*[3]					
Control	15.13[a]	14.49[b]	13.98[c]	13.44[d]	13.18[e]
Vitamin D	16.10[a]	15.21[b]	14.74[c]	14.17[d]	13.73[e]
SEM	0.47	0.40	0.41	0.40	0.40
Trt×Day *P* > *F*	0.13	0.29	0.19	0.29	0.19
b*[4]					
Control	5.49[a]	5.46[a]	5.46[a]	5.36[a,b]	5.21[a]
Vitamin D	6.81[a]	6.49[b]	6.42[b]	6.26[b,c]	6.15[c]
SEM	0.25	0.23	0.23	0.24	0.23
Trt×Day *P* > *F*	<0.01	0.01	0.01	0.02	0.01
L*[5]					
Control	42.95[a]	42.73[a]	42.82[a]	42.98[a]	42.92[a]
Vitamin D	45.43[a]	45.41[a]	45.53[a]	45.74[a]	45.92[a]
SEM	0.73	0.77	0.78	0.72	0.78
Trt×Day *P* > *F*	0.03	0.03	0.02	0.01	0.02

[a-e]Means within a row with a different superscript are significantly different (P < 0.05)
[1]Three females and 7 males fed 10% CP concentrate and hay ad libitum
[2] Four females and 6 males fed 10% CP concentrate and hay ad libitum and supplemented 750,000 IU/d vitamin D_3
[3]Redness: 60 = Red; -60 = Green
[4] Blueness: 60 = Yellow; -60 = Blue
[5]Lightness: 100 = White; 0 = Black

Table 3. Consumer panel mean scores of lean and fat color from goats fed a control or vitamin D_3 supplemented diet for 7 days prior to harvesting

	Time	Control[1]	Vitamin D_3[2]	*P > F*
Lean Color[3]				
	Day 1	5.34[a]	5.49[a]	0.39
	Day 2	4.97[b]	4.79[b]	0.23
	Day 3	4.44[c]	4.35[c]	0.35
	Day 4	3.81[d]	3.74[d]	0.32
	Day 5	3.77[d]	3.81[d]	0.39
Fat Color[4]				
	Day 1	1.24[a]	1.36[a]	0.40
	Day 2	1.60[b]	1.61[b]	0.22
	Day 3	1.79[c]	1.90[c]	0.15
	Day 4	2.03[d]	2.10[d]	0.21
	Day 5	2.17[e]	2.23[e]	0.38

[a-e] Means within an attribute and treatment with different superscripts significantly different (P < 0.05)
[1]Three females and 7 males fed 10% CP concentrate and hay ad libitum
[2] Four females and 6 males fed 10% CP concentrate and hay ad libitum and supplemented 750,000 IU/d vitamin D_3
[3]8=Extremely Bright Red; 7=Bright Red; 6=Moderately Bright Red; 5=Slightly Bright Red; 4=Slightly Dark Red; 3=Moderately Dark Red; 2=Dark Red; 1=Extremely Dark Red
[4] 5=Yellow; 4=Moderately Yellow; 3=Slightly Yellow; 2=Creamy White; 1=White

Table 4. Consumer panel mean scores of surface discoloration and overall color from goats fed a control or vitamin D_3 supplemented diet for 7 days prior to harvesting

	Time	Control[1]	Vitamin D_3[2]	*P > F*
Surface Discoloration[3]				
	Day 1	1.27[a]	1.28[a]	0.28
	Day 2	1.50[b]	1.68[b]	0.03
	Day 3	1.69[c]	2.07[c]	0.01
	Day 4	1.99[d]	2.66[d]	< 0.01
	Day 5	2.36[e]	3.19[e]	< 0.01
Overall Color[4]				
	Day 1	5.96[a]	5.88[a]	0.36
	Day 2	5.40[b]	5.20[b]	0.15
	Day 3	5.40[b]	4.81[c]	< 0.01
	Day 4	5.00[c]	4.24[d]	< 0.01
	Day 5	4.57[d]	3.69[e]	< 0.01

[a-e] Means within an attribute and treatment with different superscripts significantly different (P < 0.05)
[1] Three females and 7 males fed 10% CP concentrate and hay ad libitum
[2] Four females and 6 males fed 10% CP concentrate and hay ad libitum and supplemented 750,000 IU/d vitamin D_3
[3]7=Total Discoloration (100%); 6=Extensive Discoloration (80-99%); 5=Moderate Discoloration (60-79%); 4=Modest Discoloration (40-59%); 3=Small Discoloration (20-39%); 2=Slight Discoloration (1-19%); 1=No Discoloration (0%)
[4] 7=Like Very Much; 6=Like Moderately; 5=Like Slightly; 4=Neither Like Nor Dislike; 3=Dislike Slightly; 2=Dislike Moderately; 1=Dislike Very Much

DISCUSSION

While numerous studies documented effects of VITD supplementation on beef, the authors could not find studies in the published literature involving VITD supplementation with goats to improve tenderness. Koohmaraie (1992) proposed three possible calcium-mediated mechanisms by which pre-harvest supplementation of VITD increases postmortem tenderization: non-enzymatic weakening of structural proteins involved in stability of the Z-disk, protein solubilization due to salting-in action by calcium, and activation of calcium activated calpain proteases. Supplementing VITD in the diet prior to harvesting raises the calcium level in the intestine, circulating plasma, and ultimately the muscle. Elevated levels of calcium in the muscle subsequently activate postmortem tenderization by the calpain proteases. Several studies report an increase in plasma calcium concentration by supplementing VITD (Karges et al., 1999; Montgomery et al., 2002), and followed by a subsequent increase in calpain activity (Montgomery et al., 2002).

Swanek et al. (1997) found a 21 percent reduction in occurrence of tough steaks and a reduction in shear force values by 18 percent with VITD supplementation. In a separate study, Swanek et al. (1999) reported that VITD reduced shear values by .58 kg. Montgomery et al. (2000) determined that supplementing 5×10^6 IU/d of VITD for 10 days prior to slaughter, followed by 14 days of postmortem aging, effectively reduced WBS values of steaks from the strip loin and top round. Montgomery et al. (2002) reported similar findings when supplementing 0.5×10^6 IU/d for 10 days prior to harvesting.

Data from the present study does not agree with the aforementioned studies. However, conflicting findings from several studies found VITD as being detrimental to tenderness or having no effect on tenderness in beef. Berry et al. (2000) found VITD steaks were less tender than non-supplemented steaks when aged 7 or 21 days. Scanga et al. (2001) reported that feeding VITD 2 to 8 days before harvesting did not improve longissimus steak tenderness. Wiegand et al. (2002) concluded that supplementation of swine with VITD for 3 days prior to harvest did not improve loin chop tenderness. The researchers suggested that tenderization did not improve because the extent of supplementation was insufficient to raise intracellular calcium concentrations to activate postmortem proteolysis. In the present study, VITD levels may have not raised calcium levels in the muscle enough to activate postmortem calpain proteolysis in all goats. Therefore, the specific level of VITD supplementation required to activate postmortem proteolysis in goats requires further investigation.

Calpastatin, an inhibitor of the calpain proteolytic system, also could have affected degree of tenderness in the present study. Doumit and Koohmaraie (1999) found a negative correlation between level of calpastatin activity and tenderness. Species differences in rate of postmortem proteolysis result from the level of calpastatin activity (Ouali and Talmant, 1990; Koohmaraie et al., 1991). Pringle et al. (1997) demonstrated that Bos Indicus cattle exhibit a low level of postmortem tenderization because calpastatin activity blocks tenderization. Therefore, as with the Bos Indicus cattle, high calpastatin activity in Boer goats may decrease tenderness by blocking μ-calpain activity.

Increased levels of calcium ions activate the calpain proteolytic system postmortem. Calcium levels, influenced by calcitonin, may affect the system, thereby limiting positive effects of VITD supplementation. Boleman et al. (2004) concluded that VITD supplemented by Rovamix 500 did not improve the tenderness of various lamb muscles. They suggested that hormones such as calcitonin can limit deposition of calcium in muscles, thus limiting the amount of calcium available to activate the calpains. The role of calcitonin in this process requires further examination.

Analysis of sensory panel data in the present study may indicate why VITD chops proved less tender than CON chops. Panelists rated chops from VITD goats as less juicy, which may have affected perceived tenderness. Lower juiciness scores may indicate that VITD chops experienced greater cooking loss. In the present study, VITD goats tended (P = 0.11) to show more cooking loss than CON goats (Table 1). Wheeler et al. (1999) reported that steaks a with higher cook loss percentage produced steaks with higher WBS values. Rhee et al. (2004) reported similar findings from evaluating tenderness differences among muscles. When consumers evaluate meat subjectively, Aberle et al. (2001) identified the components of juiciness contribute to an improvement in ratings of apparent tenderness. Laakkonen et al. (1970); as well as Obuz et al. (2003); all reported that greater cooking losses resulted in a tighter meat structure, which could produce less tender meat.

In addition to assigning low juciness ratings, panelists in the present study indicated VITD chops contained more connective tissue, which contributed to lower tenderness scores. However, Montgomery et al. (2004) found VITD had no effect on perceived amount of connective tissue when evaluated by a sensory panel. Differences in ratings of perceived tenderness can be explained by amount of connective tissue in combination with sarcomere length and postmortem proteolysis (Koohmaraie et al, 2002). Rhee et al. (2004) supported this premise by demonstrating a correlation between lower tenderness ratings by trained panelists and higher WBS values in muscles with more connective tissue. While the treatment most likely did not have an affect of connective tissue deposition or cross-linking, the greater amount of connective tissue detected by the panelists may be the source of lower tenderness scores for the VITD chops. Therefore, lack of moisture and the increased levels of connective tissue detected by panelists for VITD chops, explain the lower tenderness ratings and increased WBS scores.

During the 5-day retail display period in the present study, VITD did not affect Minolta color a* values, indicating a similarity in redness of chops between the two treatments. The b* and L* values of VITD chops were greater than values for the CON chops during the entire retail display period, confirming the VITD chops was lighter and more blue in appearance. The visual panel determined that VITD and CON chops did not differ in lean appearance or fat discoloration. Beginning on day two of the display period, VITD chops showed a higher discoloration score, prompting a panelist preference for CON chops over VITD chops for the remainder of the study.

Only a few studies have observed the effect of VITD on meat color stability. Two swine studies determined that VITD improved loin eye color. The first study reported that VITD supplementation lightened chops based on both subjective and objective measures (Enright et al., 1998). The second study found that VITD supplementation produced chops with lower L* values (darker) and higher a*values (redder) when aged 14 days (Wiegand et al., 2002).

As meat ages, oxymyoglobin becomes oxidized, forming metmyoglobin. Lipid oxidation occurs in the intramuscular fat, membrane phospholipids, and intermuscular fat (Sherbeck et al., 1995). Increased levels of metmyoglobin in meat correlates with the amount of discoloration observed. Depending on the amount of discoloration present, the overall color of a product primarily influences meat purchasing decisions (Faustman and Cassens, 1990). Kannan et al. (2001) reported that various cuts of goat meat remained moderately stable in color until day four, when discoloration accelerated dramatically. On day four of the present study, panelists assigned discoloration and preference scores to CON chops indicating that discoloration began to negatively affect their preferences. However, negative scores were assigned to VITD chops earlier than CON chops. The mechanism leading to acceleration of discoloration and subsequent decline in panelist preference for VITD chops warrant further research.

CONCLUSION

Contrary to results observed from research with beef cattle, providing supplementation of 750,000 IU/hd/d VITD to goats seven days prior to slaughter produced decreased tenderness, as measured by Warner-Bratzler shear force and sensory panel analysis. Sensory panelists reported increased levels of connective tissue and decreased levels of juiciness in VITD chops, which may have contributed to panelists giving lower tenderness scores. During the 5-day retail display period, VITD supplementation did not affect lean color or fat color. Panelists assigned VITD chops higher discoloration scores beginning on day two. By day three, panelists preferred CON steaks over VITD steaks for color. While the results of the present study were contrary to published beef cattle results, they require further study to corroborate these findings and identify mechanisms that may explain these differences.

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