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Correlation of Plant Condensed Tannin and Nitrogen Concentrations to White-Tailed Deer Browse Preferences in the Cross Timbers

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ABSTRACT

Chemical plant defenses such as condensed tannins (CT) have the potential to reduce insect herbivory. Condensed tannins sometimes also reduce ruminant herbivory as a result of decreased palatability and nutrient availability in gastro-intestinal systems. However, when consumed as 1-3% of diets, CT can be beneficial to ruminants as anthelminthics and by binding to plant proteins to enhance rumen-bypass protein. Given that plant nitrogen and CT are important ruminant nutritional factors, this study was designed to investigate correlations between deer browse preference and crude protein (CP) and/or CT concentration. In this study we collected 56 preferred warm-season white-tailed deer browse species within the cross-timbers region of Texas and analyzed for CT and CP concentrations. Plant CT varied from 78.4% to 0.5% (dry matter basis, *Schinopsis balansae* CT standard) and CP ranged from 23.8% to 5.0%. However, there was no correlation between plant CT or CP concentrations and published deer preference. Our study suggests that, while CT and CP may be important components of the white-tailed deer diet, preference is not based solely on CT or CP concentrations. Further research is needed to determine if plant maturity or surrounding vegetation confound correlations between white-tailed deer feed preferences and CT or CP in those selectively browsed plants. Use of a self-standard from each plant species to measure CT of that species may also change correlations.

KEY WORDS: condensed tannins, crude protein, forage preferences, white-tailed deer

INTRODUCTION

Condensed tannins (CT), which consist of polyphenolic compounds, are studied mainly because of their known anti-nutritional effects on both ruminants and monogastrics (Waghorn 1996). Ruminants can, however, benefit from CT by protection

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of dietary protein from microbial degradation and helminthiasis (Iqbal et al., 2007). An increase in available protein has been reported to improve resistance to gastrointestinal nematodes (GIN) in sheep (Van and Skyes 1996). Intestinal nematodes such as *Haemonchus contortus* can cause an increase in susceptibility to infections, poor growth rates, and overall decreased performance (Max et al., 2005).

Excessive herbivory resulting from high densities of white-tailed deer causes a decline in palatable forage occurrence (Eve et al., 1977). Concentrate eaters like white-tailed deer might have a depressed resistance to gastrointestinal nematodes when there is a decrease in available digestible protein (Iqbal et al., 2007). However, development of a relationship between plant CT and specific white-tailed deer browse preferences has not been identified. A better understanding of white-tailed deer preference for plant CT could be used to improve white-tailed deer herd health. Evaluating the CT concentrations in common deer browse species will also provide insight in developing feeds for livestock and the growing exotic wildlife industry.

Understanding metabolic compounds such as CT can be a useful tool when assessing forage quality. Condensed tannins decrease ruminal protein degradation and have antihelminthic effects at low concentrations in ruminant diets (Iqbal et al., 2007). Reduced rumen forage protein degradation is also a benefit of low CT concentrations, up to 5% using a self-standard, in the diet (Min et al., 2003). Plant nutritive values which may impact forage selection may also have anthelminthic properties and therefore should not be overlooked when assessing forages for nutritive value (Butter et al., 2001).

The objective of this study was to determine the correlation between CT or protein concentrations to published forage preference in white-tailed deer.

MATERIALS AND METHODS

Plants Used in Study. During the months of June, July, and August 2006 and 2007, 56 plant species were collected in Brown, Palo Pinto, and Erath Counties in Central Texas. Plant collection sites ranged from heavily grazed to no livestock present within the last 10 years. Plant species were chosen based on published white-tailed deer plant preferences (Dillard et al., 2005). Condition, maturity, and location of hand-collected plants were recorded. Plants were identified at the sample site using Shinners and Mahler's Illustrated Flora of North Central Texas (Diggs et al., 1999). Several samples were taken from each species within each county. Only leaf and shoot material was collected. All plants were collected in triplicate and immediately upon harvesting, sealed in a labeled 16.5 by 13.6 cm plastic bag and stored on dry ice while in the field. Samples were subsequently stored at -20ºC until further use.

Tannin and Crude Protein Assays. The plants were oven-dried at 55ºC for a minimum of four days and ground, using a Wiley Mill, through a 1-mm screen. Material from each species was evaluated for total CT based on methods described by Terrill et al. (1992). A quebracho extract (*Schinopsis balansae)* standard (Traditional Tanners, Cave Junction, OR) was used for each plant sample rather than using a self-standard due to the large number of assayed species. Standard preparation was conducted by methods described by Wolfe et al. (2008); reported CT concentrations are relative to quebracho CT and should not be interpreted as absolute to that species (Wolfe et al., 2008). Nitrogen concentrations were estimated by combustion using a Vario Macro C-N Analyzer (Elementar, Mt. Laurel, NJ) and converted to CP concentrations by multiplying by 6.25 (Van Soest 1994).

Preference Factors. For each grass, forb, and browse species two tables summarize CP and CT values based on white-tailed preferences measured in 1996 and 1997 (Dillard et al., 2005; Tables 1-6). Preference values varied between these two years and are based on rumen analysis, frequency of plant material present in rumen, and availability of the forage (Dillard et al., 2005).

Statistical Model and Analyses. The relationship of CP and CT concentration to previously reported plant preference (Dillard et al., 2005) was determined using the REG procedure of SAS. Separate analyses were conducted for 2006 and 2007 plant samples for each type of plant sampled (browse, forbes, and grasses).

Table 1. Preference factor, crude protein (CP; P =0.16, R^2=0.19, SE=0.06), and condensed tannin (CT; P =0.28, R^2= 0.11, SE=0.03) levels for 1996 preferred browse species.

Plant Species	Classification	Preference	CP%	CT%
Phoradendron tomentosum	Browse	3.68	23.8	1.2
Rhus aromatic	Browse	2.20	9.0	5.0
Quercus fusiformes	Browse	2.09	9.1	8.0
Smilax bona-nox	Browse	1.24	11.1	15.2
Ulmus crassifolia	Browse	1.18	10.0	11.4
Ilex deciduas	Browse	0.85	11.9	1.3
Berberis trifolia	Browse	0.71	7.2	4.4
Forestiera pubescens	Browse	0.60	11.8	1.5
Juniperus ashei	Browse	0.50	7.5	18.3
Prosopis glandulosa	Browse	0.41	18.9	1.5
Bumelia lanuginose	Browse	0.35	12.8	32.0
Celtis laevigata	Browse	0.29	11.9	8.8

Higher preference factor values denote greater preference by white-tailed deer according to Dillard et al., 2005.

Table 2. Preference factor, crude protein (CP; P =0.47, R^2=0.03, SE=0.024), and condensed tannin (CT; P =0.26, R^2= 0.08, SE=0.007) levels for 1997 preferred browse species.

Plant Species	Classification	Preference	CP%	CT%
Quercus fusiformes	Browse	1.29	9.1	8.0
Rhus aromatica	Browse	1.21	9.0	5.0
Rhus lanceolata	Browse	1.08	12.8	5.7
Phoradendron tomentosum	Browse	0.94	23.8	1.2
Ilex decidua	Browse	0.83	11.9	1.3
Smilax bona-nox	Browse	0.75	11.1	15.2

Ulmus crassifolia	Browse	0.71	10.0	11.4
Cercis canadensis var. *texensis*	Browse	0.67	10.4	10.5
Zizphus obtusifolia	Browse	0.50	11.9	38.6
Celtis laevigata	Browse	0.41	11.9	8.8
Cornus drummondii	Browse	0.39	7.9	1.7
Ungnadia speciosa	Browse	0.39	12.7	30.4
Forestiera pubescens	Browse	0.35	11.8	1.5
Rhus toxicodendron	Browse	0.32	12.3	8.9
Juniperus ashei	Browse	0.31	7.5	18.3
Fraxinus texensis	Browse	0.28	12.1	1.6
Bumelia lanuginosa	Browse	0.21	12.8	32.0
Berberis trifolia	Browse	0.16	7.2	4.4

Higher preference factor values denote greater preference by white-tailed deer according to Dillard et al., 2005.

Table 3. Preference factor, crude protein (CP; P =0.03, R^2=0.37, SE=0.038), and condensed tannin (CT; P =0.03, R^2= 0.38, SE=0.007) levels for 1996 preferred forb species.

Plant Species	Classification	Preference	CP%	CT%
Lespedeza repens	Forb	2.67	16.9	78.4
Chamaecrista fasciculata	Forb	1.94	19.8	4.8
Rhynchosia spp.	Forb	1.60	18.1	1.3
Coreopsis wrightii	Forb	0.98	8.0	1.9
Chamaesyce prostrata	Forb	0.95	9.5	1.9
Eryngo leavenworrthii	Forb	0.86	9.4	1.1
Verbena bipinnatifida	Forb	0.84	9.7	1.1
Oxalis dillenii	Forb	0.73	12.7	4.9
Plantago spp.	Forb	0.69	6.4	1.4
Bifora americana	Forb	0.66	7.1	19.5
Tragia ramosa	Forb	0.40	11.5	24.0
Stillingia texana	Forb	0.27	15.6	2.0

Higher preference factor values denote greater preference by white-tailed deer according to Dillard et al., 2005.

RESULTS AND DISCUSSION

Evolutionary adaptations have allowed concentrate foragers such as white-tailed deer to thrive by consuming small quantities of highly nutritious plant material. For example, white-tailed deer avoid mature grasses because these require more rumination time and are typically less nutritious than forbs and legumes (Wilson, 1994). As a result, less than ten grass species appear on the preferred plant list (Dillard et al., 2005). This indicates a preference for more highly digestible plant material. Results from this study indicate that while CP may increase with increased preference values, CT levels have no apparent effect on preference.

Our results indicate that a correlation of preference to CP and CT does not exist for browse species (Tables 1 and 2). Forb and grass CP and CT did show a positive correlation to white-tailed deer preference although the R^2 values were low (Tables 3, 4, and 5). Although relationships between CT, CP, and preference factors did not support a strong correlation, it is important to note the presence of these factors in browse and forb species which make up the majority of white-tailed deer diets. Relationships between CT, CP, and preference factors may have resulted from limited plant species availability, plant maturity, and season of collection. Further studies looking at more species, locations, and a range of plant maturity should be conducted to better understand the correlation between plant quality and anti-quality factors with preference ratings. If funding allows, the use of self-standards for CT assay, as recommended by Wolfe et al. (2008), may also result in different levels of correlation between this plant component and other important factors such as CP and white-tailed deer preferences.

Table 4. Preference factor, crude protein (CP; P =0.4108, R^2=0.03, SE=0.45), and condensed tannin (CT; P =0.09, R^2= 0.13, SE=0.006) levels for 1997 preferred forb species.

Plant Species	Classification	Preference	CP%	CT%
Chamaesyce prostrata	Forb	2.96	9.5	1.9
Lespedeza stuevei	Forb	1.95	12.5	78.4
Lespedeza repens	Forb	1.91	16.9	78.4
Dalea aurea	Forb	1.78	13.5	1.6
Erdodium texanum	Forb	1.64	11.6	5.2
Croton spp.	Forb	1.49	14.2	33.1
Erigeron strigosus	Forb	1.48	7.4	2.2
Chamaecrista fasciculata	Forb	1.40	19.8	4.8
Rhynchosia spp.	Forb	1.39	18.1	1.3
Desmanthus illinoensis	Forb	1.08	13.9	9.6
Dancus pusillus	Forb	1.01	7.9	1.6
Oxalis dillenii	Forb	0.86	12.7	4.9
Verbena bipinnatifida	Forb	0.83	9.7	1.1
Senna roemeriana	Forb	0.78	12.0	3.1
Crsium texanum	Forb	0.78	6.9	1.7
Ambrosia psilostachya	Forb	0.69	12.7	2.0
Coreopsis wrightii	Forb	0.62	8.0	1.9
Bifora americana	Forb	0.59	7.0	19.5
Verbena halei	Forb	0.59	9.5	1.6

Plantago spp.	Forb	0.52	6.4	1.4
Lactuca ludoviciana	Forb	0.50	17.1	1.8
Tragia ramosa	Forb	0.41	11.5	24.1
Stillingia texana	Forb	0.39	15.6	2.0

Higher preference factor values denote greater preference by white-tailed deer according to Dillard et al., 2005.

Table 5. Preference factor, crude protein (CP; *P* =0.18, R^2=0.40, SE=0.13), and condensed tannin (CT; *P* =0.70, R^2=0.04, SE=1.1) levels for 1996 preferred grass species.

Plant Species	Classification	Preference	CP%	CT%
Dichanthelium oligosanthes	Grass	2.29	9.7	1.2
Elymus canadensis	Grass	1.68	6.5	1.2
Bouteloua hirsuta	Grass	1.14	10.0	1.3
Bouteloua curtipendula	Grass	1.06	5.9	1.2
Bouteloua rigidiseta	Grass	0.61	5.9	0.9
Schizachyrium scoparium	Grass	0.53	5.4	1.8

Higher preference factor values denote greater preference by white-tailed deer according to Dillard et al., 2005.

Table 6. Preference factor, crude protein (*P* =0.78, R^2=0.015, SE=0.07), and condensed tannin (*P* =0.84, R^2= 0.008, SE=0.36) levels for 1997 preferred grass species.

Plant Species	Classification	Preference	CP%	CT%
Bouteloua curtipendula	Grass	1.00	5.9	1.2
Dichanthelium oligosanthes	Grass	0.88	9.7	1.2
Bouteloua rigidiseta	Grass	0.44	5.9	0.9
Elymus canadensis	Grass	0.39	6.5	1.0
Schizachyrium scoparium	Grass	0.16	5.4	0.5
Leptochloa dubia	Grass	0.16	5.0	0.7
Bothriochola saccharoides	Grass	0.15	5.8	1.8
Bouteloua hirsuta	Grass	0.08	10.0	1.3

Higher preference factor values denote greater preference by white-tailed deer according to Dillard et al., 2005.

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The Effects of *Ascophylum Nodosumon* Swine Performance and Carcass Characteristics

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ABSTRACT

The objective of this study was to observe the effects of Tasco (*Ascophylum nodosum*) on swine growth traits and carcass characteristics. Tasco was fed to sows, piglets, and finishing pigs to determine the effects on various production traits and carcass merit. All sows in the study were from crossbred genetic lines and were represented by Yorkshire, Hampshire and Duroc breeding. The study was divided into three stages: lactation (n=48 for sows), (n=335 for piglets), finishing and carcass (n= 117). There were no differences for soundness or body condition score, yet sow weight loss showed a difference in favor of the Tasco group. The sows receiving Tasco had a trend less feed intake, less body condition loss with no affect on soundness while there was an advantage in less weight loss. Birth weight of the piglets was not different, yet piglets from the sows supplemented with Tasco were heavier at weaning ($P < 0.0001$). There were no differences for performance in the finishing phase of the study and for carcass cutability traits. Tasco fed pigs were significantly higher for marbling ($P < 0.001$), and firmness of lean ($P < 0.05$). Data showed no differences for lean color. Consequently, Tasco has a positive effect on weaning weight for piglets and enhanced pork quality.

KEY WORDS: performance, carcass, swine, pork quality

INTRODUCTION

Tasco is a dried and ground marine seaweed (*Ascophylum nodosum*) product that has shown many promising results in the cattle industry. Application of Tasco has been shown to significantly increase immune function in steers being grazed on endophyte-infected fescue pastures (Allen et al., 2001). Tasco increased serum cholesterol levels back to normal in steers being grazed in infected fescue pastures (Allen et al., 2001). In addition, Tasco demonstrated antioxidant characteristics. Steers that grazed on infected fescue pastures and were fed Tasco showed an increased amount of Vitamin E in the liver and decreased amount of Vitamin E in the serum (Montgomery et al., 2001). Tasco has been shown to increase a variety of plant antioxidant compounds when applied to forage grasses like superoxide dismutase (Ayad 1998; Zhang and Schmidt 1999). Brangus cow calf pairs were studied that were grazing infected fescue pastures during the summer and early fall months. Cows that were supplemented with Tasco showed decreased respiration rates and rectal body temperatures (Evans et al., 2001). Tasco offers many benefits to the cattle industry, yet the exploration of similar benefits and research is merited for the swine industry and its effects on pork production. Therefore, the objective of this study was to observe the effects of Tasco on performance traits and carcass characteristics.

EXPERIMENTAL PROCEDURE

This study was conducted at the Tarleton State University swine unit, Stephenville, TX. The objective of the study was to observe the effects of Tasco (*Ascophylum nodosum*) on swine performance. Tasco was fed to sows, piglets, and finishing pigs to determine the effects on various growth traits, production traits and carcass merit. All sows in the study were from crossbred genetic lines and were represented by Yorkshire, Hampshire and Duroc breeding. There were three stages of production (farrowing, nursery, and finishing) that were observed.

Farrowing Study. Thirty days prior to farrowing, sows and gilts were randomly sorted and assigned to two groups (treatment (Tasco) and control). All sows were fed four pounds of a corn/soybean meal basic gestation diet. Treatment sows were fed one ounce of Tasco, as recommended by Acadian Agrictech, as a top-dress, in addition to their daily feed during the 30 day time period. During lactation, all sows were fed ad libitum. The treatment group was fed two ounces of Tasco daily, as a top-dress, during the regular feeding regime. Control sows were fed ad libidum along with two ounces wheat bran as a placebo. Table 1 shows the nutritional values of both the gestation and lactation diet.

Table 1: Nutritive Value of Sow Diets

	Gestation	Lactation
Crude Protein (%)	12.7	15.9
Lysine (%)	0.71	0.98
Calcium (%)	0.89	1.22
Phosphorus (%)	0.78	0.88
Fat (%)	3	2.8
Metabolizable Energy (Kcal/day)	1475	1453

Approximately two weeks prior to their farrowing date, sows and/or gilts were weighed as well as given a subjective body condition score by a three-member panel of swine professionals. The body condition scoring system utilized was a Likert type scale from one to nine (1 signifying very thin and 9 signifying very fleshy/fat). In addition, a soundness score was assessed by the same team of professionals. Soundness was evaluated on a scale of one to five (1 representing very restricted and 5 representing very mobile). These figures reflect the pre-farrowing observations. Likewise at weaning, weight, body condition score, and soundness scores were obtained. During lactation several factors were recorded to observe differences in performance for those fed Tasco versus control fed sows.

Additional body function traits such as respiration rate were observed at day 14 post parturition two hours post feeding. A resting respiration rate was recorded on the sows in order to determine any stress of the sows. Also, birth and adjusted 21 day piglet weights were recorded in order to interpret the relative milking ability of the sows for those being fed Tasco or control. Finally, post weaning return to estrus was detected.

Nursery Study. Piglets were weaned between 18 and 28 days of age using an all in all out system of management. At weaning, the piglets were allotted to the same diet treatment as their respective dams. Piglets were placed in one of eight nursery pens where eight to 10 pigs were placed per pen. Thus, pigs from each treatment and control groups were placed in four different pens each to represent four replications per farrowing. There were five different farrowings throughout the study.

Piglets were fed a three-phase nursery diet. The feed was available ad libitum. The first diet (22 % crude protein) was continued until the pigs reached approximately 15 pounds. The second ration (20 % crude protein) was then fed until the piglets weighed 25 pounds. Finally, a third ration (19 % crude protein) was fed for the duration of the nursery study. Table 2 shows the nutritive value of the nursery rations.

Table 2: Nutritive Value of Nursery Diets

	PreStarter 10-15 (lbs)	PreStarter 15-25 (lbs)
Crude Protein (%)	22	20
Lysine (%)	1.5	1.35
Calcium (%)	0.9	0.9
Phosphorus (%)	0.7	0.7
Fat (%)	6.5	5

Piglets were fed and observed in the nursery for 30 days. The Tasco group was fed the same diet to that of the control group except that Tasco was mixed by hand at a rate of one pound of Tasco per 200 pounds of feed (10 pounds per ton or 0.5% of the feed).

Piglets feed intake was measured by each pen group. The nursery pigs were kept in the nursery for approximately 30 days. Initial weights and ending weights were obtained at the beginning and end of the 30 days. From the data collected, average daily gain, weight gain, and feed conversion ratio were calculated.

Growth Study. At the end of the nursery phase, piglets were given a two-week warm up period on the finishing floor without Tasco supplementation. This allowed the piglets to acclimate to the new environment as well as to the new diet. The piglets were once again allotted to the same treatment as they received in the nursery. Pigs were started on a three stage finishing schedule that was available ad libitum and contained Tasco. The initial feed was fed until the pigs reached approximately 110 lbs. The second ration was then started and maintained until the pigs averaged 160 lbs. The third ration was then started once the pigs reached approximately 160 lbs. Table 3 on the next page shows the relative nutritional value of the three rations that were fed as controls to the pigs on the finishing floor.

Table 3: Nutritive Value of Finishing Floor Diets.

	Ration #1 (50-110 lbs)	Ration #2 (110-180 lbs)
Crude Protein (%)	16.2	14.4
Lysine (%)	1	0.85
Calcium (%)	1.07	0.87
Phosphorus (%)	0.69	0.6
Fat (%)	2.8	2.9

The Tasco group was supplemented at a rate of 0.5% of Tasco (10 pounds per ton) in their diet. The pigs were fed to average 180 lbs. At that time, ending weights were recorded to determine total gain and average daily gain for the finishing phase of the study. Birth weight was used to calculate weight per day of age.

Finishing and Carcass Study. A randomly selected number of pigs (usually 20-30 per feeding period) remained in the study at 180 lbs to be fed and harvested for carcass data. These pigs continued to be fed and grew to an average of 260 lbs. The pigs were kept on the same diet while the treatment group was fed Tasco at a rate of 0.5% of the ration. Once the pigs reached the desired weight they were weighed at the Tarleton State University Swine Unit and shipped to a commercial meat packing plant in Dallas, Texas.

Upon arrival at the packing plan, they were harvested within six hours. Twenty-four hours post mortem, standard carcass measurements were obtained on all of the carcasses. Measurements such as: Carcass length (anterior edge of the aitch bone to the anterior edge of the first rib) and ham circumference were measured. Ham circumference was measured using a soft measuring tape and anatomically identifying reference points to produce consistency. The researcher used the center of the stifle joint as a reference point on the ventral side of the ham and a point two inches above the anterior edge of the aitch bone was used as a reference point on the dorsal side of the ham.

Also, backfat measures were recorded from the first rib, last rib, and the last lumbar vertebrae and an average backfat was calculated. These measurements were collected from the right side of the carcass. Next the left side of the carcass was ribbed between the 10^{th} and 11^{th} rib. Loin eye area and 10^{th} rib backfat were measured. Additionally, color, firmness, and marbling scores were obtained based on the National Pork Board Pork Quality Standards. Dressing percentage was also calculated using a hot carcass weight determined at the plant and using a standard 1% drift subtracted from the weight at the TSU farm. In addition average daily gains were calculated for the entire growing and finishing phases of the study.

Statistical analysis was conducted by using the Mixed Procedure SAS (SAS Inst. Inc., Cary, NC). For all groups, the model contained the effects treatment, group and the treatment × group interaction. Pen was included as the random variable. When significant differences were noted ($P < 0.05$), the PDIFF option of the LSMEANS statement was used for mean separation.

RESULTS AND DISCUSION

Although more research is warranted to verify results; the supplementation of Tasco positively affected seven variables in the production of farrow to finish swine. In coordination with the experimental procedure, results will be reported according to lactation, nursery, and finishing/carcass performance trials.

Lactation. Table 4 indicated differences for both the treatment and control groups at parturition and throughout lactation. Variables reported were sow weight, body condition score, and soundness score (three days pre-farrowing and at weaning), respiration rate at 14 days post partum, sow feed intake during lactation, and return to estrus after weaning for all sows. Performance changes were calculated for sow weight, body condition score, and soundness. Furthermore, birth and 21-day weights were recorded for the piglets during each trial farrowing.

Table 4. Effects of Tasco on Sow Performance at Parturition and Lactation.

Variable	Control	Standard Error	Tasco	Standard Error	P value
Sow Farrowing Weight (lbs.)	554.9	13.16	515.4	12.62	0.0356
Sow Weaning Weight (lbs.)	485.9	12.2	469.3	11.7	0.3311
Lactation Weight Loss (lbs)	69	5.82	46.16	5.58	0.0068
Farrowing Body Condition Score [a]	6.37	0.19	6.6	0.18	0.3915
Weaning Body Condition Score [a]	3.97	0.19	4.76	0.18	0.005
Lactation Body Condition Score Change	2.39	0.21	1.84	0.21	0.0705
Farrowing Soundness Score[b]	3.93	0.14	3.92	0.14	0.943
Weaning Soundness Score[b]	3.46	0.13	3.64	0.12	0.3115
Decrease in Soundness Score	0.47	0.2	0.28	0.19	0.4671
Respiration Rate[c]	44.57	1.46	48.48	1.4	0.0589

Control (n=23) Tasco (n=25)
[a]Body Condition Score (1-9) 1 = Thin 9 = Fat
[b]Soundness Score (1-5) 1 = Unsound 5 = Very Sound
[c]Respiration Rate (respirations per minute)

There were no differences for soundness or body condition score, yet sow weight loss showed a difference in favor of the Tasco group. The treatment sows only lost 46.6 lbs ($P < 0.01$) while the control sows lost 69 lbs during the lactation time period. The treatment group had an advantage of 22.84 lbs less weight loss than the control group. During this period, there was a tendency for the Tasco sows to have less body condition loss as well. There was no difference reported for respiration rate. A study by Leonard et al. (2001) reported that steers received either 0.5% or 1% supplementation of seaweed extract (*Ascophyllum nodosum*) had respirations rates that were about the same but the steers that received 1% of the seaweed extract had lower respiration rates than steers that received 0% supplementation. Williams et al. (2009) found that there was no difference between minimum and maximum respirations rates between cattle receiving Tasco and those who did not. Williams et al. (2009) also found that there was no difference in respiration rates between cattle that were exposed to different periods of thermoneutral temperatures followed by a period of heat load conditions

Three hundred thirty-five piglets were observed for weight gain during the lactation phase of the study. Birth weight of the piglets for both groups were not different, yet piglets from the sows supplemented with Tasco were .88 lbs heavier (13.71 versus 12.99) at weaning (P < 0.0001). Also, weight gain from birth to weaning was higher for the treatment pigs by .76 lbs (10.2 versus 9.44), (P < 0.0001), Table 5.

Table 5. Effect of Tasco on Piglet Growth Traits During Lactation.

Variable	Control	Standard Error	Tasco	Standard Error	P value
Piglet Birth Weight (lbs)	3.56	0.06	3.51	0.06	0.5
Piglet Adjusted 21 day Weight (lbs)	12.99	0.23	13.71	0.23	0.0001
Weight Gained (lbs)	9.44	0.2	10.2	0.2	0.0001

Control (n=180) Tasco (n=155)

The mean number of days post weaning that the sows experienced for return to estrus and daily feed intake are shown in Table 6. The control group averaged 5.44 days for the sows to be observed in standing heat post weaning, while the Tasco group averaged 4.64. However this data was not statistically different. Though not significant, the Tasco sows, on average, consumed 0.6 lbs of less feed than the control group, had significantly less weight loss during lactation and showed a tendency to return to estrus sooner than control sows. They consumed less feed while significantly maintaining a higher body condition score and weaning significantly heavier piglets (Tables 4&5).

Table 6. Effect of Tasco on Return to Estrus Post-Weaning and Sow Feed Intake.

Variable	Control	Standard Error	Tasco	Standard Error	P value
Return to Estrus (days)	5.44	0.3837	4.636	0.3129	0.1104
Sow Feed Intake (lbs)	9.227	0.3648	8.632	0.3533	0.2479

Return to Estrus - Control (n=32), Tasco (n=34)
Sow Feed Intake- Control (n=25), Tasco (n=26)

Nursery. The nursery study revealed no positive effects in favor of Tasco. While there were no differences in initial weight, final weight, and feed conversion ratio, the control group showed significant advantages in weight gained and average daily gained (Table 7). The control pigs were 1.50 lbs heavier at the end nursery study as compared to the Tasco pigs (P<0.05). The control pigs gained 0.8407 lbs per day versus 0.7911 lbs per day for the Tasco pigs (P<0.05).

Table 7. Effect of Tasco on Nursery Pig Growth Traits and Feed Conversion.

Variable	Control	Tasco	P value
Initial Weight (lbs)	14.23	14.77	0.1431
Final Weight (lbs)	39.79	38.83	0.2682
Weight Gained (lbs)	25.56	24.06	0.0136
Average Daily Gain (lbs)	0.8407	0.7911	0.0127
Feed Conversion Ratio (lbs)	1.738	1.732	0.919

Control (n=162) Tasco (n=147)

There are no previous studies for nursery age piglets; in cattle, Allen et al. (2001) found that applying Tasco to pastures during grazing season did not affect pasture weight or the weight of the steers when they arrived at the feedlot between those who grazed infected tall fescue and those who didn't. There also was no compensatory gain for those who grazed the infected fescue in the feedlot therefore; those who grazed the infected fescue remained at a lighter body weight. Allen et al. (2001) found that steers that had grazed pastures treated with Tasco required approximately 0.35kg less feed per kilogram of gain in the feedlot.

Finishing/Carcass. The third phase of the study included the finishing gain data and carcass characteristics. Even though there was a difference for the initial weight ($p<0.05$), there were no differences for average daily gain, total weight gain, slaughter weight, dressing percentage, or hot carcass weight (Table 8). The data revealed that animal slaughter weights were 251 and 251.8 lbs for control and treatment, respectively, while hot carcass weights were 187.5 and 187.8 lbs. Dressing percentage was not different in that both groups revealed a 74.6. These results concur with Allen et al. (2001) and Braden et al. (2007) who found that hot carcass weights of steers were not affected by Tasco treatment of the pastures.

Table 8. Effects of Tasco on Growth Traits in Finishing Swine.

Variable	Control	Standard Error	Tasco	Standard Error	P value
Live Weight (lbs.)	253.5	2.36	253.6	2.45	0.9055
Slaughter Weight (lbs.)	251	2.31	251.8	2.39	0.9455
Hot Carcass Weight (lbs.)	187.5	1.89	187.8	1.97	0.8344
Dressing Percentage (%)	74.6	0.002	74.6	0.002	0.6063
Initial Finishing Weight (lbs.)	67.12	1.06	64.51	1.1	0.0006
Finishing Weight Gained (lbs.)	186.3	2.34	189.5	2.42	0.0737
Average Daily Gain (lbs.)	1.782	0.026	1.778	0.027	0.7492
Carcass Length (in)	32.15	0.12	32.1	0.12	0.6055

Control (n=62) Tasco (n=55)

Table 9 indicated the data for muscling differences from pigs fed Tasco. Data showed that even though the loin eye area was larger for the Tasco fed pigs, there was no significant difference between the two groups. These results concur with Braden et al. (2007) who found no difference in LM area between cattle supplemented with Tasco and those who were not supplemented with Tasco. Furthermore, there was no difference for carcass length or ham circumference.

Table 9. Effects of Tasco on Muscling Traits in Finishing Swine.

Variable	Control	Standard Error	Tasco	Standard Error	P value
Ham Circumference (in)	30.11	0.12	30.44	0.13	0.3209
Loin Eye Area (in^2)	7.82	0.12	8.16	0.12	0.1639

Control (n=62) Tasco (n=55)

Data reported from Table 10 indicated that there were no differences in any of the measurable backfat indicators. Tasco fed pigs showed a slightly greater amount of backfat of 0.99 versus 0.98 inches of average backfat and 0.67 versus 0.66 inches of backfat at the 10^{th} rib measurement.

Table 10. Effects of Tasco on Backfat in Finishing Swine.

Variable	Control	Standard Error	Tasco	Standard Error	P value
10th Rib Backfat (in)	0.66	0.02	0.67	0.02	0.655
1st Rib Backfat (in)	1.41	0.026	1.44	0.027	0.807
Last Rib Backfat (in)	0.83	0.023	0.85	0.024	0.2727
Last Lumbar Vertebra Backfat (in)	0.69	0.021	0.69	0.022	0.4183
Average Backfat (in)	0.98	0.02	0.99	0.02	0.6143

Control (n=62) Tasco (n=55)

Table 11 revealed the effects of Tasco on pork quality. The data showed that there was no difference for color, yet Tasco fed pigs were significantly better for marbling and firmness of lean. Montgomery et al. (2001) found that color decline with increased days of retail display regardless of treatment. Steaks from steers treated with Tasco seemed to have more a more desirable color than those steaks from steers who did not receive Tasco (Montgomery et al., 2001). Treating pastures with Tasco, improved lean uniformity and decreased lean discoloration of the meat from steers who consumed the pasture treated with Tasco (Montgomery et al., 2001). Less steak browning was in all steers from pastures treated with Tasco (Montgomery et al., 2001).The control group averaged a marbling score of 1.142 and the treatment group averaged a greater amount of marbling with a score of 1.432 ($P< 0.0001$). Allen et al. (2001) also found that the application of Tasco to tall fescue increased the marbling score of steers who grazed the treated pastures versus those who grazed untreated pastures. Braden et al. (2007) found that carcasses from cattle supplemented with Tasco had greater marbling scores than cattle not supplemented with Tasco. There was also a difference for firmness score between the two groups. The control group averaged a firmness score of 3.84 while the treatment group averaged a significantly higher score of 4.04 ($P< 0.05$).

Table 11. Effects of Tasco on Carcass Quality Traits in Swine.

Variable	Control	Standard Error	Tasco	Standard Error	P value
Lean Color Score[a]	2.52	0.066	2.63	0.069	0.3064
Marbling Score[b]	1.142	0.05	1.432	0.05	0.0001
Firmness Score[c]	3.84	0.106	4.04	0.11	0.027

Control (n=62) Tasco (n=55)
[a]Lean Color (1-6) 1=Pale, 6=Dark Red
[b]Marbling Score (1-10) 1=Devoid, 10=Very Abundant
[c]Firmness of Lean (1-5) 1=Soft, 5=Firm

SUMMARY

The seaweed product Tasco has shown positive effects to both swine performance and carcass characteristics. It significantly reduced the amount of lactation body weight loss from 69 lbs in the control group to 46.16 lbs in the Tasco group ($P<0.01$). The Tasco sows weaned a significantly higher body condition score of 4.76 as compared to the control group's 3.97 ($P<0.01$). In addition, while the sows lost significantly less weight during lactation, they weaned heavier piglets. The Tasco sows weaned piglets averaging 13.71 lbs at twenty-one days, while the control sows weaned pigs averaging 12.99 lbs ($P<0.001$). The Tasco sow's piglets gained an average of 10.20 lbs throughout lactation, as compared to 9.44 for the control sow's piglets ($P<0.001$). The Tasco piglets showed lower ending weights in the nursery and gained less during the nursery phase of the study as compared to the control pigs ($P<0.05$). Tasco also improved several of the pork quality characteristics at the time of harvest. The Tasco group showed a higher marbling score of 1.432, as compared to 1.142 for the control group ($P<0.001$), as well as, a higher firmness score. Tasco fed carcasses were observed to have a firmness score of 4.04 while the control group averaged a score of 3.84 ($P<0.05$).

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Opinion Leaders' Influence on College Students' Perceptions of the National Animal Identification System

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ABSTRACT

The purpose of this study was to determine opinion leaders' (as information sources) influence on college of agriculture students' awareness, knowledge, and perceptions of the National Animal Identification System (NAIS). An online survey was used to collect data. Students (N = 92) were somewhat aware of the NAIS, and were knowledgeable about general NAIS concepts. Students' NAIS perceptions and awareness were positively associated. University professors, Internet, and family members were preferred information sources. Opinion leaders influenced students' awareness and perceptions of the NAIS. The influence from Cooperative Extension, private organizations, and university professors was moderately correlated with students' awareness of the NAIS. The role of university professors as information sources highlighted the significance of the two-step flow of communication in influencing students' perceptions of the NAIS. Hypotheses tests confirmed the existence of an indirect flow of information from mass media to opinion leaders, and then to a less informed public. University professors were more influential on students' perceptions of the NAIS than were mass media (television, radio, newspaper, Internet, and popular magazines). University agricultural educators must be cognizant about the impact their beliefs have on students' awareness and perceptions of agricultural issues.

KEY WORDS: communications, perceptions, information sources, livestock

INTRODUCTION

Rogers' (2003) definition of opinion leaders and Katz and Lazarsfeld's (1955) two-step flow of communication model provided the framework in this study. Rogers defined opinion leaders as those who provide information and advice about innovations to individuals. Because the opinion leader earns and maintains status through technical competence, conformity to norms, and social accessibility, he/she is considered an expert and is trusted for accurate and truthful information. Opinion leaders are also seen as having an influence on others and access mass media more than the average person.

Katz and Lazarsfeld's (1955) two-step flow model (Figure 1) depicts how messages flow from media to opinion leaders and from opinion leaders to a less active or informed public audience. The two-step flow model focused on decision-making in the 1940 Presidential election campaign. Evidence existed that media effects were minimal, but social influences affected voters' opinions (Lowery and DeFleur 1995). Social influence was derived from opinion leaders, those who were heavily involved with or exposed to political campaigns (Lowery & DeFleur). Therefore, people who had less knowledge or interest turned to opinion leaders for information because they trusted opinion leaders more than they trusted political propaganda.

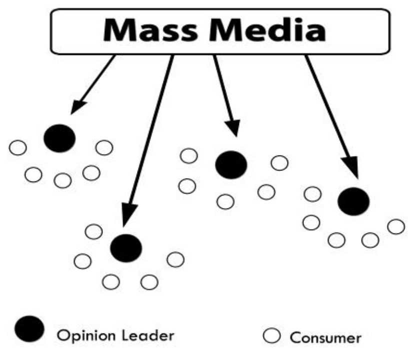

Figure 1. Two-step Flow Model: Mass Media to Consumer (Katz and Lazarsfeld, 1955).

Perceptions and Mass Media. Terry and Lawver (1995) studied university students' perceptions of agriculture issues. Their results suggested that urbanization has contributed to consumer's low awareness of agriculture and their inaccurate perceptions of agricultural industry issues. Terry and Lawver suggested that as people become removed from production agriculture, they are less concerned about their food and fiber, therefore failing to understand the benefits of agriculture to society.

Knowledge, experience, or global attitudes reported in mass media can shape and form people's perceptions (Wingenbach et al., 2003). Wingenbach et al. found that students gained awareness of biotechnology through science classes, labs, and university professors' beliefs. The authors determined that already-present global attitudes did not influence students' perceptions, but awareness of biotechnology practices influenced their perceptions.

Heuer and Miller (2006) found that mass media can influence public opinion and set a public agenda—or determine the way the public should think about a topic. Meyers and Rhoades (2006) suggested a direct relationship existed between information that appears in media and what viewers perceive as important societal issues.

Attitudes Toward Livestock Industry Issues. Nordstrom et al. (2000) assessed high school students' attitudes toward animal welfare, resource use, and food safety. All students ranked food safety as the area of most importance and concern; resource use and animal welfare were the second most important issues. Microbial contamination was ranked as a major food safety concern for both urban and rural students, while providing shelter was a primary concern for all students in regards to animal welfare issues. Nordstrom et al. concluded that agricultural education programs can provide a foundation for students on animal and environmental issues, while enhancing their knowledge and fostering dialogue related to these areas.

National Animal Identification System (NAIS). The NAIS Communications Campaign initiated a stakeholder focus group in June 2006 to identify stakeholders' awareness, attitudes, and perceptions of the NAIS (Mobley 2006). The campaign concluded that messages generated from Animal and Plant Health Inspection Service (APHIS) were inconsistent and incomplete, that printed NAIS materials were ineffective, and the NAIS Web site was not being used as an information source. The campaign also found where producers were concerned about privacy and viewed the NAIS as increased paperwork, red tape, and bureaucracy.

MATERIALS AND METHODS

The purpose of this study was to determine opinion leaders' influence (as information sources) on college of agriculture students' awareness, knowledge, and perceptions of the NAIS. The objectives were to: 1) Determine students' awareness, knowledge, and perceptions of the NAIS; 2) Determine students' information sources for livestock industry issues; 3) Determine if a relationship existed among students' perceptions, awareness, and knowledge of the NAIS; and 4) Test hypotheses that opinion leaders influenced (a) students' awareness, (b) knowledge, and (c) perceptions of the NAIS.

A correlational, ex-post facto design (Tuckman 1999) was used to determine relationships between variables and to understand the effects of opinion leaders' influence on students' awareness, knowledge, and perceptions of the NAIS.

The accessible population (N = 1,293) was undergraduate students enrolled in courses related to animal agriculture and production in the College of Agriculture and Life Sciences at Texas A&M University during the spring 2007 semester. The sample (n=296) was determined using Dillman's (2007) sampling procedures. Males and females, ranging in age from 18 to 25, and all classes of students—freshman, sophomore, junior, and senior—were included in the target audience. Stratified random sampling was used to ensure a representative sample of the population. The strata were animal science majors and non-animal science majors, and upperclassmen and lowerclassmen.

The instrument was a self-administered survey. Three scales were used: strongly agree to strongly disagree, very important to not important, and I am very knowledgeable (about the NAIS) to I have no knowledge. In addition to the scalar responses, the instrument had eight true/false questions. All questions in this instrument required an answer, which helped to determine characteristics of the survey population (Dillman 2007). Experts from animal science, agricultural education, and agricultural communications validated content validity of the instrument. A pilot study of students with similar majors and classes established face validity of the instrument. Internal consistency of each conceptual scale was tested with Cronbach's coefficient alpha (α). No significant differences in the variables of interest existed between pilot and sample responses, or between early and late respondents.

Students' awareness of the NAIS was measured with five questions (Scale = No, Somewhat, Yes); Cronbach's alpha coefficient was .77 for the awareness construct. Students' knowledge was measured with eight close-ended questions (true or false). Students' perceptions were measured with 14 close-ended statements on two separate Likert-type scales. The first scale had 10 questions on a five-point Likert-type scale (Strongly Disagree to Strongly Agree); the second scale had four questions with a three-point, Likert-type scale (Not Important to Very Important). Cronbach's alpha coefficient for the five-point scale was .86 and .73 for the three-point scale.

The two-step flow of communication from media to opinion leaders to students was measured with a series of close-ended items. Students' use of media sources was measured with nine close-ended questions on a four-point Likert-type scale. Cronbach's alpha coefficient was .88 for the media source scale. Demographic information such as gender, involvement with livestock, and participation in the NAIS program was gathered in the final section.

The researchers followed Dillman's "*The tailored design method: Mail and internet surveys*" (2007) to collect data through an online survey. Each participant received personalized pre-notice e-mail messages that informed him/her about his/her selection to participate in the study. A second personalized e-mail was sent three days after the pre-notice and contained a link to the actual study. Dillman concluded that personalized e-mails increased survey response rates (2007). Participants' names, unique passwords, and e-mail addresses remained confidential. Four e-mail reminders were sent to non-respondents. Each e-mail contained the hyperlink to the online survey and encouraged the recipient to visit the information page.

Descriptive statistics were used to describe the data. Bivariate analyses were conducted to test the direction of the hypotheses, using an alpha level of $p < .05$ to determine statistical significance. A confidence interval of .05 was used on all tests because of the available research on college students' perceptions.

RESULTS

Respondents (N = 92) numbered 46 (50%) females and 46 (50%) males (Table 1). Thirty-four (37%) were underclassmen (freshman or sophomore) and 58 (63%) students were upperclassmen (junior or senior). Sixty-eight (73.9%) students were non-animal science majors and 24 (26.1%) students were animal science majors.

Table 1. Demographic frequencies of respondents (N=92).

Variables		*f*	%
Gender	Female	46	50.0
	Male	46	50.0
Major	Non-Animal Science	68	73.9
	Animal Science	24	26.1
Class Status	Upperclassmen (Junior-Senior)	58	63.0
	Lowerclassmen (Freshman-Sophomore)	34	37.0

Students' awareness of the NAIS was measured with five statements. Students were aware of the NAIS (Table 2); 45 (48.9%) were unaware its effects on U.S. national security and 43 (46.7%) were unaware of its effects on the U.S. economy.

Table 2. Frequencies of respondents' awareness of the NAIS (N = 92).

	No		Somewhat		Yes	
Statement	*f*	%	*f*	%	*f*	%
Are you aware of how the NAIS will affect United States' national security?	45	48.9	23	25.0	24	26.1
Are you aware of how the NAIS will affect the United States' economy?	43	46.7	29	31.5	20	21.7
Do you think there is a risk of a foreign animal disease outbreak in the United States?	17	18.5	43	46.7	32	34.8
Do you think the risk [of foreign animal disease] would be severe enough to warrant the use of the NAIS?	22	23.9	39	42.4	31	33.7
Are you aware of how the NAIS will affect food safety in the United States?	33	35.9	35	38.0	24	26.1

Students' knowledge of the livestock industry and the NAIS was measured with eight true/false statements. Respondents' knowledge ranged from 7.6 to 88% correct. A majority (88%) correctly answered the statement, "The NAIS is a program that was created by the United States Department of Agriculture" (Table 3).

Table 3. Frequencies of respondents' knowledge of the NAIS (N = 92).

Statement	Incorrect		Correct	
	f	%	*f*	%
The NAIS is a program that was created by the United States Department of Agriculture. (True)	9	9.8	81	88.0
The NAIS will include all animal livestock species: cattle, horses, swine, sheep, goats, bison, poultry, cervids (elk and deer), and camelids (llamas, alpacas). (True)	18	19.6	73	79.3
The NAIS was created to track diseased livestock. (True)	22	23.9	69	75.0
Participation in the NAIS is voluntary at the Federal level. (True)	22	23.9	69	75.0
The NAIS will include livestock and pets (dogs and cats). (False)	36	39.1	55	59.8
The NAIS will allow the government to pinpoint a farm's location and record the number of livestock on the property through the use of a global positioning system (GPS). (False)	59	64.1	32	34.8
The NAIS will track and identify the movement of all livestock in the United States. (False)	71	77.2	20	21.7
The NAIS provides the government a way to continuously monitor livestock records. (False)	83	90.2	7	7.6

Note. Frequencies may not equal 100% because of missing data. Respondents' individual knowledge levels ranged from zero to eight correct responses.

Students' perceptions of the NAIS were measured with 14 statements. Respondents agreed that the NAIS did not affect them (M=2.93, SD=1.15), will help track sick animals back to the source of contamination or infection (M=2.75, SD=1.46), is an important program (M = 2.65, SD = 1.34), and is important to national security (M = 2.56, SD = 1.41) (Table 4).

Table 4. Descriptive statistics for perceptions of the NAIS.

Statement	M	SD
The NAIS does not affect me. †	2.93	1.15
The NAIS will help track sick animals back to the source of contamination or infection. †	2.75	1.46
The NAIS is an important program. †	2.65	1.34
The NAIS is important to national security. †	2.56	1.41
The NAIS will help prevent the spread of disease in livestock. †	2.53	1.45
The NAIS is an invasion of my privacy. †	2.49	1.45
My belief system influences my perceptions of the NAIS. †	2.04	1.29
I am not concerned about the voluntary NAIS becoming mandatory. †	1.99	1.35
The NAIS will have an economic benefit to the producer. †	1.88	1.54
I am well informed about the NAIS. †	1.83	1.09
As a consumer, how important is the…		
NAIS to maintain a safe U.S. food supply? ‡	2.41	0.83
Traceability of food through the food supply chain? ‡	2.37	0.72
NAIS to the U.S. economy? ‡	1.97	1.02
NAIS to national homeland security? ‡	1.86	1.02

† Five-point scale: 0.0-0.5=Unsure. 0.51-1.5=Strongly Disagree, 1.51-2.5=Disagree, 2.51-3.5=Agree, 3.51-4.0=Strongly Agree.
‡ Three-point scale: 1.0-1.5=Not Important, 1.51-2.5=Important, 2.51-3.0=Very Important.

Students' indicated the information sources used to learn about the NAIS and the level of influence (1=No Influence, 10=Most Influential) that source had on their opinion of it (Table 5). Forty-six students rated university professors as very influential information sources (M=7.40); 38 rated the Internet as an influential source (M=5.72); and 33 rated family members or friends as influential sources (M=5.69). The Cooperative Extension service was rated as somewhat influential (M=4.44) by 20 students.

Table 5. Descriptive statistics for influence of information sources for the NAIS.

Source	f	M†	SD
University professors	46	7.40	3.11
Internet	38	5.72	2.94
Family member/friend	33	5.69	2.77
Trade publications (Beef, Dairy Herdsman, Drovers)	23	5.43	2.97
Television	22	5.26	3.26
Newspapers	31	5.06	2.87
Private organizations (Texas Beef Council, Farm Bureau)	22	4.92	3.23
Radio	17	4.52	3.14
Cooperative Extension Service	20	4.44	3.29
Popular magazines (Time, Newsweek, People)	16	3.72	2.85

† Ten-point Scale: 1=No Influence…10=Most Influential.

The hypothesis that opinion leaders, as information sources, influenced students' awareness of the NAIS was tested using Pearson's Product Moment Correlations. The composite score for student awareness was correlated with each opinion leader (Table 6). Student awareness of the NAIS was substantially (Davis, 1971) positively associated with the Cooperative Extension service (r=.55, p < .05) and private organizations (r=.50, p < .05), and moderately associated with university professors (r=.33, p < .05) and the Internet (r=.31, p < .05). Therefore, the null hypothesis that opinion leaders did not affect students' awareness of the NAIS was rejected, and the alternative hypothesis was accepted as true. Statistical evidence suggested that opinion leaders influenced students' awareness of the NAIS (Table 6).

Opinion leaders did not influence students' knowledge of the NAIS. The knowledge construct consisted of eight true or false statements. Student knowledge was not correlated with any of the opinion leaders' influence. Because of insufficient evidence, the null hypothesis that opinion leaders did not affect student knowledge of the NAIS failed to be rejected (Table 6).

Table 6. Relationships between selected opinion leaders' influence on students' awareness, knowledge, and perception of the NAIS.

	Awareness		Knowledge		Perception	
Variables	*r*	Sig.	*r*	Sig.	*r*	Sig.
Cooperative Extension Service	.55*	.01	.13	.57	.22	.31
Private Organizations (Texas Beef Council)	.50*	.02	.11	.62	.36	.09
Popular Magazines (Time, Newsweek, People)	.44	.09	.03	.91	.38	.15
Television	-.41	.06	.04	.86	-.10	.67
Trade Publications (Beef, Dairy Herdsman)	.36	.10	.30	.17	.28	.19
University Professors	.33*	.02	.04	.76	.29*	.04
Internet	.31*	.04	.26	.09	.19	.21
Family members/friend	.27	.10	.15	.37	.23	.17
Newspapers	.25	.16	.09	.62	.27	.14
Radio	.15	.52	.01	.96	-.02	.94

* $p < 0.05$ (2-tailed).

Opinion leaders influenced students' perceptions of the NAIS. Students' perceptions of the NAIS had a positive, yet low association with university professors (r=.29, p < .05) (Table 6). Therefore, the null hypothesis that opinion leaders did not affect students' perception of the NAIS was rejected and the alternative hypothesis was accepted as true. Statistical evidence suggested that opinion leaders' influenced students' perceptions of the NAIS.

DISCUSSION

Overall, more students were aware that there was a risk of foreign animal disease outbreak, than were students who were aware of how the NAIS would affect food safety in the U.S. These findings are consistent with Whaley, Tucker, Sharp, and Knipe's (2003) findings that consumers believed their food was less safe in 2003 than it was in 1993. Food safety concerns from the Whaley et al. study included genetically modified foods, bacterial and pesticide contamination, use of growth hormones in livestock, mad cow disease, and bio-terrorism.

Students were equally aware of how the NAIS affected U.S. food safety and national security, but fewer students were aware of how it will affect the U.S. economy.

Perhaps their disagreement with being well informed about the NAIS sheds light on the fact that a majority of them incorrectly answered three of the eight knowledge questions. Educators of the students in this study should realize that a reliable system would enable public health officials to pinpoint animal products containing harmful pathogens. Such a system would prevent human consumption of those products, and would hold the segment of the food chain responsible and liable for any costs associated with the contamination (Vitiello & Thaler, 2001).

Overall, students were more informed about the general rather than the specific aspects of the NAIS. They believed common myths such as the use of a global positioning system to pinpoint farm locations, the ability to track and identify movement of all livestock in the U.S., and the continuous monitoring of livestock records. These three myths are reoccurring themes addressed on the APHIS Web site; however the NAIS Communications Campaigns' focus groups found that the NAIS Web site was not being used as an information source (Mobley, 2006). Further research on NAIS knowledge should be conducted to determine if other audiences believe these myths.

Reduction of pathogens in the processing industry, control of residues, backward/forward tracing in the event of a food-borne disease outbreak, and control of zoonotic pathogens are among the many benefits of an animal identification system (Vitello & Thaler, 2001). This literature was supported by our students' agreement that the NAIS will help track sick animals back to the source of infection, and that the NAIS would prevent the spread of livestock diseases. However, students disagreed that the NAIS would have an economic benefit to the producer, revealing an inconsistency with the findings of Vitello and Thaler, who cited economic burden of disease outbreaks could be reduced for the packer and producer with an identification system.

Respondents reported that traceability of food through the food supply chain was important, which contradicted the findings by Nordstrom et al. (2000) that food safety was of utmost importance and concern. Respondents reported that the NAIS was important to maintain a safe U.S. food supply and was important to the U.S. economy, confirming Terry and Lawver's (1995) conclusions that students generally held positive perceptions about the impact of agriculture on the economy and environment.

Students' indicated which information sources they used to learn about the NAIS, the influence of the source, and how often they accessed each source. Evidence of university professors' rank as a very influential source for information about the NAIS supported the findings of Wingenbach et al. (2003) that students gained awareness of biotechnology through science classes, labs, and university professors' beliefs. This finding emphasizes the impact university professors had on students concerning livestock industry issues. Respondents indicated that university professors, Internet, and family members or friends were the most favorable, while Cooperative Extension, radio, and popular magazines were the least favorable sources of NAIS information. These findings are somewhat inconsistent with those of Tucker et al. (2006) that respondents favored traditional media such as newspapers and television news. Perhaps exploratory research should be conducted to determine if college students are using information sources for livestock industry issues that were not included in the survey. Also, an investigation of how students access and process NAIS information could help agricultural educators and communicators better educate students about the impacts of the NAIS.

Perceptions of the NAIS were positively associated with awareness of the NAIS for all respondents. Lower and upperclassmen animal science majors' NAIS perceptions were very strongly associated with their NAIS awareness. The finding that knowledge and perceptions of the NAIS were not associated suggests that further research is needed because previous literature (Humphrey, 1992, as found in Wright, Stewart, & Birkenholz, 1994) found weak positive relationships between knowledge and perceptions scores related to agriculture.

Students' awareness of the NAIS was positively associated with Cooperative Extension, private organizations, and university professors, resulting in a rejection of the null hypothesis that opinion leaders did not affect student awareness of the NAIS. Opinion leaders affected students' awareness of the NAIS. This finding supported previous literature (Tucker et al., 2006; Wingenbach, et al., 2003). University agricultural educators must be cognizant about the impact their beliefs have on students' awareness and perceptions of agricultural issues.

Information seen or read through mass media channels creates the reality of science for most people (Nelkin, 1995), and the news media plays a major role in disseminating information and bringing scientific issues to the public's attention (Malone, Boyd, & Bero, 2000). In this study, mass media were not positively associated with students' awareness of the NAIS. Perhaps it was because the NAIS was not a critical issue, thereby limiting its popular media exposure.

The role of opinion leaders as information sources, such as Cooperative Extension, private organizations, and university professors in influencing students' awareness of the NAIS highlighted the significance of the two-step flow of communication. The indirect flow of information from mass media to opinion leaders and then to the less informed public (students in this case) was evident in this study. Mass mediums such as television, radio, newspaper, or popular magazines were not significantly associated with students' awareness of the NAIS. Cooperative Extension, private organizations, and university professors, however, were significantly associated with students' awareness of the NAIS, thereby suggesting that opinion leaders were more influential on students' NAIS awareness than were mass mediums.

Student knowledge was not correlated with any of the listed opinion leaders. House et al. (2004) found that female respondents with a college education had significantly higher objective and subjective knowledge levels of genetically modified foods than did those without a college education. Additional research is needed to determine the origin of college students' topic-specific knowledge about national agricultural issues. Maybe future research could determine if high school agricultural education programs influence students' knowledge of the NAIS.

Tucker et al. (2006) stated that food safety specialists and communicators can be key players in educating consumers about food biotechnology risks and benefits. It is important that information concerning food biotechnology be presented realistically, with unbiased opinions, and disseminated through commonly used mass media channels. Widespread media coverage of topics such as avian bird flu, mad cow disease, foot-and-mouth disease, and bioterrorist attacks on the food supply would undoubtedly increase awareness of food safety issues among all consumers, not just those who actively seeking food safety information. Livestock industry specialists and communicators could be key players in educating college students and consumers alike about NAIS benefits, risks, and implications. Disseminating unbiased NAIS information is important to educate students as they transition into consumer and livestock producer roles.

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Comparison of Different Management Techniques on Hay Wastage in Horses Fed Coastal Bermudagrass Square Baled Hay

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ABSTRACT

Twelve two-year old Quarter Horses in training were used to determine the amount of Coastal bermudagrass hay (*Cynodon dactylon* L.) (Coastal) wastage and incidence of colic when hay was fed in a commercial type feeder versus on the ground. A 2 x 2 Latin Square Design was used as the experimental design. Horses were housed in 3.048m x 4.267m box stalls and offered Coastal at 1.75% their body weight. In treatment 1, horses were offered Coastal on the ground for 14 continuous days. In treatment 2, horses were offered Coastal hay in a common commercial feeder for 14 continuous days. Collection of waste was conducted twice daily one hour prior to next feeding. Waste included any hay on stall floor, or any that may have fallen behind feeder or immediately in front of stall. Once waste was collected all remains were dried, weighed, and recorded. Signs of colic were observed before and after every feeding. No differences were seen in dry matter intake between treatment groups. Wastage (DM) was lower ($P<0.001$) when Coastal was fed in a commercial feeder versus when fed on the ground. No signs of colic were observed throughout the trial.

KEY WORDS: Coastal bermudagrass, horse, waste

INTRODUCTION

The price of hay in the United States has increased in recent years due to increased fuel costs and lack of supply due to drought. To compound the problem, feeding and storage practices of hay have also contributed to large annual economic losses (Gibbs, 2007). The combination of these variables has made horse ownership become increasingly more expensive. Square baled hay is generally used when horses are fed in a stall setting (Parker, 2003). Some producers prefer to feed their horses on the ground while others prefer to feed in a feeder. Opinions vary on each practice. Some believe that feeding hay on the ground is a more natural way to feed, is safer, and helps reduce ingestion of foreign materials. However, others believe that by feeding hay in a feeder, chance of colic and waste of hay may be reduced (NRC, 2007). Therefore, a better understanding of wastage and consumption of Coastal being fed to horses in a stall setting is needed to help producers make smart decisions in the current economy. The study had two objectives. 1: To determine the amount of Coastal wastage when horses were fed hay in a commercial feeder versus on the ground in a stall setting and 2: To determine the amount of colic that occurred when horses were fed Coastal in a commercial feeder versus on the ground in a stall setting.

MATERIALS AND METHODS

Twelve two-year old Quarter Horses in training were used to determine hay waste when fed Coastal on the ground or in hay feeders while being housed in 3.048m x 4.267m stalls. A 2 x 2 Latin Square design was used as the experimental design. On day 0 horses were dewormed with a common commercial anthelmentic, placed in stalls, and offered Coastal hay at 1.75% of their body weight on the ground inside the stall area. Horses were fed for 7 days before collection began to allow for any adjustment necessary to the Coastal. Horses were fed at approximately 7:00 am and 4:30 pm daily. On day 7, horses were weighed. Horses then received Coastal hay at 1.75% of their body weight on the ground for 14 continuous days. On day 15, horses were fed Coastal in the feeder for another 14 continuous days. Waste collection occurred daily one hour prior to next feeding. Signs of colic were observed before and after each feeding. The Coastal waste consisted of any hay that was on the stall ground. The process of collection consisted of hand picking through the stall to collect the Coastal waste. To insure the hay outside of the stall was included, the aisle way was swept twice daily. The Coastal waste from the front of the stalls was included and added to the total waste of that stall. The Coastal waste from each stall was collected, dried, and weighed. The same collection processed was used in both treatments; however in treatment two, all of the Coastal that remained in the feeder was considered to be edible and therefore was not considered waste. Horses were exercised daily. Stalls were cleaned of urine and fecal material daily. Clean, fresh water was provided free choice. Upon placing hay in stalls, each flake of hay was sampled for dry matter analysis and nutrient composition (Table 1). After trial was completed, statistical analysis was performed to determine differences amongst treatments

Table 1. Nutrient Analysis of Coastal Bermudagrass Hay[a].

Item	Value
DM, %	90.25
ADF[b],%	31.93
CP[c], %	11.12
TDN[d], %	53.86
Ca, %	0.28
P, %	0.18

[a]All values except DM, % are expressed on a DM basis
[b]ADF = acid detergent fiber
[c]CP = crude protein
[d]TDN = total digestible nutrients

RESULTS

Hay waste on a DM basis was lower ($P<0.001$) when hay was fed in a feeder versus when fed on the ground (Table 2). The mean percent waste for Coastal when fed on the ground, was 19.55% whereas, when fed in a feeder only 6.08% was wasted. No differences were found in dry matter intake (DMI) between treatment groups. No signs of colic were observed throughout the study.

Table 2. Dry Matter Intake and Waste of Coastal Bermudagrass Hay when Fed on the Ground Versus in Feeder.

Item	TRT 1[a]	TRT 2[b]	P Value
DMI, kg	2.3	2.31	0.967
Mean Waste, kg	0.561[c]	0.149[d]	<0.001
Waste, %	19.55[c]	6.08[d]	<0.001

[a] Hay fed on ground

[b] Hay fed in feeder

DISCUSSION

In this study it was found that feeding Coastal on the ground in a stall setting resulted in a higher waste than when compared to being fed in a feeder. This appeared to be true primarily because commercial feeders helped to reduce waste caused by urine and fecal contamination, trampling, and hay used for bedding. Similar results were found by Lawrence and Coleman (Lawrence and Coleman, 2000). No differences were found in DMI and no signs of colic were observed throughout the study. However, when hay was fed on the ground more ($P<0.001$) waste occurred when compared to feeding hay in a feeder. Due to this large significant difference, economic loss would be much greater when hay is being fed on the ground. Table 3 demonstrates the dollar loss value associated with the different feed management practices. If considering the typical mature horse weighing 1,000 pounds and consuming approximately 6.8 kg of hay per day while also assuming that a typical Coastal square bale would weigh approximately sixty pounds; that horse would consume approximately 100 bales per year. If an average bale costs $8.00 the consumer would lose approximately $107.76 a year if they chose to feed hay on the ground versus in a feeder. This number rapidly increases with the addition of more horses. Further, the moderate size horse farm owning or training ten horses could potentially lose over $1,000 per year, where the larger horse farm could lose over $5,000 per year if hay was fed on the ground. Results from this study conclude that feeding Coastal in a feeder reduces waste as well as economic loss.

Table 3: Difference In Waste Over Time Between Feeding on Ground Versus in Feeder.

Item	19.55% Loss	6.08 % Loss	$ Difference
1 bale at $8.00	$1.56	$0.49	$1.08
10 bales at $8.00	$15.64	$4.86	$10.78
50 bales at $8.00	$78.20	$24.32	$53.88
100 bales at $8.00[a]	$156.40	$48.64	$107.76
500 bales at $8.00[b]	$782.00	$243.20	$538.80
1000 bales at $8.00[c]	$1,564.00	$486.40	$1,077.60
2000 bales at $8.00[d]	$3,128.00	$972.80	$2,155.20
5000 bales at $8.00[e]	$7,820.00	$2,432.00	$5,388.00

[a]Average consumption of 1 horse over 1 year
[b]Average consumption of 5 horses over 1 year
[c]Average consumption of 10 horses over 1 year
[d]Average consumption of 20 horses over 1 year
[e]Average consumption of 50 horses over 1 year

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Chemical Control of Wolfweed in South Texas

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ABSTRACT

Wolfweed, which is considered undesirable due to its lack of wildlife or agricultural value, forms dense colonies that inhibit the growth of other plants. We hypothesize that herbicide application following a mechanical treatment, such as shredding, will result in better control of this plant. The objective was to evaluate the effectiveness of a combination of the herbicides Picloram and 2, 4-D and shredding on wolfweed control. The study site is located in south Texas, in McMullen County. Treatments were randomly allocated in three blocks on shredded and non-shredded stands of wolfweed. Herbicide used was the combination of Picloram (10.2%) and 2, 4-D (39.6%). Three treatments were evaluated: recommended dose (RD), 1% of the herbicide in water; half of the recommended dose (HD), 0.5% of the herbicide in water; and control (C). A randomized complete block design in a 2x3 factorial arrangement of treatment and three replicates was used to evaluate these treatments. Response variable was percentage of mortality of wolfweed. ANOVA was used for statistical analysis and the Duncan's multiple range test was employed as a means separation procedure. No significant ($P>0.05$) interaction was found between factors. The percentage of mortality in wolfweed after application of the herbicide on the shredded area was similar for RD (19.9%) and HD (16.6%), but different ($P<0.05$) from C (0%). On the non-shredded area wolfweed mortality was similar for RD (52.1%) and HD (46.6%), but different ($P<0.05$) from C (1.8%). These results suggest that using half the recommended dose of this herbicide mixture provide similar control of wolfweed as the recommended dose. Additionally, a higher wolfweed mortality level was obtained when applying the herbicide to non-shredded stands.

KEY WORDS: *Aster spinosus*, wolfweed, herbicide, percentage mortality, shredded

INTRODUCTION

Exotic and native shrubs and trees can be problematic for ranchers in south Texas. Control of unwanted plants can result in increased rangeland production within a few years (Holechek et al., 2004). Methods to accomplish this include chemical, biological, mechanical, fire, or by the utilization of different species of animals. Plant control in range management is simply the reduction of unwanted or undesirable plants that have invaded or increased in a plant community (Rollings et al., 1988).

The complexity of the rangeland ecosystem and the sophistication of agricultural chemicals used today make interactions of herbicides with the environment a basic concern. That concern over the fate of agricultural chemicals in the environment has long provided the impetus for carefully study of chemical residues, their persistence, and the forces which determine the rates and routes of their dissipation (Scifres 1980). According to Mitchell et al. (2004), many ranchers have changed their brush management objectives, because the wildlife habitat interests and concerns are aimed at endangered species and nongame animal. Therefore, ranchers have reduced the broadcast application of herbicides in many of these ranches. The managers are starting to depart from the broadcast herbicide control, since they want to have the ability to pick and choose the particular brush they want to eliminate or control now. One of the greatest restrictions herbicides on rangelands will have to face in the future will be the protection on endangered species. Even with that restriction, herbicides will continue to be an important tool in brush control management in the rangeland for the next one or two decades (McGinity 2004).

The Executive Order (EO) 13112 instructs federal agencies to use relevant programs and authorities to prevent the introduction of invasive species, detect and respond rapidly to control populations of such species, and monitor invasive species populations. Federal agencies are also required to provide for restoration of native species and habitat conditions, conduct research on invasive species and develop technologies to prevent introduction, and provide for environmentally sound control of invasive species. Additionally, federal agencies shall not authorize, fund, or carry out actions likely to cause or promote the introduction or spread of invasive species in the United States or elsewhere (http://ceq.hss.doe.gov/nepa/regs/eos/eo13112.html, accessed March 29, 2010). "Exotic" (alien) species are defined in EO 13112 as any species, including its seeds, eggs, spores, or other biological material capable of propagating that species that is not native to that ecosystem. "Native" species, with respect to a particular ecosystem, are those species that, other than as a result of an introduction, historically occurred or currently occurs in that ecosystem. "Invasive" species are defined as those species whose introduction does or is likely to cause economic or environmental harm or harm to human health (Executive Order 13112, February 3, 1999, http://ceq.hss.doe.gov/nepa/regs/eos/eo13112.html, accessed March 29, 2010). Within this definition, invasive species also includes those native species that readily invade and dominate disturbed areas (e.g. Wolfweed).

Wolfweed (*Aster spinosus* Benth.) is a perennial native forb that is readily found throughout the Southwestern United States and more locally along the Nueces River floodplain. It has several common names and scientific names. Other common names include: Devil-weed aster, Mexican devil-weed, and spiny aster. Other scientific names include: *Leucosyris spinosa*, *Chloracantha spinosa*, and *Erigeron ortegae* (Everitt et al., 1999; Everitt et al., 2007; USDA-NRCS). Wolfweed is a perennial plant that spreads by rhizomes and, consequently, occurs primarily in clumps or continuous stands rather than as individuals. The stems are slender, erect, and bright green. Stem height ranges from 0.5 to 2 meters, but usually averages 1 meter. Dense stands develop in which stem densities exceed 100 stems per square meter. Short thorns, variable in size and number, occur on mature stems. The stems are responsible for photosynthetic activity, since leaves are present for only a brief period in the spring. The oblong leaves are as long as 8 centimeters near the base of stems, but smaller, tapered leaves occur in the upper canopy (Mayeux et al., 1979; Everitt et al., 1999).

Wolfweed grows on a variety of slightly saline mineral soils, ranging from clay to sand. This plant grows best under periodic flooding regime, and is therefore localized to river bottoms and floodplains. It also forms dense colonies in different habitats, but it is more common in low, moist sites. It is a problematic weed on many rangelands in south Texas where soils have heavy clay content and high water holding capacity (Everitt et al., 2007). Wolfweed is highly undesirable due to its lack of wildlife or agricultural value, except to possibly provide dense cover to hogs and white-tail deer (*Odocoileus virginianus*). Dense colonies of this plant can actually serve as a barrier to other animals such as quail (*Colinus virginianus*) and turkey (*Meleagris gallapavo*).

The dense colonies of wolfweed are very hardy and thrive in low lying areas that have been abused by past management practices. These colonies are very difficult to control by fire because they lack sufficient fuel to carry or sustain a fire. Additionally, they are green throughout most of the year. Mechanical treatments such as annual shredding used in conjunction with herbicidal applications show the best promise for control.

The objective study was to evaluate the effect the herbicides Picloram and 2, 4-D and shredding on wolfweed control. We hypothesize that herbicide application following a mechanical treatment such as shredding will result in better control of this plant.

MATERIAL AND METHODS

The study was conducted on Escondido Ranch (28°05' N; 98°43' W), located in McMullen County, 25 km north of Freer, Texas, USA. The ranch encompasses 6,800 acres of south Texas brush country. The herbicide used was a combination of Picloram (10.2%), which is a systemic herbicide used for general woody plant control, and 2,4-D (39.6%), which is also a systemic herbicide commonly used in the control of broadleaf weeds. Three treatments were evaluated: recommended dose (RD), 1% of the herbicide in water; half of the recommended dose (HD), 0.5% of the herbicide in water; and control (C). A randomized complete block design in a 2x3 factorial arrangement of treatments and three replicates was used to evaluate these treatments. The response variable was the percentage of mortality of wolfweed. An analysis of variance (ANOVA) was used for the statistical analysis and the Duncan's multiple range test was used for means separation. SAS was used to perform the statistical analysis (SAS 2000).

RESULTS AND DISCUSSION

No significant ($P>0.05$) interaction was found between factors. Percent mortality of wolfweed was higher ($P>0.05$) in non-shredded compared to shredded areas in autumn. These results agree with Scifres *et al*. (1981), where they evaluated the response of whitebrush (*Aloysia lycioides* Cham.) to two different herbicides and concluded that shredding this plant before the application of either herbicide usually did not improve whitebrush control. On the contrary, Mutz *et al*. (1979) and Mayeux *et al*. (1979), reported that herbicide applied in the spring shortly after shredding increases the effectiveness of control of this plant. In our case, since the shredding was conducted in autumn when the plant was not actively growing, the response of wolfweed in terms of regrowth was not very aggressive in terms of leaf production; therefore, the lower effectiveness of the herbicide in the shredded areas may have been due to the lack of photosynthetically active tissue for the herbicide to be absorbed. Leaf presence would have increased total absorptive area of the plant and thus improved spray interception (Mayeux *et al*., 1979). The percentage of mortality of wolfweed on the shredded area resulted similar (P>0.05) for RD (19.9%) and HD (16.6%), but different (P<0.05) from C (0%). A similar results were obtained in the non-shredded area mortality resulted similar for RD (52.1%) and HD (46.6%), but different (P<0.05) from C (1.8%) (Table 1). The effectiveness of reduced doses of herbicides on control or suppression of weeds, and profitability has been reported before by Klingaman *et al*. (1991). When working with imazethapyr rate and time of application on weed species common to the Mississippi Delta soybean production area, they found percent mortality was similar when they applied the recommended rate (70 g/ha) of herbicide imazethapyr, as compared to a dose below labeled rate on common cocklebur (*Xanthium strumarium* L.), smallflower morningglory (*Jacquemontia tamnifolia* L.), and smooth pigweed (*Amaranthus hybridus* L.) if applied to 3 true-leaf or smaller weeds. This indicates that early application is critical for low imazethapyr rates to be effective. Similar results have been reported by Belles *et al*. (2000), obtaining that 50 percent of the dose of the herbicide PP-604 consistently had over 85 percent control of the weed wild oat (*Avena fatua* L.) in barley (*Hordeum vulgare* L.). In another study, Zhang *et al*. (2000), analyzed published data on the use of below labeled doses of herbicides in order to determine the efficacy and risk of controlling weed at reduced herbicide rates. They mention that utilizing below label doses might be effective since registered doses are set to guarantee adequate control over a wide range of weed species, growth stages, and weed densities. They also found that combining reduced doses of herbicides with other management practices can increase the odds of successful weed control. Dieleman and Mortensen (1998), suggest that reduced doses might be a good strategy if the objective is to place the desired plant at a competitive advantage over the weeds, rather than a total weed control. Herbicides applied at lower doses will have a fit in specific situations as they might allow increased profits to be realized by growers and minimize the risk to the environment (Blackshaw *et al*., 2006).

Table 1. Mortality of *Aster spinosus* on shredded and non-shredded areas on Escondido Ranch.

Treatment	***Non-Shredded***	***Shredded***
	Mortality of wolfweed (%)	
RD	52.1 a*	19.9 a
HD	46.6 a	16.6 a
C	1.8 b	0 b

* Values with different letter within columns are different (P<0.05)

These results suggest that using half the recommended dose of the herbicide combination of Picloram (10.2) and 2,4-D (39.6%) will control wolfweed at similar rate as the recommended dose 1% of the herbicide in water. Utilizing half of the recommended dose will result in a significant economical benefit. The economic results are a cost savings for the producer, with additional environmental benefits of reductions in residues and herbicide leaching into groundwater, or contamination through water runoff. Economically, the application of the reduced dose resulted in a reduction of $5.13 per acre, as compared to the recommended application rate which is a very significant reduction when commercial applications are conducted.

According to these results, there is no need to use a shredder on wolfweed prior to the application of the herbicide in autumn, since a higher percentage of mortality can be obtained when applying the herbicide on non-shredded stands. This is an additional cost savings of shredding, which according to production budgets and comparable area costs, results in an additional cost savings of $14 per acre.

CONCLUSION

The best result for reducing wolfweed population in autumn may be obtained with the use of 0.5% in water of Picloram (10.2%) and 2,4-D (39.6%) herbicides applied to non-shredded stands. Similar results were obtained with the reduced and the recommended dose, therefore, a considerable reduction in the cost of the treatment was obtained in addition to the biological result.

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Nitrogen Management in No-till and Conventional-till Dual-use Wheat/Stocker Systems[2]

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ABSTRACT

Winter wheat in the Texas Rolling Plains is utilized both as forage and grain crop on more than 50% of the wheat sown, and employs conventional tillage in a semi-arid region prone to severe soil erosion by wind and water. The study compared forage and grain yield response to pre-plant and top-dress N application in no-till and conventional-till dual-use wheat production systems. Five pre-plant N levels, two tillage systems, and one top-dress N application were evaluated. There was a linear increase in forage production with increasing pre-plant N application, and no significance difference in forage yield between conventional- and no-till in 3 of 4 yr. Grain production increased with increased pre-plant N, while top-dressed N enhanced grain yield an additional 20 to 40%. In 2 of 4 yr, conventional-till resulted in increased grain yield over no-till by about 10 to 12 %. Top-dressed N resulted in significant yield increases in all pre-plant N treatments but with the greatest yield increases from the 0 and 34 kg ha^{-1} pre-plant N treatments. Soil analysis data indicate that following poor wheat production years, residual nitrate N can be substantial and could offset N fertilizer requirements for the following wheat crop.

KEY WORDS: nitrogen fertility, dual-purpose wheat, grazing systems, conservation tillage

INTRODUCTION

More than 5 million hectares of hard red winter wheat are planted annually in the semiarid regions of Texas, Oklahoma, and New Mexico (Taylor et al., 2010). Crop production in the winter-active southern Great Plains is unique and versatile compared with other wheat-producing regions in the U.S. because of the common practice of utilizing wheat forage in stocker cattle grazing systems, with the option to terminate wheat grazing and still produce a grain crop (dual-use or dual-purpose systems), or as a hay crop (MacKown and Carver, 2005). Most research on winter wheat is conducted on grain-only systems. Less information is available concerning dual-use wheat production. Furthermore, studies that involve conservation tillage systems in dual-use wheat

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production are virtually non-existent, but important due to increasing wheat production costs and public sensitivity to environmental and land management issues.

The use of winter wheat as a dual-use crop is a vital component of the agricultural economies of Texas, southern Kansas, eastern New Mexico, Oklahoma, and southeastern Colorado (Pinchak et al., 1996; Ralphs et al., 1997; Redmon et al., 1995; Shroyer et al., 1993). Furthermore, the wheat-stocker industry has a comparative advantage in this region because of the proximity of feedlots. In a 20-yr study, Epplin et al. (2001) showed net returns from dual-use wheat production in Oklahoma exceeded net returns from grain-only production 3 out of 4 years. Furthermore, Sij et al. (2007) in their phosphorous placement study showed that the dual-use system was clearly superior to the graze-out system. Dual-use wheat production is complex and requires a higher level of management than a grain-only wheat production system. Successful dual-use wheat production depends on planting date, planting rate, wheat variety, nitrogen fertility, grazing and livestock management, and grain yield (Kaitibie et al., 2003; Shroyer et al., 1993). Introducing an animal component in a dual-use wheat system increases the complexity of a host of management decisions in order to optimize economic return from forage, grain yield and quality, and beef production. For example, planting date is important to the development of adequate forage prior to placement of calves. Research has shown that forage production decreases with delayed planting dates while grain potential increases with delayed planting (Epplin et al., 2000; Hossain et al., 2003; Arzadun et al., 2006).

Due to the high nutritive value of wheat forage (Schlehuber and Tucker, 1967; Shroyer et, al., 1993), it has been estimated that, annually, 30 to 80% of the wheat planted in the southern Great Plains is grazed to varying degrees (Krenzer et al., 1992; Pinchak et al., 1996; True et al., 2001). The value of forage based animal weight grains relative to the value of grain (Epplin et al., 2000; Hossain et al., 2003) is the single most important consideration in dual-use wheat production since management decisions need to be made on planting date, availability of stockers, stocking rate, beef prices, fertility, soil moisture, wheat cultivar, field by field grazing potential, and grain yield potential (Arzadun et al., 2003; Shroyer et, al., 1993). Farmers and ranchers tend to utilize wheat entirely as a forage crop (graze-out) if cattle prices are high relative to wheat grain, whereas they tend to remove cattle prior to the onset of the reproductive stage and allow the wheat to develop grain if wheat prices are high relative to cattle (graze-plus-grain). Termination of grazing is also a critical management decision. Pull-off date is dependent on when a given wheat variety reaches the early stages of reproductive development. Highest grain yields are associated when cattle are pulled off at 'first hollow stem' stage of growth (Redmon et al., 1996). A late cattle pull-off date can significantly affect grain yield and subsequent net returns from a dual-use system (Taylor, et al., 2010). Grazing 2 wk beyond first hollow stem can reduce grain yields 10% and additional 10% for each of the following 2 wk (Fieser et al., 2006).

Variable environmental conditions in semiarid regions of the world largely determine wheat forage and/or grain production (Arzadun et al., 2006; Bowman et al. 2008). In dual-use systems, wheat is generally planted in September under the conventional-till system that requires numerous field operations to prepare "clean" fields prior to seeding. Unfortunately, soil moisture is lost in the process. Without residue, wheat seedlings are unprotected from the desiccating and abrasive action of wind and blowing soil, or an unanticipated high rainfall event. Large areas become subject to replanting, creating costly delays in wheat establishment and plant growth needed in a graze and grain production system. Although many producers in the Southern Great Plains have been reluctant to adopt conservation tillage systems, conservation tillage holds promise in mitigating soil, nutrient, and moisture losses while reducing several key production costs (Ribera et al., 2004).

Inadequate weed control is cited as a limiting factor for producers in adopting reduced-tillage systems (Camara et al., 2003). Studies by Epplin et al. (1991) showed weed control costs were mainly responsible for no-till's uncompetitiveness with conventional-till in grain-only systems. More recently, herbicides, particularly glyphosate, have become more cost effective in controlling weeds. In a dual-use system, Bowman et al. (2008) showed no-till to be as effective as conventional-till and reduced-till in establishing small grain pasture when fall rainfall was adequate to establish the crop and superior to conventional-till and reduced-till when fall rainfall was delayed and soil moisture was maintained by summer chemical fallow. Although no-till has been reasonably successful on large farms in grain-only systems in north Texas, no-till has not been adopted in dual-use wheat due to perceived problems with compaction, forage production, seedling establishment, weed control, and grain yield. Tillage studies in Oklahoma in 2002-2005 by Decker et al. (2009) showed higher net returns for the conventional tillage, dual-use system while no-till generated greater returns for the forage-only systems on the larger farms. However, their results also show grain yield from the dual-use system to be higher than the later-planted grain-only system, which is not normally the case (Epplin et al. 2000; personal communication, Stan Bevers, Texas AgriLife Extension Economist). Machinery and equipment costs as well as herbicide, fuel, labor, and fertilizer costs (plus farm size) impact profitability. However, farm size continues to increase due to economies of scale which impacts equipment costs, labor, and time spent in the field. Longer-term studies with no-till versus conventional-till are needed, since it is generally recognized by promoters of no-till that it may take 4 or 5 years to fully recognize the benefits of this conservation tillage practice..

For producers to accept no-till under dual-use wheat management, the system must be economically competitive with traditional conventional-till and produce adequate forage for beef cattle as well as grain yield. Nutrient management in dual-use systems, particularly N, can be more complex than forage-only and grain-only systems. Since N is an expensive input cost in wheat production, the main objective of this research was to evaluate and identify pre-plant and top-dress N fertilizer requirements on forage and grain production in a conventional-till and no-till wheat-stocker production system using free-ranging cattle.

MATERIALS AND METHODS

Research was initiated with a grain crop in 2004 and forage and grain crops in 2005, 2007 and 2008 at the Smith/Walker field research unit located about 16 kilometers south of Vernon, Texas (lat 34.057; lon -99.243). The soil was an Abilene clay loam (fine, mixed, superactive, thermic Pachic Argiustolls) with a 1 to 3% slope. Dryland crop production in semi-arid environments like the southern Great Plains poses a greater risk due to unforeseen prolonged droughts, hail, and high winds, as evidenced by failed grain yield in 2006 due to extreme drought.

The study was nested in a larger 14-hectare pasture that had been in no-till management for 4 year Crossbred stocker cattle (*Bos taurus* L) had initial average weight of 200 kg. Plot size was 6 m by 15 m. All fertilizer was surface applied as liquid material.

Two tillage systems (no-till and conventional-till) were used. Only chemical weed control was used in the no-till system. The conventional-till system included multiple discings to remove the previous year's wheat stubble, maintain weed control, and prepare a clean seed bed. Fertilizer treatments were applied to the same plots each year in each tillage system. Pre-plant N treatments included 0, 34, 67, 101, and 135 kg N ha^{-1}, with and without 50 kg N ha^{-1} top-dressed each year in the January-early February time frame (tillering stage). A randomized complete block design with four replications was used. The entire test site received a pre-plant application of 45 kg ha^{-1} P_2O_5 as phosacid prior to initiating the study. The "Cutter" wheat variety was planted in mid-September each year at 67 kg ha^{-1}.

Approximately one week before animal placement, forage dry matter was determined for each plot by harvesting all forage to ground level with hand shears in two randomly-selected 0.5 m^2 quadrats. Subsequently, two 1.7 m^2 circular cages were randomly placed on each plot. Forage was harvested inside and in randomly-selected grazed areas outside one of the cages to determine forage production and forage availability in each plot. Following clipping, one cage was randomly repositioned (excluding clipped areas) within each plot and the procedure was repeated until cattle were removed at first hollow stem. Depending on environmental conditions and plant development, there were two to four forage harvest dates per year. The other cage remained in place to determine seasonal forage production in an ungrazed environment. Forage samples were dried at 50^0 C for 72 hours in a forced-air oven to determine dry weights. Forage protein was determined by Olsen's Agricultural Laboratory (McCook, NE) using the combustion method (AOAC method 968.06 and a Perkin Elmer 2410 combustion analyzer).

Two, 6 -m by 1.5 -m strips were machine-harvested with a plot combine from each plot and grain samples bulked to determine plot yield. Grain yield was adjusted to 130 gm kg^{-1} moisture content. Grain protein was determined by a NIR INFRATEC 1226 Grain Analyzer (Cereal Quality Laboratory, Texas A&M University, College Station). Data were analyzed using the Proc Mixed model procedure of SAS Institute (1996). Treatment effects were considered significant at $P \leq 0.05$.

There have been questions concerning the amount of N remaining in the soil profile following a failed wheat crop. Knowing this information would be helpful in determining pre-plant N application rates the following season, and perhaps improve the economics of dual-use wheat production. To aid in answering this question, soil samples were taken in August of each year following wheat harvest. Soil samples from all plots were separated into three sampling depths, bulked, and analyzed by year. In 2006, wheat was not harvested for grain due to drought (Figure 1). In 2007, wheat yields were the lowest of the 3 yr that produced grain (Figure 4).

RESULTS AND DISCUSSION

The distribution and timeliness of rainfall in late summer and fall are critical factors in establishing wheat stands and adequate forage production to support stocker cattle through the winter. In the southern Great Plains, drought is a constant threat to the dual-use production system. Figure 1 shows the rainfall patterns during wheat production over the course of the study and typical of the semiarid environment. Due to environmental conditions, it is uncommon to have two good wheat production years in sequence. Years that resulted in forage production for stocker cattle from December through February due to either pre-season or in-season rainfall include 2004-2005, 2005-2006, and 2006-2007. Forage production was inadequate due to drought during the typical grazing season in 2007-2008. However, precipitation beginning in February 2008 was adequate to produce a grain crop.

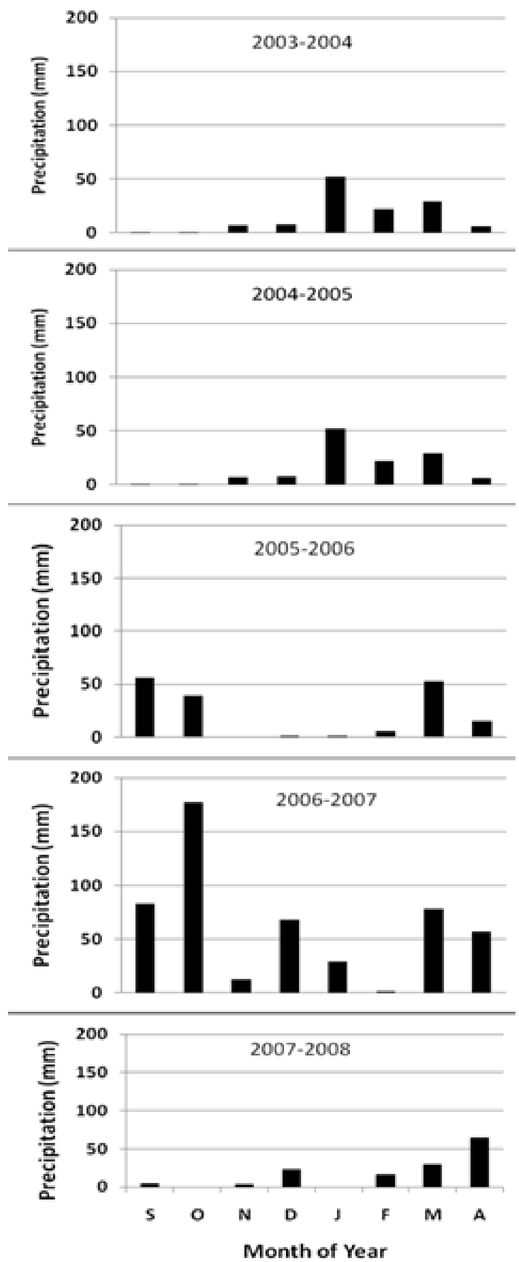

Figure 1. Precipitation patterns from September through April from 2003 to 2008 at Vernon, TX.

There was no interaction between tillage system and pre-plant N for forage production. Soil moisture level prior to planting and the rainfall pattern prior to the onset of cold weather that retards plant growth greatly affects forage development essential for acceptable beef cattle production. Due to adequate and timely rainfall, forage production in 2004-2005 increased linearly with increasing pre-plant N (Figure 2). Sparse rainfall the following growing season resulted in little forage production and no response to pre-plant N. The 2006-2007 growing season received excessive moisture, resulting in higher, but erratic, forage production among the pre-plant N treatments. Erratic forage production among N treatments may be due to field drainage patterns and low areas that allowed saturated soils to persist. This affected plant development in some plots and mean forage yield, most notably the 101 N kg ha^{-1} pre-plant treatment.

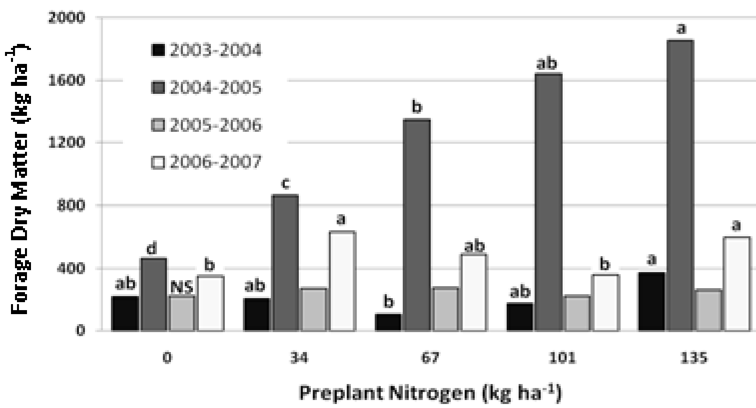

Figure 2. Effect of pre-plant N on forage production in the 4 yr that produced biomass. Within years, values followed by different letters within pre-plant N treatments are significantly different at $P \leq 0.05$.

Averaged over all pre-plant N treatments, only forage production from the 2005-2006 growing season was significantly different between conventional-till and no-till (Figure 3). It should be noted that the 2005-2006 growing season resulted in forage production that was also insufficient for commercial beef production. Therefore, in our opinion, the 2005-2006 data are questionable in interpreting tillage system benefits on forage production.

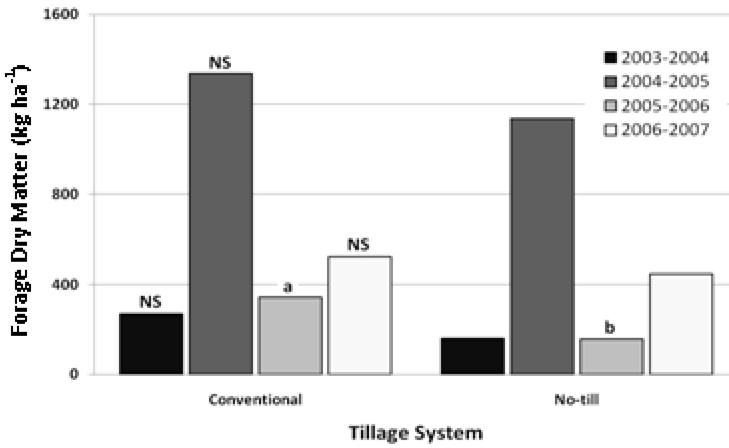

Figure 3. Forage production response by year to tillage system across pre-plant N treatments. Values followed by different letters within years are significantly different at $P \leq 0.05$.

There was no interaction between pre-plant N and tillage system for grain yield; therefore, the data were averaged over all pre-plant N treatments (Figure 4). In 2 out of 4 yr, there was no significant difference between tillage system and grain yield.

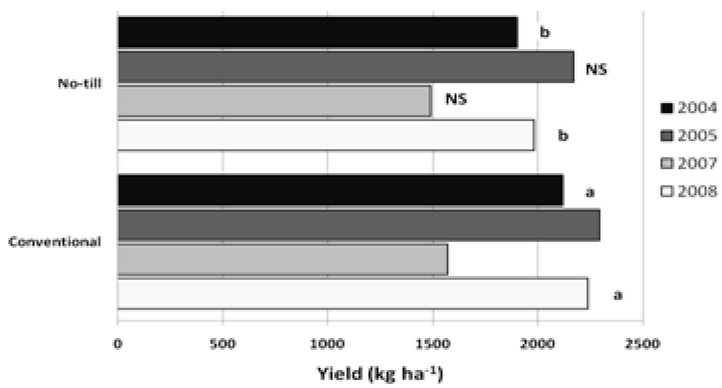

Figure 4. Grain yield response to pre-plant N treatment and two tillage treatments. Values followed by different letters within years are significantly different at $P \leq 0.05$.

There was no interaction for yield between tillage system and pre-plant and top-dressed applications of N fertilizer. Figure 5 shows the 4-yr average yield response to different levels of pre-plant N fertilizer with and without 50 kg N ha^{-1} top-dressed N. Pre-plant N at about 67 kg ha^{-1} appeared to maximize grain yield under the environmental conditions of this experiment. Top dressing N increased grain yield at all pre-plant N applications, except at the 67 kg ha^{-1}. Except perhaps at the highest pre-plant N application, top dressing 50 kg N ha^{-1} appeared to increase grain yield regardless of the amount of pre-plant N up to 101 kg ha^{-1} N (Figure 5). Our results are similar to those obtained in a grain-only, N application timing study that showed N application at tillering resulted in the highest grain yield (Melaj, et al. 2003). However, the greatest yield response to top-dressed N occurred at the 0 and 34 kg ha^{-1} pre-plant N treatments, and presumably provides the greatest economic return for the total amount of N applied.

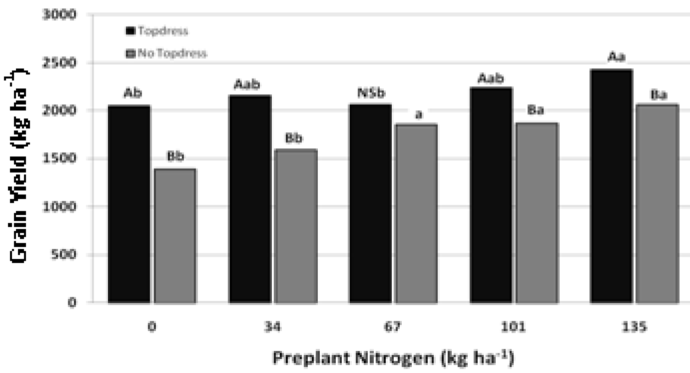

Figure 5. Effect of pre-plant N on grain yield with and without N top-dress across all years and tillage treatments (values followed by different capital letters within a pre-plant N treatment are significantly different at $P \leq 0.05$; similarly, values followed by different small case letters within no top-dress or top-dress treatments are significantly different at $P \leq 0.05$).

Forage protein is generally highest prior to the reproductive stage. Top dressing usually occurs in late January to early February in the Rolling Plains region while cattle are still on wheat pasture, but then removed in early March to allow a grain crop to develop. There was no tillage X year interaction on forage protein. Figure 6 shows forage protein from pre-plant only and pre-plant plus top-dressed plots on three selected N treatments. Over all years and tillage systems, forage protein increased with increased pre-plant N. Top-dressed N did not significantly increase forage protein over the pre-plant N-only treatments. Also, top-dressed N did not significantly increase forage protein with increased pre-plant N.

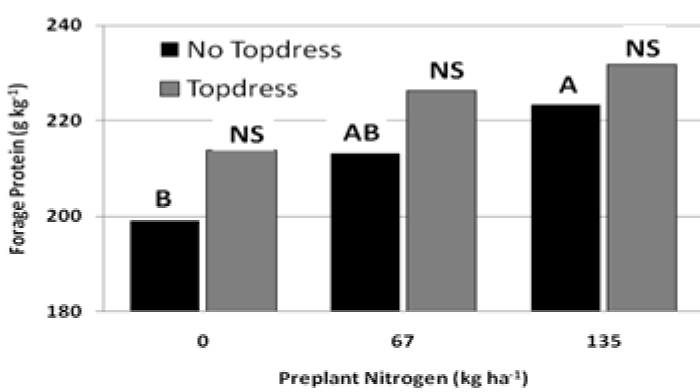

Figure 6. Forage protein from pre-plant only and pre-plant plus top-dressed plots on three selected N treatments. Values followed by different letters within no top-dress and top-dress N treatments are significantly different at $P \leq 0.05$.

There was no interaction between tillage system and N treatment on grain protein. In 3 of 4 yr, top-dressed N significantly increased grain protein (Figure 7). However, protein increases were marginal. Moreover, there is no economic justification to top-dress N for increased protein content alone, since producers in the Rolling Plains region do not receive a premium for grain protein content.

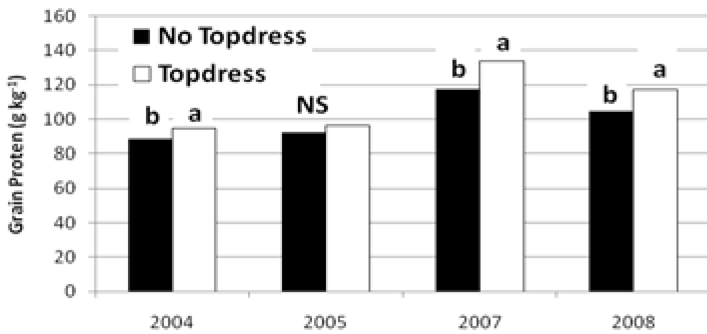

Figure 7. Effect of top-dressed N on grain protein for the 2004 – 2008 crop years. Values followed by different letters within years are significantly different at $P \leq 0.05$.

We attempted to determine the amount of residual nitrate in the soil following each wheat crop, since residual N impacts the cost of subsequent N inputs for the next season's crop. Except for 2007, nitrate levels were highest in the upper 15 cm of soil (Figure 8). The elevated nitrate level at the 15- to 30-cm depth in 2007 was most likely due to the leaching effect of higher precipitation in late spring (Figure 1) when over 400 mm of rainfall were recorded in May and June (data not shown). The elevated nitrate level in 2006 at the 0-15 cm depth reflects a failed wheat crop due to drought (Figure 1). These data indicate that following poor wheat production years, residual nitrate N may be substantial and could offset N fertilizer requirements for the following wheat crop. Soil testing to 60 cm is therefore suggested and could result in significant cost savings on N fertilizer.

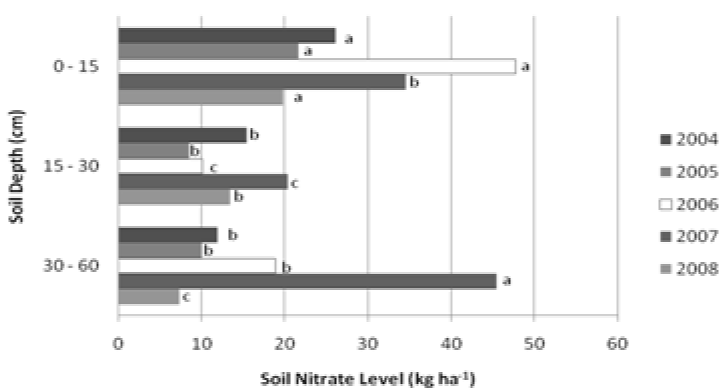

Figure 8. Residual nitrate levels following a wheat crop in the upper 60-cm of soil. Values followed by different letters within years are significantly different at $P \leq 0.05$.

CONCLUSION

A dual-use wheat production system increases the complexity of N fertilizer management in order to maximize forage, grain yield and quality, and beef yields. The current study evaluated and identified pre-plant and top-dress N fertilizer requirements on forage and grain production in a conventional-till and no-till wheat-stocker production system. There was a general linear increase in forage production with increasing pre-plant N application with no significant difference in forage yield between conventional- and no-till production systems in 3 of 4 years. Grain production increased with increased pre-plant N, while top dressed N further improved grain yield by 20 to 40%. In 2 of the 4 years conventional-till resulted in increased grain yield over that from no-till by about 10 to 12 %. Top dressing N resulted in significant yield increases in all pre-plant N applications but with the greatest yield increases when applied to the 0 and 34 kg ha^{-1} pre-plant N treatments, and presumably offers producers the greatest economic return for the amount of total N applied. Forage protein increased about 10% with increased pre-plant N applications from 0 to 135 kg ha^{-1} N, but top dressing N failed to increase protein over that of the top-dressed 0 kg ha^{-1} N pre-plant treatment. Top dressing N increased grain protein in 3 of 4 years, but the percent increase was marginal and would not bring a premium for grain quality. Our soil analysis data indicate that following poor wheat production years, residual nitrate N may be substantial and could offset N fertilizer requirements for the following wheat crop. Soil testing to 60 cm is therefore suggested and could result in significant cost savings on N fertilizer. With the prospect of improved management, technology, and equipment, our study provides supporting evidence that a no-till dual-use wheat production system can supply forage and grain yield comparable to a conventional-till dual-use wheat/stocker production system, while incorporating the positive environmental aspects of conservation tillage in a semi-arid environment.

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Economic Analysis of Manure Harvesting Equipment Utilized in Feedyards for Dust Control

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ABSTRACT

Large cattle production facility produces large amount of manure. One of the purposes of manure management is dust suppression, which becomes a greater issue in prolonged dry weather. Texas AgriLife Research and Texas AgriLife Extension Service personnel developed, compiled and analyzed a two-page written survey with the help of agricultural engineers. Survey data were utilized to determine the most frequently used manure harvesting equipment. Results showed that larger yards tended to own and operate the manure harvesting equipment themselves. Only 23% of medium-sized and 21% of large-sixed feedyards owned and operated an elevating scraper due to its high cost. The frequency for large, medium, and small-sized feedyards to hire manure-harvesting contractors were 71%, 39%, and 36%, respectively. The most frequently utilized manure harvesting implements identified in the feedyard manager survey, which were tractor-pulled box scraper, front-end loader and dump truck, had a combined hourly cost of $89.89.

KEY WORDS: dust control, manure harvesting, feed yards, particulate material (PM)

INTRODUCTION

Intensive cattle feeding operation is a major economic driver in much of the United States. In fact, feedyards under the Texas Cattle Feeders Association (TCFA) in Texas, Oklahoma and New Mexico[3]accounted for 30% of the nation's fed cattle production with a production of 7 million fed cattle in 2007. This equated to an about $7 billion industry and was a major regional stimulus. Furthermore, by the time the money circulated through regional residents and businesses, the total economic impacts were estimated at $19 billion (TCFA 2009). Feeding such a vast amount of cattle produces large quantities of manure. Manure contributes to atmospheric emissions, such as dust (particulate matter), hydrogen sulfide, ammonia, and volatile organic compounds.

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[3] TCFA represents the cattle feeding industry only in Texas, Oklahoma, and New Mexico.

Research by Sweeten (1979) revealed that beef cattle on high moisture concentrate rations excreted approximately 63 pounds of wet manure per day (at 85% moisture) per 1,000 pounds liveweight. An 850 pound steer produced eight pounds of manure solids per day. Natural processes of evaporation and biological decomposition decreased this to approximately two tons of manure (at 40% moisture) per animal per year that must be harvested from the pen surface. Quantities to be removed varied and depended on ration, animal density, feedyard surfacing material and cleaning procedures.

One of the purposes of manure management is dust suppression. According to Auvermann (2006), beef cattle receiving feed with a digestibility of 85%, 150 ft^2/hd animal spacing and a hypothetical uniform manure distribution produced over three inches of manure per year on the pen surface. Bench top experiments (Auvermann, 2006) supported conclusions drawn by Auvermann et al. (2000) that dust suppression became a greater issue as manure depth increases. Early implementation of dust control practices may reduce dust emissions. And typically a combination of techniques were implemented including: applying water to the pen surface, increasing the stocking rate in the pens, building sun shades, constructing windbreaks, and harvesting manure at optimal intervals.

This study focused on one method of dust control which is harvesting manure with equipment (Auvermann et al., 2000, Sweeten 1979). It was conducted to assist feedyard owners/managers in making informed decisions when purchasing implements. Specific equipment was identified by a survey developed and analyzed by Texas AgriLife Research and Texas AgriLife Extension, and administered by TCFA personnel.

The purpose of this study was to generate cost data for feedyard owners/operators to reference when making equipment purchasing and manure management decisions. The overall objective of this study was to identify and economically evaluate the most frequently used manure harvesting equipment. Examples of implements included: tractor-pulled box scraper, front-end loader, dump truck, spreader truck, elevating scraper, and tractor-pulled end-dump (Figures 1-4). The economic analysis was conducted by considering the following factors: 1) to determine the capital expenditure, salvage value, useful life in years, and normal annual hours of operation for 2010 model implements; 2) to establish the hourly fixed costs for interest, depreciation, insurance, registration, and taxes for each piece of equipment; 3) to identify the hourly operational costs for labor, fuel, maintenance and repairs, and lubrication of the machinery; and 4) to combine the fixed and operational costs to establish total hourly costs to own and operate the manure harvesting equipment.

Figure 1. Manure harvesting equipment (from left to right: elevating scraper, tractor-pulled box scraper, and front-end loader).
Source: Dr. Brent Auvermann, Texas AgriLife Research and Extension Center at Amarillo.

Figure 2. Manure harvesting equipment (spreader truck).
Source: Dr. Brent Auvermann, Texas AgriLife Research and Extension Center at Amarillo.

Figure 3. Manure harvesting equipment (dump truck).
Source: http://redwoodmetalworks.com/rmw-news/just-out-the-door/.

Figure 4. Manure harvesting equipment (End-dump tractor-trailer).
Source: http://talk.newagtalk.com/forums/threadview.asp?tid=146746&DisplayType=nested&setCookie=1.

MATERIALS AND METHODS

Texas AgriLife Research and Texas AgriLife Extension personnel developed, compiled and analyzed a two-page written survey that was reviewed by agricultural engineers. The survey was administered by TCFA personnel to 41 member feedyards during the first quarter of 2008. Major components of the survey focused on the manure harvesting equipment owned/operated by the feedyard and the manure collecting operations that were done by manure contractors. In the analysis, feedyards were stratified based on the number of head fed as follows:1) Small (less than 10,000 head capacity), 2) Medium (10,001 to 39,999 head capacity), and 3) Large (40,000 or more head capacity) to determine differences in operations utilized based on feedlot size[4]. The numbers related to large, medium and small-sized feedyards is 13, 14, and 14, respectively.

Survey data were used to determine the most frequently used manure harvesting equipment including: front-end loader, dump truck, spreader truck, elevating scraper, and tractor-trailer end-dump. The tractor-pulled box scraper was considered as one unit in this study because box scrapers are not self-propelled. After the most commonly used implements were identified, a cost analysis on an hourly basis was performed.

Six representative manufacturers in the Texas High Plains, South Plains, Dallas/Fort Worth, New Mexico and Oklahoma regions provided purchase price, salvage value, remaining value, useful life in years, and normal life in hours of operation for 2010 implement models. Hourly fixed costs for interest, depreciation, insurance, registration, and taxes were identified. A six percent discount rate was used to estimate cost streams in current dollars[5]. Depreciation was determined using the straight line-method with differing salvage values, dependent on each equipment. Insurance, registration, and taxes were calculated at one percent of the purchase price[6].

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[4] This stratification is based on the responses from feedyards.

[5] 6% of discount rate reflects 3% of rate of return and 3% of inflation.

[6] 1% for insurance, registration and taxes are based on responses from six representative manufactures.

Hourly components of operational costs include labor, fuel, maintenance and repairs (M&R), and lubrication. Operator labor costs were assumed to be $10.70 per hour, based on the U.S. Farm Wage Rate: Quarterly Data (NASS 2009). Actual hours of labor exceeded machine time by 10%, because it included travel and time required to lubricate and service the equipment. Consequently, labor costs were estimated by multiplying the labor wage rate of $10.70 with 1.10, to establish $11.77 for the hourly labor cost. Current diesel fuel price was averaged at $1.98 per gallon based on information collected from three distributors. Average fuel consumption (in gallons per hour) was provided by industry representatives and differed by equipment. Several manufacturers described M&R and lubrication as important expenditures because these help to prevent wear and tear and possibly extend the useful life of the equipment. Annual M&R costs were provided by manufacturers and varied by equipment. Lubrication expenditures were estimated at 15% of the diesel fuel cost. Tire replacement was a large expenditure, dependent on individual machinery, and was not included in this analysis because it varied widely by source.

Total hourly fixed and operational data were combined to arrive at a total hourly cost for each implement including: the tractor-pulled box scraper, front-end loader, dump truck, spreader truck, elevating scraper, and tractor-trailer end-dump for feedyard dust control. The results of the feedyard manager surveys were compared with the calculated total hourly cost of the most frequently operated manure harvesting equipment to determine if a correlation existed between equipment operations.

RESULTS

Manure harvesting equipment used in feedyards. Categorization was done to identify similarities or differences in manure harvesting practices to control dust among small, medium, and large feedyards (Table 1). The tractor-pulled box scraper was used by 50%, 69%, and 93% of the small, medium, and large feedyard sizes, respectively. Larger yards tended to own and operate the manure harvesting equipment themselves. For example, 100% of the large feedyards surveyed owned a front-end loader and 93% operated their own tractor-pulled box scraper. Medium-size yards (10,001 to 39,999 head capacity) were also inclined to own manure harvesting equipment, but not to the percentage of the larger feedyards.

Only 23% and 21% of medium and large capacity feedyards, respectively, owned and operated an elevating scraper possibly due to its high cost. A manufacturer also stated the elevating scraper is becoming obsolete in manure harvesting because is not flexible and requires professional personnel for operation. Across all 41 feedyards surveyed, the predominant implements owned by feedyards were the tractor-pulled box scraper, front-end loader and dump truck at 71%, 68% and 61%, respectively.

Table 1. Percentage of Manure Harvesting Equipment Owned/Operated by the 41 Feedyard Managers Surveyed for Three Sizes of Feedyards.

Equipment Type	Small-sized	Medium-sized	Large-sized	Average
	Percent of feedyards using manure harvesting equipment			
Tractor-pulled box scraper	50	69	93	71
Front-end loader	50	54	100	68
Dump truck	50	85	50	61
Spreader truck	35	39	64	46
Elevating scraper	0	23	21	15
Tractor-trailer end-dump truck	14	39	64	41

Manure harvesting in feedyards. Survey respondents indicated that manure harvesting from pens was done either by a contractor, by themselves, or by a combination of both. Large-sized feedyards tended to hire contractors more frequently with 71% of the time, while medium-sized and smaller-sized feedyards harvested manure by feedyards themselves. Of the 41feedyards surveyed, less than 10% harvested manure by a combination of feedyard personnel and manure contractors. The percentage of manure harvesting done by feedyards themselves, by hired contractor, or by feedyard/contractor combination for the three feedyard size categories is located in Table 2.

Table 2. Manure Harvesting by the Feedyard, Contractor or Combination of a Feedyard/Contractor.

Manure Harvested By	Small-sized	Medium-sized	Large-sized	Average
	Percent of feedyards using manure harvesting equipment			
Feedyard	58	54	29	46
Contractor	36	39	71	49
Combination	7	8	0	5

The capital expenditure, salvage value, useful life in years, and normal annual hours of operation for 2010 model implements. The purchase price used in the analysis of similar manure handling equipment was averaged over the manufacture's providing estimates. The elevating scraper was by far the most costly implement at $311,000. The least costly machinery was the box scraper alone at $7,000 with no salvage value at the end of seven years of useful life due to wear and tear. The purchase price of the tractor to pull the box scraper was estimated at $70,000 with a $10,000 salvage value after a useful life of ten years. The purchase price of the front-end loader and spreader truck were projected at $170,000 each. Purchase price, salvage value, projected useful life, and normal life of each equipment item can be found in Table 3.

Table 3. Purchase Price, Salvage Value, Remaining Value, Projected Useful Life in Years, and Normal Life in Hours for Manure Harvesting Equipment, June 2008.

Equipment Item	Purchase Price	Salvage Value	Remaining Value	Projected Useful Life (years)	Normal Life (hours)
Box scraper	$7,000	$0.00	$7,000	7	5,000
Tractor	$70,000	$10,000	$60,000	10	20,000
Front-end Loader	$170,000	$15,000	$155,000	15	20,000
Dump truck	$75,000	$1,500	$73,500	25	20,000
Spreader Truck	$170,000	$25,000	$145,000	10	20,000
Elevating Scraper	$311,000	$15,000	$296,000	20	20,000
Tractor-trailer end-dump	$145,000	$13,500	$131,500	25	30,000

The dump truck and tractor-trailer end-dump were the most likely equipment to travel on public highways and each had a useful life of 25 years[7]. The spreader truck was reported to travel short distances on public highways and was estimated to have ten years of useful life by industry experts.

The hourly fixed costs for interest, depreciation, insurance, registration, and taxes for each piece of equipment. Interest, depreciation, insurance, registration, and taxes constituted the total hourly fixed costs for 2010 model manure harvesting equipment and are located in Table 4. Because of the $311,000 initial capital expenditure for the elevating scraper, this implement had the largest hourly fixed costs of $2.26 of all equipment. Combining the hourly fixed cost of the box scraper at $0.45 and the tractor at $0.82, established a total hourly fixed cost of $1.27 for the unit. Even though the purchase price of the front-end loader and spreader truck were the same at $170,000, their hourly fixed costs were $1.49 and $1.97, respectively. This difference is due to the useful life of 15 years for the front-end loader and 10 years for the spreader truck.

[7] Both implements require higher hourly operational costs for labor, fuel, maintenance and repairs, and lubrication of the machinery.

Table 4. Purchase Price, Hourly Annualized Fixed Cost, Depreciation, Insurance, Registration and Taxes, where applicable, for Manure Harvesting Equipment, June 2008.

Equipment Item	Purchase Price	Hourly Annualized Fixed Cost	Hourly Depreciation	Hourly Insurance, Registration and Taxes	Total Hourly Fixed Costs
Box scraper	$7,000	$0.25	$0.19	$0.01	$0.45
Tractor	$70,000	$0.48	$0.30	$0.04	$0.82
Front-end Loader	$170,000	$0.88	$0.52	$0.09	$1.49
Dump truck	$75,000	$0.29	$0.15	$0.04	$0.48
Spreader truck	$170,000	$1.15	$0.73	$0.09	$1.97
Elevating scraper	$311,000	$1.36	$0.74	$0.16	$2.26
Tractor-trailer end-dump	$145,000	$0.38	$0.18	$0.05	$0.61

The hourly operational costs for labor, fuel, maintenance and repairs, and lubrication of the machinery. Operator labor, fuel, maintenance and repairs, and lubrication comprised the hourly operational costs for the manure harvesting equipment. Hourly diesel fuel ($1.98 per gallon) consumption costs ranged from $3.76 for the tractor-pulled box scraper unit to $29.70 for the tractor-trailer end-dump. The tractor-trailer end-dump had the highest fuel consumption rate at 15 gallons per hour, causing the hourly fuel costs to be $29.70, compared to $19.80 for the dump truck and $6.14 for the front-end loader. Hourly fuel cost for the spreader truck was $15.84 (Table 5).

The hourly labor costs obtained from the U.S. Farm Wage Rate: Quarterly Data (NASS 2009) were $10.70. Because actual labor hours exceeded machine time by 10%, hourly labor cost was $11.77, and was the same for all implements. Surveyed manufacturers described maintenance and repairs (M&R) and lubrication as important expenditures because these items prevent or deter wear and tear, and possibly extend the useful life of the equipment. Annual M&R costs were provided by manufacturers and varied by equipment, and ranged from $1.05 per hour for the box scraper alone to $5.00 per hour for the elevating scraper and tractor-trailer end-dump. Lubrication expenditures were derived at 15% of the fuel cost and ranged from $0.66 per hour for the tractor pulled box scraper as a unit to $4.46 per hour operating the tractor-trailer end-dump. The tractor-trailer end-dump had the highest lubrication expense because this implement travels predominately on public roads at 15 gallons per hour and had the longest normal life at 30,000 hours. Even though the box scraper does not have an hourly fuel rate, the equipment still requires lubrication and was estimated at $0.10 per hour, according to industry standards. Combined hourly operational costs for the tractor-pulled box scraper were $30.26, since the two are considered one unit. Total hourly operational costs ranged from $20.71 for the front-end loader to $50.93 for the tractor-trailer end-dump (Table 6).

Table 5. Diesel Fuel Consumption and Hourly Diesel Fuel Cost for Manure Harvesting Equipment, June 2008.

Equipment Item	Diesel Fuel Consumption per Hour	Diesel Fuel Cost per Gallon	Total Hourly Diesel Fuel Cost
Box scraper	0.00	$1.98	$0.00
Tractor	1.90	$1.98	$3.76
Front-end loader	3.10	$1.98	$6.14
Dump truck	10.00	$1.98	$19.80
Spreader truck	8.00	$1.98	$15.84
Elevating scraper	5.40	$1.98	$10.69
Tractor-trailer end-dump	15.00	$1.98	$29.70

Table 6. Hourly Operational Costs for Labor, Fuel, Maintenance and Repairs, and Lubrication for Manure Harvesting Equipment, June 2008.

Equipment Type	Hourly Labor Cost	Hourly Fuel Cost($/hr)	Hourly Maintenance and Repairs Cost	Hourly Lubrication Cost	Total Hourly Operational Cost
Box scraper	$11.77	$0.00	$1.05	$0.10	$12.92
Tractor	$11.77	$3.76	$1.25	$0.56	$17.34
Front-end loader	$11.77	$6.14	$1.88	$0.92	$20.71
Dump truck	$11.77	$19.80	$4.38	$2.97	$38.92
Spreader truck	$11.77	$15.84	$2.00	$2.38	$31.99
Elevating scraper	$11.77	$10.69	$5.00	$1.60	$29.06
Tractor-trailer end-dump	$11.77	$29.70	$5.00	$4.46	$50.93

Total hourly costs to own and operate the manure harvesting equipment. Fixed and operational costs were combined to establish total costs per hour to own and operate the manure harvesting equipment. Total operating costs were greater than the fixed costs due to two factors: 1) operating labor at $11.77 per hour, and 2) fuel cost at $1.98 per gallon in association with the hourly fuel consumption of individual equipment. The most frequently utilized manure harvesting implements identified in the feedyard manager survey (Table 1) which are tractor-pulled box scraper, front-end loader and dump truck, had a combined hourly cost of $89.89 (Table 7). Across the 41 feedyards surveyed, 71%, 68% and 61% of the feedyards surveyed owned/operated a tractor-pulled box scraper, a front-end loader and a dump truck, respectively. 41% owned a tractor-trailer end-dump for which fixed and operating costs totaled $51.54 per hour over the 41 feedyards. At a total hourly cost of $31.32, only 15% owned/operated an elevating scraper.

Table 7. Hourly Fixed, Operational and Total Costs for Manure Harvesting Equipment, June 2008.

Equipment Type	Total Hourly Fixed Cost	Total Hourly Operational Cost	Total Hourly Cost
Box scraper	$0.45	$12.92	$13.37
Tractor	$0.82	$17.34	$18.16
Front-end loader	$1.49	$20.71	$22.20
Dump truck	$0.48	$38.92	$39.40
Spreader truck	$1.97	$31.99	$33.96
Elevating scraper	$2.26	$29.06	$31.32
Tractor-trailer end-dump	$0.61	$50.93	$51.54

Government Assistance Program. Manure harvesting is considered an expensive method to control dust in feedyards. Equipment purchase prices and operating costs, such as labor, fuel, and maintenance and repairs may add up to be prohibitive costs for some feedyards. However, there are government assistance programs that can help alleviate the total expenses.

The Environmental Quality Incentive Program (EQIP 2009) provides financial and technical assistance to agricultural producers who apply conservation practices on their land. EQIP funding is administered by the United States Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS 2009). Reauthorized by the 2008 Farm Bill, new authorities were developed and funding was increased (Sokora 2009).

Commercial beef feedyards participating in the EQIP program must agree to meet specific technical criteria to insure their manure harvesting operations comply with current regulatory and environmental policies. These requirements are documented in a USDA-NRCS Manure Harvesting Management Plan developed specifically for each participating feedyard. Two operations known as "manure harvesting" and "manure cleanout" need to be undertaken to participate in the program. Manure harvesting is known as the "…removal of all loose, dry manure on top of the hard, compacted layer in the cattle pens. Manure cleanout is the "complete removal of the hard, compacted manure layer that is several inches thick… (Sokora 2009)."

There are three major Atmospheric Resource Quality Management (ARQM) schedules within EQIP in which a feedyard may participate. Each schedule has specific guidelines to follow and corresponding funding. For example, Schedule 1 requires one manure harvesting and one manure cleanout per year. When satisfactorily accomplished, the feedyard will receive government cost share payments of $165 to $330 per pen acre per year for a maximum of three years (Table 8). Schedules 1 and 2 were implemented with different manure harvesting dates to provide flexibility because some yards collect manure before or during the summer months (Schedule 1), while others, clean pens before the fall (Schedule 2). EQIP is a viable method to supplement manure harvesting costs if the feedyard is willing to adhere to the guidelines set forth in the Manure Harvesting Management Plan. Additional and detailed information on EQIP can be reviewed on the Texas NRCS website: http://www.tx.nrcs.usda.gov/ Programs/EQIP /index.html.

Table 8. Texas Natural Resources Conservation Service (NRCS) 2009 Environmental Quality Incentive Program (EQIP) and Atmospheric Resource Quality Management Schedules (ARQM) Schedules for Manure Harvesting and Manure Cleanout and Corresponding Cost-Share Payments.

ARQM Schedule	Manure Harvest	Manure Cleanout	Payment Received
ARQM Manure Harvest Schedule 1	1 manure harvest of all pens between March 1 to May 31 time period	1 manure cleanout between November to February time frame	$165 per pen acre (maximum 3 yrs)
ARQM Manure Harvest Schedule 2	1 manure harvest of all pens between June 1 to September 30 time period	1 manure cleanout between November to February time frame	$165 per pen acre (maximum 3 yrs)
ARQM Manure Harvest Schedule 3	2 manure harvests of all pens between March 1 to May 31 & June 1 to September 31 time period	1 manure cleanout between November to February time frame	$330 per pen acre (maximum 3 yrs)

DISCUSSION

Cattle feeding in the High Plains is a critical component to the regional economy, but creates large quantities of manure that produce atmospheric emissions, such as dust. One manure management method is the use of implements for collecting manure including: tractor-pulled box scraper, front-end loader, dump truck, spreader truck, elevating scraper, and tractor-trailer end-dump. This equipment requires a significant amount of capital. This research found that, a tractor-pulled box scraper, which 71 % of 41 feedyards surveyed owned on average, had an average purchase price of $77,000, box scraper at $7,000 and tractor at $70,000. Fixed costs for this unit were $1.27 per hour and hourly operational expenses were projected at $30.26, or a total hourly cost of $31.53. Participating in EQIP can help in defraying some of these expenses.

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Profitability of a Dryland Grazing System Suitable for the Texas High Plainsˆ

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ABSTRACT

The declining availability of groundwater will eventually force farmers and ranchers on the Texas High Plains to move to dryland production practices. Dryland production is inherently risky, and farmers need estimates of risk to effectively choose production practices and systems. We determine the profitability of a specific dryland ranching system in this paper by simulating production and profits for a wide range of rainfall and price values drawn from historic record. We find that the tobosagrass-WW-B.Dahl grazing system is profitable, but recognize that data limitations make this estimate an upper bound for the true expected profit for this system. We identify research that is needed on forage grass renewal to make more realistic risk estimates of dryland production; research that can be incorporated directly into the economic assessment presented. Specifically, we recognize the need for more estimates of dryland production practices at very low and very high precipitation levels.

KEY WORDS: old world bluestem, *Bothriochloa bladhii*, Tobosagrass, dryland production alternatives, simulating production

INTRODUCTION

The Ogallala Aquifer, one of the largest water tables in the world, lies beneath the Great Plains in the United States. It covers eight states: South Dakota, Wyoming, Nebraska, Colorado, Kansas, Oklahoma, New Mexico, and Texas, and underlies an area of approximately 174,000 square miles, 12% of which is located under Texas (High Plains Water District #1, 2009). Left undisturbed, the natural discharge rate of the Ogallala would approximately equal its natural recharge rate; but currently the Ogallala has been overdrawn by irrigation, largely for agriculture, which has caused declining

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water levels. Over 90% of water pumped from Ogallala is used for agricultural activities in the Southern High Plains. Cotton, corn, alfalfa, soybeans and wheat are the major crops in this region, as well as cattle feeding (Guru and Horne, 2000).

While Kansas had pumped 38% of its system reserves by 1980, depletions in Texas are worse: the water tables had dropped 200 feet (Lewis, 1990) and about 70% of Texas's underground water has been depleted (Weeks and Gutentag, 1984). This decline is especially serious on the Ogallala aquifer beneath the Southern High Plains of Texas given its low recharge rate. This southern portion of the aquifer formed as a deep confined overlay, and is characterized by low recharge and low hydroconductivity. This means sustained irrigation is not a feasible option in the long-run. Ranchers face the problem similarly to row crop farmers: extensive pumping of fresh water from the Ogallala to irrigate their pastures has increased pump lift (i.e. the water table has declined), escalating the costs of cattle ranching such that irrigated pastures have become less competitive. The inevitable shift to dryland production, an ostensibly system that include more range and pasture lands, appears the likely response to declining water availability in the region (Ortega-Ochoa et al., 2007b).

In order for a dryland ranching production system to be profitable on the Southern High Plains, forages need to be productive and adapted to the local climate. One proposed system combines a native grass (tobosagrass) with an introduced grass (WW-B.Dahl). In this system, cattle graze on native grassland during the March to mid-July growing season and then move to the introduced grassland from mid-July through fall, after which they are sold to market. This system has the advantage of reducing both water and pesticide use but also of maintaining sustainable forage production for cattle grazing. Together, use of these grasses reduces ranching cost and increases profits. This system also promises often under-identified ecological benefits, especially in comparison to current row cropping options (Ortega-Ochoa et al., 2007b).

At some time in the future, the agricultural economy of the Southern High Plains will depend on robust and adaptable production dryland alternatives, such as this grazing system. This study has three objectives: (1) to determine the profitability and the distribution of profits for this grazing system; (2)to evaluate the suitability of this system for inclusion in the suite of emerging dryland production alternatives; and (3) to identify key areas of study still needed to better assess these objectives.

Because of the uncertain level of precipitation in a given year, dryland production is inherently risky. In this paper, we consider the profitability of the tobosagrass-WW-B.Dahl rotation as a dryland grazing system. Because of the risk involved, determining an average-year's profit is inadequate; therefore we develop its distribution of profits under local precipitation variability to better describe the risk associated with this system. We assume that precipitation (and the resulting forage availability) and prices are the main sources of uncertainty in this production system; therefore, to determine the profit distribution, we develop a model of producer responses to available forage at differing levels of precipitation and responses to cattle delivery prices at feed yards. We then simulate the producer response, and resulting profit values, over a large set of simulated rainfall and price values to simulate profit distribution. Finally we comment on the common concerns that the forage growth response function to precipitation is poorly understood, and that, for a realistic decision tool to be forwarded to ranchers, such studies are needed for grasses not only on the Southern High Plains but across the Great Plains generally.

DATA AND METHODS

In order to determine profit distribution, there are several intermediate steps. We first explain our choice of forage and grazing system and then estimate yield response functions to rainfall. Second, we determine cattle gain with respect to per-hectare yield of WW-B.Dahl and tobosagrass, and then simulate cattle weight gain by applying the forage response functions to a simulated set of rainfall values and then calculating the resulting weight gain values. Third, we develop a set of simulated cattle prices (purchase and sale prices – which are uncorrelated with the rainfall distribution) and simulated costs of grazing cattle. Finally, we use the sets of simulated production, prices and costs to produce a set of simulated profit and calculate the profit distribution.

Forage system. Multiple old world bluestem grazing systems have been suggested and studied (Benzanilla, 2002; Ortega-Ochoa et al., 2007a; and Ortega-Ochoa et al., 2007b). These studies have shown that irrigated old world bluestem grazing is likely to be more profitable under dryland production due to the high cost of irrigation and the relative drought tolerance of the grasses (Ortega-Ochoa et al., 2007a). In this paper, we consider a single system developed by Ortega-Ochoa et al. (2007b) that keeps weaned stockers on native rangeland during winter and spring, and then moves them to WW-B.Dahl for summer after which they will be sent to the feedlot.

Found in West Texas and Arizona and southern New Mexico, tobosa (*Hilaria mutica* Buckl.) is a native and warm season perennial grass, and is a slightly spreading range grass of the family Poaceae (Magness et al., 1971). Tobosagrass is less palatable than blue grama (*Bouteloua gracilis*) and sideoats grama (*Bouteloua curtipendula*) (USDA, Plant Fact Sheet), but palatable when succulent (Magness et al., 1971). It is very drought resistant but responds readily to extra moisture during the growing season.

WW-B.Dahl ([*Bothriochloa bladhii* (Retz) S.T. Blake]) is a warm-season grass that originated near Manali, India. Initial tests began in Oklahoma, around 1965, and in 1994, this grass was named WW-B.Dahl, and released by USDA-ARS, USDA-SCS, Texas Tech University and Texas Agricultural Experiment Station (Texas Coalition for Sustainable Integrated Systems, Technical Notes). It is a late maturing grass and is drought tolerant, and potentially yields a maximum of 9 to 12 tons per acre. B.Dahl is highly palatable, compared to most other grasses with crude protein ranging from 10 to 12 %. B.Dahl also has a very small fertility requirement. Only 50 lbs. of nitrogen per acre per year is required to achieve high yields (Lyssy & Eckel Feeds, 2010).

WW-B.Dahl usually begins growing in early May, and is available for grazing by mid-May. It responds better to water and fertilizer during the first part of growing season. The forage quality is also higher at the first half of the growing season. Research has shown the crude protein in Dahl is 1% to 2% higher than other old world bluestem. Additional research has shown the average daily gain of steers is about 2.5 lbs/day from May to June. The daily gain would decrease without the protein supplement after July (Texas Coalition for Sustainable Integrated Systems, Technical Notes).

Forage yield response. Precipitation is the only water source available in this production system. In order to simulate producer response and profitability, we require a functional relationship between precipitation and forage yield. According to Sneva and Britton

(1983), the relationship between precipitation and yield can provide reliable and effective information for forecasting and adjusting the range forage estimate.

Olson et al. (1985) investigated the quantitative changes in the basal cover of forage vegetation in response to variation in precipitation and grazing intensity. They recorded 142 species throughout 25 years, and developed equations via several regressions that were used to analyze the relationships between basal cover and precipitation. They concluded that the reactions to precipitation regimes and grazing treatments may vary by species. A species may respond differently to the same precipitation regime when subjected to different grazing intensities and the species favored and disfavored will change in accordance with prevailing precipitation. The critical finding for this paper is that moderate grazing was more conducive to optimum basal cover for more of the species than other grazing intensities and that the stocking rate could be adjusted to coincide with the forage available in order to achieve optimal basal cover.

For our forage response function, we use a log quadratic functional form:

$$logY_i = \beta_1 + \beta_2 * \log r + \beta_3 * (\log r)^2 \quad (1)$$

where, Y_i is seasonal forage production in lbs (Y_1 is tobosagrass production; Y_2 is the WW-B.Dahl production) and r is seasonal rainfall in inches. We choose the log quadratic function because of its predictive ability. We fit equation (1) using datasets of forage production and rainfall and a Bayesian estimation method to account for the issues associated with the small sample sizes of the available data. Ordinary least squares regression gives wide distributions of parameter estimates when sample sizes are small; this Bayesian method gives a slightly tighter distribution.

Cattle stocking rate. Given the choice of grasses, and a function that can estimate forage amount from given rainfall, we now consider the optimal use of forage for this system. Stocking rates (i.e. the number of animals on a given amount of area over a period of time) are critical in rangeland management since the long-term health of plants is determined by the amount of forage consumed by livestock in relation to the supply of forage available (Hanselka et al., 2001). No other management practices can affect the profitability of livestock more than stocking rate (Daren and Terrence 2004). A proper stocking rate is therefore one that allows forage plants to withstand grazing during a particular time period but without permanent damage to plant welfare and without causing deterioration of rangeland productivity (Sims et al., 1976).

Grazing pressure is partially determined by the stocking rate and is defined as the ratio of forage demand (forage needed by livestock) to forage supply. As the grazing pressure increases, less forage is available on a per-animal basis, so the individual animal performance will suffer. Reduced performance is measured by decreased weight gain and reproductive capability, and then translated to lower economic returns per animal (Hanselka et al., 2001). Reduction in desirable grasses and invasion of weeds and undesirable grasses occurs when livestock are overstocked on the rangeland. As the undesirable species is more prevalent than the desirable species, animal performance and the carrying capacity of the land are all reduced (Daren and Terrence, 2004). Lower grazing pressure can preserve the forage and allow the ranch to weather crises such as drought. Because of better nutrition, higher weaning weights, fewer deaths, and lower supplement feed costs, livestock productivity and financial returns are higher over the long term under moderate or conservative grazing rather than stocking at carrying capacity (Hanselka et al., 2001).

We therefore constrain the producer in our model to stock rangeland so that only 25% of forage will be consumed. Of the total forage amount produced during a specific year, 50% is ungrazed to keep plant population healthy and to provide cover for the soil surface, and we assume that 25% will be destroyed by insects, leaving only 25% available for livestock (Hanselka et al., 2001). This strategy follows the "half consumed-half remained" rule for sustainable grazing. The rule is based on moderate utilization of annual forage standing crop, assuming uniform grazing distribution, and states that 50% of the annual peak standing crop can be removed without hurting the community relative to the species abundance or beef production (Daren and Terrence 2004).

Cattle weight gain. Cattle production, that is, seasonal weight gain, is a function of forage production and a chosen stocking rate. We use the platform and results from three separate studies to determine our cattle weight gain function. Hart et al. (1988) compared continuous grazing on mixed-grass range near Cheyenne, Wyoming from 1982 to 1987 and determined the response of average daily gain (kg/day) to grazing pressure (steer days/ton of forage). Specifically, they fit the function,

$$ADG = a - b * GP \qquad (2)$$

where, *a* and *b* are parameters to be estimated, for different grazing strategies. In a similar study, Sims et al. (1976) investigated vegetation and livestock response on sandhill rangeland in eastern Colorado, and used average daily gain and average seasonal gain per head to measure the livestock response to differential grazing pressure.

Using data from Sims et al. (1976), Torell et al. (1991) estimated equation (2) and determined the following average daily gain function,

$$ADG = 0.82 - 0.0029 * GP \qquad (3)$$

where, *ADG* is in kg/day and *GP* is grazing pressure (steer-days/ton of forage). Equation (3) gives gain per hectare by multiplying *ADG* and the stocking rate. To determine grazing pressure (GP), we apply the definition from Hart et al. (1988),

$$GP = SR * v \;/\; F \qquad (4)$$

where SR is stocking rate (animals/ha·day), v is the number of grazing days (which we fix at 120) and F is forage production (in kg/ha). The stocking rate is defined as

$$SR = {}^{F}\!/_{\text{cattle intake}} = {}^{F}\!/_{(W_{st} * .03 * v)} \qquad (5)$$

where, W_{st} is starting weight of the cattle, which we assume to be 200 kg in the spring, when the cattle start on the native grassland. The starting weight when the cattle are moved to the WW-B.Dahl is then 200 kg plus the gain from the spring grazing. Note that, when equations (5) and (4) are substituted into equation (3) the term for total forage cancels out, thus the *ADG* (weight gain per head of cattle) is the same regardless of available forage. As forage increases, however, the stocking rate increases, and the resulting average gain per hectare increases.

As explained above, since the stocking rate on the tobosagrass is less than the stocking rate on the WW-B.Dahl, the operator of the integrated system would purchase more cattle in June to raise more cattle on the WW-B.Dahl grassland, in order to make more profit. Cattle purchased in spring are grazed on tobosagrass for 120 day from March to late June, and then new cattle purchased in late June together with the cattle grazed on tobosagrass were moved to WW-B.Dahl grassland and they will be raised for 120 days until being sold in the market in late October. The starting weight of these cattle is determined by the gain on the native grassland – for simplicity, we assume that the purchased cattle are the same weight as those grazed on the tobosagrass.

Profit calculation. For the profit analysis, we use the following profit function

$$\pi = P_{fl} * W_{fl} - P_{sp} * W_{sp} - P_{su} * W_{su} - C \quad (6)$$

where, π is the net profit per hectare; P_{fl} is the sale price in the fall; W_{fl} is the animal total weight per hectare in fall; P_{sp} is the cattle purchase price in February; W_{sp} is the cattle initial purchase weight per hectare in February, and is equal to 200 kg times the stocking rate; P_{su} is the cattle purchase price in June; W_{su} is the initial weight per hectare in June, and is equal to the initial spring weight plus the gain per animal in the spring, times the stocking rate; C is the cost including labor cost, land cost, supplement cost, equipment cost on tobosa grassland and WW-B.Dahl grassland. In this model, the producer perfectly predicts forage availability when making the initial stocking-rate decision, so this cost does not include the need to purchase supplemental forage in low rainfall years.

The cattle weight values in equation (6) are determined by our stocking rate which is determined by the simulated forage amount (which is, in turn, determined by the rainfall simulation). For prices, we assume that cattle prices are log-normally distributed and sample from a distribution using observed mean and variance from a dataset of monthly prices from 1979 to 2008. We also implicitly assume that prices are independent of the individual producer's production and rainfall (correlated price and forage simulations are not possible since the forage response rate away from the mean rainfall level is poorly calibrated, since those observational data do not exist). In the integrated system, cattle are purchased in February, more cattle are purchased in the summer, and then all of the cattle are sold in the market in late October. Using the 30 years of observed data, we determine the average and variance of cattle price for February, June, and October, and we simulate a set of prices for February, June and October for the purchase and sale prices to match up with the forage simulation in determining profit. Cattle production cost on native grassland is \$195/head (Texas AgriLife extension), and the cost on WW-B.Dahl grassland is \$64/ha (Ortega-Ochoa et al., 2007a).

Data. To estimate the forage response functions, tobosagrass forage data are collected from Post, Garza County, TX (Villalobos, 1995). The data were collected for five years of production between 1985 and 1991. The WW-B.Dahl forage production data were collected for each year from 1999 to 2004 in northeast Lubbock County, TX (Ortega-Ochoa et al., 2007a). We collect seasonal rainfall data for Garza County and Lubbock County from the National Oceanic and Atmospheric Administration (NOAA) for the years corresponding to the collected forage data. More years of rainfall data were included to test which year has the greatest impact on the current year's grass production. Given that the data are limited, we use a Bayesian estimation method that can overcome some of the issues caused by small sample sizes.

Once we have estimated a forage response function, we use a set of simulated rainfall data to generate a set of simulated forage data that will, in turn, be used to determine cattle production values and then generate a set of simulated profit data. We use a dataset of rainfall previously generated by using a Markov Chain Monte Carlo (MCMC) simulation method, using a standard approach recommended by Hastings (1970) and Gelman et al. (2008). The rainfall dataset is comprised of 35,000 rainfall observations that were simulated from 92 years rainfall of observed rainfall in Post, TX.

Figure 1 shows the distribution of the simulated rainfall data. Compared to a normal distribution, the histogram of rainfall is a little left skewed, with the average rainfall of 21 inches per year.

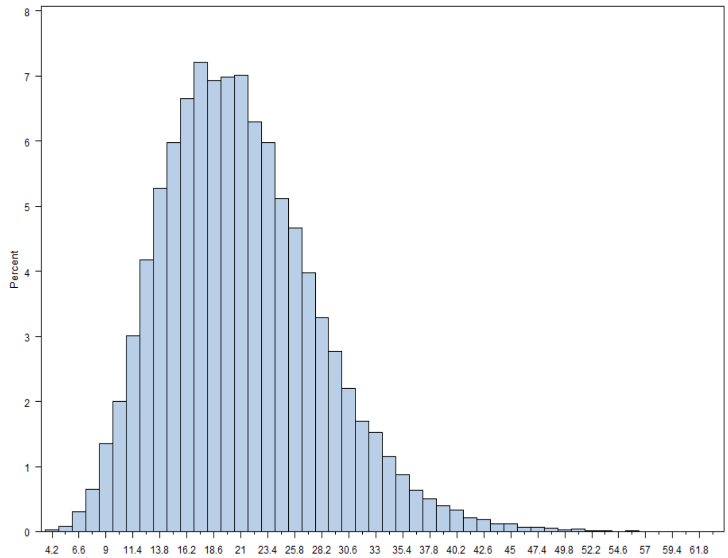


Figure 1. Simulated rainfall distribution.

RESULTS

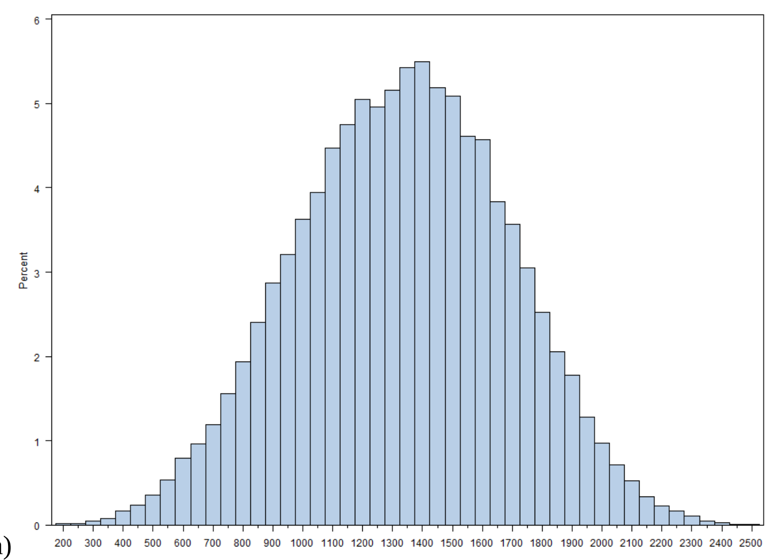
In this section, we present the distribution of the profitability of the dryland grazing system. We first provide the forage response function estimation results, along with a histogram of the simulated forage production.

Forage response estimation results. We estimate equation (1), using a Bayesian MCMC estimation method as implemented in the WinBUGS software package. We choose a Bayesian method to compensate for the small sample size of the available data. We estimate equation (1) with three different specifications of the rainfall variable for each of the two forage species: we use the current-year total rainfall (Jan-Dec), the previous-year rainfall (Jan-Dec) and rainfall from January to August of the current year. For each of these specifications we obtain the parameter estimates (β_1, β_2 and β_3 in equation 1), and use the resulting function and the rainfall data to simulate a forage production distribution. The results of these simulations are reported in Table 1.

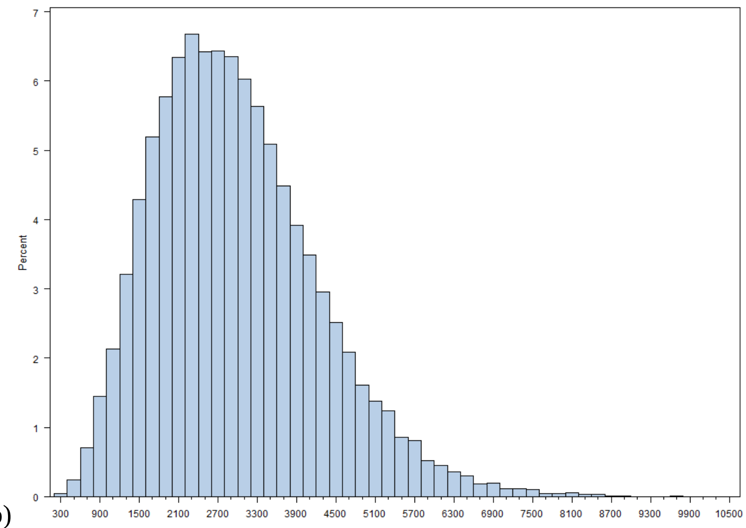
Table 1. Forage production simulations for different specifications of the rainfall variable in the forage-rainfall function.

Model	Obs	Mean(lbs/ac)	Std Dev	Min	Max
Tobosagrass					
Previous-year rainfall	35000	1051.16	187.85	236.61	1265.41
Current-year rainfall	35000	1098.65	124.49	372.83	1212.95
Jan-Aug rainfall	35000	1333.7	354	186.94	2522.82
WW-B.Dahl					
Previous-year rainfall	35000	2984.53	1257.3	244.1	10557.8
Current-year rainfall	35000	1915.23	353.42	320.75	2275.49
Jan-Aug rainfall	35000	1957.01	166.11	529.74	2088.12

We choose among these specifications by identifying the distribution that best reflects the expected production of the two grasses. For tobosagrass, the rainfall specification that produced the best simulated distribution was rainfall from January to August. For WW-B.Dahl, we choose the distribution that was generated using the previous year's rainfall. The resulting distributions are displayed in Figure 2.



(a)



(b)

Figure 2. Simulated distribution of (a) tobosagrass production and (b) WW-B.Dahl production in kg/ha, using parameter estimates from estimation of forage production from Jan-Aug and previous-year rainfall, respectively.

The rejected rainfall specification variables all generated distributions similar to that of Figure 3, which displays the distribution of tobosagrass when the tobosa forage production function was estimated using previous-year rainfall, and does not conform to expectations of grass production, which should take on a shape similar to a normal distribution.

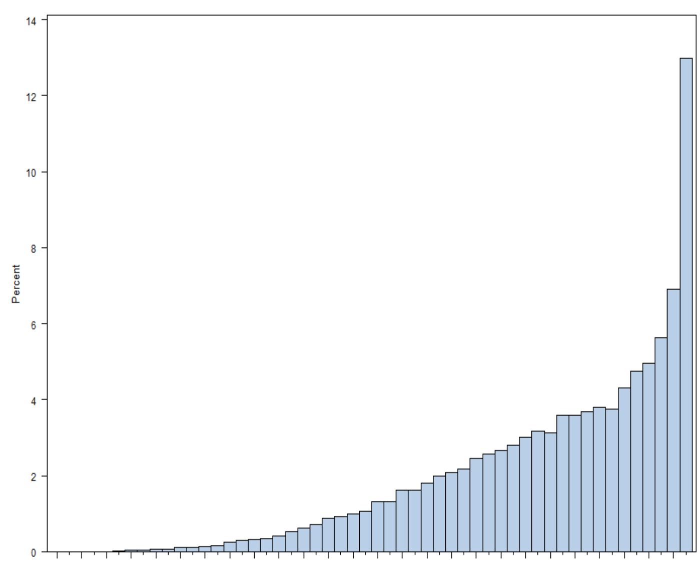


Figure 3. A "rejected" sample distribution of tobosagrass production simulation using parameter estimates generated using previous-year rainfall.

Cattle weight gain simulation. Now, for a given rainfall amount, we generate forage available on tobosagrass and WW-B.Dahl pasture, which we substitute into the weight gain functions (equations 3-5) to generate a pair of simulated weight gain observations for a single year. We then generate a distribution of weight gain by calculating simulated weight gain for each of the 35,000 simulated rainfall observations, which is reported in Table 2. The average weight gain on native grassland is 83.816 kg/ha, and 193.701 kg/ha on WW-B.Dahl grassland. The weight gain on the tobosa grassland varies from 12kg/ha to 158 kg/ha, while 90% of the weight gain lies between 47kg/ha and 120 kg/ha. Weight gain on WW-B.Dahl ranges from 16 kg/ha to 686 kg/ha, and 90% of the weight gain lies between 80kg/ha and 342 kg/ha. The weight gain distributions closely mirror their respective forage production simulations.

Table 2. Summary of cattle weight gain simulations.

Variable	Obs.	Mean(kg/ha)	Std	Min	Max
Gain on native grassland	35000	83.816	22.247	11.748	158.545
Gain on WW-B.Dahl grassland	35000	193.701	81.601	15.842	686.513

Profit simulation. We evaluate equation (6) at each of the weight gain observations and a corresponding set of simulated prices. A distribution of simulated profits is shown in Figure 4. The average profit of this integrated system is $121.2/ha, with a minimum profit of -$94/ha and maximum of $773/ha. 90% of the profit values fall between $2/ha and $298/ha. Critically, we find that the farmer has a 4% chance of loss in this dryland grazing system. In their experiment, Ortega-Ochoa et al. (2007b) reported a profit of $262/ha in 2003 and $244/ha in 2004 under non-irrigation with supplement conditions on the WW-B.Dahl pastures.

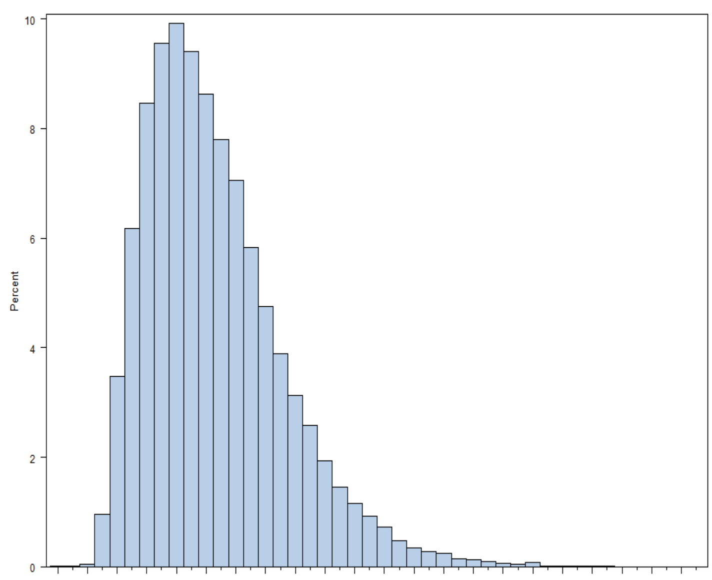


Figure 4. Distribution of simulated profit in $/ha.

DISCUSSION AND CONCLUSION

The observation that variation in forage production resulting from precipitation has an impact on cattle weight gain in dryland cattle production systems suggests that ranchers will need estimates of risk before adopting dryland production practices. In constructing a risk estimate for a specific ranching system (see section 2.1, above) we make the following observations. First, the data for dryland production of forage is scarce, limiting the reliability of any estimate or forecast of forage production. Second, even with the only somewhat reliable estimates of forage response to precipitation, we were able to produce a simulation of forage distribution that conforms to expectations of shape and placement. Third, while our estimates of average profitability were lower than some (specifically, Ortega-Ochoa et al., 2007b), they are much higher than average ranching profits per hectare observed in practice. Some of this over-estimate in profits is due to the perfect-response of the producer that we assume in this model, where the rancher perfectly predicts rainfall in a given year and adjusts stocking rate accordingly. Some of the over-estimate in profits is likely due to the forage distributions, which include forage amounts in very high rainfall and very low rainfall years which are unrealistically large, shifting the distribution to the right somewhat. Use of crop growth simulators would not have resulted in a great improvement over the simulations we derived as described above, since those simulators are calibrated with the same sparse data that are often too clustered about the mean to properly simulate production in the tails of the distribution. Better observations of dryland yield in very low and very high precipitation years will help to center the distribution of forage closer to reality. Because of these shortcomings, this estimate can be considered an upper-bound for profitability of this grazing system.

The common focus of management models on the average year or the mean profit might explain why forage growth functions have not been completed by range scientists. The primary benefit of this model is to illustrate the critical importance of recurrent drought and low precipitation stress toward a more real-world characterization of the economic strains working ranches face in semi-arid regions. Hopefully, the utility of good and detailed field work on rangelands can induce the necessary resources to answer economic questions that derive from weather stress in the short term and over time. Eventually the model presented could accommodate the inter-annual effects of protracted drought or low rainfall stress if carry-over forage response data and initial soil moisture were available.

In light of the above observations, the main contribution of this research is the platform for employing information to analyze new dryland production technologies, as well as identifying the information requirements to adequately determine risk of these new technologies. As the Ogallala aquifer draws down and farmers are forced to consider alternative dryland production technologies, their transition from irrigated agriculture will be facilitated by clearer understanding of the risk of the choices they face. In order to correctly assess that risk for specific production practices, the development of these production practices need to include observations of the technology in a wide range of climatic outcomes. Simply identifying production in an average rainfall year will not allow an accurate estimation of risk.

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Effect of Ractopamine Hydrochloride on Growth and Carcass Characteristics of Lightweight Swine

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ABSTRACT

This study was conducted by using 65 pigs to measure the effects of feeding ractopamine hydrochloride (RAC) on growth and carcass characteristics of lightweight swine. Beginning weights averaged 68.23 kg. RAC was included in the diet at 0, 5, or 10 ppm for 25 days until an average end weight of 92 kg was achieved. Loin eye area, trimness (backfat measurements), and pork muscle quality factors of carcasses were evaluated 24 hours post-harvest at a commercial processing facility by trained personnel. No differences (P>0.05) were found between treatment groups for average daily gain (ADG) or feed:gain ratio. Groups fed 5 ppm RAC had lower weight loss from drift (P<0.05). No differences (P>0.05) between treatment groups were found for dressing percent, carcass length, first rib fat thickness, tenth rib fat thickness, or loin eye area. Last rib fat thickness and last lumbar fat thickness were significantly lower (P<0.05) for the two groups fed RAC. Firmness, color, and marbling were not affected by treatment group (P>0.05). These results suggest that feeding RAC to lightweight swine can reduce last rib fat while not impacting growth or other carcass traits.

KEY WORDS: Ractopamine, pork, carcass traits, growth, fat thickness, muscling

INTRODUCTION

Pork is the most widely consumed meat in the world. Of total worldwide meat consumption, pork stands at 40%. The next closest competitors are chicken at 29% and beef at 24% (USDA 2008). Although the swine industry has experienced a down-turn in the market at times because of rising feed costs and the H1N1 flu outbreak, it is still one of the major proteins supplied by the United States agricultural industry.

Most hogs in North America are marketed at 100–127 kg. However, some Asian markets in the United States require a smaller, lighter weight carcass of 86–95 kg possessing less than 1.27cm of backfat at the last rib. To enhance this market, it would be imperative to produce lightweight, lean pigs without a negative impact on pork muscle quality. The use of growth promotants such as RAC, could allow an increased number of swine to be marketed within these specifications. Research evaluating RAC inclusion in diets fed to light-weight pigs could provide valuable knowledge to producers interested in this market.

Phenethanolamines, commonly called beta-adrenergic agonists (β-agonists) or repartitioning agents, are compounds that alter the ratio which dietary energy intake is partitioned between lean and fat tissue, resulting in a positive shift in the lean:fat ratio of growing animals (Ricks et al., 1984; and Baker et al., 1984). These are small compounds which are structural analogues of naturally occurring catecholamines such as adrenaline (epinephrine) and nor-epinephrine (Buttery and Sweet 1993). β-agonists are adrenergic agonists that act on the beta-receptor sites in an animal's body to initiate several proteins into action which results in enzyme phosphorylation. The enzyme phosphorolation cascade is important in several metabolic processes (i.e., protein accretion, lipolysis, and etc.).

Experiments in this area could help researchers to understand the physiological effects of repartitioning agents on lightweight swine so that better management practices can be implemented to achieve maximum production efficiency. Thus, the purpose of this study was to compare the effects on growth rate and carcass characteristics of lightweight (86-95 kg) hogs supplemented with two levels of RAC versus those fed a control ration.

MATERIALS AND METHODS

Experimental Design.[9] Sixty five pigs were observed for the effect of RAC on growth and carcass characteristics of lightweight swine. The products used were MoorMan's 11256AB (RAC 9g/ton) and 277AB (No RAC). Both were manufactured by Elanco in Indianapolis, IN. All feeding was conducted at the Tarleton State University Swine Center in Stephenville, Texas and all harvest procedures were conducted at Columbia Packing Company in Dallas, Texas. The experimental design of this trial was a randomized complete block with initial pig weight as the blocking factor. Each pen of pigs served as an experimental unit. Pigs were assigned to pens within a weight block to achieve an even representation on the basis of weight, breed-type, and gender. Treatments were assigned randomly to the pens of pigs within a block.

Feeding and Growth Performance. Weights were recorded throughout the study to monitor growth rates (Rice Lake Weighing Systems, Rice Lake, WI; IQ Plus® 390-DC/590-DC Digital Weight Indicator / Paul Scale, W-W Manufacturing Thomas, OK; Model 58SX Hog and Sheep Crate Scale). Weights taken at the beginning of the experiment served as initial weights. The trial began when the average pen weight reached 59 kg. Prior to the start of the study, pens and feeders were steam cleaned and sanitized in order to provide a healthy environment for the pigs. Animals were visually inspected to confirm that they were healthy and sound enough to participate in the study. Feed composition is represented in Table 1.

At this time, the acclimation period began by offering the pigs the basal ration consisting of 16% CP medicated pellets was administered until the groups attained an average pen weight of 68 kg. This ration served as the base ration fed to the control

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[9] Approval by University Animal Use Committee was not applicable.

treatment (0 ppm RAC). Feeders were cleaned out thoroughly prior to administering the individual treatment feeds. Beginning at 68 (± 0.77) kg, pigs were administered one of the three dietary treatments: the six pens in group #1 continued to receive a ration of 16% CP medicated pellets (0 ppm RAC;control). The six pens in group #2 were fed a ration of 16% CP medicated pellets with the inclusion of 5 ppm of RAC (5ppm RAC). The six pens in group #3 were fed a ration of 16% CP medicated pellets with the inclusion of 10 ppm of RAC (10ppm RAC). Groups were assigned to allow for uniform initial pen weight. All pigs were harvested when the average weight for the total group of pens reached 92 (± 1.33) kg in an average of 25 days. After all pigs were removed from the feeding pens, remaining feed was collected and weighed to adjust feed intake for feed:gain ratio calculations. All pigs were weighed immediately prior to loading at the Tarleton Swine Center and weighed immediately after unloading at the harvest location in order to measure drift weight. Travel time and distance to the harvest site was one hour and forty-five minutes and 167.4 kilometers, respectively. Animals were harvested in accordance with the packing plant's slaughter protocol and in compliance with the Humane Slaughter Act standards for humane slaughter.

Table 1. Experimental basal diet nutrient composition (as fed).

Item	Concentration
Crude Protein, %	16
Lysine, %	0.85
Crude Fat, %	4
Crude Fiber, %	5
Calcium (Ca), %	1.2
Phosphorus, %	0.6
Salt (NaCl), %	0.75
Selenium (Se). ppm	0.3
Zinc (Zn), ppm	475
Tylosin, g/ton	40

Carcass Characteristics. Twenty-four hours post-harvest, carcass traits were measured by three trained personnel from Tarleton State University. Each person collected their data separate of the others and differences in data were resolved by all personnel conferring and agreeing on measurement. The left side of each carcass was ribbed between the tenth and eleventh ribs using a 63.5cm industrial meat hand saw (Northern Tool and Equipment, Burnsville, MN). Traits obtained were: hot carcass weight (HCW, kg), dressing percentage (DP), tenth rib fat depth (10RFD, cm), first rib fat depth (1RFD, cm), last rib fat depth (LRFD, cm), last lumbar vertebrae fat depth (LLFD, cm), loin eye area (LEA, cm^2), loin eye color, loin eye firmness, loin eye marbling, and carcass length (CL, cm). Measurement of fat thickness was taken using a swine backfat probe purchased from Nasco, Inc. (product number COO1HV) (Fort Atkinson, WI) and LEA was measured using a pork and lamb loin eye grid (Nasco, Inc). Carcass length was measured on the right side of the carcass, from the anterior edge of the aitch bone to the anterior edge of the first rib using a flexible plastic tape measure (Nasco, Inc.). Marbling scores range from 1 (devoid) to 9 (abundant). Color scores range from 1 (pale pinkish gray to white) to 6 (dark purplish red). Firmness scores range from 1 (very soft) to 5 (very firm). All quality characteristics (firmness, color, and marbling) were measured subjectively by the same three trained personnel from above using techniques specified in the NPPC Composition and Quality Assessment Procedures (NPPC 2000).

Statistical Analysis. Analysis was conducted by using the Statistical Analysis System. All data were analyzed linearly using the GLM procedure of SAS (Cary, NC) (Barr and Goodnight 1972). A *P* value of 0.05 was considered significant. Model terms included effect of three treatments: 0 ppm RAC, 5 ppm RAC, and 10 ppm RAC.

RESULTS AND DISCUSSION

Growth performance, leanness, and meat quality are some of the primary economically important traits to the pork industry. Utilizing feed additives to optimize growth rates and feed efficiency of hogs can increase profits for commercial swine feeding operations. Improved leanness will result in a higher premium at time of slaughter, when sold on a value based grid market. The combination of these improvements, while maintaining acceptable meat quality, is important to the pork industry.

Growth Performance. Growth performance data is presented in Table 2. Neither initial nor final body weights were different for any of the three treatment groups ($P>0.05$). This is consistent with reports by Fernandez-Duenas et al. (2008) and Patience et al. (2008). However, Armstrong et al. (2004) reported differences in ending weights among treatment groups. This result is explained by the increased days-on-feed and increased RAC inclusion rates employed in the fore mentioned study. Average daily gain and feed to gain ratios (F:G) were not different among treatment groups ($P>0.05$). These findings were contradictory to results from similar research presented by Xiao et al. (1999), Stroller et al. (2003), Armstrong et al. (2004), See et al. (2004), and Carr et al. (2005). Drift percentage tended to decrease ($P<0.08$) for the 5 ppm treatment group, but was not statistically different. This result is similar those reported by Carr et al. (2005), which found no difference in live shrinkage among treatment groups.

Carcass Measurements.

General. Carcass traits are presented in Table 3. Inclusion of RAC in the diet did not have an effect on HCW (P>0.05). This agrees with data presented in Watkins et al. (1990) and Uttaro et al. (1993). However, this finding is different from those of Carr et al. (2005), Fernandez-Duenas et al. (2008), and Kutzler et al. (2010), who found an increase in HCW as RAC level increased. Dressing percent was not different among treatment groups ($P>0.05$). This result is contrary to reports from Watkins et al. (1990), Carr et al. (2005), and Kutzler et al. (2010). Feeding of RAC failed to significantly alter carcass length ($P>0.05$) which agrees with the findings of Stites et al. (1991), Crome et al. (1996), See et al. (2004), and Carr et al. (2005), who indicated no significance among RAC fed treatment groups for CL with finishing swine. However, Watkins et al. (1990) and Yen et al. (1990) both reported shorter carcasses with the inclusion of RAC in finishing swine diets. The reduction in carcass length can be explained by more nutrients being devoted to protein accretion than to osteogenesis due to the chemical action of ractopamine. The effect of RAC on carcass length maybe more pronounced during the finishing phase than the growing phase. However, the results from the previous studies were reported during the finishing phase.

Table 2. Effect of ractopamine hydrochloride (RAC) on growth of lightweight swine.

Item	0 ppm RAC	5 ppm RAC	10 ppm RAC	SEM[d]	*P*-value
Initial BW, kg	68.59	68.37	67.72	0.77	0.72
Final BW, kg	93.36	90.74	91.98	1.33	0.4
ADG, kg[a]	0.99	0.88	0.96	0.06	0.41
Feed:Gain, kg[b]	2.75	2.84	2.52	0.21	0.56
Drift %[c]	3.05	2.49	3.07	0.19	0.08

Within a row, means with different superscripts differ ($P<0.05$).
[a] ADG (Average Daily Gain) was calculated by total weight gain per pig divided by the number of days on feed.
[b] Feed:Gain ratio was calculated by dividing total kg of feed intake (as-fed basis) divided by total kg of gain per pig.
[c] Drift Percentage (%) was calculated by dividing the live weight recorded at the packing plant by the weight recorded prior to leaving the TSU farm then multiplied by 100.
[d] Standard Error of the Mean.

Backfat. There was no difference among treatment groups for first rib fat thickness ($P>0.05$). In contrast, Crome et al. (1996) and Webster et al. (2002) reported decreases in first rib fat thickness for RAC treatment groups. No difference between treatment groups was found for tenth rib fat thickness ($P>0.05$). These findings are similar to those reported by Carr et al. (2005) and Kutzler et al. (2010). Contrarily, Watkins et al. (1990) and Fernandez-Duenas et al. (2008) found tenth rib fat thickness to be lower for those groups fed RAC. Last rib fat thicknesses were 2.18, 1.90, and 1.84 cm for the 0, 5, and 10 ppm treatments, respectively. Groups fed 5 and 10 ppm RAC were trimmer over the last rib ($P<0.01$) than those fed the 0 ppm RAC ration. This agrees with the findings of Williams et al. (1994) which reported lower last rib fat thicknesses for RAC fed groups. However, Weber et al. (2002) and Kutzler et al. (2010) found no differences in last rib fat thickness among RAC or control treatments. No differences were found among any treatments ($P>0.05$), which agrees with findings reported by Carr et al. (2005).

Muscling. There was no difference between groups for LEA ($P>0.05$). These findings were contrary to those of Stoller et al. (2003) and Carr et al. (2005). This inconsistency could be due to the earlier stage of growth and development for the hogs used in the present experiment as compared to older, heavier finishing swine used in previous research. During the growth phase in swine, muscle growth is somewhat rapid under normal nutritional regimes. A significant effect may not arise with the supplementation of RAC as it would during the finishing stage because muscle is being developed instead of fat during the growth stage. Within the finishing stage, muscle growth slows and adipose tissue begins to deposit more readily. The difference in physiological maturity for lightweight pigs used in the current study compared to older, more mature pigs used in finishing studies could explain the results.

Table 3. Effect of ractopamine hydrochloride (RAC) on carcass characteristics of lightweight swine.

Item	0 ppm RAC	5 ppm RAC	10 ppm RAC	SEM	*P*-value
HCW, kg	65.47	64.39	64.47	0.93	0.67
DP[a]	70.14	70.99	70.09	0.57	0.47
Carcass Length[b], cm	73.33	72.28	72.77	0.87	0.7
1st rib FT[d], cm	3.43	3.29	3.3	0.13	0.71
Last rib FT, cm	2.18[x]	1.90[y]	1.84[y]	0.07	0.01
Last Lumbar FT, cm	1.85	1.64	1.61	0.12	0.37
10th rib FT, cm	1.45	1.24	1.25	0.12	0.37
LEA[c], cm^2	45.13	44.65	45.96	1.67	0.86

[x,y] Within a row, means with different superscripts differ (P<0.05).
[a] Dressing Percentage (DP) was calculated by dividing the hot carcass weight (HCW) by the live weight multiplied by 100.
[b] Carcass length was measured from the anterior edge of the aitch bone to the anterior edge of the first rib.
[c] Loin eye area, as measured at the 10th rib.
[d] Fat Thickness (FT).

***Pork Quality*.** Pork Quality data is represented in Table 4. Color scores ranged from 1 (pale pinkish gray to white) to 6 (dark purplish red). There was no difference between color scores for the treatment groups (P>0.05). These results were consistent with the findings of Stoller et al. (2003), Carr et al. (2005), Fernandez-Duenas et al. (2008), and Kutzler et al. (2010). Since lean color was not negatively impacted by RAC, this observation would support the use of this additive for the commercial swine industry. Furthermore, fluctuations in muscle color are usually a sign of abnormal pH, which in-turn can result in poor consumer acceptance (De Vol et al., 1988).

Table 4. Effect of ractopamine hydrochloride (RAC) on pork quality characteristics of lightweight swine.

Item	0 ppm RAC	5 ppm RAC	10 ppm RAC	SEM	*P*-value
Color[a]	2.07	2.29	2.04	0.1	0.2
Marbling[b]	1.06	1.04	1.01	0.03	0.56
Firmness[c]	3.42	3.69	3.52	0.29	0.71

Within a row, means with different superscripts differ (P<0.05).
[a] NPPC color standards (NPPC, 1999).
[b] NPPC marbling standards (NPPC, 1999).
[c] NPPC firmness standards (NPPC, 1999).

Marbling in pork is not regarded in high priority as in beef, yet increased marbling typically has resulted in greater consumer palatability and satisfaction (Brewer et al., 2001). Marbling scores can range from 1 (devoid) to 9 (abundant). No difference between treatment groups was found for marbling score (P>0.05). High marbling scores were not expected for this experiment, due to the stage of growth and development of the swine utilized. These findings agreed with the results of Stoller et al. (2003), Carr et al. (2005), Fernandez-Duenas et al. (2008), and Kutzler et al. (2010), who found no change in marbling scores among groups fed RAC diets and the control groups in finishing swine.

Firmness scores can range from 1 (very soft) to 5 (very firm). No differences were found for firmness scores between treatments (P>0.05). This result was similar to that reported by Stoller et al. (2003), Carr et al. (2005), and Fernandez-Duenas et al. (2008). However, Kutzler et al. (2010) observed an increase in firmness scores due to inclusion of RAC in the diet, but these changes were described as 'minimal' by the authors. Any product that had a significant effect on pork quality would most likely not be adopted by the commercial swine industry, for fear of decreased consumer acceptance.

CONCLUSIONS

Feeding RAC in growing swine diets did not have an effect on growth or feed efficiency for swine from 68–92 kg of body weight. Carcass cutability factors were also unaffected by RAC with the exception of last rib fat thickness. Dressing percentage, carcass length, first rib FT, last lumbar vertebrae FT, tenth rib FT, and LEA exhibited no differences among treatments. RAC inclusion in the diet had no effect on any of the pork muscle quality attributes measured in this study. Last rib fat thickness was lower for the two RAC-fed groups. Lower last rib fat thickness should result in higher premiums for producers. Results of this study suggest RAC can be fed in lightweight swine diets and achieve a decrease in last rib fat thickness while maintaining acceptable meat quality.

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A Taxonomic Key for Selected Turf-Type Bermudagrasses

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ABSTRACT

Bermudagrass is a widely used turfgrass on golf courses and athletic fields of the southern United States. Correct identification of individual cultivars is essential for plant breeders and when managing established turf. Contamination of bermudagrass with off-types is common. The objective is to provide data in a format that will aid in identifying turf-type bermudagrasses. Thirteen cultivars were selected, measured, and evaluated on taxonomic characteristics. A dichotomous taxonomic key was developed, and a table of data for mean leaf blade widths, vein number, and leaf margin serrations.

KEY WORDS: bermudagrass, taxonomic key, turfgrass

INTRODUCTION

Hybrid bermudagrass (*Cynodon dactylon* x *C. transvaalensis*) is one of the major turf-type grasses used in golf courses and athletic fields in the southern United States. Its use extends from the hot, humid Gulf coastal states to the arid southwestern states and north into the lower Midwest. Most clonal turf bermudagrass cultivars are developed from crosses involving two species: common bermudagrass (*Cynodon dactylon*) and African bermudagrass (*C.transvaalensis*) (Turgeon 2005). Some clonal cultivars are selections from common bermudagrass or African bermudagrass. Bermudagrass is adaptable to a wide range of soil pH, soil texture, fertility levels, and mowing heights. Established bermudagrass is a network of shoots, rhizomes, stolons, and crown tissue together that usually form a dense plant canopy. This dense plant canopy can be used to propagate clonal varieties by sod, sprigs, or plugs. In recent years, plantings of bermudagrass cultivars used for propagation have exhibited distinctive patches of variant morphology (Caetano-Anolles et al., 1997). This occurrence causes severe problems and millions of dollars of loss particularly in the golf course industry. These variant morphologies are often referred to as “off-types”. The off-types having a different color and/or texture perform differently than the surrounding turfgrass and usually require removal. The occurrence of off-type bermudagrass varieties in vegetative sources is a recurring problem (Foy et al., 2004). Turfgrass managers expect a pure variety when receiving sod, springs, or plugs for establishment of turf.

There is a need to develop an easy and reliable technique of clonal turf bermudagrass identification (Vermeulen et al., 1991). DNA fingerprinting is a technique used to identify individual plants and cultivars by their respective DNA profile. DNA

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fingerprinting is an invaluable tool for plant breeders developing improved cultivars. It is also used in disease diagnosis. Caetano-Anolles et al. (1995) provided a detailed study of genetic relationships between bermudagrass cultivars and species. Their study determined the levels of genetic variation within and between selected species of bermudagrass that exhibit a wide range of leaf blade morphologies. Caetano-Anolles et al. (1997) used DNA fingerprinting to certify authenticity of bermudagrass cultivar stocks and evaluate bermudagrass off-types origin. Their study also determined the off-types were genetically diverse and the origin clearly being from contamination rather than somatic mutation. Likewise, the study provided a foundation for contamination in sod fields and identification of mistakes in plantings. Wang et al. (2010) examined simple sequence repeat (SSR) markers for their ability to distinguish commonly grown clonal turf bermudagrass cultivars. SSR markers are locus-specific, highly polymorphic, codominant, and reproducible. SSR markers have been widely used for cultivar identification in a wide range of horticultural and agronomic crops. Wang et al. (2010) concluded that SSR markers could be used as a reliable tool to accurately identify commercially available turf type bermudagrasses. Their study demonstrated the usefulness of these markers as applications for quality control purposes and in tracing infringements on plant breeders' rights. Examples of quality control purposes could be determination of off-types in sod or sprigs on golf courses and sod farms. However, the cost for analysis of a bermudagrass sample submitted to a laboratory performing this identification is likely prohibitive, and perhaps too time consuming for the entity requiring immediate results. It is estimated that the cost of the SSR technique is in excess of $1,000 per sample and may require up to two weeks for results (Wu 2010).

Fermanian et al. (1989) documented the ability of individuals to use grass morphological characteristics in correctly identifying grass species. Their results indicated no significant differences between trained and untrained individuals' ability in identifying grass species, based on characteristics like ligule, leaf sheath, blade width, and pubescence. A sequential dichotomous key is a tool used to categorize plant species based on logical choices in fixed steps. Taxonomic keys have been developed for a wide range of cultivated plants (Winston 1999). Dichotomous keys allow the user to identify plants directly in the field or in the laboratory based on morphological features. The objectives of this study were to: a) develop a taxonomic key for selected bermudagrass cultivars; and b) measure some of the leaf blade characteristics that could also be used to aid in identification of selected cultivars.

MATERIALS AND METHODS

Bermudagrass cultivars included 'Celebration', 'Champion', 'EmeraldDwarf' (taxonomic key only), 'ForaDwarf', 'MiniVerde', 'MS Choice', 'Princess 77', 'TifDwarf', 'TifEagle', 'TifSport', 'TifWay', 'Tift 3', and 'Tift 4'. Plugs, 10.8 cm diameter of each cultivar, were obtained from the Texas A&M University's turfgrass field lab in College Station, TX and were placed into 183 cm^3 plastic pots with a media mixture of 50% sand: 50% peat moss (v:v). Specimens were labeled, maintained in an environmentally controlled facility, and trimmed every one or two weeks to 2.5 cm cutting height.

Leaf blades used for width, vein number, and marginal serration measurement were the third and fourth fully-expanded, undamaged leaves on stems. Twelve leaves were measured for each cultivar. Blade width was measured at the midpoint of the leaf blade using a micrometer capable of measurements to 0.1mm. After width measurement, the blade was removed from the plant and taped to a glass slide for viewing through a microscope at 10X. Vein number was then counted for each leaf.

Blade margin serration data were measured in a different event. After selection, blades were removed from the plant and taped to a glass slide having graduations allowing calibration to 0.001mm when placed under the microscope. Lengths are an average for 10 consecutive serrations occurring along the midpoint of the blade margin.

Third and fourth fully-expanded undamaged leaf blades were also examined for the presence of trichomes on both adaxial and abaxial blade surfaces, presence of trichomes near the ligule, and ligule characteristics. Accurate length measurement of the trichomes was not possible with available equipment, and therefore not included. We have included trichome characteristics in terms of relative length and relative number in order to provide another distinguishing characteristic of each cultivar when the key is utilized by the practitioner. These characteristics were used to construct a dichotomous taxonomic key.

RESULTS AND DISCUSSION

The results of leaf blade width, vein number, and marginal serration width by cultivar are summarized in Table 1. The taxonomic key is presented in Figure 1.

Table 1. Leaf blade width, vein number, and marginal serration width for the third and fourth leaf by cultivar.

Cultivar	Third Leaf (mm)	Fourth Leaf (mm)	Third Leaf veins	Fourth Leaf veins	Serrations Third Leaf (mm)	Serrations Fourth Leaf (mm)
Celebration	1.3(0.2)	1.3(0.2)	13(1.5)	12.3(2.0)	0.088	0.082
Champion	1.9(0.2)	1.8(0.3)	18.4(1.6)	17.8(1.5)	0.056	0.056
FloraDwarf	2.0(0.3)	1.9(0.3)	18.4(1.4)	17.9(1.9)	0.056	0.056
MiniVerde	2.0(0.2)	1.9(0.1)	18.6(1.2)	18.2(1.0)	0.062	0.060
MS Choice	1.4(0.2)	1.4(0.3)	14.2(2.0)	15.5(2.0)	0.081	0.083
Princess 77	1.6(0.4)	1.5(0.5)	14.3(2.8)	13.8(2.8)	0.089	0.078
TifDwarf	1.7(0.1)	1.7(0.1)	17.4(1.1)	16.7(1.6)	0.072	0.070
TifEagle	2.0(0.1)	1.9(0.1)	18.9(0.7)	18.7(1.0)	0.060	0.062
TifSport	1.2(0.1)	1.3(0.1)	15.8(1.7)	15.6(1.7)	0.055	0.059
TifWay	1.2(0.2)	1.2(0.3)	16.6(1.5)	16.6(2.2)	0.066	0.065
Tift 3	1.3(0.2)	1.2(0.2)	16.3(3.7)	15.5(2.1)	0.077	0.073
Tift 4	1.2(0.2)	1.2(0.3)	14.7(1.2)	14.0(1.3)	0.074	0.065

Each number is the mean of ten subsamples. Numbers in parentheses are standard deviation.

Information in Table 1, and the taxonomic key in Figure 1, may be used together as tools to potentially determine the identity of an unknown specimen, or to verify the identity of a known specimen. The user of the key and table should gather data from a minimum of 12 samples (leaves) per specimen and sample several specimens. The users of the taxonomic key who lack plant science training will most likely require additional resources that define botanical terminology and provide visual examples. The data and taxonomic key provide a quick and inexpensive way to potentially determine the cultivar in question. These tools are valuable to the person in the field that is making a management decision. Contamination in sod and sprigs continues to be problematic in bermudagrass sources.

1. Leaf Blades glabrous (8)
1. Leaf Blades have trichomes (2)
2. Blades have trichomes on the adaxial side only **Princess 77**
2. Blades have trichomes on both the adaxial and abaxial sides (3)
3. Trichomes on both sides of the blade sometimes, but may also have trichomes on just the adaxial side, and may also sometimes be glabrous (4)
3. Appear to always have trichomes on both sides of the blade (6)
4. Hairy ligule is small and not very prominent (Note: do not confuse the trichomes coming off the collar for the ligule; if the ligule is prominent, one should be able to see it by pushing down the blade rather than pulling the sheath away from the stem.) Also has trichomes off the front and back of the sheath **MS Choice**
4. Hairy ligule is obvious without pulling the sheath away from the stem (5)
5. Many long trichomes off the side of the collar and small ligule **Tift 4**
5. Few short trichomes off the side of the collar and large ligule **Tift 3**
6. Hairy ligule is small and not very prominent (Note: do not confuse the trichomes coming off the collar for the ligule; if the ligule is prominent, one should be able to see it by pushing down the blade rather than pulling the sheath away from the stem.) Also has long trichomes behind the small ligule off the top of the collar **Celebration**
6. Hairy ligule is obvious without pulling the sheath away from the stem (7)
7. Less than 10 short trichomes arising at the corners of the collar **TifWay**
7. More than 10 semi-long trichomes arising at the corners of the collar. Also has some trichomes on front side of the sheath **TifSport**
8. One or two long trichomes arising at each corner of the collar **Emerald Dwarf**
8. More than two trichomes arising at each corner of the collar (9)
9. Short trichomes that are rather difficult to see (20X magnification) arising at each corner of the collar **Champion**
9. Rather visible trichomes arising at each corner of the collar (10)
10. One trichome present on the abaxial side of the blade near the collar on at least one of the leaves of the sample **FloraDwarf**
10. No trichomes present on the blade (11)
11. Has 5 to 10 trichomes arising at each corner of the collar, which appear to be spread out rather than in a group **TifDwarf**
11. Trichomes arising at corner of the collar are in a group (12)
12. Has 3 to 5 medium length trichomes arising at each corner of the collar, one of these trichomes is much longer than the others **MiniVerde**
12. Has a few short trichomes arising from the corner of the collar with one or two being much longer. **TifEagle**

Figure 1. Taxonomic key for selected bermudagrass cultivars.

However, this key and table data are not inclusive of all bermudagrass cultivars available in the USA. New cultivars are continually being released by plant breeders. Most likely, no bermudagrass taxonomic key will ever be complete with all available cultivars. Our goal has been to provide a useful and inexpensive tool to aid the practitioner in identifying unknown bermudagrass.

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Goat Performance and Prolactin Levels as Affected by Tall Fescue Toxicosis

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ABSTRACT

Ergot alkaloids in tall fescue (*Festuca arundinacea* Schreb) infected with *Neotyphodium coenophialum* cause tall fescue toxicosis with symptoms including decreased prolactin and reduced performance. The development and use of tall fescue with "novel" (a.k.a. non-toxic), endophytes that do not produce ergot alkaloids eliminates tall fescue toxicosis in sheep and cattle. This study examined toxicosis in crossbred Boer goat (*Capra hircus*) performance and prolactin levels. Secondly, the commercial potential of a new tall fescue cultivar containing a non-toxic, novel endophytes (PDF584) was assessed for goat production in north central Texas. Grazing toxic tall fescue had no effect on goat gain, body condition score, rectal temperatures, or serum prolactin levels when compared to the other treatments. The goat's physiological ability to de-toxify ergot alkaloids in its liver is speculated to be the cause. PDF584 performed similarly to annual ryegrass and should have potential for use as cool season grazing forage in north central Texas.

KEY WORDS: boer goats, *Festuca arundinacea*, ergot alkaloids

INTRODUCTION

Tall fescue toxicosis is associated with decreased serum prolactin (Elsasser and Bolt 1987; Schillo et al., 1988; Bolt et al., 1982), reduced average daily gain (ADG), increased core body temperature and respiration rates, vasoconstriction, and lowered reproductive activity in grazing livestock (Read and Camp 1986; Hemken et al., 1979, 1981; Bond et al., 1984; Jackson Jr. et al., 1984; Zanzalari et al., 1989). Limited information is available concerning the effect of the ergot alkaloids on goat productivity. Also, no information is available concerning goat performance on tall fescues infected with a novel endophyte. The objectives of this study were to compare performance and serum prolactin levels for goats grazed on tall fescue, and evaluate the performance of a new tall fescue cultivar containing a non-toxic, novel endophyte (PDF584), likely to be released for use in north central Texas.

MATERIALS AND METHODS

All experimental procedures in this research were reviewed and accepted by the Agricultural Research Service Animal Care and Use Committee in accordance with the *Texas A&M University Guide for the Care and Use of Laboratory Animals*.

Six 0.2 ha paddocks were established in fall 2006, on Lufkin-Rader complex soil (Loamy, deep, nearly level, moderately well drained and somewhat poorly drained soils) in Commerce, Texas (33°24′ north latitude; 95°92′ west longitude). Two paddocks (reps) were planted with a wild-type tall fescue cultivar, Bulldog 51, containing a toxic endophyte, two paddocks (reps) were planted with PDF584 tall fescue, an experimental non-toxic cultivar inoculated with a novel endophyte (AR584), and two paddocks (reps) were planted using annual ryegrass. Therefore, treatments were the toxic tall fescue, non-toxic novel tall fescue, and annual ryegrass paddocks in a completely randomized experimental design. Bulldog 51 and PDF584 were supplied as seed by the Samuel Roberts Noble Foundation, Ardmore, Oklahoma. Annual ryegrass was purchased at Northeast Texas Farmers Co-op, Greenville, TX. Paddocks were planted by no-till drill with fescues seeded at 6.8 kg/ha and ryegrass seeded at 18.1 kg/ha. Paddocks were uniformly fertilized with 90.7 kg/ha of 9-23-30 on November 2, 2006 and again on November 5, 2007 with 68 kg/ha of urea. Paddocks were separated with a 7-wire electric fence system maintained with a 6000 to 9000 volt charger in each paddock. Weather data were collected for the duration of the trial using a Davis Instruments Vantage Pro weather station (Davis Instruments, Hayward, Calif.).

Experimental Design I. Crossbred Boer goats (n = 30; 23.6±9.8 kg BW) were stocked on a naturalized pasture composed predominantly of Coastal Bermuda grass and received a daily offering of 14% all-purpose pellet. Prior to grazing, goats were treated for internal parasites with Prohibit™ (AgriLabs) at a rate of [0.63 g/kg BW]. On January 7, 2008, goats were randomly allotted to 1 of 3 treatments by BW to six pasture blocks for a grazing period of 160 d in length in a put-and-take grazing system. Hutches were provided in each paddock. Water and a trace mineral salt-mixture block (United Salt, Houston, TX) were provided ad libitum, and goats were monitored daily. Shrunk weights were taken at the start and finish of the grazing period and at 3-week intervals. Initial weigh date was January 7, 2008 and continued every 21-d until June 12, 2008. For a period of 10 to 12 hours before weigh dates, goats were not fed or allowed access to water. Goats were processed randomly at 9:00 AM and shrunk weights were measured using a manual scale (Paul Scales, Duncan, Ok.). Rectal temperature and respiration rates were taken each time goats were weighed. Rectal temperatures were measured via a handheld digital thermometer (Johnson and Johnson, New Brunswick, NJ) with the probe placed approximately 3 to 4 cm into the rectum. Respiration rates were calculated on sec/10 breaths. BCS were measured (Villaquiran et al., 2000) at 21-d intervals by two trained animal science technicians and averaged. Famacha© scores were observed by a trained animal science technician on 21-d intervals and Cydectin© was administered orally to animals scoring 4 or higher. Once measurements were complete, animals were given access to water and Coastal Bermuda grass hay in pre-assigned holding pens until re-allotted to assigned paddocks.

Blood samples for prolactin analysis were collected at trial initiation on January 7 and January 31, 2008. Blood was placed into 10-ml Vacutainer© tubes and allowed to coagulate at room temperature for 30 min. Tubes were then centrifuged (3,000 x *g*, 24°C, 25 min). Serum was decanted and frozen at -80°C until prolactin analysis was performed.

Serum prolactin was analyzed at the University of Tennessee, as described by (Bernard et al., 1993) with anintra- and interassay CV of 10 and 15%, respectively.

Forage sampling was initiated before goats started grazing paddocks and continued throughout the grazing period. The samples from each paddock were then composited and a representative sample was obtained. Duplicate samples were dried at 60°C in a forced-air oven and ground coarsely to 1.5 to 2 cm lengths using a mechanical grinder. Samples were ground through a 1 mm screen using a Wiley Mill grinder and transported to the Samuel Roberts Noble Foundation for analysis. Nutrient components were reported as a percentage of acid detergent fiber (ADF), neutral detergent fiber (NDF), dry matter (DM), Ca, K, Mg, P, protein and total digestible nutrients (TDN) using NIRS (FOSS Analytical model 6500 using ISIscan™ software), located at the Samuel Roberts Noble Foundation in Ardmore, OK. Forage availability within the paddocks was determined by a plate meter method (Bransby et al., 1977) on 21-day intervals. Twenty-five randomly selected tillers were collected from each fescue paddock on 21-day intervals. Samples were placed in dampened brown paper towels and placed in Ziploc© bags. Bags were kept on ice and transported to the Samuel Roberts Noble Foundation within 24 hours of collection for analysis of endophyte (Immunoblot) and alkaloid (ELISA) presence.

Experimental Design II. Forage digestibility *in situ* was determined using three crossbred Boer goats (70.3 ± 4 kg of BW), fitted with rumen collection cannulas provided by the Texas A&M *Agri*Life Research and Extension Center, Stephenville, TX. Goats were housed in a partially open barn with provided shade and ad libitum access to Coastal Bermuda hay and water. For 2 wks. before the beginning of the experimental trial the goats were adapted to the forage. Goats were randomly assigned 1 of 3 treatments consisting of wild-type toxic tall fescue, non-toxic novelty tall fescue and annual ryegrass. Environmental temperatures were consistent with temperatures in north central Texas for July 2008 (The Weather Channel Interactive, Inc.; average temperature: high 34.4°C, low 21.1°C), with barn temperatures approximately equal to environmental temperatures. Forage samples consisted of Bulldog 51 tall fescue, PDF584 novelty tall fescue and annual ryegrass (three replications per treatment). Each treatment was randomly allocated to a specific goat with time intervals of 0, 6, 12, 18, 24, 48, and 96 h to obtain a sufficient degradation curve. Zero bags were used to estimate immediate loss of soluble nutrients and forage sample dust in the rumen while 96 h bags were used to estimate indigestible fiber (IDF) (Van Soest 1994). Dacron bags were weighed before filling with treatment material and after filling. Bags were then heat sealed at two locations on bag. An approximate 2 g sample size was placed in 10 cm x 5 cm bags (50 cm^3) and weighed to the nearest 0.01 g (Nocek 1988). A maximum of nine bags were inserted into the goat rumen at one time attached to a chain using zip ties©. Once bags were removed they were quickly rinsed in ice water to remove loose ruminal particles and arrest microbial fermentation, detached from the chain and placed into a Ziploc© bag and frozen until analysis. All bags were rinsed simultaneously to avoid differences that may be caused by rinsing. Bags were placed into a tub and manually rinsed with distilled water, stirred and squeezed, and the water drained. The process was repeated several times until water was clear. Bags were placed into a washing machine and washed twice on a 2 min rinse cycle (Cherney et al., 1990) then dried in a forced air oven at 60°C and weighed to the nearest 0.01 g.

The experimental design was completely randomized in which animal units were treated as replications and blocked over days. All statistical analyses were conducted using PROC MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). Repeated measures (physiological and blood parameters) were analyzed as a split-plot in time. Non-repeated measures (nutrient digestibility) were analyzed as a completely randomized design using one-way ANOVA. The model included main effects and their interactions.

Endophyte Presence, Alkaloid Production, and Forage Availability. In terms of endophyte presence and toxin production, the tall fescue paddocks represented the wild-type toxic and non-toxic novelty treatments as expected. Viable endophyte infection ranged from 87.5% to 95.8% in non-toxic novelty paddocks and 62.5% to 91.7% in wild-type toxic tall fescue paddocks during the study period. Ergot alkaloids were identified in 93.75% of the wild-type toxic paddocks, while the alkaloid was not present in the non-toxic novelty paddocks. As expected, the alkaloid was identified in 93.75% of the toxic endophyte-infected Bulldog 51, while the alkaloid was not present in the non-ergot alkaloid producing PDF584.

Based on plate meter readings, the annual ryegrass treatment had lower ($P < 0.0001$) forage availability across sampling dates than both the wild-type toxic and non-toxic novelty tall fescue treatments. No differences were shown between the two tall fescues treatments. Environmental conditions were favorable for forage growth during winter and spring months, but minimal decline of forage from paddocks was observed. Soil type and paddock location could be a possible cause of forage decline. There was 66% forage availability for novel PDF584 tall fescue and 37% wild-type toxic tall fescue forage availability across sampling dates.

Forage Digestibility. Forage quality of all winter paddocks were within the normal NIRS database limits. Crude protein (CP) concentrations ranged from 8.5 to 13.1% across sampling dates, ADF ranged from 43.3 to 47.7%, and NDF ranged from 62.9 to 69.0%. Annual ryegrass had higher levels of in-vitro total dry matter digestibility (IVTDMD), DM, CP, NDF and ADF compared to both two tall fescue treatments. No differences were found between the two tall fescue treatments for all the same parameters except DM where the wild-type toxic was slightly higher than the non-toxic novelty tall fescue.

In situ digestibility was not different between forage treatments (Figure 1). Treatments of wild-type toxic tall fescue, non-toxic novelty tall fescue and annual ryegrass began at the zero time point with digestibility averages of 22.7, 25.0 and 24.4%, respectively. IDF values were 81.2, 80.6 and 77.7% for the 96 hr time slot.

Physiological Effects. Suppressed serum prolactin concentrations are a widely accepted indicator of fescue toxicosis (Hoveland et al., 1983). Treatment values of serum prolactin concentrations in this current study were within normal limits published by Malven and McMurtry (1973) and did not differ among wild-type toxic and non-toxic novelty treatments or within paddocks to published findings for sheep (Parish et al. 2003a, 2003b) (Figure 2).

Normal values for rectal temperatures in healthy goats in a comfortable 23° C environment are 37° to 39°C (Walker and Dziemian 1950). No treatment effects were observed for rectal temperature across or within treatments throughout duration of the study.

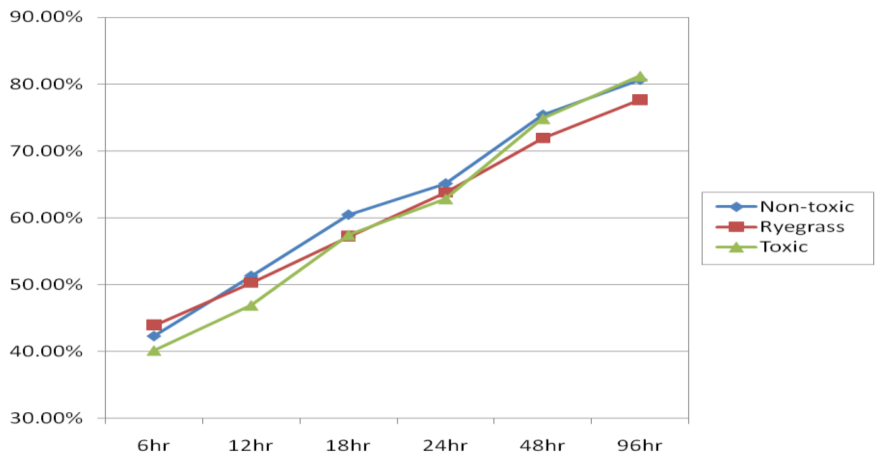

Figure 1. Cannulated Goat *In Situ* Digestibility Results from Annual Ryegrass, Wild-Type Toxic, and Non-Toxic Novelty Tall Fescue Samples.

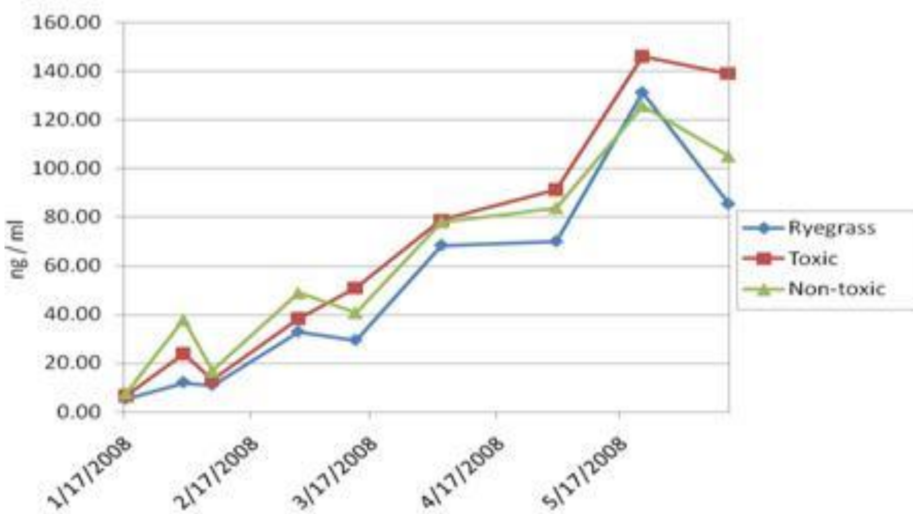

Figure 2. Serum Prolactin Levels in Boer Goats Grazing Annual Ryegrass, Wild-Type Toxic and Non-Toxic Novelty Tall Fescue.

Goats began grazing treatment paddocks with an average BW of 24.0, 23.9, and 23.5 kg for wild-type toxic tall fescue, non-toxic novelty tall fescue and annual ryegrass treatments, respectively. Final BW for the goats within paddocks were 31.75, 35.43 and 35.92 kg. Total weight gain did not differ among or within treatments in this current study.

Respiration rates were not influenced by treatment. Values collected do not vary from normal respiration rates for goats in a 23°C environment of 24 to 40 per minute (Walker and Dziemian 1950).

BCS for the goats remained constant throughout the duration of the grazing period. No differences were noted between or within treatments. All goats kept a clean coat and appearance. Environmental conditions could have contributed to lower scores, but overall scores were well within the normal range of 3 for good body condition (Spahr

2008). Optimal scores for goats are a 1 or 2 according to the Famacha© Anemia Guide. Famacha© scores were not influenced by treatment.

DISCUSSION

Grazing wild-type toxic tall fescue had no effect on goat serum prolactin levels, ADG, respiration rates, core body temperatures, BCS or Famacha© scores. Lack of ergot alkaloid influence on daily rectal temperature match data collected by De Lorme et al. (2007), Matthews et al. (2005), Stamm et al. (1994), and Fiorito et al. (1991) who also found no difference in rectal temperature of cattle or sheep on toxic or non-toxic tall fescue treatments. Both fescue treatments were confirmed through repeated immunoblot testing to harbor the endophyte, and unlike the forage in the wild-type toxic paddocks, the non-toxic novelty tall fescue forage did not produce toxic ergot alkaloids through continuous ELISA testing associated with fescue toxicosis. The non-toxic novelty tall fescue paddocks had optimal forage availability, quality, and digestibility in comparison to wild-type toxic tall fescue and annual ryegrass. Annual ryegrass had greater (P < 0.0001) forage quality and digestibility than both tall fescue treatments with lower (P < 0.02) ADF and (P < 0.0001) NDF values. Annual ryegrass CP levels of 13.10% were also greater (P < 0.0001) than both fescue treatments of 8.48 and 9.58%, respectively. However, the CP levels attained in fescue forages should be optimal for pasture grazing and at no time during the grazing period did annual ryegrass give better live weight gain than the new tall fescue containing the novel endophyte.

It is evident that ruminants grazing non-toxic novelty tall fescue do not exhibit signs of fescue toxicosis in comparison to ruminants placed on toxic tall fescue pastures (Bouton et al., 2002; Parish et al., 2003a and b). While new novel endophyte infected tall fescue varieties have resolved the reduction in animal performance, replacement of toxic endophyte infected fescue pastures can be timely and costly. Within this current study goats were visually observed consuming both wild-type toxic and non-toxic novelty tall fescue forage varieties and both treatments remained grazed close to the ground throughout the duration of the study. Clearly, goats within the study did not show signs of fescue toxicosis as reported for other animal species (Hemken et al., 1979; Paterson et al., 1995; Oliver 1997; Burke et al., 2001). The ability of goats to better handle toxins introduced into the body as compared to other ruminants may be attributed to their liver. Once toxins are in the bloodstream, they flow to the liver for rapid degradation and alteration (De Lorme et al., 2007). A goat's liver is known to detoxify harmful agents at a greater rate than other species. For example, Ivermectin© oral dewormer is applied six times higher to goats than cattle (Kaplan 2004). Ergot alkaloids have been shown in previous research to disappear rapidly from both sheep (Jaussaud et al., 1998) and goat (Durix et al., 1999) blood after an intravenous injection of ergovaline. Ergovaline levels dropped below quantification threshold (3.5 mg/ml) within 1 hr after injection. Since research on ergot alkaloid degradation by the liver in livestock has not been performed, it is impossible to determine the extent that the liver alters and detoxifies the toxins. For producers looking for a way to effectively graze tall fescue pastures in north central Texas without hindering animal production or replacing pasture forage, goats may be an animal of choice.

Cool season pasture for commercial goat production in north central Texas is currently limited to annual forage species such as annual ryegrass and cereals. The use of perennial cool season forage such as non-toxic novelty tall fescue could be an economic advantage for producers in the region due to its perennial nature. Results from this study indicate newly developed non-toxic novel endophyte-infected tall fescue cultivars such as

PDF584 produce positive goat performance similar to annual ryegrass. Therefore, if producers can achieve an acceptable level of persistence (probably 4-5 years) for this new cultivar, there should be an economic advantage for it as cool season pasture for rapidly growing goats.

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Effects of Protein or Energy Supplementation on *In Situ* Disappearance of Low- and High-Quality Coastal Bermudagrass Hay in Goats

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ABSTRACT

The objective of this research was to determine if supplementing protein or energy would improve the ruminal *in situ* disappearance of two qualities of (5.8 or 13.4% CP) Coastal Bermudagrass (*Cynodon dactylon* (L.) Pers.) hay in goats. Treatments were arranged in a 4 × 4 Latin Square design and consisted of either sodium caseinate (0.122% BW), corn starch (0.15% BW), or dextrose (0.15% BW) administered daily into the rumen; compared to a hay-only control. Goats had *ad libitum* access to Coastal Bermudagrass hay (5.8 and 13.4% CP for experiment 1 and 2, respectively) at all times during the experiment. Each period consisted of 14 days for treatment adaptation and followed by incubation of *in situ* bags. *In situ* hay samples were analyzed for dry matter, organic matter, neutral detergent fiber, and acid detergent fiber disappearance after ruminal incubation. Dry matter, organic matter, neutral detergent fiber, and acid detergent fiber disappearance were not affected ($P > 0.05$) by protein or energy supplementation in when either high- or low-quality bermudagrass was fed. Further research is needed to determine if this was due to the nutritive value of the basal diet, or the value of the diet selectively ingested by the goats from the basal diet.

KEY WORDS: small ruminant, digestion, supplements, nutritive value, forage quality

INTRODUCTION

The goat population in U.S. increased by 3% during 2007 to a total of 3.02 million head (NASS 2008), due in part to the increase of ethnic diversity in the country (Oman et al., 1999) and land fragmentation of rural areas. Because their ability to utilize woody vegetation and preference for browse and forbs, goats thrive on land with a low concentration of grasses, where bulk grazers, such as cattle, are not as well adapted (Papachristou et al., 1999; Ott et al., 2004). Because of land fragmentation of cattle ranches, goats are often raised on cultivated pastures originally designed for bulk grazers and have limited access to browse (Goodwin et al., 2004). As a result, producers often rely on grass or grass hay as a primary source of goat feed, despite their preference for browse and forbs. Browse and forbs often allow for greater selectivity by goats resulting in an intake that has greater nutrient and lesser fiber concentrations compared to grasses. Grasses can play a constructive, supportive role in goat production. It has been reported

(Packard et al., 2007a) that as the quantity of accessible browse decreased, supplementation of Bermudagrass (*Cynodon dactylon*) hay aided in increasing average daily gain (ADG) in growing meat goats.

Protein is the first limiting nutrient of cattle grazing low-quality grass forages (National Research Council 1981; Heldt et al., 1999a). Forages with a crude protein (CP) concentration less than 6 to 7% (National Research Council 1981; Titgemeyer et al., 2004) will compromise intake, digestibility (Mathis et al., 2000), and growth in ruminant animals. Degradable intake protein (DIP) in cattle is known to increase ruminal ammonia nitrogen (NH_3 N) concentrations and volatile fatty acids (VFA; Heldt et al., 1999a), as well as increase dry matter (DM), and organic matter (OM) intake and digestibility of low-quality forage (Bodine et al., 2000; Köster et al., 1996; Schmidt et al., 2006). Degradable intake protein requirements for goats have not been extensively studied. Currently, the recommended requirement for goats is 9% of total digestible nutrients (TDN; National Research Council 2007).

Cattle that graze low-quality forages are often deficient in digestible energy and protein. Although many producers supplement grains to increase energy in cattle grazing low-quality forages (Brokaw et al., 2001), it has been suggested (Caton et al, 1997) that energy supplementation reduced grazed forage intake in ruminants due to decreases in ruminal fiber digestion. The efficacy and efficiency of feeding energy concentrates to grazing ruminants in general, and browsing ruminants in particular, whose digestive systems are adapted to utilizing fibrous energy sources, requires more study.

In contrast to the vast amount of data available concerning supplementation of cattle consuming low-quality forages, data concerning energy or protein supplementation of goats is lacking. The objective of this experiment was to determine if supplementing sodium caseinate (0.122% BW), corn starch (0.15% BW), or dextrose (0.15% BW) would improve the ruminal digestion of two different qualities of (5.8 or 13.4% CP) Coastal Bermudagrass hay in goats.

MATERIALS AND METHODS

Experimental Design.[11] Four mature, ruminally-cannulated wethers were used (average BW 62 kg) in two 4 × 4 Latin Square design experiments. Each of the four treatment periods consisted of 21 days. The first 14 days were for adaptation and the final 7 days for *in situ* incubations. Goats were fed low-quality (5.8% CP; Experiment 1) or high-quality (13.4% CP; Experiment 2) Coastal Bermudagrass hay (Table 1) *ad libitum* and had continuous access to clean water and a trace mineralized salt block. Supplement treatments consisted of sodium caseinate (0.122% BW/day), corn starch (0.15% BW/day), or dextrose (0.15% BW/day) administered directly into the rumen daily at 1700 h; compared to a hay-only control. Protein (sodium caseinate) treatment levels administered were the lowest level estimated to provide sufficient DIP to maximize forage intake and digestion based on previous work with cattle (Heldt et al., 1999a; Köster et al., 1996). Energy (starch or dextrose) treatment levels administered were chosen to simulate quantities of ruminally digestible starch, commonly fed to cattle as a cereal grain supplement (Heldt et al., 1999a).

Table 1. Chemical composition (% DM) of low- and high-quality Coastal Bermudagrass hay utilized in this study.

[11] The Tarleton State University Institutional Agricultural Animal Care and Use Committee approved all experimental protocols.

	Low-Quality	High-Quality
DM[1]	96.4	94.4
OM	95.2	93.3
CP	5.8	13.4
NDF	72.5	71.3
ADF	39.4	37.5

[1]Organic matter, OM; Crude protein, CP; Neutral detergent fiber, NDF; Acid detergent fiber, ADF.

In Situ Methodology. Ground (2-mm screen) samples of Coastal Bermudagrass hay (2 g) were placed in dacron sample bags (Ankom Technology, Macedon NY); 50 ± 15 µ porosity, 5 × 10 cm size) to give a sample:surface area ratio of 20 mg:cm^2. Quadruplicate samples were incubated for 0, 2, 4, 8, 16, 24, 48, or 72 h in the rumen of the goats. Because not all bags were able to be incubated simultaneously, the incubation period was conducted over 7 days. Ten bags were placed in the goat rumen at each time tied to a tube (31 cm length). After removal, bags were stored frozen at -20°C, thawed to rinse with quadruplicate zero hour bags in water, according to procedures previously described by Vanzandt et al. (1998), and dried at 55°C in a forced-air oven for 48 h. Dry *in situ* bags were weighed upon removal from oven in order to obtain DM disappearance (DMD). Bags were opened and batched by animal and incubation time and ground using a Wiley Mill to pass through a 1-mm screen. *In situ* and control samples were analyzed for DM and OM (AOAC 1990) neutral detergent fiber (NDF; ANKOM Technology, Macedon, NY USA), and acid detergent fiber (ADF; ANKOM Technology).

The degradation profiles of DM and OM were determined using a model previously described by Ørskov and McDonald (1979). Potential degradability was calculated as PD = $a + b\ (1\text{-exp}^{-k(t-L)})$, where "*a*" is the soluble fraction, "*b*" is potentially degradable insoluble fraction, "k" is the degradation rate of "*b*," and "*L*" is the lag of degradation of "b."

Statistical Analysis. Data was statistically analyzed using SAS (SAS Inst. Inc., Cary, NC USA). The NLIN procedure was used to estimate fiber disappearance parameters. The GLM procedure was used to compare a, b, k, L, and PD across treatments. Dependent variables were a, b, k, L, and PD and the model contained the effect of treatment, goat, and period.

RESULTS

Experiment 1 (Low-Quality Hay). Rates of ruminal DM disappearance for sodium caseinate, dextrose, corn starch, and control treatments (0.051, 0.059, 0.057, and 0.050 per hour, respectively) did not differ ($P > 0.8$; Table 2). Extent of ruminal DM disappearance among sodium caseinate, dextrose, corn starch, and control treatments (53.6, 56.1, 54.1 and 53.2%, respectively) were also not affected ($P > 0.9$) by treatment. Rates of ruminal OM disappearance among sodium caseinate, dextrose, corn starch, and control treatments (0.052, 0.061, 0.057, and 0.049, respectively) were not affected ($P > 0.7$) by treatment. Extent of ruminal OM disappearance among sodium caseinate, dextrose, corn starch, and control treatments (53.0, 54.9, 53.5, and 53.1%, respectively) were not affected ($P > 0.9$) by supplement treatment. Rate of ruminal NDF disappearance among sodium caseinate, dextrose, corn starch, and control treatments (0.063, 0.062, 0.062, and 0.058%, respectively) were not affected ($P > 0.9$) by treatment. Extent of ruminal NDF disappearance between casein, dextrose, corn starch, and control treatments (44.9, 46.7, 45.4, and 45.3%, respectively) were not affected (*P* > 0.6) by treatment. Rates of ruminal ADF disappearance between sodium caseinate, dextrose, corn starch, and control treatments (0.055, 0.048, 0.049, and 0.60%, respectively) were not affected (*P* > 0.4) by treatment. Extent of ruminal ADF disappearance between sodium caseinate, dextrose, corn starch, and control treatments (40.1, 40.8, 39.9, and 38.1%, respectively) were not affected (*P* > 0.7) by treatment.

Table 2. Rumen *in situ* dry matter (DM), organic matter (OM), acid detergent fiber (ADF) and neutral detergent fiber (NDF) disappearance characteristics for low-crude protein (5.8%) Coastal Bermudagrass hay in unsupplemented goats (control) or goats supplemented with sodium caseinate (0.12% BW/day), dextrose (0.15% BW/day), or corn starch (0.15% BW/day).

Treatment	a[1] (% of DM)	b (% of DM)	PD (% of DM)	k (/h)	L (h)
DM					
Control	18.6 ± 0.8	34.6 ± 2.6	53.2 ± 2.0	0.050 ± 0.011	1.99 ± 0.56
Casein	18.9 ± 0.8	34.8 ± 2.6	53.6 ± 2.0	0.051 ± 0.011	1.28 ± 0.56
Dextrose	16.8 ± 0.8	39.2 ± 2.6	56.0 ± 2.0	0.060 ± 0.011	1.71 ± 0.56
Starch	19.2 ± 0.8	34.9 ± 2.6	54.0 ± 2.0	0.057 ± 0.011	2.95 ± 0.56
OM					
Control	17.1 ± 0.4	36.0 ± 2.2	53.1 ± 1.9	0.049 ± 0.001	1.90 ± 0.46
Casein	17.2 ± 0.4	35.9 ± 2.2	53.0 ± 1.9	0.052 ± 0.001	1.26 ± 0.46
Dextrose	16.9 ± 0.4	38.0 ± 2.2	55.0 ± 1.9	0.061 ± 0.001	2.09 ± 0.46
Starch	17.5 ± 0.4	36.0 ± 2.2	53.6 ± 1.9	0.057 ± 0.001	2.95 ± 0.46
ADF					
Control	10.6 ± 0.5	27.5 ± 2.9	38.2 ± 2.6	0.060 ± 0.008	6.09 ± 1.36
Casein	9.2 ± 0.5	30.9 ± 2.9	40.2 ± 2.6	0.055 ± 0.008	1.16 ± 1.36
Dextrose	8.1 ± 0.5	32.7 ± 2.9	40.8 ± 2.6	0.048 ± 0.008	2.69 ± 1.36
Starch	9.8 ± 0.5	30.2 ± 2.9	39.9 ± 2.6	0.049 ± 0.008	3.85 ± 1.36
NDF					
Control	40.6 ± 11.0	412.8 ± 1.7	45.3 ± 1.5	0.058 ± 0.009	0.24 ± 0.53
Casein	57.1 ± 11.0	392.1 ± 1.7	45.0 ± 1.5	0.063 ± 0.009	0.31 ± 0.53
Dextrose	37.9 ± 11.0	429.2 ± 1.7	46.7 ± 1.5	0.062 ± 0.009	0.31 ± 0.53
Starch	53.6 ± 11.0	400.8 ± 1.7	45.5 ± 1.5	0.062 ± 0.009	1.87 ± 0.53

[1]a, soluble fraction; b, potentially degradable insoluble fraction, PD degradable fraction; k, degradation rate of b; L is the lag before degradation of b.

Experiment 2 (High-Quality Hay). Rates of ruminal DM disappearance for sodium caseinate, dextrose, corn starch, and control treatments (0.038, 0.036, 0.032, and 0.035 per hour, respectively) were least for corn starch and greatest for casein, with both the control and dextrose treatments being intermediate (Table 3). Extent of ruminal DM disappearance among sodium caseinate, dextrose, corn starch, and control treatments (67.3, 67.8, 68.0, 67.2%, respectively) were not affected (*P* > 0.15) by treatment. Rates of ruminal OM disappearance among sodium caseinate, dextrose, corn starch, and control treatments were 0.039, 0.035, 0.032, 0.035 per hour, respectively and did not differ.

Extent of ruminal OM disappearance among sodium caseinate, dextrose, corn starch, and control treatments (66.9, 67.6, 67.6, 66.8%, respectively) were not affected ($P > 0.15$) by treatment. Rate of ruminal NDF disappearance among sodium caseinate, dextrose, corn starch, and control treatments were 0.042, 0.040, 0.035, 0.039 per hour, respectively with the corn starch treatment exhibiting the lesser ($P < 0.05$) rate of NDF disappearance. Extent of ruminal NDF disappearance between casein, dextrose, corn starch, and control treatments (61.3, 61.2, 61.9, and 61.8%, respectively) were not affected ($P > 0.2$) by supplement. Rates of ruminal ADF disappearance between sodium caseinate, dextrose, corn starch, and control treatments (0.060, 0.042, 0.036, 0.420 per hour, respectively) were not affected ($P > 0.5$) by treatment. Extent of ruminal ADF disappearance between sodium caseinate, dextrose, corn starch, and control treatments (55.3%, 57.4%, 57.9%, and 56.7%, respectively) were not affected ($P > 0.16$) by treatment.

Table 3. Rumen *in situ* dry matter (DM), organic matter (OM), acid detergent fiber (ADF) and neutral detergent fiber (NDF) disappearance characteristics for high-crude protein (13.4%) Coastal Bermudagrass hay in unsupplemented goats (control) or goats supplemented with sodium caseinate (0.12% BW/day), dextrose (0.15% BW/day), or corn starch (0.15% BW/day).

Treatment	a[1] (% of DM)	b (% of DM)	PD (% of DM)	k (/h)	L (h)
DM					
Control	17.8 ± 0.5	49.4 ± 1.0	67.2 ± 1.0	0.035 ± 0.001	0.95 ± 0.63
Casein	20.0 ± 0.5	47.3 ± 1.0	67.3 ± 1.0	0.038 ± 0.001	3.40 ± 0.63
Dextrose	19.2 ± 0.5	48.6 ± 1.0	67.8 ± 1.0	0.036 ± 0.001	1.82 ± 0.63
Starch	19.3 ± 0.5	48.7 ± 1.0	68.0 ± 1.0	0.032 ± 0.001	1.55 ± 0.63
OM					
Control	15.2 ± 0.6	51.6 ± 1.0	66.8 ± 1.0	0.035 ± 0.001	0.97 ± 0.62
Casein	17.4 ± 0.6	49.5 ± 1.0	66.9 ± 1.0	0.039 ± 0.001	3.47 ± 0.62
Dextrose	16.7 ± 0.6	51.4 ± 1.0	67.6 ± 1.0	0.035 ± 0.001	1.55 ± 0.62
Starch	16.4 ± 0.6	51.2 ± 1.0	67.6 ± 1.0	0.032 ± 0.001	1.36 ± 0.62
ADF					
Control	2.2 ± 0.9	54.5. ± 1.7	56.7 ± 1.0	0.042 ± 0.008	1.87 ± 1.56
Casein	4.0 ± 0.9	51.3 ± 1.7	55.3 ± 1.0	0.060 ± 0.008	6.15 ± 1.56
Dextrose	2.9 ± 0.9	54.5 ± 1.7	57.4 ± 1.0	0.042 ± 0.008	2.17 ± 1.56
Starch	3.4 ± 0.9	54.5 ± 1.7	57.9 ± 1.0	0.036 ± 0.008	1.85 ± 1.56
NDF					
Control	1.4 ± 0.4	60.4 ± 1.3	61.8 ± 0.9	0.039 ± 0.001	0.67 ± 0.32
Casein	4.2 ± 0.4	57.1 ± 1.3	61.3 ± 0.9	0.042 ± 0.001	2.91 ± 0.32
Dextrose	2.4 ± 0.4	58.8 ± 1.3	61.2 ± 0.9	0.040 ± 0.001	1.10 ± 0.32
Starch	2.4 ± 0.4	59.5 ± 1.3	61.9 ± 0.9	0.035 ± 0.001	0.74 ± 0.32

[1]a, soluble fraction; b, potentially degradable insoluble fraction, PD degradable fraction; k, degradation rate of b; L is the lag before degradation of b.

DISCUSSION

The purpose of the this study was to determine if supplemental DIP in the form of sodium caseinate, or energy in the form of dextrose or corn starch, would affect *in situ* nutrient disappearance in goats fed either high-quality or low-quality Coastal Bermudagrass hay. There were no significant ($P > 0.05$) differences among *in situ* DM, OM, NDF, and ADF disappearance when sodium caseinate, dextrose, or corn starch were supplemented in goats consuming either low-quality (5.8% CP) or high-quality (13.4% CP) Coastal Bermudagrass hay.

It has been previously reported (Olson et al., 1999) that cattle consuming low-quality (4.9% CP) tallgrass-prairie hay showed a linear increase ($P < 0.01$) in forage DM, OM, and NDF intake when fed supplemental DIP in the form of sodium caseinate (0.12% BW/day). They also found that the addition of supplemental starch in the form of corn grits (0.15% BW/day) decreased ($P < 0.01$) forage DM, OM, and NDF intake linearly. Beaty et al. (1994) reported a quadratic increase in wheat straw (3.1% CP) intake by cattle with an increase up to 30% CP concentration in supplementation.

In further contrast to our results with goats, it has been found that cattle consuming low-quality (5.2% CP) forages had 22.1% ($P < 0.01$) greater OM digestibility and 10.8% ($P = 0.03$) greater NDF digestibility when supplemented with dextrose at 7.9% of the diet ($P = 0.04$), compared to starch supplementation at the same levels (Heldt et al., 1999a,b). Conversely, beef steers fed Bermudagrass (8.2% CP) exhibited no change ($P > 0.41$) in forage OM or NDF intake ($P > 0.20$) with supplemental DIP (Mathis et al., 2000).

Many researchers have found that cattle consuming forages with a CP concentration of 7% or less show a positive intake response to protein supplementation (Bandyk et al., 2001; Beaty et al, 1994; Bohnert et al, 2001; Farmer et al., 2001). Protein supplementation in the form of DIP is generally considered to be the dietary component that is first limiting to the utilization of low-quality forages in cattle (Koster et al., 1996).

Bacterial CP can supply from 50% to essentially all microbial protein required by beef cattle. The DIP requirement for beef cattle is 13% of TDN, which is equivalent to the assumed ruminal microbial CP requirement (National Research Council 2000). By contrast, the reported degradable protein intake requirement for goats is only 9% of TDN (National Research Council 2007). The predicted DIP difference in the DIP requirement of goats, as compared to cattle, could be the result of differences in rates of nutrient passage; an increased ability to conserve N by goats through recycling (National Research Council 2007). Another possible explanation for the differences between cattle and goats, with respect to DIP requirement, is selectivity of forages; even when forage is fed as hay. Packard et al. (2007a, b) found that rejected orts left by goats, who were offered bermudagrass *ad libitum*, was lower in nutritive value than the original material offered. This supports previous reports by Pfister and Malecheck (1986), that goats are more selective in their feeding habits than sheep. Because forage intake is positively associated with rate of passage, it is possible that goats will select greater quality diets and, as a result, have greater intakes than cattle and sheep.

Goats appear to digest low-quality forages while maintaining adequate levels of production; however, some have suggested that supplementing goats with additional protein and energy feedstuffs will serve as a management tool in preventing weight loss during dry periods, when browse availability is limited (Ott et al., 2004). These authors also suggested that additional protein and energy supplementation may improve productivity of rangeland-fed goats in areas where browse is available.

There was no effect of sodium caseinate, corn starch, or dextrose on coastal Bermudagrass disappearance in goats consuming Coastal Bermudagrass hay with a total plant CP concentration either 5.8 or 13.4% CP. When we consider that bovine studies, using the same procedures, did show positive effects from these same supplement levels, we must conclude that there is an animal species difference. Greater N recycling by goats, species-specific differences in selectivity of ingested forages, and or rumination due to metabolic body size differences, and potentially smaller CP requirements for goats, are all possible explanations for the lack of response of goats fed supplements. The literature would predict positive responses in bovines.

Experiments should be conducted to determine at what point DIP and/or energy supplementation becomes beneficial for goats consuming a range of low to high-quality forages; fed in such a manner as to deprive animals of chance for selectivity, thereby depriving goats the possibility of increasing forage nutritive value intake vis-à-vis forage nutritive value offered. Until those trials are conducted, we can conclude that, unlike bovines, goats allowed to selectively feed on low-quality long-stem hay may not benefit from protein or energy supplements as readily as do bulk-grazing ruminants such as cattle.

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