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MANAGING EDITOR: Ashley Lovell, Tarleton State University, Department of Agricultural and Consumer Sciences, Box T-0040, Stephenville, TX 76402.

JOURNAL SECRETARY: Lacie Harris, Box T-0460, Stephenville, TX 76402; Phone: (254) 968-9927; E-mail: txjanr@tarleton.edu

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The Effect of Supplemental Probiotics and Spray-Dried Egg Proteins on Piglet Growth Performance Characteristics

Kelsey G. Bryan[1]
Randy M. Harp[1*]
Barry D. Lambert[1, 2]
Joe M. Cadle[1]
Wendi G. Snider[1]

[1]*Department of Animal Science and Veterinary Technology, Tarleton State University, Stephenville, Texas 76402*
[2]*Texas AgriLife Research and Extension Center,* 1229 North US Highway 281 *Stephenville, TX 76401, USA*

ABSTRACT

This study evaluated the use of a supplemental probiotic, containing spray-dried egg proteins and several different dried bacteria. The objectives of this study were to determine if the probiotic supplement affected growth performance of the piglets, fecal consistency, and the number of *Escherichia coli* and *Lactobacillus* species present in the feces. The supplemental probiotic was administered at three intervals with fecal samples being collected at four intervals. Weights were collected at five intervals. There were no differences (P > 0.05) in 21-day, weaning, nursery, or finishing floor weights between treatment and control groups. There were no differences (P > 0.05) in fecal scores in the farrowing house, nursery, or finishing floor between treatment and control groups. There were no differences (P > 0.05) in the number of *Escherichia coli* or *Lactobacillus* species present in the fecal material, between treatment and control groups, at all intervals measured.

KEY WORDS: piglets, probiotic, egg proteins, growth performance

INTRODUCTION

Consumers today are worried about consuming meat from animals who received sub-therapeutic levels of antibiotics for growth promotion while producers are worried about keeping their animals healthy and having the animals reach market weight as early as possible. These worries make it difficult for producers to please consumers and keep their animals healthy, while at the same time limiting production costs. Lowering the mortality rate of pre-weaned pigs and maintaining weight gains when weaning occurs are major economic factors associated with the profitability of swine operations. When piglets are weaned, they have a limited ability to deal with diseases because the level of immunoglobulins supplied by the colostrum may vary depending on the pathogen level they have faced and their immune system is just beginning to function (Coffey and Cromwell 2001). At weaning, piglets experience dietary and environmental changes that lower feed intake, cause poor performance, and increased susceptibility to diseases

* Corresponding author: harp@tarleton.edu

(Mathew et al. 1998). Producers prefer that their pigs reach market as soon as possible and any days off feed increases the time it takes the pigs to reach market weight, thus cutting into the producers' economical return.

Probiotics are prepared doses of live bacteria, usually in a feed type supplement form, that are given to an animal in order to repopulate the animal's digestive system with beneficial bacteria (Fuller 1989). The addition of beneficial bacteria when piglets are under stress works to improve the intestinal microflora balance, increasing nutrient absorption (Fuller 1989). Beneficial bacteria compete with harmful bacteria for substances in the digestive system. Probiotics give a boost to beneficial bacteria so they can outperform the harmful bacteria. Probiotics also stimulate the piglets to remain on feed, which lessens the amount of days the producers must feed the pigs before they reach market weight. In addition to probiotics, there are prebiotics available which work to promote a healthy intestinal microflora. A prebiotic can be defined as a non-digestible food ingredient that through metabolism promotes the growth of beneficial microflora in the intestines (Manning and Gibson 2004). A prebiotic does not stimulate the growth of harmful pathogens such as toxigenic *Escherichia coli (E. coli)* (Manning and Gibson 2004). The two common bacteria that are used to improve intestinal microflora are *bifidobacteria* and *lactobacilli* (Manning and Gibson 2004). The thought is that by increasing lactic acid bacteria, there is an increased stimulation of the immune system, specifically non-specific host defense mechanisms and certain cell types (Manning and Gibson 2004).

There is also public concern over the therapeutic and sub-therapeutic uses of antibiotics in animals. A common public perception is that sub-therapeutic use of antibiotics, which are the inclusion of antibiotics in the feed, might have an effect on the humans who consume the meat, making them resistant to the antibiotics used in the feed (Estienne et al. 2005). Probiotics, for example, could be the answer to replace sub-therapeutic uses of antibiotics. The use of probiotics may provide bacteria that can compete with organisms such as the *E. coli* in the intestine, which can limit the cases of diarrhea and the amount of antibiotics used in piglets. There is a need to find alternatives to antibiotics that will maintain the performance of pre-weaned and weaned piglets (Bhandari et al. 2008). Therefore the objective of this study was to determine if an oral probiotic supplementation affected the growth performance of the piglet, fecal consistency, and the number of *E. coli* and *Lactobacillus* species present in the fecal material.

MATERIALS & METHODS

Study Design. This study was conducted at the Tarleton State University Swine Center in Stephenville, TX, in an all-in/all-out management system. Fifty-nine crossbred (cross and Yorkshire based) sows and their piglets (n = 569) were included in the study. The same sow herd was used over five farrowings (replications) with sows being used two to three times, depending on when they farrowed. The litters were divided into two groups (treatment and control), with standardization occurring within 48 hours after birth to minimize differences in birth weights and litter sizes. When litters were divided, the assignment of the sow's previous litter was not considered. All piglets in the treatment litters received the treatment and all piglets in the control litters received no type of treatment. Control litters did not receive a placebo in order to closer mimic a commercial operation in which piglets would either receive a treatment or receive nothing. Piglets were evaluated for weight gains and fecal consistency as well as bacterial counts of fecal material. A complete randomized designed was used with litters being evenly divided into treatment and control groups in order to try to maintain an even number of piglets and litters in each group throughout the study.

Treatment Group. The treatment group in this study received an oral supplemental probiotic manufactured by Trouw Nutrition International (Putten, The Netherlands). Ingredients of the supplement can be found in Table 1.

Table 1. Probiotic Supplement.

Ingredient
Lactic Acid Producing Bacteria (*Lactobacillus acidophilus, Bifidobacterium longum, Bifidobacterium thermophilium, and Enterococcus faecium)*
Vegetable Oil
Dextrose
Sodium Aluminosilicate
Dried Egg
Sorbitan Monostearate
Dried *Bacillus subtilis*
Dried Saccharomyces cerevisiae
Vitamin A
Vitamin D3
Vitamin E

Treatment was administered orally when piglets were three days of age (3g/piglet), 18-28 days of age (weaning) (6g/piglet), and 50-65 days of age (6g/piglet) when they were moved to the finishing floor. The control piglets did not receive a placebo. All management/handling practices were the same for both groups and piglets remained on the same treatment for the duration of the study.

Farrowing House, Nursery, and Finishing Floor Procedures. Birth weights were obtained and needle teeth were clipped within 24 hours of farrowing. Each piglet received 1.5 ml of iron, penicillin, and Draxxin (IPD) (48% iron-100mg/1ml, Agri Laboratories, Ltd, St. Joseph, MO; 28% penicillin-300,000 units/ml, Norbrook Laboratories Limited, Newry, Northern Ireland; 24% draxxin-100mg tulathormycin/ml, Pfizer Animal Health, New York City, NY). When birth weights were obtained, each individual had a number written on its back with a permanent marker for identification, which was its pig number for that litter. Piglets were ear notched at 24-48 hours of age for permanent identification. When the piglets were 48-72 hours old they had their tails docked. Also, male piglets were castrated at three to seven days of age. At day seven, all piglets received a 1.5 ml booster shot of IPD as well as 1 ml of Rhinogen BPE (Intervet Inc., Millsboro, DE). When the piglets were 14 days old, they received 2 ml of RespiSure One (Pfizer Animal Health, Exton, PA). At day 21, weights were obtained for all piglets and at day 24, all piglets received a booster of 1 ml of Rhinogen BPE (Intervet Inc., Millsboro, DE) and the first of two immunizations of 2 ml of Circumvent PCV (Intervet Inc., Millsboro, DE). For piglets that were weaned before 21 days of age, the weaning weight was adjusted according to "Livestock and Carcasses": An Integrated Approach to Evaluation, Grading, and Selection. Twenty-one-day weights were used as a measurement point since there is a formula that allows weights to be adjusted to 21 days. Piglets were weaned at 18-28 days with an all-in/all-out management system. Weaning weights were obtained and used as initial weights going into the nursery period.

Fourteen days after the first Circumvent PCV vaccination, when the piglets were in the nursery, they received a booster of Circumvent PCV (Intervet Inc., Millsboro, DE) vaccination of 2 ml per head. Individual weights were obtained for each piglet when they had been in the nursery for 30 days.

Weights obtained from the piglets at day 30, in the nursery period, served as entry weights for the finishing floor. Individual pig weights were obtained after they had been on the finishing floor for 30 days.

Creep Feed Procedure. All litters had access to creep feed at 14 days of age which was ACCO Showmaster Prestarter, 10 Medicated (ACCO Feeds, Minneapolis, MN) (Table 2). Creep feed intake was measured by weighing the feed before offering it to the piglets. If the creep feed became spoiled in the feeder, it was collected, weighed, discarded, and recorded as orts. Creep feed was monitored daily and was added as needed so the piglets were allowed to eat *ad libitum.*

Table 2. ACCO Showmaster Prestarter 10 Medicated.

Item	Guaranteed Analysis
Crude Protein	25.00%
Lysine	1.70%
Crude Fat	6.00%
Crude Fiber	5.00%
Calcium	1.25%
Phosphorus	0.50%
Salt	1.25%
Sodium	0.60%
Selenium	0.3 ppm
Zinc	3,000 ppm
Chlortetracycline	400 grams/ton
Tiamulin Hydrogen Fumarate	35 grams/ton

Nursery & Finishing Floor Diets. Each litter received one bag (22.68 kg) of the ACCO Showmaster Prestarter 10 Medicated (ACCO Feeds, Minneapolis, MN) (Table 2), in the nursery and then all litters received ACCO Showmaster Starter (Bannec) Medicated (ACCO Feeds, Minneapolis, MN) (Table 3) for the remainder of the nursery period.

Table 3. ACCO Showmaster Starter (Bannec) Medicated.

Item	Guaranteed Analysis
Crude Protein	23.00%
Lysine	1.61%
Crude Fat	5.00%
Crude Fiber	3.50%
Calcium	1.29%
Phosphorus	0.70%
Salt	1.00%
Sodium	0.60%
Selenium	0.3 ppm
Zinc	3,000 ppm
Chromium	200 ppb
Carbadox	50 grams/ton
Pyrantel Tartrate	96 grams/ton

The ration for all litters on the finishing floor was ADM Alliance 12191APY (ADM Alliance Nutrition, Inc., Quincy, IL) (Table 4).

Table 4. ADM Alliance 12191APY.

Item	Guaranteed Analysis
Crude Protein	18.50%
Lysine	1.10%
Crude Fat	2.50%
Crude Fiber	4.50%
Calcium	0.60%
Phosphorus	0.60%
Salt	0.40%
Selenium	0.3 ppm
Zinc	100 ppm
Carbadox	0.01%

Fecal Scoring. Each litter received a fecal score three times weekly when they were in the farrowing house and in the nursery by the primary researcher. Litters were used instead of individual piglets due to the fact that piglets may die or be sold before the end of the study. To determine the fecal score, all of the feces were observed in the pen and it was assigned a score based on its consistency. The fecal scores were averaged for the litter (score divided by number of times observed) when the piglets left the farrowing house and the nursery. Fecal scores were scored on a scale of 0-3: 0 = normal, 1 = soft feces, 2 = thick fluid feces, and 3 = watery feces (Bhandari et al. 2008; Marquardt et al. 1999). On the finishing floor, litters were monitored for 10 days for changes in fecal consistency.

Fecal Sample Collection. Due to budget restrictions, litters were used for bacterial counts instead of individual piglets. Fecal samples were collected throughout the study from litters to determine if there was a change in the number of *Lactobacilli* species and *E. coli* present. The first fecal sample was obtained when the piglets were 48 hours of age to establish a baseline since the first treatment would be administered at three days of age. The other fecal samples were collected five days after the first treatment, five days after the second treatment, and five days after the third treatment to determine if there was a change in the number of microorganisms present as the piglets' aged.

At least four fecal samples were collected each time from the litter and combined into one sample. Due to the fact that a piglet could be sold or die any time during the study, the fecal sampling was random to ensure that enough fecal material could be collected for analysis and that consistency remained in having at least four samples. Although both treatment and control piglets were housed in the same pens, contamination of feces did not occur because fecal samples were collected from the rectum or from the top of the feces from a pig that had just defecated. The researcher had to visually see the pig defecate and that the feces did not mix with other feces on the ground.

Using a mini vortex, the sample was mixed with a phosphate buffer solution (PBS) (Table 5).

Table 5. Phosphate Buffer Solution.

Item	grams/2 liters of deionized water
Sodium Dihydrogen Phosphate (NaH_2PO_4)	1.16
Sodium Monohydrogen Phosphate (Na_2HPO_4)	5.00
Sodium Chloride (NaCl)	17.0

Bacterial Culture Analysis & Measurement. For both *E. coli* and *Lactobacilli* species plates, the Petri dishes were labeled with litter number and dilution number for identification. One blank plate with no fecal material was included, each time samples were cultured, to ensure there was no contamination. The dilution samples selected for plating were selected because in this range the number of colonies on the plates were low enough to distinguish individual colonies, which could be counted.

To test for the presence of *E. coli*, dilution samples of 10^{-5} to 10^{-8} were poured on to S-PAK membrane filters (Millipore Corporation, Billerico, MA) and filtered. After filtration, the filters were transferred to the Petri dish containing Difco Modified mTEC agar (Becton, Dickinson, & Company, Sparks, MD). After all samples had been plated, they were incubated for 18-24 hours at 35 degrees Celsius (EPA 2009).

To test for the presence of *Lactobacilli* species, a sample from each litter was mixed with BBL LBS Agar (Becton, Dickinson, & Company, Sparks, MD). The dilutions used were 10^{-3} to 10^{-6} and one milliliter of the dilution sample was placed in a Petri dish. Then 15 to 20 ml of the agar was added to the Petri dish. The Petri dishes were rotated so that the dilution sample and agar mixed. After all samples had solidified at room temperature, the plates were incubated for 72 hours at 35 °C.

Following the appropriate amount of time for incubation, colonies were counted for each sample. Plates containing less than 75 colonies were used to determine if there was a difference in the number of bacteria present. The dilution with the least amount of colonies was entered into a formula to determine the number of coliforming units per gram. If no colonies were present on any of the samples, then zero was used.

Statistical Analysis. Growth performance data, fecal consistency scores, and log transformed bacterial count data were analyzed using Proc GLM of SAS. Mean fecal consistency scores were found for each litter in the farrowing house, nursery, and finishing floor. The model contained the main effect of treatment, main effect of replication, and treatment x replication interaction. A *P*-value of 0.05 was considered significant when differences were detected; the LSMEANS statement with the PDIFF was used for mean separation. The differences in the *n* values are due to using individual piglets for growth performance and litters for fecal consistency and bacterial counts.

RESULTS & DISCUSSION

Decreasing pre-weaning mortalities as well as decreasing poor performance in the nursery is important to producers in order to limit the number of days to market weight and maintain economical returns. Producers have relied on the use of antibiotics sub-therapeutically to prevent illnesses in their swine herd but, as this practice comes under fire, producers must look for other alternatives to prevent sickness in their herds as well as reducing poor nursery performance.

Growth Performance. There was no difference ($P > 0.05$) in 21-day weight, weaning weight, nursery weight, or finishing floor weight between the treatment and control groups (Table 6).

Table 6. Effect of Supplemental Probiotics and Spray-Dried Egg Proteins on Growth Performance.

	Treatment			Control			
Variable	Wt.	*n* value	SEM[c]	Wt.	*n* value	SEM[c]	*P* value
21-day wt. (kg)[a,b]	5.830	240	0.19	5.770	252	0.22	0.63
Weaning wt. (kg)[a]	6.350	238	0.21	6.380	249	0.24	0.85
Nursery wt. (kg)[a]	17.68	228	0.45	17.73	242	0.53	0.89
Finishing Floor wt. (kg)[a]	32.45	140	1.35	32.34	124	1.21	0.90

[a] Replication effect ($P < 0.05$).

[b] Treatment x replication interaction ($P < 0.05$).

[c] Standard Error of the Mean.

For weaning ($P < 0.0001$), nursery ($P < 0.0001$), and finishing floor ($P < 0.0001$) weights there was a difference due to the effect of replication and for 21-day weight there was a treatment x replication ($P < 0.01$) interaction as well as a replication effect ($P < 0.0001$). The effect of replication and replication x treatment interaction could be due to environmental conditions since the farrowings (replications) occurred in five different months.

These results are similar to Bhandari et al. (2008), who found that the addition of a direct-fed microbial to the diet, when compared to a spray-dried porcine plasma diet or a diet containing antibiotics, yielded no difference in growth performance of the piglets who were challenged with a strain of *Escherichia coli*. Estienne et al. (2005) also found that the administration of a probiotic supplement 24 hours after birth had no effect on growth performance at 7 and 14 days of age. However, Mathew et al. (1998) found that the inclusion of yeast in the piglets' diet led to a higher daily gain for the piglets who received the yeast in a pelleted form, over those who didn't receive the yeast or the yeast in a ground form. Marquardt et al. (1999) found that the use of egg-yolk antibodies in piglets exposed to *Escherichia coli*, increased the weight gains of the treatment piglets over the control piglets. However, De Cupere et al. (1992) also found no difference in weekly weight gains between control piglets and piglets that received three different probiotics who were also infected with *Escherichia coli*. Although Taras et al. (2006) used a supplement that contained *Enterococcus faecium,* researchers reported no difference in weight gains in the nursery period between treatment and control piglets. Increase in weight gains reported in other studies may have been due to the type of probiotic used, dosage, or frequency of the treatment which is different from the current study.

Egg products contain avidin which is thought to bind with biotin, rendering the biotin unavailable to the animal. It is thought that although most egg products go through a heating process, the heating process might not inactivate all of the avidin. It is possible that the avidin in the egg products in this study may have interfered with the levels of biotin that the piglets received. Since this parameter was not measured in the study, it cannot be said if this had an effect on the piglets' growth.

Fecal Consistency. There was no difference ($P > 0.05$) in fecal consistency between the treatment and control litters in the farrowing house or nursery (Table 7). On the finishing floor, there was also no difference ($P > 0.05$) in fecal consistency between treatment and control litters (Table 7).

Table 7. Effect of Supplemental Probiotics and Spray-Dried Egg Proteins on Fecal Consistency.[a.]

	Treatment			Control			
Variable	Score	*n* value	SEM[b]	Score	*n* value	SEM[b]	*P* value
Farrowing House	0.11	29	0.04	0.20	30	0.04	0.12
Nursery	0.19	29	0.05	0.22	30	0.06	0.08
Finishing Floor	1.58	49	0.17	1.67	31	0.19	0.10

[a] Fecal consistency scale: 0 = normal, 1 = soft feces, 2 = thick fluid feces, 3 = watery feces.
[b] Standard Error of the Mean.

A higher fecal consistency score indicates a loose stool and loose stool tends to indicate that there is some type of intestinal disturbance occurring. In the nursery, the treatment group tended ($P = 0.08$) to have lower fecal scores than the control group. Bhandari et al. (2008) found that the incidences of scouring were lower 24 hours after infection in the group of piglets who received the direct-fed microbial when compared to the other treatment groups. The group who received the direct-fed microbial had lower fecal scores than the control group, although the difference was not significant except for 24 hours after infection. Findings by Marquardt et al. (1999) are similar to findings in this study as well. The researchers found that at 21 days of age piglets treated with egg-yolk antibodies had lower fecal score consistencies except for 24 hours post-infection. De Cupere et al. (1992) also found no difference in fecal consistency between the control group and groups who received *Bacillus subtils*, *Lactobacilli*, or *Streptococcus faecium*.

Escherichia coli. The number of *E. coli* present in the fecal samples between the groups was not different ($P > 0.05$) (Table 8). However, five days after the first treatment, the treatment piglets tended ($P = 0.09$) to excrete a higher number of *E. coli* in their feces, suggesting that something was occurring to cause more *E. coli* to be excreted in their fecal material. In order to maintain production levels, the sub-therapeutic levels antibiotics were not removed from the feed. By not removing the sub-therapeutic levels antibiotics, they may have influenced the outcome of this study with regard to the number of *E. coli* present in the fecal material since antibiotics work to destroy harmful bacteria in the body.

Bhandari et al. (2008) found that there was no difference in the number of *E. coli* present in the intestinal mucosa when comparing diets that contained antibiotics, no antibiotics, direct-fed microbial with no antibiotics, spray-dried porcine plasma with no antibiotics, and a diet that contained spray-dried porcine plasma and direct-fed microbial with no antibiotics. Mathew et al. (1998) also found that the addition of yeast to the piglets' diet did not affect the number of *E. coli* present in the gastrointestinal tract. Shen et al. (2009) reported that the inclusion of either a yeast culture or antibiotic growth promoter did not affect the number of *E. coli* present in the rectum.

Table 8. Effect of Supplemental Probiotics and Spray-Dried Egg Proteins on the presence of *Escherichia coli* in fecal samples.

	Treatment			Control			
Variable	log CFUs[b]	*n* value	SEM[a]	log CFUs[b]	*n* value	SEM[a]	*P* value
48 hrs old	20.10	13	0.43	20.07	14	0.42	0.35
5 days post 1st trt	19.69	13	0.39	18.41	14	0.38	0.09
5 days post 2nd trt	8.150	13	2.14	7.850	14	2.10	0.25
5 days post 3rd trt	15.82	9	1.82	17.20	12	1.53	0.12

[a] Standard Error of the Mean.
[b] CFUs = colony forming units.

Lactobacillus species. The number of *Lactobacillus* species found in the feces of the piglets was not different ($P > 0.05$) between treatment and control groups (Table 9). There was a replication effect present for five days after the first ($P < 0.001$) and third ($P < 0.005$) treatment. The difference could be due to environmental conditions since the replications occurred in five different months. In addition, the number of *Lactobacillus* species present in fecal material may have been affected by the sub-therapeutic antibiotics left in the feed to maintain a certain production level.

Table 9. Effect of Supplemental Probiotics and Spray-Dried Egg Proteins on the presence of *Lactobacillus* species in fecal samples.

	Treatment			Control			
Variable	log CFUs[c]	*n* value	SEM[b]	log CFUs[c]	*n* value	SEM[b]	*P* value
48 hrs old	6.520	13	1.57	8.510	14	1.54	0.43
5 days post 1st trt[a]	12.23	13	0.46	11.79	14	0.45	0.49
5 days post 2nd trt	14.32	13	1.03	14.02	14	1.01	0.68
5 days post 3rd trt[a]	14.37	9	1.19	14.35	12	1.00	0.99

[a] Replication effect ($P < 0.05$).
[b] Standard Error of the Mean.
[c] CFUs = colony forming units.

Bhandari et al. (2008) found no difference in the number of lactic acid bacteria present in the ileum after the inclusion of a direct-fed microbial. Shen et al. (2009) also found no difference in the number of *Lactobacilli* species present in the rectum between piglets who received a yeast culture or antibiotic growth promoter. Mathew et al. (1998)

found that the addition of yeast to the diet of piglets did not affect the number of *Lactobacillus* species present in the gastrointestinal tract. These results also concur with Pollmann et al. (1980), who found that the inclusion of a Probios or *Lactobacillus acidophilus* in the diet did not have a significant effect on the number of *Lactobacillus acidophilus* present in fecal counts between the treatment and control groups.

CONCLUSIONS

The probiotic supplement used in this study did not result in any significant differences in growth performance, fecal consistency, or number of *E. coli* and *Lactobacillus* species present in the fecal material between treatment and control groups. There was not enough of a difference in growth performance to warrant the continued use of this probiotic at the dosage and application method used in this project. Due to the fact that sub-therapeutic level antibiotics were not removed from the feed, this could have had confounding effects on the results of this study.

In the nursery, the treatment group tended (P = 0.08) to have lower fecal consistency scores than the control group; however, this is not seen in the farrowing house or finishing floor, and why it is not, cannot currently be explained. After the first treatment of probiotic, the treatment group tended (P = 0.09) to have more *E. coli* in their fecal material, although by what mechanism cannot be explained. Also, the number *E. coli* present in the fecal material could have been affected by the fact that both treatment and control piglets were housed together allowing for the ingestion of fecal material from both treatment and control piglets.

At the present time, there is no explanation for why treatment and control groups had nearly the same number of *Lactobacillus* species present in their fecal material, since the treatment piglets received several different *Lactobacillus* species on several different occasions when they received the treatment. Perhaps the *Lactobacillus* species used in this probiotic needed to be at a higher concentration in order for there to be a difference or different *Lactobacillus* species need to be used. Control piglets could have ingested feces from treatment piglets which may have affected the number of *Lactobacillus* species present in the fecal material since treatment and control piglets were housed together.

Recommendations for future research concerning the use of a probiotic include a higher dosage at treatment or replacement of antibiotics in the feed with a probiotic supplement.

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Effect of Calcium Ion Supplementation on Swine Parturition

Nathan D. Elrod[1]
Randy M. Harp[*, 1]
Kelsey G. Bryan[1]
[1]*Tarleton State University, Department of Animal Science and Veterinary Technology, Box T-0070, Stephenville, TX 76402*

ABSTRACT

The purpose of this study was to determine the effect of calcium ion supplementation on swine parturition. The focus of this trial was to determine if increased cytostolic calcium levels would reduce the inter-pig birth interval and reduce the number of Type II stillbirths. Thirty-four females were divided into either a control group (n = 17) or a treatment group (n = 17). The treatment group received 70 g of a calcium-chloride supplement, top dressed daily, for five days pre-farrowing. Results showed a reduction in inter-pig birth interval and reduction in Type II stillbirths for the treatment group as compared to the control group ($P < 0.05$).

KEY WORDS: birth interval, calcium, parturition, stillbirth, swine

INTRODUCTION

Fetal losses (mummified fetuses and stillborns) are one of the most fundamental causes for loss in commercial swine herds (Borges et al. 2005). According to González-Lozano, Rosales-Tores, et al. (2009) "Type II stillbirth" (intra-partum) deaths occur in over 30% of swine litters, with almost 8% of individual piglets being born Type II stillborn. While several factors have been associated with Type II stillbirth, e.g. infectious diseases, gestation length, parity, litter size, farrowing length, birth weight, birth interval, and dystocia (Borges et al. 2005), the primary foci of this study are the issues of litter size, farrowing length, and birth interval.

Curtis (1974) and Hurnik (1985) showed that that the interval of delivery before Type II stillbirths is greater than the interval before live births and that over 70% of Type II stillbirths occur in the last third of the birth order. Oxytocin has been definitively shown to shorten the length of farrowing, but at the same time the improper application of oxytocin has been shown to increase the incidences of birth mortality and dystocia (González-Lozano, Ramírez-Necoechel, et al. 2009).

Parkington et al. (1999) demonstrated cytostolic Calcium 2+ ions ($Ca2+$) to be of great importance to the contractibility of smooth muscle in the uterine system. Continued $Ca2+$ dependent contractions can be induced by an increase in the cytostolic $Ca2+$ concentrations beyond normal fatigue levels (Uehata et al. 1997). In addition, the transient regenerative current of uterine smooth muscle was directly dependent on the level of cytostolic $Ca2+$ (Anderson et al. 1971).

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[*] Corresponding author: harp@tarleton.edu.

The purpose of this study was to determine whether an increased cytostolic Ca2+ ion concentration in swine would: (1) reduce the inter-pig birth interval, (2) reduce the total farrow length, and (3) reduce the number of Type II stillbirths.

MATERIALS AND METHODS

Thirty-four sows and gilts of similar breed-type (Yorkshire and Hampshire Cross) from Tarleton State University's Agricultural Center and Elrod's Show Pigs were randomly assigned to one of two treatment groups. In addition, sows versus gilts were distributed across testing groups to eliminate bias. Mean parity was 2.06 for the control group and 2.29 for the treatment group, which was not different ($P > 0.05$). All sows farrowed between July and September, 2011.

Group One (n = 17; sows = eight, gilts = nine) was the control group, and did not receive any calcium chloride (CaCl) supplement. Group Two (n = 17; sows = 10, gilts = seven) was the treatment group that received CaCl supplement (Table 1) at the rate of 70 grams top-dressed over a daily feed ration. The supplementation for the treatment group began at day 109 of gestation, five days prior to the expected farrowing date. The farrowing date was based upon 114 days of gestation with day 1 of gestation considered to be 24 hours after first Artificial Insemination service. The supplementation continued until the day of farrowing.

Table 1. Calcium chloride supplement composition.

Item	%
Guaranteed Analysis	
Crude protein	Min. 4.0 %
Lysine	Min. 0.1 %
Crude Fat	Min. 9.0 %
Crude Fiber	Max. 2.0 %
Calcium	Min. 16.6 %
Calcium	Max. 19.9 %
Phosphorus	Min. 0.14 %

Prior to the beginning of supplementation, on day 108 of gestation, urine was collected from each female and the pH was determined and recorded. The urine pH readings were determined and recorded again on day 113 of gestation. Earlier research by DeRouchey et al. (2003) showed that decreasing the dietary Electrolyte Balance (dEB) (mEq/kg of diet for Na+K-Cl) by increasing the amount of CaCl in the feed supply is characterized by increased cytostolic Ca2+ blood percentages and decreased urinary pH. The rationale behind comparing the urinary pH is to verify that cytostolic Ca2+ ion concentrations were being increased in response to CaCl supplementation in the sow as indicated by a reduced urinary pH.

Prior to farrowing, on day 108 of gestation, the sow Body Condition Score (BCS) was determined for all sows. BCSs were determined by a three-member expert committee. Scores were assigned by all three members independently and subsequently averaged to determine a final BCS for each female. The scoring system was recorded in accordance with the National Pork Board Body Condition Scoring System. A score of (1) represented emaciated while a score of (5) was obese; a score of (3) was ideal and preferred (Karriker 2006). The body condition score was not limited to a single integer number. It was recorded to the nearest 0.25 of a point to ensure specificity. This was done in order to ensure that BCS was not a contributing factor to an increased risk of Type II stillbirth.

During the period of parturition for all females, the following data was obtained: litter size, number born alive, number of Type II stillbirths, farrowing length, and inter-pig birth interval. Farrow length was recorded as the time interval starting at the beginning of Stage II of labor, defined as the time of first amniotic discharge (Hurnik 1985), and ending with the expulsion of the last fetus. Inter-pig birth interval was the time between each delivered fetus. Furthermore, individual birth weights were also recorded after all piglets had been born for that litter.

Following parturition, sows were assigned a Farrowing Ease Score (FES). This score was assigned based on the following criteria: 1 indicated no assistance, 2 indicated little assistance with two or fewer piglets pulled, 3 indicated moderated assistance with three or fewer piglets pulled, 4 indicated extensive assistance with more than three piglets pulled, and 5 indicating surgical intervention such as caesarean section. A three-member expert panel was used to assess a FES. Independent scoring was performed by each member and an average was calculated for reporting.

In order to obtain statistical results that were valid, repeatable, accurate, and true representatives of the population, statistical analysis was conducted using SPSS V 17.0 (SPSS Inc. 2009). Upon consultation from professional bio-statistician Dr. Perdue (2011) and Dr. Lambert (2011) the following tests were performed. Differences in BCS, birth weight, litter size, farrowing length, and inter-pig birth interval between treatment groups were computed by *t*-test. Birth weight was also compared between Type II stillborns and live births to determine differences using the *t*-test. Differences in the pre- and post-treatment urine pH by treatment group were conducted using a Univariate ANOVA test pairing pre- and post-treatment in individuals. The Fisher's Exact Test was used to analyze the differences in the number of stillbirths between treatment groups.

RESULTS AND DISCUSSION

Birth weight (Table 2) was shown to be significant between the treatment groups ($P < 0.05$). However, as this was an increased risk of stillbirth by the treatment group having larger birth weights, it did not affect our analysis of still birth reduction due to treatment. Neither BCS nor litter size (Table 2) were different ($P > 0.05$). It was important to this trial that these factors were not contributing influences because of their increased risk of Type II stillbirth (Borges et al. 2005; Karriker 2006).

In order to demonstrate that cytostolic Ca2+ concentration was indeed being influenced by the CaCl supplementation it was determined that urinary pH levels needed to be observed in agreement with the experimentation by DeRouchey et al. (2003). There was no difference shown ($P = .825$) (7.26 v. 7.29) between treatment groups on day 108 of gestation (Table 3). Sows in the control group did not experience a difference ($P = .754$) (7.26 v. 6.98) in urinary pH from day 108 to day 113 of gestation ($P > 0.05$). However, the treatment group demonstrated a clear difference (7.288 v. 5.65) in urinary pH for the same time period ($P < 0.001$). This indicated an increase in cytostolic Ca2+ levels for treatment sows as a result of supplementation.

Table 2. Initial birth weight, BCS, and litter size by treatment group.

Item	Group	n	Mean	SD	*P*
Birth wt.	Cont	169	2.9896	.75530	
(lbs.)	Trt	178	3.1513	.75749	.047
BCS	Cont	10	3.0250	.75875	
	Trt	10	2.9750	.74954	.884
Litter	Cont	11	9.55	3.236	
Size	Trt	10	10.20	3.425	.659

Table 3. Pre- and post- treatment pH by treatment group.

Item	Group	n	Mean pH	SD	*P*
Pre-treatment	Cont	10	7.2600	.29866	
(day 108)	Trt	10	7.2880	.25939	.825
Post-treatment	Cont	10	6.9800	.43863	.754
(day 113)	Trt	10	5.6500	.69925	.001

When observing the inter-pig birth interval (Table 4) there was a decrease in the amount of time in minutes between each piglet ($P < 0.05$) for the treatment group compared to the control group. The total farrow length (Table 4) was also decreased for the treatment group ($P < 0.05$). Both of these results support the hypothesized effect of an increased $Ca2+$ diet.

Table 4. Inter-pig birth interval and farrow length by treatment group.

Item	Group	n	Mean	SD	*P*
Interval	Cont	174	25.42	37.915	
(min)	Trt	183	19.81	24.393	.048
Farrow	Cont	17	260.2	131.3	
Length (min)	Trt	17	185.8	120.9	.048

Comparing the number of Type II stillbirths in each treatment group (Table 5); a significant reduction in the number of stillbirths was demonstrated ($P < 0.05$). Furthermore, the results for the control group showed a 5.7% risk for Type II stillbirths which is congruent with results from Borges et al. (2005). In the treatment group there was a 1.6% risk of Type II stillbirths. The cross-tabulated probability of the treatment group indicated a 73% risk reduction for Type II stillbirth as compared to the control group on an individual piglet basis.

Comparing the FES of each treatment group (Table 6); there was a significant reduction in the difficulty of labor for the treatment group ($P < 0.05$) as indicated by the lower FES. This coincided with a shorter time period for inter-pig birth interval and farrow length.

In order to further eliminate bias, birth weights were compared according to delivery type as this had been shown to influence the probability of being stillborn (Borges et al. 2005). Between the two delivery types, live birth and stillborn (Table 7), there was no difference ($P > 0.05$).

Table 5. Type II stillbirths by treatment group.

Item	Group	n Live born	n Stillborn	% Stillborn	*P*
Stillbirths	Cont	164	10	5.7%	
	Trt	180	3	1.6%	.035

Table 6. Farrowing ease score by treatment group.

Item	Group	n	Mean (score)	SD	*P*
FES	Cont	17	2.3529	1.0572	
	Trt	17	1.7059	.84887	.029

Table 7. Birth weight by delivery type.

Item	Delivery type	n	Mean (lbs.)	SD	*P*
Birth weight	Live born	334	3.0713	.76837	
	Stillborn	13	3.1046	.50437	.877

CONCLUSION

In conclusion, there was a reduced inter-pig birth interval, farrow length, and the number of Type II stillbirths associated with the treatment group in this trial ($P < 0.05$). These results supported the hypothesized effect of calcium ion supplementation on swine parturition.

The original intent of observing the FES was to determine if individual sows should be eliminated from the study due to anatomical defects resulting in dystocia (*i.e.* those sows with a FES of 4 or more). While the study did report a significant reduction in FES for the treatment group, it was felt that the sow sample size would need to be increased in order to accurately determine that the reduction of FES was the result of treatment.

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THE EFFECTS OF PROTEIN SUPPLEMENTATION ON BITTERWEED TOXICOSIS IN LAMBS

Matthew C. Coffman[1]
Cody B. Scott[*1]
Corey J. Owens[1]
Richard Brantley[2]
[1]*Department of Agriculture, Angelo State University, San Angelo, Texas*
[2]*University Lands, Midland, Texas*

ABSTRACT

This study determined if a supplemented protein diet high in escape protein or consisting of sulfur-containing amino acids would reduce the likelihood of bitterweed (*Hymenoxys odorata* DC) toxicosis. Forty recently weaned Rambouillet lambs were used with eight lambs randomly allocated to each treatment. They were placed in individual pens and allowed a seven-day adjustment period. Lambs were fed alfalfa pellets at 2.5% body weight, their respective treatment diet, and bitterweed. Treatments received either a (1) cottonseed meal (CSM), (2) CSM and Distiller's Dried Grain (DDG), (3) soybean meal (SBM), or (4) SBM and DDG-based supplement. Treatment 5 received only alfalfa pellets. All supplements were isonitrogenous (37%), and lambs were fed enough supplement and alfalfa to achieve 150 g of growth per day. Bitterweed was offered immediately after supplemental diets for one hour daily for 15 days. Intake of supplemental diets, bitterweed, and alfalfa were measured on an individual animal basis. Lambs fed the SBM-based supplement ate more ($P < 0.05$) bitterweed than lambs fed alfalfa alone. Other supplemental diets did not improve bitterweed intake. None of the lambs from any treatment exhibited signs of toxicosis. Producers should consider feeding a SBM-based supplement to reduce the likelihood of bitterweed toxicosis in sheep.

KEY WORDS: intake, hymenoxon, L-cysteine, DDG, amino acids

INTRODUCTION

In 1962, it was estimated that annual losses in livestock production from bitterweed (*Hymenoxys odorata* DC) toxicity were $3.6 million in the Edwards Plateau region of Texas alone (Witzel et al. 1974). At that time, Calhoun et al. (1981) suggested that bitterweed is the most serious toxic plant problem faced by sheep producers in Texas. It is a native, cool season, annual forb that is found in semi-arid regions from Kansas and southern Colorado to Texas and west all the way to southern California (Kingsbury 1964) and is particularly common in Central and West Texas.

The invasion of bitterweed can be attributed to several factors. Periodic droughts and overgrazing reduce cover of other grasses and forbs, thereby allowing room for bitterweed to invade (Hardy et al. 1931; Sperry 1949). Bitterweed is a drought-hardy plant

[*] Corresponding author: Cody.Scott@angelo.edu.

in that it restricts growth and conserves the limited moisture it has during dry periods and resumes growth when moisture is again available (Sperry and Sultemeier 1965). More recently, increased oil and gas exploration, resulting in significant ground disturbance, has increased the amount of bitterweed in the Edwards Plateau and western Texas.

Bitterweed toxicosis is common because it is green and flowering in late fall and early winter when nutrient demands for livestock are at their highest (Ueckert and Calhoun 1988). This period coincides with warm season grasses entering into dormancy while nutrient demands increase because lambing and fluctuating ambient temperatures. Most sheep are reluctant to graze the plant because they associate its bitter taste with aversive postingestive feedback (Calhoun et al. 1981; Poage et al. 2000). However, during late fall and early winter, bitterweed may be the only green forage available (Rowe et al. 1973; Pfeiffer and Calhoun 1987). If there is a lack of other sufficient forage, hunger will eventually force sheep to graze the plant and suffer toxicosis (Ueckert and Calhoun 1988).

Hymenoxon, the toxic compound in bitterweed, is a sesquiterpene lactone with an exocyclic methylene group conjugated with the lactone carbonyl (Kim et al. 1975). This compound is also toxic to cattle and goats (Ueckert and Callhoun 1988), but they typically do not graze bitterweed in sufficient amounts to cause toxicosis. A lethal dose of hymenoxon in sheep causes symptoms such as bloating, Central Nervous System (CNS) depression, liver and kidney damage, and termination of rumen activity. It typically results in the death of the animal within 36 hours of ingestion (Rowe et al. 1973).

The amino acid cysteine contains sulfhydryl groups that can react and bind with this toxin in the rumen to form less toxic compounds (Kupchan et al. 1970). If detoxification does not occur in the rumen, toxic compounds are absorbed into the bloodstream, and travel to the liver for further detoxification in one of two reactions in the liver (Williams 1959). Phase I reactions alter existing functional groups or introduce a polar group into a non-polar compound to make it more hydrophilic and therefore, more easily excreted from the body (Bidlack et al. 1986). Phase II reactions are those that conjugate polar groups of foreign compounds with endogenous cofactors (Bidlack et al. 1986). As a result of these reactions, the xenobiotic compounds, like hymenoxon, become more hydrophilic and more easily excreted (Nebbia 2001).

Protein feeds high in glucogenic amino acids (e.g. distillers dried grains (DDG)) or feeds that contain higher levels of amino acids that escape digestion in the rumen (e.g., cotton seed meal) should aid in detoxification through Phase II reactions in the liver. These amino acids escape rumen digestion and are transported to the liver where they may be used for further conjugation with toxins.

Several studies have shown that protein supplementation can increase the consumption of some toxic plants by increasing their ability to tolerate the toxins. For example, goats increased redberry juniper (*Juniperus pinchotii* Sudw.) consumption while receiving a supplement containing cottonseed meal and DDG (George et al. 2010). Supplementation of lambs with barley and activated charcoal increased intake of the shrub big sagebrush (*Artemesia tridentata* Nutt.) (Banner et al. 2000). In addition, protein supplementation seems to reduce the likelihood of bitterweed toxicity (Calhoun et al. 1989).

Dosing sheep with the amino acid L-cysteine protects them from the acute effects of hymenoxon (Rowe et al. 1980; Calhoun et al. 1989). L-cysteine provides sulfhydryl groups for rumen degradation of toxins. Unfortunately, L-cysteine is unpalatable at levels necessary to prevent bitterweed toxicosis. Soybean meal is highly soluble in the rumen and contains moderate levels of L-cysteine. Feeding supplements containing soybean meal could potentially alleviate some bitterweed toxicity problems.

Glucogenic amino acids found in cottonseed meal and DDG may provide the substrates for toxin conjugation and excretion in the liver (Freeland and Jansen 1974). Bitterweed is apparently partially detoxified in the liver. Terry et al. (1983) reported that hymenoxon was conjugated with gluconurides and excreted in the urine. This may explain why others (Calhoun et al. 1981) have reported reduced instances of bitterweed toxicity when sheep were fed supplements containing cottonseed meal.

Accordingly, this study was designed to determine if bitterweed toxicosis can be avoided or reduced by supplementing proteins containing glucogenic amino acids, sulfur-containing amino acids, or both to aid in detoxification of hymenoxon.

MATERIALS AND METHODS

This study was conducted at the Angelo State University Management Instruction and Research (MIR) Center, San Angelo, Texas. Forty recently weaned Rambouillet ewe lambs (28.3 kg, approximately five months of age) were used in this experiment with eight lambs used per treatment. Lambs were separated into individual pens (1 m X 1.5 m), and allowed seven days for a pen-adjustment period. During this adjustment period, they were fed their supplemental diets and alfalfa pellets. Alfalfa pellets were fed at 2.5% BW daily to meet or exceed their maintenance requirements throughout the trial (NRC 2007). Sheep also received fresh water and a calcium/phosphorus mineral with trace elements *ad libitum.*

The bitterweed plants used in this experiment were harvested in early to mid-spring at the Texas AgriLife Research Station near Barnhart, Texas and transported back to the MIR Center. Plants were then air dried for two weeks post-harvest. Bitterweed was hand chopped, composited, and thoroughly mixed before feeding.

Animals in each treatment received their respective supplements each day before bitterweed was fed. Ingredients and nutrient content of each supplement is listed in Table 1. Treatment 1 received a supplement with cottonseed meal as the protein source. Treatment 2 received a supplement with cottonseed meal and distiller's grain as the protein source. Treatment 3 received a supplement with soybean meal as the protein source, and Treatment 4 received a supplement with soybean meal and distiller's grain as the protein source. Treatment 5 served as the control group and received only alfalfa pellets. All supplemental diets were isonitrogenous at 37% crude protein. The amount of supplement for each lamb was based on providing 1.9 kg^{-1} BW to meet maintenance requirements, and in addition, 64 g of additional protein was fed each day to achieve 150 g of growth per day (NRC 2007). The amount of each supplement fed was based on requirements for maintenance and growth minus the number of grams of protein provided by alfalfa pellets.

Table 1. Ingredients and nutritional value of supplemented protein feeds.

Ingredients[a]	Ration/Treatment (%)			
	1	2	3	4
Cottonseed Meal	88.7	77.5	--	--
Soybean Meal	--	--	78.7	63.0
Digestible dried grains (DDG)	--	16.2	--	26.8
Cane Molasses	3.4	3.4	3.4	3.4
Rice bran with germ	7.5	2.5	17.5	6.5
Trace Mineral Premix	0.02	0.02	0.02	0.02
Vitamin ADE Premix	0.3	0.3	0.3	0.3
Nutrient Content				
TDN[b]	70.2	72.3	73.7	76.5
Crude Protein	37.3	36.0	39.6	37.3
MEt Energy	231.3 kcal/kg	77.1 kcal/kg	2498.8 kcal/kg	1767.5 kcal/kg

[a]All percentages based on one ton (909.1 kg)
[b]Total digestible nutrients

Lambs were randomly allocated to treatments and fed one of the four treatments daily for 15 days during the feeding trial. Protein supplementation was offered every day from 1300 hours to 1400 hours prior to feeding bitterweed. Bitterweed was then offered to all animals from 1400 to 1500 hours with intake recorded daily. Lambs were all offered 35 g of dried bitterweed to begin the trial. If any lamb consumed all the bitterweed offered for two consecutive days, the amount offered was increased to 50 g on the following day and by intervals of 25 g on days after that. Lambs were then offered alfalfa pellets at 2.5% BW to meet maintenance requirements from 1500 hours to 1700 hours. The amount of alfalfa fed to control animals was increased so that they received the same amount of protein each day. Intake of supplements, bitterweed, and alfalfa pellets were monitored daily by weighing refusals. Body weight changes were monitored during this experiment by weighing the animals before the feeding trial began and after it was over.

This study design was a completely randomized design. Differences between protein supplements (treatment means) were assessed using repeated measure analysis of variance. Individual lambs nested within treatments served as replications. Treatment means were analyzed as a fixed effect, individual animals as a random effect, and days of feeding as the repeated measure. Planned linear orthogonal contrasts were also used to compare each treatment to the control diet. Intake was adjusted on a body weight basis ($g \cdot kg^{-1}$ BW) to account for variations among animals. Means were separated using Least Significant Differences (LSD) where $P \leq 0.05$. Data were analyzed using the statistical package JMP (SAS Institute 2007).

RESULTS

Supplement and alfalfa intake were similar ($P > 0.05$) across treatments and across days in both the pretrial and trial. Lambs typically ate all of the alfalfa and supplement fed each day. The treatment and treatment X day interaction for bitterweed intake was similar

($P > 0.05$); however, bitterweed intake differed ($P < 0.05$) across days of feeding (Fig. 1). Initially, animals were reluctant to consume bitterweed (0.1 g/kg BW), however by day 20 had increased intake to (1.5 g/kg BW) (Fig. 1).

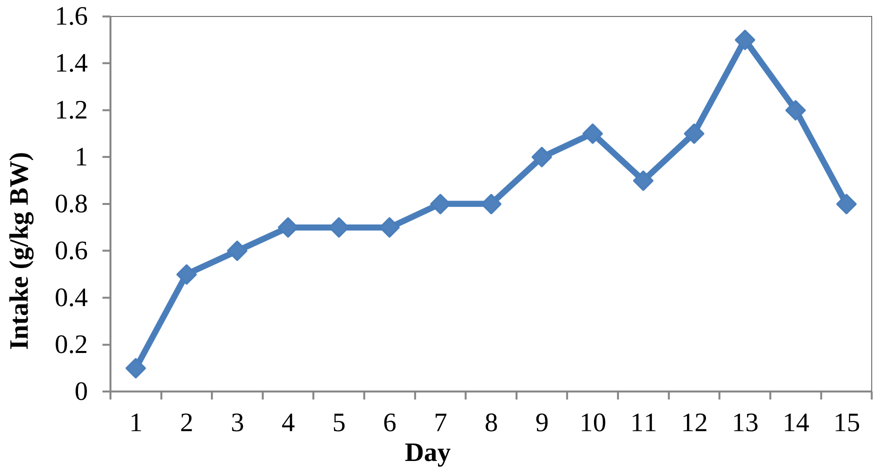

Figure 1. Average intake of bitterweed for the 15-day feeding trial.

When orthogonal contrasts were used to compare treatment means, one difference was evident. Lambs receiving the SBM supplement consumed more bitterweed than those receiving no supplement (Fig. 2). Bitterweed consumption of other groups did not differ statistically from the control group (Fig. 2).

Lambs in the CSM treatment lost weight during the trial. The control treatment gained an average of 1.4 ± 0.74 kg. The CSM/DDG treatment group gained an average of 1.7 ± 0.74 kg. The SBM treatment group gained an average of 1.74 ± 0.74 kg, and the SBM/DDG treatment group gained an average of 0.21 ± 0.74 kg. The CSM treatment group lost an average of 0.4 ± 0.74 kg (Fig. 3). No animals displayed any clinical symptoms of bitterweed toxicosis during the experiment.

DISCUSSION AND CONCLUSIONS

The results of this study indicate that lambs receiving a SBM protein supplement ate more bitterweed than lambs only receiving alfalfa pellets. When sheep are unable to meet their nutritional requirements (i.e., late fall, winter), bitterweed intake increases. In addition, most producers report higher incidences of bitterweed toxicosis in ewe lambs that are still growing and may not be able to meet their nutritional requirements from dormant, poor quality, warm season grasses. Supplementation with soybean meal should provide the substrates (L-cysteine) for rumen detoxification of hymenoxon and improve the likelihood of animals meeting their protein requirements.

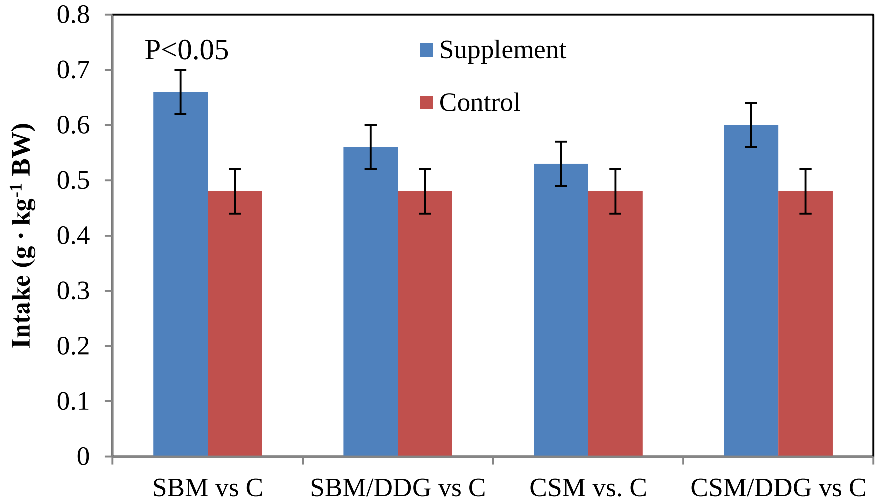

Figure 2. Comparison of average bitterweed intake between different treatments and control group for sheep fed bitterweed for one hour daily for 15 days.

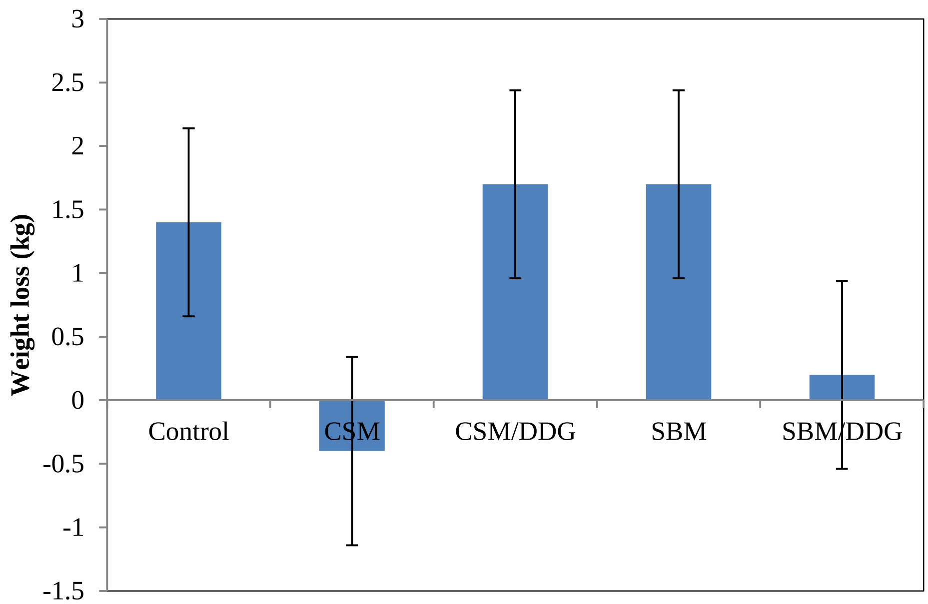

Figure 3. Average weight change of sheep after 22-day feeding trial.

The hypothesis that protein sources high in amino acids that escape rumen digestion would improve bitterweed intake was not confirmed despite that fact that other research illustrated that supplements containing both CSM and DDG improved intake of the toxic shrub redberry juniper (George et al. 2010). Given that both toxins are apparently altered and conjugated in the liver (Terry et al. 1983; Foley et al. 1995), we expected that supplementation with CSM and DDG would increase bitterweed intake. In this study, supplementation for protein sources higher in amino acids that escape rumen degradation apparently had no impact on bitterweed intake.

Other research supports the importance of supplementation to reduce the likelihood of plant-induced toxicosis. Banner et al. (2000) showed that supplementation of lambs with barley and activated charcoal increased their consumption of big sagebrush. Supplemented lambs ate an average of 304 g of sagebrush versus control sheep that ate an average of 248 g. Similarly, supplemented sheep fed a 20% crude protein diet over a 10% crude protein diet had decreased signs of toxicosis from bitterweed (Calhoun et al. 1989).

None of the lambs in this experiment showed symptoms of bitterweed poisoning. Lambs were on an adequate plane of nutrition, and were meeting their requirements for maintenance and growth. If nutrient intake had been lower, lambs may have ingested sufficient levels of bitterweed to induce toxicosis.

During periods of nutritional stress, the body undergoes a depletion of glycogen stores, and increased glucogenesis from degraded amino acids and fatty acids being utilized for energy requirements. This response to starvation reduces the animal's ability to handle plant toxins (Bidlack 1982). Detoxification requires additional expenditures of amino acids and glucose to conjugate with toxins. Thus, feeding greater amounts of amino acids and high protein diets may provide a source of amino acids that can be used to synthesize glucose in the liver, in turn playing a role in conjugation of toxins to be excreted from the body (Illius and Jessop 1995).

Bitterweed is a toxic cool season annual forb that is green and growing in pastures in west central Texas at times when most other forages are dormant. This is also a time when the nutritional requirements of range animals are at their highest. Results of this study, as well as previous studies, have shown that protein supplementation can increase consumption of toxic plants (Banner et al. 2000; Campbell et al. 2007; George et al. 2010). Most pasture supplementation in west central Texas begins around mid to late November when warm season forages enter dormancy and bitterweed plants are growing. Producers that have bitterweed present should consider feeding a soybean meal-based range supplement to their animals. This can be used as a method of protecting sheep against hymenoxon poisoning by providing the sulfur containing amino acids that apparently bind with the toxin and aid in meeting nutritional requirements, thereby reducing the likelihood of bitterweed ingestion.

ACKNOWLEDGEMENTS

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Nitrate Concentration of Water in Hydroponic System Impacts Nitrogen Concentration of Wheatgrass Roots and Shoots Differently

Valerie Gamao[1]
Harley D. Naumann[2]
Barry D. Lambert[*,3,4]

[1]*James Madison High School, 5005 Stahl Road, San Antonio, Texas*
[2]*University of Missouri, 108 Waters Hall, Columbia, MO 65211,*
[3]*Texas A&M AgriLife Research, 1229 N. U.S. Hwy 281, Stephenville, TX 76401*
[4]*Tarleton State University, Box T-0070, Stephenville, TX, 76402*

ABSTRACT

Nitrate is the most common groundwater contaminant. The objective of this experiment was to determine if *Triticum aestivum* (wheatgrass) is able to act as a phytoremediator of nitrates present in wastewater and how nitrogen (N) accumulation in wheatgrass is affected by the nitrate concentration in a hydroponic system. Wheatgrass was reared in six hydroponic units containing 0, 100, or 200 ppm added nitrate (n = 15 tanks for 100 and 200 ppm added nitrate and five for 0 ppm added nitrate control). Plants were grown for 12 days prior to harvest. The harvested shoots and roots were dried, ground, and analyzed for total nitrogen. Plants grown in 200 ppm nitrate solution contained a greater (9.9%; $P \leq 0.05$) concentration of nitrogen in the shoots than control plants with the 100 ppm nitrate solution being intermediate. Plants grown in 200 ppm nitrate solution contained a lower (16%; $P \leq 0.05$) concentration of nitrogen in the roots than control plants with the 100 ppm nitrate solution being intermediate. Nitrate and nitrate-N concentrations in the water were reduced to levels considered to be non-problematic for consumption by mature cattle for the 100 ppm treatment, but not the 200 ppm treatment.

KEY WORDS: wheatgrass, nitrate, nitrogen

INTRODUCTION

Nitrate regulation is important to both society and the aquaculture industry. Consumption of elevated levels of nitrates in drinking water has been linked to several health conditions including methemoglobinemia in infants and some forms of cancer (Weyer et al. 2001; Ward et al. 2005). Excessive nitrate intake has also been implicated as a cause of spontaneous abortions in animals (Manassaram et al. 2006). Nitrate in water often results from nonpoint sources such as agricultural and fertilizer (Loehr 1974; Keeney and Olson 1986) or point sources such as leaks from sewage treatment systems (Keeney and Olson 1986).

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*Corresponding author: blambert@tarleton.edu.

Nitrate levels potentially affect human society as drinking water quantity and quality, as well as physical health are threatened (Goff 2004). High fertilizer runoffs from urban lawns and farmlands, septic systems, and livestock discharge are one of the main reasons for nitrate being the most common groundwater contaminant (Keeney and Olson 1986). Current regulations in the United States require that the Maximum Contaminant Level (MCL) for drinking water standards should not exceed concentrations of 10 ppm nitrate-N or 45 ppm nitrate. This sole standard for nitrate level was initially set to combat a condition of methemoglobinemia, commonly known as blue baby syndrome (Knobeloch et al. 2000). This occurs due to high liquid intake compared to body weight, which results in low acidity in the stomach allowing for bacterial conversion of nitrate to nitrite. The interaction between nitrite and hemoglobin then decreases the blood's capacity to carry oxygen. There are also equally serious, chronic conditions that are suspected to develop after long-term exposure to nitrate-contaminated water. Health effects include hypertrophy of the thyroid, 15 kinds of cancer, two kinds of birth defects, and hypertension (Anjana and Iqbal 2007).

The use of cyanobacteria (photosynthetic microorganisms) to biologically remove nitrate from groundwater has shown promise (Hu et al. 2000). The use of plants for the purpose of phytoremediation of nitrate-contaminated water may also be effective (Leba et al. 1999; Sundaralingam and Gnanavelrajah 2014). *Triticum aestivum* (wheatgrass) belongs to the Poaceae family and is a type of grass commonly grown in the temperate regions of Europe and the United States. The primary objective of this research is to determine the ability of wheatgrass to be used as a phytoremediator of nitrates present in aquaculture wastewater.

MATERIALS AND METHODS

Wheatgrass seeds were planted in individual hydroponic units situated atop individual aquarium tanks containing nitrate treatments of 200 ppm, 100 ppm, or 0 ppm nitrate (control). Replications consisted of five tanks per treatment, which contained six hydroponic cups per tank. Nitrate levels were achieved by dissolving $NaNO_3$ powder in the aquarium tanks and were monitored throughout the study using nitrate test strips. Water samples (50 ml) were collected for nitrate and nitrate-nitrogen analysis upon completion of the 12-day growing period. Water samples were frozen immediately following collection and stored for later analysis by Dairy One (Ithaca, NY, USA). After the 12-day growing period, wheatgrass was harvested and sorted by plant tissue (shoots or roots) from each treatment. Harvested plant materials were dried at 55 °C in a forced air oven for 48 h, then ground to pass a 1-mm screen in a sheer mill (Wiley Arthur H. Thomas Co., Philadelphia, PA) and stored for subsequent chemical analysis. Plant tissue dry matter was determined by drying overnight at 105 °C in a forced air oven. Dried plant materials were analyzed for N using an Elementar Vario Macro C:N analyzer (Elementar Americas, Inc., Mt. Laurel, NJ).

The GLIMMIX procedure of SAS (SAS Inst. Inc., Cary, NC, USA) was used for statistical analysis of DM and N concentration of shoots and roots. The model included the main effect of N concentration on the dependent variables root and shoot percent N. Least Square means were estimated using the LSMEANS statement and when significant effects were detected in the model ($P \leq 0.05$), the LINES option with the TUKEY adjustment was used for mean separation. Prism 6 (GraphPad Software, Inc., La Jolla, CA, USA) was used for statistical analysis of 12-day water nitrate reduction. An unpaired t test was used and $P \leq 0.05$ was considered significant.

RESULTS

The effects of hydroponically grown wheatgrass on water nitrate and nitrate-N concentrations after 12 days of plant growth are shown in Table 1. Nitrate concentrations decreased in water used for the hydroponic system over the 12-day period of wheatgrass growth. There was no difference in the reduction in nitrate concentrations over a 12-day period between the 100 and 200 ppm treatments ($P = 0.27$). Water nitrate and nitrate-N concentrations of the 200 ppm treatment remained two-fold greater than that of the 100 ppm treatment over the 12-day period.

Table 1. Water nitrate and nitrogen concentrations (ppm) and reductions (%) for water containing 0, 100, or 200 ppm Nitrate before (day 0) and after (day 12) of hydroponic wheatgrass growth.

Treatments Nitrate, ppm	Nitrates, ppm			Nitrogen, ppm
	Day 0	Day 12	% Reduction	Day 12
0	0	0^{c}	-	-
100	100	73^{b}	27^{a}	17^{b}
200	200	161^{a}	19.5^{a}	37^{a}

[a, b, c] Within a column, means with different superscripts differ by ANOVA ($P \leq 0.05$). Mean separations were performed with the LINES (TUKEY) option of the LS MEANS statement in PROC GLIMMIX.

The accumulation of total N in roots and shoots of wheatgrass grown in a hydroponic system treated with 0, 100, or 200 ppm nitrate is shown in Figure 1. Accumulation of N in roots decreased with increasing water-nitrate concentrations and was less in the 200 ppm treatment than the 0 ppm control. Accumulation of N in shoots increased with increasing water nitrate concentrations and was greater in the 200 ppm treatment than the 0 ppm control. Accumulation of N in wheatgrass shoots and roots grown in 100 ppm nitrate was intermediate to the 0 ppm and 200 ppm treatments.

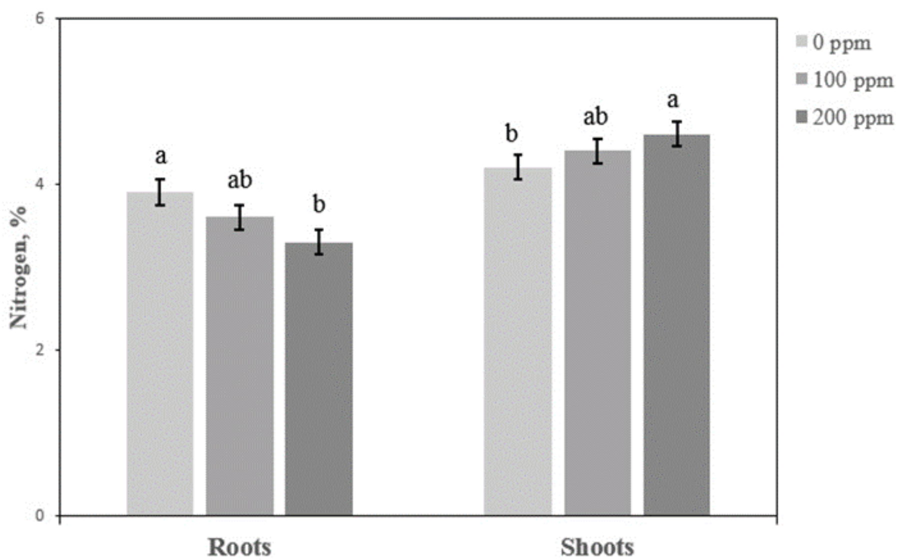

Figure 1. Plant tissue nitrogen concentration of wheatgrass grown hydroponically in water containing 0, 100, or 200 ppm nitrate.
Treatment x plant part interaction, $P = 0.01$
[a,b,c] Bars with common letter do not differ, ($P \leq 0.05$)

CONCLUSION AND DISCUSSION

A plant's capability to remediate the environment is achieved either by storing the chemicals in their structural components, using their own metabolic processes to produce a chemical that is less harmful, or by transforming harmful chemicals into trace amounts of gas. Phytoremediation is the use of living plants, particularly their structural components such as their roots and metabolic processes, to rehabilitate contaminated soil, water, or air (Macek et al. 2000). Phytoremediation is a relatively inexpensive method with estimates of $0.60 - $6.00 per 1000 gallons of remediated water (Macek et al. 2000). Some limitations of this method include the depth of the roots and the tolerance of the plant to the contaminant. A particular type of phytoremediation is called phytodegradation, where the internal and external metabolic processes of the plant drive the degradation of organic contaminants, and as the plant grows, they become incorporated into plant tissues or further degraded. The basic concept of a hydroponic system is that of growing a plant in water containing essential nutrients, such as potassium and nitrogen for growth, in the absence of soil.

Nitrate accumulation can occur in the shoots and roots and tends to accumulate in the initial growth period (Anjana and Iqbal 2007). Besides nitrate availability in the soil or water, the plant's inherent metabolism also determines accumulation rates. The primary objective of this research was to determine if the total N concentration of wheatgrass roots and shoots increases when grown hydroponically in 0, 100, and 200 ppm lab-prepared nitrate solutions. The percent nitrogen of 0 and 200 ppm nitrate treatments differed ($P < 0.05$). The plants grown in a 200 ppm nitrate water source had 3.16% N in roots and 4.89% N in the shoots. The control group with 0 ppm nitrates produced wheatgrass with 2.51% N in the roots and 4.35% N in the shoots.

The hydroponic units treated with 200 ppm nitrates had greater percent nitrogen presence in the roots and shoots when compared to the 0 ppm control. The fact that the shoots had a higher percent of nitrogen may or may not pose a potential problem regarding further use of the harvested crop as a food, feed, or cover crop. Further investigation is needed in order to accurately determine what form of nitrogen is present in the shoots. In the event that after nitrate phytoremediation the harvested wheatgrass is overly contaminated with nitrate, then the popular method of ensiling the crop, where anaerobic bacteria decompose the harmful nitrate to safer nitrogen forms, can be used to allow the making of forage. Wheatgrass could still provide a nutritional benefit to humans, provided that after its phytoremediation role in aquaculture wastewater, the crop is still safe for consumption. Wheatgrass may also be used as an alternative source of livestock feed because of its resulting higher nitrogen level if these concentrations translate into increased crude protein. In addition to the possible benefit of increased crude protein, nitrate inclusion in cattle diets has been shown to reduce enteric methane emissions by as much as 16% (Van Zijderveld et al. 2011). Methane produced by cattle can represent as much as 15% loss in metabolizable energy intake by the animal and is a potent energy trapping greenhouse gas. Mitigation efforts that do not result in negative effects on digestibility of the diet and overall animal production are of great interest. The effects of dietary nitrate on rumen physiology may be the result of changes in microbial population. Shifts in rumen-microbial populations have been observed in cattle consuming diets supplemented with nitrate-N (Lin et al. 2013).

A diet that provides essential nitrogen allows for not only higher crude protein for livestock, but wheatgrass itself could serve as a nitrogen-rich cover crop. The wheatgrass plant might be able to help the aquaculture industry relative to water remediation and also the agriculture industry in its recycling of the crop to be used as forage or cover crop. In terms of the control treatment with 0 ppm nitrates, a similar pattern of the shoots containing a higher nitrogen presence than the roots was observed. This pattern makes sense because the leaves contain chlorophyll, of which nitrogen is an important component. As for the question behind the still significant nitrogen presence in the control group with initial 0 ppm nitrate, the nitrogen might have come from a combination of the inherent nitrogen in the seed itself and its growing medium that is made of natural coconut fibers (cocotek cups lined the hydroponic cups). Wheatgrass plants grown from a 200 ppm nitrate source produced shoots and roots containing significantly more nitrogen.

Nitrate-N concentrations of water used to grow hydroponic wheatgrass decreased over a 12-day period of growth. While wheatgrass is able to phytoremediate water containing 100 ppm Nitrate-N to safe levels (below 80 ppm), it was not able to do so at the 200 ppm concentration. The hypothesis that the wheatgrass roots and shoots would contain greater N concentrations when grown in 200 ppm nitrate solutions as compared to those grown in 0 ppm nitrate was correct. The greater concentration of total N in the shoots than in the roots raises a question of whether the crop is still suited for consumption. Since nitrate-N was not measured in plant tissue, further investigation is needed to identify what form of nitrogen is actually present in those plant structures, the harmful nitrate or elemental N form, before suitable uses of the crop can be recommended. Nitrate does have a significant effect on the N composition of the wheatgrass plant, most particularly, its shoots.

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The Dairy Industry's Derived Demand for Feed Grains and Its Effect on the Cottonseed Market

Priscilla B. Argüello[*]
Jaime Málaga
Benaissa Chidmi
Jose A. Lopez
Department of Agricultural and Applied Economics, Texas Tech University, TX 79409-2132

ABSTRACT

Despite much research on feed grains and oilseeds, little is known about the dairy industry's influence on aggregate cottonseed demand. A transcendental logarithmic production model with regional dummy variables is used to estimate the U.S. dairy industry's derived demand for cottonseed meal, corn, alfalfa hay and other grains. Own-price and cross-price elasticities are estimated using a marginal approach. Two case analyses, selected plausible future price events in the feed grains market and increases in milk production, are investigated to determine the dairy industry's effect on aggregate demand for cottonseed and cottonseed prices.

KEY WORDS: Cottonseed, derived demand, dairy industry, feed grains, oilseeds

INTRODUCTION

Despite much research on feed grains and oilseeds, little is known about the U.S. dairy industry's influence on aggregate cottonseed demand. The growing demand for cottonseed has increased cottonseed prices substantially. Cottonseed prices have risen on average from $89.50 per ton in 2001 to $110 per ton in 2006 (USDA-NASS 2007). In September 2008, average cottonseed prices were estimated at $253 per ton, representing a 183% increase from 2000 and a 130% increase from 2006 (USDA-NASS 2008). During the first quarter of 2008, market prices in West Texas reached $270 dollars per ton.

The crushing industry and the dairy industry are the main components of demand for cottonseed in the U.S. Both determine the market price for cottonseed. According to Robinson (2001), "[t]ypically about half of the cottonseed … produced each year is used for dairy feeding." In many U.S. regions, the dairy industry pays a premium over the oil mill price. The oil mill determines the price it will offer for seed based on the value of the products it can obtain from cottonseed (oil, meal, hulls, and linters). The dairy industry determines the quantity of cottonseed they will use in the ration based on the nutrient characteristics, price, and the substitutability and complementarities of the nutrients found in other inputs. The migration of dairy farms from traditional production states, such as California and New York, to Southern states, such as New Mexico and Texas, is expected to have a local effect on the demand for cottonseed and market price, thus making the dairy industry's role in the determination of market price for cottonseed noteworthy.

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[*] Corresponding author: Priscilla_Arguello@yahoo.com.

There are many useful economic studies in cotton and cottonseed demand. Most studies on cottonseed analyze the U.S. crushing industry's component of demand and report the crushing industry elasticities or projected quantity demanded (Goodwin et al. 2003; Mattson et al. 2004; Food and Agricultural Policy Research Institute 2008b). Only a few studies consider external events, such as the ethanol effect on the grain commodities market and oilseed market. Such events may have a direct effect on world and U.S. demand for cottonseed and should be considered in the estimation of aggregate demand and price analysis. On the other hand, there are no studies known to the authors analyzing the U.S. dairy industry's derived demand for cottonseed. Most research conducted regarding the dairy industry and feed grains is directed towards improving production and quality, minimizing feed costs, analyzing trends in the dairy industry, and integrating management approaches, among other issues. As a result, there is a need to identify the factors that have a direct or indirect effect on aggregate demand for cottonseed, especially the dairy industry's derived demand for cottonseed which is expected to use approximately half of the cottonseed produced in the U.S. By estimating the dairy industry's demand parameters and accounting for the crushing industry's previously estimated demand, a more accurate assessment of cottonseed prices can be determined and, consequently, the level of cash funds that cotton farmers can receive during future crop years can be estimated.

This study estimates the dairy industry's derived demand for feed grains and meals using a trans-log production model and a marginal approach to estimate own-price and cross-price elasticities for the U.S. dairy industry. This study also analyzes how changes in grain prices affect the dairy industry's derived demand for cottonseed and market prices, as well as the dairy industry's effect of pulling cotton seed prices up.

The Dairy Industry's Derived Demand for Cottonseed and Other Feeds. The size of the U.S. dairy industry is determined by the demand for milk. In other words, the amount of milk that farmers will be able to sell, and thus need to produce, is directly determined by what consumers are willing to buy directly or indirectly. The number and size of farms are influenced by the demand for milk, the level of milk production per cow, economies of size, among other factors. The total number of dairy cows will be determined by the demand for milk and the level of milk production per cow. According to the USDA Census of Agriculture in 2007, there were about 9.267 million dairy cows in the U.S. According to a study by LaRue et al. (2003), the number of cows needed to satisfy the U.S. demand for milk would be 8,297 to 8,393 million in 2010 and 7,681 to 7,931 million in 2020, with production per cow of 21,722 pounds in 2010 and 25,352 pounds in 2020, representing a downward trend in cow numbers and an increase in production per cow. The increase in production per cow has resulted from improvements in breeding, genetics, feeding, and housing. According to FAPRI's U.S. and World Agricultural Outlook (2008a), the number of dairy cows in Texas will increase an average of 2% per year, from 367,000 heads in 2008 to approximately 432,000 heads in 2017. Milk production in Texas will increase an average 4% per year, from 7,828 million pounds to approximately 10,748 million pounds in 2017. Texas will produce approximately 5% of the national milk production by the year 2017 (FAPRI 2008a).

The reduction of feed cost and maintenance of productivity becomes a primary strategy of successful milk production. Dairy farmers minimize input costs of production by choosing feed grains, meals, and by-products that meet all the nutrient requirements of dairy cattle and yield the highest milk production. Feed grains have a certain degree of substitutability among them, but one cannot be fully substituted for another because they have different nutritional characteristics. By-product feeding has been regarded as a substitute for more traditional feedstuffs, such as corn and soybean meal. By-product feeding has also become increasingly important given its low cost. Cottonseed, almond hull, beet pulp, citrus pulp, corn gluten feed, corn gluten meal, and rice bran are by-products that can be economically valuable over a range of market prices and regimens. According to Kaiser (2006), the increase in ethanol production to meet demand and the renewable fuels standard will significantly increase the supply of distiller grains. Distiller grains with solubles are excellent feed resources for dairy cattle. It is the fastest growing commodity feed for livestock. However, it must be competitively priced to displace feedstuffs currently included in dairy rations and there is a limit as to how much can be used in the ration of dairy cattle mainly because of its high fat content.

Accordingly, the U.S. dairy industry's derived demand analysis must take into consideration traditional feed grains and meals, such as corn and soybean meal, as well as by-products such as cottonseed and distiller's grain, in their maximization of profits. The feed regimen usually constitutes the largest expense per hundredweight of milk produced and thus must be strategically balanced to optimize milk production.

MATERIALS AND METHODS

For the objectives of this study, input demand is the most appropriate method of estimating the U.S. dairy industry's derived demand for cottonseed meal and other feed grains, given that the dairy industry consumes feed grains in response to final consumer demand for milk. Similarly, the crushing industry consumes cottonseed in response to final consumer demand for cottonseed oil, meal, and hulls. Input demand analysis provides information on the degree and nature of interrelatedness of the U.S. dairy industry's derived demand for different inputs such as cottonseed meal, corn, alfalfa hay, and feed grains in their maximization of profits, as well as own-price and cross-price elasticities of these factors of production.

Following Wang and Lall's (1999) marginal productivity approach, a transcendental logarithmic functional form is implemented. Wang and Lall (1999) provide a useful starting point for the estimation of input demand using a marginal productivity approach and a trans-log production function. The marginal productivity approach is dual to the cost function approach as the marginal input cost should equal the marginal value of production given the assumption that firms are maximizing profits. The trans-log form and marginal approach are implemented in the estimation of the U.S. dairy industry's derived demand for cottonseed. Hence the U.S. dairy industry's derived demand for cottonseed meal, corn, alfalfa hay, and other feed grains and forages is estimated using a trans-log production function with one output, four inputs, and two dummy variables of the form,

$$\begin{aligned}\ln Q_m &= \alpha_0 + \alpha_{cs} \ln cs + \alpha_c \ln c + \alpha_g \ln g + \alpha_{ah} \ln ah \\ &+ \beta_{cs}\frac{\ln^2 cs}{2} + \beta_c \frac{\ln^2 c}{2} + \beta_g \frac{\ln^2 g}{2} + \beta_{ah}\frac{\ln^2 ah}{2} \\ &+ \gamma_{cs*c} \ln cs * \ln c + \gamma_{cs*g} \ln cs * \ln g + \gamma_{cs*ah} \ln cs * \ln ah \\ &+ \gamma_{c*g} \ln c * \ln g + \gamma_{c*ah} \ln c * \ln ah + \gamma_{g*ah} \ln g * \ln ah \\ &+ \delta_1 MWsoy + \delta_2 MWdistiller, \qquad (1)\end{aligned}$$

where Q_m is quantity of milk produced (cwt per year); *cs* is quantity of cottonseed meal purchased per cwt per year; C is quantity of corn harvested and purchased per cwt per year; *g* is quantity of aggregate grains including harvested and purchased soybean, distiller's grain, corn silage, commercial feeds and wheat per cwt per year;

ah is the quantity of alfalfa hay harvested and purchased per cwt per year; and *MWsoy* is a dummy variable for harvested soybean in Midwest region and *MWdistiller* is a dummy variable for purchased distiller's grain in the Midwest region. In other words, the ARMS data set indicated that the Midwest region had the most observations with soybean and distiller's grain as a factor input. The dummy variables measure any shifts in quantity of milk produced for dairy farmers that used soybean and distiller's grains as factor inputs in the Midwest region.

Following Wang and Lall's (1999) marginal productivity analysis, output elasticity with respect to each factor is estimated by taking the partial derivative of the trans-log production function with respect to the factor under consideration. For example,

$$\sigma_{cs} = \frac{\partial \ln Q_m}{\partial \ln cs} = \alpha_{cs} + \beta_{cs} \ln cs + \gamma_{cs*c} \ln c + \gamma_{cs*g} \ln g + \gamma_{cs*ah} \ln ah,$$

$$\sigma_{c} = \frac{\partial \ln Q_m}{\partial \ln c} = \alpha_{c} + \beta_{c} \ln c + \gamma_{cs*c} \ln cs + \gamma_{c*g} \ln g + \gamma_{c*ah} \ln ah,$$

$$\sigma_{g} = \frac{\partial \ln Q_m}{\partial \ln g} = \alpha_{g} + \beta_{g} \ln g + \gamma_{cs*g} \ln cs + \gamma_{c*g} \ln c + \gamma_{g*ah} \ln ah,$$

$$\sigma_{ah} = \frac{\partial \ln Q_m}{\partial \ln ah} = \alpha_{ah} + \beta_{ah} \ln ah + \gamma_{cs*ah} \ln cs + \gamma_{c*ah} \ln c + \gamma_{g*ah} \ln g. \quad (2)$$

Assuming perfect competition and a profit maximizing firm where the marginal cost of a factor equals the market price and the marginal value of output is equal to marginal cost, then marginal values of each factor of production ρ_{cs}, ρ_c, ρ_g, and ρ_{ah} are equal to the market price of that factor, where

$$\rho_i = \frac{\partial Q_m}{\partial Q_i} = \frac{\partial \ln Q_m}{\partial \ln(i)} * \frac{Q_m}{Q_i} = \sigma_i * \frac{Q_m}{i}, \quad (3)$$

and *i* are factor inputs: cottonseed meal, corn, grains, or alfalfa hay. Correspondingly, own-price elasticity and cross-price are estimated by

$$\varepsilon_{ii} = \frac{\sigma_i}{\beta_i + \sigma_i^2 - \sigma_i}, \quad (4)$$

$$\varepsilon_{ij} = \frac{\sigma_j}{\gamma_{ij} + \sigma_j}, \quad (5)$$

where *i* and *j* are factor inputs: cottonseed meal, corn, grains, or alfalfa hay.

U.S. dairy industry data is obtained from the Agricultural Resource Management Survey (ARMS) *2000 Dairy Production Practices and Costs and Returns Report* and the *2005 Dairy Cost and Returns Report* conducted by the National Agricultural Statistics Service (NASS). This data set includes feed operating costs such as purchased feed, homegrown harvested feed, and grazed feed. Purchased feed types include feed grains and by-products that are essential to the feed regimen, including distiller's grains. Homegrown feed types include feed grains which are later broken down by the amount actually fed to the dairy cows during that year. All these alternative feeds data are essential to the estimation of the U.S. dairy industry's derived demand for cottonseed.

In the ARMS data, each observation represents itself and many other farms through a weight or expansion factor, which is based on sales value. Through the weight variable, the sample estimates the population. A dataset with both small and large dairy farms may be heavily represented by small dairy farms and with few observations for large dairy farms. Table 1 below shows the weighted aggregate quantities of feeds used in hundred weights per year. Since the ARMS data use weights as in complex surveys, the means have to be computed incorporating the weight variable. The sampling weight can be thought of as the number of units in the population represented by the sample unit while the sum of weights can be thought as the population size.

Table 1. Descriptive Statistics of Variables in the Study.

Variable	Number of Obs.	Weighted Mean (cwt/year)	Std. Dev. (cwt/year)
Alfalfa Hay	179	81,509	74,451
Commercial Feed	57	9,538	6,075
Corn	179	86,118	74,517
Corn Silage	167	33,493	4,081
Cottonseed Meal	179	40,438	37,236
Distiller's Grain	56	19,686	13,539
Grains	179	36,314	4,844
Milk	179	37,301	4,066
Soybean	25	1,912	484
Wheat	11	4,121	2,458

Note: Sum of weights = 6,940.61.
Source: Prepared by the Author based on ARMS data.

NASS recommends the delete-a-group jackknife variance estimator to analyze the ARMS data. NASS divides the sample data into 15 nearly equal and mutually exclusive different parts and creates replicate weights by setting the full sample weight of every 15th observation to zero (Dubman 2000), such that each observation's greatest effect is measured when it is deleted from the replicate. The delete-a-group jackknife variance is estimated as

$$Var\ (\beta) = \frac{14}{15}\sum_{k=1}^{15}(\beta_k - \beta)^2, \quad (6)$$

where β is the full sample estimate and β_k is a replicate estimate with part *k* removed. This formula adjusts the degrees of freedom for each weight used. Similarly, the jackknife covariance of regression coefficients are estimated as

$$Cov(\beta) = \frac{14}{15}\sum_{k=1}^{15}(\beta_k - \beta)(\beta_k - \beta)'. \quad (7)$$

Joint linear hypothesis testing of the form $D\beta = d$ (Brick et al. 1997) are conducted as

$$F_{d,16-d} = \frac{16 - d}{15 * d}(D\beta - d)'(D * Cov(\beta) * D')^{-1}(D\beta - d), \quad (8)$$

where d is the rank of the matrix D equal to the number of linearly independent restrictions. Individual T-tests for each variable equal zero of the form $D\beta = d$ (Brick et al. 1997) are conducted as

$$T_d^2 = (D\beta - d)'(D * Cov(\beta) * D')^{-1}(D\beta - d). \tag{9}$$

The ARMS data is pooled for the years 2000 and 2005. The sub-sample consists of 179 observations which report cottonseed meal, corn, alfalfa hay, and grains as a factor of production. These inputs are either harvested or purchased, and used on farm (hundred weights per year).

According to Dubman (2000), at least 30 observations are needed for jackknife variances estimation, and 60 observations are needed for hypothesis testing. As a result, a grains and forages variable is created to account for feeds that are not reported across all observations (Table 1). The grains and forages variable includes commercial feeds, corn silage, distiller's grain, grains, soybean, and wheat.

In this study, aggregate demand consists of the dairy industry's derived demand plus the crushing industry's demand for cottonseed. According to the National Cottonseed Products Association (NCPA), approximately 5% is set aside to plant next year's crop. FAPRI (2008a) has already estimated the crushing industry's demand for cottonseed using their World Trade Model, which lists the forecasted total domestic use and total crushed cottonseed through the year 2017. This facilitates the derivation of the dairy industry's demand for cottonseed which can be estimated as U.S. production of cottonseed minus the crushing industry's demand for cottonseed minus the 5% estimate for replanting next year's crop.

The dairy industry's derived elasticities are used to determine the sensitivity of the dairy industry's demand for cottonseed from changes in own price and the price of other grains. For example, the sensitivity of the dairy industry's demand for cottonseed based on a percentage increase or decrease in the price of other grains and forages holding all other factors constant can be determined. Similarly, the output elasticity helps determine how a percentage increase in the production of milk will respond to increases or decreases in inputs demanded on behalf of the dairy industry holding all other factors constant.

The simulation of the U.S. cottonseed market generates a forecasted stream of quantities of cottonseed demanded on behalf of the dairy industry holding all other factors constant. The analysis takes into consideration external variables that have a direct effect on cottonseed prices, such as the long-term trend of increases in national milk production, as well as increases in the national price of grains due to the increased demand for grains from the increased production of ethanol.

RESULTS AND DISCUSSION

The trans-log production function is estimated under different nested hypotheses to test the validity of nonlinear restrictions. The log-likelihood ratio test which is approximated by a chi-square distribution is significant at the 1% level in favor of the unrestricted model in equation (1). Table 2 below presents the results of the estimated model in equation (1). Standard errors are estimated using the delete-a-group jackknife variance formulas described in the conceptual framework. These were estimated by taking the square root of the diagonal of the covariance matrix estimated with equation (7). Standard errors are expressed in parenthesis.

The White's (1980) test is used to examine the presence of heteroskedasticity. The White's test failed to reject the null hypothesis of no heteroskedasticity with a value of 0.1280, meaning there is evidence of homoskedasticity. In the same manner the Breusch-Pagan test for homoskedasticity is applied for quantity of milk produced depending on the seventeen explanatory variables. The test rejects the null hypothesis (< 0.001) showing evidence in favor of homoskedasticity in the model.

Table 2. Translog Production Function with One Output, Four Inputs, and Two Dummy Variables.

α_0	0.2803 (5.3191)	β_{cs}	-0.0695* (0.1973)	γ_{cs*c}	-0.0963* (0.1280)	δ_1	-0.0571* (0.1721)
α_{cs}	-0.5441 (1.4853)	β_c	0.0830** (0.5009)	γ_{cs*g}	-0.0122* (0.1044)	δ_2	-0.1788* (0.1403)
α_c	-0.5416*** (0.9716)	β_g	0.1302* (0.0966)	γ_{cs*ah}	0.0943* (0.1551)		
α_g	0.7929 (0.4132)	β_{ah}	0.0226* (0.1577)	γ_{c*g}	0.0371* (0.2836)		
α_{ah}	0.9049 (0.9511)			γ_{c*ah}	-0.0327* (0.1999)		
				γ_{g*ah}	-0.0181* (0.1607)		
Number of Observations: 179				White's Test: 0.1280			
R-square: 0.8363				Breusch-Pagan: < 0.0001			
Adjusted R-square: 0.8202				Durbin Watson: 2.0825			

Note: Parameter estimates significance levels of 1%, 5%, and 10% are denoted by *, **, and *** respectively. Standard errors are reported in parenthesis.

A Durbin Watson test for first-order autocorrelation is also estimated to test the hypothesis of no auto regression against a one-sided alternative – positive regression – at the 5% significance level. The lower and upper critical statistics for 200 observations and 16 explanatory variables (excluding the intercept) are d_L = 1.599 and d_U = 1.943. The calculated d statistic is 2.0825, which means the test fails to reject the hypothesis of no autocorrelation. First-order autocorrelation in the model does not appear to be statistically significant.

The F-test or joint linear hypothesis testing of all seventeen coefficients plus the intercept being equal to zero could not be estimated. The rank of the D matrix does not conform to equation (8) and therefore could not be tested. Nonetheless, individual T-tests for each variable equal zero of the form $D\beta = d$ (Brick et al. 1997, p.188) are estimated with equation (9) and reported in Table 2. As can be noted in Table 2, own-second derivatives and cross-second derivatives are all significant at the 1 or 5% level. First derivatives are not as significant for α_{cs} and α_c with a value at 20% and 10% significance level, but are insignificant for α_0, α_g, and α_{ah}.

Analysis of the sub-dataset shows that as quantity of milk produced increases during the years 2000 to 2005, the demand for feeds also increases. This proportionate increase is reflected in all five regions (Atlantic, South, Midwest, Plains, and West) of the U.S. There also seems to be a relationship between regional crops and the local demand for feed grains. The Midwest region has the most observations with soybean and distiller's grain as a factor input. The demand for soybean is most significant in the Lake States region and distiller's grain is most significant in the Corn Belt region. Dummy variables are added to the model, equation (1), to detect shifts in quantity of milk produced for dairy farmers that use soybean and distiller's grains as factor inputs and are in the Midwest region. The coefficient δ_1, which represents dairy farmers in the Midwest region that reported harvesting and using soybeans in their dairy operations, estimates -0.0571 quantity of milk produced per hundred weight per year with a standard error of 0.1721 and a t-value significant at the 1% level. The coefficient δ_2, which represents dairy farmers in the Midwest region that reported purchasing distiller's grains for their dairy operations, estimates -0.1788 quantity of milk produced per hundred weight per year with a standard error of 0.1403 and a t-value significant at the 1% level.

Output elasticities measure how a 1% change in the input being considered affects the quantity of milk produced. Output elasticities with respect to each factor of production are estimated using equation (2) and are presented in Table 3 below. Each factor (cottonseed meal, corn and alfalfa hay) by itself does not explain much of the variation in quantity of milk produced implying that a 1% change in quantity of cottonseed meal or corn or alfalfa hay does not have a large effect on the quantity of milk produced. However, a 1% increase in the amount of grains and forages used will increase quantity of milk produced by 0.3055%. Aggregate grains and forages include harvested and purchased soybean, distiller's grain, commercial feeds, wheat and corn silage, where commercial feeds also include custom feeds.

Table 3. U.S. Dairy Industry Output Elasticities.

Cottonseed Meal	Corn	Grains & Forages	Alfalfa Hay
0.0471	0.0340	0.3055	0.0440

Own-price and cross-price elasticities for each factor of production are estimated using equation (4) and equation (5) and are presented in Table 4. The derived demand for cottonseed meal is inelastic with respect to its own-price implying that 1% change in the price of cottonseed meal will change the quantity demanded by -0.4120%. The derived demand for feed grains and forages, and alfalfa hay are elastic with respect to own-price meaning that a percentage change in each factor's own-price will change the quantity demanded by -3.7288% and -2.2644% respectively. Grains and forages have the highest negative percentage change in quantity demanded given a change in own-price out of the four inputs studied. Corn, on the other hand, has a positive own-price elasticity implying that the output effect supersedes the substitution effect of other inputs for corn, such that a 1% increase in the price of corn will increase the quantity demanded by 0.6784%.

Table 4. U.S. Dairy Industry Own-price and Cross-Price Elasticities.

Quantity	Price			
	Cottonseed Meal	Corn	Alfalfa Hay	Grains & Forages
Cottonseed Meal	-0.4120	-0.9581	0.3333	1.3497
Corn	-0.5457	0.6784	25.3301	0.4782
Alfalfa Hay	0.3182	3.8798	-2.2644	1.6962
Grains & Forages	1.0416	0.8917	1.0628	-3.7288

The estimated cross-price elasticities of demand for cottonseed meal imply that it is considered a complement of corn with a cross-price elasticity of -0.9581% and a substitute for grains and forages, and alfalfa hay with a cross-price elasticity of 1.3497% and 0.3333% respectively (Table 4). A 1% change in the price of cottonseed meal will affect the quantity demanded of corn by -0.5457%, slightly more than it affects quantity demand of cottonseed meal, which has an own-price elasticity of -.4120. However, grains and forages have an elastic demand with respect to the price of cottonseed meal with an elasticity of 1.0416%. Alfalfa hay on the other hand has an inelastic demand with respect to the price of cottonseed meal with an elasticity of 0.3182%. In summary, the quantity demanded for cottonseed meal is sensitive to changes in own-prices and corn prices; nonetheless, an increase in the price of grains and forages helps augment demand for cottonseed.

The estimated cross-price elasticities for corn imply that corn is a complement of cottonseed meal with an elasticity of -0.5457% and a substitute for grains and forages and alfalfa hay with elasticities of 0.4782% and 25.3301% respectively (Table 4). However, a 1% change in the price of corn will change quantity demanded for cottonseed meal by -0.9581% but will change the quantity demanded for corn by 0.6784%, as well as change quantity demanded for grains and forages by 0.8917% and alfalfa hay by 3.8798%.

The estimated cross-price elasticities for grains and forages imply that it is a substitute of all other inputs (Table 4). Grains and forages have a cross-price elasticity of 1.0416% with respect to the price cottonseed meal, 0.8917% with respect to the price of corn, and 1.0628% with respect to the price of alfalfa hay. A 1% increase in the price of grains and forages, which contains harvested and purchased soybean, distiller's grain, commercial feeds, wheat and corn silage, will significantly increase the quantity demanded for alfalfa hay by 1.6962% and cottonseed meal by 1.3497%.

The simulation analysis generates a forecast of quantities of cottonseed demanded on behalf of the dairy industry holding all other factors constant. The case analysis takes into consideration external variables that have a direct effect on the quantity demanded of cottonseed or cottonseed prices. Two cases are analyzed using the dairy industry's derived price elasticities and output elasticities such as the long-term trend of increases in national milk production and increases in the national price of grains.

Increases in National Milk Production. FAPRI (2008b) estimates national milk production to increase from 185,599 million pounds in 2007 to 212,385 million pounds in 2017 with an average 1.4% increase per year. Taking these projections and the estimated output elasticities (Table 3), the dairy industry's demand for cottonseed and its relationship with milk production can be derived holding all other factors constant. Figure 1 reports the simulated quantities of milk produced on behalf of the dairy industry given changes in input use of cottonseed, holding all other factors constant.

Figure 2 depicts the stream of cottonseed demanded on behalf of the dairy industry using the simulated quantities of milk produced. Simulations are estimated for an additional 1.5% increase and 2.9% increase above estimated quantities of milk produced and 1.5% below estimated quantities of milk produced. As can be noted from Figure 2, the quantity of cottonseed demanded on behalf of the dairy industry's increases at an increasing rate given higher increases in milk production, holding all other factors constant. That is, if milk production increases at an average rate of 4.3% annually (plus 2.9% per year) the quantity of cottonseed demanded would increase beyond 6 million tons (plus 66%). Using the World Cotton Fiber Model's forecasted cotton production; cottonseed production would reach approximately 6.95 million tons for the year 2016. This would imply that the dairy industry would demand all of the cottonseed produced by 2016 if milk production increased at an average rate of 4.3%. Similarly, if milk production increased at an average rate of 1.5% annually above the FAPRI (2008b) milk production estimates the demand for cottonseed on behalf of the dairy industry would be 5.7 million metric tons in 2016 (34% increase). This represents approximately 82% of the estimated cottonseed produced. On the other hand, if milk production were to decrease 1.5% the demand for cottonseed would be 2.9 million metric tons in 2016, which represents 41% of the estimated cottonseed produced in 2016.

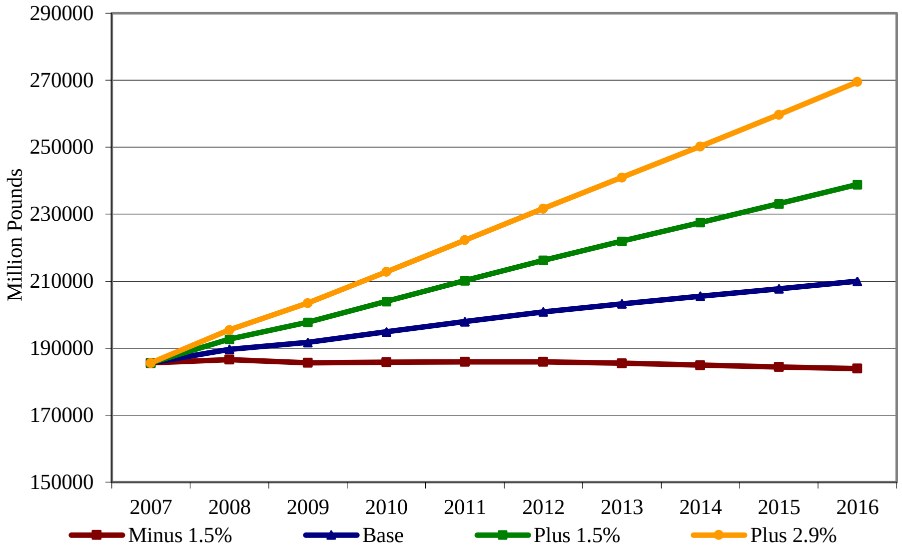

Figure 1. Projected Quantities of Milk Produced Under Different Scenarios.

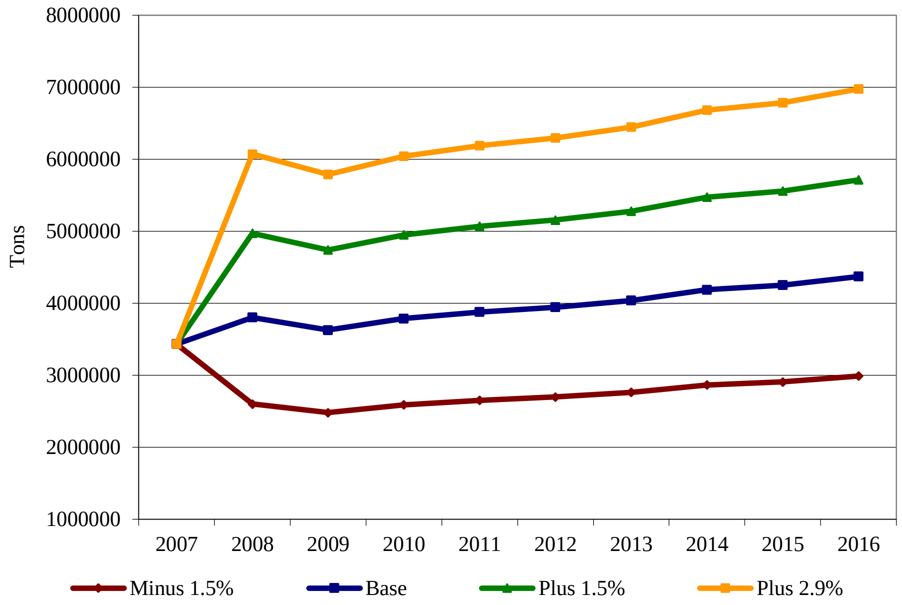

Figure 2. Dairy Industry Demand for Cottonseed Given Various Changes in Milk Production.

This simulation analysis has shed some light into the influence that the dairy industry has on quantity of cottonseed demanded. The migration of dairy farms from traditional production states such as California and New York, to Southern states such as New Mexico and Texas, may have a significant effect on the local demand for cottonseed. Texas milk production is expected to increase an average 4% per year, from 7,828 million pounds to approximately 10,748 million pounds in 2017. This is expected to have significant increases in the local demand for cottonseed.

These projected quantities of cottonseed demanded on behalf of the dairy industry given changes in milk production can be used to simulate its effect on cottonseed prices. Aggregate quantities demanded for cottonseed are the summation of the dairy industry's simulated demand for cottonseed and the FAPRI (2008a) forecasted crushing industry's demand for cottonseed plus 5% of cottonseed production that is set aside to plant next year's crop. Figure 3 shows the stream of aggregate cottonseed demanded from the simulation of changes in quantities demanded on behalf of the dairy industry given changes in milk production. Figure 3 illustrates that, holding all other factors constant, increases in milk production at a rate higher than 1.4% would imply that the dairy industry and the crushing industry demand more than exceeds the forecasted cottonseed supply for 2016. This implies that the shortage of cottonseed supply may result in increasing cottonseed prices as both industries demand more than what is produced.

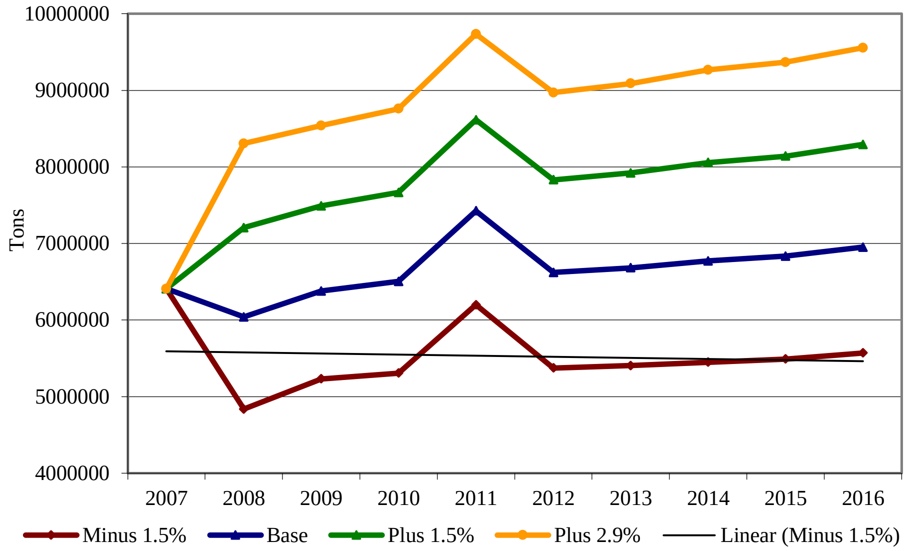

Figure 3. Aggregate Quantities of Cottonseed Demanded Given Changes in Milk Production.

Consequently, the effect that these changes in aggregate quantities demanded would have on cottonseed prices can be simulated, holding all other factors constant. Figure 4 illustrates the estimated price of cottonseed given changes in milk production. It demonstrates that given increases in quantities demanded by the dairy industry the price of cottonseed will also increase, holding all other factors constant. If milk production were to increase at an average rate of 4.3% then cottonseed prices would increase 105% by the year 2016. This implies that there is a demand increase (pulling-effect) by the dairy industry.

Increases in the Price of Grains. In order to simulate how changes in the price of grains affect the demand for cottonseed, an A-index is created using the FAPRI (2008a) forecasted prices for distiller's grains and wheat, and NASS' (USDA-NASS 2008, 2007) forecasted soybean prices. NASS also has historical data on dairy feed prices in their annual report "Agricultural Prices" (USDA-NASS 2008, 2007). Dairy concentrated feeds are forecasted using a linear regression of dairy feeds as a function of the price of corn, price of soybean and the price of wheat.[1] The corn silage price is also forecasted using a linear regression of corn silage as a function of the yield of corn production per acre, price of soybean and alfalfa hay.[2] Corn silage gross value per acre for the period 1996-2006 is obtained from the USDA-ERS annual reports on corn production costs and returns (USDA-ERS 2008). Although there is much literature that encourages using corn prices as a base price to determine corn silage price per acre, the variable resulted insignificant and is therefore dropped from the model. After estimating the A-index it was evident that corn silage price per ton was pulling the A-index price down. Corn silage represents 48.72% of the aggregate grains variable and it has the least cost per metric ton. Corn silage is dropped from the A-index in order to have an accurate estimate for grains. Figure 5 depicts the grains index estimation.

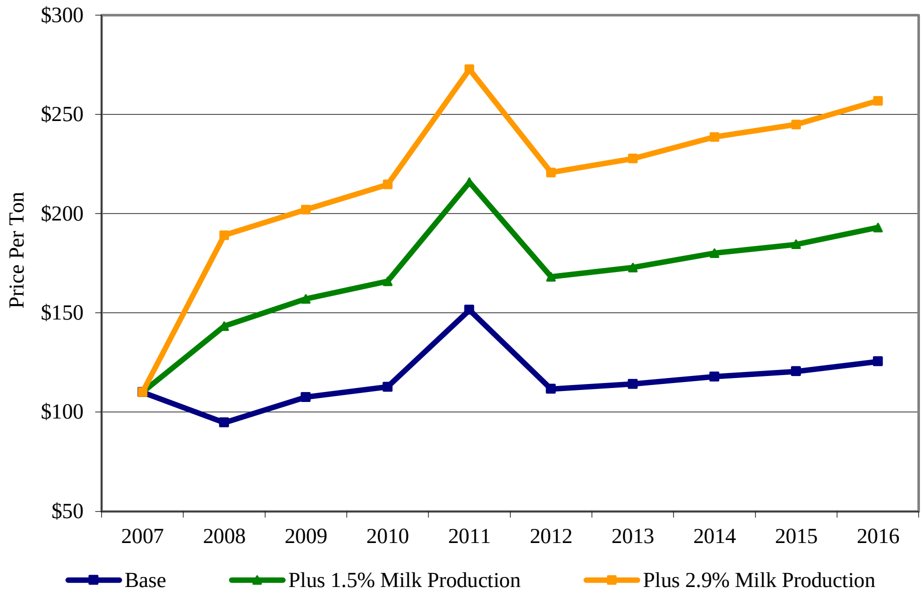

Figure 4. Price of Cottonseed Given Increases in Milk Production.

Taking the A-index projections and the cross-price elasticity of demand estimates (Table 4), the dairy industry's demand for cottonseed is derived, holding all other factors constant. Figure 6 depicts the stream of cottonseed demanded on behalf of the dairy industry using the projected grains index (base) which has an average growth rate of 1.6%. Simulations are estimated for a 0.5% increase and a 0.5% decrease in the rate of grains index prices. As can be noted from Figure 6 an additional 0.5% increase above the average grains price index rate increases the quantity demanded of cottonseed significantly, holding all other factors constant. Using the World Cotton Fiber forecast for cotton production, cottonseed production is derived. Cottonseed production is expected to reach approximately 6.9 million

[1] The linear regression explained 89.10% of the variation in the price of dairy feeds. Soybean price was significant at the 1% level, corn price was significant at the 5% level, and wheat price was significant at 20% level.
[2] The linear regression explained 82.69% of the variation in corn silage price. Corn yield and soybean price were significant at the 1% level, and alfalfa hay price was significant at 10% level.

metric tons by 2016. If grains prices were to increase at an average rate of 2.1% per year the dairy industry would demand almost all cottonseed production by the year 2016 holding all other factors constant. On the other hand, if projected grains prices were to decrease 0.5% per year the dairy industry would demand 2.6 million metric tons or approximately 38% of the estimated cottonseed production by 2016 holding all other factors constant.

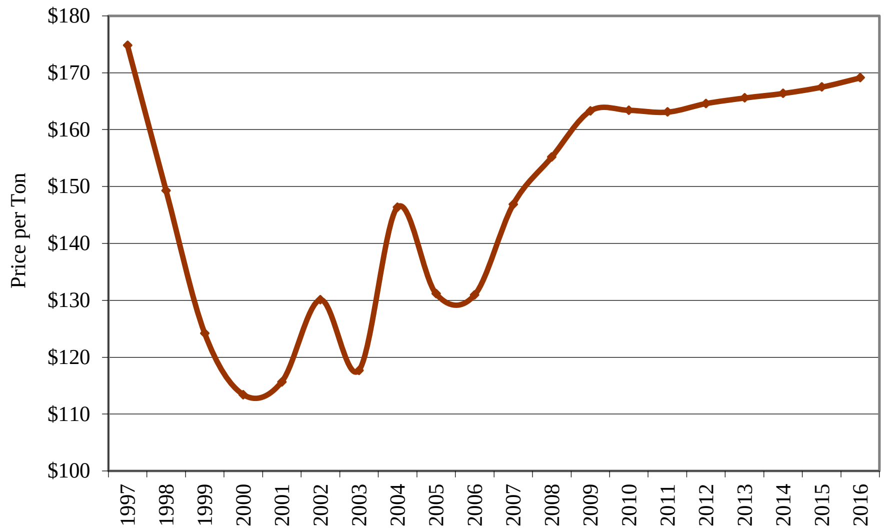

Figure 5. Grains Price Index.
Source: Prepared by the Author using the FAPRI (2008a) and USDA-NASS's (2008, 2007) Forecasted Price Estimates for Distiller's Grain, Wheat, Soybean and Historical Prices for Dairy Feeds.

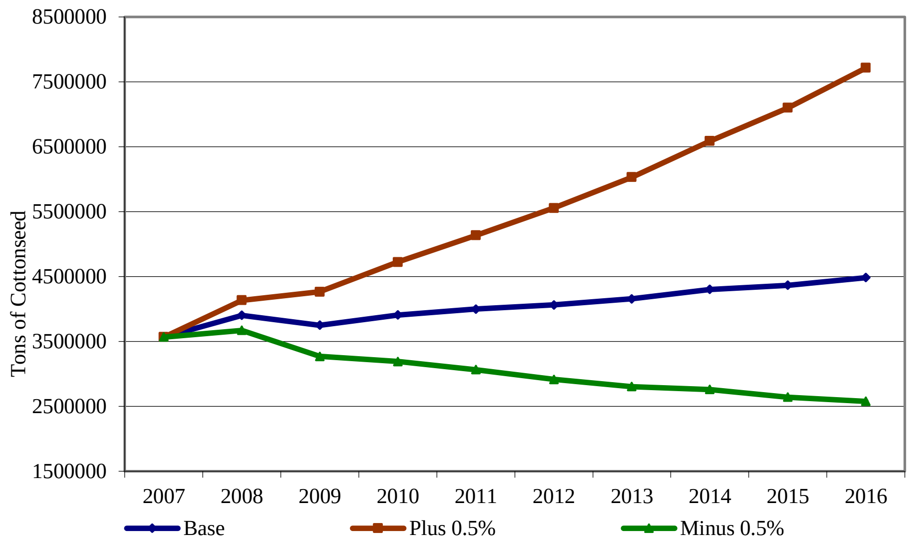

Figure 6. Dairy Industry Demand for Cottonseed Given Changes in the Grains Price Index.

These projected quantities of cottonseed demanded on behalf of the dairy industry given changes in the price of grains are then used to simulate its effect on cottonseed prices. This simulation is estimated using the changes in aggregate quantities demanded and the inverse of the derived own-price elasticity (Table 4), holding all other factors constant. Aggregate quantities demanded for cottonseed is the summation of the dairy industry's simulated demand for cottonseed and the FAPRI (2008a) forecasted crushing industry's demand for cottonseed plus 5% of cottonseed production that is set aside to plant next year's crop. Figure 7 shows the stream of aggregate cottonseed demand from the simulation of changes in quantities demanded on behalf of the dairy industry given changes in grains index prices. Figure 7 illustrates that holding all other factors constant the dairy industry and the crushing industry demand more than what the forecasted cottonseed supply will be for 2016. This implies that the shortage of supply may result in increasing cottonseed prices.

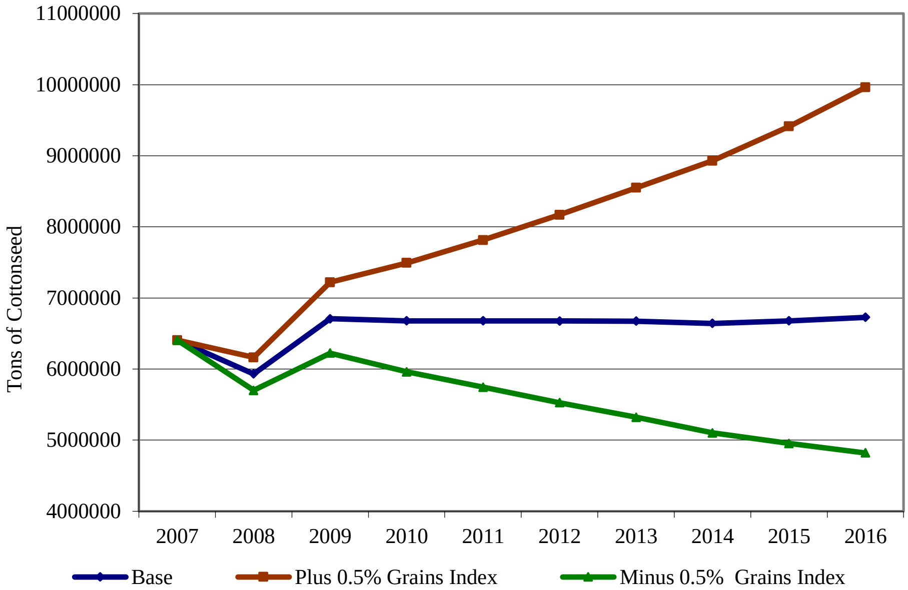

Figure 7. Aggregate Quantity of Cottonseed Demanded Given Changes in Grains Index.

Consequently, the effect that these changes in aggregate quantities demanded would have on cottonseed prices is simulated, holding all other factors constant. Figure 8 illustrates the estimated price of cottonseed given changes in the grains index. The figure demonstrates that given increases in quantities demand on behalf of the dairy industry the price of cottonseed also increases, holding all other factors constant. That is, a 2.1% increase in the gains price index (0.5% above base estimate) will lead to a 152% increase in the price of cottonseed holding all other factors constant. Yet again, this implies that there may be a demand (pulling) effect on behalf of the dairy industry. This correspondence is also expected given increases in milk production, where the dairy industry demands significantly more cottonseed, holding all other factors constant.

Finally, taking the estimated cottonseed price projections (two simulations and the FAPRI forecast), as well as quantities of cotton and cottonseed produced from the World Cotton Fiber Model, and the FAPRI (2008a) forecasted cotton prices, the aggregate gross value of production for U.S. cotton farmers can be estimated. Following USDA calculations, gross value of production for the cotton farmer is equal to the revenues from cottonseed (lbs per acre times dollars per lb) plus the revenues from cotton (lbs per acre times dollars per lb). Figure 9 illustrates that gross value of production from cottonseed may represent a significant portion of farmer's revenues by 2011. If milk production increases 4.3% cottonseed may represent 40% of gross value of production; similarly if grain prices increase 2.1% cottonseed may represent 30% of gross value of production by 2011. Using the FAPRI (2008a) price projections, cottonseed may represent 24% of gross value of production. This implies that cottonseed may switch from a minor byproduct to a significant percentage of gross value of cotton production.

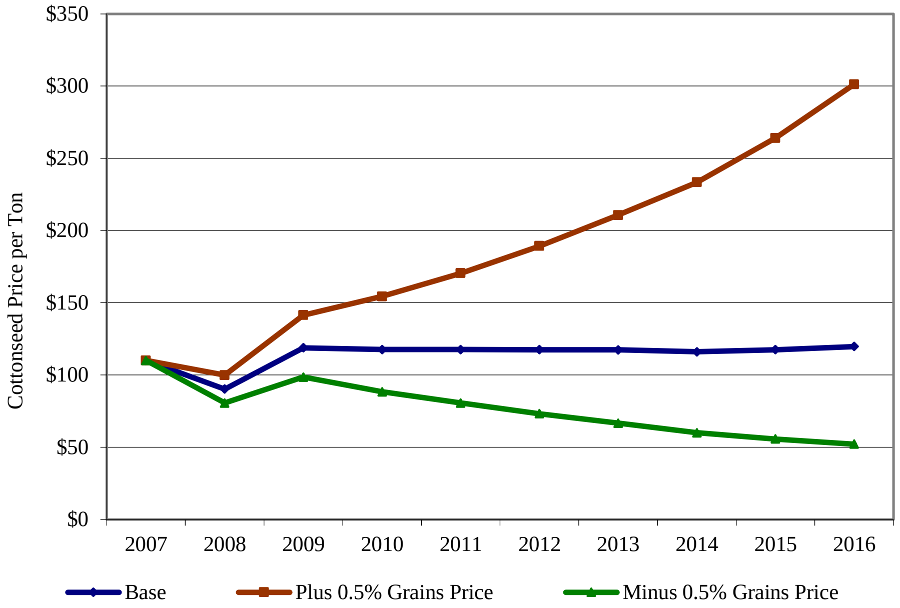

Figure 8. Price of Cottonseed Given Changes in Grains Price Index.

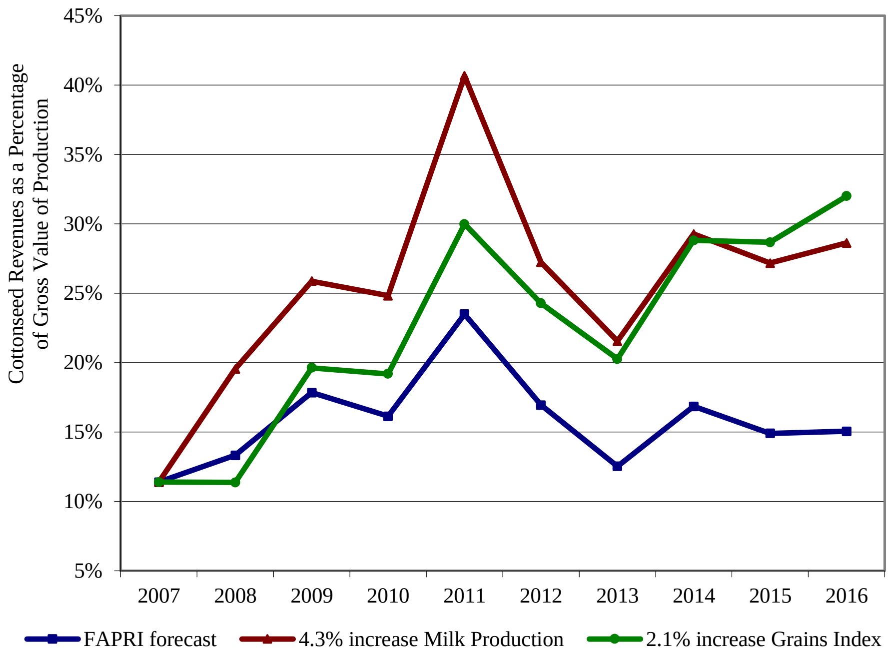

Figure 9. Simulated Cottonseed Revenues as a Percentage of Total Gross Value of Production for the Cotton Enterprise.

CONCLUSION

This study focuses mainly on the U.S. dairy industry's derived demand for cottonseed, and other feed grains and forages by estimating the industry's price elasticities as well as its output elasticities. A transcendental logarithmic production model with regional dummy variables is used to estimate the U.S. dairy industry's derived demand for cottonseed meal, corn, alfalfa hay, and other grains and forages. Following Wang and Lall's (1999), marginal productivity analysis, own-price and cross-price elasticities are estimated for the U.S. dairy industry using data from the Agricultural Resource Management Survey (ARMS).

The study provides useful insight into the sensitivity of prices and quantities demanded by the dairy industry. Output elasticities and price elasticities are further used to analyze the factors that have an effect on aggregate demand for cottonseed. Two case analyses, plausible future price events in the feed grains market and increases in milk production, are estimated to help determine its effect on aggregate demand for cottonseed and consequently its effect on forecasted cottonseed prices.

Case analyses of plausible long-term increases in dairy industry production demonstrate that the dairy industry will demand proportionately more cottonseed given increases in milk production holding all other factors constant. This implies that the migration of dairy farms to Southwestern states such as Texas, where milk production is expected to increase an average 4% per year, from 7,828 million pounds to approximately 10,748 million pounds in 2017 (FAPRI 2008a). This growth in dairy production will proportionately increase local demand for cottonseed, which means that the gross value of production of cottonseed for the cotton farmer may also increase. Regional cotton farmers can expect bigger cash revenue from cottonseed as dairies migrate to southern states.

Nonetheless, the quality of the cottonseed produced also influences the market price. According to Robinson (2001), the size and quality of the seed has decreased. Robinson (2001) states that cottonseed production per bale of cotton has decreased from 780 pounds per bale of cotton in the 1980s to 740 pounds per bale of cotton in 2001. Cotton farmers naturally focus on maximizing cotton production given that it represents 83.8% of gross value of production, while cottonseed represents only 16.2% (USDA-ERS 2008). However, if cottonseed prices continue to increase, more emphasis on the size and quality of the cottonseed will be brought to the attention of cotton farmers, meaning that future studies will now not only focus on maximizing cotton production but also maximize the size and quality of the cottonseed as its value increases. Cotton models may eventually include cottonseed. The role of cottonseed in cotton production may switch from a minor by-product to a significant part of gross value of cotton production. Revenues from cottonseed may eventually be the determining factor as to whether cotton farmers finished the crop year with profitable returns.

DISCLAIMER

The conclusions reported here are those of the authors and do not necessarily represent those of the National Agricultural Statistics Service.

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The Effect of the Master Marketer Program on Participants' Knowledge, Adoption of Practices, and Relative Price Received

Dean A. McCorkle[*1]
Xiaoyan Qin[2]
Rodolfo M. Nayga, Jr.[3]
Ximing Wu[4]
Mark L. Waller[1]
Stephen H. Amosson[5]
Jackie G. Smith[6]
Stan J. Bevers[7]
Mark Welch[1]

[1]*Texas A&M AgriLife Extension Service, Department of Agricultural Economics, Texas A&M University, College Station, TX 77843*
[2]*Former doctoral student in the Department of Agricultural Economics, Texas A&M University. Currently with the Australia National Bank, Hong Kong, China*
[3]*Department of Agricultural Economics and Agribusiness, University of Arkansas, Fayetteville, AR 72701*
[4]*Department of Agricultural Economics, Texas A&M University, College Station, TX 77843*
[5]*Texas A&M AgriLife Extension Service, Department of Agricultural Economics, Texas A&M AgriLife Research and Extension Center, Amarillo, TX 79106*
[6]*Texas A&M AgriLife Extension Service, Department of Agricultural Economics, Texas A&M AgriLife Research and Extension Center, Lubbock, TX 79403*
[7]*Texas A&M AgriLife Extension Service, Department of Agricultural Economics, Texas A&M AgriLife Research and Extension Center, Vernon, TX 76384*

ABSTRACT

The Master Marketer program is an intensive commodity marketing and risk management educational program for agricultural producers. This program combines three successful educational concepts – intensive educational programming, master volunteers, and marketing clubs – into a unique marketing and risk management program. This study analyzes the effects of the Master Marketer program on participants' market knowledge, adoption of risk management practices, and relative prices received. While the program positively affects participants' market knowledge, adoption of marketing practices, and

[*] Corresponding author: d-mccorkle@tamu.edu.

commodity prices received, this analysis suggests that graduates' reported benefits are correlated with certain demographic characteristics and farm attributes.

KEY WORDS: Extension education, risk management, marketing, evaluation

INTRODUCTION

The changing structure of agriculture continues to move in the direction of fewer, larger, and more capital-intensive farming and ranching operations. These operations tend to be highly leveraged and more specialized in their production mix, leaving them at greater risk of adverse price movements and production shortfalls. As a result, risk management, and price risk management in particular has been a major concern for agricultural producers. A survey of crop producers by Purdue University Cooperative Extension found that the most important source of risk facing producers was crop price variability (Patrick and Alexander 2004). Marketing, business, and record keeping skills were frequently identified as the major areas of education need in a survey of Michigan farmers and agribusinesses (Suvedi et al. 2010). The results of a study by Anderson and Mapp (1996) reinforced the notion that producers want to learn about specific strategies they can implement that will improve profitability. While the number of risk management education programs conducted by state agricultural extension agencies has increased in recent years, there has been concern regarding the wide variety of methods used to teach risk management. Common methods of program delivery have included one-day and half-day workshops, short courses, internet-based programs, marketing clubs, and short publications.

The concern regarding teaching methods was underpinned by a lack of formal assessments of the varying types of risk management educational programs being delivered; making it difficult to determine the effectiveness of teaching methods and program formats. The lack of evaluation results raised significant questions within the Texas AgriLife Extension Service marketing and risk management economist group about program effectiveness, and provided the motivation for an in-depth learning, planning, development, and evaluation effort for a risk management program in Texas. This study intends to fill this gap in the literature by conducting a statistical analysis of the effectiveness of the Master Marketer Program. Using participant survey responses for programs conducted from 1996 through 2004, the results indicate that Master Marketer positively affects farmers' market knowledge, adoption of marketing and risk management practices, and commodity prices received.

The Master Marketer Program. In the early 1990s, there was concern among Texas A&M AgriLife Extension Service economists that, while producers were attending risk management educational workshops, they were not developing a sufficient understanding of risk management tools to actually use them in marketing their commodities. Anecdotal evidence suggested that a number of producers were attending similar workshops every two or three years, but were not gaining enough confidence to utilize the tools. During the fall of 1993, a feasibility committee comprised of producers, agribusiness, and extension specialists began exploring the development of an in-depth risk management effort that eventually became known as Master Marketer. This process led to the following suggestions from the committee: (1) the program needs to be in-depth enough to increase participants' knowledge level; (2) the training needs to include examples and simulation exercises; and (3) use marketing clubs to gain experience and confidence from the initial training and to extend the learning activity to other producers. The committee recommended an intensive 64-hour risk management course that focuses on marketing plan development and implementation, developing enterprise budgets and breakeven costs, and basic and advanced marketing tools including futures and options, basis, financial risks, fundamental and technical analysis, production risk alternatives (crop insurance, diversification and integration), agricultural policy, international trade, value added processes, niche markets, and marketing clubs.

In January 1996, the agricultural economics extension unit of the AgriLife Extension launched the first Master Marketer program, believed to be the most intensive commodity marketing and risk management educational program for agricultural producers offered by extension. The Master Marketer combines three successful educational concepts – intensive educational programming, master volunteers, and marketing clubs into a unique marketing and risk management program. The program consists of 64 hours of intense training during four separate two-day sessions over a six-week time period. After completion of the program, graduates are strongly encouraged to start and lead a marketing club in their home area.

Master Marketer is taught at the intermediate-to-advanced level with a pre-program "leveling" workshop held for those participants in need of an introductory-level course on commodity marketing and risk management to ensure that they are ready for the program. Producers having an expressed interest in marketing and leadership are desired due to the expectation that graduates will serve as volunteers in starting a marketing club. The end result is an expansion in the number of volunteer educators and valuable educational opportunities for producers within a cost-effective framework (Waller et al. 2004). As of 2011, 23 Master Marketer programs have been conducted in Texas.

Expanding Master Marketer to Other States. Results from the program evaluation (described below) for the first six Master Marketer programs held from 1996 to 1999 yielded impressive results and attracted interest in the program from other states. Texas AgriLife Extension partnered with the University of Minnesota Extension and the Montana Grain Growers Association to secure grant funding to expand the Master Marketer program to other parts of the country and to enhance risk management education in Texas. Through this effort, 700 producers were reached through 21 Master Marketer programs conducted from 2000 to 2005: eight in Minnesota, three in Montana, nine in Texas, and one in South Dakota. Additionally, a series of one- or two-day Advanced Topic Series (ATS) short courses on specific risk management topics was developed. The target audience for these abbreviated ATS programs was Master Marketer graduates, but they were available to all producers. In 2000-2005, 81 of these short courses were conducted in Minnesota, Montana, Texas, Nebraska, Wisconsin, North Dakota, and Iowa with more than 2,000 participants.

The objective of this study is to analyze the effects of the Texas Master Marketer program on participants' knowledge of risk management strategies, adoption of risk management practices, and relative commodity prices received. Since this study did not involve a control group, the research focuses on the correlations between the implementation of Master Marketer and the various outcome measures self-reported by participants. Results of this study will provide information on the effectiveness of Master

Marketer in increasing participants' knowledge and commodity prices received. Findings can also be used as a guide in designing future educational activities.

The following sections will begin with a description of the evaluation survey method followed by a discussion of the data and variables. Model development, results, summary, and conclusions close out the paper.

Evaluation Survey Methods. An evaluation survey for Master Marketer was administered approximately two-and-a-half years after the completion of each program. This amount of time allowed graduates at least two crop years to implement any new risk management techniques learned in the program, and followed the retrospective "post-then-pre" design as described by Howard (1980), Rockwell and Kohn (1989), and Moore and Tananis (2009). While a brief description of the survey is provided here, please refer to Qin et al. (2011) to view the full survey instrument**.**

The survey contained six sections focusing on knowledge, adoption of practices, and economic impact. Section 1 of the survey gathered general information about graduates' risk management planning and marketing practices using close-ended, two-option response format (yes/no) questions for two time periods, before and after attending the program. Section 2 dealt with the types of market information and analysis that a Master Marketer graduate might use in developing their personal market outlook. Section 3 was designed to gather information about graduates' abilities to understand and willingness to use specific risk management strategies. The purpose of Section 4 was to gather information about graduates' efforts and experiences with starting and leading a marketing club. Section 5 asked graduates for estimated price impacts as a result of participation in Master Marketer. The price impact questions asked for the difference in the price received using the tools learned in Master Marketer versus the price they likely would have received had they marketed their commodities using the methods they employed before attending the program. A list of price impact ranges for corn, wheat, grain sorghum, cotton, soybeans, cattle, sunflowers, and hogs were provided for graduates to choose from. This was a close-ended question with ordered responses for nine price impact categories. For each commodity, the choices of price impacts included "no change," four ranges of price decreases, and four ranges of price increases. The price ranges were intended to represent the realistic range of possible impacts that could have been experienced by graduates. Section 6, the final section of the survey, asked for demographic and production information.

MATERIALS AND METHODS

This section explains the primary method used in analyzing the data and presents some descriptive and econometric analysis. To facilitate the econometric analysis, both binary and aggregate count index variables were constructed from the survey questions. Probit models were utilized for the binary dependent variables. For the aggregate index/count variables which were constructed by summing the binary variables, Poisson regressions were used.

Data and Variable Definition. The description of the dependent and independent variables used in the analysis are listed in Appendix 1. Included in the list of variables are individual index variables and aggregate index variables. Individual index variables describe whether or not respondents benefited from the program with respect to specific skills or risk management practices adopted. Aggregate index variables describe their pre-to-post change in knowledge and skills.

Section 1 of the survey contained seven close-ended questions in a yes/no format asking graduates about their specific adoption of risk management practices, requesting a response for both pre- and post-participation in Master Marketer. These data were entered as “yes” = 1 and “no” = 0. A binary difference index variable was created for each question by using the “after minus before” method. Therefore, the difference index variables equal 1 for graduates who improved their marketing practices (i.e., from “no” = 0 pre to “yes” = 1 post), and zero otherwise. Some respondents answered “yes” before attending the program and “no” after attending the program. Since these values represented less than 5% of all observations, these were transformed to zero: (1) Letter “d” of the first seven variables represents difference, these are the individual binary index variables created by after the minus before method. (2) For Sections 2 and 3 data, we have prefixes “s2” and “s3” included in the name of the variables. (3) For Sections 2 and 3 data, we have suffix “df” representing difference, and these corresponding variables are all created by the “after minus-before” method.

The five binary difference index variables of Section 1 were summed, yielding an aggregate count index variable. This new aggregate index variable ranges from 0 to 5 since it is the sum of five binary variables taking a value of 0 or 1, indicating the extent to which the respondent changed practices after participating in the program. Higher values indicate more overall adoption but aggregation makes it impossible to determine the specific practices adopted. Also, the same value of the variable for different respondents does not necessarily mean that the respondents adopted identical practices. Obviously, aggregation of these binary variables brings convenience at the cost of mixing different sets of information together.

Similar variable transformation procedures were done for the binary difference index variables from Sections 2 and 3, creating an aggregate binary index variable related to market outlook (three questions) and the use of risk management tools and strategies (seven questions). Sections 2 and 3 included scaled knowledge-related pre-/post questions concerning market outlook and risk management tools. Since these data are count data, the corresponding index variables created by the “after minus before” (a - b) method are also count data.

In summary, Section 1 has individual practice difference (a - b) binary index variables and a constructed aggregate binary index variable. Sections 2 and 3 have individual practice and constructed aggregate binary variables and scaled (count) index variables. Although both aggregate binary and scaled index variables indicate whether or not respondents benefited from the program, scaled index variables generally provide more information than aggregate binary index variables for the purpose of the analysis.

Section 5 contained price impact data for corn, wheat, grain sorghum, cotton, soybeans, sunflowers, cattle, and hogs. Due to a low number of observations for hogs and sunflowers, these commodities were excluded from the individual price and pooled price analysis. Regression analysis was conducted for corn, wheat, grain sorghum, cotton, soybeans, and cattle. Additionally, a new price variable was created by pooling all the individual price impact data together. Since the price impact data varies by commodity in terms of the price impact range and units (bushels, pounds, and hundredweight), a linear transformation was used for each variable so that the price impact changes for all the commodities would fall in a range between -1 and 1. Summary statistics of the dependent variables can be found in Table 1.

Section 6 of the survey concerns farm profile and demographic information: crop and livestock enterprises, vertical integration, average annual gross receipts, age, education, and business structure. These variables were included in the regression analysis as explanatory variables. For a more parsimonious regression specification, education levels were redefined from seven categories to two: one for some college, vocational technical school or less, and the other for bachelor's degree and above. Similarly, the business structure category was reduced from five to four: sole proprietorships, partnerships, corporations, and other (estate and trust). Additionally, farm size data were transformed into three groups based on their typical average annual gross receipts reported in the survey.

Table 1. Summary Statistics for All Major Dependent Variables.

Variable	Obs.	Mean	Std. Dev	Min	Max
tindx1	365	2.16	1.65	0	6
overall1	295	6.42	.82	1	7
s2scaleind	390	9.08	4.76	-2	21
s2bnind	340	1.32	1.04	0	3
s3scaleind	398	20.92	11.01	-2	53
s3bnind	322	3.23	2.09	0	7
price pooled	956	.34	.388	-1	1
prcorn	167	.125	.107	-.3	.3
prwht	227	.098	.137	-.3	.3.
prmilo	180	.155	.167	-4.5	.45
prcott	169	.022	.028	-.076	.076
prsoybn	39	.156	.109	0	.3
prcatt	169	4.63	5.47	-15	15
prsun	2	.15	.212	0	.3

Summary Statistics and Preliminary Analysis. Data for the study were collected through a 2.5-year post survey administered to 681 participants of 16 Master Marketer programs conducted from 1996 to 2004. A total of 431 Master Marketer graduates provided a valid response to the questionnaire. A comparison of farm profile and demographic characteristics of Master Marketer participants to Texas farmers in general shows that Master Marketer attendees are younger and have larger farming operations. The average age of a Master Marketer graduate is 45.1 compared to 58.9 for Texas and 57.1 for the U.S. With 2,422 average crop acres, Master Marketer graduates are in the 95^{th} percentile of farms in Texas. The median gross farm income of Master Marketers was $437,500. The Census of Agriculture indicates that only 4.2 percent of farms in Texas had gross income of $250,000 or higher (USDA-NASS 2009). Profiles of participants by production type and gross income can be found in Table 2 and Table 3. More detailed discussions on the characteristics of Master Marketer participants can be found in Qin et al. (2011).

Table 2. Profile of Master Marketer Participants by Production Type.
Dryland Crops (n = 283*)

Crop	Frequency	Percent	Mean Acres	Median Acres	Min	Max
Corn	51	18.0	707	550	50	3,000
Milo	126	44.5	823	500	10	7,000
Wheat	183	67.8	1,289	700	30	20,000
Cotton	125	44.2	957	600	15	6,500
Soybeans	14	4.9	437	400	100	800
Hay	53	19.4	247	150	10	1,000
Improved Pasture	64	22.6	687	200	20	15,000
Native Pasture**	103	36.4	2,383	1,000	25	20,000
Other Crops	15	5.3	766	500	21	3,000
No. of Farms*	283		1,900	1,150	10	20,000

* The number of farms reporting dryland crops (283) is less than the sum of the frequencies because most farms have more than one dryland crop. The mean acreage for total dryland farms does not include pasture acres. Percent totals (not shown in the table) more than 100% because most farms have more than one crop.

** Two responses representing very large native pasture acres are not included in maximum acres to protect the confidentiality of respondents.

Irrigated Crop Acres (n = 204*)

Crop	Frequency	Percent	Mean Acres	Median Acres	Min	Max
Corn	102	50	843	500	60	4,800
Milo	74	36.8	297	200	20	1,839
Wheat	102	50.5	572	250	30	3,200
Cotton	101	49.5	784	500	30	4,100
Soybeans	14	6.9	363	300	100	814
Hay	35	17.2	231	120	8	1,500
Improved Pasture	11	5.4	256	120	25	800
Native Pasture	6	2.9	1,740	1,100	240	4,600
Other Crops	26	12.7	725	363	60	4,524
No. of Farms*	204		1,378	842	8	9,934

*The number of farms reporting irrigated crops (204) is less than the sum of the frequencies because most farms have more than one irrigated crop. The mean acreage for total irrigated farms does not include pasture acres. Percent totals (not shown in the table) more than 100% because most farms have more than one crop.

Cattle Production (n = 216*)

Crop	Frequency	Percent	Mean Head	Median Head	Min	Max**
Cow-Calf	161	74.5	338	100	4	13,500
Stocker Cattle	122	56.5	1,131	463	14	16,000
Feedlot Cattle	49	22.7	1,879	450	10	50,000
No. of Farms*	216					

*Total number of farms reporting cattle (216) is less than the sum of frequencies due to many farms reporting more than one type of cattle enterprise.
** Two responses representing very large cattle enterprises are not included in the maximum number of head to protect the confidentiality of the respondents

Table 3. Profile of Master Marketer Participants by Typical Gross Income Level (n=378).

Gross Range Income	Frequency			Percent
	Crop	Livestock	Total	
$0-49,000	29	82	11	2.9
$50,000-249,000	115	84	107	28.3
$250,000-499,000	87	30	99	26.2
$500,000-1,749,000	89	34	127	33.6
$1,750,000-3,749,000	16	5	23	6.1
$3,750,000 or higher	3	5	11	2.9
Total	339	240	378	100.0
Mean	$546,801	$398,333	$744,742	
Median	$312,500	$137,500	$437,500	

Another major area of interest is the education levels of respondents. Inclusion of this variable in the regression analysis is used to investigate if farmer's educational background plays a significant role in their perception of knowledge gains from the training program. Based on participant responses, 48% of respondents have bachelor's degree while 21% of respondents have some college education experience. The percentages of only some high school (1%) and/or vocational/technical school graduates (3%) are relatively small. Meanwhile, 11% of the respondents have a high school degree, 6% have some graduate school education experience and another 10% hold advanced or professional degrees. As mentioned above, based on these observations, the respondents were divided into two groups with bachelor degree holders as the cutoff line. Specifically, dummy variable EDU11 takes a value of 1 if the respondent has some college course work or a lower education level, while dummy variable EDU22 equals 1 if the respondent has a bachelor's or more advanced degree. In the regression analysis, only explanatory dummy variable EDU11 is included, leaving EDU22 as base group. The first group accounts for 36% of the whole sample while the second group represents 64% of the respondents.

Regarding the age distribution of respondents, age-squared was included as one of the explanatory variables to identify any nonlinear age effects involved. The model also includes another variable indicating the number of years the participant has been a principal farm operator, "prinopr6." Both variables were included in all models as each variable communicates different information regarding farmers' experience.

As Table 2 shows, the majority of the respondents represent medium-to-large size operations. Survey respondents were divided into three groups according to their annual gross receipts based on the distribution of the data. To further investigate the distribution of the gross receipts data, a new variable named "NEWSALES" is created by first dividing the dollar value of the data by 1000, then taking natural log transformations to mitigate the effects of potential outliers. The mean of NEWSALES is 6.02, with a minimum of 3.2 and a maximum of 8.8. The sample standard deviation is 1.1. Meanwhile, the kernel distribution of NEWSALES approximates a normal distribution. Three dummy variables named NSCALE (1-3) were created according to the frequency of NEWSALES, and the two cut-off points are 5 and 7. NSCALE1 refers to the smallest size group which accounts for 17% of all the farms for which the values of NEWSALES are smaller than 5; NSCALE2 refers to the middle group which accounts for 64% of all the farms for which NEWSALES take value between 5 and 7; while NSCALE3 refers to the largest size which accounts for 19% for which NEWSALES are greater than 7.

In an earlier study of Master Marketer program data, the change in participants perceived knowledge of price and production risk management strategies from before to after participation in the program was found to be positive and statistically significant at the 0.01 confidence level (McCorkle 2005). Additionally, the change in graduates' use (adoption) of price risk management strategies from before to after participation in the program was positive and statistically significant.

A previous study by Qin et al. (2011) found that graduates who managed small and medium-sized farms generally gained more than those with large-sized farms in the areas of risk management practice adoption, development of personal market outlook, and risk management knowledge gained and strategies adopted. More specifically, producers with small-sized farms benefited more than those with medium or large-sized farms in almost every area. This finding is consistent with the estimation results from both Probit and Poisson models introduced in the next section. The remainder of this paper focuses on assessing the extent to which key demographic variables relate to knowledge gained, adoption of practices, and price impact.

Model Development. Three models were developed for the econometric analysis. The first model was a binary response Probit model used for all binary dependent variables analysis (McFadden 1984; Wooldridge 2002; Davidson and MacKinnon 2004). Typically, the interest in binary response models lies in the response probability:

$$p(x) = P(y = 1 | x) = \Phi(x\beta) \tag{1}$$

where, y is the response variable (explained variable), taking a value of 1 or 0, contingent on certain events; x is the vector of explanatory variables and beta is a vector of coefficients that reflect the influence of x on the response probability; and $\Phi(\cdot)$ is the cumulative distribution function of standard normal distribution. Equivalently, equation 2 models the binary difference variables:

$$P(y = 0 | x) = 1 - P(y = 1 | x) = 1 - p(x) \tag{2}$$

In this specific case, y represents the binary difference variables for sections 1-3, indicating whether or not the respondent gained knowledge or changed practices as a result of attending the program, and explanatory variable x includes a set of independent variables previously described, such as age, age squared, education level, and farm size. Equation (1) is referred to as the "index model" because it restricts the way in which the response probability depends on covariate x: $p(x)$ is a function of explanatory variables only through the index function:

$$y^* = x\beta + e, \quad y = 1(y^* > 0) \tag{3}$$

where, y^* is a latent variable; e is a continuously distributed variable independent of x, and the distribution of e is standard normal; β is the vector of parameters associated with the corresponding covariate; and $1(\cdot)$ is the indicator function. Note that β in a discrete response model has no intuitive interpretation; instead, interest is focused on the marginal effect of x_j on the response probability $p(x)$.

For the count variables, a Poisson regression model was employed with the mean function assumed to be exponential (Wooldridge 2002; Greene 2007):

$$\mu(x,\beta) = \exp(x\beta) \tag{4}$$

The density function then takes the form:

$$f(y|x) = \exp(-\mu(x,\beta))(\mu(x,\beta))^y / y! \tag{5}$$

where, $y!$ is y factorial. Since a Poisson distribution imposes a strong restriction (requiring the conditional variance to be equal to the conditional mean), we employed the pseudo likelihood approach wherein the model was estimated without specifying the conditional variance.

For the price data, a linear regression model was constructed as follows:

$$y = x\gamma + \varepsilon, \; E(\varepsilon) = 0, \; \mathrm{var}(\varepsilon) = \sigma^2 \tag{6}$$

where, y is the dependent variable and x is the vector of independent variables; γ is the vector of parameters associated with each covariate x_j; ε is the disturbance term. Estimation results for the Probit models (for binary outcomes on adoption probability), Poisson models (for count outcomes on the overall level of adoption) and linear models (for continuous outcomes on price) are presented in the following section.

RESULTS

Model Estimation for Marketing and Risk Management Behavior. For the individual binary index variables (pre and post yes/no questions related to adoption of practices) created from survey sections 1-3, the Probit model was applied. The Poisson regression models were used for the count variables related to pre and post self-assessments of knowledge gain and also the aggregate index variables (tindx1, overall1, s2scaleind, s2bnind, s3scaleind, and s3bnind). The Poisson model estimation results are presented in Table 4.

Two Probit models on individual indices indicate that graduates with less educational background benefited less from the program than those with more advanced educational background. However, for the aggregate index models as shown in Table 4, educational background of graduates plays no significant role.

With regard to business size, the results indicate that participants with medium-sized farms show larger gains than those with large farms, specifically in areas of risk management knowledge gains, tools, and strategy adoption. The results of the Poisson model (Table 4) indicate that producers with medium-sized farms received greater knowledge gains than those with small-sized farms in terms of tools used to develop market outlook. With respect to risk management knowledge gains, tools, and strategy adoption, the results indicate that producers with medium-sized farms benefit more from the program than small-sized farms. On the other hand, producers with large-sized farms show less gain than producers with small-sized farms in terms of adoption of risk management practice and strategies.

Another observation worth noting is that time (year) dummy variables show statistical significance in most of the models (Table 4, last column). Among the models considered, only two suggest that more recent graduates' perception of gains from the program may be lower than that of those graduates who attended the program in base year 1996, especially in years 2000, 2001, and 2004. For a majority of the models, we see a positive sign associated with many of the time dummies, indicating a positive time trend. For the two aggregate index models (s2scaleind and s3scaleind), joint tests show these time dummies are jointly different from zero at 5% level suggesting that a positive time trend does exist in respondents' perception of benefits from the training program. Graduates of later years were shown to benefit more than those who attended the program in years earlier. This result would suggest that the program's effectiveness has been improved over time either from changes in program structure or from instructors improving their teaching methods.

The economic impact of Master Marketer was measured by participants' change in gross income, which takes into account the price impact, planted acres and yields for crops, and the number of head and pounds produced for livestock enterprises (McCorkle et al. 2009). The mean total farm impact was $33,640 with a standard deviation of $62,055. A one-tailed t-test found each of the commodity impacts and the total farm impact to be statistically significant (greater than zero) at the .01 confidence level.

To assess the effect of the program on prices received by graduates, OLS regression models were applied on both the individual crop price changes and also the pooled price change data with the inclusion of the aggregate index variables from Sections 1-3 into the model to determine the extent to which these factors explain the variation in price impacts. Since there are two sets of aggregate index variables (binary and scaled) for Sections 2 and 3, both of which refer to the same type of information with different measures, different combinations of aggregate index variables were included in the price models to determine which model fit the data best.[1]

Model Estimation for Price Impact. OLS regression was used for all the individual price impact models, while Weighted Least Squares (WLS) regression was adopted for the pooled price data due to existence of repeated observations. As mentioned earlier, the pooled price variable is constructed by pooling all the individual price impact data together; therefore, the observations of each explanatory variable (constructed based on each graduate's survey) would be included in the regression as many times as the number

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[1] In practice, there are some price models where all the aggregate index variables were included as explanatory variables; meanwhile, in other models, only aggregate binary index variables from Sections 2 and 3, and aggregate index variables from section were included. Similarly, there were also models where only the aggregate count index variables from Sections 2 and 3, and the aggregate index variables from section 1 were included.

of crops produced by that graduate's farm. In view of the time series and cross-sectional property of the data, WLS is applied with frequency of repeated observations as the weight for data transformation; at the same time, robust variance-covariance matrix is also used to deal with possible serial correlation and heteroskedasticity.

Table 5 lists all the estimation results of different model specifications for pooled prices. Table 6 contains the adjusted R^2 and joint test results for the models containing time dummy variables. The adjusted R^2 associated with each pooled price model ranges from 7% to 13%, which suggests that a relatively small part of the variation of the dependent variable can be explained by the independent variables.

Table 4. Model Results for All Aggregate Index Variables**.**

Model	Nscale2	Nscale3	prinOpr6	newpartn6	newcorp6	verticl6	Y97-y04	R^2
tindx1 (Poisson)				-0.23			+y97	0.027
overall1 (Poisson)								0.002
s2scaleind (Poisson)	0.179		-0.008	-1.51			+97, +98, +03	0.027
s2bnind (Poisson)							+y00, +y01	0.017
s3scaleind (Poisson)	0.186	-0.001	-0.135		-0.106	0.046	+y97, +y98, +y00, +y01, +y02, +y03, +y04	0.04
s3bnind (Poisson)	0.184	-0.287					+y97, +y00, +y01, +y02	0.003

Note: 1) Only parameter estimates significant at 10% level are reported. 2) Blank spaces mean the corresponding variables are not significant at 10% level. 3) For time dummies, the magnitude of the estimate is not reported except for signs.

As previously noted, Section 1 also contains an overall variable, which asks the respondents for their overall rating of the educational quality of the Master Marketer program. This variable was included as a perceived indicator of program quality in the price impact models. As for the Section 1 aggregate binary index variable (tindx1), the Section 2 aggregate binary index variable (s2bnind), the aggregate count index variable for Section 2 (s2scaleind), the aggregate binary index variable for Section 3 (s3bnind), and the aggregate count index variable for Section 3 (s3scaleind), different combinations of these variables were analyzed in all the models. The reason being that with the exception of the aggregate binary index variable in Section 1(tindx1), Sections 2 and 3 have two sets of aggregate index variables that refer to the same set of information. Therefore, including all the index variables in the model would have caused co-linearity problems. As a result, only one type of index variable should be included in the model estimation, binary or scale.

Time dummy variables also play a significant role in the pooled price models**.** The null hypotheses stating that the coefficients of the time dummy variables are collectively zero and are rejected in all the 5 models. It is evident that there is time trend involved with the price impact data, but no consistent conclusion can be drawn here because the signs of the time dummy variables vary across different models.

In general, all the models that included both the overall and aggregate index variables performed better than the models without these variables. Also, the pooled price models fit the data much better than any individual price model due to the larger sample size. The scaled program rating variable of Section 1 (overall1) and the aggregate scale variables for Sections 2 and 3 all have significantly positive signs at the 10% level, which suggests that improvement in knowledge of personal market outlook and risk management as well as adoption of risk management skills and strategies positively contribute to price impacts perceived by respondents.

Business structure dummy variables yielded some interesting results. The models suggest that producers with operations organized as corporations benefited from the program with regard to almost all commodities. In the pooled price models, all three business types experienced greater price impacts compared with estates and trusts (other). Also, results in Table 5 indicate that producers with small-sized farms benefited more from the program than those with medium-sized and large operations. This may suggest that larger operations were already performing at a more efficient level. The education variable tells a similar story. Graduates with a relatively lower level of education background benefited more from the program compared with those that have a bachelor’s degree or higher.

Age contributes positively to the price impact while age squared enters negatively, again confirming our conjecture that age enters the model in quadratic form. Based on the pooled price model (5), the age at which a graduate benefits the most is 50. The models indicate that older people may benefit more than young people, up to a certain age, but there also exists a maximum point where benefits are reduced as age increases. [2]

The binary vertical integration variable (verticl6) was not statistically significant in many of the major price impact models, except for the price impact models of cattle, where the significant positive sign suggests vertical integration positively affects the price impact for cattle.

The price impact results are intended to be viewed with caution as these results might suggest that the use of marketing and price risk management tools can increase a producer’s net returns. However, we are unable to make such a claim since the data are self-reported.

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[2] This “optimal” age is calculated as -coefficient of age/(2*coefficient of age squared). Based on pooled price model 5 estimates listed in Table 9, the estimated age is 50.

Table 5. OLS Parameter Estimates and Standard Error for the Pooled Price Model.

Model (1 to 5)	overall1	s2 bnind	s2 scaleind	s3 bnind	s3 scaleind	age	Agesq	edu11	Nscale2	Nscale3	newsolep	newcorpt	newpartn
Newpr	N.A.	-0.003 (0.01)	N.A.	0.03* (0.006)	N.A.	0.027* (0.009)	-0.0003* (0.0001)	0.04* (0.023)	-0.06* (0.033)	-0.14* (0.037)	0.19* (0.05)	0.26* (0.05)	0.22* (0.08)
Newpr	0.09* (0.01)	N.A.	0.004 (0.003)	N.A.	0.005* (0.001)	0.03* (0.006)	-0.0003* (0.000)	0.05* (0.02)	-0.011 (0.03)	-0.018 (0.04)	0.23* (0.07)	0.33* (0.07)	0.23* (0.067)
Newpr	0.15* (0.014)	-0.017* (0.01)	N.A.	0.02* (0.005)	N.A.	0.03* (0.008)	-0.0003* (0.0001)	0.042* (0.02)	-0.06* (0.034)	-0.02* (0.04)	0.21* (0.07)	0.28* (0.07)	0.22* (0.07)
Newpr	0.10* (0.013)	N.A.	0.007* (0.003)	N.A.	0.005* (0.001)	0.025* (0.006)	-0.03* (0.0000)	0.045* (0.019)	-0.04 (0.03)	-0.06 (0.04)	0.11 (0.07)	0.22* (0.07)	0.15* (0.07)
Newpr	0.15* (0.014)	-0.02* (0.01)	N.A.	0.022* (0.006)	N.A.	0.03* (0.0089)	-0.0003* (0.0001)	0.04* (0.02)	-0.067* (0.035)	-0.12* (0.04)	0.16* (0.07)	0.24* (0.075)	0.18* (0.074)

Note: 1) Standard error of the parameter estimates is listed in the parenthesis. 2) All the estimates are transformed by multiplying 100. 3) We omitted time dummies, constant term, and three variables (tindx1, Verticl6, and prinOpr6) that are not statistically significant at 10% in any models. 4) * Means significance at 10% level.

Table 6. Adjusted R^2 and Joint Tests for Time Dummies**.**

Models	Adjusted R^2	Joint test result (if all the coefficients of time dummies are jointly different from 0)	Sign of time dummies
Pooled price model 1	0.067	F(8, 1550) = 3.99, Prob > F = 0.0001	-(y98, y00, y01,y03)
Pooled price model 2	0.11	F(8, 2250) = 6.37, Prob > F = 0.0000	-(y97,y98, y01), +(y99,y02)
Pooled price model 3	0.12	F(8, 1631) = 3.26, Prob > F = 0.001	+(y99),-(y01,y03)
Pooled price model 4	0.11	F(8, 2064) = 9.26, Prob > F = 0.0000	-(y97,y98,y01,y03),+(y99)
Pooled price model 5	0.13	F(8, 1540) = 3.83, Prob > F = 0.0002	+(y99),-(y01,y03)

CONCLUSION AND DISCUSSION

The increasing need in Texas for a highly effective marketing and risk management education program was the impetus for the birth of the Master Marketer program which has provided 64 hours of in-depth marketing and risk management education to nearly 1,000 producers since 1996. Given the prior lack of formal assessments of marketing and risk management education programs in Texas and other states, and the increasing need in Texas to demonstrate program performance and impacts for accountability purposes, the Master Marketer Team developed an extensive 2½ year post evaluation survey. Participant responses collected from the survey process over a nine-year period provide the data that was evaluated econometrically in this study, allowing for an in-depth evaluation of this unique marketing and risk management educational program.

This study investigates the effects of the Master Marketer program on participants' knowledge, adoption of risk management practices, and relative price impacts. It also explores the relationship between several demographic variables and changes in knowledge, adoption of price risk management strategies, and price impacts. Our findings indicate that graduates' reported benefits, in terms of marketing practice, price received and income, are related to certain demographic characteristics (e.g., age and education) and farm attributes (e.g., business size and structure). Specifically, we found that:

1. Age contributes to the model in a nonlinear fashion with a concave profile, indicating that older graduates may benefit more from the program up to a certain age. However, there exists a maximum point at which benefits increase at a decreasing rate as age increases. (based on pooled price model 5, the estimated maximum benefit is achieved by participants who are age 50);
2. Compared with medium operations, producers from small-sized operations benefited more from the program while producers from large operations benefited less in terms of knowledge gained, and adoption of risk management and marketing strategies;
3. Regarding adoption of risk management skills and price impacts; graduates with less education benefited more compared with those holding more advanced degrees;
4. Graduates who have been engaged in the business operation longer did not benefit as much compared with those who have less experiences as principal operators;
5. Vertical integration is positively correlated with graduates' adoption of risk management strategies and skills.

In summary, this study demonstrates that the Master Marketer program promotes among its graduates effectual marketing and risk management practices that benefit their farming operations. The analysis results provide useful insight into the various demographic factors and their effects on perceived knowledge, adoption of practices, and relative prices received. This information can be used to further improve the effectiveness and targeting efficiency of the Master Marketer program at a time when funding and program delivery methods in Texas and other states are coming under increased scrutiny. The need for Extension marketing and risk management education programs should continue given the variety of issues being faced by producers, including possible reductions in farm program safety net support, increased costs of production, and increasing price volatility.

This study relied on self-reported program evaluation data from participants of the Master Marketer program collected approximately 2½ years after the completion of each program. Confidence in the validity of the data stems from a response rate (63%) that is above the benchmark (50%) for research conducted with questionnaires (Baruch and Holtom 2008). Information was not available to examine whether responders differed from non-respondents in ways that might diminish the generalizability of the findings to the overall population of Master Marketer graduates. Any inherent weakness in this data should be mitigated to some extent considering the analysis focused on the difference in the pretest and posttest responses, rather than the reported values themselves. Nonetheless, we expect that a more careful evaluation design, such as randomized treatment assignment commonly employed in lab or field experiments, can further improve the assessment.

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Appendix 1. Variable Description.

Dependent Variables	Evaluation Section	Description
dmplan1	1	Do you have a market plan after-before (binary)?
dwmplan1	1	Do you have a written market plan after-before (binary)?
dshare1	1	Do you share your market plan with someone else after-before (binary)?
dcop1	1	Do you determine costs of production for different commodities and use these costs to set price targets after-before (binary)?
dprofit1	1	Do you build profit and/or growth needs into your price target after-before (binary)?
dnlett1	1	Do you use a general marketing advisory newsletter after-before?
dadvisr1	1	Do you employ a market advisor after-before?
tindx1	1	Section 1 index variable regarding market practices constructed by summing over the first 5 (after-before) variables. (range 0-5)
overall1	1	Section 1 overall rating of the program by respondent (range 1-7)
s2q1bidf	2	Section 2 question 1 did you use market fundamentals in developing your personal market outlook? After-before (binary)
s2q2bidf	2	Section 2 question 2 did you use your knowledge of seasonal price analysis in developing your personal market outlook? After-before (binary)
s2q3bidf	2	Section 2 question 3 did you use your knowledge of technical analysis in developing your personal market outlook? After-before (binary)
s2scaleind	2	Personal market knowledge scale data index variable created by summing over all the after-before (1-7 scale questions) scale difference variables (range from -2 to 21)
s2bnind	2	Personal market knowledge binary data index variable (yes/no questions) summing over all the after-before variables (range 0-3)

s3q4bidf	3	Section 3 question 4 did you know when the use of forward cash contracting is appropriate after-before (binary)?
S3q5bidf	3	Section 3 question 5 did you know when the use of your knowledge of basis contracts is appropriate after-before (binary)?
S3q6bidf	3	Section 3 question 6 did you know when the use of your knowledge of minimum price contracts is appropriate after-before (binary)?
S3q7bidf	3	Section 3 question 7 did you know when the use of your knowledge of hedging with futures is appropriate after-before (binary)?
S3q8bidf	3	Section 3 question 8 did you know when the use of your knowledge of hedging with options is appropriate after-before (binary)?
S3q9bidf	3	Section 3 question 9 did you know when the use of your knowledge of production contracts and/or marketing alliances is appropriate after-before (binary)?
S3q10bidf	3	Section 3 question 10 did you know when the use of your knowledge of post-harvesting marketing strategies (sell crop, buy calls; sell crop buy futures; store crop, buy puts; etc) is appropriate after-before (binary)?
s3bnind	3	Section 3 all binary variable index summing over all binary variables (range from 0 to 7)
s3scaleind	3	Section 3 all scale variable index summing over all scale difference variables (range from -2 to 53)
prcorn	5	Price impact for corn (ranges from -0.3 to 0.3)
prwht	5	Price impact for wheat (ranges from -0.3 to 0.3)
Prmilo	5	Price impact for milo (ranges from -0.45 to 0.45)
Prcott	5	Price impact for cotton (ranges from -0.076 to 0.076)
Prsoybn	5	Price impact for soy bean (ranges from 0 to 0.3)
Prcatt	5	Price impact for cattle (ranges from -15 to 15)
Newpr		Price impact pooled (after linear transformation, range from -1 to 1)

Independent Variables		Description
age	6	Age of farmers (range from 24 to 82, continuous)
agesq		Square of age (continuous)
edu11		Education dummy represent high school and other equivalent degrees (binary)
edu22		Education dummy represents bachelor and advanced degrees (binary)
newsolep		Business structure dummy, taking value 1 if farm is of sole proprietorship (binary)
newpartn		Business structure dummy taking value 1 if farm is of partnership (binary)
newcorpt		Business structure dummy taking value 1 if farm is of corporation type (binary)
newothers		Business structure dummy taking value 1 if farm is of estate or trust type (binary)
prinopr6	6	How long have you been a principal farm operator? (in years range from 2 to 61, continuous)
newsales		Total annual sales divided by 1000 and log transformed (range from 3.22 to 8.76, continuous)
Verticl6	6	Vertically integrated or not (binary)
Y96-y04		A set of time dummies spanning from year 1996 to 2004 (binary)
Nscale1		Dummy variable of farm size belongs to small group (account for 16%, binary)
Nscale2		Dummy variable of farm size belongs to medium group (account for 85%, binary)
Nsclae3		Dummy variable of farm size belongs to large group (account for 19%, binary)

Note: (1) Letter “d” of the first 7 variables represents difference, these are the individual binary index variables created by after minus before method. (2) For section 2 and 3 data, we have prefix “s2” and “s3” included in the name of the variables. (3) For section 2 and 3 data, we have suffix “df” representing difference, and these corresponding variables are all created by after-before method. For calculated variables, the program evaluation column is blank.

Sediment Accumulation in Semi-arid Wetlands of the Texas Southern High Plains

Dennis Gitz[*,1]
Richard E. Zartman[2]
Carlos J. Villarreal[3]
Ken Rainwater[4]
Loren M. Smith[5]
Glen Ritchie[2]

[1]USDA-ARS-Wind Erosion and Water Conservation Unit, 3810 4th Street, Lubbock, TX 79415
[2]Department of Plant and Soil Science, Texas Tech University, Lubbock, TX 79409
[3]Former graduate student of the Plant and Soil Science Department, Texas Tech University, Lubbock, TX 79409, currently with the USDA-NRCS, Abilene, TX 79604
[4]Water Resources Center, Texas Tech University, Lubbock, TX 79409
[5]Department of Zoology, Oklahoma State University, Stillwater, OK 74078

ABSTRACT

The purpose of this study was to evaluate the effects of watershed management system on sediment deposition in playa wetlands, depressional geomorphic features that serve as watershed runoff catchment basins which are thought to be focal points for High Plains (Ogallala) aquifer recharge. Three pairs of cropland/grassland playa wetlands in Briscoe, Floyd, and Swisher counties of Texas were selected for the study. Watershed and annulus slopes, tillage index, shape indices, and watershed to wetland area ratio were used to evaluate the effect of watershed management on sediment deposition in playa wetlands. Sediment depth was directly related to watershed land use with more sediment accumulating in playa wetlands with cropped watershed than in grassland watersheds. Tillage index suggests that cropland watershed increased wetland sediment accumulation compared to grassland watersheds. The maximum slope in the annulus surrounding the wetland was positively correlated (0.959) to wetland sediment accumulation. Shape indices suggest that the more "circular" the watershed the less sediment accumulated. Slope of the annulus was significant while shape indices and the ratio of watershed to wetland areas were not significant in predicting wetland sediment accumulation.

Keywords: Watershed Management, Playas, Post-cultural Sediment, Annulus Slope

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[*] Corresponding author: dennis.gitz@ars.usda.gov.

INTRODUCTION

The Southern High Plains (SHP) of Texas was native short-grass prairie when initially fenced for cattle. Ranching, while not dramatically altering the ecosystem, increased the grazing pressure by replacing migrating buffalo herds with cattle. Greater changes began in the 1880s when homesteaders began to occupy the area and broke the sod to plant row crops (Gibson 1932). This large influx of homesteaders dramatically changed the SHP vegetation. By the early 1900s, plows were destroying native sod. While the SHP soils are eolian in origin, plowing exposed the soil surface which was left extremely vulnerable to detachment by the wind and severe erosion. The drought of the early 1930's left little vegetative cover which in turn led to the dust bowl (Weaver et al. 1935; Weaver and Albertson 1936). It follows that the adoption of irrigation in the 1950s (Musick et al. 1990) along with the adoption of other agricultural practices mitigated such wind erosion problems (Stout and Lee 2003) and transformed the SHP into one of the most productive cropland regions in the world. While the U.S. Dust Bowl was associated with soil movement by wind, irrigation from the underlying Ogallala (High Plains) aquifer has increased water-transported sediments due to overland water flow. The regional scale land-use change to intensive row crop production has also altered the SHP ecosystem and increased overland flow of sediments to playa wetlands (Luo et al. 1997, 1999).

Playas are natural ephemeral wetlands embedded within closed-system watersheds that are the repository for runoff from the surrounding upland SHP soils. Freshwater playa wetlands and watersheds in the SHP are relatively circular in nature, giving them a “compactness” (Ebdon 1977) that is not associated with wetlands along a river. Due to a semi-arid climate and high evaporation, playas are dry for much of the year (Haukos and Smith 1994). Freshwater playa wetland topology is frequently thought of as being similar to that of a dinner plate; with a flat shallow basin surrounded by a relatively steeply angled annular region which leads up to a wide gently sloping area. These three correspond to the playa lake bottom, annulus, and the upland watershed or "interplaya region", respectively (Gurdak and Roe 2009). The playa basins generally consist of Randall soils (Fine, smectitic, thermic Ustic Epiaquerts) (https://soilseries.sc.egov.usda.gov/OSD_Docs/R/RANDALL.html) that occur within the basin floor (Zartman et al. 1996).

Watershed characteristics play an important role in determining playa geomorphology because these depressional playa wetlands naturally only receive watershed runoff. For managed playa ecosystems, irrigation or other anthropogenic runoff can also influence playa water budgets. Beasley (1972) and Tsai et al. (2007) noted that watershed slope and shape, infiltration, tillage, and vegetative cover all influence runoff into playa wetlands. Watershed-soil properties affect playa wetland sediment characteristics and sediment transport by wind less in grassland watersheds than in cropland watersheds due to the reduced wind speed caused by to permanent vegetation. The regional watershed surface exhibits increased soil-clay content from the south to north of the SHP, a distance of about 400 km (about 250 miles). Texture zones have been defined and range from the southernmost "coarse soils", those soils having sandy surface layers with sandy or loamy subsoils; through the "medium soils", those having loamy surface layers with mostly loamy subsoils; to the northernmost "fine soils," those with loamy surface layers and with clayey subsoils. (Gustavson et al. 1995; Sabin and Holiday 1995). For purposes of this paper, “sediments” are defined as post-cultural deposits that were caused by land-use practices. Sediment depth and total volume were directly related to land-use and soil texture zone (Luo et al. 1997). In the medium texture zone, cropland playa sedimentation rates averaged 9.7 mm/year while native grassland rates averaged 0.67 mm/year (Luo et al. 1997). The coarser soils had higher sedimentation rates. Hydrological events, such as rainfall or irrigation runoff, erode watershed soils (Luo et al. 1999). Cultivation decreased aggregate stability and increased sediment transport.

Due to the uses and important function of playa wetlands for Ogallala aquifer recharge, it is important to understand sedimentation processes. Sediments may be responsible for “clogging” natural drains through the basin floor, which potentially retards water infiltration into the Ogallala aquifer (Bolen et al. 1989). As deposition increases, wetland surface area increases and results in higher potential evaporation losses and a decreased playa "hydroperiod", time in which one of these ephemeral lakes exhibits ponding. Recent studies, however, have reported that sediment in cropped playas may increase seepage which could also provide a mechanism for hydroperiod shortening (Ganesan 2010; Tsai et al. 2010). Sedimentation is associated with increasing numbers of exotic and xeric plants which leads to altered plant community composition and productivity (Smith et al. 2011). The direct effect of sedimentation of soil texture on plant community composition, or of sediment loading of water on macro invertebrates is difficult to separate from hydroperiod reduction; and so has not been studied. Nevertheless, sedimentation clearly provides mechanisms for hydroperiod shortening and so is a major threat to native playa biota and ecosystem services (Haukos and Smith 1994; Smith et al. 2011).

The objective of this study was to evaluate sediment accumulation within the medium-textured zone for three sets of paired playa wetlands of the SHP. Specific objectives were to evaluate sediment accumulation as influenced by watershed management system (cropland or grassland) using: (1) annular and watershed slopes, (2) tillage index [index of the percent of the watershed under cultivation], (3) shape indices, and (4) watershed to wetland area ratio. Information gained from this study should help understanding how watershed crop management influences sediment accumulation in SHP playa wetlands.

MATERIALS AND METHODS

Playa wetlands were selected for evaluation in Briscoe, Floyd, and Swisher counties in Texas. Two playas were selected in each county, which comprised a total of three playa pairs. Paired playas within a county were chosen to have similar watershed, slope, shape, and infiltration (soil texture), but to have different watershed management (cropland versus grassland). Playa basin watersheds are characterized by a playa floor surrounded by a narrow, sloping ring of soil called the annulus. Playa-basin watersheds were considered to be the remaining area beyond the playa wetland and annulus. Terrain elevation maps were created using digital elevation models (TauDEM extension for ArcGIS [ESRI Inc. Redlands, Ca. Version 9.2]) on a pixel by pixel basis (Tarboton 1997). Watersheds were delineated using contour lines and 3D surface grids along with other surface feature maps, such as slope percent and aspect. Transects were defined which were arranged as evenly spaced spokes of a wheel radiating outward from the playa center. In practice, these were defined by using the digital elevation information, computing eight transects from the outer annulus to the center of the wetland and an additional eight transects from the outer edge of the watershed to the center of the playa. These data comprised 16 outer basin to inner basin to playa wetland basin slope segments.

The three playa wetland and watershed pairs are depicted in Figures 1-3. Wetland extent was delineated using Randall clay mapped at each of the six locations (Soil Survey Staff 2010). All playas evaluated were located in areas having a dominant Olton (Fine, mixed, superactive, thermic Aridic Paleustolls) clay loam watershed soil. The playa wetlands (inner rings) are embedded in watersheds (outer polygons) within the "medium" soil textural zone of the southern high plains described as having "loamy surface layers and mostly loamy subsoils" (Gustavson et al. 1995; Sabin and Holiday 1995). Olton clay loam is characterized as a “medium” (Allen et al. 1972) textured playa watershed soil and is generally characteristic of the soils in this zone, and of these counties in particular.

(a) (b)

Figure 1. Briscoe County, Texas (a) Cropland Playa [inner polygon] and Associated Watershed [outer polygon] and (b) Grassland Playa [inner polygon] and Associated Watershed [outer polygon].

Watershed to playa wetland area ratios were determined using the areas quantified in Table 1. For specific information on playa description and selection, see Villarreal et al. (2012). Briefly, Villarreal et al. (2012) chose three paired playas in the medium-textured soil zone of the SHP having either cropland or grassland dominated watersheds. Aerial photos were used to determine the quantity of tilled and untilled land for the watersheds (NAIP, 2012). Using pixel counts to determine the tilled and untilled watershed areas, the “Tillage Index” was computed using the criteria of Tsai et al. (2007). That tillage index is computed as follows:

$$Tillage\ Index = \frac{\text{Tilled landscape} - \text{Untilled landscape}}{\text{Tilled landscape} + \text{Untilled landscape}} \tag{1}$$

(a) (b)

Figure 2. Floyd County, Texas. (a) Cropland Playa [inner polygon] and Associated Watershed [outer polygon] and (b) Grassland Playa [inner polygon] and Associated Watershed [outer polygon].

(a) (b)

Figure 3. Swisher County, Texas (a) cropland playa [inner polygon] and associated watershed [outer polygon] and (b) grassland playa [inner polygon] and associated watershed [outer polygon].

The tillage index of the three paired playas documented the playa watershed characteristics. Watersheds with a value of one indicate that the watershed was completely tilled whereas watersheds with a value of minus one indicate that none of the watershed was tilled. Data were analyzed using the Pearson correlation method

Within each playa wetland, up to 25 soil core samples were collected (Villarreal et al. 2012). One sample was collected at the center of each playa basin and others were collected at equal intervals proceeding outwards from the center towards the annulus within the sectors defined by the wheel-spoke transects described above. Soil core samples were collected using a 50 mm-diameter hydraulic probe (Concord Environmental, Wall, NJ) with a 39 kg hammer to refusal depth or 2 m, whichever came first. Soil cores were collected in plastic sleeves then capped and analyzed for soil color and texture in the laboratory. Not all planned 25 locations could be sampled due to location or disturbance problems. Sediment depth was derived from the analysis of soil physical and chemical properties following the criteria described by Luo (1994). Briefly, after the soil cores had been taken to the laboratory, soil from along the core was compared to a standard color chart (Melville and Atkinson 1985), clay and sediment layers identified, and the depth of the sediment layer to the underlying Randall clay noted. In most cases, the A horizon of the soil profile satisfied the definition of post-cultural sediments (See Villarreal et al. (2012) for specifics on how surface and sub-surface horizons, soil color, soil structure grade and kind were interpreted.). The sediment volume in each basin was estimated using the 3D Analyst extension in ArcGIS, and the average sediment depth calculated as the sediment volume divided by the estimated playa wetland area.

Table 1. Tilled and untilled areas for the watersheds, tillage index, maximum annulus slope, maximum watershed slope and mean sediment depth (Luo 1994, 1997) for the six U.S. Southern High Plains playa watersheds/wetlands used in this study.

Playa	Tilled, ha	Untilled, ha	Tillage index	Max annulus slope, %	Max outerbasin slope, %	Sediment depth, m
BC	250	56	0.63	5	6	0.12
BG	34	96	-0.48	4	7	0.11
FC	130	11	0.84	3.6	4.9	0.11
FG	38	140	-0.56	3	5	0.09
SC	49	13	0.58	12	4	0.19
SG	33	110	-0.54	3	6	0.12

Where BC indicates Briscoe County cropland, BG indicates Briscoe County grassland, FC indicates Floyd County cropland, FG indicates Floyd County grassland, SC indicates Swisher County cropland, and SG indicates Swisher County grassland. The tillage index was calculated using the formula of Tsai et al. (2007).

Shape is an obvious characteristic of the playa and watershed but is difficult to quantify (Ebdon 1977). Shape indices for playas and watersheds were calculated from georectified images using Adobe Photoshop CS5 (Adobe Systems Inc., San Jose, CA). The parameters measured for each feature were regional areas of playa wetland or playa watershed (A), length of longest axis (L), diameter (D), and radius (R_C) of the smallest circumscribing circle, radius of the largest inscribed circle (R_I), and the radius of a circle with the same area as the feature (R_A), as described by Ebdon (1977). Lengths were converted from pixel numbers to meters based on the map scale. The largest inscribed circle and smallest circumscribing circle were created using an empty circle that was scaled to the feature of interest by visual inspection of the images and converted to m^2, and the area inside each circle was calculated. The radius parameters; R_A, R_C, and R_I were calculated as $\sqrt{A/\pi}$. We used shape indices defined by Ebdon's (1977) methods S_2, S_3, S_4, and S_5 to characterize and compare the playa wetlands and the watersheds as follows:

$$S_2 = 4A/\pi L^2 \text{ where } \pi \text{ is } 3.14, \quad (2)$$

$$S_3 = 4A/\pi D^2, \quad (3)$$

$$S_4 = R_A / R_C \text{ and}, \quad (4)$$

$$S_5 = R_I / R_C. \quad (5)$$

Shape indices S_2, S_3, S_4, and S_5 would have values of one for a circle. Less circular or more irregular shapes are identified by shape index values that become smaller and deviate more from one. The Pearson correlation was used to evaluate the relationship between sediment volume and watershed to wetland ratio.

RESULTS AND DISCUSSION

Watershed management determines runoff and sediment transport to their closed-basin playa wetlands. Beasley (1972) and Tsai et al. (2007) stated that watershed slope and shape, infiltration and tillage/vegetative cover specifically influence watershed runoff and sediment movement into playa wetland basins. These playa watersheds/wetlands were selected to minimize watershed slope and shape and infiltration (soil texture) differences so that tillage/vegetation could be selectively evaluated. While all playas and watersheds had approximately 1% slope, cropland playas had greater sediment depth accumulations than their paired grassland sites (Table 1). There were, however, differences in maximum slopes for the 16 slope transects per playa (Table 1). The maximum slope for the annulus to wetland center was *positively* correlated to sediment depth accumulation (0.959), while the maximum slope for the outer edge of the watershed to wetland center was *negatively* correlated to sediment depth accumulation (-0.541). This suggests that the annular area surround the playa wetland is responsible for sediment accumulation. Steeper slopes tend to be more easily eroded because greater energy is imparted to flowing water over a given distance along the soil surface.

Watershed management can be characterized using a tillage index in which tilled watersheds have positive tillage index values and grassland watersheds have negative values (Table 1). Average tillage index for the cropped watersheds was 0.69 compared to the average tillage index of -0.53 for the grassland watersheds. Cropland watershed tilled indices ranged from 0.58 to 0.84 and indicated that 58-84% of the watersheds were tilled. The grassland watersheds had tillage indices of -0.47 to -0.56 which indicates that 48-56% of the watersheds were untilled. These values indicate that even though the areas immediately surrounding the grassland playa wetlands were in perennial grass vegetation, large areas within the watershed were tilled. The presence of tilled areas within the watersheds reflects the intensive cultivation of the Texas Southern High Plains region; though an effort was made to identify watersheds devoid of row cropping very few could be located. The correlation between tillage index and sediment was 0.45. The low correlation is attributed to the relatively large sediment accumulation in the Swisher County cropland playa. Using regression for sediment as a function of tillage index gives a positive slope as follows:

$$SA = 0.023*TI + 0.12 \quad (r^2 = 0.2) \quad (6)$$

where, SA is average sediment accumulation (meters, Table 1), and TI is tillage index. Therefore, cropping the watersheds increases the amount of sediments that enter the playa wetlands.

The second method used to quantify sediment transport employs shape indices to characterize the watersheds and wetlands (Ebdon 1977). The measured length and diameter of the playa wetlands are presented in Table 2. The computed shape indices are presented in Table 3. Ebdon shape indices were similar between the four indices for each location and watershed/wetland area (Table 3). These minor differences were due to the differing formula in computing the indices. Only the Briscoe County, Texas cropland playa S2 index was 1.0 indicating the most compact, circular shape by Ebdon's terminology. All of the remaining areas (playa wetlands and watersheds) had Ebdon shape indices less than one, indicating more irregular shapes. While the values for S2, S3, S4, and S5 differ in formula to quantify shape indices, average S value for the wetlands was 0.741 compared to 0.574 for the watersheds. These differences indicate that, in general, the playa wetlands were more circular than the surrounding playa watersheds. These indices show that the watersheds were not compact (Figures 1-3) and that most of the watersheds (excepting the Floyd and Swisher County grassland watersheds) were elongated and rectangular in shape. For each watershed or wetland, all of the S values were consistently higher or lower for all shape indices. Shape index (S2) was negatively correlated with sediment accumulation in playa wetlands having a Pearson's correlation coefficient of r = -0.818. This relationship was similar for both the cropland (r = -0.884) and the grassland (r = -0.899) watersheds. Regression analysis for all playas had the following equation:

$$SA = -0.337*S2 + 0.321 \quad (r^2 = 0.67) \tag{7}$$

where, SA is sediment accumulation, meters and SI is shape index S2. The R^2 value was 0.669 with $\alpha = 0.0467$. Recall that the index (S2) used here is a measure of how much the longest axis of a shape deviates from that of a circle of equal area. Since the measurement is unity for a circle and decreases as a shape either becomes more elongated or exhibits a more convoluted edge, this index is also called "roundness" in some image analysis programs such as ImageJ (Schneider et al. 2012). The rounder, or more compact, the playa watershed, the less sediment is transported and subsequently accumulates.

A third factor that influences wetland sediment accumulation was ratio of playa watershed to wetland areas. Large watershed area to wetland area ratio (WWR) might suggest larger quantities of runoff and greater sediment accumulation in wetlands. As a topologically closed watershed reaches the point of runoff during a precipitation event all of the runoff must be directed to the lowest point, in this case a playa basin. A larger watershed will have a proportionally greater amount of runoff directed towards a focus. With larger watersheds considerably greater flow volumes, velocities, and erosion might be observed especially as the runoff is directed nearer to the playa. Vegetation may also interact with WWR so that vegetated areas minimize runoff while row-cropped areas enhance runoff and sediment. There was no statistically significant relationship ($R^2 = 0.15$, $\alpha = 0.43$) between WWR and sediment accumulation (Figure 4). Figure 4 visually indicates that there was more sediment accumulation at low WWR for the cultivated watersheds whereas there was less sediment at low WWR in the grassland watersheds. Correlation between sediment accumulation and WWR was -0.65 for cropped watersheds and 0.69 for grassland watersheds.

Table 2. Measured length parameters for the playa wetlands and their watersheds for six playas in the U.S Southern High Plains.

	County					
	Briscoe		Floyd		Swisher	
	Land use					
Factor	Cropland	Grassland	Cropland	Grassland	Cropland	Grassland
	Playa wetland					
L, m	721	542	448	563	367	357
D, m	805	545	463	569	372	365
Rc, m	402	272	232	285	186	183
RI, m	325	140	167	182	162	113
RA, m	365	196	201	218	171	147
	Playa watershed					
L, m	2570	1810	1730	1860	1390	1820
D, m	2580	1810	1740	1870	1400	1820
Rc, m	1290	906	872	936	700	909
RI, m	727	437	498	676	319	521
RA, m	196	673	662	774	473	686

Where L is the length of the longest axis, D is the diameter of the smallest circumscribing circle, R_C is the radius of the smallest circumscribing circle, R_I is the radius of the largest inscribed circle, and R_A is the radius of a circle with the same area as the feature, as described by Ebdon (1977).

Table 3. Shape indices for the playa wetlands and their watershed for six playas in the U.S Southern High Plains.

	County					
	Briscoe		Floyd		Swisher	
	Land use					
Factor	Cropland	Grassland	Cropland	Grassland	Cropland	Grassland
	Playa wetland					
S2	1.00	0.522	0.803	0.600	0.869	0.774
S3	0.822	0.517	0.751	0.587	0.847	0.645
S4	0.907	0.719	0.866	0.766	0.921	0.802
S5	0.808	0.514	0.721	0.639	0.871	0.619
	Playa watershed					
S2	0.666	0.552	0.590	0.691	0.459	0.570
S3	0.659	0.553	0.577	0.685	0.456	0.570
S4	0.811	0.744	0.759	0.827	0.675	0.755
S5	0.564	0.482	0.571	0.722	0.456	0.573

Where $S_2 = 4A/\pi L^2$, $S_3 = 4A/\pi D^2$, $S_4 = R_A/R_C$ and $S_5 = R_I/R_C$ as defined by Ebdon (1977).

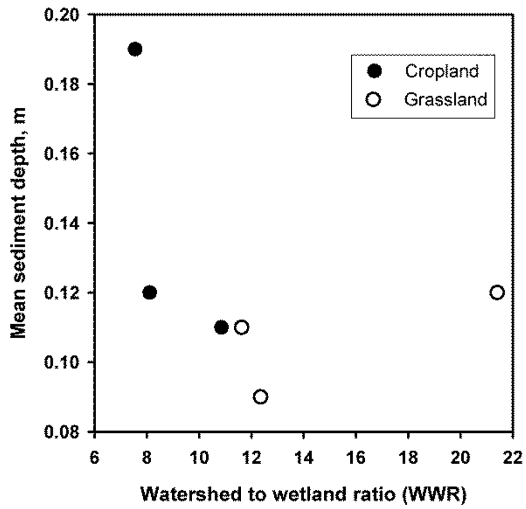

Figure 4. Mean Accumulated Sediment Depth (m) as a Function of Watershed to Wetland Area Ratio for Two Watershed Cropping Systems.

CONCLUSIONS

As shown in other studies, cropped watersheds increase sediment transport to playa wetlands compared to grassland watersheds on the Texas Southern High Plains. This study reconfirms those findings in that sediment accumulated in the cropped wetlands exceeded that for the grassland wetlands for each of the paired playa watershed evaluated. This study indicates that the slope of the annular area surrounding the playa wetland is more important for sediment transport than the slope of the complete watershed. Tillage indices for the watersheds indicated increased wetland sedimentation in tilled as compared to predominately grassland watersheds. Playas embedded in more compact, or "rounder", watersheds exhibited less sediment accumulation in both cropland and grassland. Neither the wetland shape indices nor the watershed-to-wetland ratios were significantly associated with playa sediment accumulation.

The Texas Southern High Plains is an intensively cultivated region. Little grassland remains, and what does remain is under fairly constant grazing pressure, hence it does not exhibit characteristics of what was once "native grassland". It should also be borne in mind that watersheds considered grassland can have a considerable cultivated land component. For such reasons, the increased erosion from row cropped land, and the distribution of row cropped lands within watersheds, better management practices will need to be implemented to lessen sediment movement into the wetlands.

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The Effect of Rose Root Size on Drought Stress Tolerance and Landscape Plant Performance

Derald A. Harp[*1]
Keisha Kay[1]
David C. Zlesak[2]
Steve George[3]

[1]Department of Agricultural Sciences, Texas A&M University – Commerce, Commerce, TX 75429
[2]University of Wisconsin – River Falls, River Falls, WI 54022
[3]Texas A&M University, Department of Horticultural Sciences, Texas AgriLife Extension, Dallas, TX 75252

ABSTRACT

Four rose (*Rosa hybrida*) cultivars, Carefree Beauty™ ('BUCbi', CB), 'Frontenac,' (Fr), Polar Joy™ ('BAIjoy', PJ), and Ramblin' Red™ ('RADramblin', RR), were evaluated for landscape performance and drought stress. Plants were planted in an RCB design, with four blocks, during winter 2007 and irrigated regularly during growing seasons one and two. During years three and four, plants received no supplemental irrigation. In summer 2011, temperatures exceeded 37.7 °C (100 °F) for 65 days and pan evaporation rates exceeded 70 mm·wk^{-1}. Landscape performance was rated monthly on a scale of 0 to 10, with 10 being exceptional. Plants were rated for drought stress using a 0 to 5 scale, with higher values representing increased drought stress. Plant roots were harvested by digging in a circular pattern 60 cm from the plant stem. Individual roots were carefully dug beyond the original radius until the entire length was exposed. CB and PJ had the highest landscape performance ratings, while RR had the highest drought stress scores. Though RR and Fr were similar in height, width, and shoot dry weight, PJ and CB had higher root dry weights. Strong correlations were found between landscape performance and root dry weight and root fibrosity. Drought stress was strongly correlated with root mass.

KEY WORDS: Earth-Kind, shrub roses, *Rosa*

INTRODUCTION

The rose (*Rosa hybrida*) is among, if not the most popular garden plant in the world as well as one of the most important commercial cut flowers. In 2009, roses accounted for over $209 million in wholesale sales (USDA 2009). No other group of ornamental plants provides as wide a range of plant, flowering, and blossom traits. Roses combine the best characteristics of annual bedding plants (vibrant and continued color) and perennials (durability, long-life span, and low year-to-year maintenance), but with a wealth of flower forms, colors, and scents and plant forms and habits that few other plants can provide.

[*] Corresponding author: Derald.Harp@tamuc.edu.

An emerging issue for landscape plants, including roses, in Texas and other regions is limited water availability for landscape irrigation. Drought and above-normal temperatures have forced communities to limit landscape irrigation. In response, homeowners have proven to be mindful of water resource challenges and are prepared to make changes in their landscapes to accommodate limited water supplies (Hurd et al. 2006; Spinti et al. 2004; Israel et al. 1999). In Texas, public support for xeriscape gardens resulted in the passing of Senate Bill 198 in 2013, restricting Home Owners Associations from prohibiting xeriscape landscapes (Hopkins 2013).

Additionally, in some areas, salt levels in irrigation water have increased due to a decrease in available ground water supplies and a reliance on reclaimed water for landscape irrigation (Niu and Rodriguez 2008). Soil salinity negatively affects soil plant available water and plant physiological processes, and may decrease plant growth, development, and performance.

In roses, it is a common practice to graft rose cultivars with desired ornamental characteristics onto an aggressive rootstock known to perform well under particular environmental and edaphic conditions (Pemberton 2003), including its ability to improve performance under drought stress (Niu and Rodriguez 2009). 'Dr. Huey' is an example of a cultivar with an aggressive root system that produces significantly larger root biomass than the rootstocks *R. manetti* and *R. odorata* (Cabrera 2002). The impact on performance was found in a subsequent study where *R. odorata* was found to be poorly tolerant of drought stress (Niu and Rodriguez 2009).

Modern shrub roses are typically grown as own-root cultivars. Own-root cultivars have a longer life expectancy, tend to produce fuller plants, have no rootstock suckers, and no transfer of rose mosaic (Richer et al. 2005). Many of these roses are commonly grown without pesticides and have good heat and drought tolerance (Harp et al. 2009; Mackay et al. 2008). The Earth-Kind® program of Texas A&M AgriLife Extension has identified 23 rose cultivars that thrive with a 70% reduction in landscape irrigation (Harp et al. 2009; TDA 2013). The Earth-Kind cultivars 'Belinda's Dream,' 'Climbing Pinkie,' 'Mrs. Dudley Cross,' 'Reve d'Or,' and 'Sea Foam' were also found to be tolerant of high salinity conditions with little to no reduction in shoot growth, flower number, and leaf color, as determined by SPAD meter (Konica Minolta, Osaka, Japan) readings (Cai et al. 2014)

The mechanism of drought tolerance in roses is considered to be similar to other woody species. Roses can exhibit increased cuticular wax (Jenks et al. 2001) and increased lateral root growth (Davies et al. 1996) in response to water stress. Drought also results in decreased flower number (up to 70% less) and quality (Chimonidou-Pavlidou 2004).

Root traits associated with tolerance of drought stress include small, fine root diameters, long root length, and root density, and an increased root–shoot ratio can compensate for water deficits and increased stomatal conductance (Comas et al. 2013). Therefore, the purpose of this experiment was to determine the association between root architecture and performance of four own-root rose cultivars under severe drought stress conditions.

METHODS AND MATERIALS

During winter of 2007, four planting beds were tilled to a depth of 20 cm, tilling in an additional 8 cm of composted horse bedding, and adding 8 cm of organic mulch to the surface. The mulch was maintained at a minimum depth of 6 cm throughout the experiment. A 1.7 L / hr drip irrigation system was installed with manual controls. Once prepared, 20 own-root rose cultivars (Table 1) were randomly planted into each of the four beds. Experimental design was an RCB with four blocks and each cultivar appearing once per block. During the first two years, plants were irrigated regularly to ensure proper plant establishment. During the third and fourth year, no supplemental irrigation was applied. No fertilizers or pesticides were applied with the exception of periodic use of glyphosate for weed control. Plants also were not pruned, except for the removal of dead or physically damaged branches. Cultivars were rated monthly during the growing season, April through November, for landscape performance and drought tolerance.

Table 1. Twenty rose cultivars evaluated for landscape performance in a minimal-input garden in North Central Texas.

Trademark Name	**Cultivar Name**	**Rose Class**
Alexander Mackenzie	*Rosa* 'Alexander Mackenzie'	Shrub
Sunrise Sunset	*Rosa* 'BAIset'	Shrub
Quadra	*Rosa* 'Quadra'	Kordesii
John Cabot	*Rosa* 'John Cabot'	Kordesii
Morden Blush	*Rosa* 'Morden Blush'	Shrub
Prairie Joy	*Rosa* 'Prairie Joy'	Shrub
George Vancouver	*Rosa* 'George Vancouver'	Shrub
Ole	*Rosa* 'Ole'	Shrub
Sea Foam	*Rosa* 'Sea Foam'	Trailing Rose
Yellow Submarine	*Rosa* 'BAIine'	Shrub
William Baffin	*Rosa* 'William Baffin'	Kordesii
John Davis	*Rosa* 'John Davis'	Kordesii
Polar Joy	*Rosa* 'BAIore'	Tree Form
Bright Eyes	*Rosa* 'RADbrite'	Shrub
Ramblin' Red	*Rosa* 'RADramblin'	Climber
Summer Wind	*Rosa* 'Summer Wind'	Shrub
Lena	*Rosa* 'Lena'	Shrub
Carefree Beauty	*Rosa* 'BUCbi'	Shrub
Frontenac	*Rosa* 'Frontenac'	Shrub
Sven	*Rosa* 'Sven'	Shrub

Landscape performance was on a 0 to 10 scale, based upon the following criteria: 1) flower number and quality; 2) foliage cover and quality; and 3) plant habit and vigor. Scores were assigned as follows: 10 = no deductions in any criteria; 9 = a minor deduction in one criterion; 8 = a minor deduction in two criteria; 7 = a minor deduction in all criteria or a moderate deduction for one; 6 = a moderate deduction for one criterion and a minor deduction for another; 5 = a moderate deduction for one criterion and a minor deduction for two criteria; 4 = moderate deductions for two criteria; 3 = severe deduction for one criteria and a moderate or minor deduction for another; 2 = severe deduction for two criteria; 1 = severe deduction for three criteria; and 0 = dead plant. Drought stress ratings were assigned on a 0 to 5 scale. A score of 0 was no signs of drought stress. Scores above zero were determined by giving one point for each 20% of the foliage exhibiting drought stress symptoms (wilting, color fade, discoloration, and marginal necrosis).

At the termination of the study, four cultivars, two each of the cultivars with the highest (Carefree Beauty™ and Polar Joy™) and lowest landscape scores ('Frontenac' and Ramblin' Red™) were selected for root evaluation. All plants (n = 16) of these four cultivars were carefully removed and physical plant data collected for both roots and shoots. Plants were dug by measuring a 0.6 m radius around the plant and carefully digging by hand. Roots extending beyond this radius were identified and followed to the end. Shoots were removed from the roots by cutting through the crown with a chainsaw. Shoots and roots were measured and dried for 72 hrs at 70 °C.

Landscape performance rating, drought rating, shoot height, shoot width, root width, root depth (deepest point), diameter of crown, average root diameter of largest roots (three largest, 10 cm from crown), percent fibrous roots (fibrosity, visual estimate of percentage of root architecture made up of roots smaller than 2 mm in diameter), and root:shoot ratio (dry and fresh weight) data were compared using Proc ANOVA (SAS 9.3, SAS Institute. Cary, NC). Duncan's Means Separation Test was used to compare means ($P \leq 0.05$). Proc CORR was performed to identify correlations between landscape performance and drought stress scores and physical root characteristics.

RESULTS

Mean high temperature for June, July, August, and September in Commerce is 33 °C (92 °F), 36 °C (96 °F), 37 °C (98 °F), and 33 °C (91 °F), respectively, with fewer than 18 days above 37.7 °C (100 °F) (NWS, 2011). Average precipitation during the same period is 320 mm. During summer 2011, average monthly temperature was 2–3 °C higher throughout the summer, and temperatures exceeded 37.7°C (100 °F) 65 times (Table 2). Precipitation was 72% below normal during the same time period of a normal year. The hot, dry conditions led to pan evaporation rates in excess of 70 mm/wk. By September, over 95% of Texas, including Hunt County, was considered to be in Extreme or Exceptional drought conditions (Svoboda 2011).

Because of the extreme conditions, soil moisture levels dropped to dangerously low levels. As determined gravimetrically and through time domain reflectometry (TDR), soil water content ranged from 0.019 to 0.079 m^3 H_2O/m^3 soil, well below the 0.110 m^3 H_2O/m^3 soil typical of soils in this region at the permanent wilting point. To ensure plant survival, irrigation was applied once in both July and August. On both occasions, soils were wet to field capacity (water content by volume of 0.3 m^3 H_2O/m^3 soil), as determined by TDR.

The cultivars Carefree Beauty™ (CB) and Polar Joy™ (PJ) had the highest landscape performance in 2011, while Frontenac (Fr) and Ramblin' Red™ (RR) had the lowest (Table 3). Throughout summer 2011, only RR routinely had blooms, though all foliage had dropped by July. PJ was routinely penalized due to a high level of suckering. Absent this trait, PJ easily could have had the highest landscape performance rating of all cultivars.

In terms of observable drought ratings, RR was a poor performer with an average rating of 4.75 (Table 3). All RR plants suffered from drought stress, with no score below 4 recorded in any block. PJ and Fr had the fewest observable symptoms. Due to the severity of the drought stress damage, these scores did not improve even after irrigation was applied in July and August.

Table 2. Climatic conditions during summer 2011 for Commerce, TX (Readings were compiled from a Texas A&M University – Commerce weather station).

Month	Mean High Temperature (°C)	Days above 37.7 °C (100 °F)	Total Precipitation (mm)	Pan Evaporation* (mm)
June	35.4	4	22	272
July	38.2	28	19	286
Aug	39.4	27	11	308
Sept	33.2	6	38	231

*Pan evaporation data obtained from U.S. Army Corps of Engineers data for Jim Chapman Lake, approximately 10 miles from the study site.

Table 3. Landscape performance and drought stress ratings for four rose cultivars grown in exceptional drought conditions.

Cultivar	Landscape Performance*	Drought Stress Ratings*
Carefree Beauty™ ('BUCbi')	5.5a	1.5b
Polar Joy™ ('BAIjoy')	4.75ab	0.25a
'Frontenac'	3.5b	0.5a
Ramblin' Red™ ('RADramblin')	1.25c	4.75c

*Scores with different letters in columns indicate significant differences using Duncan's Means Separation Test ($P \leq 0.05$).

Fr was the smallest with an average height of 103.5 cm and width of 44.2 cm (Table 4). In contrast, CB was the widest at 87.9 cm, and PJ was the tallest at 160.8 cm. Carefree Beauty™ had the highest shoot dry weight and CB and PJ had the highest root dry weights, with their root dry weights nearly doubling those of Fr and RR. While CB, PJ, and RR were similar in terms of height, width, and shoot fresh weight, the root dry weight of RR was much lower.

CB had a higher ($P \leq 0.01$) percentage (53.25%) of fibrous roots than PJ (30.3%), RR (27.3%), or Fr (11.0%). The cultivars with the best landscape and drought ratings, PJ and CB, also had greater root mass than Fr (Table 4).

No differences ($P \geq 0.05$) were found between the cultivars in shoot width, shoot height, root diameter, or root depth. Depth was not different among the cultivars, as plant roots extended throughout the bed, but did not penetrate into the subsoil.

Landscape ratings had a strong negative correlation ($r = -0.65$) with drought stress ratings. However, results in this test were not significant ($P \geq 0.05$) and need further study. Landscape ratings were very strongly correlated with fibrosity ($r = 0.76$, $P \leq 0.05$), root fresh weight ($r = 0.88$, $P \leq 0.01$), and root dry weight ($r = 0.89$, $P \leq 0.01$). Drought stress ratings had a very strong negative correlation with root dry weight ($r = -0.70$, $P = 0.05$). A moderate negative correlation ($r = -0.30$) was found between drought stress and root fibrosity; however, this relationship was not significant ($P \geq 0.05$) and needs further exploration.

Table 4. Physical measurements of four rose cultivars grown in exceptional drought conditions.

Rose	Shoot Height (cm)	Shoot Width (cm)	Shoot Dry Weight (kg)	Fibrosity (%)	Root Fresh Weight (kg)	Root Dry Weight (kg)
Carefree Beauty™ ('BUCbi')	119ns	88ns	3.5ns	53.3a	1.9ns	1.3ab
Polar Joy™ ('BAIjoy')	161ns	74ns	2.1ns	30.3b	2.0ns	1.5a
Frontenac	104ns	44ns	0.7ns	11.0b	0.9ns	0.5c
Ramblin' Red™ ('RADramblin')	144ns	65ns	1.6ns	27.3b	0.9ns	0.7bc

*Scores with different letters indicate significant differences using Duncan's Means Separation Test.

CONCLUSION AND DISCUSSION

Rose performance under severe drought stress is an important consideration for Texas and the southwestern U.S. where summer precipitation is routinely less than evapotranspiration. Water available for landscape irrigation is decreasing and homeowners and landscapers need plant materials capable of maintaining their quality under drought conditions.

The rose cultivars with the highest landscape ratings and lowest drought stress ratings, CB and PJ, also had root characteristics that correlated well with plant performance, increased fibrosity, and root biomass. As there were no differences in above-ground shoot length, shoot width, and dry weight, it is likely that the increased below-ground biomass allowed for a longer maintenance of plant quality as drought stress increased.

Since all cultivars used in this study are own-root cultivars, the selection of stronger performing cultivars in dry climates could be indirectly related to identifying cultivars with favorable root characteristics, in addition to shoot and leaf characters, ensuring maximum water availability during times of drought. Plant breeders can also choose to focus their breeding efforts towards developing cultivars with aggressive root systems capable of capitalizing on scarce resources in moisture deficient soils.

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PROCEEDINGS

of the

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Today's Graduates...
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April 2, 2015

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San Marcos, TX

2015 Agricultural Consortium of Texas Research Symposium

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2. **Influence of Mare Performance on Predicting Post-Partum Anestrus.** C.D. Knight, J.L. Leatherwood, M.J. Anderson, S. Brinsko, and T. Blanchard

3. **An Economic Comparison of Shallow Subsurface Drip, Deep Subsurface Drip, and Center Pivot Irrigation Systems in South Georgia for a Repeated Five-Year Crop Rotation.** T.W. Kelch, C.P. Martinez, S.S. Nair, R.B. Sorensen, and F.D. Mills Jr.

4. **Shaping Future Agriculturalists: Does Agricultural Literacy and Demographic Background Influence Student Views about Farm Policy?** K.A. Laqua, S.S. Nair, F.D. Mills, Jr., and K.W. Ferrell

5. **Infectious Disease Prevalence and Age of Feral Cats In a Population Living on the Abilene Christion University Campus.** A. Martinez, A. McCormick, I. Rojas and D. Hembree.

6. **Assessment of Agricultural Mechanics Teachers Who Competed in the State FFA Agricultural Mechanics and Tractor Technician CDE.** J. Pulley, M.J. Anderson, D. Ullrich, and J. Muller

7. **A Hedonic Analysis of Auction Prices for Beef Herd Bulls.** S. Skurja, J. Fraken, S. Cunningham and K. Bacon.

8. **Behavioral Responses of Livestock Exposed to Unmanned Arial Systems.** P. Urso, R. Tipton, M. Beverly, S. Kelley, and J. Wilson.

9. **Teaching Welding: Actual vs. Virtual Reality.** M. Watson, D. Pavelock, D. Ullrich, R. Maninger, and J. Muller.

10. **Anxiety of Welding Lowered Through Virtual Reality**. M. Watson, D. Pavelock, D. Ullrich, R. Maninger, and J. Muller.

ABSTRACTS

1. What's the Point (Worth): A Hedonic Analysis of Whitetail Semen Auction Data.

K. Barnes, J. Franken, D. Ullrich, C. Stewart, and F. Mills, Jr. *Sam Houston State University*.

The cervid or deer production and hunting industry has an economic impact of $318.4 million in Texas and $3 billion in the U.S. The antlers of whitetail bucks are prized trophies for hunters, and for this reason, breeders make great investments to manage the genetic potential for antler growth in their deer herds. Sire selection can account for up to 90% of the genetic changes in managed herds of livestock. Therefore, substantial research investigates the value of certain characteristics of sires using hedonic analysis of auction data for various types of livestock, including race horses, beef cattle bulls and semen of dairy bulls. Similar hedonic analyses are used to investigate the value of attributes of hunting leases and permits. This study investigates the value of certain attributes of whitetail bucks using a hedonic analysis of whitetail buck semen auction data. Publically available data on semen prices, buck antler scores, buck age, and whether or not the buck is typical or non-typical are collected from the Texas Deer Association website. Auction prices range from $120/straw to $12,500/straw of semen with a mean of $2250/straw. Modeling price as a function of the other characteristics in an ordinary least squares regression, indicates that an additional 10 inches antler score increases the value of a straw of semen by about $153 on average, while larger premiums are paid for Texas genetics.

2. Influence of Mare Performance on Predicting Post-Partum Anestrus

C.D. Knight, J.L. Leatherwood, M.J. Anderson - *Sam Houston State University.*
S. Brinsko, and T. Blanchard - *Texas A&M University*.

Seasonal cyclicity and post-partum anestrus in mares have long plagued conception rates at equine breeding facilities. Photoperiod and body condition of mares have shown to impact the ability of a mare to ovulate and result in a successful pregnancy following parturition. Therefore, the objective of this study was to determine if weight and body condition score (BCS) impact the ability of a mare to ovulate following parturition. Mares (n=34; 2-24 years) of similar breeding from the Texas Department of Corrections (Huntsville, TX) with expected foaling dates from January and February were utilized to test the objective; measurements of body weight (BW), calculated by a weight tape, and BCS were obtained weekly. Data were analyzed using the PROC GLM procedure of SAS to compare differences across collection dates and between ovulated and non-ovulated mares. In a comparison of weekly data collection dates of ovulated mares, no statistical difference was detected ($P > 0.10$) in either BCS or BW. This illustrates that a common BW and BCS were shared by all ovulating mares regardless of ovulation date. However, the comparison of ovulated and non-ovulated mares also show no difference ($P > 0.10$) in either BCS or BW. Therefore, it can be concluded that BCS and BW alone is not an efficient way to determine ovulation following post-partum anestrus and other markers would need to be utilized to improve accuracy.

3. An Economic Comparison of Shallow Subsurface Drip, Deep Subsurface Drip, and Center Pivot Irrigation Systems in South Georgia for a Repeated Five-Year Crop Rotation.

T.W. Kelch, C.P. Martinez, S.S. Nair, and F.D. Mills Jr. – *Sam Houston State University*.
R.B. Sorensen - *USDA-ARS National Peanut Research Lab*

Efficient irrigation systems are important for conserving water resources and ensuring profitability. Three irrigation systems on South Georgia farms were compared over a 15-year planning horizon – shallow subsurface drip irrigation (SSDI) placed 2 inches below soil surface, deep subsurface drip irrigation (DSDI) placed 10 inches ± 2 inches below soil surface, and center pivot irrigation (CPI). Over the 15-year period, a 5-year crop rotation of cotton, corn, corn, corn, and peanuts was repeated three times on a 30 acre field, common in South Georgia due to terrain constraints. A comparative investment analysis was conducted. The revenue stream for the 5-year rotation, repeated three times (i.e., 15-year planning horizon), was calculated using a 15, 10, 5-year moving average of cotton, corn and peanut prices collected from USDA-NASS and each commodity's expected yield from historical data and expert opinion. All costs of operations were assumed to be constant except for the irrigation conveyance system, and annual irrigation repairs and maintenance. All revenue and investment costs were discounted at a 3% rate to account for the time value of money. The use of personally held capital was compared to borrowed capital at a 6% and at a 9% interest rate. Results indicated that though returns were slightly lower for SSDI compared to CPI, the present value (PV) of the returns above irrigation system costs was greatest for SSDI regardless of capital expenditure scenario. Therefore, farmers may consider SSDI when updating irrigation systems.

4. **Shaping Future Agriculturalists: Does Agricultural Literacy and Demographic Background Influence Student Views about Farm Policy?**

K.A. Laqua, S.S. Nair, F.D. Mills, Jr., and K.W. Ferrell – *Sam Houston State University*.

US food and agricultural policy can be a sensitive subject among numerous constituencies. Since university agricultural students may eventually become a part of these groups, does the level of agricultural literacy and personal backgrounds influence students' views of agricultural policy? The Food and Fiber System Literacy instrument and the Consumer Preferences for Farm Policy and the USDA Budget survey were administered to students enrolled in Introduction to Professional Leadership Skills (Intro) and in Agriculture and Government Programs (Policy) at Sam Houston State University (SHSU). A two-tailed student's t-test assuming unequal variances compared agricultural literacy between students in the two courses. Results indicated students enrolled in Policy were significantly more agriculturally literate than students enrolled in Intro (p=0.0007). Subsequently, students' level of agricultural literacy and demographic background were regressed on a series of seven Likert-type scale questions related to farm policy. "I prefer less government interference in markets," was the only relationship found to be statistically significant. Students in Intro preferred less government interference compared to students in Policy (p=0.0509). Students possessing greater agricultural literacy, regardless of classification, also preferred less government interference in markets (p=0.0448). Conversely, those students identifying themselves as Democrats rather than Republicans, desired more government interference in markets (p=0.0331). Students identifying themselves as Independents had comparable views to their Republican counterparts. Based on the preliminary findings from the policy questions posed, students' academic experience, level of agricultural literacy, and political affiliation influenced only their view regarding government interference in markets.

5. **Infectious Disease Prevalence and Age of Feral Cats In a Population Living on the Abilene Christion University Campus.**

A. Martinez, A. McCormick, I. Rojas and D. Hembree – *Abilene Christian University*

Feral cats tend to aggregate in locations where there are plenty of living areas and food sources, such as university campuses. Feral cat populations are often considered to be a nuisance or a health concern. The Agricultural and Environmental Sciences Department at Abilene Christian University, in conjunction with the ACU Grounds Crew, implemented a Trap-Neuter-Return (TNR) program in 2013. In 2014, the TNR program was expanded to include health testing. All of the cats in the program were estimated to be less than 5 years old, with the majority being 2 years of age or younger. This finding raises the question of the welfare and lifespan of cats living in feral cat colonies at ACU. We found that there is a very low prevalence of infectious respiratory diseases observed at the time of examination, and conclude that the relatively short lifespans are not due to these infectious conditions. Though the causes of feral cats’ short lifespans are not fully known, we conclude that most deaths on campus are not due to FeLV/FIV due to the low prevalence of those infectious diseases among the feral cat population at Abilene Christian University.

6. Assessment of Agricultural Mechanics Teachers Who Competed in the State FFA Agricultural Mechanics and Tractor Technician CDE.

J. Pulley, M.J. Anderson, D. Ullrich, and J. Muller – *Sam Houston State University*.

There is a constant need for teachers to attend professional development, for them to better themselves and their students. This study looked at high school Agricultural Mechanics teachers to see where their professional development need is. The objective of this data determined what areas Ag Mechanics teachers are lacking, and what areas they need professional development in. This study took the Tractor Tech and Ag Mechanics test from the respective FFA CDE for the years 2006-2013, and broke the questions down into system areas, (engines, hydraulics etc.), with each system having sub-categories (maintenance, repair, and theory). The results reported no significant difference between the systems ($p=0.4928$). There was also no significant difference between the category data as well ($p=0.3033$). The Ag Mechanics data did show a significant difference between categories ($p=0.0005$). There could be several reasons for this outcome, teachers could be teaching the same every year, so the students that are returning aren't getting any better and the new students are brought up to where the returning students are at. Students could be teaching themselves to take up the slack from the teacher, so they are not getting everything that they need. The data shown can be used to plan workshops and other professional development opportunities. They can start with the lowest scoring system area and work up from there, whether they do one a year or multiple ones a year.

7. A Hedonic Analysis of Auction Prices for Beef Herd Bulls.

S. Skurja, and J. Fraken – *Sam Houston State University*.
S. Cunningham and K. Bacon – *Western Illinois University*

Cattle producers today need to take advantage of every opportunity to increase their herd's overall productivity. Herd bulls will influence a calf crop by 50% and can impact the genetics of retained heifers by up to 90% (Wagner et al. 1985). With herd bulls contributing the potential majority of future herd genetics, an in-depth study of prospective herd sire Expected Progeny Differences, or EPDs, and phenotypical traits is essential to successful cattle management. Past studies show EPDs to have limited influences on herd bull price; instead producers rely mainly on phenotypical characteristics when choosing bulls (Turner 2004; Atkinson 2010; Franken 2012; Stephens 2014). However, phenotypical traits alone do not give an accurate indication of a bull's prospective progeny's performance. As information becomes available, such as EPDs, consigners add the statistics to sale catalogs to inform prospective buyers of a bull's performance in comparison to the breed average. EPDs should give producers an advantage when selecting bulls, but the majority of producer's only focus on few EPDs, birthweight and wean-weight or year-weight. Producers should take advantage of new technologies and choose bulls who are not only appealing phenotypically, but also possess EPDs that will positively impact their herd. If producers are more attentive to EPDs, premiums will be given for bulls statistically superior to others. This study takes another look at factors that influence bull prices using new data from an Illinois auction to assess whether previous findings hold true in the current research context or if new trends are apparent.

8. Behavioral Responses of Livestock Exposed to Unmanned Arial Systems

P. Urso, R. Tipton, M. Beverly, S. Kelley, and J. Wilson – *Sam Houston State University*

Unmanned Arial Systems (UAS) are growing in popularity, their benefits in agriculture, specifically production assessments, have recently become more relevant. This study utilized an UAS to determine the flight zone, upon approach and hover, of selected livestock species: cattle, goats, and horses. Test areas were spacious so animals would not feel confined while providing space to flee when threatened. Horses were tested in two independent groups: outdoor round pens and indoor arena. Cattle were split into three groups: cows with calves (CWC), cows without calves (COC), and weaned heifers (WH). Goats were tested as a group in their home pasture. With each group, the UAS hovered, over the animals, 75 feet above ground before descending in 5 feet intervals. Environmental measurements were similar for each flight. Animals were signaled acoustically before seeing the UAS. Flight zones varied by species and group. The COC and WH allowed the system to hover at 15 feet above ground before they casually moved from the UAS. CWC, did not flee the drone, but huddled closer together around their offspring responding in a protective behavior. The goats allowed the UAS to hover at 10 feet before moving. Horses, tested indoors, expressed a startled, frightened behavior at 25 feet. The outdoor tested horses were calm and showed unstartled behaviors consistent with other specie groups. Geldings showed a much more relaxed behavior compared to mares. Understanding these behavioral responses could help producers utilize UAS for herd observations without disturbing animals in their natural environments.

9. Teaching Welding: Actual vs. Virtual Reality

M. Watson. D. Pavelock, D. Ullrich, R. Maninger, and J. Muller – *Sam Houston State University*

Theoretical learning in the classroom has become prevalent in the educational field. Students are being taught how welding works, yet have little hands-on instruction to make classroom learning effective. To help provide hands-on learning opportunities for students, many schools that are not equipped with a laboratory have moved to teaching with Virtual reality (VR). According to Dale's Cone of Learning, less than 50% of what is read or given in lecture is actually retained in the cognitive mind. Subsequently, students retain 70% in the cognitive mind by doing what is being taught. To obtain a higher retention rate VR has been brought into the educational field, by applying a theological viewpoint of welding and hands on manipulation. 29 students were split evenly into groups, some learning to weld in the laboratory and others by VR. Groups were evaluated by an American Welding Society (AWS) 1G test plate the volunteers welded after 5 practice passes. An AWS inspector evaluated the welds to find that no one passed the full D1.1 AWS test procedures, yet eliminating criteria's for root penetration. 60% of the students passed the AWS test weld by learning hands-on whereas only 6.25% passed when learning through VR. VR groups saved $71 dollars in wasted materials, not including consumables. This and other technologies are available and relatively inexpensive, but can only teach the basic manipulations and not actual welding. Much is needed in advancing technology to teach in a higher standard that industry is looking for.

10. Anxiety of Welding Lowered Through Virtual Reality

M. Watson. D. Pavelock, D. Ullrich, R. Maninger, and J. Muller – *Sam Houston State University*

Theoretical learning in the classroom has become prevalent in the educational field. Students are being taught how welding works, yet have little hands-on instruction to make classroom learning effective. To help provide hands-on learning opportunities for students, whom have disabilities or may be a little uncertain of the aspect of welding have moved to teaching with Virtual reality (VR). Anxiety and safety of others is the real reason that we are in a world of pendulum swinging towards VR over real world learning. Anxiety is an unsettling anticipation of a threatening event that has a negative impact on a person. Anxiety and fear are used interchangeably, they have different distinctions to some, yet they both are interpreted as an uncomfortable feeling VR has been brought into the educational field, by applying a theological viewpoint of welding and hands on manipulation. 29 students were split evenly into groups, some learning to weld in the laboratory and others by VR. 4 Surveys were giving to the students evaluating anxiety and confidence levels. The students of the VR groups had a lower levels of anxiety and higher confidence ratings compared to other groups during the learning process. Yet after all welds were completed the hands-on laboratory groups had higher confidence level in the welding aspect. This and other technologies are available and relatively inexpensive, but can only teach the basic manipulations and not actual welding. Yet, is a great start for those students who are worried about the hazards of welding.