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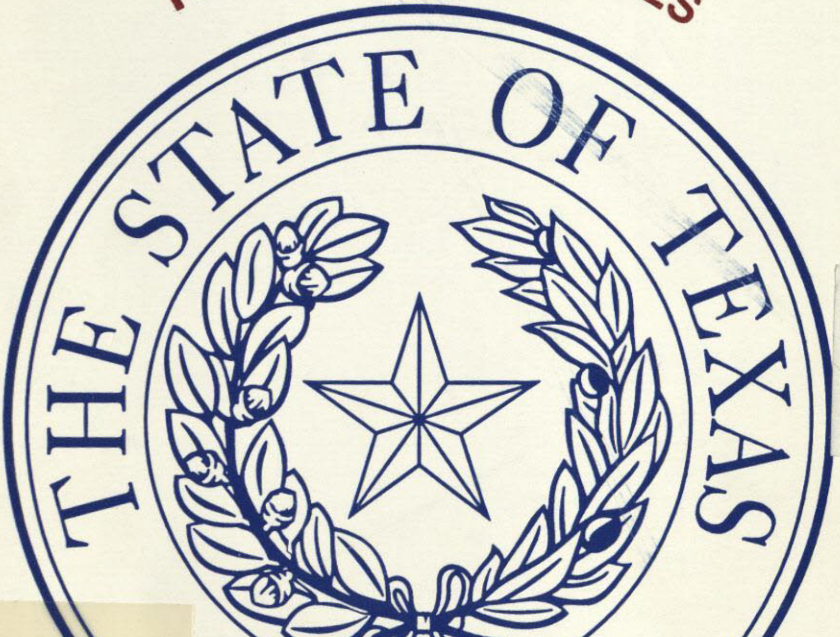

A Publication of the Agriculture Consortium of Texas

TEXAS JOURNAL OF

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EDITOR'S NOTE

After a brief hiatus caused by a shortage of manuscripts and unforseen production problems, the *Texas Journal of Agriculture and Natural Resources* is back in publication. Although Volume 5 is printed in 1994, it contains papers that were accepted for publication in 1992, and is therefore dated 1992. No volume will be dated 1991.

Many acknowledgments are in order. I thank Ron Thomason for establishing the *Journal* from ground zero, serving as editor-in-chief for the first four volumes. Following Volume 4, 1990, Leon Young took over the editorial responsibility. Dr. Young accepted all papers appearing in Volume 5, and turned the editorial position over to Joe Townsend. Dr. Townsend is responsible for the new, less expensive format based on camera-ready manuscripts. The present editor assumed responsibilities in Fall of 1993, thanks to support offered by Texas A&M University-Kingsville.

Volume 6, to be dated 1993, is in preparation. Papers are now sought for subsequent volumes. Annual calls for papers will no longer be issued. Authors are encouraged to submit manuscripts as they are completed, any time of the year. Papers can be submitted through the associate editor at each member institution or directly to the editor-in-chief.

D.T. Gardiner

Foliar Disease Control on Winter Wheat in the Northern Texas Blacklands: I. Fungicide Efficacy

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ABSTRACT

This study evaluated three fungicide treatments on three foliar diseases of winter wheat in the Northern Texas Blacklands. Twenty-five experiments were conducted over a five year period. Data from 11 different experiments are included. Grain yields and leaf ratings are reported. Fungicides were efficacious and profitable in some, but not all, situations on each of the diseases studied.

KEY WORDS: Leaf rust, stripe rust, septoria

Foliar diseases are a major yield limiting factor for winter wheat production on the Northern Texas Blacklands. Some years foliar diseases have been devastating.

The older fungicides could be used as protectants but had no curative activity. These fungicides (i.e. mancozeb) would control several foliar diseases when they were applied prior to the onset of the disease (Fehrmann, 1985; Scheinpflug, 1986). Such prophylactic applications are not practical. In recent years, a whole new group of fungicides has been introduced. They are known as ergosterol biosynthesis inhibitors (EBIs). These fungicides are systemic and have displayed both protectant and curative properties (Berg, 1986; Schwinn, 1983; Siegel, 1981). Their characteristics have greatly altered wheat disease management.

Leaf rust, caused by *Puccinia recondita*, has been the worst foliar disease of wheat in this region. It appears as scattered pustules primarily on the leaf sheaths and the upper surface of the leaf blades.

The uredia are orange-red to dark red, and the telia are dark brown in color (Weise, 1977; Zillinsky, 1983). Leaf rust can be found in this region each year but seems to be economically damaging every second or third year on susceptible varieties.

Stripe rust, caused by *Puccinia striiformis*, is an early season disease that is more severe at lower temperatures than leaf rust. The pustules develop in linear bands on the leaves and spikelets. The uredia are yellow. Stripe rust is a sporadic disease (Weise, 1977; Zillinsky, 1983).

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Two different diseases are caused by fungi of the genus *Septoria* and are difficult to separate with certainty in the field (Weise, 1977; Zillinsky, 1983). Leaf blotch, caused by *Septoria tritici*, occurs early in the season during wet years. It causes necrotic lesions on the leaf blades and leaf sheaths. Later, these areas are peppered with black dots--the pycnidia. Glume blotch, caused by *Septoria nodorum*, is generally associated with high humidity and warmer temperatures later in the growing season (Weise, 1984; Zillinsky, 1983). It is more often a problem east of the Blacklands. The fungus causes lesions on both leaves and glumes. The lesions are said to assume somewhat different shapes, and the pycnidia are less noticeable than with *S. tritici*, but these are only matters of degree.

Powdery mildew, caused by *Erysiphe graminis*, is an early season foliar disease that thrives in cool, wet weather (Weise, 1977; Zillinsky, 1983). The disease is recognized as scattered small white spots which are actually a cottony mass of mycelium on the upper surface of the leaves. It tends to fade away during warm, dry weather. The authors have not been able to measure yield responses associated with powdery mildew control because the tests were always confounded with other diseases later in the growing season.

The purpose of this research was to evaluate the efficacy of foliar applied fungicides on winter wheat in the Northern Texas Blacklands. This was a promising but unproven management technique.

MATERIALS AND METHODS

Foliar disease control experiments were superimposed on local, commercial wheat fields in a three county area. Fields were selected based on the susceptibility of the variety, uniformity of stand and yield potential. Both hard red winter wheat (HRWW) and soft red winter wheat (SRWW) varieties were included. Three fungicide application programs were used in a number of experiments on several fields. The fungicides used were: Bayleton® (Mobay Corp.), Folicur® (Mobay Corp.), mancozeb (DuPont & Co. and Rohm & Haas Company), and Tilt® (Ciba-Geigy Corp.).

Mancozeb is a protectant type of fungicide while Bayleton, Folicur, and Tilt are EBIs. Mancozeb was originally labeled in 1968, Bayleton in 1984, and Tilt in 1989. The Folicur formulation was changed in 1989. Prior to 1989 a 1.2 emulsifiable concentrate (E.C.) formulation was used. Since then, Folicur has been available as a 3.6 flowable (FL). Registration is anticipated in 1992.

The treatments used in the experiments and reported in this paper were 1) Bayleton (50 WP) at 2 ounces + mancozeb (80 WP) at 2 pounds/ acre 2) Tilt (3.6 E.C.) at 4 oz. per acre and 3) Folicur at a rate equivalent to (3.6 FL) at 6 oz. per acre.

All applications were made with a CO_2 powered backpack sprayer (R & D Sprayers, Opelousas, LA.), using a three nozzle boom and tapered flat fan spray tips. There was some variation between calibrations but the materials were generally applied in 20 gallons of water per acre at 15 pounds pressure per square inch. An electronic metronome was used to help standardize walking speeds.

The experiments were all established using a randomized complete block design and four replications. The individual plots were 8 feet wide, with a 5 foot spray pattern, and 20 feet long.

Visual disease assessment ratings were made by either two or three individuals, and a final rating was established by consensus. The rating system used for leaf rust, stripe rust and *Septoria sp*. is an approximation of the percentage of necrotic leaf surface area.

The plots were harvested with a 24 inch Suzue grain binder. The bundles were threshed with a large Vogel stationary thresher. Grain yields were recorded and final weights adjusted to 12% moisture. Moisture content was determined using a Burrow's Digital Moisture Computer Model 700.

Growth stages (GS) were determined using the Feekes Scale (Large, 1954) in which GS 9 designates a completely expanded flag leaf, and GS 10 designates the boot stage.

RESULTS AND DISCUSSION

Leaf rust can be effectively controlled with foliar fungicides as shown in Tables 1, 2, and 3.

Table 1. Mean flag leaf ratings for leaf rust on eight experiments. Fungicides applied at Feekes GS 9, 1986-89.

	Experiment								
Treatment	1	2	3	4	5	6	7	8	Mean
Untreated Check	100	93	59	70	70	59	48	70	71
Tilt	70	48	20	18	17	15	3	18	26
2 + 2*	36	55	12	18	15	12	2	15	21
Folicur	18	48	0	0	0	0	0	3	9
PR > F	.0001	.0841	.0006	.0001	.0001	.0003	.0012	.0001	

*Bayleton + mancozeb

Table 1 shows the average flag leaf rating for four replications on eight different experiments over a period of several years. It is apparent that all of the fungicide treatments reduced the number of pustules on the upper surface of the flag leaves. In every experiment, except #2, the differences were highly significant. Experiments 1 and 2 were exposed to extremely high rust pressure.

Tables 2 & 3 show the relationship between the fungicide treatment, leaf ratings and yields on two of the experiments summarized in Table 1. Both 'Mustang' HRWW and 'Vona' HRWW are susceptible to leaf rust.

Comparing leaf ratings in Table 2, both the Bayleton + mancozeb treatment and Folicur were superior to the Tilt treatment. All three fungicide treatments were significantly better than the check. The yields reflect the same differences, however, there does not appear to be a very close correlation between disease rating and yield.

Leaf ratings in Table 3 were not significantly different. However, yields showed highly significant differences. According to the Duncan's Multiple Range Test, Folicur provided the greatest yields while yields from both Bayleton + mancozeb and Tilt were greater than the check, but not significantly different from each other.

Table 2. Efficacy of selected foliar fungicides on leaf rust. Fungicides applied at Feekes GS 9, Mustang HRWW, 1986.

Fungicide	Mean Flag Leaf Rating on 3May8	Mean Yield (Bu/A)
Bayleton + mancozeb	36 a*	61.0 a
Folicur	18 a	60.9 a
Tilt	70 b	56.4 b
Untreated check	100 c	43.4 c
PR > F	.0001	.0001
C.V.		4.1
R-SQUARE		.950

* Means flanked by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

Table 3. Efficacy of selected foliar fungicides on leaf rust. Fungicide applied at Feekes GS 9, Vona HRWW, 1986.

Fungicide	Mean Flag Leaf Rating on 3May86	Mean Yield (Bu/A)
Folicur	48	55.6 a*
Bayleton + mancozeb	55	49.4 b
Tilt	48	46.2 b
Untreated check	93	36.7 c
PR > F	.0841	.0001
C.V.		6.4
R-SQUARE		.904

* Means flanked by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

Table 4 shows similar trends when stripe rust is the pathogen. Stripe rust is an early season disease that only occurs sporadically in this area. Applications were made at Feekes GS 7 (2 internodes expanded), due to its earlier appearance. There is not much stripe rust data available because many experiments are confounded with a later infection by leaf rust.

The data in Table 5 were obtained from two experiments where *Septoria sp*. were damaging. According to our ratings all of the fungicide treatments reduced *Septoria sp*. infection significantly compared to the untreated check.

Table 4. Efficacy of foliar fungicides on stripe rust. Fungicides applied at Feekes GS 7, Coker 747 SRWW, 1987.

Fungicide	Mean Flag Leaf Rating on 27 Apr	Yield (Bu/A)
Folicur	4	47.8 a*
Bayleton + mancozeb	2	45.4 ab
Tilt	2	43.8 abc
Untreated check	14	38.6 c
PR > F	.2587	.0057
C.V.		8.1
R-SQUARE		.635

* Means flanked by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

Table 5. Mean flag leaf ratings for *Septoria sp.* control with three programs. Fungicides applied at Feekes GS 9, HRWW, 1986.

	Location		
Fungicide Program	1	2	MEAN
Untreated check	81 a*	100 a	91
Bayleton + mancozeb	31 b	35 b	33
Tilt	16 b	24 b	20
Folicur	2 b	1 b	2
PR > F	.0160	.0014	

*Means flanked by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

Table 6 shows the efficacy of the fungicide treatments on *Septoria nodorum*. The fungicides were applied at GS 10.5--the stage at which the spike has been completely exerted from the boot. Based on the data from this experiment, both Tilt and Folicur appear to be more active against the organism than the Bayleton + mancozeb treatment.

In this region a fungicide application generally costs about $14 per acre. Folicur is not currently labeled and is unavailable for commercial use.

The highest yield was selected for these calculations without reference to a specific treatment or its current label status. These calculations show conclusively that with productive wheat and disease pressure, a fungicide application can be profitable at almost any wheat price.

Table 6. Efficacy of selected foliar fungicides on *Septoria nodorum.* Fungicides applied at Feekes GS 10.5, Florida 302 SRWW, 1990.

Fungicide Program	Mean Flag Leaf Rating 1 May	 8 May	Mean Yield (Bu/A)
Folicur	7 a*	50 a	47.4 a
Tilt	7 a	44 a	44.0 ab
Bayleton + mancozeb	19 b	88 b	39.4 bc
Untreated check	70 c	100 b	35.7 c
PR > F	.0001	.0009	.0282

* Means flanked by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

Table 7. Estimated returns from a fungicide application at GS 9.

	Table				
	2	3	4	6	
Best Treatment	61.0	55.6	47.8	47.4	bu/A
Check	43.4	36.7	38.6	35.7	bu/A
Difference	17.6	18.9	9.2	11.7	yield increase
Cost	14.00	14.00	14.00	14.00	fungicide +appl.
Returns/Ac	$21.20	$23.80	$4.40	$9.40	@ $2/bushel
	$38.80	$42.70	$13.60	$21.10	@ $3/bushel
	$56.40	$61.60	$22.80	$32.80	@ $4/bushel

CONCLUSIONS

Fungicides are a valuable management tool on winter wheat in northeast Texas. Disease pressure is a reflection of the susceptibility of the cultivar and the presence of inoculum. Given reasonable yield potential and disease pressure a fungicide application should prove profitable.

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Foliar Disease Control on Winter Wheat in the Northern Texas Blacklands: II. Fungicide Timing

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ABSTRACT

Several foliar fungicides were applied to control both leaf rust (*Puccinia recondita*) and Septoria leaf blotch (*Septoria tritici*) on winter wheat. The later applications provided the most effective control. An application at Feeke's growth stage 9 or 10 was most beneficial.

KEY WORDS: Leaf rust, leaf blotch

The proper timing of fungicide applications is an important component of any intensive management program. Not only is timing of fungicides important for pathogen control, but it is also critical for minimizing costs. If a field is sprayed too early, and the pathogen is polycyclic (able to reproduce more than once within a cropping season), the pathogen would have a chance to reinfect the crop before it matures. The rust disease is an example of a polycyclic pathogen. Therefore, yield loss is still possible after a fungicide application if the disease reappears during the growing season. A second application of a foliar fungicide may sometimes be required to protect the crop, but that has not been shown to be economically sound. Another problematic situation can also occur if the fungicide is applied too late. After the pathogen has established itself within the plant system, the damage may have already occurred, and may be irreversible. In this situation, no fungicide can really help the crop.

The type of fungicide is also a consideration with regard to the timing of application. A protectant fungicide must be applied about five days prior to infection. The systemic fungicides have some currative properties so timing is probably less critical.

An experiment conducted in 1985 demonstrated the potential efficacy of foliar fungicides for disease suppression and wheat grain yield increase in the Northern Blacklands of Texas (Table 1). These materials were chosen because of their activity on pathogens prevalent in the region. Yields were increased by 21.5 bushels per acre from fungicides applied at Feekes growth stage 10.2. That study prompted

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the present work concerning the timing of foliar fungicide applications. Current recommendations by some of the manufacturers suggest applications of fungicides at growth stage 8 (see Tilt label). Some reports indicate that responses due to foliar fungicides were better when fungicides were applied early or at GS 7 or 8, (Roth, 1987; Brown, 1983; Jenkins & Lescar, 1980), whereas others report higher yield responses when fungicides were applied at GS 9 and 10. (Dannenberg, et al., 1989; Conner & Kuzyk, 1988; Willis, 1984; Bissonnette et al., 1969) Rowell (1968) concluded that the progress of the epidemic in the field at the time of the application and the type of chemical to be used were the major concerns. Bissonnett (1969) reported that the most effective time of application for a protectant fungicide was when the head was emerging from the boot (GS 10.1). He also advocated a second application ten days later.

Cook (1980) found the largest positive responses to fungicides occurred when they were sprayed at "flag leaf emergence" (GS 8) and the "in-boot" (GS 10) stage. Jenkins and Lescar (1980) reported that disease control was best when the fungicides were applied after flag leaf emergence.

Brown (1983) reported that the U.K. Agricultural Development and Advisory Service recommended that a spray program be initiated before the pathogen covered 5% of the flag and/or F-1 leaves, regardless of the growth stage.

The purpose of these experiments was to attempt to determine the optimum timing of foliar fungicides in this region. Both protectant and systemic fungicides were included.

Table 1. Efficacy of selected fungicides on leaf rust, Chisholm HRWW, 1985, Feekes GS 10.2.

Fungicide program	Yield (Bu/A)
Folicur	60.7 a
Bayleton + mancozeb	57.7 ab
Tilt	52.9 b
Untreated check	40.6 c
PR > F	.0001
C.V.	6.9
R-Square	.893

MATERIALS AND METHODS

In Schuster et al. (1992) the specific research techniques were discussed in some detail. All of the experiments were randomized complete block designs with four replications. The experiments were initiated on standing wheat. The sites were selected for variety, uniformity, and yield potential. The fungicides were applied with a CO_2 powered backpack sprayer.

The fungicide treatments in the experiments reported in this paper are as follows: 1) Bayleton 50(WP) at 2 ounces + mancozeb (80WP) at 2 pounds/acre, 2) Tilt (3.6

E.C.) at 4 oz. per acre, and 3) Folicur (3.6 FL) at 6 oz. per acre. The fungicides are expressed as weight of formulated material per acre.

The plots were 20 feet long and sprayed on 8 foot centers. They were harvested with a Suzue grain binder and a large Vogel plot thresher.

RESULTS AND DISCUSSION

Some growing seasons lend themselves to fungicide trials more than others since a combination of disease pressure and wheat with yield potential is required. A susceptible variety is also required. The year 1986 was such a year. In more recent years we have experienced conditions for effective fungicide tests only in isolated situations.

Feekes growth stage 10.2 is when the majority of the spikes are 50% exerted from the boot. (Table 1). While that was late in the growing season and the rust infection was quite advanced at the time of application, the yield increases still ranged from 12 to 20 bushels per acre. Folicur was significantly better than Tilt and all of the fungicide treatments were significantly different from the check.

The data from a Folicur timing experiment on Vona hard red winter wheat are reported in Table 2.

Table 2. Efficacy of foliar on leaf rust at 4 different timings on Vona HRWW, 1986.

Timing	Mean Flag Leaf Rating on 3 May 86	Mean Yield (Bu/A)
Feekes GS 10	0 a	57.4 a
Feekes GS 9	48 b	55.6 a
Feekes GS 8	59 b	48.1 b
Feekes GS 7	59 b	42.3 c
Untreated check	93 c	36.7 d
PR > F	.0003	.0001
C.V.		6.2
R-Square		.924

There were highly significant differences in both leaf ratings and yields. The rating system was described in Schuster et al. (1992). Folicur appeared to provide complete control soon after treatment but the effect diminished through time.

Yields from plots treated with Folicur at GS 9 & GS 10 were not significantly different from each other but they were significantly greater than both the earlier applications and the check.

The leaf ratings for seven different experiments with fungicides on leaf rust are summarized in Table 3.

Table 3. Mean leaf ratings for seven experiments on leaf rust with 3 fungicides sprayed at 4 growth stages, 1986.

Timing	Tilt		Folicur			Bayleton + mancozeb		Mean
	1	2	3	4	5	6	7	All locations
Feekes GS 10	25 a	3 a	0 a	0 a	0 a	0 a	2 a	4
Feekes GS 9	70 b	18 ab	48 b	0 a	0 a	2 b	12 a	21
Feekes GS 8	93 c	23 b	59 b	1 a	6 a	3 b	18 ab	29
Feekes GS 7	93 c	55 c	59 b	17 b	25 b	3 b	36 b	41
Untreated check	100 c	70 c	93 c	70 c	59 c	3 b	59 c	65
PR > F	.0001	.0001	.0003	.0001	.0001	.0001	.0006	

Some of the yields were confounded by a late season infection of Barley yellow dwarf virus so only the leaf ratings have been reported.

The responses were somewhat different between experiments but the overall trends were quite consistent. In general, the later treatments showed fewer rust pustules and better disease control at the time of rating.

The experiment reported in Table 4 was conducted in 1991. The fungicides were applied at flowering (GS 10.5.1).

Table 4. Efficacy of selected fungicides on leaf rust, McNair 1003, SRWW, Feekes GS 10.5.1 (flowering).

Fungicide program	Flag leaf rating on 14 May 1991	Yield (Bu/A)
Folicur	0 a	68.9 a
Tilt	70 b	62.7 a
Bayleton + mancozeb	59 b	59.2 ab
Untreated check	100 c	51.5 b
PR > F	.0001	.0195
C.V.	23.4	10.2
R-SQUARE	.933	.701

The fungicide treatments were not significantly different from each other. However, both Folicur and Tilt were significantly better than the check. This experiment supports the earlier studies that have shown that the applications at later growth stages tend to provide better rust control than the same treatments applied at a less mature stage.

Several other experiments were conducted which are not reported here. Most of these experiments failed to show differences because of insufficient disease pressure. However, in none of these experiments were the earlier timings superior to the later applications.

Two experiments in 1986 had Septoria leaf blight (*Septoria tritici*) (Table 5).

Table 5. Mean flag leaf ratings for 2 experiments *Septoria tritici* with 2 materials at 4 different timings in HRWW, 1986.

Timing	Folicur	Tilt	Mean
Feekes GS 10	0 a	10 a	5
Feekes GS 9	2 ab	24 a	13
Feekes GS 8	34 b	51 ab	43
Feekes GS 7	30 ab	81 bc	56
Untreated check	81 c	100 c	91
PR > F	.0006	.0026	
C.V.	68.4	51.2	
R-Square	.801	.727	

The control of Septoria leaf blight appears to follow a similar trend to that of leaf rust. The later treatments are superior to the earlier ones but the differences were not always significant. This is somewhat unexpected because Septoria leaf blight normally occurs earlier in the growing season than leaf rust. If the earlier applications were to provide better protection, it would seem more likely on Septoria leaf blight than on leaf rust.

CONCLUSIONS

The development of the ergosterol biosynthesis inhibitor types of fungicides dramatically changed the entire stategy of foliar disease control on winter wheat. Their curative properties allow the grower to wait until after the onset of the disease to make a fungicide application. The older protectant fungicides had to be applied some time before the spore shower occurred.

The experiments that made up this study were intended to examine fungicide efficacy and to detect the optimum timing of application for maximum yields. Almost without exception the late applications were superior. Growth stages 9 and 10 proved to be the best stages to apply a foliar fungicide.

Unfortunately, only one of these treatments can currently be used legally at Feekes GS 9 or 10. The Bayleton + mancozeb combination is labeled for use at this stage while Folicur is not yet labeled and Tilt cannot legally be used after GS 8 according to the label.

It appears that wheat growers will not be able to realize the maximum economic benefit unless the fungicide labels are expanded to include the later application timings.

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Cross Hedging Cattle Rations Using Corn Futures

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ABSTRACT

The feasibility of cross hedging cattle ration costs using corn futures was investigated. Simulation results for 1985-89 showed that unpredictable variations in ration costs could be reduced up to 54% with cross hedging. The greatest reduction in hedging risk was achieved for longer hedging horizons.

KEY WORDS: Cross hedge, cattle ration, corn futures, fed cattle.

Cattle feeding is an extremely competitive and risky business. Substantial investments in a feeder animal and feed and uncertain returns from feeding increase the possibility of losses (i.e., risk). The average return above all costs from cattle feeding is estimated to be less than $11 per head, while the standard deviation of return is $37 per head (Trapp and Ward, 1990; Trapp and Webb, 1986). Potentially small and highly variable returns make risk management especially important to the economic viability of a cattle feeder.

Cattle feeders can use futures markets to remove some of the price uncertainty in feeding cattle. When a 600-800 pound feeder animal is placed on feed, a live cattle futures contract (which reflects the price of a 1,100 pound finished steer) can be sold to "fix" the price of the finished animal. Corn (or milo), the principal ingredient in a cattle ration, can be cross hedged using corn futures to protect the cattle feeder from variable ration costs. The effectiveness of a cross hedge depends on the degree of correlation between ration costs and corn futures prices (Anderson and Danthine, 1981).

This research investigates the feasibility of using corn futures to fix cattle ration costs. A feedlot manager can attract feeding customers by offering them a set ration cost for the feeding period. The cash forward sale of rations to feeding customers can be cross hedged by purchasing corn futures. It is important to an individual cattle feeder to fix the ration cost, as well as the finished price of cattle, to reduce or minimize return variance. Reducing risk should lower the return required to maintain resources in the cattle feeding industry.

The objective of this research was to determine how effectively corn futures could be used as a cross hedge for cattle rations. The second section of the paper describes a commonly used method to evaluate hedging effectiveness. The third section reports the results from a simulated experiment of cross hedging ration costs in corn futures. The final section provides a summary and the conclusions.

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CROSS HEDGING MECHANICS

A cross hedge is a futures position opposite an existing or anticipated cash position, but in a different commodity (Anderson and Danthine, 1981). For example, corn futures can be used to cross hedge a cattle ration. Because the cost of corn (or milo) is approximately 80% of the value of a cattle ration, changes in corn prices account for a large portion of changes in ration costs.

How effectively corn futures can be used as a cross hedge for ration costs depends on the correlation between ration costs and corn futures prices. The average correlation coefficient between ration costs and corn futures prices is $r=0.88$.[1] Researchers have concluded that corn futures are an effective cross hedge for hay (Blake and Catlett, 1984), wheat millfeeds (Miller, 1985), and rice bran (Elam et al., 1986). Correlation coefficients are reported for hay and corn futures prices ($r=0.93$), and for rice bran and corn futures prices ($r=0.73$). Based on the results for hay and rice bran, a correlation as high as $r=0.88$ for ration costs and corn futures prices indicates that corn futures should be an effective cross hedge for cattle rations.

To use corn futures as a cross hedge, one must first estimate the number of bushels of corn futures required to cross hedge a ton of ration. This can be accomplished by regressing the ration cost on the corn futures price:

$$R_t = b_0 + b_1 CF_t^T \tag{1}$$

where R_t equals the predicted ration cost in time t in dollars per ton; CF_t^T equals the corn futures price in dollars per bushel at time t for the corn futures contract that matures at time T, where T is the contract maturity date nearest to, but not before, time t ($T \geq t$); and b_0 and b_1 are estimated intercept and slope coefficients, respectively. The slope coefficient in Eq. (1)--called the hedge ratio--provides an estimate of the number of bushels of corn futures required to hedge one ton of ration. (Note that b_1 also indicates the change in R in dollars per ton associated with a \$0.01 per bushel change in CF.) For example, if $b_1=24.2$, then 24.2 bushels of corn futures are required to cross hedge a ton of ration. Corn futures are traded in contracts of 1,000 bushels at the Mid-America Exchange and 5,000 bushels at the Chicago Board of Trade. If the hedge ratio is 24.2, then the 1,000 bushel Mid-America contract can be used to cross hedge 41 tons (1,000/24.2) of ration.

A cattle feeder who desires to fix ration costs can accomplish this by buying 24.2 bushels of corn futures for each ton of ration needed. The long position in corn futures should be held until the actual ration is purchased, and at that time the corn futures position would be sold. The purpose in buying corn futures is to offset an unpredictable increase in the cost of ration. If ration cost increases, the corn futures position most likely will increase in value also, and the return from the corn futures position will offset the increase in the ration cost. Usually in cross hedging, the corn futures position will not change dollar-for-dollar with ration costs. This can result in the cross hedge only partially protecting the cattle feeder from an increase in ration costs.

The uncertainty in cross hedging is due to the difference in the net cost of cross hedging and the target cost. The net cost is the actual cost incurred by cross hedging, and the target cost is the expected cost determined at the time a cross hedge is placed. The net and target costs are defined mathematically in Eqs. (2) and (3).

The target cost is used by a cattle feeder in deciding whether to cross hedge a ration. The target cost is derived at the time a hedge is placed, and represents the cost a hedger expects to incur from hedging. The target cost for a cross hedge to be lifted at time t is calculated at time t-j by substituting the corn futures price for the contract maturing nearest to, but not before, time t into Eq. (1) and solving for the predicted ration cost. The result is then adjusted for hedging costs. The target cost equation for a long cross hedge is represented as follows:

$$T_{t-j}^{t} = b_0 + b_1 CF_{t-j}^{T} + b_1 HC_t \tag{2}$$

where T_{t-j}^{t} is the per ton target cost as calculated at time t-j for a cross hedge to be lifted at time t; CF_{t-j}^{T} is the per bushel corn futures price observed at time t-j for the contract which matures at time T, where T is the contract maturity date nearest to, but not before, time t ($T \geq t$); and HC_t is the per bushel futures hedging costs.

The net cost is the actual cost achieved by hedging, and is calculated at the time a hedge is lifted. The net cost is equal to the ration cost at the time the hedge is lifted, minus the return on the b_1 bushel corn futures position, plus hedging costs:

$$N_t = R_t - b_1(CF_t^{T} - CF_{t-j}^{T}) + b_1 HC_t, \tag{3}$$

where N_t is the per ton net cost for a j-period cross hedge that is lifted at time t.

An example is provided in Table 1 to illustrate the mechanics of a ration cross hedge. In the example, it is assumed that a cattle feeder decides to buy May corn futures in January to fix the cost on 200 tons of May ration. The cross hedge ratio is $b_1 = 24.2$ bushels. To cross hedge 200 tons of ration requires 4,840 bushels of corn futures (i.e., 200 tons times 24.2 bushels). One corn futures contract on the Chicago Board of Trade is 5,000 bushels, which is close to 4,840 bushels.

Target and net costs for the ration cross hedge are calculated in Table 1. When the May corn futures contract is purchased in January, the cattle feeder expects to pay \$105.57/ton for 200 tons of cross hedged May ration. The net cost calculated at the time the hedge is lifted in May is \$108.30 per ton. The difference between the net and target costs (\$2.73/ton) represents the uncertainty in the cross hedge.

A perfect cross hedge results when the net cost is exactly equal to the target cost. This occurs when the change in the ration cost is equal to the change in the value of 24.2 bushels of May corn futures. Usually in cross hedging (or even direct hedging), the net cost is not exactly equal to the target cost. In the example in Table 1, the ration cost increased by \$17.43 per ton from the target cost, while the 24.2 bushel corn futures position increased by only \$14.23 (i.e., \$0.588/bu. [\$0.60 - \$0.012/bu. hedging costs--explained below] multiplied by 24.2 bushels). The gain in the value of the corn futures position offset all but \$3.20 (17.43-14.23) of the increase in the per ton ration cost. The cross hedge partially protected the cattle feeder from the rising ration cost.

The example in Table 1 illustrates that there is risk (uncertainty) in a cross hedge. In the following section, the root mean square difference between net and target costs is used to quantify the risk in a ration cross hedge in corn futures. This concept of hedging risk has been used in practical applications (Hieronymus, 1977; Chicago Board of Trade, 1978), and in academic studies (Miller, 1985; Elam et al., 1986; Elam, 1988; Schroeder and Mintert, 1988).

Table 1. Example of a cross hedge for cattle rations using corn futures.

Date	Ration Cost	May Corn Futures
Jan. 1st	Target=49.62+24.2($2.312)[*] =$105.57	Buy 5,000 bu. at $2.30/bu.
May 1st	Buy 200 tons at $123./ton	Sell 5,000 bu. at $2.90/bu. Profit------------$0.60/bu.

Summary:
$24,600 Ration cost ($123./ton x 200 tons)
\- 3,000 Futures profit ($0.60/bu. x 5,000 bu.)
\+ 60 Futures hedging costs ($0.012/bu. x 5,000 bu.)
$21,660 Net cost for 200 tons ($108.30 per ton)

[*] The value 49.62 is the estimated intercept coefficient (b_0) from eq. (1) in the text, and 24.2 is the estimated slope coefficient (b_1). The figure in parentheses is the futures price ($2.30/bu.) plus hedging costs ($0.012/bu.)

CROSS HEDGING SIMULATION FOR CATTLE RATION COSTS

In this section, the results are reported for simulated cross hedges of cattle ration costs. The ration costs used are average monthly ration costs for cattle feedlots in the Plains region. Average monthly corn futures prices were obtained for the nearby futures contracts. Five corn futures contracts are traded each year (i.e., March, May, July, September, and December). The ration costs and corn futures prices were collected for the years 1979-89.

Hedge ratios (b_1 values) were estimated using Eq. (1). Separate regressions were estimated for each month to account for differences in the regression coefficients due to seasonal factors. The first regressions included the years 1979-84. For example, the first January regression included the six Januarys for the years 1979-84. The estimates of b_0 and b_1 from this regression were used in Eq. (2) to calculate the target cost for a cross hedge to be lifted in January 1985. Ration cross hedges were simulated for the five years, 1985-89. Each year an additional year was added to the data set, and the regression was rerun. For example, for a January 1986 cross hedge, the hedge ratio was determined from a regression including the seven Januarys for the years 1979-85. All available data (starting with the year 1979) were used in estimation to maximize the number of observations in the sample.

Target and net costs were calculated using eqs. (2) and (3). The target cost was calculated using information available at the time a cross hedge was initiated. For example, for a cross hedge to be lifted in January 1985, Eq. (1) was estimated for the years 1979-84, and the b_0 and b_1 values were used in the target cost equation (Eq. (2)). The March 1985 corn futures (nearby contract) was used as the cross hedge for the January 1985 ration. The futures hedging costs were assumed to be $0.012 per bushel (i.e., $35 per contract [5,000 bushels] for the round-turn futures commission plus $25 execution costs [1/2 cent for the bid-ask spread]). A 3-month hedge to be lifted in January 1985 was placed in October 1984. The March 1985 corn futures price observed in mid-October 1984 was substituted for CF^T_{t-3} in Eq. (2), where t-3 is mid-October 1984 and T is March 1985. The net cost for the January 1985 cross hedge was calculated at the time the cross hedge was lifted in January 1985, using Eq. (3). The procedure described above was used to calculate net and target costs for 3-month cross hedges lifted in each month for the years 1985-89. Also, net and target costs were calculated for 5- and 9-month horizons. The 5- and 9-month hedges are used by feeders to fix ration cost before the cattle are actually placed on feed (for the usual 4- to 5-month feeding period). A total of 60 cross hedges were simulated for each hedging horizon (i.e., 12 months per year times 5 years).

Mean differences (MD_1's) between net and target costs were calculated (Table 2, column 3). The MD_1's are positive, which indicates that a cross hedger will typically pay more for a ration than the expected (target) cost.

The root mean square difference between net and target costs ($RMSD_1$) can be used to measure the risks associated with the divergence between net and target costs with cross hedging (Table 2, column 4). Peck (1975) used the variance of actual returns about expected returns as a measure of hedging risk for egg producers. Holt and Brandt (1985) used a definition of hedging risk similar to $RMSD_1$ to evaluate hog hedging strategies. Assuming a normal distribution for the difference between net and target costs, $RMSD_1$ is the maximum dollar amount (per ton) that the net cost will differ from the target cost two-thirds of the time. With a value for $RMSD_1=\$6.46$, a cross hedger should expect to pay the target cost $\pm\$6.46$ per ton two-thirds of the time.[2]

The uncertainty in subsequent ration costs faced by cattle feeders without cross hedging was estimated using the RMSD between actual and projected ration costs (Peck, 1975; Holt and Brandt, 1985). Two different projections of ration costs were used--(1) target cost, and (2) current cost at the time a hedge is placed. In this study, it was assumed that the current ration cost was the most recent published ration cost. Feedstuffs (Miller Publishing Co., Minnetonka, MN.) reports ration costs monthly. For example, if a decision was being made in March, the current ration cost was the February cost. $RMSD_2$ in Table 2 is the root mean square difference for target projections; and $RMSD_3$ is the root mean square difference for current cost projections. $RMSD_2$ is lower than $RMSD_3$ for all hedging horizons. This indicates that the target cost (based on corn futures prices) provides a more accurate projection of subsequent ration costs than the current ration cost.

The usefulness of a cross hedge as a risk management tool is provided by comparing the RMSD with cross hedging to the RMSDs without cross hedging. $RMSD_1$ with cross hedging is lower than $RMSD_2$ and $RMSD_3$ without cross hedging (Table 2). This indicates that corn futures provide an effective cross hedge for cattle rations. The longer the hedging horizon, the lower is the RMSD with cross hedging compared to the RMSD's without cross hedging. For a five-month horizon, the typical feeding period for steer cattle (Dietrich et al., 1985), $RMSD_1$ with cross hedging is 10.5% lower than $RMSD_2$ (based on the target projection) and 38.4% lower than $RMSD_3$ (based on the current cost projection). A 9-month ration cross hedge would involve fixing ration costs before the cattle are put on feed. For a 9-month cross hedge, the RMSD with cross hedging is 28.5 and 53.6% lower, respectively, than $RMSD_2$ and $RMSD_3$ without cross hedging.

The results in Table 2 show the mean ration cost with cross hedging is higher than the mean cost without cross hedging (Table 2, columns 2 and 5). This indicates that

Table 2. Summary of simulated cattle ration cross hedges, 1985-89.[a]

Hedging Horizon	With Cross Hedging: Mean Net Ration Cost	Target Cost as Projection of Net Cost[b,c]: MD_1	$RMSD_1$	Without Cross Hedging: Mean Ration Cost	Target Cost as Projection of Ration Cost[d]: MD_2	$RMSD_2$	Current Cost as Projection of Ration Cost[e]: MD_3	$RMSD_3$
	(dollars per ton)							
3 Months	111.36	2.24[f]	6.46	111.15	1.81	6.54	-0.47	8.18
5 Months	112.65	2.24[f]	6.46[g]	111.15	0.52	7.22	-0.88	10.49
9 Months	113.18	2.24[f]	6.46[h]	111.15	-0.01	9.03	-1.50	13.92

[a] Number of simulated cross hedges = 60 for each hedging horizon.

[b] Target and net costs are reduced by the assumed hedging cost of $0.012 per bushel of corn futures.

[c] MD_1=average difference between net and target costs; $RMSD_1=[MSD_1]^{1/2}$ where MSD_1=mean of the squared differences between net and target costs.

[d] MD_2=average difference between actual and target costs; $RMSD_2=[MSD_2]^{1/2}$ where MSD_2=mean of the squared differences between actual and target costs.

[e] MD_3=average difference between actual and current costs; $RMSD_3=[MSD_3]^{1/2}$ where MSD_3=mean of the squared differences between actual and current costs.

[f] Significantly different from zero at the 0.05 level based on a two-tail t-test (d.f.=59).

[g] MSD_1 is significantly less than MSD_3 at the 0.05 level based on a two-tailed F-test (d.f.=(59,59)).

[h] MSD_1 is significantly less than MSD_2 and MSD_3 at the 0.05 level based on a two-tailed F-test (d.f.=(59,59)).

a cattle feeder who continuously cross hedges pays more for ration than a feeder who buys ration on a day-to-day basis. The higher net cost from cross hedging is due to an overall loss in the corn futures position.[3] Research on futures price bias (Keynesian normal backwardation) suggests that if futures prices change, on average, they are more likely to rise than fall (Chang, 1985); thus a gain should be expected on the futures position, rather than a loss (as occurred for the ration cross hedges from 1985-89). This would cause the net cost from cross hedging to be lower on average than the actual cost, assuming the hedging cost is small.

SUMMARY AND CONCLUSIONS

The feasibility of cross hedging cattle ration costs using corn futures was investigated. Simulation results for 1985-89 showed that risk associated with cross hedging was lower than without cross hedging. For a 3-month cross hedging horizon, the risk with cross hedging was 1-21% lower than without cross hedging. And, as the hedging horizon lengthened, risk associated with cross hedging decreased relative to that without cross hedging. For a 9-month horizon, the risk with cross hedging was 28-54% lower than without cross hedging.

Research on cross hedging cattle rations is important because of the number of cattle and the amount of ration fed in the U.S. In 1989, 26.2 million cattle were fed in U.S. feedlots (USDA, 1990). Each animal was fed approximately 1.65 tons of ration during the feeding period. This amounts to 43.2 million tons of ration fed in 1989. This research has shown that up to 54% of the uncertainty in ration costs can be removed with a cross hedge in corn futures. With less uncertainty, the return required to hold resources in the cattle industry will be lower, which in a competitive beef industry should mean lower beef prices for consumers.[4]

Further research is needed to determine why cattle rations cannot be more effectively cross hedged for short time horizons (3 months or less). Perhaps, ration costs adjust slowly to changes in cash corn prices over time. This would call for a dynamic hedge ratio that adjusts to the length of time a hedge is held. Another possible cause of the ineffectiveness of ration cross hedges for short time horizons is an unpredictable corn basis for the Plains. That is, the ration cost may in fact be highly correlated with the Plains cash corn price, but the Plains corn price may exhibit low correlation with the corn futures price. If the Plains corn basis is highly variable, it will be difficult (if not impossible) to improve the ration cross hedge.[5]

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ENDNOTES

[1] Separate correlation coefficients (r's) were calculated for each month of the year using data for 1979-88. The r-values range from 0.81 for June to 0.96 for December. All 12 monthly r-values are significantly different from zero at the 0.05 level.

[2] The RMSD is the same for all hedging horizons because hedging risk depends on the relationship between ration costs and corn futures prices at the time a hedge is lifted. Hedging risk does not depend on cash and futures prices at the time a hedge is placed, or the hedging horizon (Elam and Davis, 1990).

[3] The difference between the mean net (N) and actual (R) ration costs is equal to the mean of $(-b_1(F_t^T-F_{t-j}^T)+b_1HC_t)$--from Eq. (3). When the futures price decreases on average over the time period a hedge is held, then the term $-b_1(F_t^T-F_{t-j}^T)$ is positive, and $(N-R)>0$, which says that $N>R$.

[4] This assumes that the risk from variable corn and cattle prices is being shifted to speculators who are more willing to assume the risk, and for less return (i.e., lower cost), than cattle feeders.

[5] Fryar et al. (1988) developed a procedure which divides hedging risk into two components. The first component measures the portion of hedging risk due to corn basis variance (basis = Plains cash corn price - corn futures price), and the second component measures the portion due to premium/discount variance (ration cost - Plains cash corn price). This decomposition will allow one to determine whether the poor performance of 3-month ration cross hedges is due to extreme variance in the Plains corn basis.

Effects of Tractor Traffic and Soil Moisture Tension on Yield of Norgold Russet 'M' Potatoes

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ABSTRACT

The effects of tractor traffic and soil moisture tension on yield and specific gravity of Norgold Russet 'M' potato tubers were investigated. The impact of tractor traffic on the soil physical condition was evaluated by soil bulk density and penetrometer resistance; soil moisture was measured gravimetrically. Penetrometer resistance was significantly ($P > 0.05$) greater across beds in the 20 and 50 cb treatments of normal traffic rows in Year 1; in Year 2, penetrometer resistance was significantly greater only in the 50 cb treatment. Bulk density and gravimetric water content were not altered by tractor traffic. Total and marketable tuber (U.S. No. 1 and U.S. No. 2) yields were highest in nontraffic and 20 cb treatments both years. Significant differences in tuber specific gravity were observed at 50 cb Year 2.

KEY WORDS: Bulk density, penetrometer resistance, gravimetric water content, tractor traffic and moisture stress.

Potatoes (*Solanum tuberosum* L.) are economically important to the High Plains of Texas. The crop is valued at $35 million produced annually on 10,000 acres (Texas Vegetable Statistics, 1990). Current management practices for potato production are culturally intensive, which may lead to deterioration of soil structure, reduction in crop yields, and higher than necessary production costs. With growers facing ever-dwindling profit margins, efficient use of resources is essential. Two easily-altered cultural practices are tractor use and water management; thus, the effects of tractor traffic and soil moisture control were selected for this study. After repeated tractor traffic soil particles become compressed, forming a compacted layer of soil. This may impact seedbeds and furrows by increasing soil resistance (Bakken et al., 1987; Hang and Miller, 1986; Ross, 1986; Soehne, 1958; Standberg and White, 1979; Voorhees et al., 1978), limiting soil water availability (Warkentin, 1971), and restricting root growth (Strandberg and White, 1979). Potatoes grown with such cultural conditions may produce tubers that are smaller and deformed, contributing to reduced quality and lowered yields (Arnold and Sojka, 1980; Blake et al., 1960; Epstein and Grant, 1973; Flocker et al., 1960; Grimes and Bishop, 1971). This study investigated the yield and quality of potatoes when grown with these management practices: (1) normal or (2) reduced tractor traffic and soil moisture tensions of (3) 20 centibars (cb), normal irrigation, or (4) 50 cb, drier conditions.

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MATERIALS AND METHODS

Norgold Russet 'M' seedpieces were planted in Lubbock, Texas into an Amarillo fine sandy loam (fine loamy, mixed, thermic Aridic Paleustalfs), 14 March and 15 March, and hilled 28 April and 8 May in 1986 and 1987, respectively. Seed pieces were spaced 9 in. apart and planted in single rows and 36 in. centers. Blocking was done along an irrigation gradient; potatoes were grown under furrow irrigation. The experimental design was a randomized block in a split-plot arrangement with four replications per treatment. Main plot treatments consisted of two moisture tension levels: 20 cb, normal for potato culture, and 50 cb, drier conditions for water conservation. Moisture tension levels in each replication were monitored with three tensiometers placed randomly in each plot at a depth of 1 ft. Subplots consisted of four normal and four nontraffic rows, each 50 ft. in length. Tractor traffic consisted of herbicide, insecticide, and fungicide applications as needed: 21, 30, 44, 46, 56, 69 days after hilling in Year 1 and 22, 31, 39, 49, 57, 67 days after hilling in Year 2. Following each application, an additional tractor pass was made on the opposite side of traffic rows to ensure both sides of the bed were evenly subjected to wheel pressure. Pesticides were applied to potatoes in nontraffic rows with spray booms so that tractor wheels were not in contact with the soil.

Soil structure was measured by soil bulk density. Samples were taken 2, 35, and 80 days after hilling across the width of the bed at 1, 10 (center of the bed), and 20 in. and at depths of 2, 8, and 14 in. Soil strength was measured at three locations per plot by pressing a moving-tip penetrometer to a depth of 1 ft. at intervals of 1, 5, 10, 15, and 20 in. across the width of the bed (Black, 1965). Penetrometer resistance was measured prior to each irrigation when mean soil tensions reached either 20 or 50 cb. Gravimetric soil water content was used to measure soil moisture movement into the bed. Gravimetric water content was measured by removing a 3 in. soil core at a depth of 6 in. on the same dates and at the same intervals across the bed as penetrometer resistance.

One week prior to harvest the number of tubers per hill, distribution within the hill, and tuber size and shape were observed. Potatoes were harvested at maturity on July 15 and July 21 in Years 1 and 2, respectively. Potatoes were harvested from rows that had not been used for soil sampling; tubers were sorted and graded as either No. 1, No. 2, small, or cull (USDA, 1971). The specific gravity of freshly harvested No. 1 tubers was determined with a potato hydrometer. Analyses of variance and Fisher's Least Significant Difference (LSD) were used to analyze data.

RESULTS AND DISCUSSION

No differences in soil bulk density were detected among any treatments: 1.36 g/cc and 1.37 g/cc in 20 cb plots, 1.38 g/cc and 1/39 g/cc in 50 cb plots in nontraffic and traffic treatments, respectively. The amount of tractor traffic throughout the growing season and the soil moisture tension did not significantly affect soil structure of the bed. Therefore, soil bulk density measurements were not repeated Year 2. Penetrometer resistance was always lowest in the 20 cb nontraffic treatments and highest in the 50 cb traffic treatments. After six tractor passes, resistance increased across the bed in all but the center-most (10 in.) location. Gravimetric water was greatest in the normal irrigation level plots, 11.0% and 6.8% in Year 1, and 11.1% and 7.6% in Year 2, 20 cb and 50 cb soil moisture tensions, respectively. Repeated tractor traffic apparently did not affect the movement of soil moisture into the bed since gravimetric water measurements across the bed showed no significant differences as the number of tractor passes increased.

The number of tubers, tuber distribution within the hill, and size and shape of tubers varied with treatment (Figure 1). Six to nine uniformly-sized tubers grew horizontally throughout the hill in the nontraffic treatments. Whereas, in the normal traffic treatments, 10 to 12 smaller, misshaped tubers were found restricted to the center of the bed; distribution closely follows penetrometer resistance, in that resistance was lowest in the center of the bed. Yields of No. 1 tubers were highest in 20 cb, nontraffic treatments both years. Overall, marketable yields were highest in the 20 cb, nontraffic treatments and lowest in the 50 cb, normal traffic treatments. With increased traffic and drier conditions, yields of marketable tubers decreased and unmarketable tubers increased (Table 1). Penetrometer resistance increased with increased tractor traffic and soil moisture tension; tubers harvested from these plots were smaller and deformed and were growing in the center of the hill (Figure 1). Secondary growth occurred in water-stressed tubers (Hang and Miller, 1986). The lowest yields overall in our studies were recorded in 50 cb nontraffic and traffic plots. Deformed tubers contributed to the increased cull yield and the decreased marketable yield in the 50 cb plots. Yields, therefore, apparently were affected more by low soil moisture than by traffic (Table 1).

Specific gravity of potatoes was not affected by tractor traffic but was significantly ($P > 0.05$) lower in the 50 cb irrigation treatment in Year 2: 1.062 compared to 1.066 in the 20 cb treatment. Increased water within tubers occurs when moisture stress is imposed upon plants allowing for conversion of starch to sugar within the tuber (Isherwood, 1973). This is followed by a rapid influx of water into the tuber causing a rapid enlargement of the perimedullary zone which contributes to tuber deformities (as observed in the 50 cb nontraffic and traffic plots). Increases of water content in the tuber reduces the percentage of tuber solids, thereby reducing specific gravity.

Equipment costs per use are approximately $10/A (Smith and Roberts, 1988). Potato growers average six tractor uses per season (Davis and Smith, 1988), therefore, by just reducing tractor use after hilling operation costs could be reduced as much as $60/A. Additional returns to the grower may be realized with the increased yields obtained when tractor traffic is reduced. Average yield for fresh market and processing tubers in Texas is 19,500 lb/A, at a season average price of $17.90/cwt (.18/lb) (Texas Vegetable Statistics, 1990). In our research yields of marketable tubers grown with traditional cultural methods [i.e., normal (20 cb) irrigation and normal traffic] averaged over two years were 17,444 lb/A (Table 1). When tractor traffic was reduced yields averaged over two years were 19,936 lb/A (Table 1), a 2,492 lb/A increase. At $.18/lb this could result in an additional $448/A return to the grower.

CONCLUSIONS

We conclude that yields may be higher with conventional irrigation levels and reduced tractor traffic. No differences in bulk density were observed among treatments. Gravimetric water content was greatest in the normal irrigation level plots but was not affected by tractor traffic. Soil strength was highest in the low irrigation, normal traffic treatments. Yields of potatoes were highest when grown

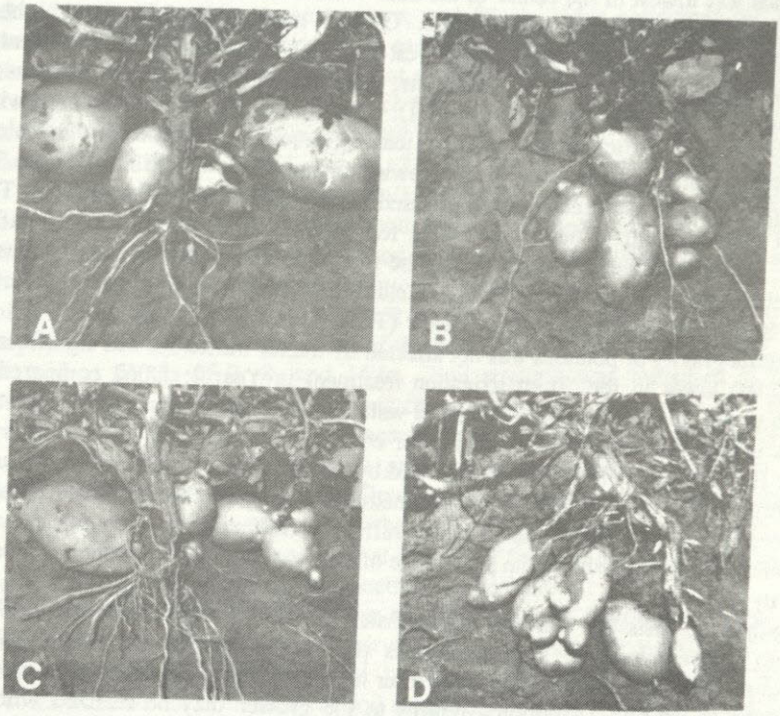

Figure 1. Distribution of Norgold Russet 'M' tubers within the hill. (A) 10 cb, nontraffic; (B) 20 cb, traffic; (C) 50 cb, nontraffic; (D) 50 cb, traffic.

Table 1. Yield of Marketable (U.S. No.1 and U.S. No. 2) and Non-Marketable (Smalls and Culls) Norgold Russet 'M' Potatoes as Affected by Soil Moisture Tension and Tractor Traffic

	Yield[1] (lb/A)							
	Year 1				Year 2			
	20cb		50cb		20cb		50cb	
Grade	Non-Traffic	Traffic	Non-Traffic	Traffic	Non-Traffic	Traffic	Non-Traffic	Traffic
Marketable	18,868aA	17,622bA	16,465cA	14,774cA	21,004aA	17,266bA	15,753cA	15,130cA
Non-Marketable	5,162aB	6,675aB	7,209aB	6,230aB	3,978aB	6,230aB	5,607aB	6,052aB

Yields followed by the same letter do not differ significantly using Fisher's LSD at P>0.05.
Lower case letters indicate differences within a row within a year. Capital letters indicate differences within a column.

with normal (20 cb soil moisture tension) irrigation levels and reduced tractor traffic, and lowest when grown with low (50 cb) irrigation levels and normal tractor traffic. Other benefits of less tractor use are obvious and include decreased field production costs, increased equipment longevity and decreased maintenance.

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The Relation Between Soil Salinity and Site Productivity of a Coastal Bend Sudangrass Pasture

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ABSTRACT

A site with a history of patchy plant growth and salt spills from oil and gas drilling activities was studied to determine the relation between soil salinity and site productivity of a sudangrass (*Sorghum sudanense*) pasture. Soils were sampled and site productivity was evaluated along a 1600-foot transect. On sites with poor productivity, soil salinity values (by $EC_{1:1}$) were greater in the 36 to 48 inch depth than in upper depths. Site productivity related significantly ($\underline{P} = 0.05$) to soil salinity by both linear and quadratic models, but the boundary line method was judged to be the best method for describing the relation.

KEY WORDS: Salt, sodium, boundary line

Patchy, nonuniform plant growth is common along the Coastal Bend region of south Texas. Often the lack of uniformly vigorous plant growth is attributed to soil salts, either originating naturally from water tables, or arising from leaks and spills from oil and gas drilling activities. Deleterious effects of salt can be either osmotic effects, general to all salts, or the effects of specific ions on specific plants (U.S. Salinity Laboratory Staff, 1954). The tolerance of plants to salt has been thoroughly investigated and relative salt-tolerance data is available for common crops (Rhoades and Miyamoto, 1990). Unfortunately most of the compiled data is based upon salinity as measured by electrical conductivity of a saturation extract (EC_e). Many laboratories have switched to 1:1, 1:2, or 1:5 soil:water extracts for simplicity (Texas Agricultural Extension Service, 1980), but the interpretation of such data can be difficult. In this study, soil salinity is reported as electrical conductivity of the filtrate of a 1:1 soil:water mixture ($EC_{1:1}$) and a regression is established allowing conversion between $EC_{1:1}$ and EC_e.

A site in Nueces County, Texas was chosen for study because of a history of nonuniform plant productivity, and the presence of gas wells and salt-water pipelines throughout the property. At the time of the study, the site was seeded to sudangrass, a moderately salt-tolerant crop (Rhoades and Miyamoto, 1990).

Plant response in laboratory studies is often linear with respect to a growth-limiting factor. However studies conducted under field conditions often show non-

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linear or weak, linear correlations between plant response and the experimental factor because factors other than the one in question come into play. A method of dealing with such data, termed the "boundary line" method , is gaining favor with field investigators (Sumner, 1987). By delineating the best response at each level of stimulus, the boundary line method estimates what the crop response to a variable would be if only that variable were limiting (Webb, 1972). The method has been used to formulate fertilizer recommendations based on soil test data.

This paper serves two objectives. It describes the relation between site productivity in a sudangrass pasture to soil salinity, and presents a useful outgrowth from that description. The outgrowth is a suggested role for the boundary line for describing plant response to soil salinity where salinity is limiting to plant growth unless some other factor supersedes the effects of salt.

MATERIALS AND METHODS

A field was chosen based on nonuniformity of plant growth. The soil was the Willacy-Clareville-Orelia association of nearly level, loamy and moderately sandy soils, with intermittent Victoria clay (Franki et al., 1965). A transect 1600 feet long was oriented through the field such that it intersected sites of good and poor plant vigor. Every 100 feet, and elsewhere as necessary, plant vigor was evaluated and soil samples were collected. Each sampling site was surveyed by profile leveling to determine relative elevation. Plant production varied markedly along the transect, ranging from dense stands of sudangrass over 5 feet tall, to spots with sparse vegetation less than 1 foot tall. On 21 July 1990, relative site productivity was assessed by assigning each site an index number between 1 and 5, similar to the range productivity evaluation system of Richardson et al. (1979). Productivity assessments from two investigators were averaged, then converted to percentage of the highest score. On 24 July 1990, 2-inch diameter soil cores were collected to a depth of 4 feet, at 1-foot increments, using a hydraulic sampler. All soils were analyzed for pH and for salt by $EC_{1:1}$. Six soils were analyzed for salt by both $EC_{1:1}$ and EC_e for comparison (U.S. Salinity Laboratory Staff, 1954; Rhoades, 1982). All soils were analyzed for organic matter (Nelson and Sommers, 1982) to identify factors other than salt (such as oil) that could limit plant growth. Selected samples were analyzed for individual cations by atomic absorption or flame emission spectrometry on ammonium acetate extracts.

RESULTS AND DISCUSSION

Site productivity did not correlate significantly to surface elevation ($r^2 = 0.01$), nor to the organic matter content ($r^2 = 0.00$) or pH of the upper foot of soil ($r^2 = 0.17$). Soil pH values in the surface foot can all be considered normal, ranging from 6.1 to 7.8. In subsurface horizons, pH ranged from 6.6 to 8.4. Organic matter ranged from 0.5 to 2.0% in the surface foot, and 0.03 to 1.8 in subsurface horizons. Subsurface organic matter was as high as 2.9% on a suspected oil-spill site near the transect.

Rather than the traditional unit of mmho/cm for EC, data are expressed in the newer S.I. unit, dS/m. The units are interchangeable, i.e., 1 mmho/cm = 1 dS/m. Site productivity index values and salinity data from 1:1 extracts are presented in Table 1. An inverse relationship between site productivity and soil salinity at the

36 to 48 inch depth, was observed over much of the transect, but not beyond the 1200 foot mark (Figure 1). Sudangrass is inhibited by EC_e of 2.8 dS/m (Rhoades and Miyamoto, 1990), which corresponds to an $EC_{1:1}$ value of about 1.4 dS/m (Figure 2). Only at the 3 to 4 foot depth did $EC_{1:1}$ values approach 1.4 dS/m. For this reason, salinity in the 3 to 4 foot depth is of particular interest for this study.

Table 1. Soil salinity as measured by electrical conductivity of a 1:1 extract and site productivity along a 1600-foot transect through a sudangrass pasture.

Site	Site Productivity	Soil Depth			
		0-12"	12-24"	24-36"	36-48"
	%	------------------ dS/m			----------------
0	32	0.16	0.57	0.17	0.29
25	15	0.16	0.16	0.15	0.20
50	62	0.17	0.16	0.16	0.16
100	32	0.16	0.17	0.17	0.16
200	10	0.32	0.41	0.57	0.86
250	10	0.29	0.19	0.59	0.46
300	15	0.34	0.41	0.47	0.83
350	10	0.28	0.29	0.38	0.51
400	62	0.19	0.15	0.17	0.15
450	45	0.15	0.16	0.17	0.19
500	62	0.20	0.20	0.29	0.21
600	87	0.20	0.26	0.25	0.21
700	62	0.20	0.18	0.22	0.29
750	10	0.22	0.48	0.54	1.47
800	62	0.26	0.29	0.33	0.39
900	100	0.22	0.14	0.16	0.15
950	32	0.18	0.24	0.37	0.46
1000	22	0.31	0.40	0.63	1.87
1050	10	0.26	0.43	1.03	2.40
1100	15	0.18	0.30	0.40	0.41
1200	45	0.12	0.29	0.34	0.47
1250	62	0.14	0.17	0.19	0.24
1300	32	0.17	0.18	0.16	0.18
1350	45	0.14	0.18	0.16	0.17
1400	32	0.22	0.18	0.18	0.18
1450	32	0.14	0.17	0.15	0.18
1500	22	0.16	0.16	0.17	0.23
1550	22	0.20	0.16	0.19	0.20
1600	22	0.14	0.16	0.14	0.17

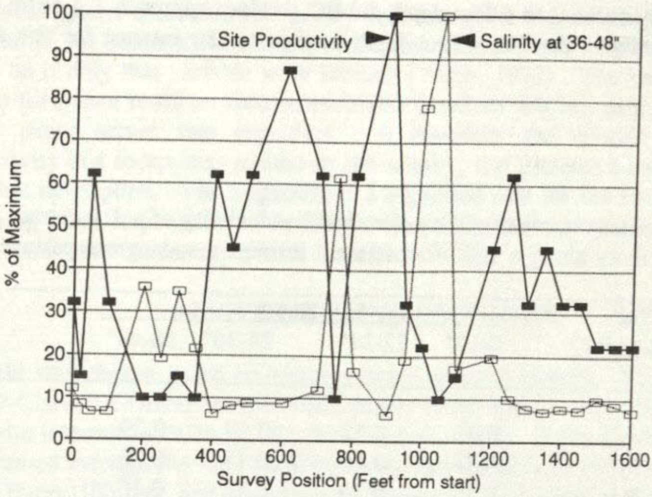

Figure 1. Site productivity and soil salinity ($EC_{1:1}$) along a 1600-foot transect through a sudangrass pasture.

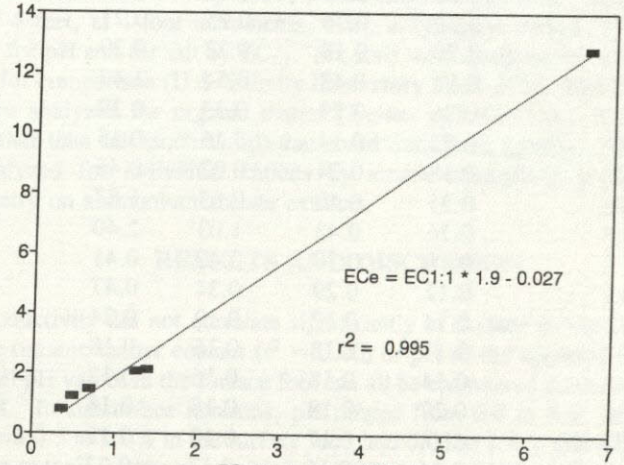

Figure 2. Linear regression relating electrical conductivity (EC) of saturation extract to EC of 1:1 extract.

Figure 3 shows the relation between site productivity and soil salinity as measured by $EC_{1:1}$ on samples taken from the 36 to 48 inch depth. Although site productivity relates significantly ($\underline{P} = 0.05$) to $EC_{1:1}$ by linear regression, an inspection of the data (Figure 3) clearly reveals that a linear model would not adequately describe the relationship. Likewise, a quadratic regression model ($Y = 21.22 X -66.83 X^2 + 57.54$) provides a significant ($\underline{P} = 0.05$) fit, but is of limited practical utility because it implies an increase in productivity at very high salt levels (Figure 3). The weakness of the boundary line method is that it does not lend itself readily to statistical analysis. The strength of the method can be observed in Figure 3. The line predicts the maximum site productivity for a given level of $EC_{1:1}$. Productivity can be less than the boundary value if something other than salinity is limiting. Note that the boundary line is linear+plateau. The plateau indicates that once a certain X value is obtained, Y values are thereafter unaffected. Linear+plateau and quadratic+plateau lines are typical of models describing field fertility studies (Cerrato and Blackmer, 1990).

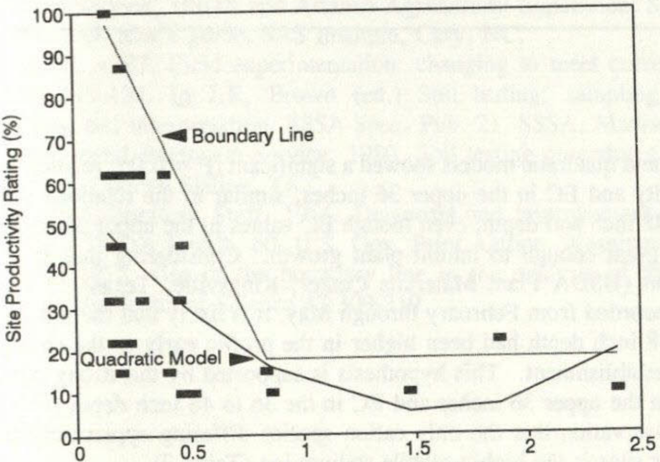

Figure 3. Relation between site productivity of a sudangrass pasture and soil salinity as measured by electrical conductivity (EC) of 1:1 extract. Boundary line and quadratic models are compared.

Table 2. Ammonium acetate extractable soil potassium (K), magnesium (Mg), calcium (Ca), and sodium (Na) from the site of greatest productivity (Site 900) and two sites of low productivity (Sites 750 and 1050).

Site	Depth	K	Mg	Ca	Na
	inches	----------------	mg/kg	--------------	
900	0-12	433	323	2800	33
	12-24	265	339	2820	37
	24-36	286	470	3760	47
	36-48	257	457	3710	42
750	0-12	370	468	2170	126
	12-24	391	910	4180	630
	24-36	371	830	3360	870
	36-48	446	820	3040	1520
1050	0-12	439	563	2730	171
	12-24	424	900	4230	630
	24-36	440	890	3660	1160
	36-48	483	705	3280	1680

Both linear and quadratic models showed a significant ($\underline{P} = 0.05$) relation between site productivity and EC in the upper 36 inches, similar to the relations illustrated for the 36 to 48 inch soil depth, even though EC values in the upper 36 inches were probably not great enough to inhibit plant growth. Considering that at a nearby weather station (USDA Plant Materials Center, Kingsville, Texas) 13 inches of rainfall was recorded from February through May, it is likely that the salt measured in the 36 to 48 inch depth had been higher in the profile early in the spring at the time of crop establishment. This hypothesis is supported by the strong correlation between EC in the upper 36 inches and EC in the 36 to 48 inch depth ($r^2 = 0.80$), and by the observation that the only cation species differing appreciably between good and poor sites is the highly mobile sodium ion (Table 2).

CONCLUSION

Plant growth and vigor at the site was patchy, as is common on salt-affected soils. At the time of the study, salinity in the upper three feet of soil was not sufficiently high to explain the patchy growth. Samples taken from the 3 to 4 foot depth revealed high concentrations of salt. The boundary line technique as is used to describe field response to soil fertility was the best technique to describe the response to soil salinity. The boundary line, derived using only the greatest productivity value obtained from a given soil salinity level, can be described by a linear+plateau segmented model (SAS, 1985). The findings established that: 1) site productivity in a sudangrass pasture was related to soil salinity, even though the upper levels of soil were relatively salt-free; and 2) the boundary line method of describing plant response to soil fertility was an adequate and practical method to describe the relation between site productivity and soil salinity.

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Serial Measurements Using Real-Time Ultrasound to Evaluate Relative Changes in Fat Thickness and Ribeye Area of Feedlot Steers

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ABSTRACT

Feedlot steers representing two breed-X groups (Salers-X, n=46 and Brangus-X, n=50) were measured ultrasonically at 28 d intervals to evaluate changes in fat thickness (FTU1), and area of the longissimus muscle (REAU1) for the possible development of prediction equations for time and weight effects on ultrasonic measurements. The Salers-X group was also measured (FTU2 and REAU2) with an additional ultrasound unit. Individual ages were not available on the cattle studied, so date of measurement was used as the time effect. Body weights were taken at time of isonification. Initial weight means were 649.5 and 798.3 (pooled SE = 61.1) lb for Salers-X and Brangus-X groups, while final weights were 1093 and 1087.9 (pooled SE = 81.3) lb, respectively. Regression equations for the Salers-X group indicated linear relationships ($P < .01$) between FTU1 for both time and weight effects. Regression coefficients, b (and R^2 values) for the Salers-X group were: b=.00045 (.51), b=-.0000079 (.57) for FTU1 on weight and time, respectively. For the Brangus-X group, linear relationships existed ($P < .01$) between REAU1 on weight and time, respectively; b=.0091 (.51) and b=-.00012 (.36). For the Salers-X group, correlation coefficients between the two machines ranged from .802 to .928 for FTU and .361 to .738 for REAU. These data could be useful for development of adjustment procedures of ultrasonic measurements for prediction of carcass merit.

KEY WORDS: Beef Cattle, Carcass Traits.

The use of ultrasonic techniques for prediction of fat thickness was initiated many years ago in beef cattle (Hazel and Kline, 1959; Stouffer, 1961) and in hogs (Panier, 1957). Advances in equipment and interest by beef industry groups has generated increasing amounts of research in the ultrasound field in recent years. Prediction of carcass attributes on the live animal through the use of ultrasonic imaging has been proposed as the method offering the most promise for incorporation of expected progeny differences for carcass merit into breed improvement programs

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(BIF, 1989). Much research has been done with ultrasound, primarily measuring fat thickness and ribeye area, as a means of predicting final carcass composition (Houghton, 1992). Little research has been done in evaluating changes in ultrasonic measures over the course of a feeding period. This information would be useful for standardizing measurements to constant time and weight endpoints for animal evaluation. Therefore, the objectives of this study were to develop prediction equations for time and weight effects on ultrasonic measurements and to measure relative change in ultrasonically predicted fat thickness and ribeye area in feedlot steers.

MATERIALS AND METHODS

Animals

The cattle used in the project were owned by the Bradley 3 Ranch and maintained at their facilities located at the ranch headquarters at Memphis, TX. Feedlot steers representing two breed-X groups (Salers-X, n=46 and Brangus-X, n=50) were used in the project. The Salers-X group calves were sired by Salers bulls while the Brangus-X group calves were sired by Brangus bulls. Both sire breed groups originated from a single producer and were calved from crossbred cows. The two groups were fed separately throughout the entire feeding period. After cattle arrived at the feedlot, they were processed and then allowed a 30 d adjustment period before the first ultrasonic image was taken. Thereafter, images were taken on 28 d intervals (8 measurements for the Salers-X and 6 measurements for the Brangus-X group) until slaughter. The animals were selected for slaughter based on individual merit as evaluated by the owner and operator of the feedlot resulting in uneven numbers per slaughter group. Selection was based on the evaluator's estimation that the animal would produce a carcass with a USDA quality grade (QG) of Choice or better with a USDA yield grade (YG) of less than 2.0.

Ultrasonic Images

Images were taken by two technicians on 28 d intervals. The last measure for each animal was obtained 24 h before slaughter. Both the Brangus-X and Salers-X group were isonified with Unit 1 (Aloka 210DX, Corometrics Medical Systems, Inc., Wallingford, CT 06492) equipped with a 3.0 MH_z, 102-mm scanning width, linear array transducer. In addition, Unit 2 (Tokyo Keiki LS 1000, Products Group International, Inc., Boulder, CO 80322) equipped with a 3.5MH_z, 102-mm scanning width, linear array transducer was used to isonify the Salers-X group. The transducer was placed at the 12th-13th rib interface lateral to the vertebrae and parallel to the rib. Both fat thickness and ribeye area images were taken at this site. To ensure proper contact between transducer and animal, corn oil (Mazola®) was placed on the animal at the isonification site and used as a couplant. At time of isonification, images were recorded on a high resolution tape with a video cassette recorder. Fat thickness was estimated on site with internal calipers available within the ultrasound unit. The recorded images were analyzed on a computer system using a software package (PlusMorph, Woods Hole Educational Associates, Woods Hole, MA 02543) to determine ribeye area. A problem was encountered with the VCR while recording the images for later analysis on d 140 for the Salers-X group resulting in a lack of data for that subclass.

Carcass Data

Animals were slaughtered at B3R Country Meats, Childress, TX. All carcass information was collected 48 h post-mortem by trained personnel employed at the processing plant. Data collected included fat thickness (FTC) and ribeye area (REAC) measurements, YG (estimated by personnel), kidney pelvic and heart fat (KPH) and QG estimates.

Statistical Analysis

All statistical analyses were computed using procedures of SAS (1990). Regression models were utilized to evaluate the linear and quadratic effects of time on feed and live weight. Pearson correlation coefficients were estimated among important variables. Variables analyzed were ultrasonic measurements of fat thickness and ribeye area, and carcass measures FTC, REAC, KPH, YG, and QG. Analyses were performed separately by breed-X group because the two groups were initially at different points on their growth curve, were placed on feed at different times, and a different technician measured each sire-breed group.

RESULTS

The initial weight differences in the cattle are shown in Table 1. The Salers-X group was lighter when the project started but the final weight means are very similar which is attributable to the individual selection criteria the owner/operator implemented to select animals for slaughter. Also shown are FTC and REAC means for the two groups. The Salers-X group had a larger estimated ribeye area with less fat thickness.

Table 1. Descriptive means and standard errors for Salers-X and Brangus-X feedlot steers[a].

Measurement	Salers-X		Brangus-X	
	Mean	SE	Mean	SE
Initial wt, lb	649.49	(51.73)[b]	799.31	(69.53)
Final wt, lb	1093.0	(64.53)	1097.9	(97.62)
FTC, in	.2947	(.0985)	.3679	(.1157)
REAC, in^2	12.20	(.9767)	11.81	(1.26)
Average days on feed	163	(20.6)	107	(27.5)

[a] FTC = carcass fat thickness, REAC = carcass ribeye area.
[b] Mean (pooled SE).

Shown in Table 2 are the means and standard errors for FTU and REAU measurements by time period for both groups. As shown, there is a general upward trend for FTU for both groups while the REAU measurements reached a peak and then plateaued on the last few measurements. In addition, the Brangus-X group had a higher initial fat thickness that continued to be higher through each measurement date. The higher initial weight and fat thickness resulted in fewer days on feed for the Brangus-X group.

Table 2. Means and standard errors of ultrasonic measures by time of measure and breed group[a].

	Salers-X		Brangus-X	
Day	FTU(in)	REAU(in^2)	FTU(in)	REAU(in^2)
0	.11 (.04)[b]	8.66 (1.09)	.17 (.03)	8.78 (.99)
28	.16 (.04)	9.39 (1.26)	.20 (.06)	9.73 (1.45)
56	.22 (.05)	9.51 (1.06)	.31 (.11)	10.40 (1.18)
84	.25 (.07)	8.98 (1.17)	.32 (.10)	10.97 (1.24)
112	.25 (.07)	11.12 (.70)	.32 (.08)	11.52 (1.34)
140	.30 (.07)		.28 (.07)	11.27 (1.06)
168	.30 (.07)	10.57 (1.11)		
196	.30 (.08)	10.74 (.757)		

[a] FTU = ultrasonic fat thickness, REAU = ultrasonic ribeye area.
[b] Standard errors in parentheses.

Presented in Table 3 are the means and standard errors of the carcass measures by slaughter group. As seen in this table, cattle were not slaughtered on exact 28 d intervals due to the individual selection criteria imposed by the operator. This resulted in a range in days on feed from 70 to 195 for the animals in the study and unbalanced subclasses between slaughter dates.

When evaluating the correlation coefficients between ultrasonic measurements and final carcass measurements for fat thickness using unit one, a trend of improvement in accuracy occurred for the Salers-X group when moving from d 0 to 196 (Table 4). However, there was no visible trend in accuracy of ultrasonic measurement of ribeye area. One possible explanation for this result is that the sample sizes were smaller in the later measurement dates, however this also would hold true for the fat thickness measurements. The smaller groups at final measurement can be attributed to the selection process imposed by the feedlot operator. Correlation coefficients for the Brangus-X group indicated the same general tendencies as those from Salers-X's. There was a general trend of improvement in accuracy for fat thickness measurements and a general improvement trend for the ribeye area measurements except for the final measurement date, possibly due to the increased experience of the technicians. When evaluating the correlation coefficients for unit two, there was a noticeable trend of improvement for FTU2 and a range of unfavorably low correlations for REAU2 ($r=.00$ to $r=.38$).

Table 3. Means and standard errors of carcass measures by slaughter group[a].

DAY	N	WT(lb)[b]	FTU1(in)	REAU1(in^2)	FTC(in)	REAC(in^2)
70	6	1135 (63.6)	.47 (.07)	11.1 (1.35)	.40 (.07)	11.8 (1.15)
84	10	1022 (79.1)	.47 (.06)	11.2 (1.12)	.41 (.09)	11.0 (.85)
105	5	1198 (58.4)	.34 (.07)	11.7 (1.26)	.33 (.09)	12.4 (1.08)
111	6	1173 (60.9)	.43 (.09)	11.4 (1.36)	.36 (.15)	12.6 (1.43)
118	5	1081 (56.6)			.39 (.04)	12.0 (1.15)
125	3	1189 (48.2)	.40 (.07)	11.2 (.5)	.35 (.07)	12.5 (.08)
139	7	1130 (41.9)	.35 (.09)		.38 (.08)	11.7 (1.24)
153	10	1088 (38.8)	.40 (.07)	10.5 (.70)	.29 (.05)	12.0 (.70)
153	7	1055 (109)	.38 (.11)	10.2 (1.41)	.31 (.16)	11.7 (1.14)
166	15	1085 (58.8)	.31 (.07)	10.3 (2.91)	.22 (.15)	9.8 (5.0)
195	9	1049 (52.7)	.30 (.07)	10.7 (.71)	.26 (.09)	12.7 (.32)

[a] WT = live weight, FTU1 = ultrasonic fat thickness from Unit 1, REAU1 = ultrasonic ribeye area from Unit 1, FTC = carcass fat thickness, REAC = carcass ribeye area.

[b] Standard errors in parentheses.

Correlations between estimates from the two machines are also shown. For the fat thickness measurements, the correlations were high between machines for all days of measurement. The ribeye area correlations were moderate on all days except d 112. This low correlation resulted from the relative inaccuracy of the Tokyo Keiki unit on that measurement date. The comparison of the two machines indicates that both measured the traits similarly. However, Unit 1 had higher correlation coefficients for fat thickness in the early measurement dates while Unit 2 had higher correlations for ribeye area in the early measurements. In addition, there were differences in ease of operation with Unit 1 being lighter weight and more portable with internal calipers that were easier and quicker to use.

Expressed in Table 5 are the regression coefficients and R^2 values for weight and time on feed effects for both breed groups. For the Salers-X group, there was a linear effect ($P < .01$) of weight on FTU1 and time on feed on REAU1 with R^2 values of .51 and .18, respectively. In addition, time on FTU1 had a quadratic effect ($P < .01$) for the Salers-X group with an R^2 value of .57. The Brangus-X group had linear effects ($P < .01$) for weight on FTU1 and weight on REAU1 with R^2 values of .36 and .51, respectively. Quadratic effects ($P < .01$) were detected for time on FTU1 and time on REAU1 with .37 and .36 R^2 values respectively.

Table 5. Regression coefficients and R-squared values for weight and time effects on ultrasonic measurements[a].

		Salers-X	
Variables	b(Linear)	b(Quadratic)	R^2
FTU1 on WT.	00045(.000079)[b]	NS	.51
REAU1 on WT	NS	NS	
FTU1 on TIME		-.0000079 (.000001)	.57
REAU1 on TIME	.0102 (.0015)	NS	.18
FTUCWT1 on TIME		-.0000000056 (000000)	.30
REAUCWT1 on TIME		.000000178(.00000003)	.40

		Brangus-X	
	b(Linear)	b(Quadratic)	R^2
FTU1 on WT	.0005 (.00005)	NS	.36
REAU1 on WT	.0091 (.0006)	NS	.51
FTU1 on TIME		-.000016 (.000003)	.37
REAU1 on TIME		-.00012 (.00005)	.36
FTUCWT1 on TIME		-.000000015 (000000)	.23
REAUCWT1 on TIME	NS		

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[a] FTU1 = ultrasonic fat thickness from unit 1, REAU1 = ultrasonic ribeye area from unit 1, WT = live weight, TIME = days on feed.

[b] Standard error of regression coefficients.

Table 6. Prediction equations for weight and time effects on ultrasonic measurements[a].

Variables	Equations	SEE[b]	R^2
<u>Salers-X</u>			
FTU1 on WT	$Y = -.1676 + .00045(x)$*	.0018	.51
REAU1 on WT	Non Significant		
FTU1 on TIME	$Y = .1061 + .0023(x) - .0000079(x)^2$**	.0035	.57
REAU1 on TIME	$Y = 8.7795 + .0102(x)$*	.08	.18
FTUCWT1 on TIME	$Y = .0002 + .000002(x) - .000000006(x)^2$**	.000004	.30
REAUCWT1 on TIME	$Y = .013 - .00005(x) + .00000018(x)^2$**	.00000003	.40
<u>Brangus-X</u>			
FTU1 on WT	$Y = -.2073 + .0005(x)$*	.0025	.36
REAU1 on WT	$Y = 1.765 + .0091(x)$*	.32	.51
FTU1 on TIME	$Y = .1584 + .0033(x) - .000016(x)^2$**	.0055	.37
REAU1 on TIME	$Y = 8.8009 + .0368(x) - .00012(x)^2$**	.082	.36
FTUCWT1 on TIME	$Y = .0002 + .000003(x) - .00000002(x)^2$	.0000	.23
REAUCWT1 on TIME	Non Significant		

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[a] FTU1 = ultrasonic fat thickness from Unit 1, REAU1 = ultrasonic ribeye area from Unit 1, WT = live weight, TIME = days on feed.

[b] Standard error of estimate.

* Linear effects ($P < .01$).

** Quadratic effects ($P < .01$).

Shown in Table 6 are the prediction equations derived from the regression coefficients expressed in Table 5. Only the significant equations are presented with their respective standard errors of the estimates and R^2 values. The Y represents the predicted fat thickness or ribeye area measurement derived from X. The X represents either the weight of the animal or number of days on feed. These equations could be beneficial in predicting final fat thickness and ribeye area measurements but in some cases need to be used with caution due to low to moderate R^2 values. Graphical representation of the prediction equations for FTU on time and REAU on weight are shown in Figures 1 and 2, respectively.

Another way of expressing the ultrasonic measurements over time is to express the FTU1 and REAU1 on a per hundred weight basis (FTU1CWT and REAU1CWT). Figure 3 shows the visual trend for FTU1. When moving from d 0 to 196, there was a general upward trend followed by a plateau for both breed groups. The plateau may have been caused by the selection criteria imposed by the operator. The curve could possibly have continued on an upward movement instead of plateauing early.

A logical occurrence appears when REAU1CWT is presented graphically in Figure 4. As time increased, REAU1CWT gradually decreased for the Salers-X group probably due to a decrease in lean gain and increase in fat gain due to physiological maturing. However, the Brangus-X group did not decrease but had a flatter trend. This can be explained by their lesser time on feed from a physiologically maturer initial point.

DISCUSSION

The use of ultrasound allowed for moderate accuracy in monitoring the change in fat thickness and ribeye area during the feeding period. However a much larger sample size is needed for development of accurate prediction equations. Relationships with time and weight indicated that these factors should be standardized when comparing animals on the basis of ultrasonic measures. It is realized that weight and time on feed are highly related in these data. However, the evaluation of time effects above those associated with weight alone were felt to be important. This agrees with data presented by Turner et al. (1990) which indicated that age adjusted ribeye area and ribeye area per hundred weight are not suitable as singular traits but ribeye area should be used in combination with age, weight and fat thickness. With R^2 values in excess of 50% in the best-fit models, these data suggest that ultrasonic data obtained from animals varying in weight and age could be standardized using linear effects of weight or quadratic effects on time.

Due to the strong relationship between weight and measures of ribeye area ($R^2 =$ 51% in Brangus-X data), some researchers have suggested that weight is a better predictor of ribeye area than ultrasound. Changes in REAUCWT and FTUCWT shown in this work illustrate that evaluation of weight alone does not allow for detection of differences in degree of muscling and fatness, either static or across time. There is still considerable variability left after removing time effects from the FTUCWT and REAUCWT measures (coefficient of variation = 26.59% and 12.25% for FTUCWT and REAUCWT, respectively, in the Salers-X group).

The feedlot operator would be able to apply fat thickness equations like those derived in this study for a method of sorting cattle. Sorting feeder cattle by frame and backfat when entering the feedyard could result in more appropriate d on feed

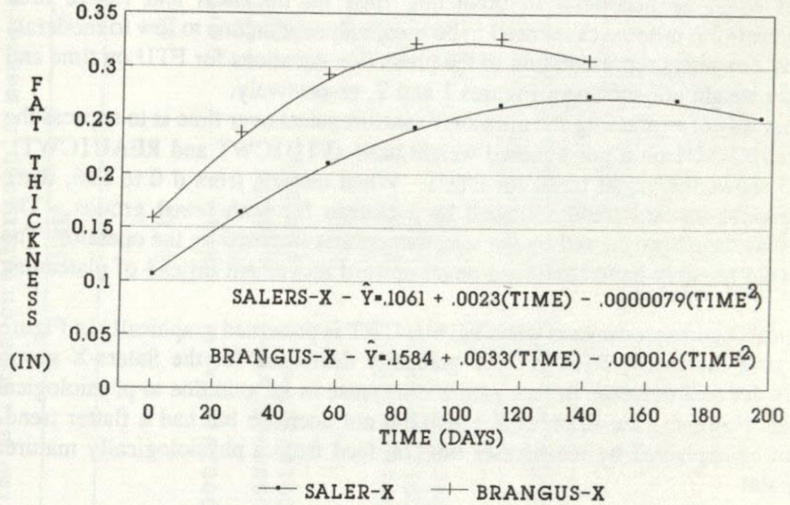

Figure 1. Regression of fat thickness on time.

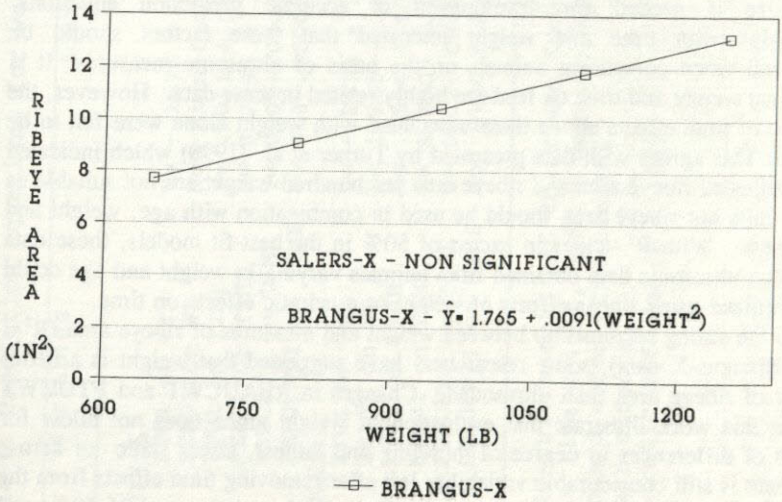

Figure 2. Regression of ribeye area on weight.

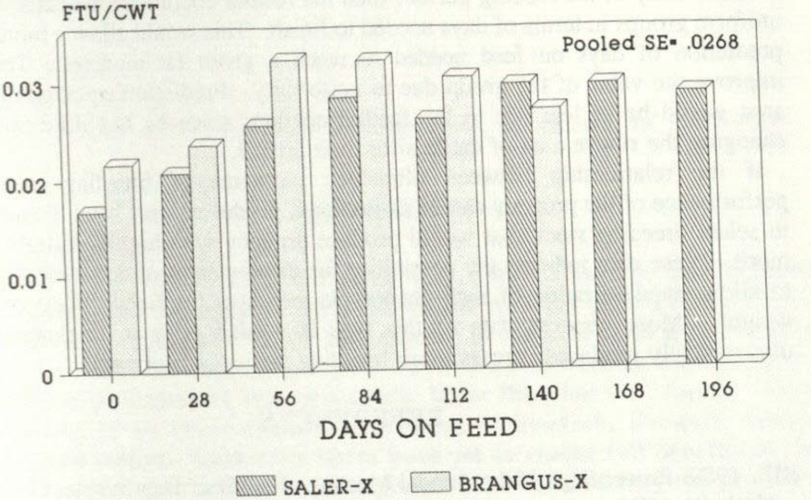

Figure 3. Fat thickness ultrasonic measurement means by day on per hundred weight basis for the Salers-X and Brangus-X groups.

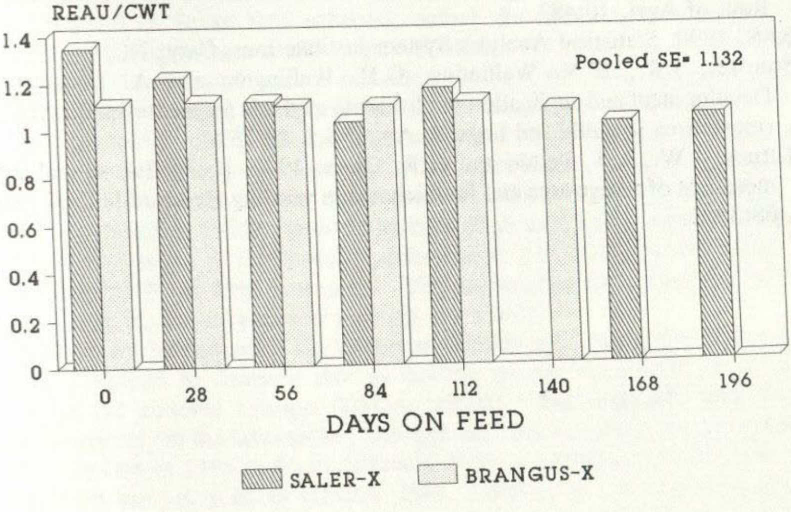

Figure 4. Ribeye area ultrasonic measurement means by day on per hundred weight basis for the Salers-X and Brangus-X group.

for cattle of different body types while achieving consistent and acceptable yield and quality grades across body type (Houghton, 1990). If a fat thickness measurement is taken early in the feeding period, then the feedlot could sort the cattle into more uniform groups in terms of days needed to finish. This would allow a more accurate prediction of days on feed needed to reach a given fat thickness. This should improve the value of the group due to uniformity. Prediction equations for ribeye area would be of less use to the feedlot operator since he has little influence in changing the ribeye area of cattle after their arrival.

If the relationship between ultrasonic measures of breeding animals and performance of the progeny can be determined, producers may have the opportunity to select breeding stock that would produce progeny with highly desirable carcass merit. These data indicate the possibility for development of adjustment equations to allow standardization of such phenotypic measures for fixed effects of age and weight. More research data of this type is needed prior to implementation of ultrasonically produced carcass merit breeding values in beef cattle.

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Evaluating the Financial Performance of Texas Farm Businesses in the 1980s

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ABSTRACT

The DuPont system of financial analysis is used to analyze the financial performance of the Texas farm sector during the recovery period of the 1980s. The results are compared with the performance of the U.S. farm sector during the same period. Although Texas farms showed a considerable improvement, their level of performance was consistently lower than for U.S. farms. Most gains appear to be concentrated in the areas of livestock, livestock related products and cotton. Cash crop farms have yet to realize full benefits of the farm recovery. These are the farms expected to be hit harder by the proposed cuts in farm subsidies under the 1990 Farm Bill. That may further slowdown the already slow farm recovery process in Texas.

KEY WORDS: ratio analysis, farm recovery, performance measures, farm sector.

Although the eleven billion dollar sales of Texas agricultural products in 1989 represent only 2% of Texas' total economic output, the agriculture industry is far more important than that share would suggest (USDA, 1991; Bullock, 1990). Texas ranks second in the nation in agricultural sales behind California, has more farms and ranches than any other state, and ranks first in sales of livestock, livestock related products and cotton (USDA, 1991; Bullock, 1990). The economic impact on the Texas economy is even more significant. Each dollar sale of agricultural products generates $3.16 in the state economy, more than oil and gas or manufacturing (Bullock, 1990). Since agriculture plays such a vital role in the Texas economy, an evaluation of its financial performance is desirable to determine the financial health of Texas farm businesses. This information can be helpful to farm borrowers, lenders, and investors in pointing out trends.

The 1980s boom-bust situation has left proportionally more Texas farm borrowers and lenders exposed to financial risk by causing greater variability in net farm income than the national average (USDA, 1990a). For example, following a nationwide recovery in the farm sector, although net farm income in Texas increased from $2.05 billion in 1985 to $3.01 billion in 1989, a turnaround in the farm real estate situation has yet to occur (USDA, 1991, 1990b). In contrast to increasing

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farm real estate values at the national level, the average per acre value of farmland and buildings in Texas has continually declined from a high of $694 in 1985 to $517 in 1989 (USDA, 1990b). Moreover, in 1988 when Texas net farm income was a record high $3.20 billion, only 37% of Texas farm businesses, compared with 46%of the U.S. farm businesses, had a favorable financial position, i.e., positive net farm income and a debt-to-asset ratio of less than 0.40 (USDA, 1991, 1990a). The collapse of farm real estate values that began in 1986 and a relatively large number of farm businesses with low or negative net farm income were partially responsible for a record number of Texas bank failures through 1989. That year they peaked at 133, two-thirds of all bank closings in the nation (Sharp, 1991).

Declining farmland values and a relatively high percentage of farm businesses with an unfavorable financial position in Texas at a time when the overall position of U.S. farm businesses was improving suggest the need for an in-depth evaluation of the Texas farm sector. This need is further evident in that past investments and loan decisions based primarily on capital gains and rising asset values have resulted in a record number of farm business foreclosures and bank failures in the state as those asset values have taken a sharp downturn (Klinefelter, 1987). The 1990 Farm Bill has added yet another reason for evaluation because under its provisions farmers will receive 15% less in subsidies for program crops and will face more uncertainty in marketing the production of any unsupported crop (Sullivan, 1991). The adverse effect on farm incomes caused by lower subsidies and increased uncertainty in the product markets may further slowdown the farm business recovery process in Texas.

Numerous studies have analyzed the financial performance of farm businesses from national, regional, and state perspectives (Morehart et al., 1988, 1990; Barbieri et al., 1989; Lines and Morehart, 1987; Penson, 1987; Lins et al., 1987; Lins, 1985; Lines and Zulauf, 1985; Hughes et al., 1985; and Musser et al., 1984). However, with the exception of Morehart et al. (1988, 1990) and Barbieri et al. (1989), the focus of all studies has been on the farm financial crisis of the early 1980s and not on the recovery period of the second half of that decade. The studies by Morehart et al. (1988, 1990) and Barbieri et al. (1989) describe the financial characteristics of U.S. farm businesses by region, type, and economic class in a given year, but make no comparative analysis over time. Moreover, no prior study has separately analyzed the financial performance of Texas farm businesses.

Therefore, the objective of this study is to evaluate the financial performance of Texas farm businesses during the farm recovery period of the 1980s and to compare it with the overall performance of U.S. farm businesses during the same period. The analyses and comparisons are made through the use of various financial ratios explained in the methodology section. The most common currently used measures of financial performance are reviewed in the following section.

CURRENTLY USED MEASURES OF FINANCIAL PERFORMANCE

The debt-to-asset ratio is the most commonly used indicator of the financial health of a farm business (Penson, 1987; Lins et al., 1987; Jolly et al., 1985). It is a balance sheet measure, computed by dividing the total liabilities by total assets at a specific point in time. The ratio is a measure of the financial solvency of a business if the business is sold. When used by itself, the debt-to-asset ratio is a poor indicator of a farm's financial position because it shows little about the income-generating potential of the business. For example, a relatively high debt-to-asset ratio does not always imply financial weakness. If the return on assets exceeds the cost of debt capital, then a high debt-to-asset ratio may reflect an appropriate decision by the management. However, in some other cases, it may reflect poor incomes and/or falling asset values (Lins et al., 1987). Given this limitation of the debt-to-asset ratio, a combined use of the balance sheet and income statement measures is considered more appropriate to evaluate the financial performance of farms (Penson, 1987; Lins et al., 1987; Jolly et al., 1985; Lins, 1985).

A few studies have analyzed the farm financial situation using other ratios in addition to the debt-to-asset ratio. For example, Jolly et al. (1985) used the debt-to-asset ratio and the return on equity ratio jointly to analyze financial stress among U.S. farms and to compare the performance of Iowa farms to that of all U.S. farms. While both income and balance sheet measures were used in this study, the analysis was based on only one year's data, and as Lins (1985) noted, "The proportion of farmers with negative net cash flows in any one year is not a reliable measure of financial stress."

Lines and Morehart (1987) developed a multidimensional ordinal variable using measures of solvency, liquidity, and profitability to assess U.S. farm financial health. The data were analyzed using a weighted ordinal logistic regression model. However, a major limitation of the model, as recognized by the authors, is that the observed data set precludes the use of exogenous variables that may be important to the analysis.

Penson (1987) suggested supplementing the debt-to-asset ratio and the rates of return on assets and equity with the times interest earned ratio, the financial leverage index, and the debt burden ratio to analyze farm financial conditions. He argued that the addition of only the rates of return on assets and equity to the debt-to-asset ratio was not sufficient for performance analysis because both rates of return could overstate (understate) the operative effectiveness of farmers in years of declining (rising) asset values. Therefore, a multiple performance criterion explained below is used to analyze performance of the farm sector in Texas.

METHODOLOGY

In this study, an extension of the DuPont system of financial analysis is used to evaluate the financial performance of Texas farm businesses (Weston and Brigham, 1981). The system can be stated as follows:

$$\begin{array}{lclclclcl} \text{Net} & & \text{Total} & & \text{Return} & & \text{Financial} & & \text{Return} \\ \text{Profit} & \text{X} & \text{Asset} & = & \text{on Total} & \text{X} & \text{Leverage} & = & \text{on} \\ \text{Margin} & & \text{Turnover} & & \text{Assets} & & \text{Multiplier} & & \text{Equity} \end{array}$$

Stated this way, the system brings together performance measures of profitability, efficiency, and solvency. The return on total assets, an overall measure of profitability, is used to compare farm operations over time. However, since both relatively high sales volume and the profitability of those sales can affect the return on total assets, it is important to isolate these two factors to evaluate the performance of farm businesses. This is accomplished by expressing the return on total assets as two separate ratios, the net profit margin and the asset turnover ratio.

The decomposition of the return on total assets into two relational components, the net profit margin and the asset turnover ratio, provides important information on the quality of management planning for profits and, therefore, to a large extent, loan repayment capacity.

The net profit margin measures the income the farmers produce after paying all costs of operating their businesses. It indicates their ability to control the level of farm business costs relative to the volume of revenues generated. The asset turnover ratio measures efficiency in asset management. The higher the value of this ratio, the more sales produced per dollar of assets invested. Turnover ratios lower than the overall industry average may represent possible under-utilization of the assets.

When a portion of a business's assets is leveraged (debt financed), the return on total assets may differ from the return on equity and the magnitude of any difference depends upon the degree of financial leverage which is measured by the debt-to-equity ratio. As the percentage of borrowed capital increases, the debt-to-equity ratio increases, indicating greater leverage. The use of borrowed capital can increase business profit and the return on equity capital. However, the converse is also true if the business is not profitable enough to have a return on total assets equal to or greater than the interest rate on borrowed capital. In that case, income earned on borrowed capital is insufficient to cover the interest charges. Given a combination of relatively high leverage and a low return on total assets, a business may be forced to use equity capital to pay part of the interest on borrowed capital. Thus, if used successfully, financial leverage increases returns to the farmer's capital; but if unsuccessful, it can contribute to an inability to pay fixed charge obligations and, ultimately, result in operating difficulties leading to financial distress or bankruptcy. Therefore, it is important to both farmers and farm lenders to evaluate the effects of financial leverage on profitability. The financial leverage multiplier which measures the percent of assets financed by net worth or equity and consequently provides an indicator of lender's risk, is also included.

Taken together, the three performance measures discussed above provide a basis for evaluating the financial performance of farm businesses over time. All ratios used in the study are defined in Table 1.

DATA

The data used in this study were obtained from Economic Indicators of the Farm Sector published annually by the U.S. Department of Agriculture. The publication provides data on farm sector balance sheet and income statement by state. Farm sector balance sheets contain the current market value of assets, liabilities, and net worth. Since the objective of this study is to analyze the financial strength of the farm businesses, personal assets and liabilities are not included on the balance sheets. Moreover, personal assets in most cases are not available to support business liabilities.

Farm sector income statements include cash and noncash components in both income and expense categories. Noncash income consists of home consumption of commodities produced on farms, imputed rental value of all farm dwellings, and the value of the change in farm business inventories. A farm business is defined as an establishment that sold or normally would have sold at least $1,000 worth of agricultural products during the previous year (Morehart et al., 1988).

Noncash expenses, on the other hand, include capital consumption (depreciation and accidental damage) and perquisites to hired labor. Net farm income reflects the net value of agricultural production during a calendar year. Using the data given in the state balance sheet and income statement, the financial ratios were computed for the Texas and U.S. farm sectors for the 1985-89 period. The results are presented in the following section.

Table 1. Definition of financial ratios used in the study.

Performance Criterion	Ratio	Definition
Efficiency	Net Profit Margin	$\frac{\text{Net Farm Income}}{\text{Gross Farm Income}}$
Efficiency	Total Asset Turnover	$\frac{\text{Gross Farm Income}}{\text{Total Farm Assets}}$
Profitability	Return on Assets	$\frac{\text{Net Farm Income}}{\text{Total Farm Assets}}$
Solvency	Financial Leverage Multiplier	$\frac{\text{Total Farm Assets}}{\text{Net Worth}}$
Profitability	Return on Equity	$\frac{\text{Net Farm Income}}{\text{Net Worth}}$

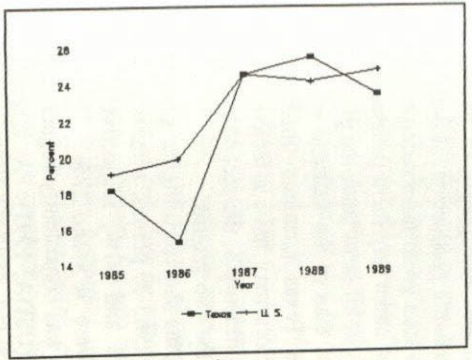
RESULTS

Five financial ratios used to evaluate the financial performance of the Texas farm sector for the 1985-89 period are presented in Table 2 and Figure 1. Based on the measures of profitability, efficiency, and solvency, the farm sector showed an improvement over time. The return on total assets, an overall measure of profitability, increased 64%, from 2.37% in 1985 to 3.88% in 1989. However, a combination of drought and low farm product prices resulted in the lowest rate of return on assets in 1986. Even though the drought conditions continued in 1987, return on total assets almost doubled compared to the previous year due largely to a 47% increase in government payments to farmers, from $978 million in 1986 to $1,441 million in 1987 (USDA, 1991).

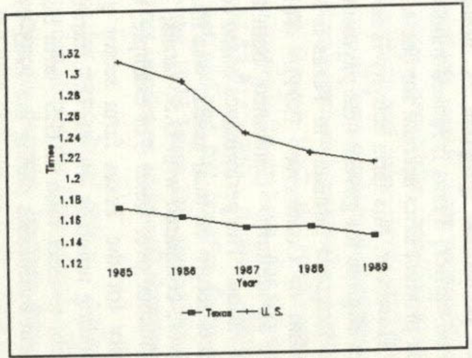
In 1988, a decline of nearly 20% in the government payments from their 1987 level was more than offset by increased cash receipts from the sale of farm products that reached a record high $10.2 billion (USDA, 1991). These record sales resulted from relatively high prices for cotton, food and feedgrains, and partial liquidation of herds due to poor grazing conditions and high feed costs brought on by the continuing drought (Bullock, 1990). The 1988 return on total assets was 4.07%, the highest during the 1985-89 period.

Table 2. Selected financial ratios of the Texas and U.S. farm sectors (calculated from USDA, 1991).

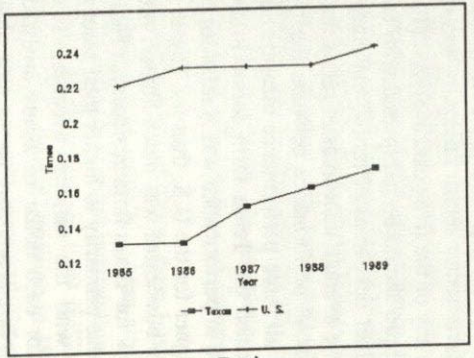
State and Year	Net Profit Margin (%)	Total Asset Turnover (Times)	Return on Assets (%)	Financial Leverage Multiplier (Times)	Return on Equity (%)
Texas					
1985	18.15	0.13	2.37	1.17	2.77
1986	15.17	0.13	1.95	1.16	2.27
1987	24.45	0.15	3.70	1.15	4.27
1988	25.40	0.16	4.07	1.15	4.68
1989	23.30	0.17	3.88	1.14	4.44
U.S.					
1985	19.02	0.22	4.25	1.31	5.59
1986	19.82	0.23	4.49	1.29	5.79
1987	24.43	0.23	5.74	1.24	7.15
1988	24.03	0.23	5.47	1.22	6.67
1989	24.65	0.24	5.88	1.21	7.09



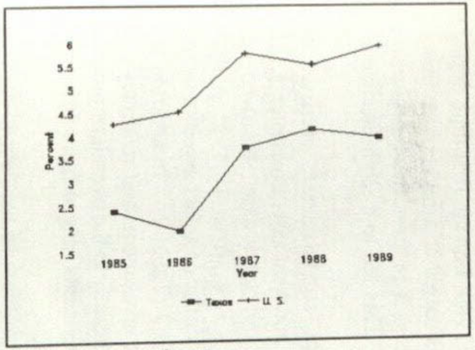
(a) Net Profit Margin



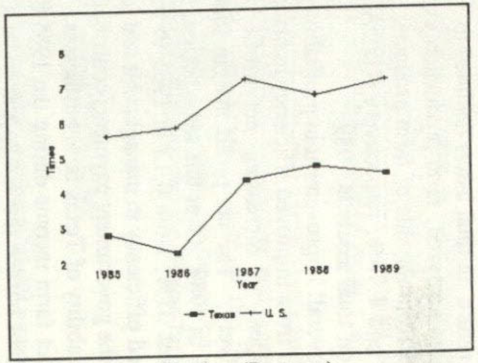
(d) Financial Leverage Mult.



(b) Asset Turnover Ratio



(c) Return on Assets



(e) Return on Equity (Percent)

Figure 1.
Selected financial ratios for
the Texas and U.S. farm sectors.

The return on total assets declined to 3.88% in 1989. For the first time during the five years analyzed, farm production expenses increased at a higher rate than cash receipts from the sale of farm products. The increases in these two categories were 5.95% and 4.96%, respectively (USDA, 1991). This led to a slight decline in the return on total assets in 1989.

The overall improvement in profitability of Texas farm businesses discussed above resulted from improved efficiency in management and total asset investments. These are evident in increasing net profit margins and total asset turnover ratios, respectively. The net profit margin increased 28.37%, from 18.15% in 1985 to 23.30% in 1989. Over this same period, sales per dollar of assets invested increased by almost 31%, from 0.13 in 1985 to 0.17 in 1989 (Table 2). In addition to the improved efficiency in management and total asset investments and relatively higher prices, the government payments contributed significantly to the overall improvement in profitability of Texas farm businesses. These payments ranged from 36% to 63% of the net farm income during the 1985-89 period.

The debt burden did not appear to be a serious problem as the debt-to-asset ratio never exceeded 0.14 during the study period (USDA, 1991). Given its relatively low financial leverage, the farm sector return on equity was only 14 to 17% higher than return on total assets in any of the five years analyzed (Table 2). However, the relatively low debt-to-asset ratio should be interpreted with caution. There may be a number of farms with higher debt-to-asset ratios, but since the data used in the study are aggregated data, the average debt-to-asset ratios may include some bias.

A comparison of the financial performance between the U. S. and Texas farm sectors shows that based on all three performance measures used in the study, the U. S. farm sector outperformed the Texas farm sector in each of the five years analyzed. Although the trend in performance was similar for both groups, the level of performance was much higher for the U.S. than for Texas. For example, return on total assets for U. S. farm businesses was much higher, ranging from 4.25% to 5.88% versus 1.95% to 4.07% for Texas farm businesses (Table 2). This difference in return on total assets was due primarily to higher total asset turnover ratios at the national level. Compared with the national average, Texas farm businesses generated less annual sales for each dollar of assets invested. This lower asset turnover ratio for Texas farm businesses may be, in part, due to the type of farm activities performed (program vs. non-program) and the quality of assets. As mentioned earlier, Texas is ranked number one in cattle production. Livestock and livestock product sales account for one-half of the total gross farm receipts (USDA, 1991). However, this farm activity is not covered under any farm program and is, thus, not eligible for government payments. Also, of all farm land, the proportional share of irrigated farmland in Texas is much less than at the national level (U.S. Department of Commerce, 1991). This makes Texas farmland unsuitable for intensive agriculture. Combined, both these factors may have affected the asset turnover ratios. The performance based on net profit margin, the second component that affects return on total assets, was mixed for the two groups.

However, compared with U.S. farms, Texas farms showed a higher growth rate in performance over time. For example, over the 1985-89 period, returns on assets and equity for the Texas farm sector grew 64% and 60%, respectively. The corresponding numbers for the U.S. farm sector were 38% and 27%.

The debt-to-asset ratio of U.S. farm businesses was consistently higher than for Texas farm businesses during the 1985-89 period (USDA, 1991). As a result, the

U.S. farm sector had a higher financial leverage multiplier in each of the five years studied. It ranged from 1.31 in 1985 to 1.21 in 1989. Combined, the relatively higher return on total assets and a successful use of higher financial leverage generated a return on equity for U.S. farm businesses ranging from 1.42 to 2.55 times that of Texas farm businesses (Table 2).

In general, both groups showed improvement in returns on total assets and equity, were successful in generating more sales per dollar of investment, and were able to reduce their debt during the 1985-89 period. However, in each of the five years analyzed, the level of performance with respect to each of the three criteria, profitability, efficiency, and solvency, was much lower for the Texas farm sector than for the U.S.

SUMMARY AND CONCLUSIONS

The financial ratio analysis of the Texas farm sector for the 1985-89 period shows a recovery from the financial stress of the early 1980's. Following a nationwide trend, the Texas farm sector realized higher returns on assets and equity and lower debt-to-asset ratios over this period. However, the recovery process has been relatively slow. As discussed in the results section, the financial performance of Texas farm businesses was at a relatively lower level than that of U.S. farms.

Even this relatively low performance of the Texas farm sector warrants a careful interpretation. The improved returns on assets and equity may be due, in part, to the declining value of farm assets which fell 10.3%, from $86.3 billion in 1985 to $77.4 billion in 1989 (USDA, 1991). As mentioned earlier, these rates of return could overstate the operative effectiveness of farmers in years of declining asset values (Penson, 1987).

The relatively low performance of Texas farm businesses has affected farm real estate values which continue to decline. Also, it has forced some farmers to liquidate part or all of their assets to retire outstanding debt that declined 22%, from $12.38 billion in 1985 to $9.68 billion in 1989 (USDA, 1991). As a result, farm sector equity in Texas fell 8%, from $74 billion in 1985 to $68 billion in 1989. In contrast, the U.S. farm sector equity increased almost 19% over the same period (USDA, 1991).

Besides livestock and livestock related products, major crops produced in Texas include cotton, food and feedgrains, oil crops, vegetables, and fruits and nuts. However, livestock and livestock related products and cotton accounted for all the gains in cash revenues generated from the sale of farm products during the 1985-89 period. Revenues generated by the other farm commodity groups have yet to reach 1985 levels (USDA, 1991). After declining through 1987, the 1989 cash receipts of $3,897 million from the sale of all farm crops in Texas have, for the first time, barely surpassed the 1985 cash receipts of $3,814 million (USDA, 1991). This shows that cash crop farmers have not yet realized full benefits from the farm recovery. Cuts in farm subsidies under the 1990 Farm Bill are bound to lower further their already low income levels. That implies an additional slowdown in the already slow recovery process in Texas.

The results have important implications for agricultural policy. As mentioned earlier, the low income level, not debt burden, beset the farm sector. Therefore, policies that are conducive to higher incomes are desirable because they not only solve the income problem, but indirectly, the debt problem as well. That means the implementation and continuation of favorable macroeconomic policies and "policies that encourage farmers' participation in educational and assistance programs that emphasize understanding, attainment, and maintenance of good farm business financial health" (Lines and Morehart, 1987) are crucial to farm sector recovery.

A major limitation of this study is its use of highly aggregated data. Ratios computed from highly aggregated financial statements tend to cause their interpretation to be more biased (Penson, 1987). Also, since the farm sector includes farms of all sizes and types, it is not possible to relate the results derived from aggregated data to those individual sizes and types of farm businesses. Even though the financial ratios developed separately for farm businesses of different size, type, and region are more meaningful to farmers, farm lenders, and investors in understanding their financial performance, lack of sufficient data at that detail level continues to be a problem for researchers. Fortunately, as the USDA Farm Costs and Returns Survey continues to refine and collect more data on farm businesses, researchers will have more flexibility in analyzing those data and interpreting results.

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Forecasting the Use of Irrigation Systems with Transition Probabilities in Texas

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ABSTRACT

An irrigation system transition probability matrix and a forecast of irrigation system adoption are estimated for Texas using the probability-constrained minimum absolute deviation (MAD) modeling approach. The results show that the adoption of advanced irrigation systems is slow, and that a transition from irrigated to dryland crop production is expected in the future.

KEY WORDS: irrigation system adoption, probability-constrained modeling.

Water availability is one of the most limiting factors of irrigated agricultural production in Texas. For example, the Ogallala aquifer provides 80% of the irrigation water in the Southern High Plains of Texas. Insignificant annual recharge, and continued mining of the Ogallala have resulted in declines of the aquifer's water table. As water levels decline, irrigation well yields decline, pumping costs increase, and the profitability of irrigated crop production is reduced. The depletion of the aquifer threatens the long-term stability of irrigated crop production and the agricultural economy of the Southern High Plains of Texas.

The adoption of water conserving irrigation systems and water conserving tillage technologies have been the common strategies followed to reduce irrigation water use. An alternative strategy for stabilizing the irrigated agricultural economy, may be to moderate the rate of ground water use and stabilize the ground water level by reducing irrigated acreage to acceptable levels. In fact, the trends of water table changes published by Musick et al. (1990) indicate that the rate of decline of ground water tables have been reduced in most areas of the Southern High Plains of Texas. In general, farmers seem to be moving away from wasteful irrigation practices or irrigated crop production due to low farm profits and high water pumping costs. However, individual users have little incentive to consider the effects of their withdrawals on future water table levels. Their actions could result in unacceptable ground water depletion rates. The transition from irrigated crop production to dryland crop production can be important to policy-makers considering alternative water conservation strategies. This information can also be valuable to those individuals interested in predicting expected depletion rates of ground water resources. The objective of this paper is to estimate irrigation systems adoption and the expected transition from irrigated to dryland crop production in Texas.

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BACKGROUND

Irrigation practices in Texas increased during the 1930s. Rapid irrigation development began in the late 1940s and peaked during the late 1970s. Thereafter, irrigated cropland declined due to ground water depletion (Lee, 1987). Irrigated cropland in Texas declined from a peak of 8.95 million acres in 1978 to 5.72 million acres in 1988 (Irrigation Association, 1988), a 36% reduction. The transition from irrigated to dryland crop production has been the major factor for the recent slow-down of ground water use (Lee, 1987).

The adoption of highly efficient irrigation systems has been another factor affecting the reduction of ground water use. Initially, irrigation systems were primarily gravity systems, including: gated pipe direct from source, open ditch, siphon tube, underground with valves, and flooding from ditches. The percentage of gravity irrigated acreage declined from 95% of the irrigated acreage in the mid-1950s to 40% in 1988. The decline in gravity irrigated acreage is primarily associated with the low water application efficiency of the gravity irrigation systems. The adoption of sprinkler irrigation systems in the 1960s greatly improved water conservation through better irrigation management and higher water application efficiencies. The use of conventional sprinkler systems, which include hand move, gun, side roll, and traveller, increased through the 1960s, thereafter their use declined due to the expansion of center pivot systems. In 1988, 19% of the irrigated acreage was irrigated by center pivot systems. There is also a small percentage of the irrigated acreage irrigated with newer irrigation systems such as low-energy precision application (LEPA) system, low-pressure sprinkler, and surge or cablegation techniques. These irrigation systems are not included in this investigation.

The transition from irrigated to dryland crop production and the adoption of more efficient irrigation systems have contributed to the reduction in the depletion rate of ground water resources. The estimation of a transition probability matrix provides useful information about the dynamic nature of irrigation system transition and the potential for water conservation.

A transition probability matrix was used by Schaible and Kim (1989) to forecast irrigation system transition in the Pacific Northwest. They estimated a transition probability matrix using the probability-constrained minimum absolute deviations (MAD) estimator (Buccola, 1982; Charnes, 1963; Charnes and Cooper, 1959; Johnson and Boehlje, 1981). Schaible and Kim (1989) showed that the probability-constrained MAD estimator is superior to the probability-constrained quadratic programming estimator when estimating transition probability with limited aggregate time series data.

In this paper, the transition probabilities of irrigation systems, and of irrigated to dryland crop production are estimated using the probability-constrained MAD estimator. A continuous series aggregate data for the state of Texas for the 1974 to 1988 period are used in this study. The transition probabilities of three irrigation systems and dryland farming are estimated. The states used in the transition probability matrix were gravity, conventional sprinkler, center pivot sprinkler, and dryland farming. The unique nature of this study is the introduction of dryland farming as a state. Schaible and Kim made the assumption that total irrigated cropland remained constant through time. This is a rather restrictive assumption, because total acreage of irrigated cropland changes due to the exit and the entry of dryland. The exclusion of dryland farming may cause the estimation of the transition probabilities to be biased, as the changes in the proportion of irrigation systems used may not represent the transition from one state to another.

THEORETICAL MODEL

The discrete-time stochastic process of finite Markov chain can be written as:

$$P[X_j,t+1:X_i,t, X_{i-1},t-1,\ldots,X_o,o] = P[X_j,t+1:X_i,t]. \quad (1)$$

Equation (1) implies that the probability distribution of the state at time t+1, depends only on the state at t and does not depend on the states of the chain passed through on the way to Xi at time t.

Given the assumption that for all states i and j and all time t, P[Xj,t+1:Xi,t] is independent of t, we have:

$$P[X_j,t+1:X_i,t] = P_{ij}, \quad (2)$$

where Pij is the transition probability from state i at time t to state j at time t+1. Equation (2) implies that the transition probability remains stationary over time, and Pij has the following properties:

$$P_{ij} \geq o \quad \text{for all i and j} \quad (3)$$

and

$$\Sigma_j P_{ij} = 1 \text{ for all i.} \quad (4)$$

Given the above information, the joint probability of Xj,t+1 and Xi,t can be written as:

$$P[X_j,t+1,X_i,t] = P[X_i,t]*P[X_j,t+1:X_i,t] = P[X_i,t]*P_{ij}. \quad (5)$$

Summing both sides of Equation (5) over all possible outcomes of the states Xi, the stochastic process then can be written as follows:

$$P[X_j,t+1] = \Sigma_i P[X_i,t]*P_{ij}. \quad (6)$$

Replacing P[Xj,t+1] and P[Xi,t] with the observed proportions Yj,t+1 and Xi,t, Equation (6) can be written in the form:

$$Y_j,t+1 = \Sigma_i X_i,t*P_{ij} + e_j, \quad \text{for all i and j}, \quad (7)$$

where Yj,t+1 is the observed proportion of state j at time t+1, Xi,t is the observed proportion of state i at time t, and ej is a random error term. Given Equation (7) and the time series data the Pij's can be estimated by appropriate regression techniques. The use of ordinary least squares estimators is not permissible due to the heteroskedasticity of the error terms. Kim and Schaible (1988) showed that the probability-constrained MAD estimator, P, is superior to the probability-constrained quadratic programming estimator. Thus, the probability-constrained minimum absolute deviations estimator is used to estimate Pij's in this study. A linear programming problem of absolute deviation minimization was set up as follows:

$$\text{Minimize } \Sigma_j \Sigma_t (Zj,t + Z'j,t), \tag{8}$$

Subject to:

$$\Sigma_i \, Pij = 1 \qquad \text{for all i,} \tag{9}$$

$$\Sigma_i \, Xi,t * Pij + Zj,t - Z'j,t = Yj,t+1 \tag{10}$$
$$\text{for all j and t, and } Zj,t,\ Z'j,t, \text{ and } Pij \geq 0.$$

Where Zj,t and Z'j,t are the absolute value of positive and negative deviations, respectively.

The assumption for the stationary Markov chain and the transition probability matrix is that the transition probability does not change over time. This assumption implies no new irrigation system inventions, no dramatic change in the pumping cost, no major droughts, and no significant changes in government programs.

ESTIMATION AND RESULTS

The total acreage of irrigated cropland in Texas increased to a peak of 8.95 million acres in 1978. Thereafter, as pointed out earlier, it decreased to 5.72 million acres in 1988. The irrigation acreage data were classified into four states: gravity irrigation, conventional sprinkler irrigation, center pivot irrigation, and dryland farming. For 1978 and earlier, the data for the irrigation states of gravity, conventional sprinkler, and center pivot were expressed as a percentage of the total irrigated acreage. The value for the dryland farming state was zero. For 1979 and thereafter, the value for each year's dryland farming was expressed as the difference between the total irrigated acreage in that year and 8.95 million acres. The data for all the states were expressed as the percentage of 8.95 million acres (the peak value of total irrigated acreage appeared in 1978). The data used is presented in Table 1.

The probability-constrained MAD modeling approach described above was applied to the irrigated acreage data using the General Algebraic Modeling System (World Bank, 1982). The transition probability matrix obtained was:

$$\begin{array}{l|llll}
 & GR & SP1 & SP2 & DR \\
\hline
GR & 0.938 & 0.011 & 0.028 & 0.023 \\
SP1 & 0.108 & 0.892 & 0 & 0 \\
SP2 & 0 & 0 & 0.937 & 0.063 \\
DR & 0 & 0 & 0 & 1
\end{array} \tag{11}$$

Where GR represents the gravity irrigation system, SP1 represents the conventional sprinkler irrigation system, SP2 represents both the center pivot sprinkler and the drip/trickle irrigation systems, and DR represents dryland farming.

The transition probability matrix above traces the transition of irrigation systems and dryland farming among the four states. Information contained in Matrix (11) can be interpreted as follows. Going across the GR row, the transition probability matrix indicates that: (1) 93.8% of the current cropland under gravity irrigation will remain under gravity irrigation; (2) it is expected that 1.1% of the current cropland under gravity irrigation will be transferred to conventional sprinkler irrigation; (3)

it is expected that 2.8% of the current cropland under gravity irrigation will be transferred to center pivot and/or drip/trickle irrigation; and (4) it is expected that 2.3% of the current cropland under gravity irrigation will be transferred to dryland farming.

The diagonal coefficients in Matrix (11) confirm Schaible and Kim's finding that farmers tend to remain with their initial investment. It seems that Texas irrigators using conventional sprinkler irrigation systems are more likely to change their irrigation system than irrigators using other irrigation systems. Also, as can be seen in Matrix (11), dryland farmers are not likely to adopt any irrigation system. In other words, if irrigators transfer to dryland farming, they are likely to remain with dryland farming. The transition from relatively inefficient irrigation systems to more efficient systems is slower than had been anticipated. As pointed out above, approximately 94% of irrigators using the gravity irrigation system are likely to remain with the gravity irrigation system, only 1.1% of those irrigators will adopt center pivot sprinkler irrigation systems, and 2.33% will transfer to dryland farming. Farmers using conventional sprinkler irrigation will not switch to center pivot sprinkler irrigation and dryland farming systems. About 6.3% of center pivot sprinkler users will be transferring to dryland farming. Overall, 8.6% of irrigated acreage is expected to be transferred to dryland farming.

Table 1. Irrigation data for the period of 1974-1988.

	System Proportion Acreage[1]				
Year	GR	SP1	SP2	DR	Total irrigated acreage
1974	0.7706	0.1878	0.0416	0	8500000
1975	0.7774	0.1756	0.0469	0	8618000
1976	0.7591	0.1749	0.0659	0	8200000
1977	0.7595	0.1634	0.0771	0	8900000
1978	0.7575	0.1624	0.0801	0	8950000
1979	0.6280	0.1575	0.0905	0.1265	7817681
1980	0.5994	0.1405	0.1050	0.1503	7604669
1981	0.5756	0.1313	0.1955	0.1741	7391660
1982	0.5540	0.1369	0.1145	0.1946	7208600
1983	0.5153	0.0603	0.1821	0.2217	6965636
1984	0.5127	0.0485	0.1832	0.2455	6752625
1985	0.4927	0.0481	0.1877	0.2679	6752000
1986	0.4559	0.0481	0.1922	0.3017	6750000
1987	0.4319	0.0469	0.1933	0.3267	6025745
1988	0.4079	0.0469	0.1933	0.3604	5724458

[1] GR = Gravity, SP1 = Conventional Sprinkler, SP2 = Center Pivot and drip/trickle, and DR = Dryland farming.

The transition matrix estimated in this study, also confirms Schaible and Kim's result that irrigators will not necessarily replace their aging irrigation systems with higher efficiency irrigation systems. This is because almost 11% of conventional sprinkler users will switch to gravity systems. Texas irrigators are different from Pacific Northwest irrigators, because no Texas irrigators using center pivot sprinkler irrigation systems will shift to gravity and conventional sprinkler irrigation systems. The switch back from conventional sprinklers to gravity irrigation may be explained due to the lack of the capital needed to replace fully depreciated irrigation systems, lack of management skills, or due to soil and topographic characteristics.

The time path of the irrigation and dryland states transition for the period 1989 to 2000 was predicted using the estimated transition probability matrix. Letting W(0) be the initial vector of proportions at time 0, the conditional expectation W(t:0) is given as:

$$W(t{:}o) = W(0)*P(n), \tag{12}$$

where n is the number of time periods, and P(n) is the n-step probability transition matrix. Given the initial transition probability matrix P, the n-step transition probability matrix can be obtained by:

$$P(n) = P^n. \tag{13}$$

Using the observed proportions in 1988 as W(0), the predicted proportions of the irrigation and dryland states were derived for the period 1989 to 2000, and are listed in Table 2.

Table 2. Predicted proportions of irrigation technologies for Texas[1].

Year	GR	SP1	SP2	DR
1989	0.3877	0.0463	0.1925	0.3738
1990	0.3686	0.0456	0.1913	0.3948
1991	0.3507	0.0447	0.1895	0.4135
1992	0.3338	0.0438	0.1874	0.4354
1993	0.3178	0.0427	0.1850	0.4548
1994	0.3027	0.0416	0.1822	0.4738
1995	0.288	0.0404	0.1792	0.4922
1996	0.274	0.0392	0.1760	0.5102
1997	0.2622	0.0380	0.1726	0.5276
1998	0.2499	0.0368	0.1691	0.5445
1999	0.2385	0.0356	0.1654	0.5609
2000	0.2275	0.0344	0.1617	0.5768

[1]GR = Gravity, SP1 = Conventional Sprinkler, SP2 = Center Pivot and drip/trickle, DR = Dryland Farming.

In 1988, approximately 36% of the total acreage was in dryland production, and the total irrigated acreage was 5.72 million (Table 1). Of the total irrigated acreage in 1988, approximately 61% was irrigated by gravity systems, 6% by conventional sprinkler systems, and about 30% by center pivot systems. By the year 2000, compared to 1988 it is expected that acreage under dryland farming will increase 21 %, the total acreage of irrigated land will be 3.75 million, and approximately 51% of the irrigated acreage land will be irrigated by gravity systems, 7% by conventional sprinkler systems, and 37% by center pivot systems. Thus, for the period 1988 to 2000, most of the changes are expected to occur in the transition from irrigated to dryland crop production.

To determine the validity of the estimated proportions in Table 2, the information expectation statistical test for a measure of badness of fit, as used by Schaible and Kim, was carried out. The information expectation test was calculated as:

$$I(P{:}P') = (N(t)/2)^{*}\ \Sigma_j\ [Pi(t) - P'i(t)]^2\ /P'i(t) \text{ for all } t, \tag{14}$$

where Pi(t) and P'i(t) are the observed and predicted proportions of the ith irrigation system and dryland state at time t, respectively. N(t) is the sample size in thousands of acres. The information expectation, I(P:P') approximately follows the Chi-Square distribution with (r-1) degrees of freedom, where r is the number of states. The test results are presented in Table 3 and indicate that for most of the years the computed statistic is less than the Chi-Square value at 0.05 probability level (7.85). This implies that for most of the years there is no significant difference between the observed and the predicted proportions.

Table 3. Computed test statistics between observed and predicted proportions.

Year	Computed test statistic[1]
1975	19.9167
1976	3.0877
1977	7.8159
1978	1.1507
1979	65.2794
1980	2.5102
1981	0.3571
1982	9.4154
1983	29.1903
1984	13.9561
1985	1.6105
1986	2.5699
1987	1.0286
1988	0.9199

[1] Chi-Square value 3, 0.05 = 7.85.

CONCLUSIONS

An irrigation system transition probability matrix and a forecast of irrigation systems and dryland farming adoption are estimated for Texas. The probability-constrained MAD modeling approach was used in this study. The results indicate that most of the changes in irrigated cropland in Texas are expected to occur in the transition from irrigation to dryland crop production, while the transition from relative inefficient irrigation systems to more advanced irrigation systems is slow. Assuming that the stationary Markov process holds, it is estimated that in the year 2000, approximately 65% of currently irrigated land will remain in irrigation, and 51% of that will be irrigated by gravity systems. That rapid ground water depletion and the apparent benefits from the adoption of more advanced irrigation systems have not influenced farmers away from inefficient irrigation systems, may suggest the existence of institutional and/or economic barriers that limit the adoption of advanced irrigation technologies.

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A Comparison of Microbial Cellulase and Live Cell Rumen Inoculum for Estimating *In Vitro* Digestibility of Range Grasses

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ABSTRACT

Three commercial-grade cellulase enzymes and a live cell rumen inoculum were used to compare *in vitro* digestible dry matter of five high cellulose grass species in advanced stages of maturity in the Trans-Pecos, Texas. Three prediction equations were developed to define the relationships between *in vitro* rumen inoculum techniques and those using cellulase enzymes. All microbial cellulase techniques reliably estimated digestibility, although the rumen inoculum provided a greater extent of digestibility ($P \leq 0.01$) than the cellulases. Different grass species exhibited varied levels of digestibility ($P \leq 0.01$). Prediction equations between the rumen fluid and cellulase techniques were well correlated ($r^2 = 0.69$ to 0.81) and highly significant ($P \leq 0.01$). These data suggest that enzyme digestibility estimates are effective and may be accurate predictors of live cell dry matter digestibility of range grasses consumed by ruminants.

KEY WORDS: alkali sacaton, Arizona cottontop, blue grama, IVDDM, Johnsongrass, sideoats grama, Trans-Pecos

Digestibility of feedstuffs containing cellulose is an important nutritive aspect of range forages. It is useful for livestock producers to know nutritive values of specific forages to apply effective grazing management and to improve supplemental feeding management for grazing animals. The method developed by Tilley and Terry (1963) is a standard procedure to assess *in vitro* digestible dry matter (IVDDM) of forages. This method, however, requires a readily available source of fresh rumen fluid from a ruminant fed a forage consistent with the samples to be analyzed. Rumen fistulated animals are expensive to obtain and maintain (Goto & Minson, 1977), and rumen fluid activity varies when taken at different times and from animals grazed on different forages. This variation results in poor precision (Tilley & Terry, 1963).

Recently developed methods involving microbial cellulase could be used to replace rumen fluid as the digestion media for *in vitro* digestibility assessments (Bughrara et al., 1985; Gabrielsen, 1986; Dickerson et al., 1988). The use of commercially

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available microbial cellulase as a digestion media would eliminate the need for rumenally fistulated animals, and potentially provide a reliable and repeatable method to analyze grazeable forages (Donefer et al., 1963). Microbial cellulases give accurate predictions of dry matter digestibility (Bughrara et al., 1985; Gabrielsen, 1986), but may not be as precise when used on coarse, low-quality forage (Bughrara et al., 1985; Dickerson et al., 1988). Marten et al. (1988) reported that immature plants are subject to more complete digestion with cellulase enzymes than mature forages.

The objectives of this study were to: 1) test different cellulase sources for repeatable cellulolytic activity for determination of IVDDM of forage grasses; 2) assess differences in digestibility estimates among selected range grasses; and 3) correlate IVDDM estimates of microbial cellulase solutions with those made with live cell rumen fluid inoculum to assess the utility of microbial cellulase digestion media as a predictor of dry matter digestibility.

MATERIALS AND METHODS

Five grasses were selected for analysis based on their regional abundance and importance as forage species in the Trans-Pecos of Texas: sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.]; blue grama, [*Bouteloua gracilis* (H.B.K.) Lag. *ex* Steud.]; Arizona cottontop [*Digitaria californica* (Benth.) Henr.]; Johnsongrass [*Sorghum halepense* (L.) Pers.]; and alkali sacaton [*Sporobolus airoides* (Torr.) Torr.]. Six individual plants of each species were collected at maturity on 3 October 1988 northeast of Alpine, Texas, and on 2 November 1988 on the Nation's Ranch between Fort Davis and Balmorhea, Texas. Each plant was clipped at ground level, placed in a paper bag and air dried. Plants were ground in a Wiley mill to pass a 0.040 in. mesh screen, and composite samples were made for each species and thoroughly mixed.

Percent IVDDM of the composite samples was determined using three different cellulase enzymes and rumen fluid. Commercially available cellulases derived from *Penicillium funiculosum* and *Aspergillus niger* were used, as well as Cabisco Chemicals No. 85-3630. Rumen fluid was obtained from a rumenally fistulated steer grazed on mature standing forage in pastures with botanical composition comparable to those pastures sampled for grasses.

For the cellulase enzyme treatment the procedure outlined by Dowman and Collins (1982) was followed. This procedure was modified by using a consistent level (0.70 oz./qt.) of each cellulase, with 0.007 oz. of each forage sample, instead of varying the amounts of cellulase enzyme. A constant level of cellulase enzyme may affect the efficacy of one enzyme more than others, but provides a baseline to compare each treatment. The *in vitro* digestibility technique with rumen fluid inoculum followed procedures outlined by Ellis (unpublished), using 0.018 oz. samples of each forage. For each technique, duplicate subsamples, together with duplicates of a standard forage (oat hay) were analyzed. Each subsample pair was averaged and treated as a single observation. Only pairs with less than ± 3% difference from the pair mean were used as an observation, and four replicate observations were analyzed for each combination of grass species and cellulase enzyme. Digestibilities were corrected for bias using the standard forage as outlined by McLeod and Minson (1979).

Analysis of variance and Duncan's new multiple range test were used to identify significant differences ($P \leq 0.01$) among species and digestion treatments. Linear regression and correlation procedures were performed to determine predictability of cellulase digestibilities relative to rumen fluid inoculum. Samples of all species were combined for each source of cellulase enzyme providing a sample size of 16 for each regression analysis. All analyses were performed using MSTAT (Freed et al., 1987).

RESULTS AND DISCUSSION

Each digestion media had an apparent cellulolytic effect on the mature forages tested, and each dry matter digestibility was significantly different ($P \leq 0.01$) when compared using one-way analysis of variance. Rumen fluid inoculum was most effective (49%), followed by *P. funiculosum* (43%), Cabisco No. 85-3630 (39%) and *A. niger* (33%). *Aspergillus niger* was the least effective enzyme source, in contrast with results from Clark and Beard (1977) who reported that *A. niger* was able to degrade a wide variety of substrates. Extent of digestion was greater for rumen fluid inoculum than for the cellulase enzymes, but all sources exhibited similar efficiencies of digestibility among the grass substrates (Table 1).

Table 1. Mean percent digestibilities (±SE) for each grass species within each digestion media.

Enzyme Source	Johnsongrass	Arizona cottontop	Sideoats grama	Blue grama	Alkali sacaton
			%		
Rumen Fluid	69.27 (0.57)	53.20 (0.27)	47.48 (0.62)	38.12 (1.41)	37.23 (0.86)
Penicillium funiculosum	55.74 (1.58)	42.78 (2.29)	40.73 (0.91)	39.63 (1.32)	34.35 (1.98)
Cabisco Chem. No. 85-3630	52.53 (0.86)	38.12 (1.62)	37.51 (0.29)	36.53 (1.41)	25.08 (1.87)
Aspergillus niger	45.93 (1.89)	30.97 (0.20)	31.87 (0.54)	32.26 (3.40)	30.66 (1.02)

Johnsongrass (55%) was significantly more digestible than other grasses. Arizona cottontop (41%) and sideoats grama (40%) were intermediate in IVDDM whereas blue grama (37%) and alkali sacaton (32%) were significantly less digestible than the other species. A two-way analysis of variance of the data produced a digestion media by grass species interaction, demonstrating a forage-specific response to different cellulase sources. This indicated that certain cellulases may be more effective in hydrolyzing dry matter in particular grasses and suggests that within a comparison trial, the same digestion media and technique should be applied to all samples for results to be comparable.

Estimates of IVDDM using each cellulase source were significantly correlated ($P \leq 0.01$) with the IVDDM estimates using the rumen fluid source (Table 2). The coefficients of determination were lower than those found by Bughrara et al. (1985), but their values were derived for individual grass species, rather than combined species. In addition, grasses used in the current study were coarse, mature warm season species, recognized as having low digestibilities (Barton et al., 1976; Dickerson et al., 1988). Results of this study were comparable to those found for mixed species composition analysis (Dickerson et al., 1988), which is more representative of rangeland grazing conditions.

Table 2. Regression equations and coefficients of determination (r^2) for three cellulase enzymes predicting digestibility based on live cell rumen inoculum IVDDM.

Cellulase enzyme	Regression	r^{2**}
Penicillum funiculosum	$Y=-9.99+1.384x$	0.81
Cabisco No. 85-3630	$Y=-6.06+1.410x$	0.80
Aspergillus niger	$Y= 6.37+1.285x$	0.69

**All coefficients of determination significant ($P<0.01$).

Correlations (r=0.83 to 0.91) among the three cellulase sources and rumen fluid were also significant ($P \leq 0.01$). Because cellulases hydrolyze the same beta-bonds in cellulose, correlations should be high; however, efficacy of different cellulases would be expected to vary. The regressions in Table 2 indicate that the cellulase enzymes used provided reliable predictors of rumen fluid digestibility for mature warm season range grasses. These results, as well as those of others (Donefer et al., 1963; McLeod & Minson, 1982; Bughrara et al., 1985; Dickerson et al., 1988), suggest that the use of cellulase enzymes can provide accurate and lower cost evaluations of IVDDM than the use of rumen fluid.

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Vegetation Response to Continuous versus Short Duration Grazing on Sandy Rangeland

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ABSTRACT

This 8-year study compared the response of rangeland vegetation under continuous grazing vs. short duration grazing management systems. The study was conducted on a native rangeland site with a sandy soil in the Texas Rolling Plains. Yearling steers grazed the continuous grazing and short duration grazing paddocks at approximately the same stocking rate so that the study's comparison between grazing systems was not confounded by stocking rate. The continuous grazing treatment averaged 25.5 steer days acre^{-1}year^{-1} while the short duration grazing treatments averaged 27.0 steer days acre^{-1}year^{-1}. The short duration grazing treatments varied during the 8-year study, ranging from 4- to 36-paddock rotations. Plant species composition and forage production were monitored in all treatment paddocks. Over the entire 8-year study period, no significant changes in plant species composition or forage production were detected between continuous grazing and short duration grazing treatments.

Grazing management systems designed to allow plant recovery after grazing are reputed to increase the yield from desired forage plants more so than continuous grazing. One widely promoted rotational grazing system is short duration grazing (SDG). Savory and Parsons (1980) indicated that after SDG is properly applied "there is usually an increase in herbage production which frequently requires an increase in herd size." Further, Savory (1978) stated, "Our experience has been that doubling the stocking rate has been the rule rather than the exception with properly planned and executed short duration grazing." Others are more skeptical, insisting that one should not expect to increase stocking rates by more than 30% with these systems and that they are more valuable for maintaining productivity of rangelands and pastures than for increasing forage production (Gammon, 1984). After careful consideration of available research on SDG, Pieper and Heitschmidt (1988) concluded that stocking rate will always be the overriding factor affecting grazing impacts on rangelands. Van Poollen and Lacey (1979) also concluded that

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stocking rate was more important than grazing system in maintaining or improving range forage production.

To find out whether we could increase forage production through SDG, we initiated a study in the Rolling Plains of Texas in 1980. Our major objective was to compare forage yield and species composition changes under continuous *versus* short duration grazing management in a multi-year study.

SITE DESCRIPTION

The study site is native range on a sandy soil located in Garza County, approximately 10 mi northeast of Post, Texas, in the Rolling Plains (Gould, 1975). The average growing season is 216 days, beginning about 5 April and terminating on 7 November. Minimum daily temperatures average 27 F and occur during January. The average maximum temperature is 95 F and occurs in July. Annual Class A pan evaporation averages 100-105 inches. Winters are characteristically dry with low rainfall. Average annual precipitation is 18.8 inches, 75% of which occurs between April and October (Richardson et al., 1965).

The study site soil is a Brownfield fine sand, a member of the loamy, mixed thermic, arenic Aridic Paleustalfs (Richardson et al., 1965). The range site is a deep sand and is in mid-seral ecological condition. Climax vegetation for the site is a tallgrass prairie with scattered sand shinnery oak (*Quercus havardii*) mottes. Currently, the site is dominated by sand shinnery oak, sand sagebrush (*Artemisia filifolia*), yucca (*Yucca glauca*), western ragweed (*Ambrosia psilostachya*) and a variety of grasses including fringed signalgrass (*Brachiaria ciliatissima*), sand dropseed (*Sporobolus cryptandrus*), hooded windmill grass (*Chloris cucullata*), little bluestem (*Schizachyrium scoparium*), fall witchgrass (*Leptoloma cognatum*), and sand paspalum (*Paspalum setaceum*).

METHODS AND MATERIALS

The 80-acre study site was divided into a 20-acre continuously grazed paddock, four 5-acre paddocks, and four 10-acre paddocks. Because yearling steers were used to impose treatment and were not on study paddocks continually, no attempt was made to obtain animal performance data. Rather, evaluation of vegetation response among grazing treatments was the overall objective of the study. Although treatments varied somewhat over the 8-year study period, in each year continuous grazing was compared to SDG. At least four paddocks and up to 36 paddocks were used for the SDG treatments. Gammon (1984) found 6 to 10 paddocks sufficient to provide the desired range recovery. More paddocks proved to be of limited value. The variations in SDG used in this study are described below.

Grazing Systems

Treatment Year 1 (1980)

Continuous grazing was compared with two simulated 8-paddock SDG rotations. Each simulated SDG system consisted of four paddocks grazed intermittently as if they were four consecutive paddocks within an 8-paddock rotation. Steers were moved to nearby pastures for the time required for the animals to have grazed the other four paddocks that did not exist (Gammon and Roberts, 1980). One SDG system was stocked at 1.6 times the continuous rate and we tried to stock the other SDG system at 2 times the continuous rate. Each paddock was rested about 50 days after being grazed.

Treatment Years 2 through 6 (1981-1985)

Continuous grazing was compared to simulated 18- and 36-paddock SDG rotations. Stocking rate was kept approximately the same among grazing treatments. Four paddocks were grazed under each SDG treatment for the prescribed period and animals were moved to adjacent pastures for the time required for them to have grazed the other 14 or 32 paddocks that did not exist. Each paddock was rested for about 50 days after being grazed.

Treatment Year 7 (1986)

Continuous grazing was compared to four simulated 6-paddock rotations. Stocking rate was the same among grazing treatments. The four 10-acre paddocks were halved so the study then had 12, 5-acre paddocks in addition to the continuous paddock. Only three paddocks existed for each of the four sets so the animals were removed from the paddocks for the amount of time required to have grazed the non-existent paddocks in each set. Paddocks were rested for an average of 38 days during this grazing season.

Treatment Year 8 (1987)

Continuous grazing was compared to a 4-paddock and an 8-paddock SDG rotation. Paddocks were rested 21 and 49 days, respectively, for the two SDG treatments. Stocking rate was similar among grazing treatments.

Stocking Rates

Proper stocking rate for the area is about 24.3 steer days acre^{-1} under yearlong continuous grazing. At this stocking rate, about one-third of the usable forage is harvested during winter when plants are dormant. To significantly increase stocking in this study, our goal was to stock each treatment for at least 24.3 steer days acre^{-1} during the growing season only (generally from March or April to October or November). Beginning and ending dates (which varied among years because of variability in spring soil moisture necessary for green-up of vegetation), steer numbers, and other data are given in Table 1.

SDG paddocks were sampled in two sets referred to as SDG-1 and SDG-2. SDG-1 samples were from the SDG treatments with fewer paddocks each year.

Vegetation Sampling

At least four 100-point step-point transects in each paddock (Evans and Love, 1957) were used to estimate species composition during 1980, 1983, 1984, and 1987. Shrub overstory composition was estimated by recording whenever a sample point occurred beneath a shrub's canopy. Forage standing crop was estimated from 20 caged 4.8-ft^2 plots per treatment each year of the study. Current year's herbaceous growth was clipped to a 1-inch stubble height and oven-dried at 140 °F for 48 hours prior to weighing. Standing crop was measured during late July or August during 1980-1982 and later in the fall other years.

Data Analysis

Analysis of variance was used to test the hypothesis that plant species composition and forage production did not differ between grazing treatments. Grazing treatments (continuous and short duration) were not replicated in space. However, it is possible to test treatment effects, year effects, and the treatment x year interaction with analysis of variance if the statistical inferences drawn are limited to the particular pastures in the study (Wester, 1992).

Table 1. Grazing season and stocking rates for the grazing treatments.

Year	Treatment	Date		Steers	Steer days
		Begin	End	(No.)	per acre
1980	Continuous	28 Mar	11 Nov	2	22.8
	4-Paddock SDG (1.6 X)[1]	28 Mar	17 Nov	10	36.5
	4-Paddock SDG (2.0 X)[1]	28 Mar	17 Nov	10	39.5
1981	Continuous	15 Apr	25 Sept	3-4	38.9
	18-Paddock SDG	16 May	22 Oct	46-51	38.0
	36-Paddock SDG	16 May	22 Oct	45-51	38.0
1982	Continuous	9 Apr	17 Dec	2	25.2
	18-Paddock SDG	9 Apr	2 Nov	18	25.2
	36-Paddock SDG	9 Apr	2 Nov	18	25.2
1983	Continuous	11 Mar	1 Nov	2	23.5
	18-Paddock SDG	11 Mar	7 Sept	18-22	25.7
	36-Paddock SDG	11 Mar	7 Sept	18-22	22.7
1984	Continuous	13 Jun	25 Sept	2	10.4
	18-Paddock SDG	13 Jun	25 Sept	19	12.3
	36-Paddock SDG	13 Jun	25 Sept	19	10.4
1985	Continuous	4 May	29 Jan[2]	2	27.0
	18-Paddock SDG	15 May	7 Mar	17	24.1
	36-Paddock SDG	15 May	7 Mar	17	23.2
1986	Continuous	13 May	13 Oct	3-7	36.2
	6-Paddock SDG	13 May	17 Oct	4-9	36.2
	6-Paddock SDG	13 May	17 Oct	4-9	36.2
1987	Continuous	29 Apr	2 Sept	2-4	19.6
	4-Paddock SDG	29 Apr	2 Sept	3-6	19.4
	8-Paddock SDG	29 Apr	2 Sept	3-6	19.3

[1] Stocked at 1.6 or 2 times the continuous rate.
[2] Ending date in 1986.

RESULTS AND DISCUSSION

Grazing animals encountered a lack of forage before the grazing season ended in the double-stocked pastures in 1980. This prohibited us from attaining twice the number of steer days acre^{-1} that we had obtained with continuous grazing. Consequently, in each of the remaining years of the study, we attempted to maintain all stocking rates equal among grazing treatments. Our objective was to test if short duration grazing (SDG) provides a differential vegetation response to continuous grazing management when stocking rates are similar for both grazing systems.

Precipitation during the study period varied from well above the 18.8-inch long-term annual average most years to slightly below average during 1982 and 1984 (Table 2). Growing season precipitation (January-September) in 1983 and 1984 was only about half that of the other years of the study, and forage production consequently was reduced during these dry years. Despite low forage production, stocking rates were maintained at about the target rate (24.3 steer days acre^{-1}) during 1983 (Table 1). However, a dry spring and 2 consecutive dry growing seasons with low forage production forced a reduced stocking rate (about 11 steer days acre^{-1}) in 1984. In 1987, the stocking level was below target because we terminated the study early: the grazing impact through the summer was at the target rate, vegetation sampling had been completed, and we believed that nothing would be gained by two more months of grazing. Throughout the 8-year duration of the study, stocking rates averaged 25.5 and 27.0 steer days acre^{-1} for continuously grazed and SDG paddocks, respectively.

Table 2. Rainfall recorded during the study near Post, Texas.

Year	Jan - Mar	Apr - Jun	Jul - Sept	Oct - Dec	Total
	Inches				
1980	1.33	8.09	9.38	3.13	21.93
1981	2.31	8.57	5.88	8.02	24.78
1982	1.15	11.70	2.13	3.10	18.08
1983	2.62	5.50	1.28	11.78	21.18
1984	0.56	3.20	3.96	8.02	15.73
1985	2.29	8.26	7.35	7.92	25.82
1986	0.20	6.71	9.61	6.58	23.10
1987	3.28	12.53	7.30	TRACE	(23.11)

Nine grasses, 6 forbs and 1 shrub comprised 80 to 90% of the species composition on study pastures (Table 3). Eight of the 9 grasses are traditionally considered increasers or invaders under heavy continuous grazing (Richardson et al., 1965). Little bluestem was the only grass present that tends to decrease under continuous grazing. Of the forbs, only western ragweed acts as an increaser under continuous grazing. Erect dayflower (*Comelina erecta*), a palatable plant, is expected to decrease under heavy continuous grazing. All other forbs were annuals whose abundance depended on climatic conditions.

Over the 8-year study period, no changes were detected ($P>0.05$) in species composition due to grazing system. Generally, species changes from year to year in one grazing treatment were reflected by similar changes in other treatments. Apparent trends due to treatment were inconsistent. For example, from 1980 to 1987, shrub understory composition declined from 14 to 8% under continuous grazing with little change occurring in the SDG treatments; nevertheless, shrub overstory increased 6 to 9% in all treatments (Table 3). Sand shinnery oak overstory increased 10% from 1980 to 1987 in all treatments. However, sand shinnery oak had no more understory hits than in 1980. This indicates that the increase in oak overstory involved a larger canopy spread that was not accompanied by an increase in plant numbers. Fringed signalgrass, a stoloniferous species that is opportunistic in covering bare ground in sandy ranges, increased 14% under continuous grazing, and 6 and 13% in the two SDG treatments (Table 3).

Plant cover changes attributable to climatic variation were conspicuous between 1983 and 1984 due to unusual weather in 1983. May was a reasonably good forage growth month in 1983 with 3.24 inches of rainfall. However, with only 0.93 inches of rainfall from the end of May to 15 July, there was little forage growth. Also, August and September rains were insufficient to provide plant growth. Then, over 9 inches of rain fell from 7 to 20 October, and there was a small amount of plant growth. Three weeks of record cold in December 1983 (NOAA, 1983) caused severe winter injury or death of many grass plants. Consequently, grass species composition declined in 1984 by half in all grazing treatment pastures, and forb and shrub composition approximately doubled. We believe that the regrowth following the 15 July rain and the mid-October rains was insufficient to recharge root and stem base carbohydrates. Consequently, the severe cold in December killed many of the weakened grasses and others had only one or two live tillers per plant during the summer of 1984. The composition of the longer-lived perennials, such as little bluestem and purple threeawn (*Aristida purpurea*), was not affected by these climatic events. By 1987, the grasses had nearly recovered to their original composition. The stoloniferous fringed signalgrass actually increased its coverage.

Forage production varied considerably from year to year (Table 4) depending on rainfall and other climatic influences (e.g., winter-killed grasses in 1983-84). However, changes in standing crop due to grazing treatment through the eighth growing season were not statistically significant ($P>0.05$).

Table 3. Species composition (%) from step-point transects.

	1980			1983			1984			1987		
	CONT	SDG 1[1/]	SDG 2	CONT	SDG 1	SDG 2	CONT	SDG 1	SDG 2	CONT	SDG 1	SDG 2
Grasses												
Aristida purpurea	1	1	1	2	2	1	2	2	3	2	2	3
Brachiaria ciliatissima	26	21	20	24	21	20	17	8	10	40	34	26
Cenchrus incertus	5	4	6	13	9	6	1	2	2	5	5	6
Chloris cucullata	5	13	10	4	6	8	2	2	3	3	2	5
Leptoloma cognatum	10	8	10	10	8	11	2	1	1	5	2	8
Paspalum setaceum	6	5	6	9	6	6	1	1	1	7	6	6
Sporobolus cryptandrus	6	8	8	8	6	4	4	7	6	5	5	4
Schizachyrium scoparium	1	2	1	T[2/]	2	1	2	4	4	1	2	2
Stipa comata	T	1	1	T	1	2	T	T	T	T	1	2
Other grasses	6	10	5	2	5	6	5	5	2	2	9	6
Total grasses	66	73	68	72	66	65	36	32	32	70	68	68
Forbs												
Ambrosia psilostachya	8	7	6	6	9	8	5	5	3	2	2	2
Aphanostephus ramosissimus	2	1	1	2	2	2	14	14	10	6	5	6
Eriogonum annuum	2	1	2	3	2	3	5	2	2	3	2	2
Hymenopappus flavescens	4	2	3	1	T	T	0	0	0	1	1	1
Comelina erecta	1	T	T	1	1	T	1	1	1	1	T	1
Heterotheca latifolia	T	0	T	1	2	3	6	10	3	2	1	1
Other forbs	3	4	6	5	7	8	7	7	13	7	9	4
Total forbs	20	15	18	19	23	24	38	39	32	22	20	17
Shrubs												
Quercus havardii	14	8	12	7	8	7	24	21	27	7	9	12
Other shrubs	0	4	2	2	3	4	2	8	9	1	3	3
Total shrub understory	14	12	14	9	11	11	26	29	36	8	12	15
Shrub overstory												
Artemisia fillifolia	1	3	2	1	1	1	1	2	3	1	3	2
Quercus havardii	28	24	33	21	22	18	26	27	32	38	33	43
Xanthocephalum sarothrae	1	5	3	1	1	2	1	1	2	T	1	1
Yucca glauca	1	2	2	2	2	1	1	2	2	1	3	3
Other shrub overstory	1	0	2	0	0	0	0	1	0	1	0	1
Total shrub overstory	32	34	42	25	26	22	29	33	39	41	40	50

[1/] SDG systems divided into 2 sets. SDG 1 is SDG treatment having fewer paddocks each year.

[2/] T indicates values under 0.5%.

Table 4. Standing crop of herbaceous plants for eight years under continuous and two levels of short duration grazing management.

Year	Treatment	Grass	Forbs
		lbs/acre	
1980[1]	Continuous	778	304
	4-Paddock SDG (1.6 X Continuous)	716	134
	4-Paddock SDG (2 X Continuous)	744	451
1981[1]	Continuous	945	614
	18-Paddock SDG	834	389
	36-Paddock SDG	978	433
1982[1]	Continuous	954	366
	18-Paddock SDG	783	312
	36-Paddock SDG	957	550
1983[2]	Continuous	286	239
	18-Paddock SDG	308	236
	36-Paddock SDG	342	182
1984[2]	Continuous	282	182
	18-Paddock SDG	197	250
	36-Paddock SDG	266	177
1985[2]	Continuous	1474	21
	18-Paddock SDG	1377	23
	36-Paddock SDG	1097	9
1986[2]	Continuous	1513	Trace
	6-Paddock SDG	1549	4
	6-Paddock SDG	1260	Trace
1987[2]	Continuous	1468	320
	4-Paddock SDG	1315	228
	8-Paddock SDG	1499	302

[1] Vegetation clipped in late July or August.
[2] Vegetation clipped in October or November.

CONCLUSIONS

By maintaining equivalent stocking rates among grazing treatments (except for the first year), any differences in vegetation response among treatments are likely due to grazing system and not stocking rate. During 8 years, species composition changed dramatically among years but little variation existed among grazing treatments, indicating that climatic variation had more influence on species composition in this study than grazing system. Likewise, standing crop of vegetation varied greatly among years but no difference in standing crop existed among grazing treatments ($P > 0.05$).

This study supports a growing body of research that shows stocking rate is more important than grazing system in managing natural rangelands (Gammon, 1984; Skovlin, 1987; Pieper and Heitschmidt, 1988; Bryant et al., 1989; Fourie and Bransby, 1988). Nevertheless, we believe that continuous grazing has the least potential of any grazing system for increasing the abundance of desired plants on rangeland (Gammon, 1984). We also believe that most any grazing system can maintain range condition, provided that the range is not overstocked. However, if one overstocks no grazing scheme will be effective in maintaining or improving range condition.

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Broiler Chick Response to Feeding Heat-Treated Ground Full-Fat Raw Soybeans

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ABSTRACT

Two separate experiments were conducted. In each experiment 440 one day-old commercial broiler chicks were fed starter diets formulated to be isonitrogenous and isocaloric, and containing either commercially processed soybean meal or ground full-fat raw soybeans heated at 100 C and 121 C for 30 and 60 min. The chicks were separated by sexes and reared in battery cages, ten per group. Weekly body weights and feed consumption were obtained on each treatment group. Body weight and feed utilization were significantly reduced when the ground full-fat raw soybeans were used in the starter diet. Autoclaved cooking temperatures of 100 C and a cooking time of 60 min appeared to be the best combination used for cooking the ground full-fat raw soybeans. The response of broiler chicks to feeding ground full-fat raw soybeans appears to be age related. The chicks overcame much of the body weight depression after 3 weeks of age.

KEY WORDS: body weight, feed utilization, cooking temperatures, cooking duration

The use of ground, full-fat soybeans in poultry rations as a source of protein and energy has been investigated by several researchers. Wood et al. (1971), White et al. (1967), Hull et al. (1968), and Smith and Scott (1965) found that chicks receiving diets containing ground raw soybeans had significantly lower body weight gain throughout a 6-week growing period, when compared to birds fed cooked soybean meal.

The nutritive quality of soybeans can be increased by heating. McNaughton and Reece (1980) stated that both moisture and cooking time affect trypsin inhibitor content and broiler growth. Trypsin inhibitor is regarded by many to be the most important proteolytic inhibitor in the poultry diet. Borchers et al. (1984) also found that cooking time affects trypsin inhibitor activity. Autoclaving at 1.02 atmospheres pressure for 4, 10, 15, and 30 min. resulted in 82, 39, 15, and 0% of the original

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trypsin inhibitor activity, respectively. Similarly, Carew et al. (1961) and Carew and Nesheim (1962) evaluated heat treatment time (0, 10, 30 min.) and pelleting on trypsin activity and observed no improvement in the quality of soybean meal. High cooking temperatures reduce the nutritive value of some of the critical amino acids, particularly arginine and methionine.

Little definitive information is available on the relationship between cooking time and temperature on the nutritive quality of raw soybean utilized as a feed ingredient for growing broilers. In addition, evidence for an age-related factor associated with feeding raw soybean is controversial. Alumot and Nitsan (1961) and Wood et al. (1971) have noted an age-dependent function. Salmon and McGinnis (1968) did not support the age-dependent factor observed by Alumot and Nitsan (1961).

Locally grown raw soybeans, properly processed, have a place in the formulation of diets for commercial broilers and other poultry. Their use in poultry diets can be cost-effective by eliminating some of the various steps in the processing of the meal and the extraction of the oil. In addition, it can reduce transportation and some storage costs of the oil. Animal fat and plant oils are added to poultry diets to increase energy requirements. Soybeans are high in protein and oil. Modern poultry companies in the U.S. continue to quest for information on the full use of soybeans, because of the economic potential. Hence, a major objective of the study was to measure the relationship between cooking temperature and cooking time on the nutritive value of ground full-fat raw soybean when used in broiler diets. The second objective was to investigate the age-dependent factor in feeding full-fat raw soybean meal to finishing broiler chickens.

MATERIALS AND METHODS

Two experiments, both factorially designed, compared the effects of different cooking temperatures and cooking durations on the feeding value of ground full-fat soybeans in broiler chick diets. Both experiments utilized Hubbard X Hubbard commercial broiler crosses. The diets were computer formulated to contain 21.58% crude protein (CP) and 3212 kcal of metabolizable energy (ME) per kg of feed (Table 1). All other nutrient requirements were formulated to meet the National Research Council (NRC, 1984) standards. Water was available *ad libitum*. The photoperiod was 24 hours of continuous lighting. The duration of each experiment was 6 weeks.

Data were collected weekly, and the analyses of data were based on analysis of variance procedures outlined in Snedecor and Cochran (1967). Duncan's multiple range test was applied to separate the treatment means (Duncan, 1955). Parameters measured were body weight and feed conversion.

The ground full-fat soybeans used in both experiments were heat-treated in an autoclave at 1.02 atmospheres pressure before incorporation into the diets.

Experiment 1

Two hundred day-old broiler chicks were separated by sex and assigned equally to 5 dietary treatments in a 5 X 2 factorially designed experiment. Each dietary treatment was assigned to two replicate groups of ten males and ten females each. Diet 1 contained commercial solvent extracted soybean meal; Diet 2 consisted of

Table 1. Composition of the broiler diets in Experiment 1.

Ingredients	Diets[1] 1	 2	 3	 4	 5
	-------------------	-------	%	-------	-------------------
Corn, yellow	50.37	50.37	50.37	50.37	
Soybean meal (44%)	37.47	37.47	--	--	--
Soybean meal (raw) (38%)	--	--	47.20	47.20	--
Cottonseed meal (41%)	--	--	--	--	25.69
Meat & bone meal (50%)	--	--	--	--	5.00
Calcium carbonate	1.40	1.40	1.27	1.27	--
Mono-Cal-Phos	1.76	1.76	2.15	2.15	1.66
Salt (NaCl)	.50	.50	.50	.50	.50
Broiler vitamin premix	.50	.50	.50	.50	.50
DL-Methionine (98%)	.19	.19	.18	.18	.25
Lysine	--	--	--	--	.20
Coban	.05	.05	.05	.05	.05
Blended fat	7.76	7.76	--	--	7.00
Analysis:					
ME (kcal/kg)	3212	3212	3212	3212	3212
Crude protein (%)	21.58	21.58	21.58	21.58	21.58

[1] Legend (treatment of soybean meals)
(1) unheated commercial soybean meal
(2) heated commercial soybean meal at 121 C 30 min.
(3) ground raw soybean meal heated at 100 C for 30 min.
(4) ground raw soybean meal heated at 121 C for 30 min.
(5) non-soybean meal diet.

Vitamin concentrate provided the following micronutrients per kilogram of diet: vitamin A, 8,800 IU; vitamin D3, 2,200 IU; vitamin E, 2.75 IU; menadione, 2.2mg; riboflavin 4.4 mg; D-pantothenic acid,12.1 mg choline chloride, 500 mg; niacin, 22 mg; vitamin B12, .013mg; biotin, .055 mg; thiamin, 1.1 mg.

Table 2. Composition of the broiler diets in Experiment 2.

Ingredients	Diets[1]					
	1	2	3	4	5	6
	-------------------------			%	-------------------------	
Corn, yellow	50.35	50.35	47.96	47.96	47.96	47.96
Soybean meal (44%)	37.47	37.47	--	--	--	--
Soybean meal (raw) (38%)	--	--	47.38	47.38	47.38	47.38
Calcium carbonate	1.40	1.40	1.33	1.33	1.33	1.33
Mono-Cal-Phos	1.76	1.76	2.16	2.16	2.16	2.16
Salt (NaCl)	.42	.42	.42	.42	.42	.42
Broiler vitamin premix	.50	.50	.50	.50	.50	.05
DL-Methionine (98%)	.20	.20	.20	.20	.20	.20
Coban	.05	.05	.05	.05	.05	.05
Vegetable fat	7.85	7.85	--	--	--	--
Total (%)	100.0	100.0	100.0	100.0	100.0	100.0
Analysis:						
ME (kcal/kg)	3212	3212	3212	3212	3212	3212
Crude protein (%)	21.58	21.58	21.58	21.58	21.58	21.58

[1] Legend (treatment of soybean meals)
(1) unheated commercial soybean meal
(2) heated commercial soybean meal
(3) ground raw soybean meal at 121 C 30 min.
(4) ground raw soybean meal heated at 100 C for 30 min.
(5) ground raw soybean meal heated at 121 C for 30 min.
(5) non-soybean meal diet.

Vitamin concentrate provided the following micronutrients per kilogram of diet: vitamin A, 8,800 IU; vitamin D3, 2,200 IU; vitamin E, 2.75 IU; menadione, 2.2mg; riboflavin 4.4 mg; D-pantothenic acid,12.1 mg choline chloride, 500 mg; niacin, 22 mg; vitamin B12, .013mg; biotin, .055 mg; thiamin, 1.1 mg.

commercial solvent extracted soybean meal heated for 30 min at 121 C in an autoclave; Diet 3 contained ground, full-fat raw soybean meal heated for 30 min at 121 C. The soybean meal in Diet 5 was replaced with cottonseed meal and meat and bone meal to serve as a negative control (Table 1).

Experiment 2

In Experiment 1, the effect of cooking time of the ground full-fat raw soybeans became a factor of concern in interpreting the body weight data. Consequently, cooking duration, as well as cooking temperature, were incorporated into the second experiment.

Experiment 2 was 6 X 2 factorially designed, utilizing six diets with soybean serving as the main protein source to all diets.

Two hundred and forty day-old broiler chicks, equally divided by sexes, were randomly assigned to 24 battery brooder cages, with 10 chicks of one sex per cage. Diets used in Experiment 2 are show in Table 2. Diet 1 served as the control and contained commercial solvent extracted soybean meal (44% protein). Diet 2 contained commercial solvent extracted soybean meal autoclaved at 121 C for 30 min. Diets 3, 4, 5, and 6 contained ground full-fat soybeans heated as follows: diet 3 consisted of ground full-fat soybeans heated for 30 min at 100 C, diet 4 contained ground full-fat soybeans heated for 60 min at 100 C, Diet 5 contained ground full-fat raw soybeans heated for 30 min at 121 C, and Diet 6 was autoclaved for 60 min at 121 C. Feed samples from Experiment 2 were collected from each diet and analyzed for urease activity.

RESULTS

Experiment 1

Chicks fed Diets 3, 4, and 5 weighed significantly ($P < .05$) less than the control (Diet 1), even as early as the first week of growth (Table 3). The chicks receiving Diets 3 and 4 maintained considerably lower body weights through 3 and 6 weeks of age, than those on Diets 1 and 2. (Table 3). When mean body weights of chicks on Diets 3 and 4 were compared on percentage basis with mean body weight of chicks on Diet 1, the birds became adjusted to the ground full-fat raw soybean as with age. Also, the higher cooking temperature used to process the soybeans for Diet 4 (121 C) resulted in an 89 g advantage in body weight over the chicks fed Diet 3, where the soybean was cooked at 100 C. The lowest body weight was obtained with Diet 5 in which soybean meal was replaced with cottonseed and meat and bone meal. Body weight at 6 weeks of age was depressed to an average of 1176 g, as compared with 1718 g for the control, possibly because of gossypol toxicity.

Feed conversion was significantly affected ($P < .05$) by diets at 3 and 6 weeks of age (Table 3). However, chicks fed the heat-treated ground full-fat raw soybean (Diets 3 and 4) had depressed feed conversion during the early stage of growth. There were no statistically significant sex by diet interactions; hence, treatment least squares means of the males or females were combined giving equal weight to sexes.

Table 3. The effect of diets on body weight and feed conversion (g feed per g body weight) at 3 and 6 weeks of age in broilers combining sexes (Experiment 1).

Diets	Body weights			Feed conversion	
	1-wk	3-wks	6-wks	3-wks	6-wks
	----------	g	------------		
1	169 a*	678 a	1673 a	1.153 a	1.499 a
2	170 a	692 a	1695 a	1.134 a	1.543 a
3	116 b	537 b	1363 b	1.213 b	1.736 b
4	113 b	562 b	1452 b	1.189 ab	1.712 b
5	121 b	438 c	1176 c	1.305 b	1.564 a

*Means within columns with the same letter are not significantly different (P <.05).

Diet Legend:

1. Unheated commercial soybean meal.
2. Heated commercial soybean meal at 121 C for 30 min.
3. Ground full-fat raw soybeans heated at 100 C for 30 min.
4. Ground full-fat raw soybeans heated at 121 C for 30 min.
5. Non-soybean meal diet.

Table 4. The effect of diets on body weight and feed conversion (g feed per g body weight) at 3 and 6 weeks of age in broilers combining sexes (Experiment 2).

Diets	Body weights			Feed conversion	
	1-wk	3-wks	6-wks	3-wks	6-wks
	------------	g	------------		
1	138 a*	598 a	1755 a	1.385 c	1.575 c
2	136 a	645 a	1637 a	1.453 c	1.683 b
3	87 c	348 c	1155 b	1.708 a	1.835 a
4	106 b	533 b	1662 a	1.590 c	1.738 a
5	84 c	320 c	974 b	1.723 a	1.948 a
6	115 b	531 b	1596 a	1.620 b	1.759 b

*Means within columns with the same letter are not significantly different (P <.05).

Diet Legend:

1. Unheated commercial soybean meal.
2. Heated commercial soybean meal at 121 C for 30 min.
3. Ground full-fat raw soybeans heated at 100 C for 30 min.
4. Ground full-fat raw soybeans heated at 100 C for 60 min.
5. Ground full-fat raw soybeans heated at 121 C for 30 min.
6. Ground full-fat raw soybeans heated at 121 C for 60 min.

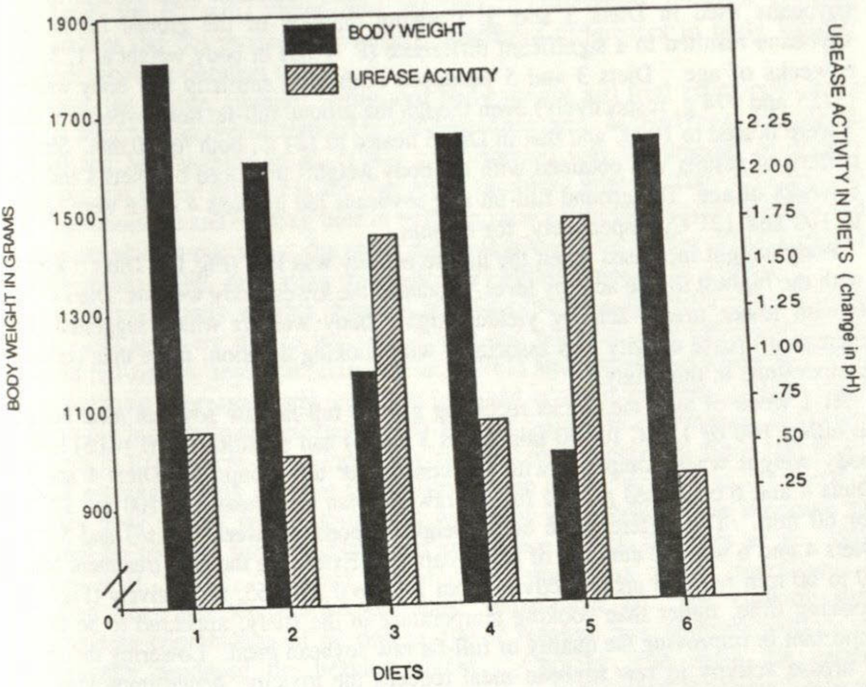

Figure 1. The influence of dietary urease activity on 6-week body weight of broilers combining sexes in Experiment 2.

Diet Legend:

1. Unheated commercial soybean meal.
2. Heated commercial soybean meal at 121 C for 30 min.
3. Ground full-fat raw soybeans heated at 100 C for 30 min.
4. Ground full-fat raw soybeans heated at 100 C for 60 min.
5. Ground full-fat raw soybeans heated at 121 C for 30 min.
6. Ground full-fat raw soybeans heated at 121 C for 60 min.

Experiment 2

Significant dietary treatment effects (P <.05) on body weight were noted throughout the 6 weeks of Experiment 2 (Table 4). Body weights of birds fed Diet 1 (the control) and Diet 2 were significantly (P< .05) greater at 1 and 3 weeks of age than those for the other four diets. Diets 3, 4, 5, and 6 contained variously treated ground full-fat raw soybean meal. Among the groups fed ground full-fat raw soybeans, body weights of those fed Diets 4 and 6 were significantly (P <.05) heavier than those fed Diets 3 and 5 at both 3 and 6 weeks of age. The soybeans used in Diets 4 and 6 were heated for 60 min, compared with 30 min for the soybeans used in Diets 3 and 5. Cooking duration of the ground full-fat raw soybeans resulted in a significant difference (P <.05) in body weight at 1, 3, and 6 weeks of age. Diets 3 and 5 produced birds with similarly low body weights (1155 and 974 g, respectively) even though the ground full-fat raw soybeans in Diet 3 were heated to 100 C and that in Diet 5 heated to 121 C, both for 30 min. Similar pattern of results was obtained with the body weights produced by Diets 4 and 6 at 6 weeks of age. The ground full-fat raw soybeans fed in Diets 4 and 6 were heated to 100 and 121 C, respectively, for 60 min.

Body weight increased when the urease activity was low (Fig.1). Diets 3 and 5, with the highest urease activity level, produced the lowest body weights. Diets 4 and 6 with lower urease activity yielded higher body weights which suggested that increased urease activity was associated with cooking duration, more than cooking temperature in this study.

At 1 week of age, the chicks receiving ground full-fat raw soybean meal heated to either 100 or 121 C for 30 min (diets 3 and 5) had significantly (P=.05) lower body weight when compared with the controls or the groups fed Diets 4 and 6. Diets 4 and 6 contained ground full-fat raw soybean meal heated at 100 and 121 C for 60 min. The difference in body weight response between Diets 3 and 5 and Diets 4 and 6 was the duration of heat treatment. Extending the heat treatment from 30 to 60 min reduced urease activity from 1.75 to 0.35-0.65, respectively (Fig. 1). Cooking time, rather than cooking temperature in the study, appeared to be more important in improving the quality of full-fat raw soybean meal. Lowering the level of urease activity in raw soybean meal reduces the toxicity, hence improving its nutritive value for broiler chickens.

At 6 weeks of age, the broilers receiving ground full-fat raw soybean meal heated to 100 and 121 C for 60 min (Diets 4 and 6, respectively) were similar in body weight to the controls (Diets 1 and 2) (Table 4). The broilers fed ground full-fat raw soybeans heated for only 30 min weighed significantly (P<.05) less than the controls or the birds fed the full-fat soybean meal cooked for 60 min.

The poorest feed conversion at 6 weeks of age was obtained from broilers fed full-fat raw soybean meal cooked at 100 C for either 30 or 60 min, and the treatment group receiving meal cooked at 121 C for 60 min (Table 4). Birds in the positive control group (Diet 1) had the best feed utilization (1.575 feed conversion).

The difference in mean body weight between Experiment 1 and Experiment 2 was seasonally related. Experiment 2 was done in the fall.

DISCUSSION

It is well documented that ground full-fat, raw soybeans depress growth. White et al. (1967), Salmon and McGinnis (1968), Hull et al. (1968), and Wood et al. (1971) have shown that birds receiving ground full-fat raw soybean diets were significantly smaller in body weight to 6 weeks of age than birds fed heat-treated full-fat soybean meal. In the current study, ground full-fat raw soybeans also depressed body weight and feed efficiency to 6 weeks of age. It appeared that the two cooking temperatures used (100 and 121 C) were adequate, provided the ground raw soybeans were autoclaved for 60 min, rather than 30 min. Differences between cooking temperatures did not produce statistically significant differences in body weight; however, cooking duration did.

Urease, the trypsin inhibitor, influenced body weight and feed efficiency. Body weight improved as urease activity in the diets decreased. McNaughton and Reece (1980) and McNaughton et al. (1981) demonstrated that the amount of trypsin inhibitor and urease activity in the diet relate to chicks growth. They also showed that both moisture and cooking time of soybean meal affect the trypsin inhibitor and urease activity. In our study, the entire diet was assayed for urease activity, rather than soybeans alone, supporting the findings of McNaughton et al. (1981).

The depressed body weights observed in chicks fed ground full-fat raw soybeans at an early age were due to low feed intake and possibly poor utilization of the ground full-fat raw soybeans. Carew et al. (1961) and Carew and Nesheim (1962) also attributed depressed body weight to low feed intake in the early growth stage, and to the high cellulose content of the ground full-fat raw soybeans. It became obvious in Experiment 1 that increasing the cooking temperature from 100 to 121 C did not significantly improve the nutritive value of raw soybean as measured by weekly body weight change through 6 weeks of age. Most of the literature has focused on cooking time (McNaughton and Reece, 1980; Borchers et al., 1984, Carew et al., 1962). The lack of definitive information on the interaction of cooking time and temperature prompted Experiment 2. The cooking time-temperature combination of 60 min at 100 C resulted in a soybean product that consistently produced the heaviest chicks. Cooking time made the greatest difference in growth rate to 6 weeks of age (approximately 560 g). Growth rate was actually depressed by increasing cooking temperature of the full-fat raw soybean meal from 100 to 121 C (approximately 120 g). Renner et al. (1953) and Haywood et al. (1936) reported that excessive heat will either destroy or render unavailable several essential amino acids, particularly lysine and arginine. The consistent depression in growth rate in the current study would suggest that the full-fat raw soybean meal was over-heated when cooked at 121 C, and that the most optimal combination of temperature and cooking time evaluated was 100 C and 60 min.

In this study, feeding cooked full-fat raw soybean meal depressed growth rate significantly by 1 week of age. As the birds became older, the depressing effects of heat-treated full-fat raw soybeans on growth began to subside, suggesting that the chicks, as they grew older, were able to adjust to the cooked full-fat raw soybean meals utilized. This was particularly noticeable in Experiment 1 and in treatments 4 and 6 in Experiment 2. Alumot and Nitsan (1961) and Wood et al. (1971) recognized an age-dependent function when feeding heated full-fat soybean meal; however, this was disputed by Salmon and McGinnis (1968). Our data suggests an age-dependent function associated with cooking procedure and age of chick.

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Effects of Reduced Tillage on Soil Temperature and Plant-Extractable Water

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ABSTRACT

Tillage systems influence soil temperature, available water, and subsequently, growth of cotton (*Gossypium hirsutum* L.). Field experiments were conducted in Corpus Christi, Texas, to determine how conventional tillage (CT) and reduced tillage (RT) systems influence soil temperature and plant-extractable water. Cotton was planted following sorghum [*Sorghum bicolor* (L.) Moench], the residues of which were managed either by reduced or conventional tillage. The study consisted of field measurements of soil temperature and volumetric water content. Average soil temperatures under RT were about 2 °C lower than CT. Plant-extractable water was 2.1 cm (0.8 inches) greater in RT than CT.

Tillage and cropping systems offer promising alternatives for crop producers on the coastal plain of Texas, where 12 or more tillage operations are typically required for a cotton crop. Interest has surged in tillage systems that reduce the number or depth of tillage operations and maintain crop residues on the soil surface all or part of the year. Much of this interest stems from higher yields with reduced tillage under semi-arid conditions (Unger and Wiese, 1979; Lyle and Bordovsky, 1987).

Crop residues can influence soil physical properties and subsequent crop response. Crop residues directly influence soil water content, evaporation, percolation and capillarity (Jones et al., 1969; Lal, 1976). The upper soil layers in an RT field are generally wetter and cooler than comparable CT fields (Thomas and Frye, 1984). Anderson (1987) reports that during the growing season, RT and CT have the same minimum temperatures at 5 to 7 cm depth, but RT has lower maximum soil temperatures. Growing conditions favor cotton where the mean temperature is not less than 25 °C. The minimum, optimum, and maximum temperatures for germination and early growth of cotton are about 16, 34, and 39 °C, respectively. Most rapid growth and flowering occurs at temperatures of 33 to 36 °C (Martin et al., 1976).

The objective of this study was to compare the effects of reduced tillage (RT) and conventional tillage (CT) on soil temperature and plant-extractable water in a cotton-sorghum rotation on the coastal plain of South Texas. Although soil water content is related to soil temperature, this study did not attempt to describe that relationship.

Accepted 19 Jun 1992. *Corresponding author.

MATERIALS AND METHODS

The study was conducted at the Texas A&M Research and Extension Center, Corpus Christi, Texas. The climate in this region is subtropical and semiarid. Humidity is high during most of the year because the prevailing southeasterly winds bring moist air from the Gulf of Mexico.

The RT employed in this study was developed at the Texas A&M Center. It differed from CT in primary tillage, and in number and depth of tillage operations. Primary tillage was done by sweeps in RT and by bedder in CT. Tillage depth in RT was 7.5 cm (3 inches) and in CT was 15 cm (6 inches). Table 1 shows the tillage operations performed during the 1989-90 crop growing season. Cotton (TAMCOT CAB-CS) was planted on 19 March 1990.

Table 1. Sequence and number of field operations for cotton under conventional tillage (CT) and reduced tillage (RT),Corpus Christi Texas, 1989-1990.

Operation	CT	RT
Shred sorghum stubble	1	1
Disk stubble	1	1
Plow stubble	1	
Cultivate middles		1
Root plow		1
Apply herbicide	1	1
Cultivate middles	1	1
Re-bed	1	
Cultivate middles	1	
Disk beds	1	
Disk and apply herbicide	1	1
Mark rows	1	
Apply fertilizer	1	1
Plant and apply herbicide	1	1
Roll crop	1	1
Cultivate	3	3
Total number of operations	16	13

The experimental site included three soil types: Victoria Clay (Fine, montmorillonitic, hyperthermic Typic Pellusterts), Clareville Complex (Clareville series is Fine, montmorillonitic, hyperthermic Pachic Argiustolls), and Orelia Fine Sandy Loam (Fine-loamy, mixed, hyperthermic Typic Ochraqualfs). Blocking was used to minimize variation due to soil types. Tillage was the main-plot factor, and soil depth was the sub-plot factor in a split-plot design with four replications. Plots contained 18 61-m (200-foot) crop rows.

Soil temperatures were measured by thermocouples placed at depths of 0, 2.5, 7.5, 12.5, 17.5, 27.5, 42.5, and 72.5 cm (0, 1, 3, 5, 7, 11, 17, and 29 inches) in randomly selected sites within cotton-after-sorghum plots (Fraser, 1968). At each depth a pair of thermocouples was oriented in opposite directions to obtain an average reading. Thermocouple readings were taken using a microcomputer thermometer. Soil temperatures were measured once, twice or three times per day, on a random basis. Volumetric soil water content was measured by neutron probe. Plant-extractable water for each depth and plot was considered to be the difference between soil water contents on the days the soil is wettest and driest (Ritchie, 1981).

RESULTS

Rainfall for the first two months of 1990 was 105 mm (4.1 inches). After planting cotton in March, the growing season was one of the warmest and driest of the decade. Rain occurred on four days in March, seven days in April, five days in May, three days in June, and eight days in July. Rainfall totals were 53 mm for March, 100 for April, 37 for May, 9 for June, and 38 for July (2.1 inches for March, 3.9 for April, 1.5 for May, 0.4 for June, and 1.5 for July).

Temperature

Soil temperature readings were grouped and analyzed according to time of day (Table 2). Temperature differences were significant between tillage systems ($P < 0.05$) and soil depths ($P < 0.01$). There was no significant interaction between depth and treatment. In general differences between treatments were slight in the morning and appreciable in the afternoon and evening. Late in the season, the differences in soil temperature diminished, presumably because of less ground cover resulting from severe drought.

Water

By 6 June, soil water content, at most depths were greater in RT than in CT. Water content declined steadily from the first reading on 25 April through 11 July. The last reading, taken on 24 July, indicated a slight increase over 11 July in RT plots. The effect of RT and CT on soil water content is shown in Figure 1. Plant-extractable water (Table 3) was based on the difference between water contents on 25 April and 11 July. Considering the mean of the five soil depths from 15 cm to 90 cm (6 to 35 inches), RT significantly ($P < 0.05$) increased plant-extractable water. Effects of soil depth were also significant ($P < 0.01$). However, differences between tillage treatments at any single depth were not significant, nor was there a significant interaction between depth and treatment. Adding over the five soil depths indicates a total increase of 2.1 cm (0.8 inches) of plant-extractable water in the soil profile under RT (Table 3). Water content in the upper 15 cm (6 inches) could not be measured by neutron probe and was omitted from the statistical analysis. By gravimetric analysis, however, topsoil volumetric water content means were estimated to be 26 % for CT and 24 % for RT on 25 April, with standing water in CT. On 11 July, topsoil water content means were estimated to be 7.3 % for CT and 8.5 % for RT.

Table 2. Soil temperatures from depths of 0 to 72.5 cm (0 to 29 inches) for conventional tillage (CT) and reduced tillage (RT), averaged over the 1990 cotton growing season, Corpus Christi, Texas.

Soil Depth (cm)	Treatment	
	CT	RT
	--------- °C ---------	
Morning (0800 to 1200 hr)		
0.0	34.9	32.7*
2.5	32.4	32.1
7.5	30.9	30.2
12.5	30.5	30.1
17.5	30.8	30.5
27.5	31.4	30.9
42.5	31.3	30.8
72.5	29.9	29.7
Afternoon (1201 to 1700 hr)		
0.0	44.9	42.4*
2.5	40.2	38.4*
7.5	36.5	34.5*
12.5	33.9	32.5*
17.5	32.5	31.3*
27.5	31.1	30.6
42.5	30.8	30.3
72.5	29.7	29.4
Evening (1701 to 1900 hr)		
0.0	42.8	41.5*
2.5	38.6	38.7
7.5	36.5	35.2*
12.5	34.4	33.2*
17.5	33.1	31.7*
27.5	31.1	30.3*
42.5	30.5	29.6*
72.5	29.4	28.7

*Means in the row are significantly different ($P < 0.05$).

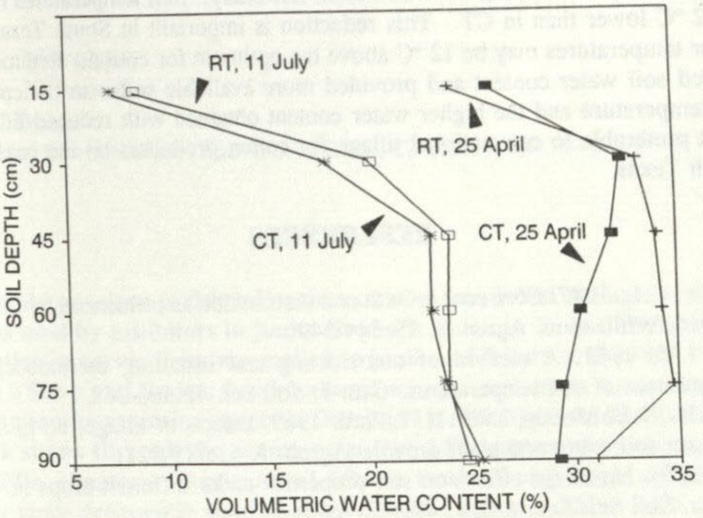

Figure 1. Effects of conventional tillage (CT) and reduced tillage (RT) on volumetric water content when greatest (25 April 1990) and least (11 July 1990) during the cotton growing season in Corpus Christi Texas. Water contents are reported at soil depth increments of 15 cm (6 inches).

Table 3. Plant-extractable water between 15 and 90 cm (6 and 35 inches) soil depth, for cotton grown in Corpus Christi, Texas, 1990, as affected by conventional tillage (CT) or reduced tillage (RT).

	Treatment	
Soil Depth (cm)	CT	RT
	-------- cm -------	
15 to 30	2.0	2.1
30 to 45	1.6	1.8
45 to 60	1.1	1.8
60 to 75	0.7	1.3
75 to 90	0.4	0.7
Mean	1.1	1.5*
Total	5.6	7.7

*Means in the row are significantly different ($P < 0.05$).

CONCLUSIONS

Practical implications can be drawn from this study. Soil temperatures in RT are about 2 °C lower than in CT. This reduction is important in South Texas, where summer temperatures may be 12 °C above the optimum for cotton. Reduced tillage increased soil water content and provided more available water to the crop. The lower temperature and the higher water content obtained with reduced tillage may make it preferable to conventional tillage for cotton producers on the coastal plain of South Texas.

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Unethical Fitting and Showing Practices in Junior Livestock Shows

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ABSTRACT

This study was done to determine the extent of fraudulent fitting and showing practices used by exhibitors in junior livestock shows in Texas. To obtain this information, a survey form was mailed to junior exhibitors at the 1990 Houston Livestock Show and Rodeo, to agricultural science teachers in Areas III, V and VI and to county extension agents in Districts 4 and 5. More students enter state livestock shows through the county extension 4-H program than through high school FFA chapters. Agricultural science teachers visit their students and projects more frequently than county extension agents. About 25% of those surveyed had knowingly used illegal drugs in preparing market animals for show ring competition while approximately 47% had either registered crossbred animals or knew someone that did, and 37.5% were aware of falsification of data other than parentage on registration certificates. Recommendations to help eliminate fraudulent practices in fitting and showing livestock include limiting the amount of auction money paid to winners, stricter enforcement of existing rules, closer supervision of animal projects, increasing the percentage of show animals tested for drugs, body clipping market steers and establishing a "Livestock Hotline" for anonymous reporting of offenders to livestock offices.

Parents have encouraged their children to participate in 4-H or FFA activities because these organizations have long had the reputation for teaching leadership, regimentation, responsibility, and self-confidence. The exhibition of market animals in junior livestock shows over the last several years has become extremely competitive. Competition has become more intense as the amount of prize money has increased; in fact, grand champion animals are sold from $35,000.00 to $221,000.00 at major livestock shows in Texas. What was originally designed and intended to be a learning experience for youngsters has gradually become a quest for big money. Thus to a few, winning at any price has become the objective, and the values that were first considered so precious have been forgotten.

To gain a competitive edge to win with an animal, fraudulent practices have been employed, which include the use of illegal drugs and chemicals, physical alteration of natural color, falsification of registration certificates and using custom fitters to feed and prepare animals for show ring exhibition.

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The most highly publicized and most often implemented unethical fitting and/or showing practice is the use of illegal drugs and chemicals on the animals that are being exhibited. Tranquilizers, diuretics, and steroids are rather easily purchased and used by veteran exhibitors.

In discussing show ring ethics, animal breeders cannot be excluded. Their role has become important since the basic animal genotype is determined on the farm. Some purebred breeders have infused genes from exotic breeds into their herds to add bone, height and overall size and scale, but register the offspring as purebred. These calves will have distinct advantages in size, scale and bone over purebred calves at the livestock show.

Breeders also have falsified birth dates by as much as 180 days on calves. Reasons for this are obvious. A 16-month old heifer or bull competing in a class of 12-month old calves will appear to have grown faster, and will possess much more size and scale than other calves in the class.

Another recent controversial topic is use of the professional custom fitter. A fitter's job is to take a calf from the day of purchase, halter break, feed, train for the show ring, groom, and make the calf "show ready". The original purpose of student involvement in livestock shows was to teach certain basic values (responsibility, leadership, etc.). The custom fitter is the best example of completely bypassing the student's learning opportunities. The youngster seldom sees or has only limited involvement with the animal until show day.

The purpose of this study was to identify fraudulent fitting and showing practices and the extent of their use among a group of Houston Livestock Show and Rodeo exhibitors, parents, county extension agents and agricultural science teachers. Also, recommendations that may curtail or eliminate these practices will be proposed.

Merits of the Show Ring

An important feature of the show ring is the opportunity it affords aspiring animal breeders to improve their stock, by presenting to them an ideal to work toward. The ideals established in the show ring by exhibition have a marked influence on the opinions and practices of breeders and permeate the field of agricultural education (Swett, 1941).

Competition in the junior livestock division at the major livestock shows in Texas has been limited to members of 4-H Clubs or FFA Chapters within the State Junior Livestock Show (Houston Livestock Show and Rodeo, 1989).

Participation in the show ring educates young people and helps them (1) set and meet goals, (2) become aware of profits and losses through record keeping activities, (3) achieve a higher level of self-esteem and (4) develop a sense of responsibility. Link (1990) suggests that showing beef cattle merely complements the overall education a youngster receives about the industry. The carcass contests, meats identification team and livestock judging team all help round out the experience.

Illegal Residues

Just as the use of steroids by athletes brought scandal into the sports arena, cattlemen are increasingly calling attention to themselves in much the same way (Anderson, 1990). In this case, the illegal use of drugs is not in the feedlot, but rather in the show ring, where adverse publicity affects the entire industry.

In 1989, the Houston Livestock Show and Rodeo became the first organization of its kind to test show animals for the presence of drugs (Quarles, 1990, personal communication). According to Leroy Shafer, assistant general manager (1991, personal communication), seven animals auctioned during the 1991 Houston Livestock Show, including a breed reserve champion that sold for $12,000, were disqualified and the money returned to the buyers because the animals tested positive for illegal drugs. These animals were exhibited by youngsters who had previously signed releases indicating they knew the use of drugs was not permitted. The reserve champion Southdown lamb's urine had residue of lasix, a diuretic commonly used to remove water from the body tissue of an animal. Shafer said, "The second drug found was acepromazine, a pain reliever typically used to reduce swelling in animals. If these drugs would have been found in a shipment of meat, the entire load would have been condemned and the owner fined or imprisoned."

Some livestock show officials are taking the responsibility to monitor some of these problems. Last year, at the request of show officials, the Texas Veterinary Medical Association began testing all first and second place animals exhibited at the San Antonio Livestock Exposition, Southwestern Exposition and Livestock Show in Ft. Worth, and the Houston Livestock Show and Rodeo (Anderson, 1990).

Custom Fitters

Exhibitors who misuse drugs are also suspected of hiring professional fitters to care for and maintain their animals (Chriss, 1991). "There are some real masters," said Harlan Ritchie (1991, personal communication), a nationally recognized livestock judge from Michigan State University. Ritchie, who has seen the best of the custom fitters, said, "You're going to be influenced, I don't care how good you are. The professional fitter has the edge. They are as good as portrait artists. No matter how good you are at judging, its tough to see through them. They can take a good animal and make it great."

METHODOLOGY

Data collection for this project began in May, 1990 with a series of personal interviews with the management staff of the Houston Livestock Show and Rodeo. As a result of these meetings a survey form was developed to determine the extent of fraudulent practices in junior livestock shows.

Three survey groups were specifically targeted: 1990 Houston Livestock Show junior market exhibitors and their parents, agricultural science teachers from areas III, V and VI and county extension agents from Districts 4 and 5. Respondents to the survey were guaranteed complete anonymity and all information provided was kept confidential.

Houston Livestock Show and Rodeo provided names and addresses of possible participants in each target group. The list of exhibitors was monitored to eliminate duplication. A total of 1,945 survey forms was mailed in October 1990 and a self-addressed, stamped return envelope was included to encourage participation.

The survey used (Exhibit 1) is presented below. The participants in the survey seemed quite eager to offer information, advice and suggestions, as well as criticisms and accusations. More than one-half included their names and addresses on the returned forms.

Exhibit 1. Questions from the survey instrument.

For each question, please circle all answers that apply.

1. YOUR/PRESENT INVOLVEMENT ...
   Student Parent C.E.A. A.S.T. Custom Fitter Other ____

2. IF INVOLVED AS A STUDENT OR PARENT, DO YOU SHOW THROUGH 4-H OR FFA, OR BOTH? ____________.

3. WHICH OF THE FOLLOWING SPECIES DO YOU EXHIBIT?
   Cattle Swine Sheep

4. HOW OFTEN IS YOUR PROJECT SUPERVISED BY YOUR AG TEACHER OR COUNTY AGENT?
   More than once per month Less than once per month
   Only once or twice Never

5. INDICATE ANY/ALL MEDICATIONS OR DRUGS USED IN THE PREPARATION AND EXHIBITION OF LIVESTOCK:
   a. Steroids ... Equipoise Repository testosterone
      Probolic Winstrol V Other
   b. Tranquilizers ... Ace Promazine Thiamine
      Rompun Other __________
   c. Diuretics ... Lasix Disal Other __________
   d. Anthelmintics (wormers) ... Ivermectin Dichlorvos
      Levamisole Tramisol Other __________
   e. Antibiotics ... Penicillin Combiotic LA200 Other ____

6. HAVE YOU EVER KNOWINGLY USED A DRUG OR MEDICATION ON AN ANIMAL THAT WAS CONSIDERED ILLEGAL BY THE LIVESTOCK SHOW INDUSTRY? YES NO

7. HAVE YOU OR OTHERS YOU KNOW USED CROSSBREEDING WITH REGISTERED STOCK (Angus x chi = Reg. Angus; Simmental x Hereford = Reg. Hereford)
   Yes No Yourself Others

8. HAVE YOU OR OTHERS YOU KNOW EVER FALSIFIED REGISTRATION PAPERS ON ANIMALS?
   YES NO YOURSELF OTHERS
   IF SO, IN WHAT WAY?
   Birthdates Breeding Parents Ownership Other ____

RESULTS AND DISCUSSION

A total of 797 responses were received for a 41% return. Numbers of respondents, by category (student, parent, teacher, agent), are presented in Table 1. Breakdown of student exhibitors by affiliation (FFA, 4-H) is presented in Table 2.

Table 1. Number of responses from students, parents, agricultural science teachers, (AST) and county extension agents (CEA).

	Students	Parents	AST	CEA	Other	Total
Number	497	142	134	21	3	797
Percent	62	18	17	3	0.4	100

Table 2. Affiliation of exhibitors (4-H, FFA or both).

Respondents	FFA#	%	4-H#	%	FFA & 4-H	%
Student (496)	159	32	237	48	100	20
Parent (142)	22	16	60	42	60	42
Total (638)	181	28	297	47	160	25

The number as well as the types of market animals exhibited by 4-H and FFA members are shown in Table 3. The data in this table indicates that when cattle (steers) are exhibited, the majority are entered through 4-H programs. Also, when junior exhibitors show other market animals such as sheep at the same show, the majority of the entries are through the 4-H program.

The frequency of project visitation and supervision by County Extension Agents and Agricultural Science Teachers is presented in Table 4. The data indicates that Agricultural Science Teachers visit their students and projects much more frequently than County Extension Agents. In many cases, students enrolled in 4-H programs are never visited by their agents, or if visited, only once or twice during the duration of the project. A significant difference in supervision occurs between the two groups which can partially be explained by the distance to be traveled by county agents who also have less opportunity to talk to their students.

Table 3. Number and type of animals exhibited by students enrolled in FFA or 4-H or in Both FFA and 4-H (student and parent response).

Species	FFA No.	FFA %	4-H No.	4-H %	FFA & 4-H No.	FFA & 4-H %
Cattle	19	11	76	26	24	15
Swine	66	36	59	20	29	18
Sheep	22	12	47	16	11	7
Cattle & Swine	19	11	34	11	36	23
Cattle & Sheep	1	0.5	26	9	10	6
Swine & Sheep	42	23	27	9	20	13
All species	12	7	28	9	30	19
Total	181	100	297	100	160	100

Table 4. Comparison of project supervision by county extension agents and agricultural science teachers (student and parent response).

Project supervision	4-H No.	4-H %	FFA No.	FFA %
More than once per month	41	14	106	59
Less than once per month	48	16	53	29
Only once or twice	107	36	19	10
Never	101	34	3	2

Note: Responses from exhibitors that participated in both 4-H and FFA programs are not included in Table 4.

The rules and regulations governing the exhibition of animals is clearly outlined in the premium list or catalog of each livestock show. Certain drugs and chemicals are prohibited for use in market animals by the livestock shows and to sell market animals that contain drug residues in meat used for human consumption is unlawful. Even though steroid use is prohibited, 63 or 7.9% of respondents indicated that they gave steroids to market animals while 339 or 42.5% used tranquilizers and 198 or 24.8% had given diuretics to show animals (Table 5). In total, 25% of respondents had given illegal drugs to animals being fitted for the show ring.

Table 5. Medications and types of drugs used by 797 respondents in the preparation and exhibition of livestock.

Drug Class	Used No.	Used %	Not used No.	Not used %
Steroids	63	8	734	92
Tranquilizers	339	43	458	57
Diuretics	198	25	599	75

Because about 25% of respondents indicated that they used illegal drugs in show animals, either drug testing procedures are inadequate or unenforced, or the exhibitors are very sophisticated in their application and subsequent action. This means that one out of every four market animals that are exhibited have been fitted in a manner that violates the rules of the livestock show. Such practices place other exhibitors at a distinct disadvantage.

In addition to the use of drugs, other fraudulent practices have also occurred with animals being exhibited at shows. About 47% of respondents indicated that either they had registered crossbred animals and had entered the animals in the show as purebreds or they knew someone that did.

Another fraudulent practice involving purebred animals included the falsification of registration papers. Reported violations on the survey included incorrect birth dates, breeding, parentage or ownership, and 37.5% said that they had falsified registration papers using incorrect data or knew someone who had.

RECOMMENDATIONS

From the data presented in this study, several recommendations can be made to help eliminate fraudulent practices in the fitting and showing of market animals in the junior livestock shows in the state of Texas.

Under the present system, show animals are sold at auction and in some instances the highest bid for champion animals may exceed $220,000. Competitive advantages in the show ring are more significant when large amounts of money are involved, so over a period of time unethical practices have become more intense and more frequent.

The first and probably most important recommendation would be to limit the amount of money awarded to a junior exhibitor. Rather than pay awards entirely in cash, it might be advisable to present prizes or scholarships. Also, by reducing the amount paid for the grand champion, more money might be available to pay other exhibitors that also showed outstanding animals but were unable to receive championship honors.

Another recommendation would be to enact strict enforcement of the rules printed in the show premium list by the superintendent of each show. Additional testing and stricter enforcement would be more costly, but these activities may be worthwhile uses of the proceeds.

Closer supervision of animal projects by competent adult supervisors would reduce

Closer supervision of animal projects by competent adult supervisors would reduce the use of custom fitters and greatly reduce drug and chemical use.

An idea that has been discussed among livestock exhibitors for several years would be to "slick shear" or "body clip" market steers. Such a practice would practically eliminate the need for custom fitters and allow junior exhibitors with limited skills to clip their animals and ready them for exhibition in the show ring.

A recommendation that would work alone or in concert with those previously discussed would be to establish a "Livestock Hotline" for anonymous reporting of fraudulent practices. A reward for confirmable information would probably increase the success of such a procedure, and the hotline could be used during both market and breeding animal shows.

The livestock show is one of the best junior instructional tools in the field of animal science. As one young exhibitor aptly implied, the exhibition of animals should be a learning experience for young people--parents, teachers and agents should only supervise and offer support.

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Effects of Sodium Chloride, Sodium Hexametaphosphate And Freezer Time on Restructured Beef Chuck Steaks

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ABSTRACT

This study evaluated the effects of sodium chloride, sodium hexametaphosphate and length of freezer storage on restructured beef chucks. One-third pound (151 g) ground beef chuck steaks were prepared from two piece boneless chucks. Four different sodium chloride (NaCl) and sodium hexametaphosphate (HMP) combinations were used: 0% NaCl, 0% HMP; 2% NaCl, 0% HMP; 0% NaCl, 0.5% HMP; and 2% NaCl, 0.5% HMP. While mixing the restructured product for 15 minutes, water was added at the 3% level. The four formulations were passed through a patty machine and then stored at a temperature of -20 °C for 0, 4, 8, and 12 week periods. Various quality attributes of restructured beef steaks were studied. The taste panelists detected a significant ($P<0.05$) improvement in tenderness, flavor and visual appearance with the 2% NaCl, 0.5% HMP treatment. Warner-Bratzler shear force values and the triangle differentiation tests indicated significant ($P<0.5$) differences between treatments.

The demand for retail cuts derived from the chuck portion of the beef carcass has declined drastically. Recent studies conducted by the American Livestock and Meat Board have identified consumer buying habits as changing and forcing demand for chuck retail cuts. Thus, interest has been shown in converting the lower valued, tougher cuts of meat into higher valued meat items.

Current restructuring technology offers alternative methods of preparation using NaCl, various phosphates and additional non-meat ingredients. These ingredients can be used to produce an increasing variety of portion controlled meat products that can be formed into different shapes with a desired texture and tenderness.

Restructured meat products may offer many benefits (Field, 1982) to compete in the retail market. Several such benefits are portion control, extended shelf life, convenience of preparation, economical means of utilizing the trim, and utilization of lower grade carcasses to form products of uniform quality (Barr et al., 1979). Thus, restructured beef chuck steaks are a positive alternative as opposed to the less desirable retail cuts of the chuck portion of the beef carcass.

The chuck portion of the beef carcass makes up nearly 30% by weight of the total carcass but only 22% of its value (Patterson and Parrish, 1986).

The objective of this study was to investigate the influence of NaCl, HMP, and freezer time on restructured steaks derived from the beef chuck.

The research was funded in part by the Houston Livestock Show and Rodeo. Accepted 30 June 1992. *Corresponding author.

MATERIALS AND METHODS

Processing

The present research study was conducted at the Sul Ross State University Meat Science Laboratory in Alpine, Texas.

Two piece boneless vacuum packaged chucks were used to formulate three replications. Each chuck was randomly allocated into four groups and trimmed of excessive fat and connective tissue. Intact muscles were ground first through a coarse grinder plate (2.5 cm) and then ground through a fine grinder plate (0.3 cm). The ground muscle was then allowed to equilibrate overnight (no ingredients added). Each of these formulations were then tested for fat content using the modified Babcock Analysis (AOAC, 1990). The final product consisted of 85% lean and 15% fat. Three percent water was added to the final products. The additives used in the study, NaCl, HMP, and H_20, were food grade.

Additive treatments applied to restructured steaks were as follows: T1, restructured steaks prepared with 0.0% NaCl and 0.0% HMP; T2, restructured steaks prepared with 2.0% NaCl and 0.0% HMP; T3, restructured steaks prepared with 0.0% NaCl and 0.5% HMP; T4, restructured steaks prepared with 2.0% NaCl and 0.5% HMP.

All ingredients and ground meat treatments were combined and mixed for 15 minutes in a Leland Food Mixer. All non-meat ingredients were dissolved in water and added during the initial stages of mixing.

Immediately after mixing, each formulation treatment was passed through a Hollymatic Patty Machine, manufacturing three restructured steaks to a one pound ratio. The restructured beef chuck steaks were then individually wrapped in polyethylene bags and frozen at -20 °C. Products were then analyzed at 0, 4, 8, and 12 week intervals for sensory, visual and textural properties.

All steaks were cooked using a Blodgett convection oven. Prior to cooking, the oven was preheated to a temperature of 177 °C (350 °F). The restructured beef chuck steaks were then inserted and allowed to cook to an internal temperature of 61 °C (120 °F) before being flipped and cooked to a final internal temperature of 86 °C (170 °F). These temperature measurements were determined by inserting the thermometer into the center of each steak.

Test Procedures

A taste panel consisting of seven individuals was used to test the steaks. The panelists evaluated the color of the fresh meat product prior to cooking. Immediately after cooking, steaks were evaluated for tenderness, cooked color, flavor, and personal preference.

Three triangle differentiation surveys were given to panel members to determine their ability to distinguish treatments. The surveys were: Survey 1) 0.0% NaCl, 0.0% HMP vs 2.0% NaCl, 0.0% HMP; Survey 2) 0.0% NaCl, 0.0% HMP vs 0.0% NaCl, 0.5% HMP; Survey 3) 0.0% NaCl, 0.0% HMP vs 2.0% NaCl, 0.5% HMP.

Shear force (Kg) was estimated with steaks from each formulated treatment and storage period. Steaks were placed in a Blodgett convection oven. Steaks were broiled to an internal temperature of 86 °C (170 °F). The cooked steaks were wrapped and placed in a 2 °C cooler for 45 minutes before testing. This provided adequate firmness to ensure uniform cores (Will and Henrickson, 1976). From each steak, five 0.25 cm cores were taken at five areas on each individual steak. Each core was sheared once and the average of the five measurements was recorded.

Data were treated by analysis of variance (Barr et al., 1979) using a completely random design (Steel and Torrie, 1980) with split plot treatment arrangements. Where significant differences were found, means were separated by Duncan's Multiple Range Test (Snedecor and Cochran, 1980). Treatments were characterized as the main effect with the storage time being the sub-unit. Data were analyzed using MSTAT (Nissen, 1986). Significant differences were accepted at the 5% level.

RESULTS AND DISCUSSION

The triangle differentiation test yielded data that were consistent throughout the study. There was a significant difference ($P<0.05$) in Survey 1 responses (Table 1), indicating that the taste panel could detect a difference between the product treated with 0.0% NaCl, 0.0% HMP and the product treated with 2.0% NaCl, 0.0% HMP. In Survey 2, no significant difference ($P>0.05$) between products was detected, indicating that HMP alone has no effect on flavor or appearance when integrated into a meat product. Survey 3 indicated a difference ($P<0.05$) between the control (0.0%, NaCl, 0.0% HMP) and the treatment with 2.0% NaCl, 0.5% HMP. This agrees with Mandigo et al. (1973) that NaCl improves flavor.

Shear force values are presented in Table 2. The control (T1) with no additives or preservatives, proved to be different ($P<0.05$) from other treatments in the first month of shear force testing. However, the control product stabilized after about 2 months experimentation. The shear strength test illustrated no difference ($P>0.05$) between T1 and T3 3 at the 4 and 8 week periods. However, at the 12 week period, the control product was significantly ($P<0.05$) less tender.

Table 1. Mean correct and incorrect responses in triangle differentiation test to determine panel member's ability to detect taste differences between products.

% NaCl, %HMP	Correct responses	Incorrect responses
Survey 1 0.0%NaCl, 0.0%HMP vs 2.0%NaCl, 0.0%HMP	104 (93%)	8 (7%)
Survey 2 0.0%Nacl, 0.0%HMP vs 0.0%NaCl, 0.5%HMP	58[a] (52%)	54[a] (48%)
Survey 3 0.0%NaCl, 0.0%HMP vs 2.0%NaCl, 0.5%HMP	101 (90%)	11 (10%)

[a] Means in a row followed by the same letter are not significantly different ($P<0.05$).

Table 2. Mean shear force (kg) as affected by NaCl and HMP treatments and freezer storage time. The higher number indicates the tougher product.

		Freezer storage			
Treatment	NaCl, HMP	0 weeks	4 weeks	8 weeks	12 weeks
T1	0.0%, 0.0%	3.74	2.41	2.425[a]	2.737
T2	2.0%, 0.0%	2.32	1.73[a]	2.353[a]	2.134[a]
T3	0.0%, 0.5%	2.96[a]	2.31	2.109	1.840[a]
T4	2.0%, 0.5%	2.80[a]	1.73[a]	1.50	1.256

[a]Means in a column followed by the same letter are not significantly different ($P<0.05$).

Treatment 2 (2.0% NaCl, 0.0% HMP) was the most tender steak at the fresh product state and the 4 week period. However, at the 8 and 12 week periods, T4 produced the most tender steaks (Table 2).

Shear force increased linearly with time with the exception of T4. Significant differences in shear force existed between each individual treatment storage time. As shown in Table 2, shear strength was affected by the addition of NaCl and HMP.

With all four treatments, sensory panel tenderness was directly proportional to shear force values. All treatments were evaluated on a scale from 1 (extremely poor) to 8 (excellent) (Table 3). The product from T1 was preferred over T3 the first month and then became the lowest evaluated in tenderness throughout the remainder of the study. Treatment 2 was relatively tender and continued to be stable at the 4 and 8 week periods. At the end of the 12 week period the tenderness evaluation dropped. Treatment 3 was a relatively tender product over time. Treatment 4 was the most preferred in tenderness compared to all other products. Throughout the experiment, T4 was significantly ($P<0.05$) higher in tenderness evaluation. The observations in this study did not agree with Neer and Mandigo (1977) that a product becomes tougher with time.

Table 3. Mean tenderness values as affected by NaCl and HMP treatments and freezer storage time. Higher numbers indicate the more tender product.

Treatment	Freezer storage			
NaCl HMP	0 weeks	4 weeks	8 weeks	12 weeks
0.0%, 0.0%	5.321[a]	4.643[a]	4.179[a]	4.394
2.0%, 0.0%	5.357[a]	4.857[a]	4.965	4.822[a]
0.0%, 0.5%	4.857	4.322	4.179[a]	4.857[a]
2.0%, 0.5%	5.536[a]	4.750[a]	5.036	5.821

[a]Means in a column followed by the same letter are not significantly different ($P<0.05$).

Sensory panelists detected significant differences ($P<0.05$) for appearance and flavor among restructured beef chuck steak treatments (Table 4). The restructured steaks from T4 produced the most eye appealing product. This is in agreement with Pepper and Schmidt (1975). Treatments 1, 2 and 3 resulted in decreasing scores over storage time, whereas T4 resulted in a significant increase.

Analysis of the taste panel data indicated significant differences ($P<0.05$) in flavor scores between treatments for restructured beef chuck steaks (Table 5). There was a significant ($P<0.05$) tendency for flavor scores to decrease over storage time. These data are in agree with Miller et al. (1985). Treatment 4 proved to be the most desirable product for flavor. Pepper and Schmidt (1975) also reported that sensory panelists preferred restructured meat products containing NaCl and phosphate in comparison to 0.0% NaCl, 0.0% PO_4.

Table 4. Mean appearance values as affected by NaCl and HMP treatments and by freezer storage time. Higher values indicate greater visual appeal.

Treatment NaCl HMP	Freezer storage 0 weeks	4 weeks	8 weeks	12 weeks
0.0%, 0.0%	4.643[a]	4.286[a]	4.321	4.143
2.0%, 0.0%	4.607[a]	4.355[a]	4.607[a]	4.857
0.0%, 0.5%	4.536[a]	4.072	4.072	4.465
2.0%, 0.5%	4.893	4.464	4.786[a]	5.394

[a] Means in a column followed by the same letter are not significantly different ($P<0.05$).

Table 5. Mean flavor values as affected by NaCl and HMP treatments and by freezer storage time. Higher values indicate better flavor.

Treatment NaCl HMP	Freezer storage 0 weeks	4 weeks	8 weeks	12 weeks
0.0%, 0.0%	5.321[a]	4.643[a]	4.179[a]	4.393
2.0%, 0.0%	5.357[a]	4.857[a]	4.965	4.822[a]
0.0%, 0.5%	4.857	4.322	4.179[a]	4.857[a]
2.0%, 0.5%	5.536	4.749[a]	5.036	5.821

[a] Values in a column followed by the same letter are not significantly different ($P<0.05$).

CONCLUSIONS

The data from the triangle differentiation test were consistent throughout the study, indicating that the panelists could detect a significant difference between products. The addition of NaCl and HMP to restructured beef chuck steaks increased sensory panel acceptability. Shear force increased linearly with time, with the exception of T4. Appearance and flavor scores generally decreased over storage time, but T4 showed an increased acceptability. It appeared that freezer storage, for up to 84 days, did not effect the sensory properties of T4.

This study suggests that the meat industry may benefit from adding NaCl and phosphate to steaks restructured from the chuck portion of the beef carcass.

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Sodium Chloride and Sodium Tripolyphosphate Effects on Characteristics of Restructured Beef Roasts

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ABSTRACT

Restructured roasts were manufactured from three-piece boneless chucks. Four different treatments were prepared with eight replications. Excess fat and connective tissue were trimmed from the chuck muscles prior to processing. Half of the lean and 5% added fat were emulsified for 5 minutes, the rest of the lean was added and the product was emulsified again for 30 seconds. The mixture was divided into four equal portions to undergo treatment. Treatments contained different concentrations of sodium chloride (NaCl) and sodium tripolyphosphate ($Na_5P_3O_{10}$): T1 (0%, 0%), T2 (0%, 0.3%), T3 (1.7%, 0%), T4 (1.7%, 0.3%). Cooking loss, water holding capacity, Warner-Bratzler shear force, and sensory evaluations were conducted. Results showed significant differences ($p < .001$) between treatments for cooking loss and water holding capacity, but no difference ($p > .05$) between treatments in shear force. Sensory panel evaluations for flavor indicated preference for roasts containing NaCl, with or without $Na_5P_3O_{10}$, over roasts without NaCl.

Meat restructuring is a recent innovation in the packing and processing industry. Interests in meat restructuring technology began in the early 1940s but were not pursued until the late 1970s for economic reasons (Seideman and Durland, 1983). The primary function of restructuring is to render less desirable carcasses or less tender cuts into a more palatable and acceptable meat product. Economic pressure to minimize cost and maximize product use provides the incentive to develop new products using less valuable carcasses and carcass components and to increase product value (Seideman and Durland, 1983). Lower-grade carcasses (mature cows and bulls) that are normally used as ground meat, can now be used more efficiently (Marriot et al., 1988; Berry et al., 1986; Huffaman et al., 1984; Seideman et al., 1982). On better carcasses, the less tender or unpopular portions such as the chuck, shank, plate, and flank can be reformed into more consumer-acceptable products.

If restructured beef industry is to succeed, meat packers and processors must produce a restructured product to the specifications and needs of the consumer. Historically, restaurants and institutions have used some restructured meats due to the uniformity and portion control of the products (Chu et al., 1989).

For the average consumer, however, the product must first have eye appeal, no one will buy something that does not look good. Although many restructured meat items are pre-cooked, they still need to resemble intact muscle. A restructured roast

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must have the appearance and texture of a regular roast. Also, the product must be palatable. It should be tender yet cohesive. Upon serving, the meat should cut easily but remain intact, carry a fair amount of juiciness, and be flavorful. Although different seasonings are used, the taste should resemble that of intact muscle.

The purpose of this study was to analyze the cooking loss, water holding capacity, shear force, and the consumer flavor response of restructured beef roasts manufactured with varying levels of NaCl and $Na_5P_3O_{10}$.

MATERIALS AND METHODS

This research was conducted in the Meat Science Laboratory at Sul Ross State University, Alpine, Texas. Three-piece boneless vacuum packaged chucks (USDA Choice) were used in the study. Four different treatments were manufactured with eight replications. The chucks were trimmed of excess fat and the major muscle areas separated. External connective tissue was then trimmed from the individual muscle areas along with any external fat still present. The lean muscle tissue was then cut into approximately 0.75-inch cubes and the weight was recorded. Marbling was estimated at 15% and remained constant throughout the study. Fat (5%) was added to the lean to formulate a ratio of 80% lean to 20% fat.

Processing

Half of the lean along with the 5% fat were emulsified (Hobart Silent Cutter) for 5 minutes. The rest of the lean was added and the contents were emulsified again for 30 seconds. The mixture was divided into four equal portions and the different treatments performed. All ingredients used in this study were food grade. All restructured roasts regardless of treatment contained 0.9% ground white pepper, 0.1% celery seed, and 0.25% granulated onion. The treatments were as follows: Treatment 1 (T1), 0% NaCl, 0% $Na_5P_3O_{10}$; Treatment 2 (T2), 0% NaCl, 0.3 $Na_5P_3O_{10}$; Treatment 3 (T3), 1.7% NaCl, 0% $Na_5P_3O_{10}$; Treatment 4 (T4), 1.7% NaCl, 0.3% $Na_5P_3O_{10}$.

Test products were mixed for 4 minutes (Leland Food Mixer, model 7000) and stuffed (Vogt 12-1/2 Ideal Stuffer) into 11- by 30-inch fibrous casings. A 0.5 gram sample from each treatment was retained for determination of water holding capacity (WHC). Products were then chilled overnight before cooking.

A Blodgett convection oven was preheated to 350 ^{0}F and the four roasts inserted after the uncooked weights had been recorded. The roasts were cooked to an internal temperature of 120 ^{0}F before being flipped and cooked to a final internal temperature of 150 ^{0}F. The roasts were cooled at room temperature for 10 minutes, weighed, then stored in the cooler overnight. The percent cooking loss for each treatment was calculated.

Analytical Procedures

The water holding capacity was determined by the filter paper press method, as used by Kim, 1988. Four pre-dried Whatman No. 1 filter papers were placed on four separate 12 by 6 inch plexiglass plates. A 0.5 gram sample from each treatment was placed on the corresponding filter paper. The plates containing the samples were then stacked and a cover plate added. The samples were pressed simultaneously with a Carver Laboratory Press (Type C) at 500 psi for 1 minute. The filter paper was removed from the press and dried at room temperature. The area of total juice (Ring Zone) and meat film were marked and traced with a Compensating Polar Planimeter (Lietz, Model 47788). The WHC was recorded as the meat film area divided by the total juice area.

Shear force (in lbs.) was measured using three of the core samples taken from each treatment. Each core was sheared twice and the average of six measurements was recorded.

After the casing was removed, a 1-inch thick slice was taken from the center of each treatment. Fifteen 0.5-inch diameter core samples were extracted at various locations on each slice and placed in a numbered container. A seven-member taste panel was established to test the various treatments. A Duo-Trio Differentiation test was used to determine an individuals ability to distinguish between treatments. The panelists also evaluated the individual treatments for flavor. A six point scale was used (1--highly unacceptable to 6--highly acceptable) to evaluate the product flavor.

The data accumulated were analyzed using SPSS/PC+ vol. 3.0 (SPSS Inc., 1986). Multivariate Analysis of Variance (MANOVA) was performed to detect differences in cooking loss, water holding capacity, and shear force. One Way Analysis of Variance was used to detect differences between variables and treatments, using Duncan's Multiple Range Test to test homogeneity of treatments. Significant differences were accepted at $P<0.05$.

The Duo-Trio Differentiation test was analyzed by the number of correct responses in relation to the number of total responses. The Flavor Evaluation of Treatments test was analyzed to determine the sample mean and the standard deviation of each treatment to rate the flavor of individual treatments on a qualitative basis.

RESULTS and DISCUSSION

Results (Table 1) indicate that the use of NaCl with $Na_5P_3O_{10}$ in the formulation of restructured beef roasts was very effective ($p<.001$) in reducing cooking loss and increasing water holding capacity. Restructured roasts made with 1.7% NaCl and 0.3% $Na_5P_3O_{10}$ had less cooking loss and higher water holding capacity than roasts made with 1.7% NaCl, roasts made with 0.3% $Na_5P_3O_{10}$, and roasts with neither NaCl nor $Na_5P_3O_{10}$. These results support the findings of Mann et al. (1989), Marriot et al. (1985), and Huffman et al. (1984). There was no significant difference in shear force tenderness ($p>.05$) among the four formulations.

Results of the sensory evaluation for flavor indicates that restructured roasts made with both NaCl and $Na_5P_3O_{10}$ have no measurable difference in flavor from roasts made with NaCl alone, but are more flavorful than restructured roasts without NaCl.

Based on flavor, the product of Treatment 1 was considered unacceptable, whereas the product from Treatment 2 was slightly unacceptable and products from Treatments 3 and 4 were considered slightly acceptable. These findings expand on the findings of Huffman et al. (1984). This test also reported that roasts with no NaCl and 0.3% $Na_5P_3O_{10}$ were more flavorful than roasts with neither additive.

CONCLUSIONS

The use of $Na_5P_3O_{10}$ in conjunction with NaCl for the manufacture of restructured beef roasts resulted in decreased cooking loss and increased water holding capacity, but had no effect on tenderness compared to restructured roasts containing NaCl only, $Na_5P_3O_{10}$ only, and neither NaCl nor $Na_5P_3O_{10}$. Roasts containing NaCl were more acceptable to flavor panelists than those with no NaCl. The manufacture of restructured roasts containing NaCl and $Na_5P_3O_{10}$ might be beneficial to the industry for reducing cooking loss, increasing water holding capacity, and increasing flavor.

Table 1. Mean and standard deviation (SD) of cooking loss, water holding capacity (WHC), Warner Bratzler shear force, and flavor evaluation as affected by various treatments of sodium chloride and sodium tripolyphosphate.

Treatment		Cooking loss		WHC		Shear force		Flavor	
NaCl,	$Na_5P_3O_{10}$	Mean	SD	Mean	SD	Mean	SD	Mean	SD
		%				lbs			
(1) 0%	0%	30.1^a	2.8	43.29^a	12.05	2.74^a	0.80	2.4^a	1.2
(2) 0%	0.3%	28.1^a	5.4	61.07^b	18.99	2.44^a	0.44	2.7^a	1.4
(3) 1.7%	0%	23.3^b	4.1	85.71^c	10.79	3.21^a	1.28	4.3^b	1.2
(4) 1.7%	0.3%	15.0^c	5.0	93.50^c	9.89	2.78^a	0.69	4.2^b	1.1

Note: Means within a column followed by different letters are significantly different ($P<0.001$).

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Carcass Traits and Palatability of Barbados Sheep and Spanish Goats Raised Under Feedlot Conditions

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ABSTRACT

Data from 72 adult females consisting of 36 Barbados ewes and 36 Spanish goat nannies with their offspring were used to determine carcass traits, dressing weights, shear force values and eating quality of the two species. An analysis of variance for carcass weights, dressed weights, shear force values, uncooked weights, cooked weights, and weight loss showed no significant differences ($P > 0.05$) between weights of Barbados lambs and Spanish kids. In sensory evaluation of the Barbados sheep and the Spanish goats, the seven sensory panelists evaluated both meat of the lambs and kids as acceptable. Panelists were unable to tell the difference between the meat of the two species. Shear force values did not differ significantly between species. Therefore, this study suggests that Barbados lamb may be interchangeable with Spanish goat meat (of similar maturity and weight) with regard to palatability attributes.

KEY WORDS: sensory evaluation, lamb, kid, *Ovis corsican, Capra hircus*

Barbados sheep (*Ovis corsican*) originated in West Africa and were introduced to the Island of Barbados well over 300 years ago (Mason, 1980). This breed of sheep was introduced to the United States by the USDA in 1904 (Shelton, 1979). The Barbados sheep of the United States have many of the characteristics of the breed on the Island of Barbados, but differ in that the rams of the U.S. strain generally are horned, vary more in color pattern, and individual sheep have some wool (Levene and Spurlock, 1983). This breed of sheep retains at least some of the year-round breeding tendency of the original strain.

Barbados sheep are raised on many ranches in western Texas for three reasons: 1) meat--the flavor of the meat is similar to that of Spanish goat; 2) hunting--rams have large horns which make the head a trophy for hunters; and 3) novelty--Barbados is a non-wool producing breed with an exotic appearance (Shelton, 1979).

The Spanish goat (*Capra hircus*) is referred to as the "roughneck" of the domestic breeds. This breed of goat in the American Southwest is considered a mixed breed and is kept mainly for meat production. The Spanish goat breed is derived from the Granada, Murcia, and Malaga breeds of Spain (Ensminger and Parker, 1984). Due to this origin they are highly variable in appearance. Colors range from solid black, black and white, solid brown, to brown and white in a variety of patterns. Most males and females are horned.

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The ability of the Spanish goat to exist largely upon brush and yet yield acceptable quantities of edible meat is unparalleled among domestic farm animals (Dollahite, 1972). There is little classification or grading of live goat or goat carcass. The animal typically is sold by the head without regard to size, sex or condition.

MATERIALS AND METHODS

Barbados lambs and Spanish goat kids were produced and raised in a feedlot system. All lambs and kids were fed a complete feed containing 16% protein, with supplemental alfalfa hay daily. From 66 lambs and kids produced in this system, 18 were selected for slaughter and further analysis. The selection process was based on weight (24.0 to 85 lbs.) and age (44 to 185 days). For slaughter the range was narrowed (48 to 70 lbs.) to reduce variation in size.

Nine Barbados lambs and nine Spanish goat kids were slaughtered at the Sul Ross State University Meat Laboratory following conventional procedures. Hot carcass weights were obtained by rail scale. Carcasses were chilled at 38 °F for 24 hours postmortem. The carcasses were removed from the cooler and weights were obtained using electronic scales. *Longissimus dorsi* (LD) muscles were removed from the carcasses from the 6th to the 12th rib. The posterior portion of the loin was designated for sensory. Shear force analysis was obtained from the anterior of the loin. The *psoas major* (PM) muscles also were removed. The remaining portion of the loin was used for sensory evaluation. The LD and PM were placed in individual freezer bags, frozen at 6 °F, and stored for subsequent analysis.

For shear force testing the anterior 3.5 inch portion of the loin was removed from the freezer and thawed for about 24 hours at 38 °F. The conventional oven was preheated to 350 °F. Internal temperatures of the LD muscles were taken using a meat thermometer. The LD muscles were cooked fat side up until reaching 120 °F, then turned and cooked until reaching a final temperature of 150 °F. Cooking loss was determined after the LD cooled for 15 minutes. The LD portions were placed in the cooler at 38 °F for 24 hours, then removed from the cooler and cut into 1 inch steaks. Two cores (1.3 cm diameter) were removed from each steak and shear analyses were done (two analyses per core) using the Warner-Bratzler shear.

For the sensory evaluation, similar thawing, cooking and holding procedures were followed as for shear force evaluation. The sensory evaluation was composed of seven panelists who evaluated the Barbados lambs and Spanish goat LD and PM muscles. The panelists indicated whether or not they could distinguish a difference between lamb and goat meat samples, and judged the acceptability of the samples. The rating system was based on overall juiciness, and tenderness: 1. Highly unacceptable, 2. Unacceptable, 3. Slightly unacceptable, 4. Slightly acceptable, 5. Acceptable, and 6. Highly acceptable.

RESULTS AND DISCUSSION

Presented in Table 1 are the means and standard deviations for: carcass and dressed carcass weight, uncooked, cooked, weight loss for shear and sensory evaluation and shear force values. Analysis of this data revealed no significant difference ($P > 0.05$) between Barbados lambs and Spanish kids for any traits.

Table 1. Means and standard deviations (SD) of carcass weights and shear force values (Kg) for Barbados lambs and Spanish kids. None of the differences between species was significant ($P > 0.05$).

Traits	BARBADOS LAMBS (n=9) Mean	SD	SPANISH KIDS (n=9) Mean	SD
Live Weight	24.96	3.03	25.97	3.32
Hot Carcass Weight	11.99	1.28	12.41	1.69
Weight Loss	12.91	1.94	13.52	1.82
Cold Carcass Weight	11.28	1.19	11.68	1.68
Total Weight Loss	13.62	1.93	14.22	1.66
Shear % Cooking Yield	75.00	0.33	72.70	0.40
Sensory % Cooking Yield	60.20	0.50	59.70	0.50
Shear Force Values	9.98	4.08	11.89	5.26

The sensory traits of the LD and the PM muscles of the Barbados lambs and Spanish kids were evaluated as acceptable (data not shown). In 52% of evaluations, panelists could not tell the difference between lamb and kid meat.

CONCLUSION

Both Barbados lamb meat and Spanish kid meat were evaluated as acceptable in sensory traits. Slightly more than one-half of the panelists could not detect a difference in the two meats. The shear force values of the Barbados lamb and the Spanish kids showed no significant differences. The data indicated that Barbados lamb meat may be interchangeable with Spanish goat meat (of the same approximate maturity and weight) with regard to palatability attributes.

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Dry Matter Digestibility of Fourwing Saltbush (*Atriplex canescens*) Mixed with Blue Grama (*Bouteloua gracilis*)

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ABSTRACT

Fourwing saltbush [*Atriplex canescens* (Pursh) Nutt.] is a widespread shrub in arid regions of the western United States, is highly palatable, and possesses high dry matter digestibility (DMD). This study compared the DMD of fourwing saltbush at four phenological stages of development when mixed in different proportions (100, 75, 50, 25 and 0%) with blue grama [*Bouteloua gracilis* (H.B.K.) Lag. *ex* Steud.]. Fourwing saltbush had higher DMD when alone than when mixed in any proportion with blue grama ($P \leq 0.05$). Dry matter digestibility was also higher in fourwing saltbush at earlier stages of phenological development ($P \leq 0.05$). Adding fourwing saltbush in any proportion to blue grama enhanced DMD. Further, it had positive or negative associative effects on DMD depending on mixture proportion and stage of development. These associative effects may be attributed largely to crude protein levels of the forage mixture.

KEY WORDS: Associative effect, Trans-Pecos

Fourwing saltbush, a native, facultative-evergreen shrub widely distributed in western North America, provides forage for livestock and wildlife (Peterson et al., 1987; Plummer et al., 1966). It furnishes relatively large amounts of essential nutrients, including protein, phosphorus, calcium, and carotene, even during winter months (Shoop et al., 1985), and has a crude protein content as high as 24.2% (Welch, 1978).

Fourwing saltbush is a major constituent of cattle diets when it is abundant (Shoop et al., 1985). It commonly occurs in association with numerous semiarid species, and is consumed with them. Cattle on the central shortgrass plains eat appreciable amounts of saltbush when it is available, especially during winter (Shoop et al., 1985). In the Chihuahuan Desert it grows with other forage species, including blue grama (*Bouteloua gracilis*), alkali sacaton (*Sporobolus airoides*), sideoats grama (*Bouteloua curtipendula*), honey mesquite (*Prosopis glandulosa*), and catclaw acacia (*Acacia greggii*).

To optimize forage use, grazing managers should understand associative effects of fourwing saltbush on digestible nutrients when consumed with other forages. The digestibility of dry matter content of fourwing saltbush may vary with phenological stage of development, and proportion of different species in the diet.

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The objectives of the study were to: 1) determine how DMD of fourwing saltbush varied through the growing season; 2) determine if combining fourwing saltbush with blue grama enhanced DMD of the forage mixture; and 3) determine what proportion of fourwing saltbush gave the greatest digestibility enhancement to the forage mixture.

METHODS AND MATERIALS

Plant materials used in this study were collected throughout the Trans-Pecos and grown in a common plot in Alpine, Texas. New twigs and leaves of fourwing saltbush were collected in 1988 at four different stages of phenological development: before seed development (8 June); at first sign of seed development (21 August); at full seed maturity (5 October); and once seeds dried on the plant (4 November). Blue grama samples (leaves and stems) were collected on 4 November, after plants had cured. A single collection date was used for blue grama to provide a comparison standard for the varying effects of saltbush phenology.

Six plants were sampled at each date, air dried and ground in a Wiley Mill to pass through a 0.02-inch mesh screen. Samples were then dried in a convection oven at 104 °F for 7 hrs and partitioned into the following mixtures for each of the four phenological sample periods:

Fourwing saltbush	100%	75%	50%	25%	0%
Blue grama	0%	25%	50%	75%	100%

Dry matter digestibility was determined using the *in vitro* digestibility technique described by Ellis (unpublished, Texas A&M University Forage Digestibility Lab). Rumen inoculum was collected from a single fistulated steer (Hereford-Angus crossbred) grazing on pastures containing the forage species analyzed in this study. Fermentations were conducted in 3 oz. polypropylene tubes containing about 0.018 oz. of test forage, 1.2 fluid oz. of medium and 0.3 fluid oz. of rumen fluid inoculum. Duplicate subsamples, together with duplicates of a standard oat hay forage (with digestibility estimates established from *in vivo* methods) were analyzed. Each subsample pair was averaged and treated as a single observation. Only pairs with less than ± 3% difference from the pair mean were used. Undigested neutral detergent fiber was taken to represent truly indigestible dry matter of the sample, and true digestibility was calculated by deduction. The Kjeldahl method was used to determine crude protein (CP) for the six samples of fourwing saltbush and blue grama (AOAC, 1984), and percent CP for the forage mixtures calculated from proportionally weighted means.

One-way analysis of variance and Duncan's new multiple range test were used to compare results among species proportion treatments and among sample dates ($P \leq 0.05$). Least squares linear regression was used to assess relationships between DMD and proportion of fourwing saltbush in the forage samples ($P \leq 0.05$). All analyses were performed using SPSS/PC+ (SPSS, 1988).

RESULTS AND DISCUSSION

Dry matter digestibility of fourwing saltbush alone was significantly higher than when mixed with blue grama (Table 1). In each case, a greater proportion of fourwing saltbush resulted in enhanced DMD. This relationship was also true for crude protein (Table 2). Digestibility within a forage mixture was significantly higher at earlier phenological stages of development (Table 1). The same trend was apparent for CP (Table 2). Dry matter digestibility decreased with greater proportions of blue grama in the forage mix (Figure 1). Conversely, the greater the proportion of fourwing saltbush, the more digestible the forage mixture became. This was further illustrated in the linear regressions for sample mixture DMD for each fourwing saltbush phenological stage (Figure 2). All regressions were significant, with $r^2 \geq 0.60$.

Table 1. Mean dry matter digestibility (%) of fourwing saltbush at different phenological stages when mixed in varying proportions with blue grama.

% Fourwing saltbush	Collection dates (1988) 8 Jun	21 Aug	5 Oct	4 Nov
100	71.24 a,A[1]	67.92 a,AB	61.21 a,BC	60.22 a,C
75	62.98 b,A	55.50 b,B	57.73 a,B	57.85 a,B
50	60.17 b,A	52.17 c,B	43.92 b,C	47.83 b,BC
25	48.00 c,A	48.87 c,A	42.86 b,A	47.09 b,A
0	38.11 d,A	38.11 d,A	38.11 b,A	38.11 c,A

[1] Means followed by the same lower case letter within a column, and means followed by the same upper case letter within a row are not significantly different at $P \leq 0.05$.

Table 2. Crude protein (%) of fourwing saltbush and blue grama forage mixtures.

% Fourwing saltbush	Collection dates (1988) 8 Jun	21 Aug	5 Oct	4 Nov
100	17.48	17.14	13.38	11.77
75	14.93	14.67	12.08	10.64
50	13.39	12.33	10.49	9.53
25	9.84	9.75	8.89	8.41
0	7.30	7.30	7.30	7.30

Pure fourwing samples were higher in DMD than any other combination. Although fourwing saltbush may constitute the bulk of the diet when it is young and lush, or when the selection differential is so narrow that dietary choices are limited, it is not selected in the diet at all times (Shoop et al., 1985). Other species, which apparently offered the animals more balanced nourishment, were often selected.

The *in vitro* estimated digestibility of fourwing saltbush-blue grama mixtures was different than that calculated from weighted estimates of pure sample digestibilities. For example, the estimate obtained from actual digestion was different for 50% mixtures when compared to the weighted averages obtained from digestibility of pure samples (Figure 3). This clearly demonstrated that associative effects were present when the two forages were mixed and subjected to fermentation. Early in the summer, DMD was about 5% greater than expected when 50% of the forage mixture was composed of fourwing saltbush. This suggested that the associative effects improved digestibility when fourwing saltbush harvested at that time was mixed with grass in the diet.

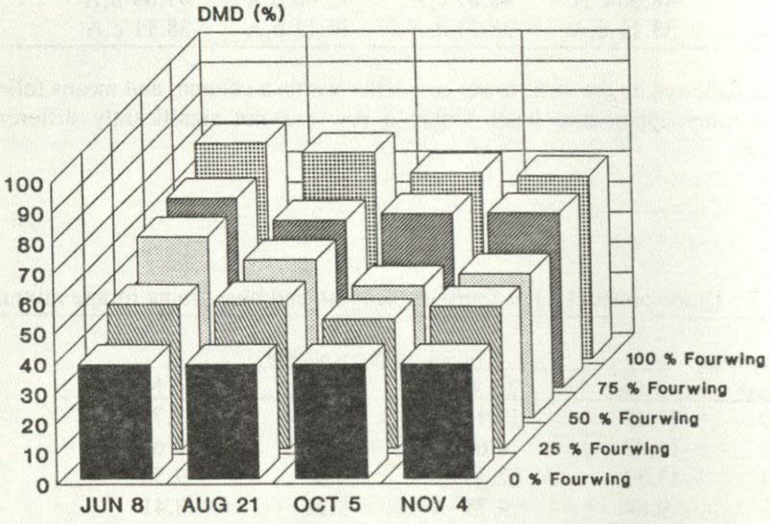

Figure 1. Dry matter digestibility (%) for different forage mixtures of blue grama and fourwing saltbush collected at four stages of phenological development.

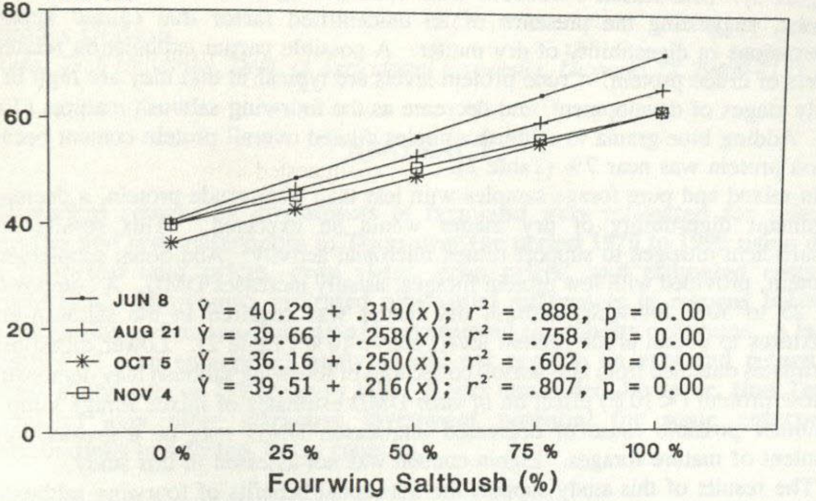

Figure 2. Linear regressions of dry matter digestibility at four phenological stages for five combinations of fourwing saltbush and blue grama.

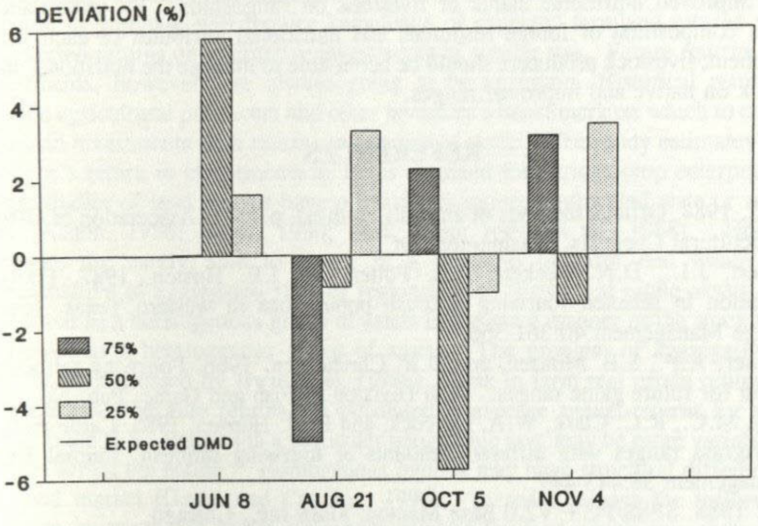

Figure 3. Deviation of actual dry matter digestibility (DMD) from expected DMD for three forage mixture proportions (25, 50 and 75% fourwing saltbush) at four sample periods. Actual DMD is the mean of analyzed replicated forage samples. Expected DMD was calculated from a weighted mean of relative proportions of DMD using estimates of DMD from 100% fourwing saltbush and 100% blue grama. The deviation was derived by subtracting expected DMD from actual DMD.

Conversely, when fourwing saltbush obtained from mid-season collections was mixed with blue grama, digestibilities were as much as 6% less than expected (Figure 3). Mid-season collections were made during early and late seed maturity phases, suggesting the presence of an unidentified factor that caused apparent depressions in digestibility of dry matter. A possible partial explanation relates to levels of crude protein. Crude protein levels are typical in that they are high in the early stages of development, and decrease as the fourwing saltbush matures (Table 2). Adding blue grama to saltbush samples diluted overall protein content because grass protein was near 7% (Table 2).

In mixed and pure forage samples with less than 10% crude protein, a decreased ruminant digestibility of dry matter would be expected. This results from insufficient nitrogen to support rumen microbial activity. Additional supplemental protein, provided with low protein forages, usually increases DMD. A composition of 25 to 50% fourwing saltbush dry matter was required in the saltbush-grass mixtures to obtain crude protein levels above 10% (Table 2). Lower digestibility estimates obtained from late-season collections of fourwing saltbush may demonstrate a low protein (<10%) effect on *in vitro* DMD estimates of mixed forage samples. Another possible cause of depressed late-season DMD may be a greater lignin content of mature forages. Lignin content was not assessed in this study.

The results of this study support the nutritional benefits of fourwing saltbush in ruminant diets. Digestibility declined through the growing season, but was always greater than that of blue grama. The DMD of blue grama was enhanced by the addition of fourwing saltbush, and mixtures with the highest proportion of fourwing saltbush had the highest digestibilities. Undoubtedly fourwing saltbush contributes to an improved nutritional status of livestock on rangelands. By understanding species composition of forage resources and nutritional attributes of each forage component, livestock producers should be better able to manage the nutritional status of stock on native and improved ranges.

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Estimation of Historical Returns to Land for Selected Texas Counties and Crop Enterprises

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ABSTRACT

Historical returns to investments in farmland were estimated for selected counties and crop enterprises in Texas over the period 1976 to 1990 using data on historical land prices, crop yields, crop prices, and estimated costs of production. The results indicated substantial differences in returns between participation and nonparticipation in government commodity programs. A large number of crop enterprises analyzed did not provide an expected return in excess of the rate on US treasury bills. It was concluded, however, that Texas farmland may offer attractive investment potential for some enterprise combinations in selected Texas counties.

KEY WORDS: farmland, investment

Agricultural land is owned and operated for the purpose of receiving a return to the land. The returns received will likely vary according to region, crop produced, government payments and management level. For investors in agricultural land, the decision to purchase will require knowledge of expected farmland returns relative to expected returns on alternative investments of similar risk. Future returns to land investments, however, are always going to be uncertain. Historical returns can provide agricultural producers and other investors a benchmark on which to compare farmland investments with returns to alternative assets. This study estimates a farm operator's return to investments in Texas cropland for various crop enterprises.

Past studies of land returns have primarily examined aggregated state or regional data (Alston, 1986; Barry, 1980; Burt, 1986; Irwin et al., 1988). However, investors are rarely able to invest in a portfolio of farm real estate assets representative of aggregated state or regional data. Farm real estate assets should be viewed as a heterogenous group of assets in the same manner as the stock market is viewed as a heterogenous group of assets. The problem of aggregation was specifically discussed by Irwin et al. (1988), "Risk in farm real estate returns may be understated because returns are calculated as average annual returns for all real estate in the U.S. Returns in a particular geographic area may be more variable than returns across the nation." Homogenous regions may have structural differences in the land market (Gertel and Canning, 1990). In some regions the influence of nonfarm investors can create a stronger demand for land which may reduce land price variability. Also, different areas may have different weather patterns or soil types which may result in varying yield histories. For example, irrigated farmland would be expected to have less yield variability than unirrigated farmland, thus

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contributing to differences in land price variability. As contrasted with the previous studies cited above, this study estimates returns to cropland for specific as opposed to aggregated regions.

One option is to examine total returns to land as the cash rent divided by the real estate value. This approach, however, assumes that all land is rented on a cash rent basis. The largest portion of agricultural land is owned by farmers and a large proportion of rental arrangements are crop share type arrangements rather than cash rent. Cash rent statistics are typically reported as regional or state averages for all crops. Also, the amounts and terms of cash rents are frequently determined prior to the crop year. Therefore, examination of land returns using cash rent ignores many of the impacts that different crops, regional weather patterns, government programs and management levels may have on the variability of returns.

This study estimated returns to farmland assuming the land is owned and operated by an agricultural producer. A historical series of farmland returns which incorporated regional differences in costs, land values, yields, and prices were estimated for selected counties and crop enterprises in Texas. Returns were estimated assuming the owner has full equity. Of course, many farm operators do carry debt. The USDA estimates that approximately 50% of US farms hold some outstanding liabilities (Morehart et al., 1990). The impacts of leverage are examined by comparison of the estimated returns with interest rates on farm loans. Estimated returns were utilized to compare differences in returns between regions and crops produced and the influence of government programs on farmland returns. The paper proceeds by first describing the procedures and data required to estimate land returns. A subsequent section provides a discussion of the counties and crops chosen for the analysis with results and implications presented in the final section.

DATA AND PROCEDURE

Counties for which returns were estimated are displayed in Figure 1. These counties were chosen from different crop reporting districts established by the Texas Agricultural Statistics Service (TASS). Crops were chosen from counties analyzed to represent typical crop production patterns within those regions. The specific crops and associated crop reporting district are further described in Table 1. Returns as a proportion of the total land investment were calculated using estimated crop receipts, production costs, and land values as shown in Equation 1.

$$\begin{aligned}
(1)\quad \text{ROL}^i_{jt} = {} & \{(\text{SAPRICE}^i_{jt} * \text{YLD}^i_{jt}) + \text{OINC}^i_{jt} + \\
& [(\text{TARGET}^i_t - \text{SAPRICE}^i_{jt}) * \text{YLD}^i_{jt} * \text{GVT}] - \\
& \text{PREHAR}^i_{jt} - (\text{HARCOST}^i_{jt} * \text{YLD}^i_{jt}) - \\
& (\text{ASIDEACRE}^i_t * \text{ASIDECOST}^i_{jt}) - \text{MACHFIX}^i_{jt} - \\
& (\text{RETAX}_t * \text{AVELAND}^i_{jt}) \} \\
& /\text{AVELAND}_{jt} * [1 + (\text{ASIDEACRE}^i_t) * \text{GVT})].
\end{aligned}$$

Where:

ROL^i_{jt} = Estimated return on land for crop i in county j for year t as a proportion of the land investment.

SAPRICE^i_{jt} = Season average price per unit (bushel, pound, etc.) for crop i in county j for year t.

YLD^i_{jt} = Average per acre yield for crop i in county j for year t.

OINC^i_{jt} = Other crop income per acre received for crop i in county j in year t.
TARGET^i_t = Government target price per unit for crop i for year t.
GVT = A binary variable representing participation in government programs.
0 = no participation.
1 = participation.
PREHAR^i_{jt} = Estimated preharvest cost per acre for crop i in county j in year t.
HARCOST^i_{jt} = Estimated harvest cost per unit for crop i in county j in year t.
ASIDEACRE^i_t = Required setaside as a proportion of total acres for crop i in year t.
ASIDECOST^i_{jt} = Estimated variable and fixed machinery cost per setaside acre for crop i in county j for year t.
MACHFIX^i_{jt} = Estimated fixed cost of machinery and equipment per acre for crop i in county j in year t.
RETAX_t = Real estate tax as a percent of market value for year t.
AVELAND_{jt} = Past four quarter moving average value of land for county j in year t.

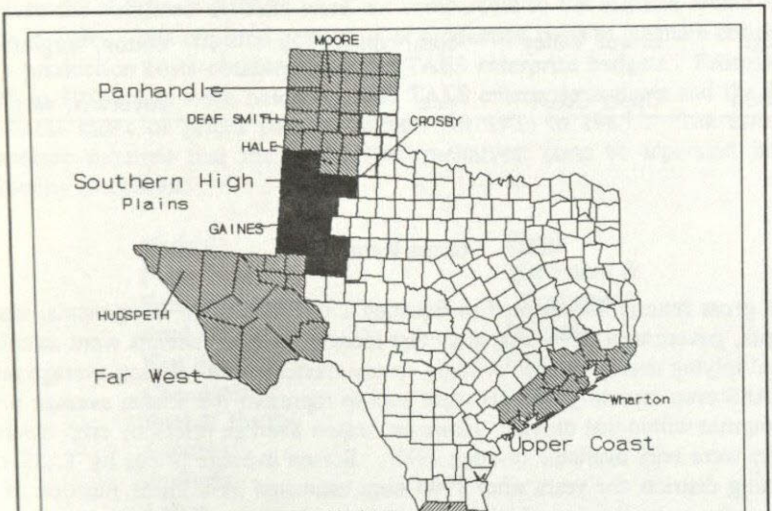

Figure 1. Diagram of counties and associated crop reporting districts chosen for analysis.

Table 1. Crop enterprises, counties and associated crop reporting districts analyzed.

County	Crop Reporting District	Irrigated Crops	Dryland Crops
Moore	Panhandle	corn, sorghum, wheat	wheat
Deaf Smith	Panhandle	corn, sorghum, alfalfa, wheat	sorghum, wheat
Hale	Panhandle	corn, cotton, wheat sorghum, soybeans	cotton, wheat
Crosby	South Plains/ heavy soils	cotton, sorghum	wheat
Gaines	South Plains/ sandy soils	cotton, sorghum	sorghum
Hudspeth	Far West	cotton	
Hidalgo	Lower Valley	corn, cotton	cotton, sorghum
Wharton	Upper Coast	rice	soybeans, sorghum

Gross Returns

The gross returns documented in Equation 1 included three components; market receipts, government payments, and other income. Market receipts were calculated by multiplying season average price by county average yield. Season average prices by TASS crop reporting districts were used to represent the season average prices for counties within that district. However, season average prices by crop reporting district were only available through 1985[1]. Season average prices by TASS crop reporting districts for years after 1986 were estimated as a linear function of the state season average price which is described by the following relationship,

(2) $\text{SAPRICE}^{i}_{jt} = \alpha + \beta\ \text{TXPRICE}^{i}_{t}$

where is TXPRICE^{i}_{t} represents season average price for crop i in Texas for year t; α is an intercept term, and β is a slope coefficient. Equation 2 was estimated using ordinary least squares techniques over the period 1976 through 1985 with the results displayed in Appendix 1. In all but 4 of the 19 cases, Equation 2 explained 85% or more of the variation in season average price by TASS district. These estimates were subsequently used to generate crop reporting district season average prices for 1986 to 1990.

County average yield data for 1976 to 1990 were obtained for each crop analyzed using TASS publications. Equation 1 considered both deficiency payments and commodity loan receipts as government program payments. Income from receipts obtained from sources other than crop sales, such as grazing income from wheat and sale of cottonseed were also included in Equation 1 as other income.

Costs

The production costs described in Equation 1 were separated into preharvest cost, harvest cost, cost of maintaining setaside acres, and fixed costs. Costs were estimated using Texas Agricultural Extension Service (TAES) enterprise budgets. Enterprise budgets are constructed annually by TAES personnel for each crop reporting district. These budgets represent approximations of actual crop costs. They should, however, reflect any technical changes in production technology. Crop costs estimated for each crop reporting district by TAES were used to represent production cost for counties within that district. For example, costs estimated for crop enterprises located in the Panhandle were used to represent costs for Deaf Smith, Hale and Moore counties. The previously mentioned budget cuts for the Texas Department of Agriculture in 1986 also resulted in a redefinition of TASS crop reporting districts. The redefinition created an inconsistency in the data because the redefined districts were not comparable to the districts which existed prior to 1986. This required generation of production costs to maintain consistency with production costs obtained from the TAES enterprise budgets. Estimation of 1976 to 1985 costs were based on 1986 TAES enterprise budgets and the USDA historical index of prices paid by farmers for 1976 to 1985. The estimation procedure required that the TAES 1986 preharvest costs be separated into the following categories:

Variable
Feed
Feeder Livestock
Seed
Fertilizer
Chemicals
Fuel & Energy
Supplies
Services
Labor
Other

Fixed
Machinery & Equipment
Irrigation
Land
Other

The categories listed above correspond to the components used in the USDA index of prices paid by farmers. Production costs for 1976 through 1985 for the redefined TASS crop reporting districts were recursively estimated using the USDA index of prices paid by farmers and 1986 TAES data in a manner described by Equation 3 for fertilizer cost. This procedure assumes that the technology which existed in 1985 was equivalent to the technology which existed in 1976. Equation 3 demonstrates the estimation of fertilizer cost for 1985 using estimated fertilizer costs for 1986 and USDA index of prices paid for fertilizer.

$$(3) \quad FERT^{j}_{t} = FERT^{j}_{t+1} * \left(1- \left(\frac{INDF_t - INDF_{t+1}}{INDF_t}\right)\right)$$

where: $FERT^{j}_{t}$ = Estimated fertilizer cost for crop j in year t.

$INDF_t$ = USDAs index of prices paid for fertilizer in year t.

Harvest cost per production unit was estimated for each crop for 1986 from the TAES budgets. Harvest cost per unit for 1976 to 1985 was estimated recursively using the index of prices paid for services (INDS) obtained from USDA data and 1986 level of harvest cost per unit.

$$(4) \quad HARCOST^{i}_{jt} = HARCOST^{i}_{jt+1} * \left(1- \left(\frac{INDS_t - INDS_{t+1}}{INDS_t}\right)\right)$$

where: $INDS_t$ = Index of prices paid for services in year t.

Total harvest cost per acre was subsequently estimated by multiplying the harvest cost per harvested unit by county average yield as shown in Equation 1.

Costs estimates for maintaining diverted acres for each crop were based on setaside requirements. The setaside cost per acre was obtained from TAES enterprise budgets for 1986 to 1989 with per acre costs for 1976 to 1985 generated using the USDA index of prices paid. The estimated cost of maintaining the diverted acres includes the variable costs plus the fixed cost of machinery and equipment.

Fixed costs considered in the analysis included insurance, depreciation, taxes, and interest associated with machinery and equipment and real estate taxes. Data on the average tax rate for Texas agricultural land was obtained from USDA (1990).

Fixed irrigation charges were omitted from the analysis because it was assumed that these charges would be capitalized into the land cost. As with other costs, the amount of fixed machinery and equipment cost per unit for 1976 through 1985 was estimated recursively using the index of prices paid for machinery and the 1986 level of fixed machinery and equipment cost.

The residual remaining in the numerator in Equation 1 after all calculations have been performed represents a residual return to land. This residual was subsequently divided by the average land value for the year to estimate farm operator returns as a percent of land value. It should be recognized that this represents a return per harvested acre and does not incorporate abandonment (i.e. acres planted but not harvested). Readers knowledgeable about Texas agriculture would recognize that abandonment does occur frequently on the Texas High Plains with dryland wheat and to a lesser extent with dryland cotton. Abandonment is less common in other areas and other crops. Readers should consider these factors when examining the results.

Average values of irrigated and unirrigated cropland for each TASS crop reporting district for 1976 to 1990 were determined from quarterly surveys conducted by the Dallas Federal Reserve Bank (unpublished). The number of survey respondents was not reported until 1986 and was not reported for 1990. Small numbers of survey respondents were indicated in some crop reporting districts (Table 2). Statistical procedures generally require a minimum of 25 to 40 observations depending on accuracy desired and the sample variance to insure that the sample reflects the population. The average number of respondents indicates a possibility of inadequate size samples in the Lower Valley and Far West crop reporting districts. In their statistical releases, the Dallas Federal Reserve Bank uses 3 and 4 quarter moving averages to smooth any bias due to the small sample sizes. In this analysis, land values represented a 4 quarter moving average.

Table 2. Average number of quarterly survey respondents by crop reporting district, 1986 - 1989.

	Average Number of Respondents	
Crop Reporting District	Dryland	Irrigated
Panhandle	29.5	28.4
South Plains	25.8	24.9
Far West		3.8
Lower Valley	6.9	8.3
Upper Coast	205.0	122.2

Capital gains on farmland were added to the returns obtained from farm operations to estimate the total returns to land:

(5) $TOTRET^i_{jt} = ROL^i_{jt} + CAPGAIN_{jt}$,

where $TOTRET^i_{jt}$ represents total operating returns and capital gains for farmland producing crop i in county j in year t; $CAPGAIN_{jt}$ represents the estimated amount of capital gain for cropland in county j for year t.

Capital gains were calculated based on changes in the land values over the period (Equation 6).

(6) $CAPGAIN_{jt} = (AVELAND_{jt} - AVELAND_{jt-1})/AVELAND_{jt-1}$

Distinctions were made between participation and nonparticipation in government programs. Calculations of returns for participation assumed that producers were fully enrolled in government programs. This implied producers received the season average price for harvested yield plus government deficiency payments, commodity loan receipts and other income. However, participation required that some land may have to be set aside. This was accounted for by increasing the average land investment in the denominator of Equation 1:

$$AVELAND_{jt} * [1 + (ASIDEACRE^i_j) * GVT)].$$

RESULTS

Means and standard deviations calculated using Equation 1 are displayed in percentage terms in Table 3 for selected irrigated crop enterprises and Table 4 for selected dryland crop enterprises. The figures include both the residual return from farm operations and capital gains. The data displayed in Table 5 specifically details historical capital gains on farmland for the crop reporting districts analyzed. Comparison of capital gains statistics with total returns shown in Tables 3 and 4 provides an indication of the relative influence of capital gains versus residual returns on returns to land. Aggregated statistics calculated by USDA indicate that a majority of the variability in returns on agricultural assets is due to capital gains (USDA, National Financial Summary-1990). The results in this study indicates that when examined on a disaggregated basis, a large portion of the variability in returns to land investments is due to variability in the residual returns to farm operators. For example, the average annual capital gain for Panhandle irrigated farmland was -0.41% with a standard deviation of 8.22%. In contrast, estimated average annual total returns for irrigated crops produced in the Panhandle ranged from -1.56% for wheat in Hale county to 37.01% for sugar beets in Deaf Smith county (Table 3)[2]. Also, the average standard deviation for irrigated crop returns in the Texas Panhandle ranged from 9.37% for sorghum produced in Moore county to 21.41% for sugar beets produced in Deaf Smith county.

The results indicate that nonparticipants in government programs would have received lower expected total returns with higher standard deviations than government program participants over the analysis period. Mean returns of irrigated crops declined by approximately 30% and mean dryland crop returns declined by approximately 60% when government program payments were excluded. In some instances the standard deviation of dryland returns with government program participation was slightly higher than the option assuming no government participation. This occurred with cotton in Hale and Hidalgo counties and wheat in Moore county (Table 4). This is probably due to the shortness of the data series and that government programs have regularly increased the returns to land for these crops thus increasing the upper range of returns.

Mean returns are generally positive when full government participation is considered. Exceptions for irrigated crop enterprises included sorghum in Gaines, Crosby, and Hale counties and irrigated wheat in Hale county. Dryland sorghum in Gaines and Hidalgo county also resulted in negative returns when government payments were included. The negative returns are merely an indication that prices and yields of these crops were insufficient to cover costs. Producers have responded to these negative returns through reductions in acreage. For example, planted acres of sorghum in Gaines county declined from approximately 100,000 acres in 1976 to less than 30,000 acres in 1990. Exclusion of government program payments contributed to an increase in the number of crops analyzed displaying negative expected returns. Approximately 40% of expected irrigated returns were negative when government program payments were excluded. These negative returns primarily concentrated among sorghum and cotton enterprises.

Highest returns occurred for sugar beets, alfalfa, and rice. In the case of sugar beets, government program payments are made to the processor with the processor negotiating a price contract with the producer. The contract price received by the producer does not distinguish the market price from the government payment making it infeasible to estimate a return to sugar beets which differentiated between government program participation and nonparticipation. While sugar beet returns are apparently high, it should be realized that acreage is limited by processor contracts, thus restricting any major expansion of acreage in response to high levels of returns. High returns were also shown for alfalfa production in Deaf Smith, rice in Wharton county and cotton production in Hudspeth county. The accuracy of total returns for Hudspeth county, however, may be limited by small sample sizes.

Table 3. Estimated total percentage returns to irrigated crop enterprises for selected Texas counties (1976 - 1990).

		Government Program Participation		No Government Program Participation	
Crop	County	Mean	Standard Deviation	Mean	Standard Deviation
		%			
Corn	Deaf Smith	14.82c	12.07	8.20	19.61
Corn	Hale	10.28b	12.30	5.21	20.71
Corn	Hidalgo	0.05	17.49	-1.35	19.54
Corn	Moore	14.39a	10.08	7.73	18.67
Cotton	Crosby	5.50	14.51	-2.89	21.31
Cotton	Gaines	13.36b	20.33	4.02	23.34
Cotton	Hale	10.36b	15.63	-0.15	18.78
Cotton	Hidalgo	11.94b	15.46	5.99	18.18
Cotton	Hudspeth	18.83a	17.80	9.68	17.65
Sorghum	Crosby	-5.20	13.69	-9.73	17.63
Sorghum	Deaf Smith	4.08	9.58	-0.60	15.38
Sorghum	Gaines	-2.89	13.89	-5.91	17.01
Sorghum	Hale	-1.75	12.48	-5.96	17.54
Sorghum	Moore	7.74b	8.90	3.53	15.71
Soybeans	Hale			2.84	15.15
Rice	Wharton	20.05a	17.63	12.05c	20.44
Alfalfa	Deaf Smith			33.67a	18.01
Sugar Beets	Deaf Smith	37.01a	21.41		
Wheat	Deaf Smith	5.37d	10.16	0.68	14.20
Wheat	Hale	-1.56	9.37	-6.28	14.02
Wheat	Moore	7.74b	9.91	2.67	13.19
	AVERAGE	8.96	17.91	3.76	21.13

a = Significantly different from 0 at the .0001 level of significance.
b = Significantly different from 0 at the .01 level of significance.
c = Significantly different from 0 at the .05 level of significance.
d = Significantly different from 0 at the .10 level of significance.

Table 4. Estimated total percentage returns to dryland crop enterprises for selected Texas counties (1976 - 1990).

		Government Program Participation		No Government Program Participation	
Crop	County	Mean	Standard Deviation	Mean	Standard Deviation
		%			
Cotton	Hale	10.36	25.42	0.45	22.35
Cotton	Hidalgo	21.13	47.46	4.22	46.07
Sorghum	Deaf Smith	15.15a	11.26	13.42b	13.77
Sorghum	Gaines	-2.87	13.84	-5.31	16.89
Sorghum	Hidalgo	-3.16	27.23	-7.18	29.67
Sorghum	Wharton	7.22	20.59	5.08	22.86
Soybeans	Wharton			9.46	25.50
Wheat	Crosby	3.77	14.71	1.50	16.50
Wheat	Deaf Smith	13.31a	9.87	11.45	11.82
Wheat	Hale	5.33d	10.85	3.16	12.01
Wheat	Moore	5.02	26.27	-0.64	25.94
	AVERAGE	7.57	23.20	3.24	24.09

a = Significantly different from 0 at the .0001 level of significance.
b = Significantly different from 0 at the .01 level of significance.
d = Significantly different from 0 at the .10 level of significance.

Table 5. Expected capital gains and standard deviation of capital gains for dryland and irrigated farmland in selected Texas crop reporting districts (1976 - 1990).

	Dryland		Irrigated	
Crop Reporting District	Mean	Standard Deviation	Mean	Standard Deviation
	%		%	
Panhandle	1.21	7.99	-0.41	8.22
South Plains	3.09	12.88	2.14	10.57
Far West			3.56	18.06
Lower Valley	-2.73	21.54	0.82	14.92
Upper Coast	4.04	17.41	2.43	14.64

T-statistics indicated that none of the mean capital gains were significantly different from 0 at the .10 level of significance or less.

A complete analysis of land returns should focus not only on means and standard deviation but covariances. While covariances may indicate the diversification possible through a combination of enterprises, it is beyond the scope of the current study. An alternative available which does provide useful information would be a comparison of expected total returns with the risk free rate of return. The risk-free rate of return represents a lower bound to the returns which rational investors would expect. Also, numerous studies have shown that investments in agricultural assets display little systematic risk and under financial theory should provide a return approximately equal to a risk free asset (Barry, 1980; Irwin et al., 1988). This simply means that most of the variability in returns to agricultural assets is random and not related to returns in the stock market or macroeconomic changes. Investors in agricultural assets could, through holding several assets, diversify away the variability associated with agricultural assets. Therefore, diversified investors would view agricultural assets as risk-free investments and require a return no greater than the risk-free rate.

One indicator of the risk free rate is the rate on US treasury bills. The average annual treasury bill rate over the period was 7.99% (Ibbotson, 1990). Results indicate that 11 of the 19 irrigated crop enterprises analyzed for the full government program participation option produced returns greater than the risk free rate. It was also indicated that 5 of the 20 returns on irrigated crops with no government program participation were greater than the treasury bill rate. Returns for dryland crops were much lower relative to the treasury bill rate. Only 4 of 10 dryland crops produced average annual returns greater than the treasury bill rate when government program participation was included. Only 3 dryland crop average annual returns were greater than the treasury bill rate when no government program participation was considered.

Results presented in Tables 3 and 4 can also be used to determine which county/crop enterprises could have supported debt over the analysis period[3]. This can be done by comparing estimated returns with the cost of debt over the period. The average annual interest rate paid by farmers on Farm Credit System debt for the period was 10.99%.[4] Results indicated that only 4 of 19 irrigated enterprises receiving government payments would have produced returns in excess of the cost of debt. Only 2 of 20 the irrigated enterprises not receiving government payments would have received returns in excess of the cost of debt. Results for the dryland enterprises indicated that 4 of the 10 enterprises receiving government payments would have had the potential to support debt while only 2 of the 11 enterprises not receiving government payments could have supported debt.

SUMMARY AND CONCLUSIONS

A historical series of farmland returns was estimated for selected counties and crop enterprises in Texas using data on land prices, crop yields, crop prices and estimated costs of production. When examined on a disaggregated basis, returns to land were highly variable. A large portion of the variation was explained by the selection of crop enterprise. This is in contrast to analysis of aggregate farming returns by USDA which indicate that the variation in returns to agricultural assets is due to changes in the price of assets. Positive expected returns are indicated for most crop enterprises. However, the exclusion of government program payments results in large declines in mean returns and increases in standard deviations in most cases.

Institutional investors in farm real estate such as insurance companies or pension funds may be restricted from participation in government commodity programs. Therefore, investment potential is limited for these investors among the enterprises analyzed. A majority of the enterprises analyzed did not return in excess of the treasury bill rate when government payments were excluded. Of the enterprises analyzed, only a small portion would have had the potential to service debt over the period. The results indicated, however, that net returns in excess of the risk free rate can be earned in some cases, demonstrating that farmland may offer attractive investment potential for individuals or institutions not restricted from participating in government programs. For example, a parcel of farmland in Deaf Smith county that produced equal proportions of irrigated corn and sugar beets along with dryland wheat and sorghum would have an expected total return of about 19%.

Results from this study should be qualified because of the limited time period analyzed, quality of data, and level of aggregation. The time period analyzed (1976 to 1990) includes the farm financial bust of the 1980s and excludes much of the period of rising nominal real estate prices which occurred between 1950 and 1977. The period of analysis was limited, however, by the availability of data on land values at crop reporting district level. It is recognized that TAES enterprise budgets are approximations and are subject to error. Farm accounting data would be a preferable data source for costs but was not available over the time period for the enterprises analyzed. It is also recognized that the feasibility of investment in farmland is best analyzed at the farm level. Variances of yields may be less at the county level than at the farm level due to covariances between farms. County level data on yields, however, was the lowest level of aggregation available. The results are limited to crop enterprises analyzed and no implications can be drawn beyond these counties and crops. Also, returns are estimated for harvested acres and do not consider the additional cost which may be associated with acres planted but not harvested.

This study has not attempted to consider the impacts of covariance or determine combinations of enterprises which may have investment potential. These topics are left for future study. Despite the limitations of the study, the historical returns developed in this study should provide Texas agricultural producers and investors in agricultural land a benchmark on which to compare investments in farmland with returns to alternative assets.

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ENDNOTES

1. Budget cuts for the Texas Department of Agriculture in 1986 prevented the collection and reporting of several important data series including season average prices for each crop reporting district.

2. Assuming full participation in government programs.

3. The returns presented in Tables 3 and 4 are returns on assets which assume no leverage. The reader can easily determine a return on equity which assumes leverage using the following relationship:

$$ROE = \frac{ROA - i\,(D/A)}{(D/A)}$$

   where: ROE = return on equity; i = cost of debt; (D/A) = debt to asset ratio; ROA = return on assets, which is equivalent to $TOTRET^{i}_{jt}$ from Equation 5.

4. The average rate on Farm Credit System loans represented a weighted average of rates on Federal Land Bank loans and Production Credit loans. Average rates paid by US farmers on Federal Land Bank Loans and Production Credit Association loans were weighed based on the amount of Federal Land Bank and Production Credit Association outstanding debt in Texas.

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