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Volume 4 1990

ARTICLES

HEDGING FEEDER CATTLE IN THE TEXAS PANHANDLE

James Davis and Emmett Elam[1]

ABSTRACT

Feeder cattle producers have traditionally hedged their cattle on a one-to-one basis, that is one pound of futures is used to hedge one pound of expected production. This paper deals with the situation where the producer needs to hedge off-weight steers and heifers. Because the feeder cattle futures prices reflect the prices of 600-800 pound feeder steers, the prices of the feeder cattle futures contract do not change in the same dollar amounts as do the prices of the off-weight steers and heifers. In this situation, a cross hedge should be used. In order to reduce hedging risk when cross hedging, a hedge ratio must be estimated. Tables showing hedge ratios and hedging risk for various weights of Texas Panhandle steers and heifers are presented in the paper.

KEY WORDS: Feeder cattle, hedging, futures, basis, hedging risk

INTRODUCTION

The feeder cattle industry in the Texas Panhandle is affected by many diverse factors including weather, feed prices, government policies, and world market conditions. These dynamic conditions often lead to wide fluctuations in the market price for cattle, especially in the case of feeder cattle. Because feeder cattle prices are so sensitive to these factors, there is a considerable amount of price risk involved in the production and marketing of feeder cattle.

However, cattle producers have a valuable tool which can allow them to shift price risk to speculators. The feeder cattle futures contract, traded on the Chicago Mercantile Exchange (CME) since 1971, can be used to hedge (lock in an approximate price) the purchase or sale of feeder cattle.

Traditionally, feeder cattle have been hedged on a one-to-one basis (i.e. one pound of futures for one pound of expected production). This type of hedging is best suited for feeder steers in the 600-800 pound weight range, which is the weight range specified in the feeder cattle futures contract. But, cattle producers often need to hedge off-weight steers and heifers (that is, any feeder animal other than a 600-800 pound steer). This is difficult because the cash prices of these off-weight cattle move differently from futures prices. Although the feeder cattle contract can no longer be settled by delivery, the cash settlement price is based on the price of 600-800 pound steers. The difference in the movement of the cash price for off-weight steers and heifers relative to the futures price brings about the need to estimate hedge ratios as a means of equating changes in the value of the cash and futures positions. If the feeder cattle to be hedged are not 600-800 pound steers, regression analysis can be used to estimate the relationship between the price of the cattle of a particular weight range and sex and the futures price. The estimated slope coefficient from the regression is commonly called the hedge ratio, and represents the pounds of futures required to hedge one pound of cash feeder cattle.

Although hedging is commonly believed to be a means of reducing price risk (or uncertainty), hedging does not literally lock in an exact price. In actual practice, there is a certain amount of risk involved in hedging. This risk comes from the fact that the net price received from a hedge (cash price received from the cattle plus return from the futures market) is seldom exactly the same as the target price (the price anticipated at the time the hedge was placed). A statistical measure of hedging risk is the standard deviation of the net price about the target price. The standard deviation is in dollars per hundredweight which provides a common sense interpretation of the risk measure.

The second section of the paper briefly reviews articles which deal with hedge ratios and hedging risk for agricultural commodities. An example is given in the third section of a traditional hedge (on a pound-for-pound basis) for 600-800 pound steers. This example is useful in introducing the reader to hedging, and illustrates how 600-800 pound steers are typically hedged. Estimates of basis risk for 600-800 pound steers are reported in the fourth section. The fifth section provides a detailed discussion of hedge ratios and examples of their use. Estimates of hedge ratios are presented for steers and heifers using cash prices from the Amarillo Livestock Auction. A discussion of hedging risk and actual estimates of hedging risk for Texas Panhandle feeder cattle is included. Conclusions are given in the last section of the paper.

PREVIOUS HEDGING STUDIES

The feeder cattle futures contract was first traded as a delivery futures contract. The most noticeable problem with a delivery contract was a volatile basis, even for par grade animals located at delivery points. The volatility of the basis was a major factor in the lack of commercial interest in delivery contracts because of the amount of hedging risk associated with a volatile basis. Cash settlement was introduced with the September 1986 contract as a means to reduce the amount of variation in the basis (Kilcollin, 1985; CME, 1985; and Cattle-Fax, 1985).[1] Basis variation was expected to decrease due to the elimination of problems associated with the delivery of animals, and because cash settlement was supposed to force the futures price to equal the final cash settlement price (Paul, 1987; CME, 1985; and Cattle-Fax, 1985).

Before the change to cash settlement, research indicated that a more stable basis would be achieved with the adoption of cash settlement futures. Studies by Elam and Thompson (1987) and by Elam (1988) found that hedging risk could be reduced for Arkansas feeder cattle. Schroeder and Mintert (1988) concluded that hedging risk could be reduced at four locations in the U.S. by switching to cash settlement. According to Paul (1987), the behavior of feeder cattle prices since the adoption of cash settlement (with the September 1986 contract) supports the proposition that the basis has become less volatile. The only results that do not show basis risk decreasing with cash settlement are for Virginia steers (Kenyon, 1988).

The problem that feeder cattle producers face in hedging is that they often need to hedge off-weight steers and heifers, and no futures contract exists for these animals. Typically, off-weight steers and heifers are hedged on a one-to-one basis (i.e. one pound of futures to hedge one pound of expected production). This is referred to in this paper as a traditional hedge. Many of the basis tables for use in hedging feeder cattle are constructed with the traditional hedger in mind. The basis tables are for cattle in the 600-800 pound range (e.g, Texas A&M University (Davis, et.al., 1989), and Oklahoma State University (Ikerd, undated)). But when the cattle producer needs to hedge off-weight cattle, these basis tables are not really what he needs because the use of the hedge ratio changes the basis relationship.

Anderson and Danthine (1981) theorized that when dealing in a good for which no futures contract exists, a cross hedge may be appropriate. A cross hedge is the use of the futures market to fix a price for a commodity for which no futures contract exists. Anderson and Danthine developed the idea of the hedge ratio, which is important in cross hedging because the units of the cash commodity may not be the same as the units of the futures. Cross hedging calls for the use of a hedge ratio to reduce hedging risk.

Several applications of cross hedging have been reported (e.g., feeder pigs cross hedged with hog and corn futures (Hieronymus (1977, pp. 216-17), and Miller (1982)); wheat mids cross hedged with corn, oats, wheat, and soybean meal futures (Miller (1985)); rice bran cross hedged with corn futures (Elam, Miller, Holder (1986)); wholesale beef prices cross hedged with live cattle futures (Hayenga and DiPietre (1982), and Miller and Luke (1982))). To effectively cross hedge off-weight feeder cattle, a hedge ratio must be estimated to allow for differences in movement of cash and futures prices. Hedge ratios have been estimated for feeder cattle in various weight ranges (Elam, 1988; and Schroeder and Mintert, 1988).

EXAMPLE OF A TRADITIONAL HEDGE FOR 600-800 POUND FEEDER STEERS

Hedging is a process by which the feeder cattle producer can transfer price risk to a speculator in the futures market. However, the hedger assumes basis risk in the process. The basis is equal to the difference

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between the cash price and the futures price (basis= cash-futures). If it is assumed that the basis is constant, the net price from hedging a commodity will equal the price the hedger expected to receive at the time the hedge was initiated. However, the basis is not constant. The actual basis (at the time the hedge is lifted) can be larger than the expected basis (predicted for the time when the hedge is lifted), or it can be smaller than the expected basis. Because of the possibility that the actual basis can be different from the expected basis, there is risk involved in hedging. The greater the variation of the expected basis about the actual basis, the greater the risk. This definition of hedging risk has been used in practical applications (Hieronymus, 1977, p. 208); and Chicago Board of Trade, 1978), and academic studies of hedging (Miller, 1985; Elam, Miller and Holder, 1986; and Elam, 1988).

An example is shown in Table 1 for a cross hedge for 600-800 pound steers to be sold in October. It is assumed that the hedge is placed in April. Because the producer anticipates selling the cattle in October, the hedge should be placed in the October feeder cattle futures contract. The October contract is sold at $78.70 with an expected basis of -$2.00. (Note that all prices throughout the paper are in dollars per hundredweight.) The producer's target price is $76.70 at the time the hedge is placed in April. The target price is calculated by adding the expected basis to the price at which the futures contract is sold ($78.70+(-$2.00)).

Table 1. Example of Hedging 600-800 Pound Feeder Steers.

Date	Cash	Feeder Cattle Futures	Basis
April	Target Price = $76.70	Sell 1 lb. October Feeder Cattle Futures at $78.70	Expected - $2.00
October	Cash Sale Price = $71.25	Buy 1 lb. October Feeder Cattle Futures at $73.50	Actual - $2.25
		Gain + $5.20	$0.25 Decline

Cash Sale Price ($71.25) + Futures Gain ($5.20) = Net Price ($76.45)

Between April and October, feeder cattle prices in the cash market decline. In October, the cattle are sold at the producer's local cash market at $71.25, and the October feeder cattle futures contract is offset at $73.50 for a gain of $5.20 ($78.70-$73.50). The producer's actual basis is -$2.25 which is $0.25 less than was expected. The net price the producer received for the hedged cattle is $76.45. The net price is the sum of the price received from the sale of the cattle in the cash market plus the gain (or minus the loss) in the futures market ($71.25+$5.20).

The difference between the target price and the net price is $0.25, which is the amount the actual basis differs from the expected basis. This $0.25 difference between the net price and the target price represents hedging risk. The net price will always differ from the target price by the amount that the actual basis differs from the expected basis. The risk a hedger faces is the chance that he will receive a net price that is different from the target price. Hedging risk for a traditional hedge is mathematically shown in Elam and Davis (1990).

A hedge does not completely erase risk from the producer's considerations. The producer simply changes the area in which he is taking a risk. When the producer owns unhedged feeder cattle, he is speculating on the price level of his cattle in the cash market. In the example shown in Table 1, the producer would have received $71.25 if he had not hedged the cattle, which is $5.20 less than the net price from hedging. When the producer decides to hedge, he accepts hedging risk as a problem to be tolerated (rather than price level risk). In the example in Table 1, hedging risk is represented by the difference between the net and target prices ($0.25). Because price relationships are historically more predictable than price levels, it should be less risky for the producer to predict his local basis, than to speculate on the actual level of prices in the cash market.

ESTIMATED HEDGING RISK FOR 600-800 POUND FEEDER STEERS

In estimating hedging risk for Texas Panhandle feeder cattle, three series of prices were used. Average cash prices of feeder cattle were collected for the Amarillo Livestock Auction for the period January 1977 to December 1988 (Agricultural Marketing Service, USDA, LS-214 forms). The prices from the Amarillo auction were broken down by weight and by sex. The weights were in 100 pound intervals from 300-800 pounds for both steers and heifers, and in a 200 pound interval from 800-1000 pounds for steers. The Amarillo auction prices are representative of feeder cattle prices in the Texas Panhandle.

Cash settlement futures prices were collected from the Wall Street Journal for the day of the Amarillo auction (usually Monday or Tuesday), and the U.S. Feeder Steer Price (USFSP) was obtained from the CME and Cattle-Fax. The USFSP is the weighted average steer price used to cash settle feeder cattle futures (see footnote 1). The USFSP was used as a proxy for cash settlement feeder cattle futures prices that were not available prior to trading of the September 1986 contract. The justification for this is the fact that cash settlement futures prices will approximately equal the USFSP when the contract expires (Elam, 1988; and Schroeder and Mintert, 1988).

Since a feeder cattle futures contract does not exist for February, June, July, and December, a different procedure had to be used to develop a proxy for the cash settlement futures price for these months. An approximate price was derived by taking the average difference between the average USFSP for each of the months for which there was no contract and the average USFSP for the next contract month, and then subtracting this difference from the USFSP for the month for which there was not a contract. For example, the proxy for the cash settlement futures price for February 1981 was derived by subtracting -$2.44 (the average difference between the February and March USFSP's) from the February USFSP to obtain an approximate February price for the March 1981 cash settlement futures contract (that is, February 1981 price for the March 1981 cash settlement feeder cattle futures contract = February USFSP- (-2.44)). Proxies for cash settlement futures prices were used until September 1986 when the cash settlement futures price was available.

Table 2 shows the basis information for 600-700 and 700-800 pound feeder steers from 1977-88. The average basis, the high (most positive) basis, the low (most negative) basis, and the standard deviation of the basis are shown in Table 2. (The variance is the average of the squared deviations from the mean; and the standard deviation is the square root of the variance (Alder and Roessler (1975, p. 48).) The average basis tends to be positive in almost every month for both 600-700 and 700-800 pound steers. The highest average basis is for 600-700 pound March feeder steers, where the average basis is $2.27 (i.e., March cash price is $2.27 over the March futures contract price). The lowest average basis is for 700-800 pound June feeder steers, where the average basis is -$2.90.

The greatest range in the nearby basis for one month is for 600-700 pound June feeder steers, where the basis ranged from -$5.28 to +$5.43. The wide variation in the June basis is partly due to the fact that the nearby futures contract is August, which is two months away.

The greatest amount of hedging risk as measured by the standard deviation of the basis is for 600-700 pound June steers. The standard deviation of the June basis is $2.02. As was shown in the example in the previous section, the difference between the actual and the expected basis

[1]In cash settlement, all contracts remaining open at contract expiration are settled in cash based on the final settlement price, rather than by physical delivery of steers. The final settlement price is a weighted average of actual cash market prices for 600-800 pound steers that are expected to grade 60-80% Choice at slaughter. The final settlement price is known as the U.S. Feeder Steer Price (USFSP), and is calculated by the market information organization Cattle-Fax. The USFSP is derived using auction and direct sales prices from 27 states. The procedure used to calculate the USFSP is explained by the CME (1985).

Table 2. Average Basis, High Basis, Low Basis, and Standard Deviation of the Basis for 600-800 pound Amarillo Steers, 1977-88.

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
					(dollars per hundredweight)							
600-700 lbs.												
Avg Basis	1.84	-3.33	2.27	1.72	0.91	-1.24	-0.13	1.25	0.93	0.62	0.98	0.65
High Basis	3.38	3.55	5.08	6.18	6.30	5.43	4.68	3.13	3.35	3.44	3.53	3.58
Low Basis	-3.09	-1.92	-1.00	-1.33	-2.46	-5.28	-2.36	-1.60	-1.56	-2.57	-2.35	-1.67
s a/	1.01	1.19	1.41	1.38	1.62	2.02	1.70	0.97	1.07	0.96	1.38	1.09
700-800 lbs.												
Avg Basis	0.73	-1.47	0.90	0.18	-0.94	-2.90	-1.71	-0.17	-0.58	-0.70	-0.41	-0.67
High Basis	3.38	1.53	2.99	2.36	1.88	0.93	0.68	2.13	1.22	2.17	3.13	1.94
Low Basis	-3.09	-5.19	-2.36	-3.39	-4.21	-6.65	-4.90	-5.32	-4.01	-4.07	-4.28	-4.67
s	1.43	1.55	1.35	1.40	1.44	1.60	1.21	1.44	1.40	1.11	1.64	1.52

a/ "s" is the standard deviation of the basis.

is equal to the difference between the net price and the target price. Therefore, the standard deviation of the basis is a measure of hedging risk. Assuming a normal distribution for the basis, the net price received from hedging 600-700 pound June steers will differ from the target price by no more than $2.02 two-thirds of the time, and by no more than $4.04 (two standard deviations) ninety-five percent of the time.

The least amount of hedging risk is for 600-700 pound October steers where the standard deviation of the basis is $0.96. This number is interpreted in the same manner as in the explanation above.

CROSS HEDGING FEEDER CATTLE

Many times cattle producers may wish to hedge lighter or heavier weight steers or heifers. In this case, a cross hedge should be used. The example in Table 1 illustrates a hedge of 600-800 pound steers and assumes a one-to-one relationship between the pounds of expected production and the pounds of feeder cattle futures sold as a hedge. But when a cross hedge is used, a one-to-one relationship may not be the optimum risk minimizing position. This is due to the fact that the prices of feeder cattle of different weight ranges and sex do not move in the same dollar amount. For example, the relationship between the price of 400-500 pound steers at Amarillo during November and the price of November feeder cattle futures (which reflect the price of 600-800 pound steers) is shown in Figure 1. The slope of a regression line fitted to the two series of prices for the years 1977-88 is 1.2. The slope coefficient indicates that each $1 change in the price of feeder cattle futures is associated on average with a $1.20 change in the price of 400-500 pound steers.

If a cattle producer hedges 1 pound of expected production of 400-500 pound steers with 1 pound of feeder cattle futures, he will be partially hedged because of the difference in the variability of 400-500 pound steer prices and futures prices. According to the regression relationship in Figure 1, each $1.20 change in 400-500 pound steer prices is associated with a $1 change in futures prices. If the hedge is pound for pound, the change in the value of the cash position will be 1.2 times as great as the change in the value of the futures position. Ideally when hedging, the value of the futures position should change dollar for dollar with the value of the cash position. When hedging 400-500 pound steers, this requires a larger futures position to make the change in the values of the cash and futures positions equal.

The particular size of the futures position can be determined from a regression of cash on futures prices.

(1) $$C_t = a + bF_{t-j} + e_t$$

where "a" and "b" are estimated intercept and slope coefficients, respectively, and e_t is the estimated random error term. The estimated slope coefficient from the regression is the hedge ratio, which is the number of pounds of futures needed to hedge one pound of cash feeder cattle.

An example is shown in Table 3 for a cross hedge for 400-500 pound steers to be sold in November at Amarillo. It is assumed that the hedge is placed in April. The hedge ratio for November 400-500 pound steers is 1.2, which indicates that 1.2 pounds of November futures should be sold for each 1 pound of expected production of November steers (hedge ratios are reported in Table 4). The target price for the hedge is $90.17. The target price is calculated by adding the average November generalized basis for 400-500 pound Amarillo steers (Table 5) to the sum of 1.2 multiplied by the April price of the November feeder cattle futures contract (-$3.43+1.2($78.00)). The generalized basis of -$3.43 represents the average difference in value of 100 pounds of 400-500 pound steers at Amarillo during November and 120 pounds of feeder cattle futures at the same time.

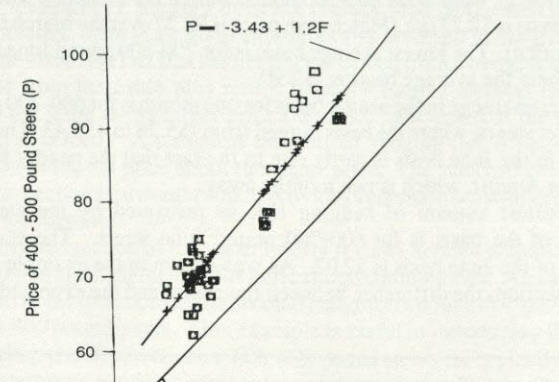

Figure 1. November Cash Price of 400-500 Pound Steers at Amarillo vs. November Feeder Cattle Futures Price, 1977-88.

Table 3. Example of Hedging 400-500 Pound Feeder Steers.

Date	Cash	Futures Cattle Futures	Generalized Basis
April	Target Price = -$3.43 + 1.2($78.00) = $90.17	Sell 1.2 lbs. November Feeder Cattle Futures at $78.00	Expected - $3.43
November	Cash Sale Price = $83.50	Buy 1.2 lbs. November Feeder Cattle Futures at $74.00	Actual - $5.30
		Gain 1.2($4.00) = $4.80	$1.87 Decline

Cash Sale Price ($83.50) + Futures Gain ($4.80) = Net Price ($88.30)

Determining the target price is similar for cross hedging 400-500 pound steers compared to hedging 600-800 pound steers. The difference is that in a traditional hedge the basis (C_t-F_t) is added to the futures price, whereas in a cross hedge the generalized basis (C_t-bF_t) is added to the sum of the hedge ratio (b) multiplied by the futures price.

Because 1.2 pounds of feeder cattle futures are required to hedge 1.0 pound of 400-500 pound steers, the sale of one 44,000 pound feeder cattle futures contract will hedge approximately 81 head of November steers. If the producer anticipates selling 400 head of 400-500 pound steers in November, he would need to sell 216,000 pounds (1.2 x 450 pounds x 400 head) of November futures. This is approximately five feeder cattle futures contracts.

During April, 1.2 pounds of November feeder cattle futures are sold for each pound of expected production of November steers. The April selling price of the November futures contract is $78.00. Between April and November, cash and futures prices decline. The 400-500 pound steers are sold during November for $83.50, and at the same time, the futures position is offset at $74.00. The gain on the futures position is $4.80 per hundredweight of cash feeder cattle (1.2($78.00-$74.00)). The net price the producer receives for the hedged cattle is $88.30. The net price for a cross

Table 4. Hedge ratios for Amarillo Feeder Cattle, 1977-88.

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
						(pounds)						
Steers:												
300-400 lbs.	1.22	1.37	1.53	1.59	1.70	1.71	1.61	1.45	1.40	1.48	1.31	1.33
400-500 lbs.	1.11	1.24	1.33	1.38	1.39	1.45	1.39	1.21	1.24	1.25	1.20	1.20
500-600 lbs.	1.03	1.13	1.14	1.15	1.19	1.21	1.20	1.08	1.12	1.08	1.05	1.07
600-700 lbs.	0.98	1.03	1.05	1.04	1.04	1.05	1.08	1.04	1.02	1.02	0.98	0.99
700-800 lbs.	0.95	0.96	1.00	0.97	0.97	0.98	1.00	0.98	0.96	0.96	0.94	0.91
800-1000 lbs.	0.74	0.82	0.89	0.89	0.90	0.98	1.08	0.83	0.83	0.86	0.81	0.77
Heifers:												
300-400 lbs.	1.12	1.24	1.36	1.39	1.48	1.54	1.46	1.34	1.36	1.34	1.20	1.22
400-500 lbs.	1.06	1.13	1.18	1.23	1.26	1.26	1.27	1.13	1.16	1.16	1.08	1.11
500-600 lbs.	0.99	1.02	1.03	1.06	1.08	1.10	1.10	1.04	1.05	1.05	1.04	1.05
600-700 lbs.	0.97	0.95	0.96	0.96	1.00	1.04	1.03	0.99	0.97	0.98	0.96	0.97
700-800 lbs.	0.83	0.88	0.91	0.85	0.94	1.34	1.12	0.95	0.96	0.98	0.95	0.95

Note: The hedge ratio (b-value from eq. (1) in text) is the number of pounds of feeder cattle futures required to hedge one pound of cash feeder cattle.

Table 5. Generalized Basis for Amarillo Feeder Cattle, 1977-88.

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
						(dollars per hundredweight)						
Steers:												
300-400 lbs.	-2.81	-13.30	-18.11	-19.83	-26.16	-28.92	-24.83	-13.01	-11.32	-17.26	-6.00	-10.41
400-500 lbs.	-0.24	-9.81	-11.27	-12.31	-11.68	-19.36	-16.47	-4.53	-7.22	-7.39	-3.43	-6.91
500-600 lbs.	2.01	-6.12	-3.91	-3.64	-6.19	-10.40	-9.29	-1.60	-4.33	-1.53	0.89	-1.81
600-700 lbs.	2.99	-1.77	-0.83	-0.71	-1.67	-4.60	-5.37	-1.04	-0.65	-0.58	2.47	1.34
700-800 lbs.	3.79	1.03	1.12	2.28	0.82	-1.46	-1.44	1.06	2.17	1.87	3.54	5.36
800-1000 lbs.	15.34	8.80	6.37	5.15	3.42	-3.35	-8.79	8.50	8.55	6.47	9.75	12.32
Heifers:												
300-400 lbs.	-8.75	-17.75	-20.89	-20.50	-24.65	-31.52	-27.91	-19.07	-21.28	-20.83	-12.87	-16.11
400-500 lbs.	-7.01	-13.17	-12.66	-14.11	-16.04	-18.94	-19.55	-10.42	-12.35	-13.13	-7.53	-11.22
500-600 lbs.	-3.78	-7.12	-5.15	-6.34	-8.99	-12.36	-11.85	-6.61	-8.21	-8.80	-7.41	-8.64
600-700 lbs.	-2.68	-3.19	-1.62	-1.53	-5.12	-9.44	-8.24	-4.13	-3.65	-4.64	-3.91	-4.08
700-800 lbs.	5.43	0.86	1.11	-4.47	-2.38	-29.66	-14.31	-2.71	-3.96	-5.83	-4.25	-4.09

Note: The generalized basis is G=C-F, which is the a-value from eq. (1) in the text.

hedge is calculated in the same way as it is for a 600-800 pound steer hedge when b=1. That is, the net price is the sum of the cash sales price for the cattle plus the return from the futures market ($83.50+$4.80=$88.30).

The difference between the net and target prices is -$1.87, which is the same as the difference between the actual November generalized basis and the expected generalized basis (-$5.30-(-$3.43)). This difference represents hedging risk, just as the difference between the net price and the target price represents hedging risk when b=1. Although the mechanics of a cross hedge and a hedge are somewhat different, the concept is basically the same for both. A detailed explanation and mathematical representation of cross hedging is provided in Elam and Davis (1990).

Hedging risk for cross hedges is reported in Tables 6 (steers) and 7 (heifers). The standard deviation of the net price about the target price is one measure of hedging risk. Also included in Tables 6 and 7 are ranges for net minus target prices. The range gives the largest negative and positive amounts that the net price has missed the target price for the years 1977-88. As measured by the standard deviation, hedging risk is greatest for 300-400 pound steers sold in May, where the standard deviation of net minus target prices is $5.28. Assuming a normal distribution for net minus target prices, there is approximately a 68% chance that the net price will be within $5.28 per hundredweight (either positive or negative) of the target price. The range in the net price about the target price for May 300-400 pound steer hedges is from -$10.74 to $8.98. This indicates that over the period 1977-88 the net price was as much as $10.74 below the target price and as much as $8.98 above the target price.

Table 6. Hedge Risk for Amarillo Feeder Steers, 1977-88.

Weight (pounds)	300-400	400-500	500-600	600-700	700-800	800-1000
	(dollars per hundredweight)					
Jan						
s a/	4.60	2.43	1.50	1.00	1.30	1.40
Range b/	-8.35 to 12.54	-5.47 to 6.56	-4.51 to 3.78	-4.64 to 1.57	-3.05 to 2.72	-2.61 to 2.42
Feb						
s	5.16	3.59	2.15	1.16	1.49	1.43
Range	-9.84 to 9.77	-8.58 to 7.69	-4.11 to 6.22	-1.91 to 3.23	-3.17 to 3.05	-3.13 to 2.91
March						
s	4.63	3.04	1.64	1.31	1.35	1.60
Range	-7.62 to 9.68	-5.45 to 5.45	-3.23 to 3.26	-3.42 to 2.51	-3.21 to 2.09	-3.84 to 3.27
April						
s	4.71	3.63	2.39	1.31	1.36	1.76
Range	-9.98 to 7.52	-5.17 to 8.63	-2.83 to 6.29	-2.74 to 3.63	-3.03 to 2.80	-3.53 to 3.06
May						
s	5.28	3.48	2.43	1.58	1.42	2.13
Range	-10.74 to 8.98	-8.40 to 5.51	-5.21 to 5.72	-4.07 to 4.59	-3.09 to 3.19	-4.89 to 4.05
June						
s	5.17	4.39	2.89	1.98	1.60	1.62
Range	-7.22 to 12.08	-8.79 to 8.86	-5.15 to 7.82	-4.74 to 6.25	-3.45 to 3.94	-4.15 to 2.52
July						
s	5.17	4.15	2.34	1.52	1.24	1.23
Range	-9.81 to 10.46	-6.19 to 11.18	-3.42 to 6.02	-3.02 to 4.32	-3.17 to 2.38	-4.09 to 1.49
Aug						
s	4.52	3.10	1.77	.91	1.44	1.79
Range	-9.12 to 8.38	-7.40 to 9.79	-3.51 to 6.26	-2.64 to 1.61	-5.01 to 2.31	-5.24 to 2.90
Sept						
s	4.32	3.68	1.95	1.05	1.32	1.89
Range	-9.57 to 7.58	-6.21 to 9.35	-2.82 to 5.26	-2.56 to 2.09	-2.79 to 2.10	-3.29 to 3.04
Oct						
s	4.08	2.41	1.64	.95	1.03	1.61
Range	-10.48 to 9.35	-5.51 to 5.11	-3.57 to 3.78	-3.37 to 2.59	-3.00 to 2.76	-2.57 to 3.93
Nov						
s	4.37	3.47	2.03	1.38	1.53	1.92
Range	-8.39 to 10.26	-7.22 to 7.89	-3.78 to 4.04	-3.06 to 2.55	-3.17 to 3.40	-4.99 to 3.30
Dec						
s	5.27	2.95	1.91	1.09	1.20	1.48
Range	-9.52 to 10.22	-5.16 to 5.22	-3.62 to 4.40	-2.19 to 2.93	-2.35 to 2.31	-4.85 to 2.88

a/ "s" is the standard deviation of the net price from the target price.
b/ Range is the greatest negative and the greatest positive amount that the net price has missed the target price.

Table 7. Hedge Risk for Amarillo Feeder Steers, 1977-88.

Weight (pounds)	300-400	400-500	500-600	600-700	700-800
	(dollars per hundredweight)				
Jan					
s a/	3.10	2.20	1.31	1.23	1.61
Range b/	-4.81 to 7.94	-3.79 to 4.62	-2.57 to 3.11	-3.37 to 3.41	-5.43 to 3.21
Feb					
s	4.65	3.47	2.07	1.83	1.60
Range	-8.52 to 7.28	-5.55 to 6.78	-3.75 to 4.31	-4.33 to 4.97	-3.55 to 3.62
March					
s	4.02	2.66	1.68	1.32	1.51
Range	-7.62 to 9.67	-5.59 to 4.43	-4.35 to 3.65	-3.94 to 2.68	-4.42 to 2.62
April					
s	4.31	3.24	1.64	1.05	1.07
Range	-7.71 to 6.67	-6.08 to 7.12	-3.53 to 3.78	-2.10 to 2.69	-1.81 to 1.80
May					
s	4.40	3.18	1.81	1.11	1.30
Range	-8.06 to 6.79	-6.98 to 6.88	-4.01 to 2.89	-2.07 to 2.12	-2.50 to 2.34
June					
s	6.91	4.06	2.22	2.10	1.64
Range	-11.61 to 13.22	-7.32 to 9.54	-3.48 to 5.47	-2.83 to 5.46	-2.35 to 3.62
July					
s	4.92	3.46	2.17	1.37	1.43
Range	-12.31 to 10.70	-8.12 to 5.81	-3.53 to 5.09	-2.49 to 3.71	-4.01 to 2.82
Aug					
s	3.93	2.80	1.59	1.28	1.80
Range	-7.34 to 10.50	-4.61 to 8.32	-2.58 to 3.03	-3.40 to 3.19	-6.37 to 2.61
Sept					
s	4.44	3.23	1.90	1.40	1.54
Range	-8.14 to 8.30	-5.33 to 4.83	-3.47 to 3.95	-2.80 to 3.03	-3.99 to 2.39
Oct					
s	3.62	2.70	1.75	1.32	1.52
Range	-8.40 to 5.85	-5.46 to 5.38	-4.06 to 3.58	-2.66 to 3.17	-3.21 to 3.58
Nov					
s	4.01	2.83	1.88	1.35	1.51
Range	-7.50 to 6.55	-5.35 to 4.11	-3.84 to 3.39	-2.94 to 2.56	-2.60 to 3.25
Dec					
s	4.25	3.15	2.23	1.49	1.64
Range	-7.69 to 8.05	-5.94 to 7.03	-4.31 to 5.48	-4.13 to 3.15	-4.11 to 2.99

a/ "s" is the standard deviation of the net price from the target price.
b/ Range is the greatest negative and the greatest positive amount that the net price has missed the target price.

The least amount of hedging risk is for 600-700 pound steers sold in August (Table 6). The standard deviation of the net price from the target price is $0.91, which indicated a 68% chance that the actual net price received will be within $0.91 per hundredweight of the target price. Hedging risk tends to be lowest for steers weighing 600-800 pounds. This was expected because the USFSP, which is used to cash settle the feeder cattle futures contract, is based on 600-800 pound steer prices.

CONCLUSIONS

The traditional manner in which feeder cattle are hedged is on a one-to-one basis. As we have seen, this method of hedging is not the optimal risk reducing position when hedging off-weight steers and heifers. In these situations, a cross hedge should be used instead of the traditional hedge.

The results of this study were as expected. Hedge ratios were found to be approximately 1.0 for feeder cattle in the 600-800 pound range. The results also show that hedge ratios tend to be higher for lighter weight cattle and lower for heavier weight cattle.

Hedging risk was found to be lowest for 600-800 pound steers, where the standard deviations of net minus target prices ranged from $0.91 to $1.98. The least amount of hedging risk was for 600-700 pound feeder steers to be sold in August (standard deviation of $0.91). The greatest amount of hedging risk was for 300-400 pound steers and heifers, where the standard deviations of net minus target prices ranged from $3.10 to $6.91. The standard deviation of $6.91 was for 300-400 pound heifers to be sold in June. Overall, hedging risk tended to be greater for cattle with weights that were outside the 600-800 pound range, which shows the need for using hedge ratios when cross hedging off-weight feeder cattle.

While this study used information from the Amarillo Livestock Auction and applies to the Texas Panhandle, the procedures used are applicable to other markets. There would be differences, however, in the magnitude of the hedge ratios and the actual amount of hedging risk in other markets

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REGENERATION POTENTIAL OF DISTAFF THISTLE IN CENTRAL TEXAS

Carolyn E. Phelan, Christopher A. Call, and Barron S. Rector[1]

ABSTRACT

Seed production and seed reserves in the soil were determined for distaff thistle (Carthamus lanatus) at two grazed range sites in central Texas. Seed production ranged from 345 to 376 seeds/ft². Seed bank density ranged from 16 to 23 seeds/ft², with 84% or more of the seed occurring in the top 1 inch of soil. Greater than 58% of the seeds extracted from soil samples were viable as determined by a tetrazolium test. Persistent testa halves (seed coat segments), remaining in the soil after germination, ranged from 37 to 72/ft², with 91% or more occurring in the top 1 inch of soil. Seeds were harvested from one site and exposed to different light/dark and dark/light regimes over a 14-day period to determine light requirements for germination. Seeds exposed to at least 12 h of light per day during initial imbibition had mean germination times of about 3.4 days and greater than 80% cumulative germination. Light enhanced the germination responses of seeds kept in darkness during the first 7 days of the 14-day period. A small portion (10%) of non-dormant seeds germinated in total darkness.

Key words: Rangeland, soil disturbance, light-sensitive seed, seed bank, germination.

INTRODUCTION

Distaff thistle (Carthamus lanatus), an introduced, overwintering annual from the Mediterranean region (Correll and Johnston, 1970), is presently found on a variety of disturbed rangelands in 21 counties of central Texas, and is spreading rapidly. Distaff thistle is a serious weed problem in parts of California, Australia, Argentina, Chile, and Morocco (Holm et al., 1979). Dense stands of this prickly weed can decrease forage production and reduce livestock access to more palatable forage species.

Seeds germinate late summer through fall in response to increasing precipitation and decreasing temperatures. Plants overwinter in a rosette stage, and main stem elongation occurs in early spring. Flowering and seed production can extend into mid-summer, depending on available soil moisture (Figure 1). Distaff thistle populations may be controlled by properly timed herbicide, mechanical, or burning treatments (Meadly, 1957; Quinlivan and Pearce, 1964). Due to the prolonged dormancy of seeds in the soil (Pearce and Quinlivan, 1968), the control strategy should consider the effects of soil disturbance on plant regeneration. Soil disturbance brings the light-sensitive seeds to the soil surface, fulfilling the light requirement for germination (Wright et al., 1980), and setting the stage for the establishment of a new stand.

Research on the regeneration potential of distaff thistle on disturbed rangeland in central Texas is nonexistent. A field study was conducted to characterize seed production and seed bank reserves, and a laboratory study was conducted to determine the effect of length of light exposure on germination response.

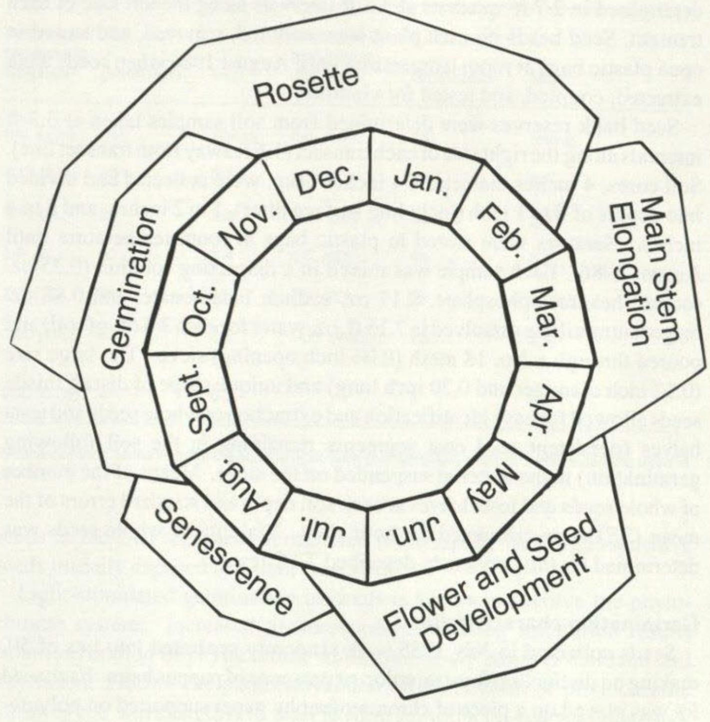

Figure 1. Life cycle of distaff thistle (Carthamus lanatus) in central Texas.

MATERIALS AND METHODS

Study sites

The field study was conducted in 1985 and 1986 on two adjacent range sites at the Goodrich Ranch in Burnet County, Texas, near the eastern edge of the Edwards Plateau resource region. The adobe range site, at an elevation of 1,590 ft, is dominated by distaff thistle, threeawns (Aristida spp.), hairy tridens (Erioneuron pilosum), red grama (Bouteloua trifida), fall witchgrass (Leptoloma cognatum), bur clover (Medicago hispida), and upright prairie coneflower (Ratibida columnaris). The soil is a Brackett sandy loam (fine-loamy, carbonatic, thermic, shallow, typic Ustochrepts). The redland range site, located 330 ft downslope from the adobe site, is dominated by distaff thistle, Texas wintergrass (Stipa leucotricha), silver bluestem (Bothriochloa saccharoides), buffalograss (Buchloe dactyloides), tumble windmill grass (Chloris verticillata), and upright prairie coneflower. The soil is a stony loam (clayey, mixed, thermic, lithic Rhodustalfs). Vegetation composition on both range sites indicated that retrogression had occurred as the result of heavy livestock use (Soil Conservation Service, 1979). Average annual rainfall for the area is 30 inches. May and September are the peak rainfall months (National Oceanic and Atmospheric Administration, 1986). The mean frost-free period for the area is 230 days.

Seed population dynamics

Preliminary seed production data were obtained from distaff thistle plants in a 23x23 ft plot on the adobe site in July 1985. Seed heads on all 474 plants in the plot were counted, removed, placed in open plastic bags, and stored at room temperature until September 1985. Seeds were then counted and tested for viability by a 2, 3, 5 - triphenyl tetrazolium chloride (TTC) test (Copeland, 1978). Four replicates of 25 undamaged seeds each were soaked in distilled water for 24 h at 78°F, bisected and placed in a 1% solution of TTC for 24 h at 78°F in complete darkness. Percent viability was determined by visually evaluating intensity of staining and staining patterns under a 10-power lens.

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Three randomly located 100 ft-long transects were established in representative distaff thistle populations on the adobe and redland sites in July 1986, just prior to seed dissemination. Plant population density was determined in 2.7 ft^2 quadrats at 3.3-ft intervals along the left side of each transect. Seed heads on each plant were counted, removed, and stored in open plastic bags at room temperature until August 1986 when seeds were extracted, counted, and tested for viability.

Seed bank reserves were determined from soil samples taken at 3.3-ft intervals along the right side of each transect (1.6 ft away from transect line). Soil cores, 4 inches diameter x 4 inches deep, were collected and divided into depths of 0 to 1 inch (including surface litter), 1 to 2 inches, and 2 to 4 inches. Samples were stored in plastic bags at room temperature until August 1986. Each sample was mixed in a dispersing solution (0.35 oz. sodium hexametaphosphate, 0.17 oz. sodium bicarbonate, and 0.88 oz. magnesium sulfate dissolved in 7.15 fl. oz. water for each 3.5 oz. of soil) and poured through a No. 18 mesh (0.04 inch opening) sieve. The large size (0.12 inch diameter and 0.20 inch long) and unique shape of distaff thistle seeds allowed for easy identification and extraction of whole seeds and testa halves (persistent seed coat segments remaining in the soil following germination) in the material suspended on the sieve. Means of the number of whole seeds and testa halves at each soil depth and standard errors of the mean (SE) were calculated for both sites. Viability of whole seeds was determined by the previously described TTC test.

Germination characteristics

Seeds collected in July 1985 were randomly separated into lots of 50, making no distinction for size, color, or presence of pappus hairs. Each seed lot was placed on a piece of chromatography paper supported on polyurethane foam (0.25 inch thick) in a plastic tray (5x5.5x1.5 inches). Five cotton wicks extended into a 7.15 fl. oz. reservoir of distilled water, maintaining wetness of the paper. Trays were wrapped with clear polyethylene film to reduce evaporation and stabilize relative humidity (Berkat and Briske, 1982). Half of the trays were wrapped in two layers of aluminum foil to exclude light. All trays were placed in a controlled environment at the beginning of the light period (60/78°F night/day temperature regime with a 12-h photoperiod, simulating conditions in central Texas in September/October). A light intensity of 1,000 foot-candles was maintained at tray level. Seeds were exposed to light treatments of: 1 day light/13 days dark (1L); 3 days light/11 days dark (3L); 5 days light/9 days dark (5L); 7 days light/7 days dark (7L); 14 days light (14L); 1 day dark/ 13 days light (1D); 3 days dark/11 days light (3D); 5 days dark/ 9 days light (5D); 7 days dark/ 7 days light (7D); and 14 days dark (14D).

Germinated seeds were counted under a green safety light every day over the 14-day period. Seeds were considered germinated when the cotyledons were exposed and radicle length was 0.2 inches or greater (Copeland, 1978). Germination rates were estimated by calculating the mean time in days taken for nondormant viable seeds to germinate (Ellis and Roberts, 1978).

Trays were arranged in a completely randomized design with four replications per treatment. The entire experiment was repeated, and data from both trials were combined for statistical analysis. Cumulative germination percentages (adjusted by an arcsine transformation to normalize percentage values before analysis) and mean germination time values were analyzed by analysis of variance. Treatment means were compared by least significant difference ($P<.05$).

RESULTS AND DISCUSSION

Seed population dynamics

Prior to seed dispersal in July 1986, mean plant density along line transects at the adobe site was 10 plants/ft^2 with 1.4 seed heads/plant and 28 seeds/seed head. Mean plant density at the redland site was 11 plants/ft^2 with 1.3 seed heads/plant and 29 seeds/seed head. With 92% viable seed at both sites, the extrapolated estimate of viable seed production was 345 and 376 seeds/ft^2, respectively, for the adobe and redland sites. Plant population density and seed production can vary from year to year at the same site. Prior to seed dispersal in July 1985, mean plant population density on the 23x23 ft pilot plot adjacent to the line transects established later on the adobe site was 1 plant/ft^2 with 5.5 seed heads/plant and 29 seeds/seed head. With 95% viable seed, the extrapolated estimate of viable seed production was 140 seeds/ft^2, less than half the estimated viable seed production from line transects in 1986.

Distaff thistle seeds were most abundant near the soil surface at the two study sites. Seeds recovered from the 0 to 1 inch depth comprised 96 and 84%, respectively, of the total number of seeds occurring in the 4-inch deep soil cores at the adobe and redland sites (Table 1). Most distaff thistle seeds remained near the soil surface due to their large size and the presence of numerous rigid pappus hairs (30 to 50 hairs, up to 0.35 inch in length). Seeds buried at depths greater than 1 inch may have been incorporated by livestock hoof action, cached by rodents, covered by soil during erosional deposition, or may have fallen into cavities left after plant removal or decomposition.

Seed densities at all three soil depth increments were greater at the redland site than the adobe site (Table 1). Seed bank differences at the two sites can be explained, in part, by differences in soil depth and by topographic orientation. The coring apparatus regularly penetrated through the shallow top-and subsoil horizons into limestone parent material at the adobe site, but only penetrated into the friable topsoil horizon at the redland site. During occasional heavy thunderstorms, soil and associated surface-lying seeds (including distaff thistle) were transported down-slope from the adobe site to the redland site.

Table 1. Density, viability, and frequency of occurrence of whole seeds, and density and frequency of occurrence of testa halves of distaff thistle (*Carthamus lanatus*) from three soil depths at two range sites in Burnet County, Texas, 1985.

Range site	Soil depth	Density of whole seeds[a]	Viability of whole seeds	Frequency of samples with whole seeds	Density of testa halves[a]	Frequency of samples with testa halves
	(inches)	(no./ft^2)	(%)	(%)	(no./ft^2)	(%)
Adobe	0-1	15±3	78	38	35±8	41
	1-2	0	-	0	1±0.3	6
	2-4	1±0.3	100	4	1±0.3	4
	0-4	16		42	37	42
Redland	0-1	19±4	65	53	66±13	70
	1-2	2±1	58	8	2±1	11
	2-4	2±1	73	8	4±2	16
	0-4	23		54	72	71

Greater than 78% of the seed recovered from soil cores at the adobe site and 58% of the recovered seed at the redland site were viable as determined by a tetrazolium test (Table 1). Distaff thistle seeds buried at similar depths in a loamy sand in Western Australia (warm Mediterranean climate) remained viable for 5 to 6 years (Pearce and Quinlivan, 1968).

Densities of testa halves in soil cores followed the same trends as those of whole seeds. Testa halves were more abundant near the soil surface at both sites, and densities at all three soil depth increments were greater at the redland site than the adobe site (Table 1). Persistent testa halves, when divided by two, provide an indication of the number of seeds that may have germinated over the past several years. Accordingly, about 18 and 33 seeds/ft^2 may have germinated in the top 1 inch of soil of the adobe and redland sites, respectively. The presence of testa halves at 1 to 2 and 2 to 4 inches indicates that limited germination may have occurred at greater depths, however, the seedlings may not have reached the soil surface and survived.

In an Australian study (Pearce and Quinlivan, 1968), 96% of the original distaff thistle seeds planted in the top 1 inch of soil emerged as seedlings over a 4-year period, whereas only 3.4 and 1.2%, respectively, emerged from the 1 to 2 and 2 to 4 inch soil depths.

Several consecutive soil cores along each transect contained seed and testa halves at each soil depth increment while several subsequent consecutive soil cores were completely devoid of seed and testa halves. The uniform sampling pattern along the line transects may have underestimated clustered seed reserves (Bigwood and Inouye, 1988). Such clustered spatial distributions have been observed in other seed bank studies, and can have ecological ramifications in terms of seed predation or density-dependent competition among establishing seedlings (Bigwood and Inouye, 1988).

These results and results from the distaff thistle seed burial study in Western Australia (Pearce and Quinlivan, 1968) demonstrate that distaff thistle does form a persistent seed bank (Thompson and Grime, 1979). Persistent seed banks: confer potential for regeneration where disturbance of established vegetation is temporally and/or spatially unpredictable (e.g. livestock grazing); permit populations to establish themselves rapidly without immigration if environmental conditions prevent or greatly reduce seed production for one or several years; and represent an overlapping of generations, increasing genetic variability and stability within populations (Baskin and Baskin, 1985; Thompson and Grime, 1979). The most consistent feature of species forming persistent seed banks is the inhibition of germination by darkness, which may be enforced or perhaps induced by burial in the soil (Wesson and Wareing, 1969).

Germination characteristics

In general, earlier and longer exposure to light enhanced the germination of distaff thistle seeds (Table 2). Highest cumulative germination, approaching the viability (95%) of the seed population, was attained in the 14L treatment which received 12 h of light each day of the 14-day trial. Cumulative germination decreased slightly as length of initial exposure to light decreased from 14 days to 3 days (14L to 3L treatments). Germination after 1 day of exposure to light (1L treatment) was markedly lower than the treatments with longer initial light exposures. Seeds in the 1L treatment may not have been sufficiently hydrated to respond to the 12 h light period during the first day of imbibition before being placed in the dark for the remaining 13 days of the germination trial. Distaff thistle seeds from a population in New South Wales, Australia required up to 24 h for complete imbibition (Wright et al., 1980) and several other herbaceous dicots with light sensitive seed from temperate climates required 24 hours or more for complete imbibition and maximum photoresponsivity (Frankland and Taylorson, 1983). Cumulative germination percentages of seeds initially exposed to 1 and 3 days of darkness (1D and 3D treatments) were slightly lower than those of seeds in the 3L, 5L, and 7L treatments. Germination decreased significantly as the length of initial exposure to darkness increased from 3 to 14 days (3D to 14D treatments). Some seeds in the 5D, 7D, and 14D treatments may have passed the period of light sensitivity (beyond 24 h) associated with full imbibition and remained in a dormant state. The low percentage of seeds germinating in complete darkness in the 14D treatment were considered to be non-dormant. Similar trends in germination were reported for a distaff thistle population in New South Wales (Wright et al., 1980).

Mean germination time was most rapid and differed little for seeds in the 1L, 3L, 5L, 7L, and 14L treatments, and was significantly slower for seeds in the 1D, 3D, 5D, 7D, and 14D treatments (Table 2). All treatments initially exposed to light initiated germination on day 2 and completed germination by day 5. As the length of initial exposure to darkness increased by 2-day intervals for treatments 1D to 7D, mean germination time increased by approximately 2 days. Upon exposure to light, seeds in these treatments required about 3 days to attain maximum germination. The non-dormant

Table 2. Cumulative germination and mean germination time (MGT) of distaff thistle (Carthamus anatus) seeds exposed to different light/dark and dark/light treatments in a controlled environment with a 12 hour photoperiod.

Sequence of exposure to light/dark[a]	Germination	MGT	Sequence of exposure to dark/light[a]	Germination	MGT
(no. days)	(%)	(days)	(no. days)	(%)	(days)
1/13 (IL)	80	3.2	1/13 (ID)	86	4.0
3/11 (3L)	89	3.3	3/11 (3D)	85	5.9
5/9 (5L)	90	3.4	5/9 (5D)	74	8.2
7/7 (7L)	91	3.5	7/7 (7D)	73	10.2
14/0 (14L)	93	3.3	14/0 (14D)	10	4.5
LSD (0.05)	4	0.3		4	0.3

[a]Alpha-numeric terms in parentheses are light/dark and dark/light treatment abbreviations used in the text.

seeds in the 14D treatment germinated more rapidly than light-sensitive seeds initially exposed to a dark treatment.

Light-stimulated germination of seeds is known to involve the phytochrome system. Increased photoresponsivity during imbibition results from rehydration of phytochrome molecules in dry seeds (Frankland and Taylorson, 1983). The photoconversion of the Pr form of phytochrome (absorbs red wavelengths) to the Pfr form (absorbs far-red wavelengths), along with greater amplitudes of temperature fluctuation and changes in plant hormone levels, may stimulate germination by altering membrane properties (Baskin and Baskin, 1985). Distaff thistle seeds on or near the soil surface have the greatest chance for germination because: available soil moisture for imbibition is greatest near the surface after small rainfall events, physiologically significant amounts of light rarely penetrate more than 0.2 inches through soils (Tester and Morris, 1987), and diurnal temperature fluctuations are greater near the surface than at a depth of 3 or 4 inches.

Management implications

An understanding of seed production potential, seed reserves in the soil, and environmental factors that influence germination should allow managers to better determine expected densities of distaff thistle under certain environmental and management conditions, the type and amount of control required, and the response of distaff thistle populations following vegetation or soil manipulation (Roberts, 1986). Distaff thistle plants from these populations in central Texas have the potential to produce large numbers of seed that develop persistent seed banks and characteristically germinate near the soil surface over an extended period in the fall and early winter.

Prevention of seed development should be the primary consideration when planning control measures for distaff thistle. Herbicides are best applied during the young rosette stage (Figure 1) after all germination and seedling development has taken place. 2,4-D (2,4-dichlorophenoxy acetic acid) amine and ester formulations have satisfactorily controlled distaff thistle in Western Australia (Meadly, 1957; Quinlivan and Pearce, 1964) and at the adobe site in central Texas (Thompson, 1986). Mowing is an option if site conditions permit close cutting and the operation is timed properly. If plants are mowed too early (March), seed may develop on the regrowth, while late mowing (June/July) may not prevent seed development (Meadly, 1957). In addition, seeds have been observed to mature if plants are cut at the flowering stage (Figure 1) without being destroyed. After plants have flowered, burning may be the best method for destroying the current seed crop and removing dense stands. If revegetation is being considered, the seedbed should be prepared in the fall and seeding should be delayed as long as possible to allow distaff thistle seedlings to be controlled by herbicides. Based on seed longevity and germination requirements, the most economical approach may involve minimizing soil disturbances and implementing grazing practices that maintain a good vegetation cover on rangelands, because other control methods will have to be repeated over several years to control seedlings developing from persistent seed banks.

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VISITOR RESPONSE TO FIRE ANTS IN TEXAS PARKS

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ABSTRACT

This study analyzes the impact of Red Imported Fire Ant (RIFA), Solenopsis invicta (Buren), infestations on recreational visitation to Texas state park facilities. Data representing a nineteen year period were analyzed for thirty-five park facilities. Tests of significance were conducted to determine if visitation to parks with RIFA infestations was affected. Analysis indicates that RIFA's presence in Texas state park facilities at the infestation levels existing in the study period have not affected visitation to those facilities.

INTRODUCTION

Visitors to public recreational park facilities have tolerated pestiferous insect, arachnid (i.e. ticks, mites, spiders, etc.), plant and other biological organisms since parks were first established. Most persons seeking a picnic site consider the presence of any of these pests as a negative influence on enjoyment and prefer sites devoid of such members of the plant and animal kingdoms. However, many picnickers and outdoor activists have come to expect to find that biologically adaptive pest commonly referred to as ants. How many of us have ever been fortunate enough to ingest a meal in an open area without being bothered by ants? Not only does the presence of ants tend to decrease the potential enjoyment of a picnic or outing but their bites and/or stings can result in immense pain leaving a much more lasting impression than merely tolerating their presence.

This study considers the impact of the presence of an ant pest while estimating the aggregate demand for recreational park visitation in the state of Texas. This pest is reported to have been introduced into Mobile, Alabama between 1938 and 1943, and is known as the red imported fire ant (RIFA), Solenopsis invicta (Buren). The RIFA has become an agricultural and urban pest to much of the southern United States. Posing a risk to human health, RIFA also causes damage to a wide range of objects, including machinery, crops, and livestock (Banks, Lofgren and Wojcik, 1978; Wojcik and Lofgren, 1982; and Wojcik, 1986 and 1987).

Spreading in a fan like fashion, RIFA was first recognized to be in Texas in 1953 (Culpepper, 1953). Since then, RIFA's territory within the state has reached approximately 76,827 sq. miles, representing 29 percent of the state (Cokendolpher and Phillips, in review). With this spread of the pest comes an increase of RIFA infested Texas state parks and public exposure to the ant. According to the Texas Parks and Wildlife Department, park operations change very little when a park becomes infested with RIFA (Riskind, 1988). Park personnel chemically treat mounds in "use" areas where conflict could occur. Because of environmental concerns, park administrators generally attempt to minimize chemical use. Therefore, persons visiting RIFA infested parks often come into contact with the pest and establish attitudes about any change in utility caused by the presence of RIFA.

Michalson (1975) reported that Washington state recreational park visitors responding to questionnaires were willing to incur the expense and/or inconvenience to travel to parks which were not infested by Mountain Pine Beetle, Dendro'ctonus pondero'sae (Hopkins). Similarly, Texas state recreational facilities infested by RIFA may be losing park visitors due to visitors attempting to avoid this pest. Or, park visitors may view RIFA as an unavoidable nuisance similar to flies and mosquitoes, continuing to visit parks when RIFA is present.

Whether recreational park visitation is affected by RIFA's presence has not been determined. The purpose of this study is to estimate the impact of the presence of RIFA on recreational park visitation in the state of Texas. An aggregate demand model representing park visitation as the dependent variable was developed. The null hypothesis being tested is that RIFA has no impact on park visitation.

Predominant study methods found in current literature presenting results which explore the response of park visitors to the introduction of a negative influence on their recreational enjoyment will typically use one of two approaches: the travel cost method (TCM) and the contingent valuation method (CVM). The CVM approach relies on the stated intentions of a cross-section of the affected population to pay for recreation use of resources contingent on changes in their availability (Stoll, Shulstad, and Smathers (eds.) 1983; and Cummings, Brookshire, and Schulze (eds.) 1986). The values reported represent the maximum willingness to pay rather than forego the recreation opportunity. Although this method could be used to determine the estimated cost of RIFA in Texas parks, it would merely provide the anticipated impact based on visitor attitudes towards RIFA rather than actual intentions. Attitudes with respect to RIFA may be formed largely by such sensational writings as that written by Emily Yoffe (1988), an article appearing in the Texas Monthly entitled "The Ants From Hell". Thus, it was felt that attitudes may not realistically reflect future intentions to return to infested parks.

The TCM approach to the estimation of the nonmarket value of recreation is based on observed behavior of a cross-section of users in response to direct out-of-pocket travel cost and the opportunity cost of time (see Dwyer, Kelly, and Bowes 1977; McConnell 1985; Rosenthal, Loomis, and Peterson 1984; and Ward and Loomis 1986). The total use of the recreation site is measured objectively, usually in visitor days, using vehicle recorders, camper-registration records, etc. In a Mountain Pine Beetle study in Washington state recreational parks, Michalson (1975) used procedures similar to TCM to collect cross sectional data by interviewing approximately 500 recreational users in six campgrounds of the Targhee National Forest. All areas of the Targhee National Forest have some Mountain Pine Beetle infestation. Three campgrounds were defined as infested (over 50 percent of the trees were affected by Mountain Pine Beetle), and three as non-infested (10-20 percent of the trees infested). He developed statistical demand models for infested, non-infested, and all of the campgrounds in the study. Thus, he was able to determine the Mountain Pine Beetle's impact on park visits. His questionnaire determined origin-destination data, transfer costs of the recreation trip, a profile of the recreational user, and a catalog of the activities in which the responding camper participated. He estimated the annual economic losses of recreation values based on a reliable comparison of visitors' attitudes visiting infested and non-infested campgrounds. Although this method of estimating the cross-sectional impact of the introduction of a pest to public recreational parks is shown to be valid, it is very expensive in terms of both time and money, and again does not necessarily reflect what will actually occur. Alternatively, the current paper reports an estimate of the actual historical impact of RIFA on park visitation in Texas.

METHODS

Secondary data from both state and federal agencies were used in this study. Texas Parks and Wildlife Department (TPWD) provided in-house summaries of annual number of visitors and revenues generated from entrance fees and concession receipts representing individual parks (TPWDa-

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c). The summaries were developed from park entrance registration forms. Another publication provided by TPWD described available facilities, size and location of each park in the state park system (TPWDd). Texas statewide population and per capita income were obtained from the U. S. Bureau of Census. Population between census time periods was interpolated at an average rate between years. A study by Cokendolpher and Phillips (in review) described the movement of RIFA and years in which counties became infested with the pest. It was assumed that infested counties have infested parks. Thus, county infestation dates established by Cokendolpher and Phillips were assumed to represent park infestation dates.

Data for thirty-five parks over a 19 year period (fiscal years 1969 to 1987) were gathered. Data for fiscal year 1976 for some variables were unavailable, reducing the number of study years to eighteen over the nineteen year study period. Criteria for those parks selected to be used in the study were i) they represent an outdoor recreation state park facility used primarily for overnight camping, and ii) annual data for the eighteen years during the study period were complete.

Time is required for RIFA to become introduced into an area, become established, and reproduce to a pestiferous population level allowing visitors to react to the presence of the pest. Therefore, the data for the thirty-five parks were separated into three categories based on whether a park: a) never had RIFA during the study period (four parks); b) had RIFA during the entire study period (nine parks); or c) became infested with RIFA during the study period (twenty-two parks). Two analysis were then conducted. The first analysis represented a test to determine whether parks infested with RIFA throughout the study period had lower visitation than parks free of the pest throughout the study period. This data set consisted of thirteen parks comprising nine infested and four non-infested parks. Acreage of parks without RIFA ranged from 573 to 1869 acres, while parks with RIFA ranged from 105 to 4860 acres.

The second analysis represented a test to determine whether parks becoming infested with RIFA during the study period had fewer visitors after infestation than before. This data set consisted of twenty-two parks having an average of 1,123 acres ranging from 105 to 5200 acres. Analyzing this data was difficult, because the time required for the pest to become introduced into a park and to reach a population density considered pestiferous by visitors has not been determined. Therefore, in an effort to account for this lack of information the data were analyzed numerous times allowing the variable representing RIFA's presence to be lagged by successive years. Thus, when the variable was lagged by five years this signified that the RIFA population density reached a pestiferous status in its fifth year in the parks. It was assumed that park aesthetics, facilities and/or attractions were not changed during the study period and when a county becomes infested, the parks within the county are also infested.

To accomplish the study objectives, demand analysis must be used to estimate the impact particular variables have on the level of visitation to Texas state parks. Among other variables, a qualitative variable was developed for the presence of RIFA. The estimated statistical significance/insignificance of this variable was used to determine whether RIFA's presence has altered park visits. Several variables required modification and/or omission from the model due to the inflexible nature of using these data. For the purpose of this study it was desirable to use regressors which were consistent with previous studies. The unit of observation is a given park in a given year. The dependent variable park visitation (PV) was transformed from yearly park totals to a per capita basis as advised by Brown et al. (1983).

The model was developed to include as many of the explanatory variables as was possible with available data. Independent variables used in the model included Texas per capita income (TPCI) representing income of the population most likely to attend the parks, average cost per visit to each park (AVGCOST) representing the ratio of gross receipts from visitor expenditures and total number of visitors, park size in acres (ACRES), annual average price per barrel of crude oil (OIL) used as a travel cost proxy, and a qualitative variable representing the presence of RIFA (RIFA). The annual average price per barrel of crude oil was used as a travel cost proxy for the model.

The general model (aggregate visitation model) analyzed was:

$$PV = f(TPCI, AVGCOST, ACRES, OIL, RIFA) \quad (1)$$

where:

PV = number park visitations per capita people,

TPCI = Texas total per capita income, dollars per year,

AVGCOST = per capita visitor expenditures developed as a ratio of gross receipts and park visitation,

ACRES = park size in acres,

OIL = average price per barrel of crude oil (travel cost proxy)

RIFA = dummy variable representing the presence (1) or absence (0) of RIFA.

Anticipated relationships between dependent and independent variables are represented in the signs of derived coefficients of explanatory variables. It was expected that results would indicate a positive relationship exists between the dependent variable PV and independent variables TPCI and ACRES. Thus, it was anticipated that as visitors' incomes increase and/or as park acreage increases, then the number of visitors will also increase. It was expected that results will indicate a negative relationship exists between the dependent variable PV and independent variables AVGCOST, and OIL. Therefore, it was anticipated that as the cost of visiting parks increase, through either expenses at parks or the expense of getting to parks, visitation to parks will decrease. It was expected that if RIFA has affected park visitation, that the impact would cause a decrease in visitor enjoyment, resulting in a decrease in park visitation.

The choice of mathematical functional form for outdoor recreation demand was addressed by Ziemer, Muesser and Hill (1980). They reported that the selected form can have a significant impact on resulting recreation demand equations. To identify the most appropriate functional form necessary for this study, the data were analyzed using the semilog (the dependent variable logged), and log-log functional forms. To alleviate any problems in data transformation to the logarithmic form, the RIFA dummy variable assumed the value of 2.7183 in the presence of RIFA, and 1 in the absence of RIFA.

Advanced statistical procedures were required because the data represented the combination of time-series and cross-sectional groups. A time-series group is represented by eighteen study years of data for one park, while a cross-sectional group is represented by observations of all parks during one time period. The data used in this study represent park observations made over time and observations made over groups of parks within periods. The combination of both types of data is referred to as "pooled time-series and cross-section data".

Time series data often pose problems of correlation between periods (i.e. serial correlation) while cross-sectional data often result in unequal variances (i.e. heteroskedasticity) between experimental units, or parks as in this case. Therefore, because of the potential problems which may result from using this data, residuals from the ordinary least squares (OLS) estimation of equation (1) were tested for heteroskedasticity by park, and for serial correlation over time. The estimated Durbin-Watson statistic was 0.5446, indicating the presence of positive autocorrelation. The assumption of homoskedasticity was rejected using the Goldfeld-Quandt test ($P<.01$) (Pindyck and Rubinfeld, 1976, p. 104-105). To correct the data for the combined problems of autocorrelation and heteroskedasticity the data were transformed using pooling procedures outlined by Kmenta (1986, p. 618). Therefore, differences between parks such as distance from populated areas or varying attractions will not affect analysis results.

RESULTS AND DISCUSSION

Results of testing the two nonlinear functional forms (semilog and log-log) on the data are listed in Table 1. Both models resulted in relatively high coefficients of multiple determination (R^2) with a difference of only .069 between the two models. The Student t-values in parenthesis beneath their respective parameters indicate that ACRES and OIL are insignificant at the 5 percent level in the semilog model, while only OIL is insignificant at the 5 percent level in the log-log model. Whether statistically significant, or not, both models provide signs of the estimated coefficients which are consistent with a priori expectations. Because the log-log model held more variables as significant at the 5 percent level, and there is so little difference between the model coefficients of multiple determination, the log-log functional form was accepted as the most appropriate form for the data set, and used for further analysis.

A test to determine whether parks infested with RIFA throughout the study period had lower visitation due to the presence of the pest, than parks free of the pest throughout the study period was conducted. Thirteen parks comprising nine infested and four non-infested parks were represented in this phase of the analysis. The resulting parameters and Student t-values of the log-log model are listed in Table 2. The model provides signs of the estimated coefficients consistent with a priori expectations. The Student t-values in parenthesis beneath their respective parameters indicate that OIL and RIFA are insignificant at the 5 percent level.

A test of analysis was next conducted on data representing twenty-two parks which became infested with RIFA during the study period. The purpose of this phase of the study was to determine whether park visitation was affected when the presence of the pest was recognized by visitors in parks which had become infested during the study period. As previously stated, the time required for the pest to become introduced into a park and to reach a population density considered pestiferous by visitors, has not been determined. Therefore, the data were analyzed eleven times allowing the variable representing RIFA's presence to be lagged by successive years. Because parks became infested at different times, some parks are omitted from the data set when the lagging of the RIFA variable indicates that the park was infested throughout the study period, or not infested during the study period. Therefore, differences in data observations occurred between analysis of the lagged models. The resulting parameters and Student t-values of the log-log lagged models are listed in Table 3. Each model provides signs of the estimated coefficients consistent with a priori expectations. The Student t-values in parenthesis beneath their respective parameters indicate that OIL and RIFA are insignificant at the 5 percent level for each model. The RIFA variable's statistical insignificance agrees with results listed in Table 2, suggesting that either the state park system is keeping "use" areas sufficiently clear of RIFA such that visitors are not being bothered, or visitors are viewing RIFA as a necessary nuisance which must be tolerated if wishing to continue visiting parks.

CONCLUSIONS

It has been shown that the current level of RIFA infestations within the Texas park system has not affected park visitations to date. This implies that RIFA has caused no discernable economic impact to the state park system. Perhaps factors other than RIFA are more important to park visitors in determining park visitation rates if RIFA are considered in the same category by visitors as flies, mosquitoes, etc. Alternatively, the results could imply that the Texas park system is successfully controlling RIFA at a minimal level which satisfies their environmental concerns while also protecting visitor enjoyment. The results of this analysis apply only to those levels of infestation considered within the study. Therefore, RIFA infestation levels greater than those considered cannot be estimated from the results of this study.

Table 1. Results of analysis for two nonlinear functional forms.

Independent Variables	Functional Form Semilog	Log-Log
Intercept	-4.627 (-38.261)@	-11.735 (-12.877)
Per Capita Income	$8.0x10^{-5}$ (7.625)	0.610 (5.530)
Average Cost per Visit	-1.159 (-9.019)	-0.346 (-9.409)
Acres	$-1.0x10^{-5}$ (-0.186)	0.242 (4.302)
Oil	-0.008 (-1.781)*	-0.112 (-1.392)*
R^2	0.929	0.860
# Obs.	396	396

@Student t statistics are in parenthesis
*Insignificant at the .05 level

Table 2. Results of analysis for parks infested (not infested) throughout study period using log-log form.

Independent Variables	Coefficient (t-value)
Intercept	-16.011 (-10.422)@
Per Capita Income	0.721 (4.736)
Average Cost per Visit	-0.515 (-9.446)
Acres	0.707 (6.752)
Oil	-0.058 (-0.563)*
R^2	0.975
# Obs.	234

@Student t statistics are in parenthesis
*Insignificant at the .05 level

Table 3. Results of lagging the initial effects of RIFA's presence using log-log form.

Time Lagged	Intercept	TPCI	AVGCOST	ACRES	OIL	RIFA	No. Obs.	R^2
Lag(0)'	-12.767	0.746	-0.356	0.246	-0.134	-0.083	396	0.872
	(-11.419)@	(5.273)	(-9.382)	(4.238)	(-1.594)*	(-1.509)*		
Lag(1)	-12.050	0.698	-0.347	0.178	-0.109	-0.042	396	0.823
	(-11.655)	(5.359)	(-9.810)	(3.201)	(-1.345)*	(-0.808)*		
Lag(2)	-13.105	0.776	-0.316	0.249	-0.090	-0.070	360	0.921
	(-12.537)	(6.367)	(-9.026)	(4.422)	(-1.052)*	(-1.428)*		
Lag(3)	-12.775	0.726	-0.321	0.255	-0.119	0.004	360	0.913
	(-11.643)	(5.661)	(-9.143)	(4.522)	(-1.394)*	(0.070)*		
Lag(4)	-12.529	0.693	-0.320	0.254	-0.116	0.028	360	0.912
	(-11.015)	(5.157)	(-9.185)	(4.512)	(-1.389)*	(0.547)*		
Lag(5)	-12.395	0.675	-0.320	0.254	-0.109	0.038	360	0.912
	(-10.618)	(4.836)	(-9.146)	(4.510)	(-1.287)*	(0.724)*		
Lag(6)	-11.445	0.567	-0.258	0.270	-0.104	0.065	360	0.886
	(-9.848)	(3.941)	(-7.691)	(5.522)	(-1.150)*	(1.275)*		
Lag(7)	-11.799	0.619	-0.256	0.268	-0.114	0.029	360	0.886
	(-9.848)	(3.941)	(-7.691)	(5.522)	(-1.150)*	(1.275)*		
Lag(8)	-12.484	0.697	-0.272	0.271	-0.139	0.067	378	0.970
	(-11.551)	(5.323)	(-7.714)	(5.396)	(-1.723)*	(1.333)*		
Lag(9)	-13.172	0.797	-0.264	0.268	-0.159	-0.010	378	0.978
	(-11.551)	(5.323)	(-7.714)	(5.396)	(-1.723)*	(-0.187)*		
Lag(10)	-12.810	0.747	-0.265	0.267	-0.149	0.028	378	0.970
	(-11.897)	(5.835)	(-7.573)	(5.335)	(-1.861)*	(0.595)*		

'Indicates years RIFA variable is lagged
@Student t statistics are in parenthesis
*Insignificant at the .05 level

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SOURCES AND ANALYSIS OF RISING UNIT COSTS OF PRODUCING COTTON ON THE TEXAS SOUTHERN PLAINS

Marcus S. Bednarz and Don E. Ethridge[1]

ABSTRACT

The cost of producing a pound of cotton on the High Plains of Texas has been rising faster than in other regions of the U.S. These rising costs may occur from two basic forces—yields and/or rising input use and/or costs. This study analyzed these factors for both irrigated and dryland cotton and estimated how much of the increase in cost per pound has been due to each of these factors. It was found that during the 1977-1987 study period, yield declines have been responsible for more of the per pound cost increases in the Southern High Plains than have the input costs per acre.

Key words: Cotton, costs, yields, Texas High Plains.

INTRODUCTION

The Texas Southern High Plains cotton industry is a major cotton producing region in the United States and the world, accounting for approximately 20% of total U.S. cotton production of about 12.5 million bales per year. Consequently, events affecting Texas Southern High Plains cotton production can have substantial economic impacts in the world market.

Over the past 25 years, the region has undergone many changes. Neal and Ethridge (1986) indicated that "cotton yields in the Texas High Plains have declined at a rate of 10 pounds per acre per year since 1965", although the region has experienced large increases in yields in 1987 and 1988. Costs of production have also increased from \$89/planted acre in 1974 to \$244 in 1985 for the Southwest while increasing from \$164 to \$400 for the U.S. over the same period (Andrew and Ethridge, 1987). On the South Plains, variable costs of production per pound in 1985 were 12% above the national average and total costs of production per pound of cotton were 24% above the national average (Ethridge, 1988). This indicates that the South Plains had become a relatively high cost producing area of the U.S. by 1985 from being a relatively low cost area in 1970. This trend shows that this region is gradually becoming less competitive in national and world markets.

With unit costs of production increasing, farmers must have higher prices for their crops to continue to operate. Because the prices for output are determined in international markets, higher prices will not occur in response to rising regional costs. Thus, some South Plains producers have been or could be forced to cease production, causing the region's production to decline. To address problems of competitiveness and efficiency, the sources of the cost increases must be understood. The objective of this study was to determine how much of the higher unit cost of producing cotton in the Texas Southern High Plains cotton industry has been due to increasing input costs and how much has been from declining yields.

ANALYTICAL FRAMEWORK & METHODS

The two major factors involved in the increase in unit costs of producing cotton—the increase in input costs and the declining yields—can be examined with the concept of average costs. Average costs (average total cost, ATC; average variable cost, AVC; and average fixed cost, AFC) are the costs incurred in producing a pound of cotton. Average costs for cotton production may be stated as:

AC per pound=[cost per acre] ÷ [pounds of cotton produced per acre] (1)

AC (average costs) may indicate ATC, AVC, or AFC and cost per acre is total, variable, or fixed.

There are three ways for the average costs to rise: (a) the numerator increases, (b) the denominator decreases and/or (c) both. Manipulation of equation (1) yields the percentage change in the cost of producing a pound of cotton:

$$\% \Delta \text{ cost/lb.} = [\% \Delta \text{ cost/acre}] - [\% \Delta \text{ lbs./acre}] \quad (2)$$

where Δ represents "change in".

The study area included seventeen of the major cotton producing counties in the Texas Southern High Plains (Figure 1). The counties were grouped into four regions. Data on both yields and costs were available for this group of counties/regions over a period of time.

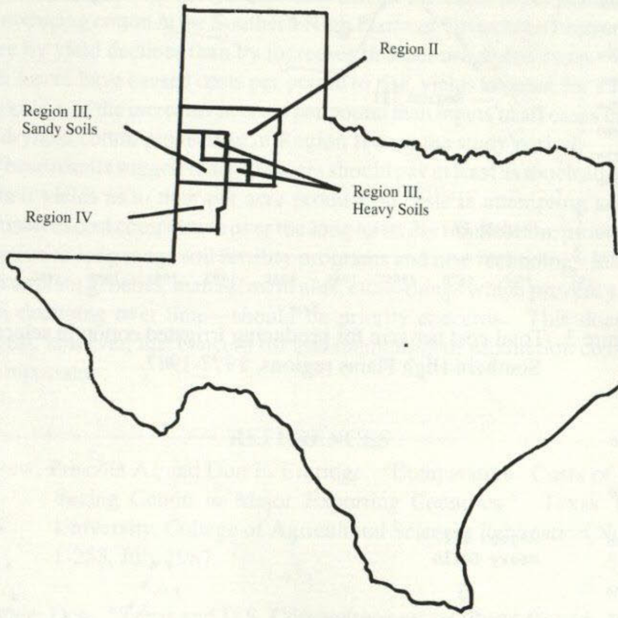

Figure 1. Study area.

The data used in determining the changes in costs per acre over time were from the Texas Agricultural Extension Service (TAEX) Annual Crop Enterprise Budgets (1978 to 1988). These budgets are estimates of yearly production inputs used and their cost per acre for typical cotton farms. Each crop budget corresponds to a particular region for the years 1977 through 1985. The counties considered in this study were assigned to their corresponding budgets. According to economists at TAEX, the budgets are a more accurate measure of prices and practices of the previous year than the year specified on the budgets. In view of this, each budget was assigned to the previous year; e.g., the 1978 crop budgets were used in estimating 1977 per acre costs of production. Total cost per acre for dryland and irrigated cotton are shown in Figures 2 and 3, respectively.

[1]Authors are former student and Professor, respectively, Department of Agricultural Economics, Texas Tech University; Marcus Bednarz was also a recipient of a Cotton Foundation scholarship in 1988/89. Appreciation is extended to Terry Ervin, Charles Dodson, Norman Hopper, and Jennifer Stratton for their assistance on the manuscript. Texas Tech University College of Agricultural Sciences Publication No. T-1-310.

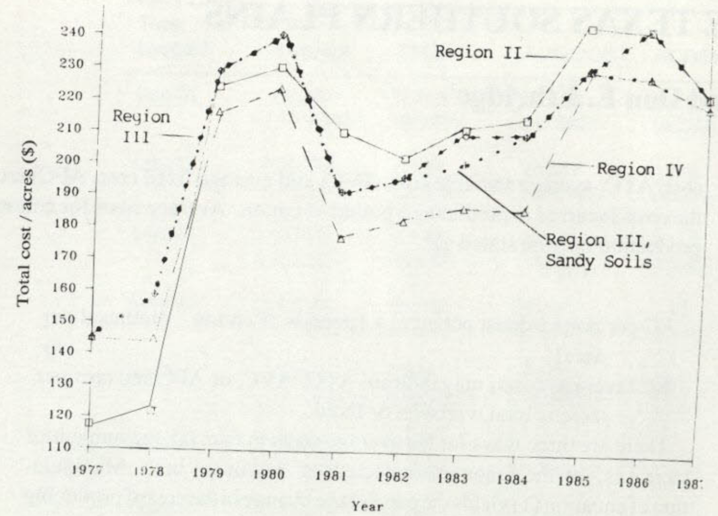

Figure 2. Total cost per acre for producing dryland cotton in specified Southern High Plains regions, 1977-1987.

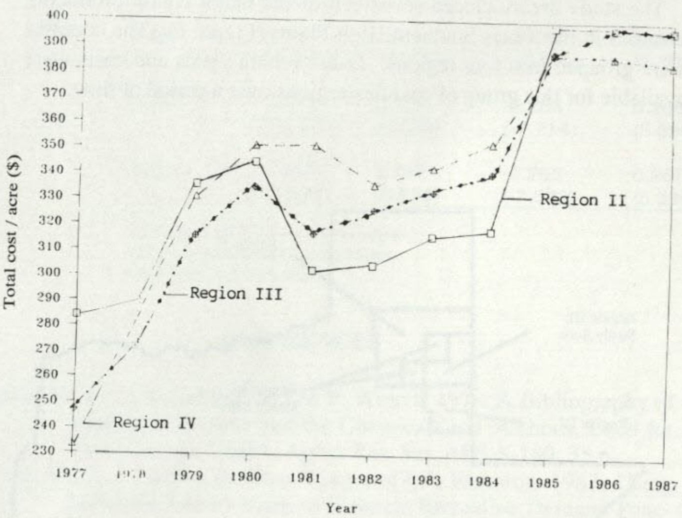

Figure 3. Total cost per acre for producing irrigated cotton in selected Southern High Plains regions, 1977-1987.

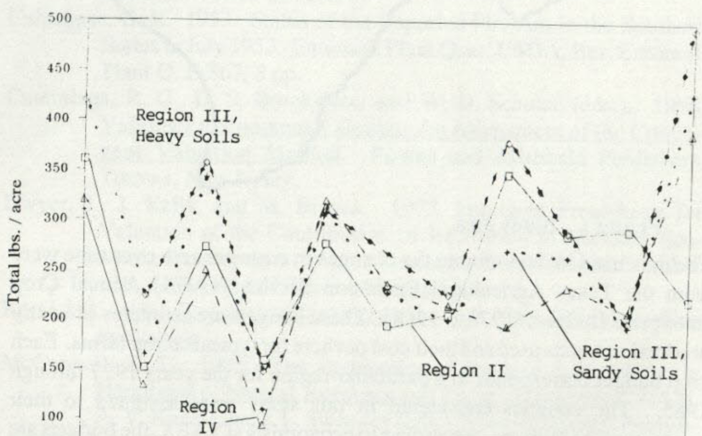

Figure 4. Dryland cotton yields by Southern High Plains region, 1977-1987.

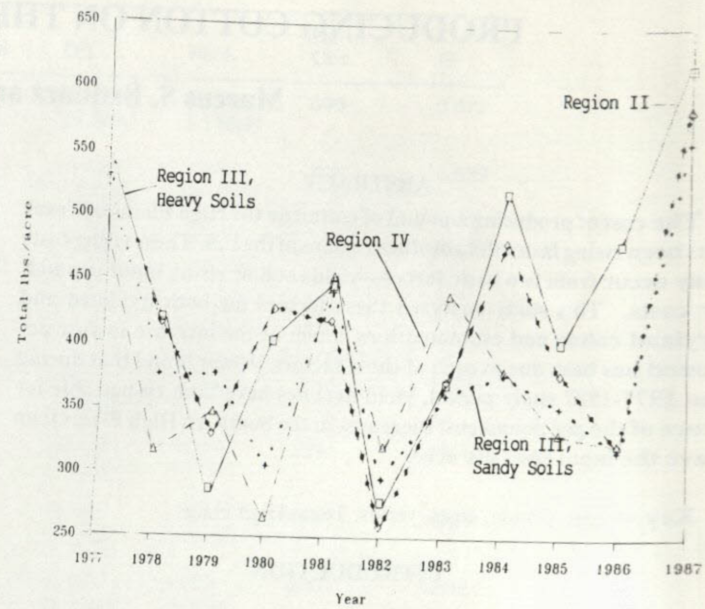

Figure 5. Irrigated cotton yields by Southern High Plains regions, 1977-1987

In analyzing the changes in yields per acre over the ten year period, data from the Texas Agricultural Statistics Service (1977 to 1987) were used. These data provided yields in pounds of irrigated and dryland cotton per harvested acre on a county basis. The weighted average yields (Figures 4 and 5) for each group of counties were incorporated into a spreadsheet for each area for each year. Note that the large increase in yields in 1987 is in sharp contrast to the declining yield trend from 1965 to 1985.

The purpose of the study was to determine how much of the production cost increases have been due to yield effects and how much due to input costs. This involves breaking the change in cost per pound of cotton into the proportion due to changes in yields and the proportion due to changes in cost per acre. Annual costs per pound of lint were calculated, then annual changes and percentage changes were computed. The annual changes in cost per acre and yields were calculated with the following formulas:

$$\%\ \Delta\ \text{cost/acre} = [\text{cost/acre in year 2} - \text{cost/acre in year 1}] \div [(\text{cost/acre in year 1} + \text{cost/acre in year 2}) \div 2] \quad (3)$$

$$\%\ \Delta\ \text{yield} = [\text{pounds/acre in year 2} - \text{pounds/acre in year 1}] \div [(\text{pounds/acre in year 1} + \text{pounds/acre in year 2}) \div 2] \quad (4)$$

The denominator in each relationship indicates that the percentage change is the average over the range of the change. Using this procedure, the percentage changes were calculated for each of the 10 annual changes over the 11 years; the changes were determined for average variable, average fixed, and average total costs for both irrigated and non-irrigated cotton in each of the four designated areas of study.

To estimate the proportion of the changes in the cost per pound of cotton due to yields and input costs, the following relationships were derived from equation (2):

$$\%\ \text{change due to yield changes} = [(\%\ \Delta\ \text{cost/acre}) \div (\%\ \Delta\ \text{cost/lb.})] \quad (5)$$

$$\%\ \text{change due to input cost changes} = [1 + (\%\ \Delta\ \text{lbs./acre}) \div \ - 1] \times 100 \quad (6)$$
$$(\%\ \Delta\ \text{cost/lb.})] \times 100$$

FINDINGS

The results of the analysis are summarized in Table 1. Average annual changes in costs per pound of cotton produced over the 11 year period in each of the four specified regions of the Texas Southern High Plains are shown in the first three columns. The proportion of these changes due to annual yield changes and annual per acre cost changes are shown in the last six columns.

Table 1. Cotton cost per pound changes and proportions due to per acre costs and yields on the Texas Southern High Plains, 1977-1987.

High Plains	Average Annual Percentage Change In Cost Per Pound			Percent of Annual Change in Cost Per Pound Due to Yield Changes			Percent of Annual Change in Cost Per Pound due to Per Acre Input Cost Changes		
Region/Soil	AVC	AFC	ATC	AVC	AFC	ATC	AVC	AFC	ATC
DRYLAND									
Region II	4.3	3.8	4.3	140.7	-279.8	-124.6	-40.7	379.8	224.6
Region III Heavy Soil	3.9	1.0	3.0	103.8	32.1	-124.8	-3.8	67.9	-20.7
Region III Sandy Soil	2.0	-1.2	1.0	94.8	119.5	96.0	5.2	-19.5	4.0
Region IV	1.5	0.3	2.6	72.4	39.5	56.2	17.6	60.5	45.8
IRRIGATED									
Region II	2.2	0.2	1.6	94.1	84.6	88.3	5.9	15.4	11.7
Region III Heavy Soil	4.8	2.4	4.1	98.0	105.6	77.0	2.0	-5.6	23.0
Region III Sandy Soil	4.5	2.5	4.0	79.0	50.0	88.5	21.0	50.0	11.5
Region IV	4.0	1.1	3.2	66.3	-446.8	68.0	33.7	556.8	32.0

Differences between percentage changes in the same column were tested. None of the differences in percentage changes in AVC, AFC, or ATC were statistically different at the .05 level of significance.

Changes in Costs of Producing Cotton

The average annual percentage change in average variable, average fixed, and average total cost per pound of producing cotton varied substantially among regions and between irrigated and non-irrigated over the study period. Variable cost per pound of lint on dryland cotton rose an average of 4.3% per year in Region II while rising only 1.5% per year in Region IV. On dryland cotton, fixed cost per pound of cotton decreased 1.2% per year in the sandy soils areas of Region III, but rose 3.8% per year in Region II. Considering both fixed and variable costs in dryland cotton production, average total cost rose the fastest in Region II (4.3% per year) and the slowest in region III, sandy soils (1.0%).

A different pattern of cost increases occurred in irrigated cotton production. Average total cost increased at the fastest rate in Region II (1.6% per year). Region II had the lowest cost increase with both variable and fixed costs with 2.2 and 0.2% per year, respectively. The low cost increases in Region II in irrigated cotton are due in part to its more abundant underground water supply relative to the other three regions.

Overall, costs tended to rise at a faster rate in irrigated production than in dryland production, with the only exception being in Region II where cotton production is less concentrated (a smaller portion of total farmland) than in the other three regions.

Sources of Cost Increases

The percentage of the average annual cost changes in the first three columns of Table 1 are provided in the last six columns of Table 1. The first column shows the percentage change in AVC per pound; columns four and seven show the percentage of that change in cost per pound which was due to yield changes and input cost changes, respectively. For example, of the 1.6% annual increase in ATC for irrigated cotton in Region II over the study period (column 3), 88.3% (column 6) was a result of yield decreases and 11.7% (column 9) was a result of input cost changes.

In dryland cotton in Region II, yield changes (increases) resulted in a decrease in average total cost per pound of cotton while costs associated with input use and input costs resulted in a larger increase in average total cost per pound. That is, input costs per acre caused a +224.6% increase in cost per pound while yield changes caused a -124.6% increase (a decrease), and the sum of the two effects was 100%; the two together constitute 100% of the 4.3% average annual increase in total cost per pound in Region II. In Regions III, sandy soil and IV, yield changes and input cost changes both caused ATC to increase; i.e., 96.0% plus 4.0% in Region III, sandy soil and 56.2% plus 45.8% in Region IV. In Region III, heavy soil yield decreases caused a cost increase while input costs resulted in a total cost per pound decline.

In irrigated cotton there is a more stable pattern across regions. With both AVC and ATC, both yield declines and input costs caused cost increases and the proportion of the cost increases due to yields being consistently greater than the proportion due to inputs. The same pattern is evident on dryland cotton with variable costs—cost increases are due much more to yield decreases than to input cost increases over the period studied.

CONCLUSIONS

The findings of this analysis indicate that the increases in per pound costs of producing cotton in the Southern High Plains of Texas have been caused more by yield declines than by increases in input usage and costs. While both forces have caused costs per pound to rise, yields account for a larger proportion of the increases in costs per pound than inputs in all cases except for dryland cotton production in Region II over the study period.

These results suggest that producers should pay at least as much attention to their yields as to their per acre production costs in attempting to keep themselves cost competitive over the long term. By implication, producers' attention to long range soil fertility programs and new technology in areas such as plant genetics, management aids, etc.—things which prevent yields from declining over time—should be priority concerns. This does not suggest, however, that concern for and monitoring of production costs are not important.

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RECENT WATER QUALITY TRENDS IN GUADALUPE MOUNTAINS NATIONAL PARK, TEXAS

Ernest B. Fish[1]

ABSTRACT

Protection of the limited water resources in Guadalupe Mountains National Park is a primary concern of National Park Service managers. A two year sampling program at one spring and at four sites in McKittrick Canyon examined temperature, pH, nitrate-nitrogen, ortho-phosphate, sulfates, chlorides, dissolved oxygen, total hardness and calcium hardness. A non-parametric modification of the sign test, the Cox-Stewart test for trend, was used to evaluate changes in water quality parameters over time. There are some indications of trends in the data; however, these are not presently sufficiently consistent nor of sufficient magnitude to warrant modification of current management strategies.

Key Words - water quality, Guadalupe Mountains National Park, water quality trends

INTRODUCTION

The purpose of this study was to monitor various water quality parameters over time and to evaluate changes.

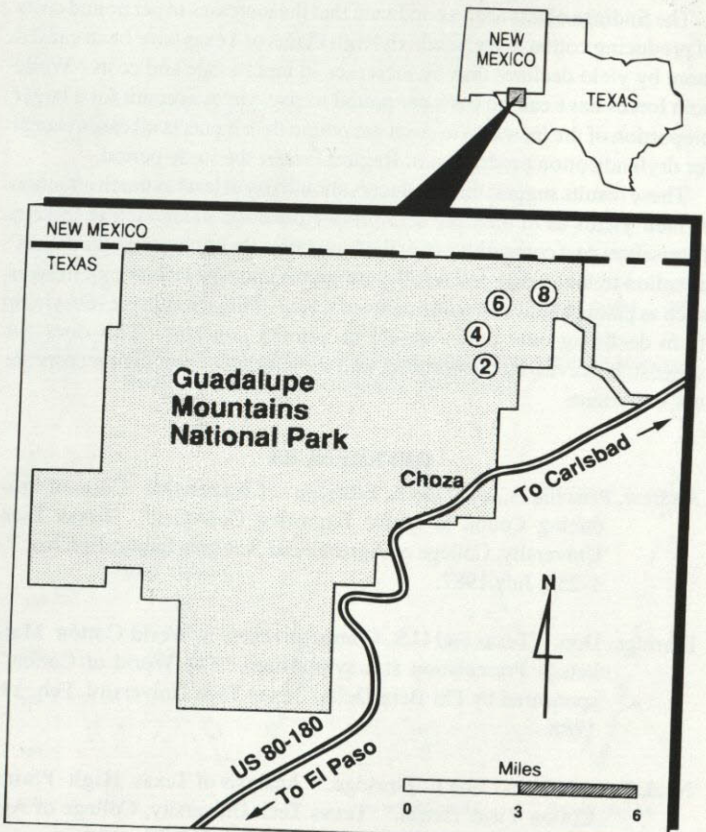

Figure 1. Study area and sample site locations

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Located on the southern end of the Guadalupe Mountains in the Trans-Pecos region of Texas, the park is between El Paso, Texas, and Carlsbad, New Mexico (Fig. 1). The Guadalupe Mountains are composed largely of limestone, a remnant of the huge Capitan Barrier Reef. The mountains have the form of a 'V' with the apex pointing south and culminating abruptly in El Capitan, a prominent scarp face. The park contains within its boundaries the entire vegetative gamut from xeric desert shrub to mesic coniferous forest and includes animals as diverse as cottontails (Sylvilagus spp.), mountain lions (Felis concolor), porcupines (Erethrizon dorsatum) and elk (Cervus elaphus) (National Park Service, 1973).

Protection of the limited water resources in the park is a primary concern of National Park Service managers. With over 100,000 visitations annually, the impact of each person is important in the preservation of this unique ecosystem (National Park Service, 1975; 1978). Early accounts of water resources in the Guadalupe Mountains were made by Marcy (1859), Richardson (1904) and King (1948).

Numerous factors, including land use and the resultant interaction of runoff, affect water quality. The natural water quality and those elements which affect that quality require establishment in order for valid management decisions to be made. The park's water resources, primarily groundwater, reflect a strong relationship between their natural chemistry and the sedimentary geology of the area (Dasher, 1980; Dasher et al., 1981). The limestone substratum of the region is manifest in a well buffered calcium carbonate-magnesium carbonate system with bicarbonate the principal anion (Lind, 1979). Other geologic elements contributing to the natural system include sandstone, alluvial material, carbonate, and evaporative sediments (King, 1948).

A potentially significant input to the chemical character of the water resources of this area is the flow of dissolved solids from decomposition of organic material. Nutrient flow or output of dissolved solids from an ecosystem in streamflow is affected by catastrophic flood and erosion events. Brown (1980) suggested that, on a geologic time scale, such events may assume a significant importance. Events such as the 1969 or 1978 floods in McKittrick Canyon had a flushing effect on organic material which had accumulated during intervening years. Due to a lowering of available nutrients it seems that these disturbances may have lowered diversity in aquatic fauna populations (Lind, 1971).

Since its authorization as a National Park by Public Law 89-667, 15 October 1969, several water quality studies have been conducted along the stream in McKittrick Canyon and at certain springs to establish baseline parameter values and to evaluate human impacts (Lind, 1971; 1979; Kelley, 1979; Dasher, 1980; Dasher et al., 1981; Fish and Dvoracek, 1980; Brothers and Fish, 1980; Fish, 1987). Lind (1971) suggested that a cesspool located near the Hunter line camp picnic area was contributing nitrate-nitrogen and orthophosphate to McKittrick Canyon Stream. After this facility was closed in 1970, Dasher (1980) concluded that the contribution was no longer significant. During his sampling Dasher (1980) found the highest nitrate-nitrogen and chloride levels for any of his McKittrick Canyon sites to be at the Pratt Lodge well. He inferred that this may have been due to the proximity of a cesspool located 180 feet from the well. Brothers and Fish (1980) conducted a tracer dye study involving the cesspool and well. They found no evidence of contamination but recommended subsequent monitoring because the cesspool did not meet design standards established by the Texas Department of Health Resources. Fish (1987) examined water quality parameters for five sample dates in each of four years (1979, 1980, 1981, 1982) and concluded that although there were some trends, concentrations were within expected natural ranges and values probably represented natural phenomena associated with normal fluctuations.

In 1987 park managers expressed a desire to reestablish water quality monitoring at selected sites in order to evaluate current trends.

METHODS

Parameters investigated were selected to provide general information on the quality of water for aquatic life and for a drinking water supply. They would also indicate possible pollution from human impacts. Water samples were collected monthly in one-quart polyethlene containers, and dissolved oxygen samples in 2 ounce glass stoppered bottles. Flow measurements were not recorded during sampling due to the remoteness of the sites and restrictions on placing permanent flow measuring devices in the park. To insure comparability all sampling was conducted during "normal base flow" conditions, avoiding particularly any runoff influenced flows. Normal base flow conditions for the spring were less than 20 gallons/minute and for the McKittrick Canyon Stream sites less than 900 gallons/minute.

Sampling sites included four locations on McKittrick Canyon Stream and Choza spring. All locations were identical to sites extensively documented by Dasher (1980) used in previous studies. Financial considerations precluded a comprehensive sampling of all previously studied locations and the collection of site specific visitor use data.

A Hach DR-EL/4 field analysis water quality test kit was employed for all sample testing. The kit uses visual and single-beam analytical spectrophotometer techniques for colorimetrically measuring concentrations of particular substances in water. Table 1 indicates the parameters of interest and the specific test procedure employed.

One of the first indications of differential usage impact would be a trend in parameter values over time. The Cox-Stuart test for trend (Daniel, 1978) was applied to appropriate parameters using data obtained from May 1987 through April 1989. This nonparametric statistical test is a modification of the sign test in which sequentially obtained values are paired and the sign of the difference is recorded. The data are said to display an upward trend if a sufficient number of the later observations are greater in magnitude than those of earlier observations. Likewise the data exhibit a downward trend if a sufficient number of the earlier observations tend to be larger than the later observations. The test can also be applied in a "flow" situation to indicate trend along the path of flow.

Table 1. Water quality analysis procedures.

Parameter	Test Procedure
Temperature C	Mercury thermometer -20 to 100 celsius
pH	*Wide range, 4-20, colorimetric spectrophotometer method
Nitrate-Nitrogen (ppm)	*High range, 0-30 ppm, cadimum reduction spectrophotometer method
Ortho-phosphate (ppm)	*Reactive phosphorus, 0-2 ppm, ascorbic acid spectrophotometer method
Sulfates (ppm)	*Sulfate, 0-150 ppm, turbidimetric spectrophotometer method
Chlorides (ppm)	*Chloride, 0-125 ppm, mercuric nitrate digital titration method
Dissolved Oxygen (ppm)	*Oxygen, 0-20 ppm, modified azide-winkler digital titration method
Total Hardness (ppm @ $CaCO_3$)	*Hardness, 0-250 ppm, EDTA digital titration method
Calcium Hardness (ppm @ $CaCO_3$)	*Calcium, 0-250 ppm, buret titration method

*Source: Hach Chemical Company, 1978. Methods manual Hach direct reading engineer's laboratory models DR-EL/1, DR-EL/3, DR-EL/4. Hach Chemical Company, Ames, Iowa.

RESULTS

Table 2 presents the means and ranges for the water quality parameters measured at each sampling location. Table 3 indicates the statistically significant outcomes for trend over time when the Cox-Stuart test was applied with the null hypothesis, Ho: There is no trend present in the data; versus the alternative hypothesis, Ha: There is either an upward trend or a downward trend. Assuming that a P value of 0.100 or less is sufficiently critical in this case, it appears, based on the number of tests performed for each parameter that there is a consistent indication of a downward trend for nitrate-nitrogen in the McKittrick Canyon Stream samples.

Table 2. Means and ranges of selected water quality parameters in Guadalupe Mountains National Park. Monthly samples from May 1987 through April 1989.

Parameter	Location				
	MK-2	MK-4	MK-6	MK-8	Choza
Temperature C	10.2 1.0-20.0	10.9 2.0-19.5	13.0 7.0-18.0	13.7 10.0-17.0	15.0 7.0-22.0
pH	8.0 6.7-8.9	8.1 7.7-8.7	8.0 7.7-8.6	7.8 6.5-8.6	8.2 7.7-8.8
Nitrate-Nitrogen (ppm)	0.28 0.00-1.10	0.29 0.00-1.10	0.42 0.00-1.50	0.42 0.00-1.80	0.23 0.00-0.90
Ortho-Phosphate (ppm)	0.05 0.00-0.25	0.08 0.00-0.50	0.07 0.01-0.22	0.05 0.00-0.18	0.05 0.00-0.14
Sulfate (ppm)	10.8 4.0-17.0	9.4 5.0-12.5	9.0 6.0-12.0	10.8 6.0-17.0	14.8 8.0-19.0
Chlorides (ppm)	3.6 0.0-16.0	3.5 0.0-20.0	3.6 0.0-22.0	3.2 0.9-8.0	3.8 0.00-17.0
Dissolved Oxygen (ppm)	8.1 4.0-11.9	8.0 3.2-15.2	9.0 4.5-20.4	7.0 3.0-9.4	8.0 4.0-10.6
Total Hardness (ppm @ $CaCO_3$)	254 223-330	260 249-287	268 254-290	271 256-292	268 243-290
Calcium Hardness (ppm @ $CaCO_3$)	138 120-160	156 140-180	173 140-210	170 140-190	161 140-180

Table 3. Cox-Stuart trend results over time at selected locations in Guadalupe Mountains National Park. (Significant outcomes P< 0.10; direction of trend)

Parameter			Location		
	MK-2	MK-4	MK-6	MK-8	Choza
Temperature					
pH					
Nitrate-Nitrogen	—	—	—	—	
Ortho-Phosphate					
Sulfate			++		—
Chlorides					
Dissolved Oxygen					
Total Hardness					
Calcium Hardness					

A second set of Cox-Stuart tests was performed to test for trend in parameter values along the flow path in McKittrick Canyon. The tests were performed for the appropriate parameters by pairing the following sites: 2-6 and 4-8. Table 4 indicates the results of the testing by showing the trend for statistically significant results of the test.

Table 4. Cox-Stuart trend results along flow path in McKittrick Canyon. (Significant outcomes $P < 0.10$; direction of trend)

Parameter	Location Pair	
	MK-2 vs MK-6	MK-4 vs MK-8
Temperature		
pH		—
Nitrate-Nitrogen		++
Ortho-Phosphate		—
Sulfate	—	
Chlorides		
Dissolved Oxygen		
Total Hardness	++	++
Calcium Hardness	++	++

DISCUSSION AND CONCLUSIONS

Fish (1987) noted a downward trend for sulfates and nitrate-nitrogen; and, an upward trend for chlorides for various time intervals from 1979 to 1982. In the current study, chloride values did not display consistent trends; sulfate values appeared to be trending upward only at sample site six in McKittrick Canyon and downward at Choza spring; all of the sample sites in McKittrick Canyon indicated a downward trend in nitrate-nitrogen values. Both Dasher (1980) and Fish (1987) discussed a trend for a general increase in the parameters of total hardness and calcium hardness along the flow path in McKittrick Canyon which is evident in the current study. Fish (1987) also found a downward trend in sulfate values between sites two and six and an upward trend in nitrate-nitrogen between sites four and eight.

Based upon the data obtained in this study, it appears that there are minimal detrimental impacts on the water quality parameters studied in Guadalupe Mountains National Park as a result of current recreational use patterns and intensities. Major trends occurring in the data along the flow path in McKittrick Canyon are probably an indication of normally expected chemical changes rather than being a result of the trend in visitor use intensity which also occurs along the flow path.

Concentrations of nitrate-nitrogen, because of its close association to life processes, are likely to be influenced by the activities of plants and animals. In this study a general downward trend was found which has a favorable connotation in terms of quality. However, it should also be noted that the nitrate-nitrogen concentrations are generally low and well within limits for human consumption. The majority of the values obtained are similar to concentrations normally associated with rainwater [(0.20 ppm), Riffenburg, 1925] therefore it does not seem appropriate to place an undue emphasis on the trend indication at this time.

While there are some indications of trend over time and along the flow path in McKittrick Canyon Stream, these are not presently sufficiently consistent nor of sufficient magnitude and direction to warrant modification of management strategies.

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NUTRITIONAL PARAMETERS OF SEVEN IMPROVED GRASSES ON THE TEXAS HIGH PLAINS

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ABSTRACT

Seven improved grass species were evaluated for nutritional parameters of new growth at 30-day intervals and regrowth 30 days after initial harvest. The species were Blackwell switchgrass (Panicum virgatum), El Reno sideoats grama (Bouteloua curtipendula), Morpa weeping lovegrass (Eragrostis curvula), and four old world bluestem selections including Caucasian (Bothriochloa caucasica), WW517 (B. intermedia var. indica), Ganada (B. ischaemum var. ischaemum), and WWspar (B. ischaemum var. ischaemum). Established stands located in Garza county (Post) on a fine sand and in Lubbock (Lubbock) and Terry counties (Brownfield) on sandy loam soils were sampled monthly from May to September and in December. Samples were analyzed for crude protein and in vitro digestible organic matter (IVDOM). Crude protein declined through the season with no single species consistently different from the others. However, sideoats grama did not decline as rapidly as other species during July and August. The IVDOM for all species declined through the season but not as rapidly as did crude protein. The decrease averaged about 20 percentage points from May to December for standing phytomass and 10 percentage points for 30-day regrowth. Regardless of nutritional parameter, quantities measured were below maintenance requirements for 500 lb steers by July.

INTRODUCTION

Since the inception of the Conservation Reserve Program in 1986, about 2,967,000 acres have been returned to grass cover (ASCS, 1989). This acreage was planted on land classified as marginal for successful row crop production. At the end of the 10-year lay out period this grassland can be grazed or returned to marginal crop production with its inherent erosion problems. However, if these grassland areas are grazed, this conversion to high yielding forage species has been shown to increase the potential for economic gains (Cotter and Dahl, 1984).

In addition to the quantity of forage available, the nutritional quality influences grazing animal performance. The nutritional value of grass changes with season, developmental stage, and environmental conditions (Blaser, 1964; Cogswell and Kamstra, 1976). The rapid change in forage nutrition should be considered when using improved grasses in a grazing system. Two basic measures of quality are considered reasonable indicators of animal performance. These are crude protein and **in vitro** digestible organic matter (IVDOM) (Minson, 1980; Marten, 1981). If the quality as well as the quantity of available forage is considered when making management decisions, optimal use of the resource is possible.

MATERIALS AND METHODS

Study Areas

Three areas with coarse-textured soils were chosen for this project. The first site was in Lubbock county (Lubbock). The soil is an Acuff loam (Blackstock, 1979), which is a fine loamy mixed thermic Aridic Paleustolls. The second site was located in Terry county (3 miles north of Brownfield). The soil at this site is a loamy fine sand of the Amarillo series (Sanders, 1962) which is a loamy fine mixed thermic Aridic Paleustalfs. The third site, located in Garza county (Post), is more undulating and sandier than the other sites. The soil at this site is a fine sand of the Brownfield Series and classified as a loamy mixed thermic Arenic Aridic Paleustalfs (Richardson et al., 1975).

The climate of the southern High Plains is warm temperate, subtropical and characterized by dry winters, long summers, high winds, and high evaporation. The average frost free period is 211 days from early April to early November (NOAA, 1981). Annual precipitation averages 18 inches with about 75% occurring as convection storms from April to October. However, monthly and annual totals vary greatly. In the three counties included in this study, annual precipitation has ranged from 3.18 to 43.31 inches.

During this study annual rainfall varied from 22.20 inches at Post in 1981 to 14.84 inches at Brownfield in 1982 (Marietta 1985). These totals were from 3.39 inches above the long-term average to 2.36 inches below average. Overall, 1981 had the most precipitation during the study. In addition, the distribution of rainfall during the 1981 growing season was more beneficial for plant growth than in 1982 or 1983. Late July and August rains resulted in increased growth late in the growing season. In 1983, heavy October rains resulted in excellent greenup and regrowth.

Forage Analysis

Seven species were selected for evaluation and included two native and five introduced grasses. The native grasses were Blackwell switchgrass (**Panicum virgatum** L.) and El Reno sideoats grama [**Bouteloua curtipendula** (Michx.) Torr.]. Introduced grasses were Morpa weeping lovegrass [**Eragrostis curvula** (Schrad.) Nees.] and four old world bluestems (OWB) which included Caucasian [**Bothriochloa caucasica** (Trin.) C.E. Hubb.], WWspar [**B. ischaemum** (L.) Keng var. **ishchaemum**], Ganada [**B. ischaemum (L.) Keng var. ischaemum**] and WW517 [**B. intermedia** (R.Br.) var. **indica**]. Each of the introduced grasses used were adapted to the region and recommended for this area (Dalrymple, 1978). All species were seeded in both 1981 and 1982. Plots were sampled one year following the establishment year.

Samples for chemical analysis were obtained from forage yield samples. Two subsamples for each species, at each sampling period, location, and treatment were obtained. The chemical analysis samples were composed of all above ground phytomass. Thus, the samples contained leaf tissue, culms, reproductive culms, and fruits in proportion to their occurrence in the field.

The samples were ground in a Wiley mill to pass a 40 mesh screen and stored in air-tight containers. Percent crude protein on a dry weight basis was determined using standard micro-Kjeldahl techniques (AOAC, 1980). Percent IVDOM was determined using the first stage of the modified Tilley and Terry (1963) procedure followed by neutral detergent extraction (Van Soest et al. 1966; Van Soest and Wine, 1967). The values were adjusted for percent organic matter and dry weight (Harris, 1970). Fresh weights were recorded for the Lubbock samples and were used to calculate moisture content on a fresh weight basis. All samples were dried to a constant weight in a forced air drier at 122°F and weighed.

Statistical analysis of the quality measures consisted of analysis of variance and LSD ($P<0.05$) mean separation test (Cramer and Walker, 1982) among species for each treatment, location, sample period, and year. Analysis across locations and years were performed.

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RESULTS

Crude Protein

Crude protein concentrations varied among locations for both standing phytomass and 30-day-old regrowth at each sample date in 1982 and 1983 (Tables 1 to 3). Plants from Lubbock had the highest values followed by Post. At Brownfield crude protein levels averaged across species were from 32 to 47% less in 1982 and 18 to 38% less in 1983 than those at Lubbock for standing phytomass. The reduction in regrowth crude protein from Lubbock to Brownfield averaged 35% in 1982 and 30% in 1983.

As the season progressed the crude protein levels generally decreased for all samples. For the standing phytomass samples, crude protein levels decreased rapidly with maturity of the plants. The regrowth crude protein levels also decreased but at a slower rate. One exception was for standing phytomass of weeping lovegrass at Lubbock in 1982 when crude protein increased from 5.7% in June to 7.4% in July. This was due to production of new shoots and leaves after seed shatter in June.

When increases were observed in regrowth crude protein, it was due in part to a reduction in the quantity of material present. In addition, when production was low the material was primarily leaf tissue. One example of this was weeping lovegrass at Brownfield in 1982 where from July to August to September crude protein values increased from 4.3 to 6.7 to 7.5% while production decreased from 360 to 220 to 40 lb/ac.

At Lubbock crude protein levels in 1982 ranged from 20.7% for switchgrass to 12.0% for weeping lovegrass in May (Table 1). A portion of this variability can be attributed to differences in growth stage since the switchgrass sample was composed only of leaf tissue whereas the weeping lovegrass had already flowered; thus, the samples contained stem and reproductive tissue. The remaining species were developmentally intermediate and had intermediate crude protein levels. In May 1983 the species did not develop in the same sequence. The switchgrass had begun growth earlier than the other species and was more mature in 1983 than in 1982; thus, the crude protein level was reduced to 13.8%. Weeping lovegrass initiated growth later in 1983; thus, its crude protein level was 14.0% which was two percentage points higher than in 1982.

By mid-July the range of crude protein values was from 8.3 to 5.3% in 1982 and from 7.6 to 4.5% in 1983. For the most part, crude protein would be deficient for most classes of livestock by this time since 8.5% is considered the amount needed for maintenance for 500 lb steers (NRC, 1976). The regrowth values were generally above the 8.5% threshold value.

The relative rank of the species changed with sampling date and year for the standing phytomass. No single species or group of species was consistently better or worse than the other species. Sideoats grama crude protein level did not change as rapidly as the other species from July to August and was generally intermediate to the other species.

Crude protein content was higher at Lubbock and lower at Brownfield across species as well as months and years. Only during May did crude protein at Brownfield average above 8.5% (Table 2) and with few exceptions was deficient for livestock by mid-June. During 1982, May was the

Table 1. Monthly crude protein (%) content of standing biomass and 30-day-old regrowth for 1982 and 1983 at Lubbock.

Treatment	Date	Species						
		Switchgrass	Sideoats grama	Weeping lovegrass	WWspar OWB	WW517 OWB	Ganada OWB	Caucasian OWB
Standing biomass (crude protein %)	May/82	20.7_{a}[1]	13.1_{c}	12.0_{c}	16.2_{b}	15.5_{b}	16.0_{b}	14.0_{bc}
	Jun/82	9.3_{a}	9.0_{b}	5.7_{c}	8.9_{b}	11.8_{a}	12.2_{a}	12.1_{a}
	Jul/82	8.3_{a}	7.2_{a}	7.4_{a}	5.3_{b}	8.2_{a}	7.4_{a}	6.9_{a}
	Aug/82	5.3_{ab}	6.5_{a}	5.5_{ab}	4.3_{ab}	6.6_{ab}	3.2_{b}	4.6_{ab}
	Sep/82	3.1_{b}	3.4_{ab}	4.3_{a}	3.5_{ab}	3.8_{ab}	4.0_{ab}	4.4_{a}
	May/83	13.8_{b}	13.2_{bc}	14.0_{ab}	15.7_{a}	12.6_{bc}	14.0_{b}	11.9_{c}
	Jun/83	10.5_{bc}	11.3_{ab}	9.2_{c}	11.3_{ab}	11.8_{ab}	12.5_{a}	9.0_{c}
	Jul/83	7.1_{ab}	7.0_{ab}	4.5_{c}	6.0_{bc}	6.4_{b}	7.6_{a}	5.6_{bc}
	Aug/83	5.7_{ab}	7.2_{a}	2.4_{c}	5.2_{ab}	5.7_{ab}	6.8_{a}	3.7_{bc}
	Dec/83	3.5_{c}	7.1_{ab}	7.1_{ab}	8.2_{a}	9.1_{a}	5.1_{bc}	5.9_{b}
30-day-old regrowth (crude protein %)	May/82	20.7_{a}	13.1_{c}	12.0_{c}	16.2_{b}	15.5_{b}	16.0_{b}	14.0_{bc}
	Jun/82	13.3_{ab}	11.4_{abc}	9.6_{c}	11.5_{abc}	11.6_{abc}	13.7_{a}	10.1_{bc}
	Jul/82	12.3_{a}	10.6_{a}	11.3_{a}	10.6_{a}	12.1_{a}	12.0_{a}	11.6_{a}
	Aug/82	9.8_{ab}	8.1_{b}	9.1_{ab}	8.7_{ab}	8.5_{b}	10.7_{a}	9.9_{ab}
	Sep/82	10.7_{b}	9.4_{c}	12.3_{a}	11.1_{b}	8.8_{c}	9.1_{c}	9.5_{c}
	Dec/82	4.3_{c}	4.0_{c}	8.7_{b}	10.8_{ab}	13.3_{a}	8.1_{b}	7.8_{b}
	May/83	13.8_{b}	13.2_{bc}	14.0_{ab}	15.7_{a}	12.6_{bc}	14.0_{b}	11.9_{c}
	Jun/83	15.0_{b}	13.4_{bc}	17.6_{a}	13.3_{bc}	14.2_{bc}	14.1_{bc}	12.5_{c}
	Jul/83	10.9_{abc}	10.9_{abc}	11.9_{a}	10.0_{bc}	9.0_{cd}	11.2_{ab}	8.0_{d}
	Aug/83	10.1_{a}	8.0_{cd}	10.5_{a}	8.7_{bc}	8.4_{bc}	9.6_{ab}	6.7_{d}
	Dec/83[2]		12.0_{b}	16.3_{a}	17.3_{a}	16.1_{a}	16.7_{a}	11.1_{b}

[1] Within each row the means followed by the same letter were not significantly different at P<0.05 as determined by LSD test.

[2] Ninety-day-old regrowth.

only sample period in which there was a difference between species for crude protein.

At Post in May 1982 standing phytomass of Ganada OWB was highest with 16.5% crude protein while weeping lovegrass was lowest with 8.9% (Table 3). During both May and June crude protein was above 8.5% for all species and averaged 11.8% in May and 10.7% in June. The regrowth crude protein averaged above 8.5% until September except for weeping lovegrass and Caucasian OWB which were below 8.5% in July and August, respectively. Seeding failure in 1982 was due to low levels of precipitation and resulted in only one year of data collection for the Post study area.

Table 2. Monthly crude protein (%) content of standing biomass and 30-day-old regrowth for 1982 and 1983 at Brownfield.

Treatment	Date	Species						
		Switchgrass	Sideoats grama	Weeping lovegrass	WWspar OWB	WW517 OWB	Ganada OWB	Caucasian OWB
Standing biomass (crude protein %)	May/82	9.5$_{a}$[1]	8.9$_{ab}$	6.7$_{c}$	9.6$_{a}$	8.0$_{b}$	9.3$_{a}$	9.0$_{ab}$
	Jun/82	6.7$_{b}$	7.4$_{ab}$	6.0$_{b}$	5.8$_{b}$	6.7$_{b}$	8.7$_{a}$	6.7$_{b}$
	Jul/82	3.1$_{c}$	4.1$_{ab}$	6.2$_{ab}$	5.0$_{abc}$	4.6$_{abc}$	6.4$_{a}$	5.2$_{abc}$
	Aug/82	2.7$_{b}$	3.2$_{b}$	2.4$_{b}$	2.6$_{b}$	3.4$_{ab}$	4.4$_{a}$	2.7$_{b}$
	Sep/82	1.7$_{bc}$	2.1$_{abc}$	3.2$_{a}$	2.7$_{ab}$	1.8$_{abc}$	1.6$_{bc}$	0.9$_{c}$
	Dec/82	1.2$_{a}$	1.9$_{a}$	1.5$_{a}$	1.4$_{a}$	1.3$_{a}$	11.5$_{a}$	1.3$_{a}$
	May/83	12.4$_{ab}$	11.2$_{abc}$	9.1$_{c}$	10.7$_{bc}$	10.5$_{bc}$	13.4$_{a}$	11.0$_{bc}$
	Jun/83	6.3$_{c}$	8.5$_{b}$	4.3$_{d}$	7.4$_{bc}$	6.9$_{c}$	11.0$_{a}$	8.7$_{b}$
	Jul/83	6.0$_{a}$	5.3$_{ab}$	2.7$_{c}$	4.8$_{ab}$	5.5$_{ab}$	6.3$_{a}$	3.8$_{bc}$
	Aug/83	4.3$_{a}$	4.2$_{a}$	3.8$_{a}$	4.5$_{a}$	4.6$_{a}$	4.0$_{a}$	3.6$_{a}$
	Dec/83	3.1$_{bc}$	3.7$_{bc}$	2.3$_{c}$	4.6$_{b}$	6.4$_{a}$	4.9$_{ab}$	3.9$_{bc}$
30-day-old regrowth (crude protein %)	May/82	9.5$_{a}$	8.9$_{ab}$	6.7$_{c}$	9.6$_{a}$	8.0$_{b}$	9.3$_{a}$	9.0$_{ab}$
	Jun/82	6.7$_{b}$	5.8$_{b}$	5.7$_{b}$	7.4$_{ab}$	6.5$_{b}$	8.8$_{a}$	5.8$_{bc}$
	Jul/82	8.3$_{ab}$	7.9$_{ab}$	4.3$_{c}$	8.9$_{a}$	9.9$_{a}$	7.8$_{ab}$	6.3$_{bc}$
	Aug/82	8.5$_{a}$	7.7$_{a}$	6.7$_{a}$	7.9$_{a}$	7.9$_{a}$	8.1$_{a}$	7.3$_{a}$
	Sep/82	7.5$_{a}$	6.4$_{ab}$	7.5$_{a}$	5.7$_{ab}$	7.1$_{ab}$	5.2$_{b}$	5.3$_{b}$
	Dec/82	3.6$_{a}$	3.6$_{a}$	4.6$_{a}$	4.9$_{a}$	4.0$_{a}$	3.7$_{a}$	4.3$_{a}$
	May/83	12.4$_{ab}$	11.2$_{abc}$	9.1$_{c}$	10.7$_{bc}$	10.5$_{bc}$	13.4$_{a}$	11.0$_{bc}$
	Jun/83	9.2$_{bc}$	10.8$_{ab}$	8.1$_{c}$	9.8$_{b}$	9.2$_{bc}$	12.1$_{a}$	9.3$_{bc}$
	Jul/83	9.6$_{a}$	7.5$_{b}$	7.6$_{b}$	6.9$_{bc}$	7.1$_{bc}$	7.8$_{b}$	5.8$_{c}$
	Aug/83	8.5$_{a}$	7.0$_{cd}$	6.0$_{a}$	7.0$_{d}$	7.4$_{bc}$	7.5$_{b}$	6.3$_{a}$
	Dec/83[2]	5.4$_{c}$	5.7$_{c}$	6.0$_{bc}$	10.0$_{ab}$	11.9$_{a}$	12.9$_{a}$	7.7$_{bc}$

[1] Within each row the means followed by the same letter were not significantly different at $P<0.05$ as determined by LSD test.

Table 3. Monthly crude protein (%) content of standing biomass and 30-day-old regrowth for 1982 at Post.

Treatment	Date	Species						
		Switchgrass	Sideoats grama	Weeping lovegrass	WWspar OWB	WW517 OWB	Ganada OWB	Caucasian OWB
Standing biomass (crude protein %)	May/82	12.6$_{b}$[1]	10.3$_{cd}$	8.9$_{d}$	11.5$_{bc}$	11.5$_{bc}$	16.5$_{a}$	11.7$_{bc}$
	Jun/82	12.2$_{a}$	9.7$_{ab}$	9.4$_{b}$	10.8$_{ab}$	10.5$_{ab}$	12.2$_{a}$	10.4$_{ab}$
	Jul/82	7.6$_{a}$	6.3$_{a}$	6.4$_{a}$	7.7$_{a}$	7.4$_{a}$	7.8$_{a}$	6.3$_{a}$
	Aug/82	4.9$_{ab}$	4.4$_{b}$	3.8$_{b}$	6.2$_{a}$	5.3$_{ab}$	5.2$_{ab}$	4.0$_{b}$
	Sep/82	3.3$_{ab}$	3.8$_{a}$	3.3$_{ab}$	3.6$_{a}$	3.3$_{ab}$	3.2$_{ab}$	2.4$_{b}$
	Dec/82	1.5$_{a}$	2.3$_{a}$	1.6$_{a}$	1.5$_{a}$	1.6$_{a}$	2.7$_{a}$	1.6$_{a}$
30-day-old regrowth (crude protein %)	May/82	12.6$_{b}$	10.3$_{cd}$	8.9$_{d}$	11.5$_{bc}$	11.5$_{bc}$	16.5$_{a}$	11.7$_{bc}$
	Jun/82	11.7$_{abc}$	10.6$_{cd}$	8.9$_{d}$	14.4$_{a}$	11.3$_{bcd}$	13.8$_{ab}$	13.5$_{ab}$
	Jul/82	11.3$_{b}$	8.7$_{c}$	7.5$_{c}$	8.7$_{c}$	8.3$_{c}$	13.1$_{a}$	8.8$_{c}$
	Aug/82	10.4$_{a}$	8.5$_{bcd}$	7.9$_{cd}$	8.8$_{abc}$	8.7$_{abc}$	10.2$_{ab}$	6.9$_{d}$
	Sep/82	5.7$_{abc}$	5.6$_{abc}$	5.3$_{bc}$	6.7$_{a}$	5.7$_{abc}$	6.2$_{ab}$	4.7$_{c}$
	Dec/82[2]	2.6$_{c}$	2.5$_{c}$	6.7$_{a}$	4.7$_{ab}$	6.0$_{a}$	3.3$_{bc}$	3.9$_{bc}$

[1] Within each row the means followed by the same letter were not significantly different at $P<0.05$ as determined by LSD test.

Ninety-day-old regrowth.

IVDOM

The IVDOM levels generally decreased as the season progressed but not as rapidly as the crude protein values. The decrease averaged about 20 percentage points from May to December for the standing phytomass and about 10 percentage points for the regrowth (Tables 4 to 6). Year was not as important as with crude protein.

Using Minson's (1980) conversion equation for metabolizable energy to IVDOM, 56% IVDOM was needed for maintenance of 550 lb steers. This was equivalent to 4.4 Mcal/lb of metabolizable energy. As with crude protein, IVDOM levels were below NRC (1976) standards for livestock production by mid-July for standing phytomass but were generally sufficient for the regrowth samples.

At Lubbock the IVDOM levels of the species were varied in June and July 1982 and June, July, and December 1983 for the standing phytomass (Table 4). Species differed for regrowth in August and September 1982 and in July 1983. Weeping lovegrass was lower in IVDOM than the remaining species and the OWBs were generally higher. The same trends were maintained in the regrowth but sideoats grama was reduced to levels similar to that of weeping lovegrass.

Species were different in IVDOM at Brownfield for standing phytomass in May through September 1982 and in July, August, and December 1983 (Table 5). As at Lubbock, weeping lovegrass was generally lower in IVDOM than the other species. The IVDOM levels of 30-day regrowth were

Table 4. Monthly IVDOM (%) of standing biomass and 30-day-old regrowth for 1982 and 1983 at Lubbock.

Treatment	Date	Species						
		Switch-grass	Side-oats grama	Weeping love-grass	WWspar OWB	WW517 OWB	Ganada OWB	Cauca-sian OWB
Standing biomass (IVDOM %)	May/82	67.0$_{a}$[1]	57.0$_{bc}$	51.2$_{c}$	62.0$_{ab}$	60.2$_{abc}$	63.1$_{ab}$	62.6$_{ab}$
	Jun/82	57.7$_{a}$	48.7$_{b}$	39.8$_{c}$	55.1$_{ab}$	56.4$_{a}$	57.7$_{a}$	54.0$_{ab}$
	Jul/82	45.1$_{bc}$	44.5$_{bc}$	41.1$_{c}$	45.8$_{bc}$	52.4$_{a}$	50.1$_{ab}$	48.8$_{ab}$
	Aug/82	40.3$_{b}$	39.1$_{b}$	41.1$_{ab}$	46.8$_{ab}$	49.4$_{a}$	42.6$_{b}$	40.8$_{ab}$
	Sep/82	35.2$_{b}$	32.9$_{b}$	34.0$_{b}$	39.3$_{ab}$	43.6$_{a}$	38.9$_{ab}$	38.4$_{ab}$
	May/83	66.2$_{a}$	62.2$_{a}$	59.2$_{a}$	64.4$_{a}$	59.4$_{a}$	60.6$_{a}$	63.7$_{a}$
	Jun/83	54.0$_{b}$	56.1$_{ab}$	43.4$_{c}$	58.2$_{ab}$	61.4$_{a}$	60.0$_{a}$	58.8$_{ab}$
	Jul/83	53.6$_{a}$	48.8$_{ab}$	33.1$_{b}$	49.1$_{ab}$	48.6$_{ab}$	53.5$_{a}$	50.9$_{ab}$
	Aug/83	38.3$_{bc}$	31.7$_{cd}$	26.5$_{d}$	46.5$_{ab}$	50.2$_{a}$	43.5$_{ab}$	31.5$_{cd}$
	Dec/83	41.9$_{bc}$	38.4$_{c}$	41.7$_{bc}$	47.2$_{ab}$	50.6$_{a}$	45.4$_{abc}$	50.5$_{a}$
30-day-old regrowth (IVDOM %)	May/82	67.0$_{a}$	57.0$_{bc}$	51.2$_{c}$	62.0$_{ab}$	60.2$_{abc}$	63.1$_{ab}$	62.6$_{ab}$
	Jun/82	59.0$_{a}$	51.9$_{ab}$	48.2$_{b}$	56.5$_{ab}$	56.8$_{ab}$	56.8$_{ab}$	54.5$_{ab}$
	Jul/82	58.5$_{a}$	51.2$_{a}$	53.3$_{a}$	59.8$_{a}$	58.7$_{a}$	59.7$_{a}$	57.2$_{a}$
	Aug/82	58.7$_{a}$	49.4$_{b}$	47.6$_{b}$	60.5$_{a}$	60.3$_{a}$	60.7$_{a}$	60.7$_{a}$
	Sep/82	59.9$_{ab}$	55.9$_{b}$	51.0$_{c}$	60.8$_{a}$	62.0$_{a}$	61.9$_{a}$	63.5$_{a}$
	Dec/82	27.5$_{b}$	44.0$_{a}$	41.7$_{ab}$	59.3$_{a}$	53.4$_{a}$	59.0$_{a}$	59.0$_{a}$
	May/83	66.2$_{a}$	62.2$_{a}$	59.2$_{a}$	64.4$_{a}$	59.4$_{a}$	60.6$_{a}$	63.7$_{a}$
	Jun/83	57.2$_{ab}$	56.3$_{b}$	59.8$_{ab}$	60.9$_{ab}$	63.9$_{a}$	61.7$_{ab}$	60.0$_{ab}$
	Jul/83	60.7$_{a}$	45.2$_{c}$	51.4$_{bc}$	57.3$_{ab}$	56.1$_{ab}$	57.0$_{ab}$	51.2$_{bc}$
	Aug/83	52.2$_{a}$	51.4$_{a}$	48.0$_{ab}$	51.0$_{a}$	54.7$_{a}$	49.4$_{ab}$	41.6$_{b}$
	Dec/83[2]		53.4$_{b}$	57.2$_{ab}$	61.2$_{a}$	61.8$_{a}$	62.5$_{a}$	60.5$_{a}$

[1] Within each row the means followed by the same letter were not significantly different at P<0.05 as determined by LSD test.

[2] Ninety-day-old regrowth.

Table 5. Monthly IVDOM (%) of standing biomass and 30-day-old regrowth for 1982 and 1983 at Brownfield.

Treatment	Date	Species						
		Switch-grass	Side-oats grama	Weeping love-grass	WWspar OWB	WW517 OWB	Ganada OWB	Cauca-sian OWB
Standing biomass (IVDOM %)	May/82	59.9_{a}[1]	51.5_{cd}	47.5_{c}	56.9_{ab}	60.3_{a}	61.3_{a}	55.3_{ab}
	Jun/82	51.2_{b}	40.6_{c}	42.9_{c}	56.5_{ab}	57.9_{ab}	59.1_{a}	54.3_{ab}
	Jul/82	42.7_{b}	39.2_{b}	40.1_{b}	49.3_{ab}	55.5_{a}	55.1_{a}	41.8_{b}
	Aug/82	39.8_{b}	42.6_{ab}	20.9_{c}	49.7_{a}	48.2_{ab}	50.5_{a}	19.9_{c}
	Sep/82	37.6_{dc}	39.1_{bcd}	25.5_{e}	48.1_{abc}	51.9_{a}	49.3_{ab}	36.3_{d}
	Dec/82	29.2_{a}	36.2_{a}	26.5_{a}	40.4_{a}	40.9_{a}	41.1_{a}	37.9_{a}
	May/83	67.6_{a}	59.7_{bc}	55.1_{c}	62.4_{abc}	60.3_{abc}	62.9_{ab}	60.3_{abc}
	Jun/83	54.0_{ab}	52.0_{ab}	40.1_{b}	46.6_{ab}	62.6_{a}	63.0_{a}	53.4_{ab}
	Jul/83	48.0_{a}	46.4_{a}	26.8_{b}	49.9_{a}	46.7_{a}	52.2_{a}	45.5_{a}
	Aug/83	46.2_{bcd}	37.1_{cd}	26.0_{e}	39.5_{bcd}	44.4_{abc}	49.2_{a}	34.3_{de}
	Dec/83	43.9_{ab}	20.8_{c}	16.5_{c}	49.7_{ab}	54.6_{a}	51.8_{ab}	38.2_{b}
30-day-old regrowth (IVDOM %)	May/82	59.9_{a}	51.5_{cd}	47.5_{c}	56.9_{ab}	60.3_{a}	61.3_{a}	55.3_{ab}
	Jun/82	56.7_{ab}	44.4_{c}	46.4_{c}	57.6_{ab}	58.2_{a}	58.1_{a}	53.4_{b}
	Jul/82	60.1_{a}	51.1_{b}	43.0_{b}	60.4_{a}	60.8_{a}	61.9_{a}	47.5_{ab}
	Aug/82	58.9_{a}	50.2_{bc}	44.1_{c}	60.4_{a}	60.5_{a}	61.2_{a}	55.1_{ab}
	Sep/82	54.6_{b}	52.2_{b}	42.7_{c}	54.7_{b}	59.7_{a}	53.7_{b}	54.1_{b}
	Dec/82	46.8_{ab}	46.7_{ab}	37.5_{b}	57.4_{a}	56.4_{a}	50.1_{ab}	52.1_{ab}
	May/83	67.6_{a}	59.7_{bc}	55.1_{c}	62.4_{abc}	60.3_{abc}	62.9_{ab}	60.3_{abc}
	Jun/83	61.3_{ab}	56.0_{ab}	51.8_{b}	58.4_{ab}	60.4_{ab}	62.8_{a}	61.1_{ab}
	Jul/83	54.2_{a}	51.6_{a}	46.2_{a}	51.1_{a}	55.0_{a}	55.2_{a}	50.7_{a}
	Aug/83	50.9_{ab}	46.8_{ab}	33.0_{c}	48.8_{ab}	44.7_{b}	54.9_{a}	43.7_{b}
	Dec/83[2]	54.0_{a}	44.9_{b}	35.1_{c}	55.6_{a}	60.3_{a}	57.9_{a}	52.8_{ab}

[1] Within each row the means followed by the same letter were not significantly different at $P<0.05$ as determined by LSD test.

[2] Ninety-day-old regrowth.

Table 6. Monthly IVDOM (%) of standing biomass and 30-day-old regrowth in 1982 at Post.

Treatment	Date	Species						
		Switch-grass	Side-oats grama	Weeping love-grass	WWspar OWB	WW517 OWB	Ganada OWB	Cauca-sian OWB
Standing biomass (IVDOM %)	May/82	63.9_{c}[1]	58.0_{dc}	54.5_{d}	60.4_{abc}	59.9_{bc}	62.9_{ab}	62.8_{ab}
	Jun/82	58.1_{ab}	52.2_{bc}	51.5_{c}	59.6_{a}	61.9_{a}	61.6_{a}	58.1_{ab}
	Jul/82	43.3_{bc}	38.7_{c}	35.0_{c}	49.0_{ab}	52.7_{a}	56.3_{a}	51.1_{ab}
	Aug/82	50.7_{a}	49.0_{a}	36.7_{b}	52.0_{a}	55.0_{a}	54.6_{a}	50.7_{a}
	Sep/82	42.3_{ab}	43.8_{ab}	36.3_{b}	45.4_{a}	49.5_{a}	46.3_{a}	45.6_{a}
	Dec/82	28.8_{b}	37.2_{ab}	31.8_{b}	43.5_{a}	38.5_{ab}	41.8_{a}	35.4_{ab}
30-day-old regrowth (IVDOM %)	May/82	63.9_{c}	58.0_{dc}	54.5_{d}	60.4_{abc}	59.9_{bc}	62.9_{ab}	62.8_{ab}
	Jun/82	61.6_{a}	55.3_{b}	49.7_{c}	61.5_{a}	62.6_{a}	63.7_{a}	62.1_{a}
	Jul/82	57.2_{ab}	53.9_{ab}	50.8_{b}	59.8_{a}	59.9_{a}	61.8_{a}	57.9_{ab}
	Aug/82	58.5_{ab}	55.7_{b}	47.9_{c}	61.0_{ab}	60.2_{ab}	63.7_{a}	58.0_{b}
	Sep/82	54.0_{b}	53.6_{b}	47.4_{c}	57.5_{ab}	57.9_{ab}	61.2_{a}	41.8_{c}
	Dec/82[2]	41.2_{a}	39.2_{a}	40.4_{a}	48.8_{a}	47.4_{a}	50.2_{a}	47.8_{a}

[1] Within each row the means followed by the same letter were not significantly different at $P<0.05$ as determined by LSD test.

[2] Ninety-day-old regrowth.

different for species in June, August, and September 1982 and August and December 1983. Weeping lovegrass was from 6 to 16 percentage points below the average IVDOM levels.

At Post IVDOM over species varied in May through August for standing phytomass and in June, August, and September for regrowth (Table 6). As at Brownfield, IVDOM was lower for weeping lovegrass over the season and for sideoats grama early in the season.

Moisture Content

There was a difference between species at each sampling period and between years in moisture content at Lubbock (Table 7). The general trend was a reduction in moisture content as the season progressed. The largest monthly decrease was between July and August which coincided with summer dormancy. The moisture content was generally higher for switchgrass and lower for sideoats grama compared to the other species.

Table 7. Monthly moisture content (%) of fresh weight yield samples of standing biomass and 30-day-old regrowth in 1982 and 1983 at Lubbock.

Treatment	Date	Species						
		Switch-grass	Side-oats grama	Weeping love-grass	WWspar OWB	WW517 OWB	Ganada OWB	Cauca-sian OWB
Standing biomass (moisture %)	May/82	78.3_{a}[1]	69.5_{c}	73.4_{b}	70.4_{c}	69.5_{c}	66.1_{de}	68.7_{cd}
	Jun/82	71.5_{a}	56.3_{d}	59.0_{c}	67.3_{b}	68.2_{b}	67.8_{b}	68.1_{b}
	Jul/82	69.0_{a}	55.9_{e}	62.9_{c}	60.0_{d}	65.7_{b}	58.8_{d}	59.7_{d}
	Aug/82	51.5_{a}	25.6_{e}	37.5_{b}	27.9_{de}	34.4_{bc}	31.2_{cd}	28.4_{de}
	Sep/82	44.9_{a}	19.8_{c}	29.7_{b}	23.5_{bc}	26.4_{bc}	22.3_{bc}	28.7_{b}
	May/83	71.0_{a}	58.2_{d}	65.7_{b}	63.5_{bc}	59.7_{bcd}	61.1_{bcd}	65.0_{b}
	Jun/83	70.7_{a}	59.3_{e}	61.9_{d}	71.5_{a}	68.2_{b}	70.6_{a}	66.2_{c}
	Jul/83	59.7_{a}	49.2_{d}	50.3_{cd}	53.0_{bcd}	54.2_{bc}	53.4_{bcd}	56.0_{ab}
	Aug/83	50.5_{a}	36.3_{b}	38.5_{b}	36.1_{b}	34.5_{b}	35.8_{b}	34.5_{b}
30-day-old regrowth (moisture %)	May/82	78.3_{a}	69.5_{c}	73.4_{b}	70.4_{c}	69.5_{c}	66.1_{de}	68.7_{cd}
	Jun/82	74.8_{a}	59.1_{d}	65.1_{c}	71.1_{b}	69.9_{b}	69.6_{b}	70.1_{b}
	Jul/82	77.3_{a}	64.3_{d}	69.1_{c}	75.9_{a}	75.1_{ab}	72.9_{b}	75.8_{a}
	Aug/82	63.3_{a}	52.8_{d}	60.2_{ab}	55.7_{cd}	59.1_{bc}	57.6_{bc}	60.7_{ab}
	Sep/82	50.5_{a}	41.8_{ab}	51.5_{a}	39.4_{b}	32.6_{b}	34.3_{b}	38.7_{b}
	May/83	71.0_{a}	58.2_{d}	65.7_{b}	63.5_{bc}	59.7_{bcd}	61.1_{bcd}	65.8_{b}
	Jun/83	75.0_{a}	62.1_{d}	72.9_{b}	73.8_{ab}	70.7_{c}	72.6_{b}	70.1_{c}
	Jul/83	64.4_{ab}	56.8_{c}	63.2_{abc}	60.9_{abc}	59.4_{bc}	61.3_{abc}	75.8_{a}
	Aug/83	54.4_{a}	40.8_{bc}	51.2_{a}	38.3_{c}	41.6_{bc}	49.6_{ab}	40.2_{c}

[1] Within each row the means followed by the same letter were not significantly different at $P<0.05$ as determined by LSD test.

DISCUSSION

The samples were composed of all above ground phytomass; thus, the chemical quality measures would be lower than the quality of the diet livestock would select since portions of the above ground phytomass normally would not be consumed by livestock. The selectivity of livestock was observed by Krueger and Curtis (1979) when monocultures of switchgrass were grazed beginning at the late-joint stage. The steers selectively grazed the leaves and top plant parts, improving their crude protein intake over the level of the clipped samples. Working with Blackwell switchgrass and Caucasian OWB, Anderson and Matches (1983) concluded that whole plant IVDMD (**in vitro** dry matter disappearance) may not predict the actual performance of cattle as a result of selective grazing or problems with the IVDMD procedure. Selective grazing would be of greater concern with switchgrass and the OWBs than the other species since these species had a larger percentage of stem tissue.

As the plants matured the quality decreased for all species for both the standing phytomass and regrowth. This was consistent with the trends reported in the literature. Voight et al. (1981) measured daily decreases in IVDMD of 0.46 percentage points per day from jointing to anthesis for four weeping lovegrass selections. The IVDMD of regrowth continued to decrease 0.02 percentage points over the season despite equal aged material. The crude protein and IVDMD levels were higher than those measured in the present study. This was probably due to earlier initial harvests and nitrogen fertilization. The daily decline in IVDOM measured in the present study were less in 1982 and similar in 1983 to the decline measured by Voight et al. (1981) for weeping lovegrass. The differences were probably the result of varying developmental stages since Voight calculated decline based on growth stages that occurred before the first harvest in the present study. The regrowth IVDOM of weeping lovegrass did not decline in 1982; however, in 1983 a decline of 0.06 units was measured. Averaged over years this rate of decline was similar to that measured by Voight et al. (1981).

The same trend in quality was observed for Blackwell switchgrass and Caucasian OWB by Anderson and Matches (1983). The IVDMD decreased 2.0 percentage units per week for every week the initial harvest was delayed; concurrently the crude protein declined from 1.0 to 1.6 units. The weekly decline in IVDOM was generally greater for Caucasian OWB and similar for switchgrass in the present study. The varying responses of these species was probably the result of harvest date and growth stage differences. Holt and Dalrymple (1978) measured decreases in IVDMD of weeping lovegrass from April to August of 10 to 20 units which was similar to the decline in the present study.

The OWBs decreased in quality with maturity (Horn and Taliaferro, 1979) and by August the IVDMD, cell contents, and crude protein levels had decreased enough to affect feeding value. Caucasian OWB was consistently lower in quality than Plains OWB. However, the variability among harvest dates was often larger than the difference between selections (Horn and Jackson 1979). This relationship was also found in studies by Taliaferro et al. (1984).

The moisture content of forages can be an indicator of preference and/or intake. Hyder et al. (1966) indicated that moisture contents below 50% on a fresh weight basis can reduce intake and cause loss of feed efficiency. At Lubbock moisture content dropped below 50% by August for all species except switchgrass which generally had the highest moisture content. The moisture content of the regrowth was higher but was below 50% in September 1982 and August 1983 for sideoats grama and the OWBs.

The response of these species to fertility would explain a portion of the variation in crude protein and IVDOM levels among locations in the present study. Soils similar to those of the Lubbock study area are used extensively in row crop agriculture and are considered highly fertile. The stand at the Post study area was established in a small area of native range recently cleared which had not been farmed previously. The Brownfield stand was established on highly eroded soils with a long history of row crop production. Generally, increases in fertility increased the crude protein and IVDMD levels as well as total production of these species when grown in monocultures (Denman et al., 1953; McMurphy et al. 1975; Taliaferro et al., 1975; Perry and Baltensperger, 1979). The increase was usually greater for crude protein than IVDMD. Seasonal average crude protein levels of Morpa weeping lovegrass and Plains OWB increased from about 7 to 11% and 7 to 9%, respectively, when 300 lb/ac of nitrogen was added (Taliaferro et al., 1975). The IVDMD increased about 4 and 1 percentage points, respectively. Similar trends were maintained for successive harvest dates for both switchgrass and weeping lovegrass (McMurphy et al., 1975).

Due to the decrease in quality as the forage matures, a grazing management scheme that harvests the spring growth early in the season and encourages regrowth would be most effective with these species. The timing of first harvest will vary between species but should be completed before heading (Voight et al., 1981; Anderson and Matches 1983). The length of time between harvests which would optimize the quality and yield would vary between years, seasons, and species. The harvest interval should seldom exceed seven weeks for the OWBs (Taliaferro et al., 1984) and four weeks for weeping lovegrass (Voight et al., 1981). Longer intervals may be used with the native species, switchgrass, and sideoats grama.

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ALLELOPATHIC EFFECTS OF TWO GRASSES ON SEED GERMINATION OF THREE WILDLIFE FOOD PLANTS

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ABSTRACT

There is growing interest among landowners in south Texas to include wildlife food plants in planting mixtures with introduced grasses. The objective of this study was to determine effects of leachate from buffelgrass (Cenchrus ciliaris) and Kleberg bluestem (Dichanthium annulatum) on seed germination of 3 grasses commonly planted for bobwhite quail (Colinus virginianus). Seeds of sorghum (Sorghum almum), 'Verde' Kleingrass (Panicum coloratum), and blue panicgrass (P. antidotale) were placed on substrata moistened by leachate of roots or leaves of buffelgrass or Kleberg bluestem. Experiments were conducted in a controlled environment chamber at 59-77° F (12 hours with darkness-12 hours with light). Kleberg bluestem leachate affected the seed germination of 'Verde' Kleingrass and blue panicgrass, while buffelgrass leachate affected seed germination of all tested species. Further research is needed to determine if similar results occur under field conditions.

INTRODUCTION

Management of grazing land for game animals in addition to livestock is currently of economic importance in south Texas (Pitman and Holt, 1983). Growing interest exists among south Texas landowners in planting wildlife food plants in mixtures with introduced forage grasses that have low value for wildlife, such as buffelgrass (Cenchrus ciliaris) and Kleberg bluestem (Dichanthium annulatum).

Many plants produce phytotoxic chemicals that inhibit the growth of neighboring plants (Rice, 1979). Knowledge of the allelopathic effects of buffelgrass and Kleberg bluestem on seed germination and growth of wildlife food plants may help landowners in selecting food plants to include in range seeding mixtures with these introduced grasses. Nurdin and Fulbright (1990) found that percent germination of Illinois bundleflower (Desmanthus illinoensis) seeds was lower on substrata moistened with Kleberg bluestem root or buffelgrass leaf leachate than on substrata moistened with distilled water. Buffelgrass root leachate reduced germination of partridge pea (Cassia fasciculata).

Sorghum (Sorghum almum), Kleingrass (Panicum coloratum), and blue panicgrass (P. antidotale) produce seeds that are eaten by bobwhite quail (Colinus virginianus) (Guthery, 1986). The objective of this study was to determine the effects of leachate from Kleberg bluestem and buffelgrass on seed germination of these 3 species.

MATERIALS AND METHODS

Fresh roots and leaves of buffelgrass and Kleberg bluestem were randomly collected from improved pastures 2.5 miles north of Kingsville, Texas. Samples were collected in August and September, 1985. Soil was rinsed from the roots and leaves of both species with tap water and then 7 ounces of each material was soaked in 0.4 gallons of distilled water for 48 hours at 72° F. Leachate of each species and plant part was filtered through 4 layers of cheese cloth and then vacuum filtered through medium-fast filter paper (Whatman No. 541). The filtrate was stored in a refrigerator at 36-39°F for 24 hours before use in experiments.

Water potential of leachate samples was measured before each experiment with a freezing point depression osmometer. Water potential of Kleberg bluestem leaf, Kleberg bluestem root, buffelgrass leaf, and buffelgrass root leachates averaged -0.10, -0.07, -0.17, and -0.11 MPa, respectively. Bell (1974) stated that the results of tests for allelopathy showed that concentrations exceeding 50 milliosmoles (about -0.11 MPa) should be interpreted with care because plant growth may have been reduced by osmotic effects rather than by phytotoxins. The pH of distilled water, Kleberg bluestem leaf, Kleberg bluestem root, buffelgrass leaf, and buffelgrass root leachates averaged 5.89, 5.62, 5.85, 5.92, and 6.29, respectively.

Seeds of blue panicgrass, sorghum, and 'Verde' Kleingrass were obtained from commercial sources. One hundred seeds each of blue panicgrass or 'Verde' Kleingrass, or fifty seeds of sorghum were germinated on substrata moistened with 3.5 ounces of either distilled water or leachate. The substrata consisted of two layers of 4 inch diameter filter paper on a layer of creped cellulose placed in 5 by 5 by 2 inch plastic boxes. For each species and treatment, 4 plastic boxes were arranged in a randomized complete block design within a controlled environment chamber set at alternating temperatures of 59° F for 12 hours (with darkness) and 77° F for 12 hours (with fluorescent lights). Photosynthetic photon flux density averaged 21° mol/yd^2/s. Experiments were conducted twice. The number µ of germinated seeds was recorded every 4 days for 20 days.

The germination rate index (GRI) was calculated as the summation of the germination percentage at each count divided by the total number of days for germination (Maguire, 1962). The corrected germination rate index (CGRI) was obtained by dividing GRI by the final germination percentage and then multiplying by 100 (Hsu et al., 1985; Evetts and Burnside, 1972). Seeds were considered germinated when both the radicle and coleoptile were more than one half the length of the seed (Fulbright et al., 1983). Radicle lengths of 3 randomly selected seedlings in each box were determined at the end of each experiment.

Analysis of variance and Tukey's test were used to compare the effect of treatments on seed germination, radicle length, and corrected germination rate index (Walpole and Meyers, 1978). Percent germination data were subjected to arcsine transformation for analysis. Values presented in the text are untransformed means for all experiments.

RESULTS

Sorghum

Mean percent germination of sorghum seeds on substrata moistened by Buffelgrass leaf or root leachate was lower ($P<0.05$) than that of seeds germinated on substrata moistened with distilled water (Table 1). However, mean percent germination of seeds on substrata moistened with Kleberg bluestem root or leaf leachate was similar ($P>0.05$) to that of seeds on substrata moistened with distilled water. Radicles of seedlings grown on substrata moistened with buffelgrass leaf leachate were shorter ($P<0.05$) than those of seedlings grown on substrata moistened with distilled water and other leachates. No significant ($P>0.05$) difference existed between the

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Table 1. Effects of Kleberg bluestem and buffelgrass leachate on mean percent germination, radicle length (inches) and corrected germination rate index (CGRI) of 3 grasses at 50-77° F (12 hours with darkness, 12 hours with light).

Germination parameter or species	Leachate treatment: Control (Distilled water)	Kleberg bluestem Leaf	Kleberg bluestem Root	Buffelgrass Leaf	Buffelgrass Root
Sorghum					
% Germination[1]	80.7a[2]	73.2ab	72.5ab	58.0b	62.7b
Radicle length	3.0a	2.9a	2.3a	0.7b	3.0a
CGRI	16.6a	16.7a	16.6a	13.6b	16.0a
'Verde' Kleingrass					
% Germination	52.1a	40.2b	43.2ab	40.1b	40.6b
Radicle length	1.3a	0.9bc	1.0ab	0.7c	0.9bc
CGRI	14.1a	12.8ab	13.2ab	12.7b	12.5b
Blue Panicgass					
% Germination	75.6a	69.5a	69.4a	64.9a	71.6a
Radicle length	0.9a	0.9ab	0.7abc	0.5c	0.6bc
CGRI	13.9a	12.9b	13.2ab	13.1ab	13.4ab

[1]Percent germination data was transformed using arcsine √% x 0.01 for analysis.
[2]Means in the same row followed by the same letter are not significantly (P>0.05) different according to Tukey's HSD test.

control and other treatments. Mean CGRI of sorghum seeds germinated in buffelgrass leaf leachate was less (P<0.05) than of seeds in the control and other leachates.

'Verde' Kleingrass

Mean percent germination of 'Verde' Kleingrass seeds on substrata moistened by Kleberg bluestem leaf, buffelgrass leaf or root leachate was lower (P<0.05) than that of seeds on substrata moistened with distilled water (Table 1). Buffelgrass leachate reduced percent germination more than Kleberg bluestem leachate. Radicles of 'Verde' Kleingrass seedlings grown on substrata moistened with Kleberg bluestem leaf, buffelgrass leaf, or root leachate were shorter (P<0.05) than radicles of seedlings grown on substrata moistened by distilled water (Table 1).

Mean CGRI of 'Verde' Kleingrass seeds germinated on buffelgrass leaf or root leachate was less (P<0.05) than that of seeds in the control. However, Kleberg bluestem root or leaf leachate did not affect (P>0.05) CGRI of 'Verde' Kleingrass.

Blue panicgrass

There were no significant (P>0.05) differences in mean percent germination of blue panicgrass between the control and treatments (Table 1). Mean radicle lengths of blue panicgrass seedlings grown on substrata moistened by buffelgrass leaf or root leachate were lower (P<0.05) than that for the control. Mean CGRI of blue panicgrass seeds germinated in Kleberg bluestem leaf leachate was less (P<0.05) than that for the control. There were no significant (P>0.05) differences between control and other treatments.

DISCUSSION

The results of this study indicated that Kleberg bluestem leachate may contain chemicals that affect seed germination of 'Verde' Kleingrass, and blue panicgrass, while buffelgrass leachate affects germination of all 3 grasses. Buffelgrass leachate appeared more inhibitory than that of Kleberg bluestem to germination.

Concentrations of leachates used in this study were similar to those used by other investigators (Bokhari, 1978; Rice, 1972). However, the concentration of phytotoxins leached from Kleberg bluestem and buffelgrass in the field is unknown. In field experiments, Hussain et al. (1982) found that buffelgrass inhibited the growth of several forbs and grasses, including blue panicgrass. Further research is needed to determine if results similar to those obtained in this study would occur under field conditions.

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ELASTICITY OF BREAKEVEN PRICES BETWEEN AGRICULTURAL ENTERPRISES

Carl R. Dillon and James E. Casey[1]

ABSTRACT

The concept of breakeven price elasticity between agricultural enterprises is introduced. The technique is highly flexible and allows for sensitivity analysis of breakeven prices between enterprises. An application of the approach to corn and soybean production in East Texas indicates that for a fluctuation in the price of soybeans, a lower relative change in the corn price is required for corn production to maintain an equal level of returns above costs.

KEY WORDS: Breakeven prices, elasticity, decision tools

Agricultural producers encounter and must deal with a countless array of varied decisions. Participants in the market face a complex environment that creates a need for simple, practical decision aids. Given the situation of the agricultural production sector, survival of the farm or ranch may depend on implementing sound economic decisions based upon logical analysis of all relevant information. The resources of the agricultural production industry are often readily acceptable to a variety of different enterprises, thus giving producers several options. Breakeven prices thus play an important role in the decision-making process of choosing between enterprises. Beyond the static notion of breakeven prices, however, is the dynamic concept of breakeven price elasticity.

Given the significance of the selection of alternative agricultural enterprises on profits, the need arises for an easy, adequate tool of analyzing the relative importance of these enterprises to an individual farmer or rancher. The objective of this study is to develop a technique to facilitate the decision-making procedures necessary in the selection of production enterprises and to investigate the price sensitivity of the indicated crop mix. Theoretical development of the model is presented first. This is followed by calculations and analytical interpretations of an application to a specific example involving corn and soybean production in East Texas, which precedes summary and conclusions.

THEORETICAL DEVELOPMENT OF THE MODEL

Breakeven analysis involves direct application of the decision-making process, which is often regarded as being comprised of the following interrelated stages: 1) identification of the problem, 2) summarization and organization of relevant data, 3) conceptualization of alternative solutions, 4) analytical determination of an alternative plan to be executed, and 5) active implementation and evaluation of the decision (Bender et al.; Manicus and Kruger). The decision-making process is a logical, stepwise approach to the selection of competing alternatives in order to accomplish a particular goal (Pappas et al.). As such, the process implies an analysis of data and the information that data analysis yields in estimating the optimal activities to pursue. Decisionmaking is also fundamentally inseparable from at least three underlying factors: 1) data which serves as the nucleus of the decision, 2) the analysis of this data as a means by which they are interpreted, and 3) the decisionmaker's personal judgment (Downey and Trocke).

Intertwined in the decision-making process is the need for applicable analytical procedures which can assist in the process of deciding among alternative courses of action. The decision-making process in an agricultural production framework relies upon several analytical techniques including whole farm and partial budgeting (Kay; Luening). Systematic approaches in the development and analysis of farm and ranch enterprise budgets and whole farm budgets can assist in the study and comparison of alternative enterprise mixes (Krenz). Nested within enterprise budgeting techniques is the concept of breakeven analysis which can assist managerial decisionmaking (Kay). Thus, to accomplish the production management decision-making procedure, breakeven analysis as complemented by breakeven price elasticities can be utilized to provide information in the evaluation of agricultural enterprises. Breakeven price analysis has been developed and discussed (Kay; Tucker; Harris), as well as extended and applied (Casey; Collins et al.; Lacewell et al.). The concept of breakeven price elasticities adds a dimension of sensitivity analysis.

Typically, the goal of the agricultural producer is to select the enterprise mix that will maximize the individual's net returns. Of the economic variables (yield being considered a noneconomic variable) which affect net returns, prices of the outputs are probably the most volatile. A practical yet simple model for analysis of this equivalency may be obtained through breakeven comparisons.

To simplify the presentation of the model developed within the context of this study, an example of corn versus soybeans in East Texas is used. Note however that the mathematical research methods derived herein are readily adaptable to other enterprises. Net returns of the crops are estimated as follows:

(1) $NR_c = P_c * Q_c - C_c$

(2) $NR_s = P_s * Q_s - C_s$

Where:

NR_c = net returns of corn per acre, dollars

P_c = price of corn, dollars/bushel

Q_c = quantity of corn per acre (yield), bushels

C_c = production cost of corn per acre, dollars

NR_s = net returns of soybeans per acre, dollars

P_s = price per bushel of soybeans, dollars/bushel

Q_s = quantity of soybeans per acre (yield), bushels

C_s = production cost of soybeans per acre, dollars

An important attribute of this analysis is the great amount of flexibility it possesses. By using variable or total costs, a breakeven equation for either may be estimated. Therefore, one could use breakeven price elasticity above variable costs to analyze the sensitivity of breakeven prices for a producer considering short run enterprises (fixed costs constant). This is because fixed costs would be equal for the enterprises in question. To study the sensitivity of breakeven prices to new production enterprise alternatives where fixed costs have not been incurred, breakeven price elasticity above total costs may be used. As always, the relevant factor is to consider additional costs resulting from the course of action in question. Also, as long as logical consistency is retained, the varied units of the different elements do not alter the model's adaptive characteristics. Thus, stocker cattle may be compared to peanuts if cattle are put on a per acre basis.

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In order to examine the breakeven prices for equivalent net returns between the two products, net returns of the two products are set equal:

(3) $NR_c = NR_s$

Substituting the net return equations for corn and soybeans (equations 1 and 2 respectively) into equation 3 and solving for the price of corn:

(4) $P_c = ((C_c - C_s)/Q_c) + (Q_s/Q_c)P_s$

This linear relation indicates the expected positive functional relationship between P_c and P_s (since both quantities are positive, the slope Q_s/Q_c is also positive). If net returns between the two enterprises are to remain equal, a rise in P_s would by necessity require an increase in P_c.

An additional dimension of flexibility of this analytical procedure is demonstrated in the ability to examine returns above variable costs, returns above total costs, or gross returns for the two enterprises. Notably, this affects the intercept of the breakeven price equation only. Hence, the equations of breakeven prices for returns above variable costs, returns above total costs, and gross returns are parallel.

Several theoretical concepts can be drawn from Equation 4. One underlying notion behind this equation is that of the breakeven responsiveness of one price to the other. This measurement of breakeven elasticity is especially important to producers, individuals in agribusiness and policy makers alike since it would provide information on the percentage change of output price among enterprises required for them to remain equally profitable. It would also provide an indication of which enterprises are most sensitive to price fluctuations thereby signaling that the manager should concentrate attention to those price levels. Breakeven price elasticity between enterprises therefore provides a measure of relative price risk associated with production mix decisions.

By definition, it will be stipulated that breakeven price elasticity is:

(5) $\varepsilon_{BP} = \% \Delta P_c / \% \Delta P_s$

Where:

ε_{BP} = breakeven price elasticity

$\% \Delta P_c$ = percent change in price of corn

$\% \Delta P_s$ = percent change in price of soybeans

This equation illustrates that breakeven price elasticity will provide the percentage change in the price of corn that must accompany a one percent change in the price of soybeans to maintain equal net returns between the two crops. The elasticity of breakeven prices is therefore a measure of the responsiveness of output prices (to other output prices) required to maintain equivalent profits between agricultural enterprises.

Actual calculation of Equation 5 can be tedious when viewed in its definitional form; consequently, further simplification reveals:

$\% \Delta P_c / \% \Delta P_s = (\Delta P_c/P_c) / (\Delta P_s/P_s)$

$= (\Delta P_c/P_c) * (P_s/\Delta P_s)$

$= (\Delta P_c/\Delta P_s) * (P_s/P_c)$

(6) $= (\partial P_c / \partial P_s) * (P_s / P_c)$

Where:

ΔP_c = change in the price of corn

ΔP_s = change in the price of soybeans

Note that $(\partial P_c/\partial P_s)$ is merely the slope of Equation 4 (given exogenous costs and quantities), which is the positive constant of Q_s/Q_c. Substituting this in Equation 6, the final computational equation is derived:

(7) $\varepsilon_{BP} = (Q_s / Q_c) * (P_s / P_c)$

Equation 7 indicates that the ratio of prices is a major factor affecting breakeven price elasticity. In addition, the ratio of quantities (yields) of the agricultural enterprises plays a predominant role as affected by such factors as variable weather conditions and alterations in technology. In order to demonstrate the application of this decision model, an actual example of corn and soybeans is given and the results are analyzed.

RESULTS AND ANALYSIS OF CORN AND SOYBEAN PRODUCTION

Application of this procedure requires data on the quantities yielded per acre for each crop and the relevant costs (variable, total, or none) on a per acre basis for each crop. Using Texas Crop Enterprise Budgets of the East Texas District (Texas Agricultural Extension Service), the case of dryland corn and soybean production for 1988 under typical management is investigated. Corn yield is 70 bu/ac (bushels per acre) and soybean yield is 25 bu/ac. Corn variable costs per acre are \$160.68 while total costs per acre are \$216.30. The variable costs for soybeans are \$122.36 per acre with total costs at \$165.56. The budget prices for corn and soybeans are \$2.86 per bushel (including deficiency payments) and \$6.15 per bushel, respectively. Corn possesses higher returns above variable costs than soybeans (\$39.52/ac compared to \$31.39/ac), but soybeans performed more favorably over total costs than corn. Returns above total costs are -\$16.10 per acre for corn and \$13.81 per acre for soybeans.

Breakeven analysis is implemented with these data in order to assimilate the budgeting procedure across the two crops. Specifically, the sensitivity of the breakeven price of corn that maintains net returns equal to those of soybeans are studied under fluctuating soybean prices. Within the context of this decision framework, the appropriate data is substituted into Equation 4 and simplification is performed. For analysis of returns above variable costs the breakeven price of corn is given by:

$P_c = (160.68 - 122.36) / 70) + (25 / 70)P_s$

$P_c = 0.55 + 0.3571 P_s$

Similarly, regarding consideration of total costs, the following is obtained:

$P_c = (216.30 - 167.56) / 70) + (25 / 70)P_s$

$P_c = 0.70 + 0.3571 P_s$

The intercept of the total costs breakeven corn price equation is greater than that of variable costs as expected given that corn is more profitable than soybeans over variable costs and soybeans are more profitable than corn with respect to total costs. Additionally, by setting the price of soybeans at the budget price of \$6.15, the breakeven corn price of \$2.75 for variable costs and \$2.90 for total costs is calculated. While this unto itself may prove beneficial in the decision-making process, uncertainty of prices creates a fundamental concern in production planning. The agricultural manager is likely to also consider the responsiveness of the breakeven price of one enterprise as the price of the other enterprise changes. Study of breakeven price elasticities enables this sensitivity analysis to be performed. Solving Equation 7 with the data provided indicates:

$\varepsilon_{BP} = (25/70) * (P_s / P_c)$

$\varepsilon_{BP} = (0.3571) * (P_s / P_c)$

For the budget price of soybeans and the computed breakeven corn prices, the elasticity of breakeven prices is found to be 0.80 for returns above variable costs (0.3571 * 6.15/2.75 = 0.80) and 0.76 for returns above total costs (0.3571 * 6.15/2.90 = 0.76). This means that, at this breakeven price level, the price of corn must increase only 0.80% for every 1.00% the price of soybeans increases to remain equally profitable over variable costs. Likewise, a 0.76% increase in the price of corn is required to retain equal returns above total costs when the soybean price rises 1.00%. Alternately, however, soybeans can sustain a greater decrease in price relative to corn to retain equivalent returns. Thus, breakeven corn prices to soybean prices are inelastic at this level for the conditions analyzed indicating the relatively higher price risk associated with soybean production decisionmaking. With the uncertainty of prices, an individual farmer may prefer corn to soybean production under situations of increasing prices of the two crops but prefer soybean production when the crop prices are declining given the resulting breakeven price elasticity. It further denotes that economic decisions regarding production between the two substitutes are somewhat sensitive to price alterations. As the elasticity increases, farm managers should concentrate more heavily upon price levels in decisionmaking. Thus, if the breakeven corn price elasticity between soybeans exceeds the elasticity between corn and sorghum, farm managers might pay closer attention to soybean price as a more sensitive substitute for corn production.

More detailed breakeven analysis results are provided for returns above variable costs in Table 1. Breakeven corn prices and breakeven price elasticities are shown for selected soybean price levels. A one dollar increase in soybean price must be accompanied by about a $0.36 increase in corn price for breakeven status between production of the crops to be obtained with regards to returns above variable costs (Figure 1). Note that the slope of the breakeven equation of 0.36 is less than the budget ratio of corn price to soybean price at 0.47. This reinforces the potential advantage of corn production for a farmer in a breakeven situation between the two agricultural enterprises. It also indicates the need for careful evaluation of all relevant information in production management decisionmaking. Recall that under the conditions projected under static budget analysis, however, a farmer would not be operating in a breakeven situation between the two crops. The breakeven corn price elasticities increase over the entire range studied, more sharply at first and less so with increasing soybean prices. This is also depicted graphically in Figure 2, which displays the breakeven corn price elasticity increasing at a decreasing rate with respect to soybean prices.

TABLE 1. BREAKEVEN CORN TO SOYBEAN PRICES AND BREAKEVEN CORN TO SOYBEAN PRICE ELASTICITIES FOR RETURNS ABOVE VARIABLE COSTS.

SOYBEAN PRICE	BREAKEVEN CORN PRICE	BREAKEVEN PRICE ELASTICITY
0.00	0.55	0.0000
0.50	0.73	0.2460
1.00	0.90	0.3948
1.50	1.08	0.4946
2.00	1.26	0.5661
2.50	1.44	0.6199
3.00	1.62	0.6618
3.50	1.80	0.6954
4.00	1.98	0.7230
4.50	2.15	0.7459
5.00	2.33	0.7654
5.50	2.51	0.7820
6.00	2.69	0.7965
6.50	2.87	0.8092
7.00	3.05	0.8204
7.50	3.23	0.8303
8.00	3.40	0.8392
8.50	3.58	0.8472
9.00	3.76	0.8545
9.50	3.94	0.8611
10.00	4.12	0.8671
10.50	4.30	0.8726
11.00	4.48	0.8777
11.50	4.65	0.8824
12.00	4.83	0.8867
12.50	5.01	0.8908

NOTE: Calculations are based on the following data from Texas Agricultural Extension Service.

	UNITS	SOYBEANS	CORN
YIELD	BU/AC	25.00	70.00
VARIABLE COSTS	$/AC	122.36	160.68

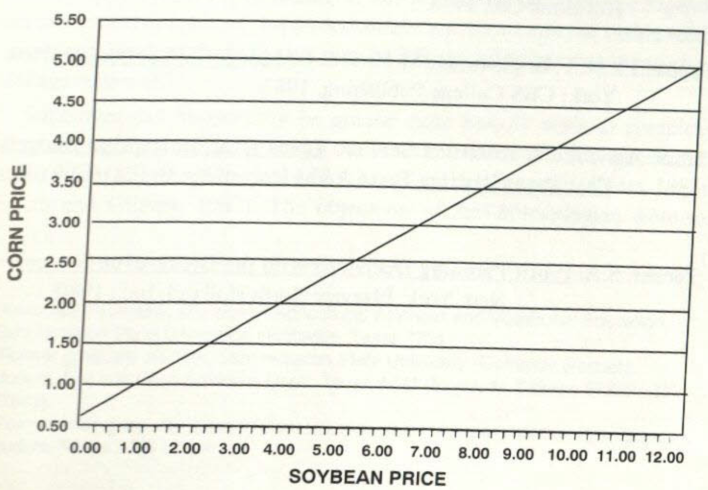

FIGURE 1. BREAKEVEN PRICE FOR CORN AND SOYBEANS RETURNS ABOVE VARIABLE COSTS

Breakeven analysis of returns above total costs provide results similar to those found for variable costs as demonstrated in Table 2. The linear relationship between breakeven corn price and soybean price under total cost considerations is graphically presented in Figure 3. Breakeven price elasticity again increases at a decreasing rate. Higher breakeven corn price are required for total cost considerations, as depicted by the parallel lines between Figure 1 and Figure 3. Noticably, the only difference between variable and total cost breakeven analysis equations is the intercept. The characteristic inelastic breakeven corn price to soybean price is present for total cost analysis as it is for variable costs (Figure 4). The general structure of the breakeven price elasticity is similar for both variable and total costs (Figure 2 and Figure 4).

TABLE 2. BREAKEVEN CORN TO SOYBEAN PRICES AND BREAKEVEN CORN TO SOYBEAN PRICE ELASTICITIES FOR RETURNS ABOVE TOTAL COSTS.

SOYBEAN PRICE	BREAKEVEN CORN PRICE	BREAKEVEN PRICE ELASTICITY
0.00	0.70	0.0000
0.50	0.87	0.2041
1.00	1.05	0.3390
1.50	1.23	0.4348
2.00	1.41	0.5064
2.50	1.59	0.5618
3.00	1.77	0.6061
3.50	1.95	0.6422
4.00	2.12	0.6723
4.50	2.30	0.6977
5.00	2.48	0.7195
5.50	2.66	0.7383
6.00	2.84	0.7548
6.50	3.02	0.7693
7.00	3.20	0.7822
7.50	3.37	0.7937
8.00	3.55	0.8041
8.50	3.73	0.8134
9.00	3.91	0.8219
9.50	4.09	0.8297
10.00	4.27	0.8368
10.50	4.45	0.8434
11.00	4.62	0.8494
11.50	4.80	0.8550
12.00	4.98	0.8602
12.50	5.16	0.8651

NOTE: Calculations are based on the following data from Texas Agricultural Extension Service.

	UNITS	SOYBEANS	CORN
YIELD	BU/AC	25.00	70.00
TOTAL COSTS	$/AC	167.56	216.30

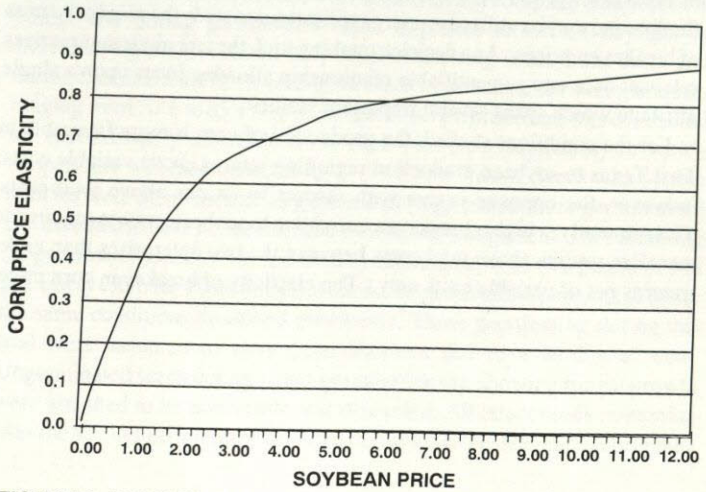

FIGURE 2. BREAKEVEN PRICE ELASTICITY FOR CORN AND SOYBEANS RETURNS ABOVE VARIABLE COSTS

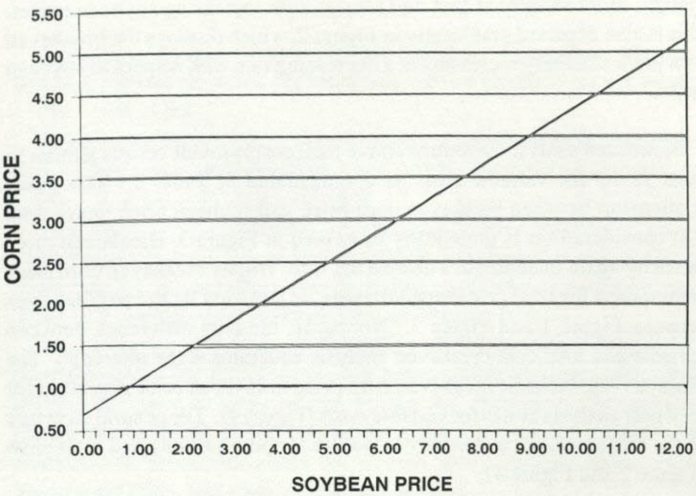

FIGURE 3. BREAKEVEN PRICE FOR CORN AND SOYBEANS RETURNS ABOVE TOTAL COSTS

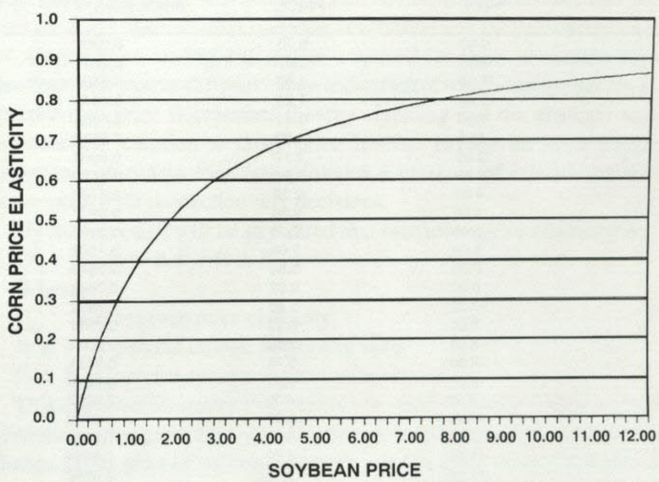

FIGURE 4. BREAKEVEN PRICE ELASTICITY FOR CORN AND SOYBEANS RETURNS ABOVE TOTAL COSTS

SUMMARY AND CONCLUSIONS

The concept of breakeven price elasticity allows for sensitivity analysis of breakeven prices between agricultural enterprises. The procedure is flexible and may be utilized in many applications to study the responsiveness of breakeven prices. As a decision-making tool, the technique summarizes relevant data into a quantifiable relationship allowing focus upon a single attribute which spans several important factors.

For the conditions studied, the production of corn is more favorable in East Texas to soybean production regarding returns above variable costs; however, the opposite is true with respect to returns above total costs. Consequently, a higher breakeven corn price to soybean price is required to equalize returns above total costs between the two enterprises than under returns net of variable costs only. The elasticity of breakeven corn prices is inelastic relative to soybean prices in terms of both returns above variable costs and returns above total costs for East Texas as based upon projections for 1988 derived from budget analysis (Texas Agricultural Extension Service). The breakeven corn price elasticity, under both variable and total cost analysis, demonstrates characteristics of increasing at a decreasing rate in relation to rising soybean prices. As soybean prices alter, less relative fluctuation in corn price is needed to keep corn production on an equal level of returns with soybean production.

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THE EFFECT OF DEFOLIATION INTERVAL ON THE YIELD AND SEED PRODUCTION CHARACTERISTICS OF SUBTERRANEAN CLOVER

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ABSTRACT

A two-year study was conducted at Huntsville, Texas on a bermudagrass (*Cynodon dactylon*) pasture overseeded to subterranean clover (*Trifolium subterraneum* cv. Mt. Barker). A 0.25 m^{-2} (2.7 ft^2) quadrat from a 2.25m^{-2} (24.5 ft^2) caged area was hand-clipped to a height of 4 cm (1.5 in) at 7-, 14, and 30-day intervals to determine the effect of clipping frequency on sward and clover dry matter production, seed yield, seed size, germination percentage, and hard seed content. The 7-day clipping interval significantly reduced total seasonal sward dry matter production in 1988 (a dry spring), but not in 1989. Clover dry matter production was also reduced with the 7 day treatment in 1988, but actually increased in 1989. Apparently, the more frequent clipping treatment favored the clover over grasses when precipitation was adequate early in the growing season. Total seed production was lowest for the 30-day clipping treatment in both years. The 7-day clipping treatment produced greater amounds of seed than either of the other two clipping treatments in both 1988 and 1989. Though differences in high temperature germination percentage (lack of hard seededness) were not detected between treatments in either year, 1988 seed had significantly higher germination percentages than 1989 seed.

INTRODUCTION

Subterranean clover (*Trifolium subterraneum* L.) is commonly interseeded into warm season perennial grass pastures throughout the southern U.S. for winter annual forage production. Due to the tolerance of subclover to moderately acid soils (pH 5.5 to 7.0), it is generally considered a suitable forage crop in high rainfall areas. It is adapted to a wide variety of soil types, ranging from a fine sandy loam to clay. Prolific seed production, hard-seededness and the seed burying ability of subclover contribute to its maintenance of a seed reserve, thus sustenance of a stand during adverse as well as favorable environmental conditions. Subclover is now being widely grown where the climate is relatively warm, the winters moist, and the summers dry (Quinlivan, et al., 1973).

Reseeding of this winter annual legume has the potential to provide high-quality grazing during late fall, winter, and spring, without the additional expense of nitrogen fertilizer. The persistence of subclover depends on successful burr burial, hard-seededness, and the number of viable seeds produced. Each of these factors may be influenced by grazing pressure or foliage removal.

Subclover can supposedly be grazed quite heavily without complete destruction of the stand, although under certain defoliation treatments the stand might be reduced as a result of heavy grazing pressure (Evers, 1988; Smith and Gilbert, 1987). The objectives of this investigation were to determine the effects of defoliation interval of subterranean clover on (i) total seed yield, (ii) seed size, (iii) percent hard-seededness, (iv) total plant dry matter yield, and (v) changes in the botanical composition of the sward.

MATERIALS AND METHODS

A 2.5 acre Alicia bermudagrass pasture was overseeded with Mt. Barker subterranean clover on 25 September 1987 and 1 October 1988 at the rate of 20 lbs acre. The soil type on which the study was conducted is a Falba fine sandy loam (a fine, montmorillonitic, thermic, Typic Albaqualfs). Soil pH on the site ranges from 5.6 to 6.5. Fertilizer and lime were applied according to soil test recommendations. Forage samples for dry matter determination and botanical composition were collected at 7-, 14-, and 30-day intervals by clipping with a pair of rechargeable electric hand clippers. A non-clipped control was used for comparing seed yield and seed characteristics only.

Four replications of each treatment were arranged in completely randomized design. Sixteen cages (4.95 ft length x 4.95 ft width x 30 in height) constructed of concrete reinforcement wire were used and secured with tent stakes at each corner. At their respective clipping dates, a 0.25 m^2 (2.7 ft^2) quadrat from the center of each cage was clipped at a height of 4 cm (1.5 in). All plots were harvested with a pair of Disston electric grass shears. The remaining area of each plot was subsequently mowed to the same height with a rotary power mower (Craftsman Super-Lite Starter) to maintain a uniform height of the plot as if the area were rotationally grazed. Following collection, samples were dried at 43°C (110°F) for 48 hours, then weighed for determination of dry matter yield. Each sample was hand-separated into clover, grass and weed components for determination of changes in sward composition and total dry matter production.

Following maturation of the clover, the top growth and 2.5cm (1 in) of soil was removed from one quadrat in each plot. Seeds were collected using sieving techniques. After separating the burrs and freeing them from adhering soil, they were carefully threshed by hand with corrugated rubber sheeting to extract the seeds. Seed weights and numbers were recorded. According to Ballard (1961), freshly harvested seeds of dormant strains of subterranean clover do not germinate at 22°C (72°F) or higher. In this case, both one-year-old (1988) and freshly harvested (1989) seed were subjected to identical treatments. All seed were maintained in complete darkness both before and during germination tests. Exposure to diffuse daylight or florescent lighting occurred only while extracting seeds from burrs and during examination. Prior to testing, all seeds were maintained at temperatures ranging from 70°F to 85°F. An initial germination procedure was conducted on approximately 25 seeds from each plot (four replicates) in which temperature was maintained at 25°C (78°F) for 7 days. Seeds with visible radicles were then counted as germinated (high temperature germination) and assumed to have no seed dormancy mechanisms present. The remaining (ungerminated) seeds were scarified by rubbing between two pieces of 440 grit emery cloth for 10 seconds and tested for germination percentage under the same conditions described previously. Those germinating during this trial were assumed to have been dormant due to a hard seed coat. Ungerminated seeds during either germination test showing fungal growth were assumed to be non-viable and discarded. All intact seeds remaining after the second germination test were assumed to possess some dormancy

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mechanism other than an impervious seed coat. Prior to conducting analyses of variance, all percentage data were subjected to an arc sine transformation. Following analyses of variance, differences between treatment means were determined by Fisher's LSD test (P<.05).

RESULTS AND DISCUSSION

Figure 1 presents cumulative sward dry matter production for both years at roughly 30 and 60 days following the initial clipping date. The 7-day clipping frequency significantly reduced the total sward dry matter production in both years. However, the 14- and 30-day treatments produced the highest total dry matter yields in 1988 and 1989 respectively. Figure 1 illustrates that frequent grazing or clipping can decrease the total sward dry matter yield, particularly if soil moisture is limited. Such was the case prior to the 4 April, 1988 and the 10 May, 1989 harvests. Less than 1 in of rain was received during the 30 days prior to the 2 May, 1988 harvest while about 4 in of precipitation fell in the preceeding 30 day period. This variation in rainfall had a pronounced effect on dry matter production. Plant available soil moisture was fairly uniform throughout the spring of 1989. The approximately 6 in of rain received during March, April, and May were uniformly distributed.

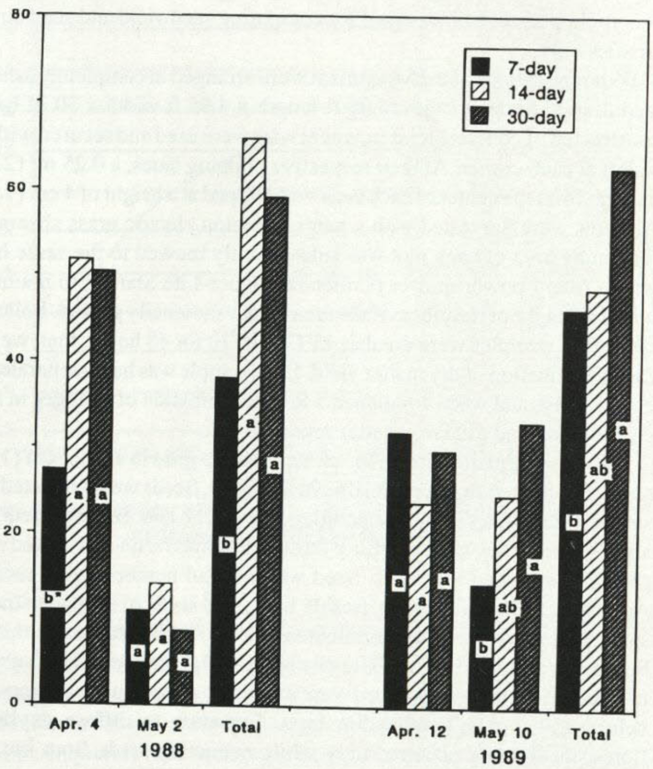

Figure 1. Mean cumulative sward dry matter production as affected by clipping frequencies of 7-, 14-, and 30-day intervals.

*Mean bars within a group containing the same letter are not significantly different at the 5% level according to Fisher's LSD.

The mean percentage of clover and non-clover biomass for both years is presented in Figure 2. In 1988, the clover component of the stand remained relatively high even near clover maturity (2 May). In 1989, all treatments contained considerable non-clover biomass at both the mid-April and May samplings. However, the percentage of non-clover dry matter increased as the time between clippings increased. Apparently, the growth habit of subclover is such that it is favored by the more frequent defoliation compared to the more vertically oriented, taller growing grasses and various dicots.

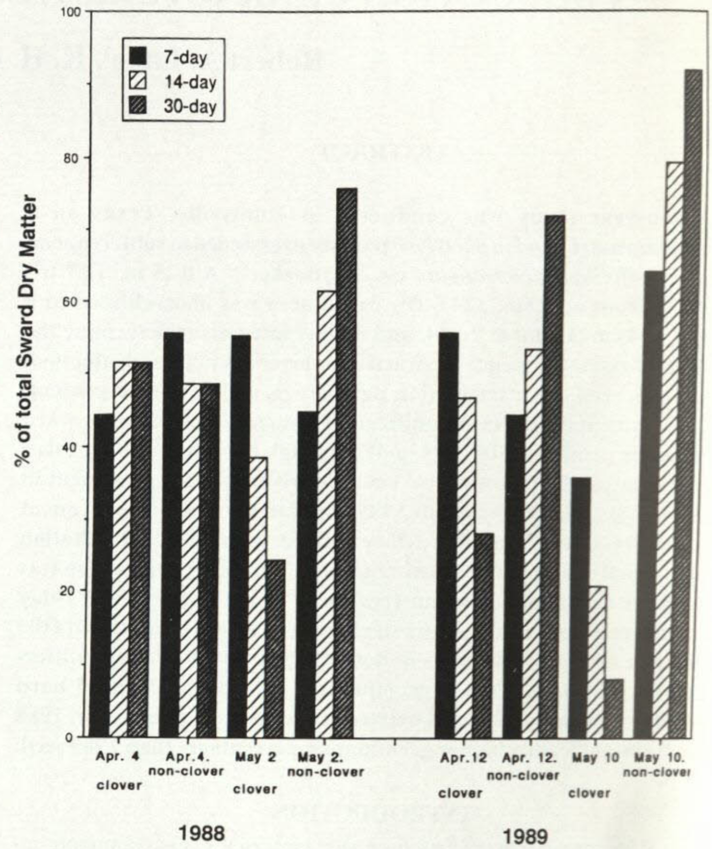

Figure 2. Mean percentage (dry matter basis) of subterranean clover and non-clover (grasses and weeds) as affected by clipping intervals of 7-, 14-, and 30-days.

Tables 1 and 2 indicate seed production was highest in the unclipped plots in 1988 while in 1989 the 7-day treatment produced the greatest seed yield. Clipping frequently had no effect on high temperature germination, percentage of seeds possessing seed coat dormancy or some other dormancy mechanism (tables 1 and 2). There was a difference between years for high temperature germination (table 3). This is in agreement with earlier research which found that subterranean clover has reduced dormancy with the passage of time. Apparently, the loss of dormancy in older seeds is due to some internal, biochemical change and is not related to a reduction in seeds possessing a hard seed coat (table 3).

Table 1. The effect of clipping frequency on seed characteristics of subteranean clover, Huntsville, Texas, 1988.

Clipping Frequency	Seed Production	Seed Weight	High Temp. Germination	Seed Coat Dormancy	Other Dormancy
	no./25m²	mg/seed	---------	%	---------
7-day	125ab*	5.008a	22a	4a	57a
14-day	119ab	5.303a	33a	12a	48a
30-day	45b	4.400a	23a	5a	46a
unclipped	301a	5.698a	35a	5a	46a

* Means within a column having the same letter are not significantly different(P<0.05).

Table 2. The effect of clipping frequency on seed characteristics of subterranean clover, Huntsville, Texas, 1989.

Clipping Frequency	Seed Production	Seed Weight	High Temp. Germination	Seed Coat Dormancy	Other Dormancy
	no./25m²	mg/seed		%	
7-day	407a*	4.108a	14a	7a	64a
14-day	139ab	3.984a	12a	8a	51a
30-day	84b	4.202a	15a	8a	64a
unclipped	192ab	4.521a	14a	4a	65a

* Means within a column having the same letter are not significantly different($P<0.05$).

Table 3. Variation in subterranean clover seed produced in 1988 and 1989, Huntsville, Texas.

Year	Seed Production	Seed Weight	High Temp. Germination	Seed Coat Dormancy	Other Dormancy
	no./25m²	mg/seed		%	
1988	148a*	5.102a	31.4a	14.1a	44.6a
1989	219a	4.204a	20.0b	14.9a	52.2a

* Means within a column having the same letter are not significantly different($P<0.05$).

CONCLUSIONS

The 14- or 30-day treatment produced the highest total dry matter yield, while plots clipped at 7-day intervals always had the lowest yields. Obviously, clipping or grazing too frequently can reduce total sward dry matter production. Even under dry conditions, frequent defoliation did not greatly reduce the percentage of clover within the sward. Frequent clipping generally favors subterranean clover over grasses and other weed species, especially when precipitation is adequate (normal).

Subterranean clover swards appear capable of high seed production even when severely defoliated by weekly clippings and when growing under conditions of moisture stress. These results suggest that an intensive grazing system would not impair stand persistence of subclover. The 7-day treatment apparently encouraged greater initiation of floral axes close to the soil surface. Thus the flowers and their resulting seeds were not subject to removal upon clipping treatment. Both greater seed production and a more competitive clover stand may be achieved by allowing or imposing short grazing intervals.

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LOW ENERGY PRECISION APPLICATION IRRIGATION FOR COTTON PRODUCTION IN THE TEXAS SOUTHERN HIGH PLAINS

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ABSTRACT

In this study the farm level economic feasibility of converting a center pivot low-pressure irrigation system to a low-energy precision application (LEPA) irrigation system for cotton production in the Southern High Plains of Texas is evaluated. The irrigation conversion is economically feasible. Therefore, the adoption of LEPA in the Southern High Plains of Texas is a viable alternative for cotton producers to assure continued profitability of agricultural operations and future firm survival.

INTRODUCTION

The Southern High Plains of Texas (SHPT) land resource area is located in the southern part of the Great Plains region of the United States. Average rainfall ranges from 10 to 20 inches per year, so supplemental irrigation in agricultural crop production is common in the area. Most of the water used for irrigation is obtained from the Ogallala formation, a major underground aquifer extending over portions of the states of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, and Texas which covers over 220,000 square miles (High Plains Associates, 1982).

Substantial increases in agricultural production have occurred in the SHPT from widespread use of irrigation since the 1940s. However, continued water withdrawals from the Ogallala have resulted in declines of the water table ranging from 50 to 200 feet (Lee, 1987; Mapp, 1988).

Rising water extraction costs associated with deeper water tables and increased energy prices have resulted in significant changes in irrigated acreage of the four major crops (corn, cotton, sorghum, and wheat) produced in the region. For example, combined irrigated acreage of those four crops declined from a high of 4.8 million acres in 1976 to 3.2 million acres in 1985, a reduction of over 33 percent. In particular, corn and sorghum (about 90 percent of which were irrigated) declined by 40 percent from 1975 to 1985 (Lansford et al., 1987). Those changes occurred because of lower profits per unit of production as compared to other irrigated areas (Mapp, 1988). Thus, efficient utilization of irrigation inputs available to producers in the SHPT has become a key component for enterprise profitability and firm survival.

In this study, the conversion of a center-pivot low-pressure sprinkler irrigation system to a low-energy precision application (LEPA) irrigation system for cotton production in the SHPT is evaluated. The conversion of a center-pivot low-pressure sprinkler irrigation system to a LEPA irrigation system is achieved by the attachment of flexible tubing which extends downward having a nozzle on the end. The primary objective of this study is to determine the farm level economic feasibility of that conversion. Although a LEPA irrigation system should decrease water use to obtain crop yields similar to those resulting from other irrigation systems, it is assumed in the economic feasibility evaluation of the conversion that producers continue to extract the same amount of water. Analysis of issues of contemporary social interest such as the implications of adopting LEPA to conserve underground water resources for use by future generations are beyond the scope of this study.

THE LOW ENERGY PRECISION APPLICATION (LEPA) IRRIGATION SYSTEM

Irrigation may be the least efficient and most expensive operation involved in the production of irrigated crops because irrigation activities are high consumers of energy (Lyle and Bordovsky, 1981). The amount of energy used in irrigation depends on the rate (gallons/minute) and depth of water extraction. Nearly two thirds of the irrigation pumps in the SHPT are powered by internal combustion engines using natural gas, whereas the remainder are powered by electric motors. Low water-application efficiency and excess energy consumption impair profitability, and thus regional competitiveness, in agricultural production. However, these conditions may be beyond the control of the agricultural producer who must rely on current technologies.

Precise control of water application to the root zone of plants with surface irrigation methods is difficult due to variability in soil intake rate, length of run, and many other factors (Lyle and Bordovsky, 1981). Developments in irrigation system technologies after World War II evolved rapidly with the introduction of lightweight and aluminum pipe. Center-pivot, side roll, and solid set high pressure irrigation systems enabled greater control over water application rates. Gains in control of water applications were possible largely at the expense of greater levels of energy used to distribute water on croplands. Additionally, water application efficiency of high pressure sprinkler irrigation systems, can be impaired by climatological conditions. For example, Clark and Finley (1975) found that spray evaporation losses from solid set high pressure sprinklers ranged from 17 percent with wind speeds of 15 mph to 30 percent with wind speeds of 20 mph. The SHPT experiences occasional wind velocities higher than those reported by Clark and Finley (1975) during the cotton growing season, and center pivot high pressure sprinkler irrigation is the most popular type of irrigation system used in the area.

Low pressure sprinkler irrigation systems were developed in an attempt to alleviate some of the water application efficiency problems as well as the high energy required to operate high pressure sprinkler systems. These low pressure irrigation systems were of the same basic design as the high pressure systems, but water pressure is decreased at least 50 percent. Water application efficiency levels of 80 and 85 percent can be attained with low pressure sprinkler irrigation systems.

More recent technological advances in irrigation systems have provided agricultural producers with a new system referred to as Low Energy Precision Application or LEPA. Although this irrigation system is still in experimental stages, it has already proved to be efficient when compared to other low pressure irrigation systems (Lyle and Bordovsky, 1983). This system can be added onto existing low pressure sprinkler systems by adding flexible tubing to the pipe drops on the low pressure system. The tubing extends down to approximately twelve to sixteen inches above the ground. Although the tubes have a nozzle on the end, LEPA nozzles spray water in a manner which confines the application to a single furrow per nozzle (details on LEPA specifications are provided by Lyle and Bordovsky, 1981; Stoecker and Lloyd, 1984). One of the two major advantages of LEPA over other low pressure irrigation systems is that evaporation losses are reduced to a minimum resulting in water application efficiency in excess of 98 percent. The other advantage of LEPA is that it requires only five to ten

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pounds of end pressure, whereas other low pressure irrigation systems require fifteen to thirty pounds.

CONVERSION OF A CENTER PIVOT LOW PRESSURE SPRINKLER TO A LOW-ENERGY PRECISION APPLICATION IRRIGATION SYSTEM

A cost analysis, summarized in the form of two partial budgets, was conducted to evaluate the conversion of a 1,389 foot long center-pivot low-pressure sprinkler irrigation system to a LEPA irrigation system for 139 acres of cotton located in the western SHPT. The budgets included electricity costs for both irrigation systems. The LEPA's system budget also included additional labor and maintenance costs associated with its operation. Costs of other variable inputs such as fertilizer, labor, insecticide, herbicide, and tillage operations were not included in those budgets because they are the same regardless of the irrigation system used. The cost of the conversion was obtained from Valley Ag-Electric, Inc. in Lamb County, Texas. Table 1 depicts an itemized list of the conversion costs.

Table 1. Itemized Conversion Costs of a 1,389 Foot Long Center Pivot Low Pressure Irrigation System to Low Energy Precision Application Irrigation System, Hockley County, Texas, 1989.

Item	Cost
278 Gooseneck pipes	$ 702.70
278 3' drops	908.82
278 Steel collars	231.11
278 PVC collars	277.95
2224 Feet LEPA hose	1,624.02
556 LEPA hose clamps	113.68
556 3/4" H.B. x 3/4" M.P.T.	203.00
139 Low flow regulators	761.26
139 Medium flow regulators	548.10
556 Stainless steel ties	73.08
278 LEPA nozzles	1,502.60
Labor to install LEPA	894.00
TOTAL CONVERSION COST	$ 7,839.94

Source: Valley Ag-Electric, Inc., Lamb County, Texas, 1989.

Irrigation costs for alternative size horsepower motors over different number of operating days per year were obtained from Lamb County Electric Cooperative, Inc. Assumptions made in deriving irrigation costs were: motors would operate for 24 hours a day at 100 percent of rated capacity and 89 percent efficiency, the price per kilowatt was $0.0465, and cotton would be irrigated 90 days per year. The annual irrigation electricity cost for operating both systems was estimated at $7,994.58 per year. Additional labor and maintenance costs associated with the operation of the LEPA system were estimated at $249.10 per year (Valley Ag-Electric Inc.)

The major difference between LEPA and other irrigation systems is that LEPA reduces water evaporation, resulting in increased water application efficiency (in most cases above 98 percent) and increased cotton lint yields. A 1984 evaluation of the center-pivot low-pressure irrigation system used in this study by the Hockley County Soil Conservation Service, showed that the actual water application efficiency of the system was 77.46 percent. That is, 77.46 percent of the water applied through the irrigation system was actually delivered to the ground. Local farm records show that average cotton yield for the 1984, 1985, 1987, and 1988 crop years was 1.36 bales (680 lbs.) of lint per acre.

During the crop years of 1986, 1987, and 1988 the Hockley County Soil Conservation Service conducted tests indicating an average increase of 21.84 percent in cotton lint yields by using LEPA. Similar increases due to LEPA have been documented for soybeans by Lyle and Bordovsky, 1983. Thus, using 21.84 percent as an estimate of the expected cotton yield increases obtained by LEPA, the expected lint yields in this study would be 1.657 bales (828.5 lbs.) per acre.

Assuming a price of $0.60/lb. for cotton lint, the increase in cotton lint yield would provide an additional $89.10 per acre for an increase in annual total gross revenue to land, overhead, risk, and management of $12,391.13 over that obtained with the low pressure sprinkler irrigation system. Adjusting this value for the additional LEPA labor and maintenance costs of $249.10, results in a total gross return increase of $12,142.03 (Table 2).

Table 2. Partial Budget Comparing the Low Pressure Sprinkler (LPS) to the Low Energy Precision Application (LEPA) System, Hockley County, Texas, 1989.

System	Yield (lbs./A.)	Operating Cost (OC)	Total Gross Revenue(TGR)	TGR - OC	Change in TGR - OC
LPS	680.0	$7,994.58	$56,740.56[a]	$48,745.98	
LEPA	828.5	$8,243.68[b]	$69,131.69	$60,888.01	$12,142.03

[a] Assumes a $0.60/lb. cotton lint price. Obtained as the product of number of acres in the circle (139.07), cotton lint yield (680), and per pound cotton lint price ($0.60).

[b] Includes the additional labor and maintenance cost of $249.10.

Agricultural producers must consider lint price variability in their decision to convert low-pressure sprinkler systems to LEPA. Thus, alternative cotton lint price scenarios may be used to evaluate the additional annual gross revenue generated by the adoption of LEPA. Furthermore, because the conversion of the center pivot from low pressure sprinkler to LEPA is an investment, the economic feasibility of the investment must be evaluated through time.

Table 3 depicts the increases in total gross revenues across alternative cotton price scenarios ranging from $0.35/lb. to $0.75/lb. Once the expected increases in cotton yields associated with the conversion from low pressure sprinkler to LEPA is considered, it can be seen that nominal total gross return annual increases range from $6,979.06 to $15,239.82, depend-

Table 3. Increases in Total Gross Returns Across Alternative Cotton Price Scenarios Due to LEPA's Increased Water Application Efficiency in Cotton Production, Hockley County, Texas.

(1) Cotton Price ($/lb.)	(2) Nominal Annual Increase ($)	(3) Present Value of Increases ($)	(4) Cost of LEPA ($)	(5) Net Present Value of Investment (3)-(4)	(6) Benefit Cost Ratio (3)/(4)
0.35	6,979.06	50,576.49	7,839.94	42,736.55	6.45
0.37	7,392.10	53,569.73	7,839.94	45,729.79	6.83
0.39	7,805.14	56,562.97	7,839.94	48,723.03	7.21
0.41	8,218.18	59,556.21	7,839.94	51,716.27	7.60
0.43	8,631.21	62,549.45	7,839.94	54,709.51	7.98
0.45	9,044.25	65,542.69	7,839.94	57,702.75	8.36
0.47	9,457.29	68,535.93	7,839.94	60,695.99	8.74
0.49	9,870.33	71,529.16	7,839.94	63,689.22	9.12
0.51	10,283.37	74,522.40	7,839.94	66,682.46	9.51
0.53	10,696.40	77,515.64	7,839.94	69,675.70	9.89
0.55	11,109.44	80,508.88	7,839.94	72,668.94	10.27
0.57	11,522.48	83,502.12	7,839.94	75,662.18	10.65
0.59	11,935.52	86,495.36	7,839.94	78,655.42	11.03
0.61	12,348.56	89,488.60	7,839.94	81,648.66	11.41
0.63	12,761.59	92,481.84	7,839.94	84,641.90	11.80
0.65	13,174.63	95,475.08	7,839.94	87,635.14	12.18
0.67	13,587.67	98,468.32	7,839.94	90,628.38	12.56
0.69	14,000.71	101,461.50	7,839.94	93,621.62	12.94
0.71	14,413.75	104,454.70	7,839.94	96,614.86	13.32
0.73	14,826.78	107,448.00	7,839.94	99,608.10	13.71
0.75	15,239.82	110,441.20	7,839.94	102,601.30	14.09

ing on the cotton price level. If the life span of the conversion of the irrigation system is ten years, and an 8 percent discount rate is used, the associated present value of the increases of gross returns from the conversion ranges from $50,576.49 to $110,441.20 over this ten year period. Taking into consideration the LEPA conversion cost the associated net present value of returns associated with the irrigation system conversion would range from $42,736.55 to $102,601.30.

Another indicator of the economic feasibility of the conversion of the irrigation system is given by the benefit-cost ratio which ranges from 6.45 to 14.09 (Table 3). For example, for a $0.45/lb. cotton price the benefit cost ratio is 8.36. This implies that benefits are 8.36 times the cost, or that for every $1.00 of investment, benefits would equal $8.36. Furthermore, careful examination of the information in Table 3 reveals, that the pay-back period of the investment would be less than one year for all cotton price scenarios with the exception of the $0.35/lb. and $0.37/lb., in which it would be a little longer than one year. In other words, the conversion of the center pivot low pressure sprinkler to LEPA system would pay for itself in less than one year in most of the cotton price scenarios analyzed. Considering that cotton prices in the SHPT during the last fifteen years have varied from $0.46/lb. in 1975 to $0.69 in 1980 (Texas Department of Agriculture), the economic feasibility of the irrigation system conversion is established.

CONCLUSION

The primary objective of this study was to determine the farm-level economic feasibility of converting a 1,389 foot long center pivot low pressure sprinkler irrigation system to a LEPA irrigation system for cotton production in the SHPT. Because of increased water application efficiency obtained with LEPA, the conversion would be economically feasible. Some drawbacks are associated with the use of LEPA, such as increased concern for row spacing, increased maintenance costs, and increased labor requirements. Nevertheless, LEPA is a viable option to farmers in the SHPT because the benefits from its use outweigh the costs.

Few LEPA systems are currently in use in the SHPT. Widespread adoption of LEPA in the SHPT would improve agricultural water use efficiency.

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RELATIONSHIPS AMONG PROTEIN SUPPLEMENTATION, SELECTED BLOOD CONSTITUTENTS, AND PERFORMANCE OF GRAZING STEERS

John S. Pitts, Ted McCollum and Carlton M. Britton[1]

ABSTRACT

Beef steers grazing tobosagrass (Hilaria mutica [Buckl.] Benth.) range in western Texas were allocated to 3 groups (10 head/group) and fed either 0.00, 0.75, or 1.50 lb/hd/day of cottonseed meal each year of a 2-year study. Steer weights and samples of blood were collected at 21-day intervals beginning in April and ending in July to evaluate relationships among plane of nutrition, average daily gain (ADG), and selected blood components. Plasma was analyzed for glucose (GLU), non-esterified fatty acids (NEFA), thyroxine (T4), and triiodothyronine (T3). No consistent relationships were observed between supplement level and blood constituents. Serum GLU, T3, and T4 generally declined through each season as forage quality declined but did not closely reflect changes in daily gain of steers (r=0.04, -0.05, -0.01, respectively). Environmental factors may have had a greater effect on daily gain than diet quality and, therefore, precluded the development of any useful relationships among blood components and ADG.

INTRODUCTION

Monitoring the nutritional status of free-grazing animals by present methods is expensive and time consuming for researchers and virtually impossible for producers. Estimates of fecal output and diet digestibility are required for estimating forage intake. If these methods can be replaced by more efficient means of arriving at nutritional status, both researchers and producers would benefit.

Different blood constituents have potential for use as indicators of nutrient intake and nutritional status of ruminants. Several blood constituents have been related to energy intake. Plasma non-esterified fatty acids (NEFA) are expected to increase as energy intake decreases and adipose tissue is mobilized (Bowden and Hironaka 1975). This relationship has been observed in white-tailed deer (**Odocoileus virginianus**) (Seal et al. 1978), heifers, and cows (**Bos taurus**) (Russel and Wright 1983, Bowden 1971).

Bowden and Hironaka (1975) observed elevated levels of glucose (GLU) as the body condition of non-pregnant, non-lactating Angus and Hereford beef cows improved. Combinations of GLU and growth hormone have been positively correlated with weight gain in cows (Hart et al. 1979).

In studies with white-tailed deer, triiodothyronine (T3) was strongly related to energy intake, increasing from 304 to 394 ng/dl when dietary energy was increased from a low to a moderate level (Seal et al. 1978). Baccari et al. (1983) developed correlations between weight gain and T3 in Holstein heifers (r=0.91) indicating the T3 may reflect changes in weight gain in cattle. Relationships between growth rate and thyroxine (T4) have been observed in weaned sheep (Rhind et al. 1984).

The objectives of this study were to describe the relationships among plane of nutrition (level of supplementation) and blood constituents, and to determine if these blood constituents could be used to predict weight change in grazing steers.

MATERIALS AND METHODS

Study Area

This study was conducted at the Texas Tech Experimental Ranch in Garza County, Texas. The area is dominated by a clay flat range site with gently sloping clay soils (fine, montmorillonitic, thermic Typic Chromusterts). Tobosagrass (**Hilaria mutica** [Buckl.] Benth.) is the dominant forage. Soil depressions contain alkali sacaton (**Sporobolus airoides** [Torr.] Torr.) and the more upland areas produce buffalograss (**Buchloe dactyloides** [Nutt.] Engelm.). Average yearly forage production, in excellent condition, is 1500 lb/ac (Richardson et al. 1965).

The climate is warm, temperate, and subtropical with dry winters. Average rainfall is 19 in. (Fig. 1) occurring mainly from May to October from convective thunderstorms. Drought is common. Average length of the growing season is 216 days. Mean elevation is 2600 ft (Richardson et al. 1965).

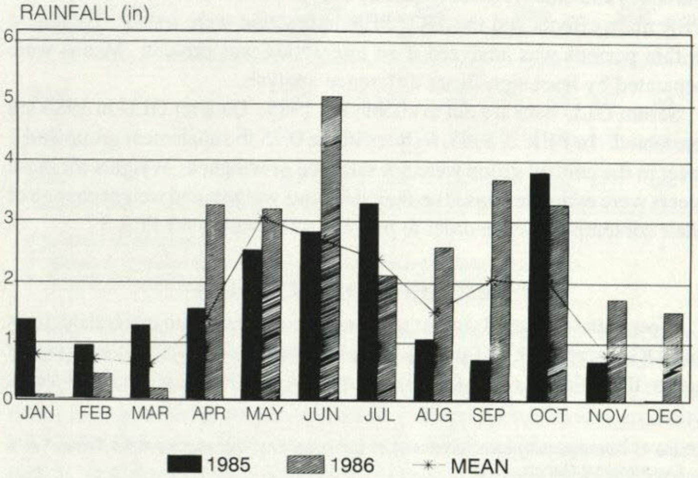

Figure: Monthly precipitation at the Texas Tech Experimental Ranch for 1985 and 1986 with the long term mean for Post, Texas.

Field Trials

Three herds, grazing 6-pasture grazing cells, were fed 1 of 3 rates of protein supplement (0.00, 0.75, or 1.50 lb/hd/day of cottonseed meal). Prorated amounts were fed 3 times per week in community troughs. Cell areas were 168, 225, and 235 ac. Stocking rate was based on forage production so that forage allowance/hd/day was similar in all three cells. Steers were rotated through the cells on 42-day cycles with length of stay in each pasture from 4-10 days.

Each cell was stocked in March each year with 27 to 57 crossbred steers (**Bos taurus x Bos indicus**) weighing 450-550 lbs. Steers were allowed to adjust to the grazing system and the 3-day feeding routine before trials began in April. In early to mid April, all steers were weighed after overnight fasting from food and water. This routine was repeated at 21 day intervals until July. In 1985, cattle were weighed on 23 April, 14 May (PER 1), 4 June (PER 2), 2 July (PER 3), and 23 July (PER 4). Steers were initially weighed on 7 April in 1986 and subsequently weighed on 28 April (PER 1), 19 May (PER 2), 9 June (PER 3), and 30 June (PER 4).

Ten steers from each treatment group were randomly selected for blood sampling before grazing started. Steers were selected from the middle weight class of the herd with a range of 50 lb. At 0700 h the evening before weighing, the 30 steers were sorted from the main herd to facilitate sampling and minimize excitement of the animals prior to sampling. Blood samples were taken and weights recorded between 0700 and 0800 hours the following morning. Two 10-ml blood samples were drawn from each steer via jugular puncture.

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Blood samples were immediately placed in ice and refrigerated overnight to allow the samples to coagulate. The following morning, samples were centrifuged at 3000 rpm for 10 min and the serum was extracted and frozen.

Laboratory Analyses

Serum T3 and T4 were determined by radioimmunoassay (T3 Set TKC31 and T4 Set TKT41, Diagnostic Products Corporation, Los Angeles, CA). Serum glucose concentration was analyzed colorimetrically using glucose oxidase (Glucose Set 510, Sigma Diagnostics, St. Louis, MO). Non-esterified fatty acids were determined by a colorimetric procedure (NEFA C Set 990-75401, Wako Pure Chemical Industries, Ltd., Osaka, Japan).

Statistical Analysis

Data were initially analyzed with treatment (TRT) and period (PER) as main effects and year as a repeated measure. Model components were TRT, PER, TRT*PER, YEAR, YEAR*TRT, YEAR*PER, and YEAR*TRT*PER. The YEAR*TRT interaction was significant for most variables and data were subsequently analyzed within year. Treatment and PER main effects and the TRT*PER interaction were tested. Treatment within periods was analyzed if an interaction was present. Means were separated by least significant difference analysis.

Serum GLU data are not available for 1985. Data for GLU in 1986 are presented. In PER 2, 1985, 6 steers in the 0.75 lb supplement group and 1 steer in the control group were not sampled or weighed. Weights for these steers were estimated based on their pervious weights and weight change of their contemporaries in order to provide ADG values for PER 3.

RESULTS AND DISCUSSION

Steer gains followed similar patterns in both years with marked declines in ADG during PER 3 (Table 1). Supplemented steers generally had greater gains than the control (CON) group except at PER 3 when CON steers outgained high supplement (HS) and low supplement (LS) steers (P<0.05). Period 3 coincided with the greatest amount of precipitation. Precipitation may have reduced grazing time or possibly increased cold stress. Traveling to and from feeding grounds through clay mud may have increased energy expenditure. Average daily gain for 1985 and 1986 for all groups was 1.3 lb and 1.4 lb, respectively.

Table 1. Average daily gain (lb/hd/day) of steers grazing tobosagrass at the Texas Tech Experimental Ranch.

1985								
Cottonseed meal (lb/hd/day)	4/23 to 5/14 Mean	SD	5/14 to 6/04 Mean	SD	6/04 to 7/02 Mean	SD	7/02 to 7/23 Mean	SD
0.00[1]	0.84^{b}	0.84	1.71	0.42	1.03	0.48	0.86^{b}	0.60
0.75	1.73^{a}	0.75	1.84	0.81	0.65	0.51	0.87^{b}	0.52
1.50	1.69^{a}	0.68	2.08	0.41	0.62	0.69	1.79^{a}	0.79
1986								
Cottonseed meal (lb/hd/day)	4/07 to 4/28 Mean	SD	4/28 to 5/19 Mean	SD	5/19 to 6/09 Mean	SD	6/09 to 6/30 Mean	SD
0.00	1.59	0.58	2.02	0.73	0.07^{a}	0.53	1.66	0.35
0.75	2.00	0.43	1.88	0.57	-0.95^{b}	0.53	2.15	0.66
1.50	1.87	0.40	2.80	0.42	-0.54^{b}	0.56	2.17	0.54

[1] N=10 for all treatments.
[a] Means in a column followed by a different letter are different (P<0.05).

Relationships between supplement level and NEFA were not consistent between years (Table 2). Serum NEFA tended to be greater in the HS group in 1985 compared to the other groups (P=0.11) but no difference was observed between the HS and CON group in 1986. The HS and CON groups had greater NEFA than the LS group in 1986 (P<0.01). In both years NEFA increased (P<0.05) through the season as forage quality declined.

Table 2. Serum non-esterified fatty acid (mE/l) level in steers grazing tobosagrass at the Texas Tech Experimental Ranch.

1985										
Cottonseed meal (lb/hd/day)	5/14 Mean	SD	6/04 Mean	SD	7/02 Mean	SD	7/23 Mean	SD		
0.00[1]	0.7	0.2	0.4	0.2	0.7	0.4	0.7	0.3		
0.75	0.8	0.3	0.4	0.1	0.6	0.2	0.6	0.2		
1.50	0.6	0.2	0.6	0.3	0.8	0.2	1.0	0.4		
MEAN	0.7^{x}	0.3	0.5^{y}	0.2	0.7^{x}	0.3	0.8^{x}	0.3		
1986										
Cottonseed meal (lb/hd/day)	4/28 Mean	SD	5/19 Mean	SD	6/09 Mean	SD	6/30 Mean	SD	MEAN Mean	SD
0.00	0.7	0.3	0.7	0.4	0.7	0.2	0.9	0.3	0.7^{a}	0.3
0.75	0.5	0.2	0.3	0.1	0.6	0.1	0.7	0.3	0.5^{b}	0.2
1.50	0.8	0.3	0.6	0.3	0.8	0.2	0.7	0.3	0.7^{a}	0.3
MEAN	0.7^{x}	0.3	0.5^{y}	0.3	0.7^{x}	0.2	0.7^{x}	0.3		

[1] N=10 for all treatments.
[x,y] Means in a row followed by a different letter are different (P<0.05).
[a,b] Means in a column followed by a different letter are different (P<0.05).

No relationship was observed between NEFA and ADG in any period of the study (Table 3). Values for NEFA remained between 0.44 and 0.98 mE/l during both years and did not follow any consistent pattern. The

Table 3. Correlation coefficients for weight gain and blood constituents of steers grazing tobosagrass at the Texas Tech Experimental Ranch, 1985 and 1986.

	Average Daily Gain			
	PER 1[1]	PER 2	PER 3	PER 4
NEFA[2]	0.03	0.04	0.15	0.01
GLU[3]	0.25	0.21	-0.73*	0.43*
T3[4]	-0.05	0.07	-0.52*	0.38*
T4[5]	-0.03	0.20	0.41*	-0.43*

[1] PER=period, 21-day intervals beginning 23 April, 1985, and 7 April, 1986.
[2] NEFA=serum non-esterified fatty acids.
[3] GLU= serum glucose.
[4] T3=serum triiodothyronine.
[5] T4=serum thyroxine.
* Significant (P<0.05).

lack of relationship between NEFA, plane of nutrition, and growth may be partly due to excitation of the steers during collection which may have caused temporary elevated levels of NEFA (Bowden 1971). Because steers were gaining weight throughout each year (with the exception of the supplemented groups in PER 3, 1986) NEFA concentration would be expected to remain low (Russel and Wright 1983, Bowden and Hironaka 1975). Weight loss by the supplemented groups in PER 3 of 1986 was not reflected by elevated NEFA levels. This suggests that weight loss was a function of reduced gut fill rather than actual mobilization of body tissue. Although NEFA concentration has shown some potential for determining nutritional status of lactating cows with high energy demand (Russel and Wright 1983, Bowden 1971), current results indicate that NEFA level has little value in prediction of ADG in growing steers. A similar conclusion was drawn by Warren et al. (1982) with growing fawns. GLU declined seasonally for all treatments ($P<0.01$; Table 4). Serum GLU was positively correlated with ADG in PER 1 and PER 4, and negatively correlated in PER 3 when ADG was negative (Table 3).

Differences in GLU did not occur among treatments (Table 4). This response differs from Richardson (1984) where GLU concentration was elevated by reducing the protein-to-energy ratio in the diet. The negative response to reduced gain in PER 3 would indicate that GLU may be related to diet quality rather than total dietary intake since gains, and likely forage intake, dropped during this period with only a slight decline in forage quality and GLU. Richardson (1984) found elevated GLU with increased level of intake. In agreement with Richardson (1984), it appears that GLU is not useful in determining nutritional status of grazing animals.

Table 4. Serum glucose levels (mg/dl) in steers grazing tobosagrass at the Texas Tech Experimental Ranch in 1986.

Cottonseed meal (lb/hd/day)	4/28		5/19		6/09		6/30	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0.00[1]	70.3	7.5	65.7	6.4	60.2	4.7	55.2	10.5
0.75	71.4	8.2	67.7	6.9	59.4	12.9	54.3	7.8
1.50	67.5	17.3	66.7	11.5	58.4	11.6	55.9	13.4
MEAN	69.7^{x}	11.6	66.7^{x}	8.3	59.3^{y}	10.0	55.1^{y}	10.5

[1] N=10 for all treatments.
^{x,y} Means in a row followed by a different letter are different ($P<0.05$).

Table 5. Serum triiodothyronine (ng/dl) levels in steers grazing tobosagrass at the Texas Tech Experimental Ranch.

1985								
Cottonseed meal (lb/hd/day)	5/14		6/04		7/02		7/23	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0.00[1]	93^{b}	63	112	43	63^{b}	34	58	24
0.75	84^{b}	35	74	34	88^{ab}	26	85	36
1.50	134^{a}	46	83	32	115^{a}	56	83	25
1986								
Cottonseed meal (lb/hd/day)	4/28		5/19		6/09		6/30	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0.00	93^{b}	25	128	30	118^{b}	24	88^{b}	10
0.75	123^{a}	25	144	20	150^{a}	38	131^{b}	35
1.50	126^{a}	21	146	22	150^{a}	15	162^{a}	22

[1] N=10 for all treatments.
^{a,b} Means in a column followed by a different letter are different ($P<0.05$).

Table 6. Serum thyroxine (ug/dl) levels in steers grazing tobosagrass at the Texas Tech Experimental Ranch.

1985										
Cottonseed meal (lb/hd/day)	5/14		6/04		7/02		7/23		MEAN	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0.00[1]	4.2	0.5	4.7	0.7	4.7	0.8	4.6	0.8	4.5^{b}	0.7
0.75	5.4	1.6	5.0	2.0	6.0	1.7	4.7	1.3	5.4^{a}	1.6
1.50	5.0	1.0	5.1	1.4	6.2	1.0	5.5	0.7	5.5^{a}	1.1
MEAN	4.9^{y}	1.2	4.9^{y}	1.2	5.6^{x}	1.4	4.9^{y}	1.0		
1986										
Cottonseed meal (lb/hd/day)			4/28		5/19		6/09		6/30	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD
0.00			4.7^{b}	0.8	3.6^{b}	0.9	4.2^{a}	0.6	3.2^{a}	0.6
0.75			4.7^{b}	0.8	1.8^{c}	0.6	2.4^{b}	0.8	1.3^{b}	0.5
1.50			5.7^{a}	1.1	5.6^{a}	1.3	3.6^{a}	1.5	2.1^{b}	0.6

[1] N=10 for all treatments.
^{a,b} Means in a column followed by a different letter are different ($P<0.05$).
^{a,y} Means in a row followed by a different letter are different ($P<0.05$).

Serum T3 levels tended to be greatest for the HS group during 1985. In 1986, HS and LS steers had higher T3 levels ($P<0.05$) during most of the grazing season (Table 5). The HS and LS groups had greater T4 levels ($P<0.01$) than the CON steers in 1985, HS and CON steers tended to have greater T4 in 1986 (Table 6). Correlations of thyroid hormones to ADG were also inconsistent with positive correlations observed between T3 and ADG at PER 4, and negative correlation at PER 3 (Table 3). Serum T4 was inversely related to ADG at PER 4, and positively related at PER 3. Kahl et al. (1977) found relationships between increased rate of gain and increased T3 and T4 levels. In this study, serum T3 more closely reflected treatment and weight gain than T4 which differs from Kahl et al. (1977). Baccari et al. (1983) showed strong correlations ($r=0.91$) between T3 and weight gain in heifers which would more closely agree with our study.

Supplementation did not consistently affect any of the blood variables. Forage crude protein remained above 6.5% throughout this study (Pitts 1989) and steers were probably able to select diets adequate in crude protein. This would explain the lack of response in ADG among treatments and would probably account for the lack of significant effects of supplementation on the measured blood constituents.

Inconsistencies in the relationships between blood constituents and ADG among periods were evident. Serum T3 and T4 exhibited a random relationship to ADG and NEFA was nonsignificantly related to ADG during all periods. Serum GLU appeared to parallel declining forage quality irrespective of steer performance. Inconsistencies in the relationships among blood components and ADG indicate that other factors were involved that could not be associated with relationships among blood constituents and performance.

Relationships between blood constituents and declining dietary quality were observed, however, no consistent relationship was evident among the blood parameters and animal gains. Predictive equations were developed by period but coefficients of determination were less than 0.48 and error of the predictions was over 0.22. The lack of similarity in response among different periods may reflect environmental changes and forage quality changes as well as inherent changes resulting from steer maturation. Trends observed in this study between blood constituents and diet quality would warrant further investigation into this relationship. A performance response to supplementation may be observed during periods of drought and during late summer and winter months. Separation of performance among supplemented groups of steers should provide better relationships between the observed blood constituents and ADG.

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AN ANALYSIS OF RECREATION EXPENDITURES BY U.S. CONSUMERS, 1939 - 1988

James W. Kitchen[1] and Paul D. Hutchison[2]

ABSTRACT

This empirical study examines the increases in average recreation expenditures during the period 1939 to 1988 to determine if consumers are spending more "real" dollars, of their personal consumption expenditures, on recreation. The analysis seeks to examine the reasons for these increases, and reviews trends in the twelve classifications of recreation. Finally, a validated recreation expenditures model is used to project future recreation expenditures.

Key Words: consumer recreation expenditures, disposable personal income (DPI), personal consumption expenditures (PCE), recreation classifications, recreation expenditures model.

INTRODUCTION

Since the earliest recorded civilizations, man has always had some degree of unobligated time. Historians describe countless forms of recreational pursuits which have been used to fill leisure hours, particularly by the wealthy and influential social classes of each era. It has only been within the past century, among the more highly industrialized nations, that both leisure and economic growth have made it possible for recreation to be widely available to all social classes (Kitchen, Miller and Graves, 1982).

Today's American has approximately twenty-five more free hours per week than did the citizen of 100 years ago (Barach, 1964). Use of this increased leisure time is a challenge, and it would be reasonable to assume that some of it might be spent in some form of recreation (Kitchen and James, 1970).

The purpose of this study was to determine if Americans are spending a greater percentage of their income on recreation, or if the increased spending on recreational pursuits is due to larger incomes from the rapid growth of the United States (U.S.) economy? Additionally, perhaps, the increase in expenditures upon recreation may only be the result of a much larger population spending at approximately the same per capita rate. All of these possible solutions were examined in an attempt to determine the source of the increasing sums being spent upon recreation (Kitchen and James, 1970).

Projections were made of future expenditures upon recreation assuming current trends continue. These projections will provide a tentative base for planning of facilities and services to meet the future recreational needs of the population.

METHODOLOGY

The first step in an analysis of consumer expenditures on recreation is to gather the most reliable data. The Economic Report of the President, 1989, yielded figures for Disposable Personal Income (DPI) and Personal Consumption Expenditures (PCE). U.S. Department of Commerce Publications (July 1989, 1989) provided data for twelve classifications and three sub-categories of recreation expenditures, and total consumer expenditures on recreation. Each classification and sub-category of recreation expenditures is designated by the U.S. Department of Commerce as either a durable good, non-durable good, or a service (See Table 1).

TABLE 1. U.S. Department of Commerce classifications of recreation expenditures

CLASSIFICATION	DESIGNATION
1 Books and Maps	Durable
2 Magazines, Newspapers, and Sheet Music	Non-Durable
3 Non-Durable Toys and Sport Supplies	Non-Durable
4 Wheel Goods, Durable Toys, Sports Equipment, Boats, and Pleasure Aircraft	Durable
5 Radio and TV Receivers, Records, and Musical Instruments	Durable
6 Radio and TV Repair	Service
7 Flowers, Seeds, and Potted Plants	Non-Durable
8 Admissions to Specified Spectator Amusements	Service
8a Motion Picture Theaters	Service
8b Legitimate Theaters and Opera, and Entertainments of Non-Profit Institutions	Service
8c Spectator Sports	Service
9 Clubs and Fraternal Organizations Except Insurance	Service
10 Commercial Participant Amusements	Service
11 Pari-Mutuel Net Receipts	Service
12 Other	Service

Dollar amounts, from the U.S. Department of Commerce (July 1989, 1989), are listed in terms of current dollars for each year, and therefore include inflationary effects and price changes over time. To remove inflationary effects and express the data in "real" terms, each classification and category was inflated or deflated by using the implicit price deflator (1982 = 100). Implicit price deflators for each year were acquired from the Economic Report of the President, 1989.

From these data and a regression analysis, a prediction model of consumer expenditures on recreation was developed. The model has been validated (Kitchen, et al., 1982; Kitchen and Hutchison, 1990) over a twenty-year period.

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RESULTS

Five-year average consumer recreation expenditures from 1939 to 1988 are presented in billions (1982 dollars) in Table 2. From 1939 to 1988 total recreation expenditures increased by $154.386 billion (+583%).

TABLE 2. Average annual consumer expenditures on recreation by recreation expenditure classification, 1939-1988 (in billions, 1982 dollars).

YEARS	TOTAL	BOOKS AND MAPS (1)	MAGAZINES AND NEWSPAPERS (2)	NONDURABLE TOYS AND SPORTS (3)	WHEEL GOODS & DURABLE TOYS (4)	RADIO & TV RECEIVERS (5)	RADIO & TV REPAIR (6)	FLOWERS, SEEDS & PLANTS (7)
1939-43	26.488	1.308	4.011	2.122	1.320	2.467	0.291	1.376
1944-48	34.793	1.696	4.488	3.053	2.073	2.726	0.657	1.627
1949-53	40.056	1.881	5.447	5.186	2.386	5.737	1.473	1.687
1954-58	45.483	2.239	6.200	6.151	3.715	6.872	2.141	1.789
1959-63	53.649	2.720	6.618	8.061	4.489	7.178	2.651	2.305
1964-68	74.195	3.726	8.080	10.887	7.403	12.447	2.862	3.741
1969-73	95.755	5.221	9.645	13.525	11.555	17.065	3.381	4.413
1974-78	112.731	6.045	9.663	14.602	15.900	22.337	4.032	5.210
1979-83	135.451	6.788	11.260	16.663	19.445	24.435	3.151	4.757
1984-88	180.874	8.206	12.943	21.515	28.400	37.253	2.747	5.448

YEARS	ADMISSION SPECTATOR EVENTS (8)	MOTION PICTURE THEATERS (8a)	LEGITIMATE THEATER (8b)	SPECTATOR SPORTS (8c)	CLUBS ETC. (9)	COMMERCIAL PARTICIPANT AMUSEMENT (10)	PARI-MUTUEL RECEIPTS (11)	OTHER (12)
1939-43	7.770	6.486	0.612	0.672	1.501	1.485	0.447	2.390
1944-48	10.521	8.633	0.942	0.946	1.919	1.949	1.163	2.921
1949-53	7.786	5.935	0.841	1.010	2.159	2.105	1.244	2.965
1954-58	6.413	4.551	0.980	0.882	2.282	2.488	1.531	3.662
1959-63	5.521	3.098	1.101	1.322	2.467	4.324	1.919	5.396
1964-68	6.672	3.227	1.247	2.198	2.697	5.238	2.473	7.969
1969-73	7.725	3.715	1.197	2.813	2.956	5.523	2.789	11.957
1974-78	7.227	3.256	1.312	2.659	2.881	6.668	2.728	15.438
1979-83	7.788	3.306	2.058	2.424	3.550	11.344	2.315	23.955
1984-88	8.532	3.266	2.831	2.435	4.183	13.211	2.174	36.262

Since 1939, several classifications realized significant increases. Wheel goods and durable toys increased $27.08 billion (+2,052%), and radio and TV receivers increased $34.786 billion (+1,410%). The only decrease was in the sub-category of motion picture theaters which declined $3.22 billion (-50%).

As shown in Table 3, average Disposable Personal Income (DPI), in billions (1982 dollars) increased from $609.7 billion in 1939 to $2,623.0 billion in 1988 (+330%). Average Personal Consumption Expenditures (PCE) also increased, from $516.3 billion in 1939 to $2,432.2 billion in 1988 (+371%).

An increase in total recreation expenditures is also apparent from average per capita recreation expenditure data (Table 4). Per capita, DPI increased from $4,554 in 1939 to $10,839 in 1988 (+138%). From 1939 to 1988 average per capita recreation expenditures increased from $198 to $747 (+277%).

TABLE 3. Average annual disposable personal income and personal consumption expenditures 1939-1988 (in billions, 1982 dollars).

YEARS	DISPOSABLE PERSONAL INCOME	PERSONAL CONSUMPTION EXPENDITURES	PCE AS A PERCENT OF DPI
1939-43	$ 609.7	$ 516.3	84.68%
1944-48	728.0	630.6	86.62%
1949-53	813.7	750.2	92.20%
1954-58	973.8	889.8	91.37%
1959-63	1,131.8	1,037.4	91.66%
1964-68	1,426.5	1,289.9	90.42%
1969-73	1,742.0	1,559.8	89.54%
1974-78	2,012.7	1,806.9	89.77%
1979-83	2,253.8	2,045.1	90.74%
1984-88	2,623.0	2,432.2	92.73%

TABLE 4. Average annual per capita disposable personal income and consumer expenditures on recreation 1939-1988 (1982 dollars).

YEARS	POPULATION (MILLIONS)	PER CAPITA (DPI)	PER CAPITA RECREATION EXPENDITURE
1939-43	134	$ 4,554	$198
1944-48	142	5,127	245
1949-53	154	5,284	260
1954-58	168	5,796	270
1959-63	184	6,151	292
1964-68	197	7,241	377
1969-73	208	8,375	460
1974-78	218	9,233	517
1979-83	230	9,799	589
1984-88	242	10,839	747

Figure 1 graphically illustrates the movement in consumer expenditures on recreation from 1939 to 1988. This figure shows average actual recreation expenditures and projected recreation expenditures (1982 dollars) to the year 2003 (Kitchen and Hutchison, 1990).

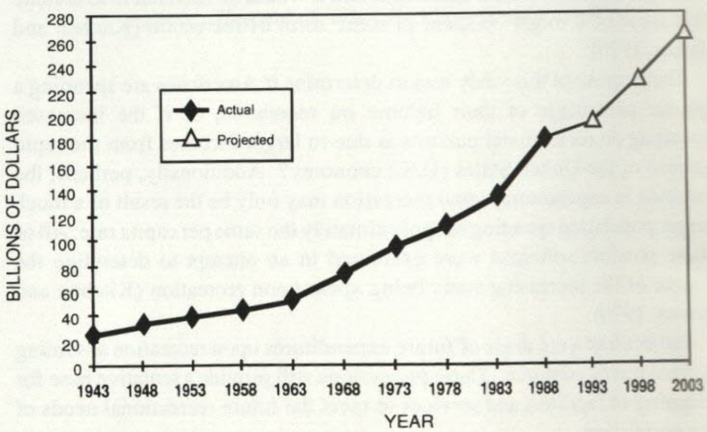

Figure 1. Consumer expenditures on recreation, 5-year averages (1982 dollars).

Further analysis of consumer spending showed that in 1939-43 consumers were spending $4.35 of each $100 of DPI on recreational pursuits as compared to $6.89 in 1984-88. Although an increase of $2.54 of each $100 of DPI on recreation expenditures over the past fifty years may not appear significant, it represents an increase of 58.4% for recreation expenditures relative to DPI.

Additionally, from 1939 to 1988 while consumers' PCE remained relatively stable as a percentage of DPI, recreation expenditures also increased as a percent of PCE. In 1939-43, consumers were spending $5.14 of each $100 of PCE on recreation as compared to $7.43 of each $100 of PCE on recreation in 1984-88. This is an increase of 44.5% ($2.29) relative to PCE over the fifty-year period.

Projections of expenditures on recreation were made using a model based on annual expenditures from 1939 to 1988 (Kitchen and James, 1970; Kitchen, et al., 1982; Kitchen and Hutchison, 1990). The model assumes that recreation expenditures, as all consumption expenditures, depend primarily upon money available for a family to spend, Disposable Personal Income (DPI). Linear regression analysis using DPI and total recreation expenditures for the years 1939 to 1988 (1982 dollars) was used to determine coefficients for Y = a + bX with DPI as the independent variable.

TABLE 5. Estimated annual consumer expenditures on recreation: for 1989-2003 (in billions, 1982 dollars).

1989	$181.1
1990	187.1
1991	193.3
1992	199.6
1993	206.2
1994	212.9
1995	219.8
1996	227.0
1997	234.3
1998	241.9
1999	249.7
2000	257.7
2001	266.0
2002	274.5
2003	283.2

Previous projections developed by the model have proved to be very accurate (+/- 5%).

To use the model for predicting future recreation expenditures, an estimation of future DPI is needed. Examination of DPI trends for 50 years showed an average annual increase of 3.65%, while DPI trends for the most recent 20 years showed an average annual increase of 2.97%.

The recreation expenditures model (Y = -20.595 + 0.070587X) and projections of DPI with an annual increase of 2.97% were used to make annual projections of consumer expenditures on recreation (Table 5).

CONCLUSIONS

It is apparent that increases in spending on recreation have resulted primarily from increases in DPI. In constant 1982 dollars, average DPI has risen from $609.7 billion in 1939-43 to $2,623.0 billion in 1984-88. Concurrently, increased available leisure time has promoted a shift in the make up of the Personal Consumption Expenditure dollar. This shift from other personal consumption forms of expenditures to recreation has been a gradual process. All indications seem to point to the fact that increasing sums of money will continue to be spent on recreational items.

There have been notable shifts in expenditure patterns within the recreation market itself over the past fifty-year period (Table 2). Between the years 1939-1988, three categories (4, 5, 12) exhibited major increases as a percent of total recreation expenditures; and, three categories (2, 8, 9) showed a major decline. From 1969-1988, the shift within the recreation market itself seemed to indicate a trend towards investment in more expensive and durable commodities. Recreational items which served the person at home or close to home were increasing. Conversely, the service-type items in general were decreasing. Perhaps, this was directly related to the cost of fuel required to attend these types of activities, and the increased cost of the activity itself.

Projections, based on regression analysis, indicate that consumers will continue to spend increased sums of money on recreation. No accurate predictions can be made concerning shifts in expenditures within the recreation sector itself. These shifts will depend upon consumer preference which may be influenced by the introduction of new products or services.

In its simplest form, the combination of increased leisure time and increased DPI point to an ever-expanding leisure market. Consumer preferences and trends in the economy will decide how these increased sums of money will be spent within the recreation market in the future. Examples of specific impacts on traditional agriculture and natural resource management may include: land use changes from production agriculture or forestry to recreation; expanded activity in the horse industry from increased pari-mutual wagering and/or pleasure riding; and, the creation of alternative income sources for rural landowners from hunting or fishing activities.

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OCCUPATIONAL STATUS AND EDUCATIONAL NEEDS OF GRADUATES FROM THE COLLEGE OF AGRICULTURAL SCIENCES, TEXAS TECH UNIVERSITY, 1971-1986

Lewis Eggenberger and Marvin Cepica

ABSTRACT

The purposes of this study were to determine the occupational status of Texas Tech University (TTU) College of Agricultural Science graduates from 1971 to 1986 and to evaluate the graduates' perceptions of their academic undergraduate program.

A random sample of one-half the graduates who earned their degrees between 1971 and 1986 were mailed questionnaires. This yielded a sample of 1720 graduates. After one follow up mailing to nonrespondents, a total of 35.6% (612) of the graduates returned a questionnaire. A third mailing to nonrespondents consisted of a postcard to determine first job, current occupational status and the agricultural cluster that best described their occupation. This resulted in responses from 248 additional graduates. Consequently, the occupational status of 50.0% (860) of the graduates was determined.

Graduates (860) employed in agricultural occupations were categorized into six occupational clusters as described in the U.S.D.A. publication "Employment Opportunities for College Graduates in the Food and Agricultural Sciences." The percentages employed in each cluster at the time of this study were scientist, engineer or related specialist, 18.5%; manager or financial specialist, 20.3%; marketing, merchandising or sales representative, 12.8%; education, communication or information specialist, 13.6%; social service professional, 2.1%; and agricultural production specialist, 32.7%.

Graduates in agricultural occupations (612) indicated a need for increased emphasis in the following subject areas: computer instruction, 89.4%; leadership, 54.3%; internships, 51.1%; and international agriculture, 31.7%.

Two-thirds of the graduates in agricultural occupations indicated the following business subject areas as needing an increased emphasis: business management, accounting and bookkeeping, business finance, and marketing. Fifty-seven percent of the graduates recommended increased emphasis in oral communications and 48% believed instruction in written communications should be increased. One-fourth of the graduates thought instruction in mathematics and statistics should be increased.

INTRODUCTION

Through the years occupational requirements have changed. Therefore, university curricula must constantly change to keep pace with professional needs. To determine occupational status and assemble educational information in order to revise the curriculum requirements for future students, colleges of agricultural sciences should continually monitor their alumni. The objectives of this study were to: (1) determine the occupational status of Texas Tech University (TTU) College of Agricultural Science graduates from 1971 to 1986; (2) compare occupational information obtained from TTU graduates with data in "Employment Opportunities for College Graduates in the Food and Agricultural Sciences," a report of the United States Department of Agriculture (U.S.D.A., July, 1986 by Coulter, Stanton, and Goecker); (3) evaluate their perception of the academic undergraduate program in the College of Agricultural Sciences; and (4) obtain descriptive information such as salaries, future employment opportunities, and how graduates obtained information concerning their first and current jobs.

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Previous studies conducted by Cepica (1969), Townsend (1967), and Ward (1972) were reviewed to determine the methods, procedures, and recommendations concerning follow-up studies of college graduates. McKenna (1983) provided useful examples of how to survey alumni and procedures for implementing the survey. Coulter, et.al. (1986) projected expected employment opportunities for college graduates in the food and agricultural sciences through 1990.

METHODS

Data were secured through the mailing of a questionnaire to a random sample of Texas Tech University Agricultural Sciences graduates who earned their degree between the years 1971 and 1986. The questionnaire was developed by project directors and staff and was subsequently reviewed and revised based on suggestions from a graduate research class, College of Agricultural Sciences department chairpersons, and the college curriculum committee.

A letter of transmittal from the Dean of the College and the appropriate chairperson accompanied the questionnaire and defined the study. A stamped, addressed, return envelope was included in the mailing. Materials were mailed to 1720 randomly selected graduates. (Fifty percent of the graduates who earned their degree between 1971 and 1986.) A follow-up mailing was conducted which included the same questionnaire and another letter encouraging response. A total of 612 graduates (35.6%) responded to the questionnaire. To determine if those who did not respond were similar to the respondents, a postcard was mailed to the 1102 who did not respond to the first and second mailing of the questionnaire, requesting the graduates' first employment after leaving college, their present occupation, and the agriculture clusters which best described their occupation at the time of the study. The clusters listed were those used in Coulter, et. al. (1986). A total of 248 graduates (14.4%) returned the card.

RESULTS

Employment

A chi-square test considering the occupational categories of agriculture and non-agriculture revealed no statistically significant difference between the questionnaire respondents and those who returned the postcard (computed chi-square = 2.038, $p > .05$). Data obtained from the questionnaire and the postcard reveal that 66.5% of the graduates were employed in agricultural occupations at the_time of this study (Table 1).

TABLE 1. GRADUATES RESPONDING TO QUESTIONNAIRE AND POSTCARD BY CURRENT OCCUPATIONAL CATEGORY[a]

Occupational Graduates	Questionnaires		Postcard		Total	
Category	n	%	n	%	n	%
Agriculture	416	68.0	156	62.9	572	66.5
Non-Agriculture	196	32.0	92	37.1	288	33.5
Total	612	100.0	248	100.0	860	100.0

[a]Chi-square value =2.038. Table value at five percent level and one degree of freedom is 3.841. Not significant

TABLE 2. GRADUATES' OCCUPATIONAL CATEGORY IN FIRST OCCUPATION BY YEAR OF GRADUATION

Occupation Graduates	1971-75 n	1971-75 %	1976-80 n	1976-80 %	1981-86 n	1981-86 %	Total n	Total %
Agriculture	122	80.3	148	79.6	185	67.5	455	74.3
Non-Agriculture	30	19.7	38	20.4	89	32.5	157	25.7
Total	152	100.0	186	100.0	274	100.0	612	100.0

[a]Chi-square value =12.137**. Table value at one percent level and two degrees of freedom is 9.210. Significant

Fewer recent graduates (1981-1986) are employed in an agricultural occupation immediately upon graduation than graduates who completed their degree in 1971-1975 or 1976-1980 (Table 2). Approximately two-thirds of the 1981-1986 graduates entered an agricultural occupation upon graduation as compared to 80% of those who graduated between the years of 1971-75 and 1976-80. These differences were determined to be significant at the .01 level when the data were analyzed using chi-square.

The geographical location of graduates by occupational categories was determined using regions designated by the first three digits of the United States Postal Zip Code. Over 45% of the graduates in an agricultural occupation were located in the West Texas region. Over one-third (36.4%) of those in non-agricultural employment were also located in this region. The major cities in the West Texas region are Amarillo, Lubbock, Abilene, Midland, Odessa, and El Paso.

Employment by Occupation Cluster

Coulter, et. al. (1986) categorized employment opportunities into six major occupational areas as shown in Table 3. The occupational clusters were included in the questionnaire for graduates to classify themselves so that the present occupations of Texas Tech graduates in agricultural employment could be compared to the career opportunities projected in the U.S.D.A. publication. Each graduate selected the occupational cluster that represented his/her employment. Table 3 indicates the percent of expected employment opportunities for college graduates as projected by the U.S.D.A. Office of Higher Education and the percent of Texas Tech graduates who were presently employed in agriculture within the same agricultural occupation categories.

TABLE 3. PROJECTED EMPLOYMENT OPPORTUNITIES IN AGRICULTURE NATIONALLY BY EMPLOYMENT CLUSTERS COMPARED TO SURVEY RESPONDENTS IN AGRICULTURAL EMPLOYMENT

Cluster	Agricultural Annual Employment Opportunities[a] %	Texas Tech Graduates in Agricultural Employment[b] N	%
Scientist, Engineer or Related Specialist	29	106	18.5
Manager or Financial Specialist	14	116	20.3
Marketing, Merchandising or Sales Representative	32	73	12.8
Education, Communication or Information Specialist	6	78	13.6
Social Service Professional	11	12	2.1
Agricultural Production Specialist	8	187	32.7
Total	100	572	100.0

[a]Source: "Employment Opportunities for College Graduates in the Food and Agricultural Sciences," a publication prepared by Higher Education Programs, United States Department of Agriculture.

[b]Responses from questionnaire and postcard of those graduates in agricultural employment.

Traditionally a large percentage of TTU agriculture graduates enter farming and/or ranching due to the intensive agriculture production in West Texas. Consequently, more graduates (n=187, 32.7%) were presently employed in cluster six as agricultural production specialists. This is four times the expected future employment opportunities predicted by the U.S.D.A. publication. These graduates had entered areas of agricultural employment such as ranching, farming, grain/seed production and production of horticultural plant materials.

The percentage (13.6) of Texas Tech graduates who were employed as education, communication and information specialists, or in cluster four, was more than double the six percent of national opportunities forecast by the U.S.D.A. publication.

Employment and Income Expectations

Overall, agriculturally employed alumni were optimistic regarding opportunities for new graduates as they rated opportunities "good" with a mean value rating of 2.67 on a four point scale ("excellent" = 4, "good" = 3, "poor" = 2 and "none" = 1). The graduates in agricultural occupations rated cluster three, marketing, merchandising or sales representatives, as having the highest opportunity for the new graduate with a mean rating of 2.91. The lowest opportunity rating given by the graduates in agricultural occupations was for cluster six, agricultural production specialist, with a mean rating of 2.41 for the new graduate. The 305 respondents who reported their salaries, earned a median income of $27,000.

Graduates believed a need existed for additional advisement and assistance in obtaining their first employment. Only 10.1% of the graduates indicated they received information leading to employment from the University Career Planning and Placement Center.

Curricular Perceptions

Graduates were asked to evaluate various subject areas based on "educational needs met," "increase emphasis," "decrease emphasis" and "not needed."

Of the graduates who were in an agricultural occupation at the time of the survey, 89.4% indicated increased emphasis was needed in computer instruction and over 54% desired additional leadership instruction. This may be because graduates did not have the opportunity to complete a computer or leadership course when they earned their degrees. Fifty-one percent of the respondents also requested the internship program to be increased. Increased instruction in international agriculture was desired by 31.7% of the graduates.

Two-thirds of the graduates in an agricultural occupation indicated the following business areas as needing an increased emphasis: business management, 67.2%; accounting and bookkeeping, 66.0%; Business Finance, 65.1%; and Marketing, 65%.

Graduates also recommended increased emphasis concerning courses in communications. Fifty-seven percent of the graduates who were in an agricultural occupation believed additional instruction in oral communications was needed and 48% believed increased emphasis in written communications was needed. A need for increased emphasis in mathematics and statistics was expressed with 24.1% recommending increased emphasis in mathematics and 22.9% in statistics.

Music Appreciation and Visual Art Appreciation were indicated as not needed by 71.5% and 60.5% of the graduates respectively.

When asked the question, "Do you believe your B.S. degree adequately prepared you for your occupation," 71.2% of the graduates in agricultural occupations responded "yes" while 54.0% of the graduates in non-agricultural occupations replied "yes".

Concerning "general comments on your education", 53 respondents stated their college education was excellent and 151 stated it was good to very good. The other 408 graduates did not respond to this question.

Graduates had positive comments about their professors and indicated that the professors should be the strongest part of the department and should challenge students with subjects current to the present agricultural industry. One graduate stated, "The degree taught me to be adaptable to constant change in agriculture today."

CONCLUSIONS AND RECOMMENDATIONS

Graduates believed a need existed for additional advisement and assistance in obtaining their first employment. Also, they indicated an increased need for computer instruction, leadership courses, and internships. The administration and faculty of colleges of agricultural sciences should respond to the graduates perceptions.

College of Agriculture faculty should recognize that opportunities may exist for marketing, merchandising, and sales representatives as the projected need is considerably larger than the Texas Tech graduates who have employment in this cluster. Also, the faculty should be aware of the number of graduates who have become agricultural production specialists, as 32.6% were employed in agricultural production at the time of this study. Because of the intensive agricultural production in this area, a higher percentage of Texas Tech graduates may become agricultural production specialists than the eight percent predicted opportunities nationally.

College administrations and faculty should study the data pertaining to the graduates' opinion as to whether course areas should be increased or decreased and consider revising curricula accordingly. Special attention should be given to business, communications and certain agricultural courses.

Another concern among graduates was employment upon graduation. College faculty may want to determine why relatively few students used the University Career Planning and Placement Center.

Another reason the college must continually seek to improve advisement and placement of graduates is because the percentage of graduates in agricultural occupations is declining. Eighty percent of the 1971-1980 graduates and 67.5% of 1981-1986 graduates entered into agricultural occupation for first employment, resulting in a decline of 12.5% of graduates entering into agricultural occupations from the earlier years. Agriculture faculty should advise students into career clusters that have the largest opportunities for employment. Also, an individual within the Agriculture Colleges could be assigned the duty of coordinating a placement program.

At the time of this study, 45.2% of graduates were employed in the West Texas region. Implications were that to enhance employment potential, graduates entering agricultural occupations may need to be more willing to accept jobs throughout the United States.

Continuous systematic follow-up of graduates to develop relevant curriculum programs, efficient student advisement, and improved placement programs should be a priority of all College of Agriculture programs.

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THE IMPACT OF A GRAIN SORGHUM FUTURES MARKET ON HEDGING RISK FOR TEXAS GRAIN SORGHUM

Emmett Elam and John Smith[1]

ABSTRACT

During the 1970's, grain sorghum futures traded at the Chicago Mercantile Exchange and the Kansas City Board of Trade (KCBT). There was very little trading interest in either contract, however. In 1988, the KCBT revised its grain sorghum futures contract and initiated trading in the revised contract in May 1989.

Because a sorghum futures contract has not always been available in the past, corn futures have been widely used by elevators, feedlots, and farmers to hedge grain sorghum. However, basis risk in a cross hedge in corn futures is greater than in a direct sorghum futures hedge. This research estimates that hedging risk can be reduced 17-34 percent by hedging sorghum in the KCBT sorghum futures market compared to cross hedging sorghum in corn futures. This level of reduction in hedging risk should encourage the use of the KCBT sorghum futures market to hedge sorghum.

Key Words: Grain sorghum, futures, corn, hedge, cross hedge, hedging risk.

INTRODUCTION

Grain sorghum is the second largest U.S. feedgrain crop behind corn. From 1981-85, an average of 7,400 million bushels of corn was produced in the U.S. compared to 840 million bushels of sorghum (U.S. Dept. of Agriculture). The average dollar value of corn production over this period was $19.4 billion, compared to $2.0 billion for sorghum. From 1981-85, thirty-two percent of U.S. sorghum production was exported (U.S. Dept. of Agriculture). Grain sorghum is primarily used as a feed ingredient in livestock rations. Studies have shown that sorghum contains 95% of the nutritional value of corn (Kansas City Board of Trade, 1989a, Appendix 26).

During the 1970's, grain sorghum futures traded at the Chicago Mercantile Exchange for five years and the Kansas City Board of Trade (KCBT) for three years. There was very little trading interest in either contract, however. In 1988, the KCBT revised its grain sorghum futures contract, and resubmitted it to the Commodity Futures Trading Commission. The KCBT's revised contract was approved in February 1989, and trading began on May 5, 1989. The KCBT believes the revised sorghum futures contract will succeed as a pricing and risk-management tool because of the change in agricultural policy toward more market orientation. "As market factors become ascendent, inherent [price] risk increases, stimulating a greater need for a viable hedging mechanism" (Kansas City Board of Trade, 1989a, p. 21). A second reason the sorghum contract is expected to succeed is because changes have been made to correct problems that existed in the earlier contract. These include (1) adding three delivery points in addition to Kansas City; (2) restricting the standards for delivering No. 3 sorghum; and (3) allowing flat transit billing, as opposed to freight paid to another destination.

This research estimates the impact of a sorghum futures contract on hedging risk for Texas grain sorghum. In the past, corn futures have been widely used by elevators, feedlots, and farmers to hedge grain sorghum (Kansas City Board of Trade, 1989a, p. 18). Corn is a close substitute for sorghum in livestock rations, and thus factors that affect corn prices also affect sorghum prices. The link between corn and sorghum prices makes it possible to use corn futures as a cross hedge for sorghum. "To cross hedge is to assume a futures position opposite an existing cash position, but in a different commodity" (Leuthold, Junkus, and Cordier, 1989, p. 146). A cross hedge is called for when a futures market does not exist for a commodity.

The problem a sorghum trader faces when hedging sorghum in corn futures is greater basis risk (where basis=sorghum cash price-corn futures price). This results because the relationship between cash sorghum prices and Chicago corn futures prices is not as close as the relationship between cash sorghum prices and Kansas City sorghum futures prices. Thus, a sorghum futures market is expected to provide a more effective hedge for sorghum than a cross hedge in corn futures (Stalcup, 1989).

When comparing sorghum futures and corn futures as hedges for cash sorghum, an objective measure of hedging risk is needed. This is developed in the second section of the paper from a simple regression of cash on futures prices. The standard deviation of the regression residuals serves as a measure of hedging risk. In the third section, hedging risk is calculated for cash sorghum hedged in sorghum futures versus corn futures for three locations in Texas. The last section provides a summary of the results and the conclusions.

HEDGING RISK

Hedging can be used to reduce price risk associated with an existing (or anticipated) cash position. For example, a cattle feeder can "lock in" a price for corn (an energy ingredient in cattle rations) by buying corn futures. If the price of cash corn should rise after the hedge is placed, the long position in corn futures will provide a return which can be used to offset the higher price paid in the cash market. In this sense, hedging shifts price level risk to futures speculators (Hieronymus, 1977, pp. 148-51).

Hedging does not completely eliminate price risk because the relationship between cash and futures prices (or basis) is always changing. Consider the situation of a cattle feeder who is making a decision in April about pricing corn he will be feeding in September. He decides to purchase September corn futures to lock in a price for corn in September. The feeder anticipates that the price of corn at his local market will be $0.10/bu. under the September futures price when the hedge is lifted in September. If September corn futures is trading at $2.80/bu., the price the hedger expects to achieve by hedging is $2.70/bu (Table 1). The expected price from hedging is called the target price.

The actual price achieved by hedging, called the net price, depends on the relationship between cash and futures prices in September. If the cash price at the feeder's local elevator is $0.10/bu. under the September futures price when the hedge is lifted in September, the net price from hedging will be equal to the target price of $2.70/bu. (Table 1). However, if the cash price is more than $0.10/bu. under the September futures price when the hedge is lifted, the net price will be under the target price (and vice versa). For

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Table 1. Example of Sorghum Hedge.

Date	Cash	September Futures	Basis = Cash-Futures
April	Target Price = \$2.70	Buys at \$2.80	-\$0.10 (expected Sept. basis)
September	Buys at \$3.00	Sells at \$3.10 Gain \$0.30	-\$0.10 (actual basis)

Effective net buying price:
\$3.00 cash purchase price in September
0.30 gain on futures
\$2.70 net price

example, if the cash price in September is \$0.25/bu. under the September futures price, then the net price from hedging will be \$2.55/bu., which is \$0.15/bu. under the target price (Table 2).

Table 2. Example of Sorghum Hedge with Basis Risk (i.e., Net Price Is Not Equal to Target Price).

Date	Cash	September Futures	Basis = Cash-Futures
April	Target Price = \$2.70	Buys at \$2.80	-\$0.10 (expected Sept. basis)
September	Buys at \$2.85	Sells at \$3.10 Gain \$0.30	-\$0.25 (actual basis)

Effective net buying price:
\$2.85 cash purchase price in September
0.30 gain on futures
\$2.55 net price

The above example illustrates that hedging involves risk (or uncertainty) because the net price achieved by hedging can be different from the target price. Risk for a hedge can be measured by calculating the variation of the net price about the target price. This concept of hedging risk has been used in practical applications (Hieronymus, 1977, p. 208; Chicago Board of Trade, 1978), and academic studies of hedging (Miller, 1985; Elam, Miller and Holder, 1986; Elam, 1988; and Schroeder and Mintert, 1988). Equations for the target and net prices are required to develop a mathematical definition of hedging risk.

The target price is derived at the time a hedge is placed, and represents the price a hedger expects to achieve by hedging. The first step in deriving the target price is to estimate the relationship between the cash price at the hedger's local market and the nearby futures price:

$$(1) \qquad C_t = b_0 + b_1 F_t^t + v_t$$

where C_t is the actual per bushel price of cash sorghum at time t; and F is the per bushel futures price at time t for the futures contract maturing nearest to, but not before, time t; b_0 and b_1 are estimated intercept and slope parameters, respectively; and v_t is the regression residual with expected mean of zero and variance of $E[(v_t)^2]=\sigma_v^2$.

To reduce basis risk, a hedge is typically placed in the futures contract that is at, or nearest to, maturity. For example, if a hedge will be lifted in September, then it should be placed in the September sorghum futures contract. By comparison, if the hedge is to be lifted in October, it should be placed in the nearby futures contract which is December. Sorghum futures contracts trade (or mature) only five times per year—March, May, July, September, and December.

The estimated slope parameter from eq. (1), b_1, indicates the number of bushels of the nearby futures required to hedge one bushel of cash sorghum. For example, if b_1=0.9, then 0.9 bushel of futures is required to hedge 1.0 bushel of cash sorghum. If the cash position is 10,000 bushels, a hedge would require the sale of 9,000 bu. (10,000 x 0.9) of futures. The KCBT sorghum futures contract is for 5,000 bushels, so a hedge for a 9,000 bushel cash position would call for the sale of two KCBT contracts (which is closest to 10,000 bushels).

The target price for a hedge to be lifted at time t is calculated at time t-j by substituting the futures price for the contract maturing nearest to, but not before, time t into eq. (1) and solving for the predicted cash price:

$$(2) \quad T_{t-j}^t = b_0 + b_1 F_{t-j}^t,$$

where T_{t-j}^t is the target price as calculated at time t-j for a hedge to be lifted at time t. The target price is the per bushel cash price the hedger expects to receive/pay for cash sorghum at the hedger's local market at time t. In the example in Table 2, the target price is \$2.70/bu. Note that the target price in the example is derived in April at the time the hedge is placed.

After a hedge is lifted, the net price for the hedge is calculated. The net price represents the actual price achieved from hedging. In the example in Table 2, the hedge is lifted in September and the net price (\$2.55/bu.) is calculated. The net price for a hedge is the sum of the cash price at the time the hedge is lifted plus the return on the futures position:

$$(3) \qquad N_t = C_t + b_1(F_{t-j}^t - F_t^t),$$

where N_t is the per bushel net price for a j-period hedge that is lifted at time t.

The target price from eq. (2) reflects the price a hedger <u>expects</u> to achieve by hedging, whereas the net price from eq. (3) represents the <u>actual</u> price achieved by hedging. The difference between the net and target prices is obtained by subtracting eq. (2) from (3):

$$(4) \quad N_t - T_{t-j}^t = C_t - b_0 - b_1 F_t^t.$$

Eq. (4) shows that the difference between net and target prices is equal to the difference between the cash price at the time a hedge is lifted

(C_t) and the predicted cash price, $\hat{C}_t = b_0 + b_1 F_t^t$. This difference is equal to v_t, which is the regression residual from the regression of cash on nearby futures prices (eq. (1)):

$$(5) \quad N_t - T_{t-j}^t = v_t.$$

A measure of the risk involved in hedging is the standard deviation of the difference between the net and target prices:

$$(6) \quad \text{Std. Dev. } (N_t - T_{t-j}) = \sigma_v.$$

where σ_v is the standard deviation of the regression residuals from a price level regression (eq. (1)). The standard deviation is preferred over the variance as a measure of hedging risk because it is in dollars per bushel, rather than in dollars per bushel squared. Equations (5) and (6) show that hedging risk is directly related to the uncertainty in the relationship between a hedger's local cash price and the nearby futures price at the time a hedge is lifted. This risk is quantified in the regression residual, v_t.

In the following section, the measure of hedging risk from eq. (6) is used to compare hedging risk for grain sorghum hedged in the Chicago Board of Trade corn futures market versus grain sorghum hedged in the KCBT grain sorghum futures contract.

HEDGING RISK FOR SORGHUM HEDGED IN SORGHUM FUTURES VS. CORN FUTURES

Hedging risk was estimated for cash sorghum hedges using Thursday cash prices for No. 2 Yellow Sorghum for three locations in Texas—High Plains (represented by the Triangle Area from Plainview to Canyon to Farwell), Houston, and Corpus Christi (Texas Dept. of Agriculture, 1977-88). Thursday prices were used because Kansas City sorghum prices are reported for Thursday in the Grain and Feed Market News (U.S. Department of Agriculture). Corn futures prices were collected for the same day of the week as the cash sorghum prices (U.S. Dept. of Agriculture, and Wall Street Journal). Because sorghum futures prices were not available on a historical basis, Kansas City No. 2 Yellow Sorghum prices were used as a proxy for sorghum futures prices (U.S. Dept. of Agriculture). Cash prices have been used as proxies for futures prices in feeder cattle hedging studies where a historical series of cash settlement futures prices was not available (Elam, 1988; Schroeder and Mintert, 1988). The justification is that cash and futures prices will be approximately equal at the time a contract matures (Hieronymus, 1977, p. 152). Cash sorghum prices from Kansas City should approximate sorghum futures prices at contract maturity because Kansas City is the primary delivery point on the KCBT sorghum futures contract.

Hedging risk was estimated for a direct sorghum hedge versus a cross hedge in corn futures using the standard deviation of the difference between net and target prices. The standard deviation (O_v from eq. (6)) was calculated from the residuals from regressions of (1) cash sorghum price on sorghum futures price, and (2) cash sorghum price on corn futures price. Separate regressions were run for each of the three markets, and for each of the months of March, May, July, September, and December (the five months that sorghum and corn futures trade).[1] The standard deviations for a direct sorghum hedge compared to a cross hedge in corn futures are shown in columns 2-3 of Table 3. The percentage changes in hedging risk are shown in column 4.

The average reduction in hedging risk for a direct hedge over a cross hedge ranges from 4-29 percent. The average reduction is greatest for the Texas High Plains (29 percent) and smallest for Corpus Christi (4 percent).

Table 3. Hedging Risk for a Direct Sorghum Hedge Compared to a Cross Hedge in Corn Futures, by markets, 1977-88.

	Estimated Hedge Ratio[a]			Bushel-for-Bushel Hedge[b]		
Market	Sorghum Futures	Corn Futures	Change in Hedging Risk	Sorghum Futures	Corn Futures	Change in Hedging Risk
	dollars per cwt.		percent	dollars per cwt.		percent
Texas High Plains						
March	0.189	0.282	-33.0	0.191	0.327	-41.6
May	0.138	0.266	-48.2	0.136	0.281	-51.7
July	0.233	0.309	-24.6	0.261	0.418	-37.5
September	0.203	0.268	-24.3	0.248	0.406	-39.0
December	0.202	0.242	-16.6	0.199	0.285	-30.0
Average			-29.4			-34.0
Houston						
March	0.193	0.257	-25.0	0.205	0.269	-23.8
May	0.338	0.298	13.4	0.333	0.294	13.3
July	0.218	0.339	-35.5	0.216	0.390	-44.5
September	0.222	0.259	-14.4	0.230	0.267	-13.7
December	0.224	0.261	-14.2	0.233	0.272	-14.4
Average			-15.2			-16.6
Corpus Christi						
March	0.209	0.228	- 8.5	0.222	0.337	-34.1
May	0.280	0.254	10.6	0.297	0.304	2.1
July	0.234	0.330	-29.0	0.234	0.386	-39.4
September	0.221	0.227	- 2.6	0.217	0.257	-15.5
December	0.264	0.247	7.1	0.260	0.286	- 9.3
Average			- 4.5			-20.1

[a]The estimated hedge ratio is b_1 from eq. (1) in the text
[b]In a bushel-for-bushel hedge, one bushel of futures is used to hedge one bushel of cash sorghum. The hedge ratio for a bushel-to-bushel hedge is b1-1.00.

Hedging risk is reduced with a direct hedge in the High Plains for all five months that sorghum futures trade, with the smallest reduction being 17 percent for December. By contrast, for the Corpus Christi market, July is the only month in which hedging risk is reduced more than 10 percent. For the other four months for Corpus Christi, hedging risk is reduced for two months with a direct hedge, but for the other two months, hedging risk increases. The only other situation in which hedging risk increases with a direct hedge over a cross hedge is for May at Houston. May is at the end of the marketing season for sorghum, and relatively small amounts of sorghum are traded/exported during May. Prices at times during May are not reported; and prices that are reported are typically based on small lots of sorghum. Because of the above reasons, relatively little weight should be given to the figures for Corpus Christi and Houston for May.

The results for hedging risk presented in columns 2-4 of Table 3 assume that an estimated hedge ratio is used to determine the size of the futures position.[2,3] However, most sorghum is currently hedged on a bushel-to-bushel basis using corn futures (Kansas City Board of Trade, 1989a, p. 19). A bushel-to-bushel hedge involves using one bushel of futures to hedge one bushel of cash sorghum. The hedge ratio for a bushel-to-bushel hedge is b_1=1.0. Textbook examples of hedging typically use bushel-to-bushel hedges (Hieronymus, 1977, pp. 175-78; and Chicago Board of Trade, 1978).

Because of the widespread use of bushel-to-bushel cross hedges in the sorghum trade, it seemed appropriate to measure the change in hedging risk for direct hedges versus cross hedges on a bushel-to-bushel basis. This should provide a more accurate indication of the actual reduction in hedging risk that would be achieved in practice when a direct sorghum hedge is used compared to a cross hedge in corn futures. Hedging risk for a bushel-to-bushel hedge can be calculated as described in the previous section, with the exception that the hedge ratio is assumed to be b_1=1.0. Hedging risks for bushel-to-bushel hedges are shown in columns 5-6 of Table 3, and the percentage changes in hedging risks for direct over cross hedges on a bushel-to-bushel basis are shown in column 7.

The results for bushel-to-bushel hedges are similar to those in columns 2-4 for the situation where a hedge ratio was estimated. However, one difference is that bushel-to-bushel hedges typically show a greater reduction (or smaller increase) in hedging risk. This is most noticeably true for the Corpus market where bushel-to-bushel hedges show on average a 16

[1]Separate regressions are typically run for each season of the year to allow for seasonal differences in hedging risk (Elam, 1988; Schroeder and Mintert, 1988; Schroeder, 1988).
[2]The hedge ratio is the slope coefficient (b_1) from a regression of cash sorghum prices on sorghum or corn futures prices. Hedge ratios were estimated for the three locations and five months sorghum futures trade (March, May, July, September, and December). To save space, average hedge ratios are reported below (and specific monthly hedge ratio estimates are available from the authors).

Market	Direct Hedge Ratio	Cross Hedge Ratio
High Plains	0.97	0.81
Houston	1.06	0.92
Corpus Christi	0.94	0.82

The average cross hedge ratio is less than the average direct hedge ratio for each of the three markets. Also note that the direct hedge ratios are closer to 1.0 than the cross hedge ratios. A direct hedge ratio of 1.0 indicates that one bushel of sorghum futures is required to hedge one bushel of cash sorghum.
[3] The purpose in using an estimated hedge ratio is to reduce hedging risk (Elam and Davis, 1990). In the case of a cross hedge, the cash commodity is different from the futures commodity, and thus the change in cash and futures prices can be different. For example, the cash price of sorghum may decline on average by $0.45 per bushel when the corn futures price declines by $0.50 per bushel. When using corn futures to cross hedge sorghum, this situation calls for a position of 0.9 bushel of corn futures for each bushel of cash sorghum. The 0.9 is the cross hedge ratio, which is the estimated slope coefficient (b_1) from a regression of cash sorghum price on corn futures price (equation (1)). The hedge ratio represents the relative change in cash sorghum and corn future prices. A cross hedge for 50,000 bushels of cash sorghum will require the sale of 45,000 (50,000 x 0.9) bushels of corn futures. Then if the cash sorghum price declines by $0.45 per bushel and corn futgures price by $0.50 per bushel, the decline in the value of the sorghum position ($22,500=$0.45x50,000 bushels) will be exactly offset by the gain in value of the short corn futures position ($22,500-$0.50x45,000 bushels).

percentage point greater reduction in hedging risk for direct over cross hedges than that for the situation where a hedge ratio was estimated (columns 2-4).

CONCLUSIONS

Hedging risk for Texas cash sorghum positions is estimated to be reduced 17-34 percent with a direct sorghum hedge compared to a cross hedge in corn futures (based on the results for bushel-to-bushel hedges). This level of reduction in hedging risk should encourage the use of the KCBT sorghum futures market to hedge cash sorghum.

An advantage of a sorghum futures contract for the U.S./Texas sorghum industry is that it will improve the image of sorghum as a desirable feedgrain. In the past, a sorghum futures contract has not always been available; and therefore the corn futures market has been used for discovering the equilibrium price that equates the demand for and supply of sorghum. Cash sorghum traders look to corn futures prices as a benchmark, and adjust sorghum prices according to the particular demand-supply situation in the sorghum market. The need to interpret sorghum's market value relative to its corn-futures reference complicates sorghum pricing ..." (Kansas City Board of Trade, 1989a, p. 17). It is particularly difficult for foreign buyers to determine fair value for sorghum because they do not have timely access to information needed to interpret sorghum-corn price relationships. This puts them at a competitive disadvantage in their dealings with more knowledgeable parties. Foreign buyers are important to the domestic sorghum industry because approximately one third of U.S. sorghum production is exported. Importers have been wary about buying sorghum because there was no futures market on which to base pricing decisions (Kansas City Board of Trade, 1989b, p. 7).

If a sorghum futures market can develop, it should benefit the Texas sorghum industry in that (1) it will provide a more effective hedge for cash sorghum, and (2) it should improve the image of sorghum as a desirable feedgrain, which will encourage foreign purchases of U.S. and Texas grain sorghum.

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EVALUATION OF AN ELECTRONIC DEVICE FOR COUNTING THE CALLS OF WHITE-WINGED DOVES

Donald G. Waechtler and Charles A. DeYoung[1]

ABSTRACT

In Texas, white-winged dove *(Zenaida asiatica)* populations are indexed by subjective determinations of their level of calling. An electronic call-counter was developed and tested as a potentially more objective way to measure level of calling in white-winged dove colonies. Major features were a frequency filter to eliminate non-whitewing noise, use of a parabolic reflector to reduce the sound-reception angle, and a sensitivity switch to control the signal amplitude accepted. The call-counter worked satisfactorily during extensive field testing. The relationship between calling measured by the device and active nests was positive. Additional research is needed on the relationship between calling and nest density in white-winged dove populations.

INTRODUCTION

Estimates of spring breeding populations are critical for proper management of white-winged doves in Texas (Waggerman, 1976). Texas white-winged doves concentrate in the southernmost counties of Willacy, Cameron, Hidalgo, and Starr. Nesting occurs in heavily foliated native brush and mature citrus groves, making visual counts difficult.

Furthermore, active nest counts to index populations are too expensive for management purposes. Thus for years the population has been surveyed through call-counts, which may be roughly linked to nesting density, and ultimately, population size (Uzzell, 1949). In quality habitat, white-winged doves nest in dense colonies (Blankinship, 1966) where their calling merges into a continuous sound. Once calling noise becomes continuous (in colonies of about 20 pairs/acre), the human ear has difficulty differentiating between colonies having high, but different numbers of birds. Waggerman (1976) estimated that 15% of the extreme south Texas population nests at these high densities.

Electronic devices have been used to measure bird calls more objectively. Graber and Cochran (1959) used a parabolic reflector to study nocturnal migration of birds. Calls from birds flying overhead were received with the aid of the reflector and stored on tape. This technique gave an indication of what species were migrating at night and also their relative abundance. Mangold (1974) used a high fidelity tape recorder to reduce the effects of differences in observer's abilities to hear clapper rail *(Rallus longirostris)* calls. He also found that a parabolic reflector was a useful sound gathering device.

We developed and field-tested an electronic call-counter that could be used to count bird calls in many applications, but particularly in dense white-winged dove colonies. We field tested the electronic call-counter by comparing the level of calling measured by the device to the density of whitewing nests in the vicinity.

DESIGN OF THE COUNTER

The major design objectives for the counter were that it (1) receive and register whitewing calls but little else, and (2) allow the operator to reduce the area monitored until calls no longer overlapped (single calls are much easier to count versus a continuous sound).

An audiospectrogram and a low frequency spectrum analyzer were used to determine the frequency of tape-recorded whitewing calls. The calls were 625 + 30 H_z with a wave length of one-half a meter. A frequency band-pass filter was used to eliminate extraneous sounds outside the calling frequency range. Sound was gathered by a Realistic Super Cardiod Dynamic, Model No. 33-922 microphone.

Two parts of the counter aided in reducing the overlap of calls. First, a six-position sensitivity switch allowed the operator to select different amplitudes. The higher the calling level of a colony, the more restricted the amplitude setting selected (to receive only separate, high amplitude calls). Second, the microphone was mounted on a parabolic reflector of 1.2-m diameter in order to reduce the sound reception angle to less than 180 degrees (Halliday and Resnick, 1965). The microphone was located at the focal point of the reflector, which was determined by adjusting the microphone to find the point of maximum reception (Thourel, 1960). The shape and size of the monitoring area at each of the six sensitivity settings was determined by moving a constant 625 H_z sound source across a grid in front of the reflector. Varying strengths of signal reception, which were measured with an ammeter, revealed sample area shape. Sample area at each setting was calculated in square meters and all data were standardized to the largest area (resulting from setting six).

The sound of whitewings was ultimately displayed on a counter which registered from 0 to 225 counts. A small red light on the counter also flashed each time the equipment registered a count. Fig. 1 contains a block diagram of the equipment and processes. Complete circuit diagrams and major electronic components of the call-counter were given by Waechtler (1977).

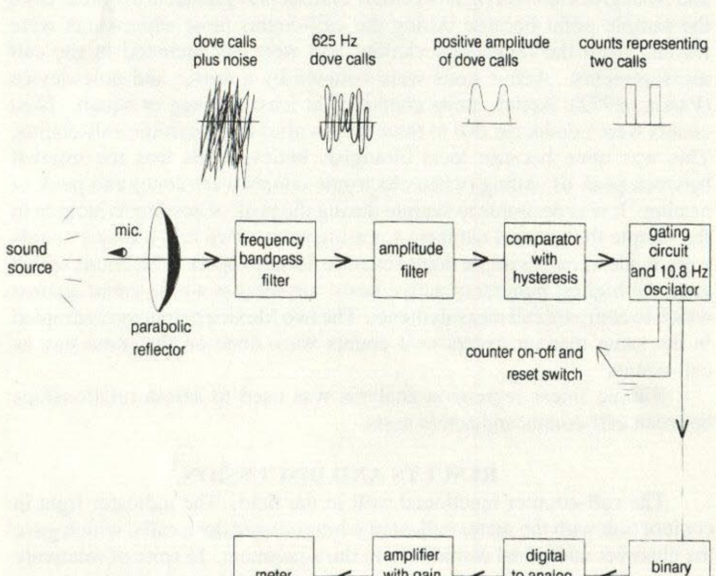

Fig. 1. Diagram Showing major components and processes of an electronic device for counting the calls of white-winged doves.

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FIELD METHODS

The electronic call-counter was field tested in south Texas and Mexico. A good representation of equipment operation was obtained by listening to calling whitewings and simultaneously watching the meter and indicator light on the counter. As an additional step, nest counts were conducted in areas where calls had been monitored by the counter to determine any correlation between measured calling and observed nesting density.

Local biologists recommended field sites which contained high-density whitewing colonies. In Texas, three native brush colonies and two citrus areas were selected for testing the call-counter. The Kelly and La Paloma brush areas were about 50 acres in size whereas the Abrams brush area was about 40 acres. The City Refuge and Rio Queen citrus areas were in Hidalgo County. In an effort to measure calls from an extremely high density whitewing colony, another study area was established in Mexico near San Rafael. This native brush track, about 30 acres in size, was about 150 miles south of McAllen, Texas.

Thirty-six sampling points (34 in Texas and two in Mexico) for call counts were established along the edges of the areas at sites of high-intensity calling. Calls were recorded as counts registered by the meter of the call-counter, and were not necessarily individual dove calls. On the Texas areas, calling was measured on four separate days at each sampling point during the peak calling period (Waggerman, 1976). The daily call-count at each point was the average of three, one-minute counts: a center count with the reflector aimed directly into the brush, and counts with the reflector aimed 30 degrees left and right of center. While reading calls, the reflector was tilted 5 degrees backward to direct it toward the calling birds which were 12-30 ft above ground level. The daily average counts for each point were averaged for the four sampling days to obtain an overall mean count for each point. The same number of counts were recorded at the two Mexico points, but all were done in one day rather than four. All call-counts were conductede in the first two hours of daylight.

Minute-by-minute variations in calling of individual birds at each sample point appeared to effect the consistency of electronic call-counts. To sample this variation, calls were measured every 15 minutes from 0600 to 1200 hrs on two consecutive days at a point in the Kelly study area.

Counts of active nests were made at each sampling point to determine if a correlation existed with the electronic counts. At each point, transects 40-yards long by 10-yards wide radiated from the sample point in the center and 30 degrees left and right of center. Transects began about 10 yards from the sample point because during the call-counts most whitewings were flushed from the immediate vicinity and were not included in the call measurements. Active nests were counted by a mirror and pole device (Parker, 1972). Active nests contained at least one egg or squab. Nest counts were conducted two to three weeks after the electronic call-counts. This was done because local biologists believed this was the interval between peak of calling (when electronic counts were done) and peak of nesting. It was desirable to sample during the peak of nesting to include in the sample the greatest number of nesting pairs. Two nest transect counts were made at each sample point seven to 10 days apart. The count which gave the highest number of active nests was used as a base count against which to compare call measurements. The two Mexico points were sampled in the same manner except nest counts were done on the same day as call-counts.

Simple linear regression analysis was used to assess relationships between call-counts and active nests.

RESULTS AND DISCUSSION

The call-counter functioned well in the field. The indicator light in conjunction with the meter indicated white-winged dove calls, which gave the observer additional confidence in the equipment. In spite of relatively rough use in and out of trucks and in hot, dusty conditions, few failures were experienced, and these were easily repaired.

For a dove calling at the fringe of the reception area, the counter would register only a few counts. However, birds calling within about 15 yards of the reflector registered many counts . This occasionally led to problems with a close, loud bird overwhelming the meter's capacity with counts far out of proportion to its representation in the calling population. The same phenomenon occasionally occurred when loud extraneous noises caused the equipment to register many counts of non-whitewing noise. This happened because the frequency spectrum of the extraneous source at close range overlapped into the frequency range of whitewing calls. Such an erroneous sample was disregarded by the observer.

Counts of active nests revealed a range of 4 to 76/acre in Texas; whereas, the Mexico points yielded 180 and 204/acre. Regression analysis of averaged call-counts versus active nests/acre for the 36 sample points yielded a high R^2 value of 0.87 (Fig. 2). However, there was a large gap in the data between the Texas and Mexico points, causing the two Mexico points to exert a large influence on the relationship. A regression without the Mexico points yielded a R^2 of 0.29. Thus, there was a positive relationship between the electronically measured calls and active nest counts, but additional data will be needed to determine its usefulness.

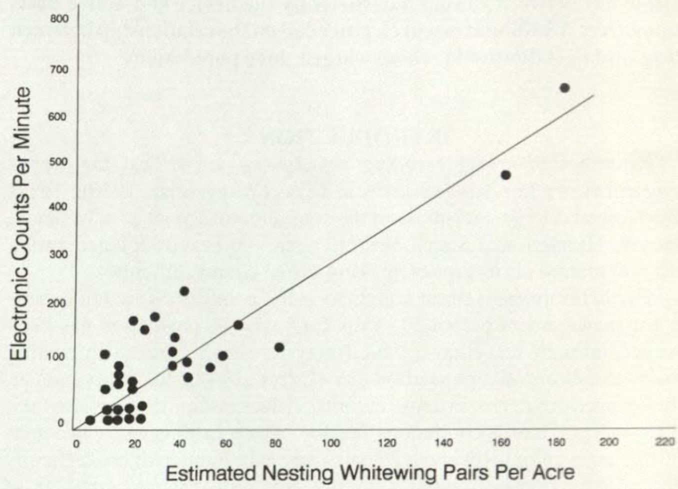

Fig. 2. Relationship in white-winged dove colonies between electronically mesaured calling level and nest density.

Both white-winged dove calling and counts of active nests were variable. The calls measured on two mornings at the Kelly area illustrate this fact (Fig 3). During the first two hours of daylight, calling levels varied considerably. Furthermore, nesting activity versus calling intensity ap-

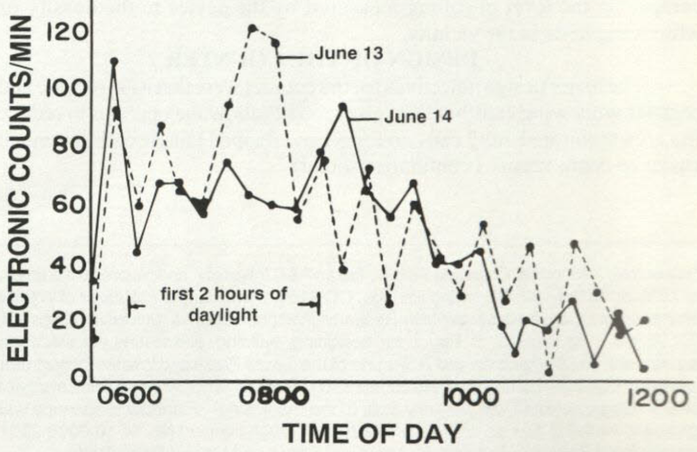

Fig. 3. Calls from a white-winged dove colony measured with an electronic device every 15 minutes for two consecutive mornings.

peared to differ between colonies. Some of the areas with high calling levels seemedto have few active nests and others with less calling had many active nests. Additional research is needed to better understand the relationship between nesting and calling in whitewings. Different levels of nest predation among colonies may have contributed to the variation (Blankinship, 1966). Overall, the electronic call-counter developed in this study worked satisfactorily and should be a useful aid in surveying whitewing colonies in the spring. Additionally, the device should be useful for many purposes in ornithology. To adapt to another species would involve merely changing the frequency and amplitude filters.

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