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MANAGING EDITOR: Sara Zahn, Campus Box 156, Texas A&M University-Kingsville, Kingsville, TX 78363. Phone: (512) 595-3719. FAX (512) 595-3713.

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Response of Herbaceous Vegetation to Short Duration Grazing in Central West Texas

Cody B. Scott
Walter H. Schacht
Clayton S. McCown*
Department of Agriculture, Angelo State University, San Angelo, TX 76909

ABSTRACT

Short Duration Grazing (SDG) played a significant role in grazing management practices in Texas during the 1980s. The Soil Conservation Service estimates that about 320 ranches in Texas use SDG or cell grazing on over 1.3 million acres. The objective of this study was to evaluate basal cover of herbaceous vegetation in the SDG system as affected by plant community and by distance from cell center over a 10-year period. There was an increase ($P<0.05$) in percent basal cover of perennial herbaceous plants for the 2 vegetation mixes studied during the 10-year period. The increase in basal cover may be attributed to SDG but the primary cause of the positive response was probably the favorable precipitation received during the study period. Basal cover of herbaceous vegetation was also affected ($P<0.05$) by distance from cell center. Differences in basal cover with distance from cell center suggest that uniform utilization by livestock did not occur within our cell.

KEY WORDS: basal cover, livestock distribution, cell grazing, grazing systems

As with most specialized grazing systems, a goal of SDG is to maintain or improve range condition while optimizing animal production. Strategies associated with SDG, which allow for improvement in the forage resource, concentrate on the control of frequency and severity of defoliation of key plant species coupled with uniform utilization of forage plants (Savory and Parsons, 1980; Savory, 1983; Savory, 1988). Proponents of SDG report uniform utilization of herbaceous vegetation through control of spatial distribution of livestock (Savory and Parsons, 1980; Savory, 1983; Savory, 1988). Control of spatial distribution is purportedly achieved by high stock densities which force livestock to make balanced use of desirable and less desirable sites. The effect of SDG on livestock distribution is controversial because of a lack of supporting literature. Results of short-term studies conducted in Texas (Pitts and Bryant, 1987; Walker et al., 1989a; Walker et al., 1989b; McKown et al., 1991) indicate that SDG and conventional grazing systems are similar in livestock distribution and utilization patterns. Secondly, proponents of SDG generally suggest that cell grazing is applicable to most ecosystems and plant communities (Savory, 1983). Researchers working in Texas and the Southwest region, however, have suggested SDG has limited application in arid and semiarid regions (Pieper and Heitschmidt, 1988; Bryant et al., 1989). Therefore, the objective of our study was to examine the long-term effects of SDG on percent basal

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cover of herbaceous vegetation of 2 different plant communities and at various distances from central watering facilities.

MATERIAL AND METHODS

This study was conducted at the Angelo State University Management, Instruction, and Research (MIR) Center located 5 miles north of San Angelo, Texas. The MIR Center is situated in the transition zone between the Rolling Plains and the Edwards Plateau. Soils are predominantly clay loams in the Angelo series (deep, nearly level, calcareous soils). Average annual precipitation for the MIR Center area is 18 inches, but annual precipitation ranged from 14 to 32 inches over the ten years of the study.

Approximately 25% of the study area is covered by brush strips dominated by mesquite (*Prosopis glandulosa*). Intervening areas were rootplowed in the mid-1970s and reseeded to 2 different mixtures of introduced and improved, native midgrasses (Table 1). The only difference between the 2 mixtures was the variety of sideoats grama (*Bouteloua curtipendula*). Each mixture was seeded in 3 different pastures which were later incorporated in the SDG system at the MIR Center. The pastures seeded to the mixture including the 'El Reno' variety of sideoats grama are referred to as the El Reno pastures, whereas the pastures seeded to the mix including the 'Premier' variety are the Premier pastures.

Table 1. Percent composition of the two seeding mixtures used at the MIR Center.

Grass Species	El Reno mixture	Premier mixture
Sideoats grama variety El Reno	50	0
Sideoats grama variety Premier	0	50
Green sprangletop	20	20
Kleingrass	20	20
K-R bluestem	10	10

Several native mid- and shortgrass species, not included in the seeding mixture, became prevalent on the study site. The major midgrass species are silver bluestem (*Bothriochloa laguroides*), sand dropseed (*Sporobolus cryptandrus*), and windmill grass (*Chloris sp.*). Buffalograss (*Buchloe dactyloides*) and curly mesquite (*Hilaria belangeri*) are the primary shortgrasses, while threeawns (*Aristida* sp.) and numerous species of forbs are also common throughout the study area. Although annuals are present following favorable levels of precipitation, generally, they make up only a small portion of the total basal cover of herbaceous vegetation. Basal cover refers to the cross sectional area of vegetation at ground level (SRM, 1989).

In 1979, SDG was installed on 1400 acres of this improved rangeland, including the intervening brush strips. The 13 pastures of the SDG unit, or cell, were each approximately 80 acres in size and arranged in a wagon-wheel design. The grazing cycle consisted of nongrazing periods of approximately 90 days and 2 to 10-day grazing periods. Length of these periods depended on such factors as forage characteristics of a particular pasture, plant growth rates, climatic factors, and time of the year. Initial descriptions of SDG implied a certain amount of rigidity in management as number and length of grazing and nongrazing periods as well as order of pasture rotation were to be predetermined and maintained over time. Savory (1983), however, stressed the need for flexibility in making grazing management decisions when using SDG. In particular, movement of livestock through the various paddocks of a SDG unit should follow plant and animal responses rather than a fixed schedule. Most practitioners of SDG now realize the importance of following a flexible schedule and base their movements on such factors as forage conditions of various pastures, weather patterns, and livestock performance. Consequently, grazing and nongrazing periods may vary to meet the aforementioned criteria.

Average stocking rate for the cell was 15 acres per animal unit year (AUY), which is considered a heavy stocking rate for the region. The stocking rate, however, fluctuated widely (i.e., from a destocked condition to 9 acres per AUY) in response to annual precipitation and available forage. The livestock mix was 3 AU of cattle to 2 AU of sheep. White-tailed deer were also common in the cell at approximately 15 acres per deer.

After establishment of the cell, 4 permanent line transects were systematically located in each pasture at approximately 1000-ft intervals radiating out from the cell center to the periphery. The transects were placed parallel to the cell center and 100 ft long. At each transect location, percent basal cover of herbaceous plant species was estimated using the line interception method (Canfield, 1941). Basal cover has often been used to evaluate dynamics in plant communities dominated by grasses (Cook and Stubbendieck, 1986). The initial sampling period was in the summer of 1981, followed by summer collections in 1984, 1986, 1988, and 1990.

Data from the 3 pastures seeded to the El Reno mixture and the 3 pastures seeded to the Premier mixture were used for analysis. All data were summarized by pasture (replication) within year and analyzed using analysis of variance procedures for a randomized complete block design with repeated measures. Seeding mixture and distance from cell center were whole plot factors with year as the repeated factor. Level of significance for mean separation was at $P<0.05$ and significantly differing means were separated by LSD test (Steel and Torrie, 1960).

RESULTS AND DISCUSSION

Percent basal cover of herbaceous vegetation for pastures planted to the El Reno mixture was higher ($P<0.05$) than that of the Premier mixture for the 10 years of this study (Table 2). Although relative species composition of sideoats grama was similar for the two treatments, basal cover of sideoats grama on the El Reno pastures was considerably higher than on the Premier pastures. In forage production for livestock consumption, however, the Premier pastures appeared to be more productive. For the past 4 years, the Premier pastures provided an average of 147 stock days per ac. (SDA) while the El Reno pastures provided only 96 SDAs. The El Reno sideoats grama is a rhizomatous plant while Premier is a bunchgrass. The spreading growth form of El Reno could largely explain its higher basal cover. The difference in basal cover between the two treatments was also due to the relatively high degree of cover by native midgrasses, shortgrasses, and forbs (Table 2). Differences in SDAs between plant communities may be the result of the bunchgrass growth form of Premier sideoats grama producing more total available forage.

Table 2. Basal cover (%) of herbaceous vegetation as affected by seeding mixture and distance from cell center averaged over years.

Vegetation component	Seeding mixture		Distance from cell center (ft)			
	El Reno	Premier	1000	2000	3000	4000
Seeded species						
Sideoats grama	2.4	1.9	0.7b	1.9b	2.1b	4.0a
K-R bluestem	0.2	0.2	0.2	0.3	0.2	0.2
Kleingrass	0.5	0.5	0.3	0.4	0.8	0.4
Native species						
Midgrasses	1.7	1.4	1.3	1.1	1.9	1.8
Shortgrasses	1.5	0.8	0.6	1.5	2.1	0.3
Threeawns	0.5	0.8	0.2b	0.4b	0.5b	1.7a
Other grasses	0.4	0.6	0.4	0.4	0.9	0.4
Forbs	1.0	0.7	1.1	1.0	0.6	0.6
Total	8.2a	6.9b	4.8c	7.0b	9.1a	9.4a

Values within rows and by category (i.e., mixture and distance) followed by different letters are significantly different ($P<0.05$).

Over the 10 years of this study, there was an increase ($P<0.05$) in percent basal cover of herbaceous vegetation across the two treatments (Figure 1). Basal cover remained at similar ($P>0.05$) levels from 1981 through 1986 but increased to higher ($P<0.05$) levels in 1988. Although basal cover of herbaceous vegetation declined ($P<0.05$) between 1988 and 1990, basal cover in 1990 was higher ($P<0.05$) than the pre-1988 levels.

Much of the increase in percent basal cover can be attributed to significant ($P<0.05$) increases in native midgrasses, shortgrasses, and threeawns (Figure 2). Over the 10 year period, the seeded species either maintained relatively constant levels, i.e., sideoats grama and K-R bluestem (*Bothriochloa ischaemum*), decreased sharply ($P<0.05$), i.e., kleingrass (*Panicum coloratum*), or appeared infrequently, i.e., green sprangletop (*Leptochloa dubia*) (Figure 3). Increases ($P<0.05$) in native grasses occurred in 1986 and 1988 while kleingrass and green sprangletop declined in basal area during the early part of the study. Basal cover of forbs varied over the

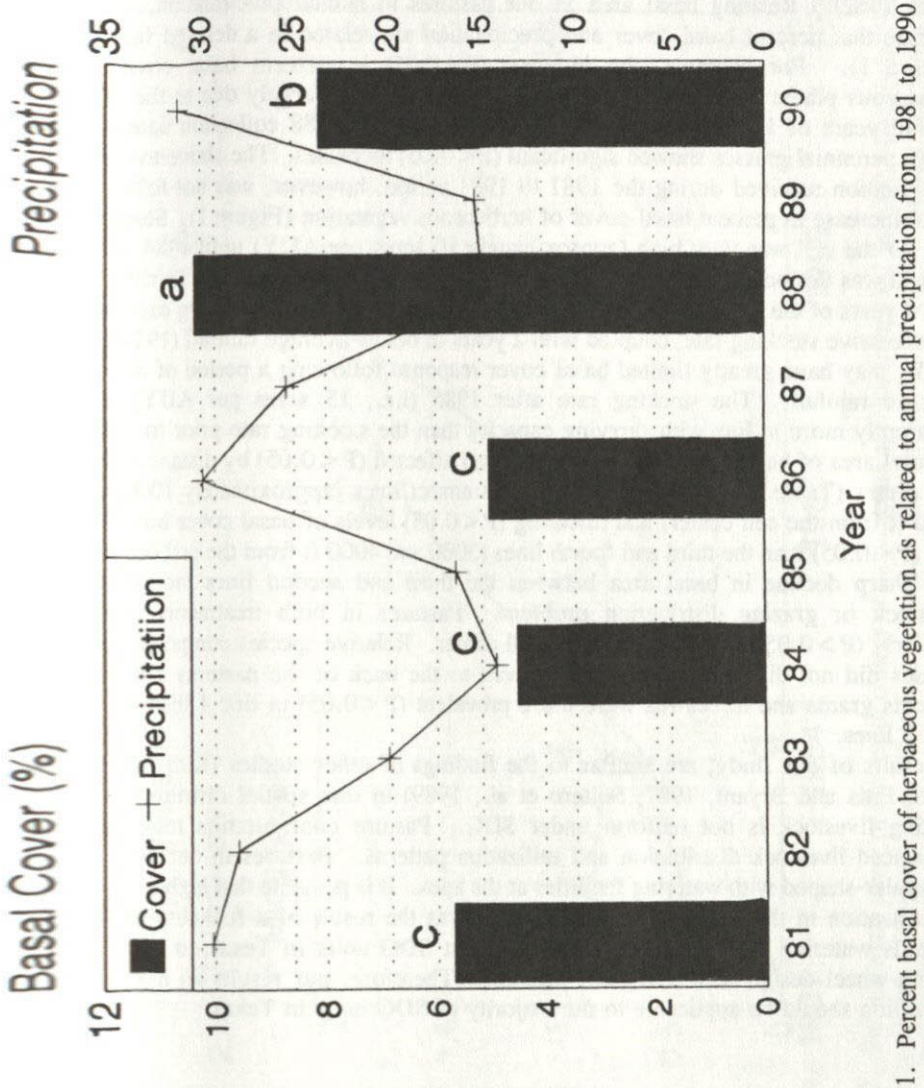

Figure 1. Percent basal cover of herbaceous vegetation as related to annual precipitation from 1981 to 1990 at the MIR center. Different letters indicate year differences ($P < 0.05$) in percent basal cover.

years in response to precipitation; however, forbs generally accounted for only about 10% of total herbaceous plant basal cover.

Dynamics in basal area of the herbaceous plant species may have been related to grazing management practices and grazing resistance of the various plant species; however, annual precipitation appeared to play an equally important role. We assumed that basal area of grasses was not substantially influenced by seasonal precipitation and temperature. Instead, changes in basal area were a result of longer-term (2 or more growing seasons) shifts in climatic conditions (Paulsen and Ares, 1962). Relating basal area in our pastures to annual precipitation, could indicate that percent basal cover and precipitation are related in a delayed fashion (Figure 1). For example, the increase ($P<0.05$) in percent basal cover of herbaceous plants between 1986 and 1988 may have been largely due to the high rainfall years of 1986 and 1987. Between the 1986 and 1988 collection dates the native perennial grasses showed significant ($P<0.05$) increases. The above-average precipitation received during the 1981 to 1983 period, however, was not followed by an increase in percent basal cover of herbaceous vegetation (Figure 1). Stocking rate for the cell was very high (approximately 10 acres per AUY) until 1984 when the cell was destocked for 1 year because of drought and lack of forage. During the first 4 years of the study, stocking rate was apparently higher than carrying capacity. An excessive stocking rate, coupled with 2 years of below average rainfall (1984 and 1985), may have greatly limited basal cover response following a period of above-average rainfall. The stocking rate after 1985 (i.e., 15 acres per AUY) was apparently more in line with carrying capacity than the stocking rate prior to 1984.

Basal area of herbaceous vegetation was also affected ($P<0.05$) by distance from cell center (Table 2). The first and second transect lines (approximately 1000 and 2000 ft from the cell center) had differing ($P<0.05$) levels of basal cover but were less ($P<0.05$) than the third and fourth lines (3000 and 4000 ft from the cell center). The sharp decline in basal area between the third and second lines indicated a livestock or grazing distribution problem. Pastures in both treatments varied similarly ($P>0.05$) with distance from cell center. Relative species composition of grasses did not differ greatly from the front to the back of the pastures although sideoats grama and threeawns were more prevalent ($P<0.05$) in line 4 than in the first 3 lines.

Results of our study, are similar to the findings of other studies (Kirby et al., 1986; Pitts and Bryant, 1987; Soltero et al., 1989) in that spatial distribution of grazing livestock is not uniform under SDG. Pasture configuration may have influenced livestock distribution and utilization patterns. Pastures in our cell are triangular-shaped with watering facilities at the apex. It is possible that higher levels of utilization in the front portion of pastures was the result of a funneling action towards watering facilities. Nevertheless, most SDG units in Texas do utilize a wagon-wheel design with triangular pastures. Therefore, our results on livestock utilization should be applicable to the majority of SDG units in Texas.

CONCLUSION

Basal cover of herbaceous vegetation increased over the 10 years of the study in both seeding treatments within our SDG unit. Much of this increase may be attributed to increases in basal area of the native perennial grasses in response to the

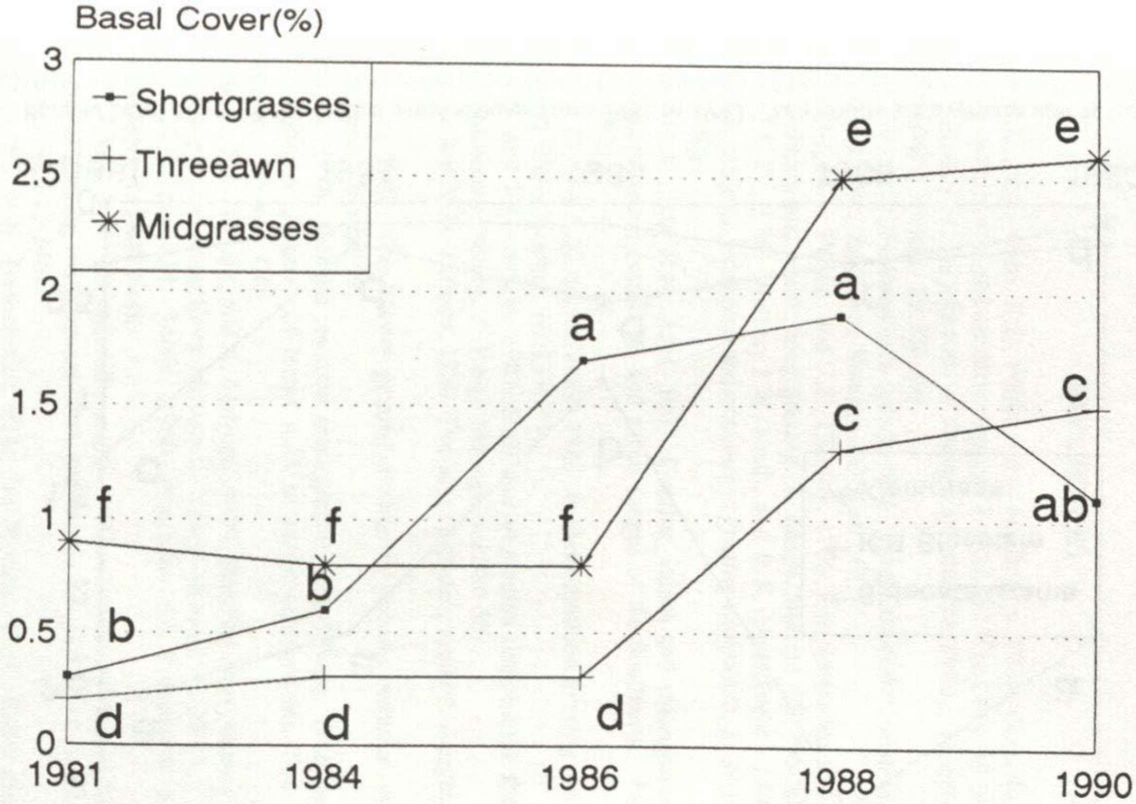

Figure 2. Percent basal cover of the major classes of native grass species from 1981 to 1990. Data points are averages across treatments. Different letters within species indicate year differences ($P<0.05$). Absence of letters indicates no significant ($P>0.05$) differences among years.

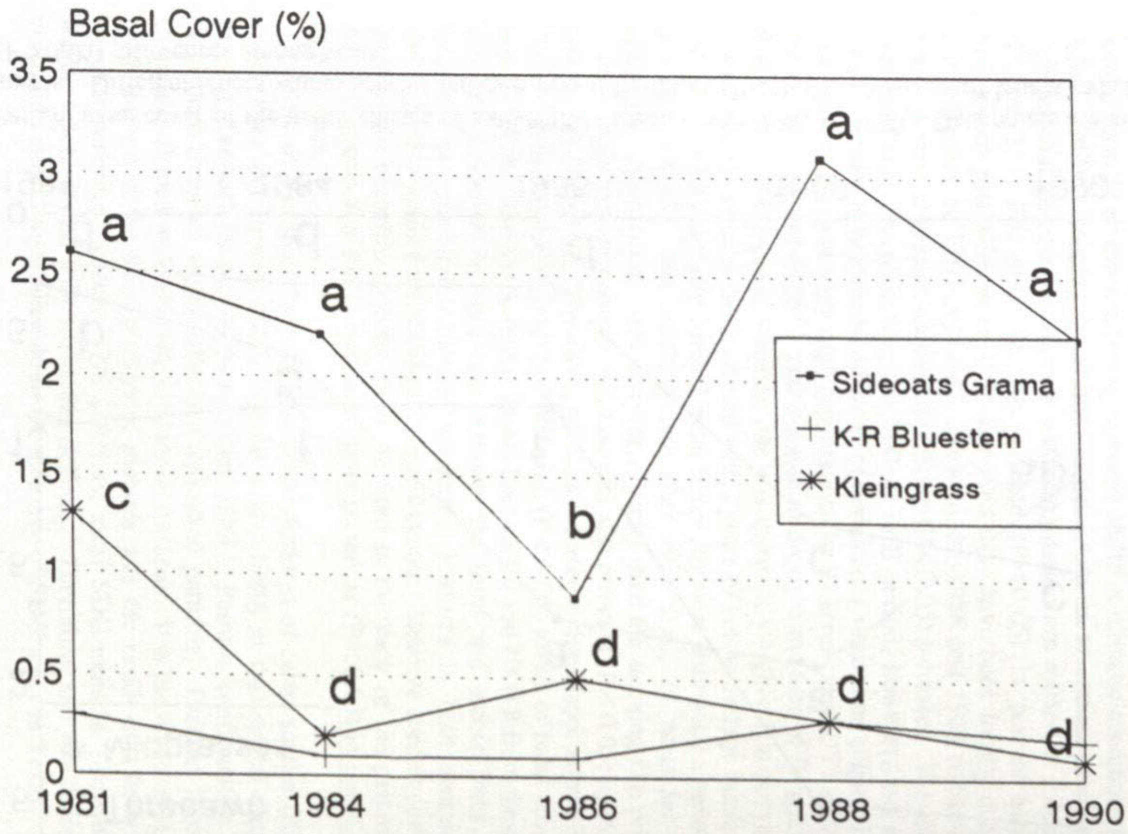

Figure 3. Percent basal cover of the seeded grass species from 1981 to 1990. Data points are averages across treatments. Different letters within species indicate year differences ($P < 0.05$). Absence of letters indicates no significant ($P > 0.05$) differences among years. Green sprangletop is not shown because only a trace was recorded.

above-average precipitation years of 1986 and 1987. Furthermore, it appears that achieving and maintaining the proper stocking rate may have aided in the increase in percent basal area in our study. Finally, the relatively low percent basal cover of herbaceous vegetation in the front portion of the pastures indicates that the experimental pastures were not evenly utilized. Therefore, the hypothesis that SDG leads towards uniform utilization of the forage resource is not supported by the results of our study.

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A Qualitative Characteristics Model of County Youth Fair Animal Prices

Carl Dillon*
University of Arkansas, 221 Agricultural Bldg., Fayetteville, AR 72701
David Moorman
Sam Houston State University, PO Box 2088, Huntsville, TX 77341-2088

ABSTRACT

Regression techniques were used to study the responsiveness of final bid prices in a Texas county youth fair auction for five livestock types: steer, barrow, lamb, chicken, and rabbit. A qualitative characteristics model framework is used including buyer characteristics, exhibitor (seller) attributes, and the placement of the animal. Prices received were largely uninfluenced by buyer or seller characteristics; however, non-caucasian exhibitors received a lower price for barrows.

KEYWORDS: livestock auctions

The marketing arena of a county youth fair is an atypical economic environment. A multitude of factors, economic and noneconomic, affect the pricing decisions made in such a setting. As a consequence, the disaggregation of the effects of various phenomena on price determination is complex. Nonetheless, information regarding the pricing policies for animals auctioned in a youth livestock fair can be obtained using a qualitative characteristics framework. The purpose of this study is to investigate the level of influence of personal buyer and exhibitor characteristics on purchase prices to highlight potential areas of concentration in the management of county youth fairs, using a specific case of a Texas county youth fair auction. Specifically, the objective is to analyze the effects of exhibitor attributes and characteristics of the buyer on the prices received and present the qualitative characteristics regression framework used in this analysis. Since data from a single fair is used, the results provide insights only and are not necessarily applicable to other fairs. Discussions with fair administrators and participant groups has indicated an interest in determining the extent of any effects of social characteristics such as age, race, sex, and youth group affiliation on prices received. In addition to this important issue is the framework under which this problem is analyzed as a potential for further study of other auctions (youth fair or otherwise) and related market structures potentially influenced by personal buyer and seller characteristics.

Research has addressed price determination through negotiation between processors and farmer bargaining associations (French, 1987), auction

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environments (Hamm et al., 1985; Johnson, 1957), and cattle prices as a function of livestock attributes (Menkhous and Kearl, 1976), but such studies have not addressed determination of prices in the setting of a youth fair livestock auction. Since its initial inception and early expansion (Waugh, 1928; Theil, 1952; Lancaster, 1966; Houthakker, 1952), qualitative characteristics analysis has largely focused upon hedonic models. Hedonic price research has been conducted on issues of functional form (Lucas, 1975; Blackley et al., 1984) and theoretical and methodological aspects (Ladd and Martin, 1976; Ladd and Suvannant, 1976; Ladd and Zober, 1977; Rosen, 1974). Although the popularity of hedonic price models has increased (Carl et al., 1983; Eastwood et al., 1986; Edmonds, 1983; Milon et al., 1984; Wilson, 1984; Cox et al., 1984; Ethridge and Davis, 1982; Pardew et al, 1986; Jordan, et al., 1985; Unnevehr, 1986; Messonier and Luzar, 1990), a qualitative characteristics framework can be used which focuses upon the characteristics of the buyer and the seller in addition to the attributes of the item being purchased. In a youth fair livestock auction, the characteristics of the exhibitor, of the animal and of the purchaser bidding upon the animal are factors affecting the actual price received.

BACKGROUND INFORMATION

The fair being studied holds an annual show and auction where livestock exhibitors compete in several categories. There are divisions for both breeding livestock and market livestock, but the auction is limited to market animals. The top fifteen places for five market animal categories are sold: steers, barrows, lambs, broilers, and rabbits. Exhibitors must be members of either a 4-H club or a local Future Farmers of America (FFA) to participate. Exhibitors are of school age (elementary through high school) and are residents of one of the two towns within the county (A or B). After all animals have been judged and assigned appropriate placements, the auction is held. Exhibitors cannot sell more than one animal at the auction. Consequently, an exhibitor who wins fifth place steer and tenth place chickens is likely to withdraw the chicken entry because of expected auction prices even considering the market price of the non-auctioned animal. The grand champion animal of each type is auctioned first followed by the reserve champion and so on until the last place animals are auctioned at the end. For a given place, animals are auctioned in the following order: steers, barrows, lambs, chickens, and rabbits. With the exception of steers, the entire fifteen place categories have always been filled; however, in some years there has been insufficient participants in the steer contest to fill all fifteen places. The livestock auction is open to the public; buyers of animals generally come from the county. Individuals, businesses, and groups also participate in the bidding. General observation of the auction indicates that bidding can intensify near the end of the auction. Consequently, the price received for last place animals is often higher than previous places.

DEVELOPMENT OF THE MODEL

Given the differences of the current scenario from many economic frameworks, coupled with the estimation of prices as a function of characteristic attributes, it seems that a qualitative characteristics price determination framework is an appropriate method for analysis. The traditional qualitative framework which focuses on characteristics of the good being sold (represented by placement variables in this model) can be modified to include attributes of the buyer and the seller. Given the background information provided, several variables can be included in the model. Under a hedonic modeling framework, inclusion of factors measuring the attributes of the product sold is essential. For the youth fair auction, this is largely comprised of the type of animal sold (represented herein by five different models) and by placement (i.e., ordinal ranking) of the animal with prices declining from first through fifteenth place. Heated bidding for grand champion (first place), reserve champion (second place), and last place (usually 15th place) may also deserve special attention as they would be expected to raise prices in excess of what a placement variable may capture. Accounting for these places separately is necessary because, unlike most single place alterations, effects of going from second to first, for example, is different from going from 11th to 10th place. Performance of the general economy, weather, fair advertisements, and other factors can potentially influence the general level of auction prices from year to year.

The exhibitor's age, town of residence, youth group affiliation (4-H or FFA), sex, race, and town of residence relative to the buyer could affect prices. Individual buyers who are white collar professionals may offer prices different from businesses or groups of individuals. Residence of buyers may also affect prices, particularly whether or not the exhibitor is from the same town. Other components such as buyer's relationship to exhibitor, political power of exhibitor's family, goodwill, and philanthropic desires are not directly considered due to inability of collecting the data or measuring and modeling these factors. Buyer and seller characteristics are necessary model variables for satisfying the study objective but directional influences are not hypothesized given a lack of theoretical basis for doing so. A mathematical description (with hypothesized signs for place variables provided parenthetically below the variable) of each of the five models is:

$$P = \beta_o + \beta_1 PL_{(-)} + \beta_2 A + \beta_3 TA + \beta_4 4H + \beta_5 M + \beta_6 R + \beta_7 BP + \beta_8 BG + \beta_9 BB + \beta_{10} BA + \beta_{11} BO + \beta_{12} ST + \beta_{13} Y88 + \beta_{14} Y89 + \beta_{15} Y90 + \beta_{16} GC_{(+)} + \beta_{17} RC_{(+)} + \beta_{18} LP_{(+)} + \epsilon$$

where:

P = Price of animal (final bid)
PL = Placement of animal (1 through 15)
A = Age of exhibitor
TA = Binary variable of value 1 for Town A exhibitors, 0 otherwise
4H = Binary variable of value 1 for 4H exhibitors, 0 otherwise
M = Binary variable of value 1 for male exhibitors, 0 otherwise
R = Binary variable of value 1 for non-caucasian exhibitors, 0 otherwise
BP = Binary variable of value 1 for individual buyers who are white collar professionals, 0 otherwise
BG = Binary variable of value 1 for buyers who are in groups, 0 otherwise
BB = Binary variable of value 1 for individual buyers who are businesses, 0 otherwise
BA = Binary variable of value 1 for buyers who are from Town A, 0 otherwise

BO	=	Binary variable of value 1 for buyers who are outside of the county, 0 otherwise
ST	=	Binary variable of value 1 when buyer and exhibitor are residents of the same town, 0 otherwise
Y88	=	Binary variable of value 1 for 1988, 0 otherwise
Y89	=	Binary variable of value 1 for 1989, 0 otherwise
Y90	=	Binary variable of value 1 for 1990, 0 otherwise
GC	=	Binary variable of value 1 for the grand champion (1st place), 0 otherwise
RC	=	Binary variable of value 1 for the reserve champion (2nd place), 0 otherwise
LP	=	Binary variable of value 1 for the last place animal, 0 otherwise

Data were obtained from the fair association for all five animal categories from 1987 through 1990 (Table 1). Data include the prices received for the animal, the age,residence, sex and the race of the exhibitor, the placement of the animal, and the type and residence of the buyer. The average auction price for animals trended downward from the order in which they are auctioned: steers at $2633, barrows at $1586, lambs at $1339, chickens at $1063, and rabbits at $953. Maximum values and standard deviations followed the same trend. Minimum values parallelled this trend but with equal values of $850 being observed for barrows and lambs while chickens and rabbits both displayed a $500 minimum value. The average age of exhibitors selling at the auction was highest for steers and lowest for chickens. The average age for exhibitors selling in the lamb auction was higher than for barrows, but both barrows and lambs had higher seller age than rabbits. Town A exhibitors comprised 76% of the steers sold, 65% of barrows and lambs sold, 60% of chickens, and 50% of rabbits. Since all exhibitors must reside within the county, all other exhibitors were from the only other town in the county (Town B). The 4-H Club comprised 41% of steers auctioned, 55% of barrows, 50% of lambs, 90% of chickens, and 80% of rabbits, dominating the smaller livestock categories. Males sold 88% of steers auctioned while females sold 50% of lambs. Both chicken and rabbit sales were 40% attributed to female exhibitors while barrows were sold by 55% male exhibitors. Non-caucasian exhibitors sold the largest proportion in barrows at 13% with 12% selling steers, 8% chickens, and 5% lambs and rabbits.

Buyers are categorized as individual professional white collar workers, individual blue collar workers, individual businesses, or buyer groups. Buyer groups are defined as more than one individual or entity uniting for the purchase of an animal. Professional white collar buyers were most predominant in the chicken auction at 8% while buyer groups represented 48% of the purchases of chickens auctioned. Buyer groups represented about 40%-43% for the remaining animal categories with the exception of barrows where buyer groups purchased about 32% of the animals sold. Businesses bought 50% of barrow; 45% of rabbit; 43% of lamb; representing the largest purchasing category in these markets. Furthermore, businesses bought 33% of steers and about 32% of chickens. Town A provided the major portion of buyers ranging from 63% for rabbits to 81% for steers. While exhibitors were all from either Town A or B, buyers were not. Buyers from outside of the county purchased 13% of lambs and 5% of steers. Given the larger population of Town A, the greater purchasing by entities from this area and placement by students from Town A was not unexpected. Furthermore, the buyer and seller of livestock auctioned at the fair were from the same town approximately 67% of the time.

Table 1. Descriptive Summary Statistics of the County Fair, by Animal Type.

		Steer	Barrow	Lamb	Chicken	Rabbit
Number of Observations		42	60	60	60	60
Price	- Minimum	1400	850	850	500	500
	- Maximum	8000	4500	3600	2500	2000
	- Mean	2633	1585	1338	1062	953
	- Standard Deviation	1455	646	552	367	296
Age	- Minimum	9	8	9	8	8
	- Maximum	19	19	19	19	18
	- Mean	15	14	14	12	13
	- Standard Deviation	3	3	3	3	3
TA	- percent	76	65	65	60	50
4H	- percent	40	55	50	90	80
M	- percent	88	73	50	60	60
R	- percent	12	13	5	8	5
BP	- percent	5	3	3	8	5
BG	- percent	43	32	42	48	40
BB	- percent	33	50	43	32	45
BA	- percent	81	72	72	65	63
BO	- percent	5	8	13	10	7
ST	- percent	67	67	62	70	63

Legend:
Price = Price of animal (final bid)
Age = Age of exhibitor
TA = Binary variable of value 1 for Town A exhibitors, 0 otherwise
4H = Binary variable of value 1 for 4-H exhibitors, 0 otherwise
M = Binary variable of value 1 for male exhibitors, 0 otherwise
R = Binary variable of value 1 for non-caucasian exhibitors, 0 otherwise
BP = Binary variable of value 1 for individual buyers who are white collar professionals, 0 otherwise
BG = Binary variable of value 1 for buyers who are in groups, 0 otherwise
BB = Binary variable of value 1 for individual buyers who are businesses, 0 otherwise
BA = Binary variable of value 1 for buyers who are from Town A, 0 otherwise
BO = Binary variable of value 1 for buyers who are outside of the county, 0 otherwise
ST = Binary variable of value 1 when buyer and exhibitor are residents of the same town, 0 otherwise

RESULTS AND ANALYSIS

Linear regression was performed on all five models using Ordinary Least Squares (OLS) (Table 2). Overall the models seemed to perform acceptably with F-values ranging from 3.3 for the rabbit model to 11.6 for the lamb model. The models were significant at the 0.0001 or greater significance level. Unless specified, significance is defined for the 0.05 level. Adjusted coefficients of determination (R^2) indicated that from 41% to 83% of the variation in prices was explainable by the factors considered.

The estimate for the grand champion dummy variable was positive and highly significant (0.0005 or greater significance level) for all models considered. The intercept was statistically significant at the 0.05 level for the lamb, chicken, and rabbit auctions. Additionally, the last place dummy variable was significant for both the rabbit model and for the lamb model, where the reserve champion variable was also statistically significant. With the exception of 1990 for the steer and barrow

Table 2. Regression Results (Ordinary Least Square), by Animal Type.

	Steer	Barrow	Lamb	Chicken	Rabbit
F-value	11	8	12	43	3
R^2	0.91	0.79	0.84	0.63	0.59
Adjusted R^2	0.83	0.69	0.77	0.47	0.41
Beta Values and Standard Errors†					
Intercept	2159.12 1560.67	876.37 633.97	2086.06* 362.54	1039.32* 338.73	779.12* 298.51
PL	-34.70 39.90	6.95 16.77	-0.61 14.39	-5.47 11.96	-5.21 10.02
A	40.15 79.99	23.33 31.30	-27.36 18.61	15.43 14.61	1.52 14.41
TA	-476.59 330.08	-60.47 154.67	21.20 126.62	-3.73 123.54	-105.55 94.90
4H	292.74 465.15	47.45 201.14	-39.95 105.03	-103.46 141.92	-88.25 111.19
M	-265.10 448.61	44.05 139.97	136.44 89.91	-28.14 87.48	4.24 70.48
R	-494.10 432.48	-437.94* 184.03	-89.92 301.30	-155.26 147.48	-39.13 164.12
BP	97.91 601.00	465.13 339.66	102.41 272.08	74.58 202.94	191.57 190.78
BG	-328.88 341.38	-130.89 173.65	-544.63* 142.89	-244.34 150.13	22.72 120.96
BB	-456.25 339.85	33.27 163.61	-505.40* 134.20	-131.06 148.50	-9.11 119.73
BA	-217.57 350.73	25.98 150.97	-16.50 126.81	178.01 127.50	48.69 103.66
BO	-609.12 831.50	253.70 242.18	-286.88 221.68	126.03 216.54	91.72 177.92
ST	271.38 343.09	0.69 144.69	-151.60 125.24	-74.84 115.16	199.68* 98.88
Y88	504.59 295.05	2.15 158.49	69.20 109.67	-11.91 109.45	183.91 100.26
Y89	383.91 465.62	100.76 159.00	-145.24 108.27	-92.39 110.99	8.13 93.27
Y90	1026.73* 283.08	415.59* 160.20	34.36 114.26	45.23 111.56	-7.82 88.54
GC	4141.84* 411.01	1932.30* 266.09	1496.38* 205.50	763.79* 197.77	713.44* 156.26
RC	609.13 417.25	393.60 275.53	679.40* 172.82	248.78 163.19	243.93 147.85
LP	334.79 435.42	483.49 260.12	564.09* 181.50	273.73 174.45	464.00* 172.02

†See table 1 for legend. Standard Errors are reported below Beta estimates.
*Significant at the $\alpha=0.05$ level.

models, the auction year did not influence many price levels. The buyer group and business classifications of purchasers seemed to pay less for lambs than individuals.

Of all exhibitor attributes analyzed, only race was significant. Non-caucasians exhibiting barrows received less than their caucasian counterparts. The only other significant finding was that a higher amount was paid to exhibitors of the same town as the purchaser for the rabbit auction. Contrary to expected results, the continuous variable for placing was not significant in any of the models. Additionally, the estimate was different than the hypothesized sign for the barrow model. However, the signs associated with the grand champion, reserve champion, and last place dummy variables were all positive as expected. All models display a positive intercept. Other variables which displayed a like directional influence across all five models were race and professional white collar buyers. Consequently, in all cases non-white exhibitors did not receive prices equivalent to their white counterparts. However, caution is given with interpretation to this finding for two reasons. First, the non-caucasian binary variable was statistically significant in only one of the five models (barrows). Secondly, there are few observations for non-white exhibitors ranging from 8 for the barrow market to only 2 for the steer market. Sufficient data for non-white sellers may not have been present to indicate statistical significance for the race indicator variable in models other than the barrow market.

Given the models' overall successful performance coupled with a lack of many significant parameters, the likelihood of degrading multicollinearity comes into question. There is also reason to believe that individual independent variables are highly correlated, especially age and membership in 4-H versus FFA since only high school students can participate in FFA. Since degrading multicollinearity is a data problem rather than a model formulation problem (excepting the dummy variable trap of a perfect identity), empirical investigation based on the original models is needed. Consequent observation of correlation matrices, eigen-values, variance inflation factors, condition indices, and variance decomposition proportions indicated that degrading multicollinearity was a distinct possibility in each model. Ridge regression was used to correct for multicollinearity and experiments conducted to determine the sensitivity of results to alterations in the ridge coefficient by using a ridge trace. Correcting for multicollinearity by larger sampling is not an option because of limited data and exclusion of additional variables is unjustified theoretically and precludes the empirical investigation of influences attributable to omitted variables. Ridge regression is used for these reasons to permit trading of a little bias in parameter estimates for a substantive decrease in variance of parameter estimates and to allow analysis of the implications of multicollinearity to the problem at hand. Qualitative results under ridge regression were similar to those provided by OLS in that few additional variables become significant under asymptotic T-values or changed signs. Notable exceptions to the largely paralleling results to linear regression include the reversal of the directional movement for the placement variable in the barrow model to a negative relationship as expected. Other variables displaying an alteration in sign under ridge regression compared to OLS are given in Table 3. However, none of these variables were ever significant even under consideration of asymptotic T-values. Additional variables did become significant under consideration of the asymptotic T-values as follows: the placement variable (steer, lamb, chicken), the professional buyers variable (barrow, lamb), the buyers group variable (chicken), the Town A buyers variable (chicken), and the last place variable (barrow). Consequently, while ridge regression analysis displayed magnitudinal changes, signs associated with statistically significant parameters were unaltered from OLS results.

Concerns over whether or not the models were homoscedastic given the potential difference in the variance of errors associated with different placements were tested

Table 3. Ridge Regression Results (RR), by Animal Type.

	Steer	Barrow	Lamb	Chicken	Rabbit
	Beta Values and Standard Errors†				
Intercept	2434.93	1675.25	1734.81	1113.29	967.58
PL	-61.89*‡	-9.50¶	-14.22*‡	-8.71*‡	-6.45
	18.77	6.69	5.16	4.16	3.62
A	5.05	-6.29¶	-10.09	5.91	2.94
	26.48	9.39	8.58	6.45	5.38
TA	-50.15	32.36¶	-72.46¶	-10.02	-20.17
	186.38	61.14	49.57	36.47	31.34
4H	-29.75¶	-23.83¶	-72.60	-20.21	-57.05
	136.04	53.80	47.72	63.61	38.70
M	115.13¶	-0.65¶	-6.25¶	-24.51	-12.16¶
	314.58	71.39	50.41	39.19	34.33
R	-290.42	-245.85*	-108.14	-50.23	-76.63
	265.05	102.99	199.69	70.25	76.98
BP	121.50	484.54*‡	421.61*‡	65.90	68.55
	372.55	166.14	134.60	66.63	75.44
BG	69.41¶	-112.01	-98.14*	-98.87*‡	5.10
	147.82	60.55	44.77	33.08	29.81
BB	-125.36	0.74	-125.88*	-44.19	14.33¶
	161.44	55.72	44.55	36.88	29.20
BA	105.40¶	-12.72¶	9.99¶	80.10*‡	-21.43¶
	209.52	64.24	53.27	37.25	32.03
BO	-109.73	87.81	13.35¶	8.84	-13.87¶
	520.32	106.22	61.96	57.58	64.25
ST	187.41	5.67	-76.47	-78.78	32.16¶
	165.05	61.74	48.01	40.17	32.48
Y88	26.08	-37.99‡	35.80	7.35¶	58.70
	179.97	69.70	56.24	43.25	36.80
Y89	139.75	13.85	-80.73	-26.87	-2.14¶
	264.87	67.29	58.09	42.94	-37.31
Y90	413.82*	173.53*	36.23	36.05	-22.83
	182.91	66.49	55.26	43.09	38.00
GC	1826.43*	835.86*	614.65*	399.05*	314.75*
	271.35	117.96	95.39	75.53	65.79
RC	131.95	105.81	249.06*	94.50	96.58
	270.61	138.29	100.07	77.79	66.63
LP	25.67	241.88*‡	261.92*	111.32	182.52*
	267.93	118.30	98.12	76.38	63.21

* - Significant at the $\alpha = 0.05$ level for asymptotic T-values.

† - See Table 1 for legend. Standard errors are reported below Beta estimates.

‡ - Variable is significant (asymptotically) under ridge regression but not ordinary least square.

§ - Variable is significant under ordinary least square but not ridge regression.

¶ - Variable possesses different signs under ridge regression and ordinary least square.

using the Goldfeld-Quandt test and the Park-Glejser test (Kennedy, 1987). The Goldfeld-Quandt test provided indication that at the 0.05 significance level heteroscedasticity existed in the barrow model. Additionally, the Park-Glejser test provided evidence that at the 0.05 level of significance, the steer, lamb, and rabbit models displayed heteroscedasticity. Given these test results, Weighted Least Squares (WLS) was performed on all five models. The weights were calculated from the regressions used to conduct the Park-Glejser test by taking the parameter estimate of the log of the placement variable regressed as an independent variable to the log of the error terms. Transformations were based on these parameter estimates and yielded results not unlike those of standard OLS.

While the magnitudes were altered, the directional relationships remained unaffected under WLS as did the significance of most variables (Table 4). However, parameter estimates for some additional variables did become significant under the performance of weighted linear regression: the intercept, Town A exhibitor, and race variables for the steer model; the last place variable for the barrow model; the professional buyers variable for the lamb model; the last place variable for the chicken model; and no additional significant variables for the rabbit model. The same town variable did become insignificant for the rabbit model under WLS.

Linear regression (OLS) was used to examine the possibilities of autocorrelation when ordered by the placement variable. The Durbin-Watson test for autocorrelation indicated that no model possessed problems of autocorrelation. However, the Durbin-Watson test results fell within the range which is inconclusive. Disturbances terms were therefore considered not to be unduly correlated.

The need for the use of SUR (Seemingly Unrelated Regression) as a result of correlated disturbance terms was examined by regressing each model's error term against all remaining model errors. Only the steer and lamb models demonstrated statistical significant correlation of error terms at the 0.05 level. Application of SUR techniques to these two models did not substantively change the results although the magnitudes of parameter estimates differed. The steer model experienced a change in the sign on the professional buyer indicator variable but it remained insignificant. The lamb model displayed a change in parameter signs for the professional buyer, 1988, and 1990 variables but these remained insignificant with the last place variable retaining positive effects but becoming insignificant. Statistical significance of all other variables remained unaltered for both models.

Determination of whether exhibitor attributes and the buyer characteristics cause significant influences upon the prices received for the livestock auctioned can be accomplished by conducting an F-drop test with a reduced model. This is done by comparing the full model with a reduced model in which the dependent price variable is predicted as a function of the following independent variables: placement, grand champion, reserve champion, and last place. Reduced model regression results by animal type are recorded in Table 5. All of the five models still perform favorably overall as indicated by the F-value and adjusted coefficient of determination (R^2). The intercept and grand champion variables are statistically significant and positive for every model. Additionally, the last place variable was statistically significant and positive for the lamb and rabbit models. The reserve champion variable was positive for each of the five models but was not significant. The placement variable was not significant in any of the models and was negative as expected in all models except the barrow model, paralleling results for the full models. All estimates were signed as expected with this exception.

To test whether any of the variables removed from the full model were significant, an F-test was used. The null hypothesis that all parameter estimates dropped from the model are equivalent to zero is tested against the alternative that at least one of the parameter estimates is nonzero. There was no statistical evidence to support the

Table 4. Weighted Regression Results (Weighted Least Square), by Animal Type.

	Steer	Barrow	Lamb	Chicken	Rabbit
F-value	11.34	3.87	11.48	2.04	2.97
R^2	0.91	0.64	0.84	0.47	0.57
Adjusted R^2	0.83	0.47	0.77	0.24	0.37
Beta Values and Standard Errors†					
Intercept	2612.78*‡	728.74	2035.66*	948.57*	933.14*
	852.56	685.74	295.08	309.85	269.29
PL	-39.37	5.88	-3.87	-6.81	-6.71
	22.27	17.77	11.44	11.41	8.93
A	7.10	26.75	-10.05	11.59	0.56
	45.73	34.01	14.49	14.23	12.33
TA	-452.88*‡	-22.75	75.98	31.99	-65.62
	174.52	153.69	124.07	113.58	82.65
4H	147.93	71.34	-11.38	-175.33	-87.96
	300.47	216.15	85.57	126.75	97.03
M	-205.71	93.42	53.52	13.86	-20.14
	225.42	137.50	68.94	80.42	63.63
R	-479.39*‡	-393.31*	-136.43	-141.87	-19.12
	200.16	188.70	189.03	125.92	154.46
BP	291.93	110.49	637.81*‡	176.17	180.47
	353.72	437.36	208.71	195.51	159.38
BG	-106.15	-124.59	-663.87*	-152.23	6.82
	198.71	171.92	131.47	139.33	101.77
BB	-208.45	69.39	-662.97*	-60.59	-13.08
	191.28	168.82	130.58	134.53	104.38
BA	-226.11	57.80	-59.21	165.45	-37.28
	177.12	152.10	119.09	116.97	85.35
BO	-272.92	294.38	-360.05	204.51	-67.23
	427.77	232.76	222.32	203.89	147.71
ST	299.40	-74.15	-157.94	-25.91	116.06§
	197.20	139.86	118.17	110.80	83.23
Y88	243.42	26.10	-39.25	17.87	89.70
	147.28	161.43	90.90	103.46	90.76
Y89	436.44	128.59	-86.52	18.84	81.52
	387.63	156.21	87.31	111.17	84.78
Y90	847.09*	487.60*	87.81	100.57	-15.27
	171.34	161.83	100.09	106.70	80.16
GC	4009.92*	2017.67*	1263.69*	841.47*	696.38*
	496.87	432.87	369.48	287.96	222.85
RC	604.09	406.54	637.96*	245.40	264.13
	361.71	384.19	252.66	217.60	179.13
LP	311.18	549.56*‡	288.84*	319.95*‡	427.81*
	230.46	239.33	119.33	142.98	131.74

†See Table 1 for legend. Standard Errors are reported below Beta estimates. *Significant at the $\alpha = 0.05$ level.
‡Variable is significant under weighted least square but not ordinary least square.
§Variable is significant under Ordinary Least Square but not weighted least square.

claim that any of the estimates for the parameters dropped from the model were significantly different from zero for the steer, chicken, and rabbit models. However, there was statistical evidence to support the alternative hypothesis that at least one of the dropped variables was significantly different from zero for the barrow and lamb models (Table 5). Given the full model regression results for the barrow model, it seems likely that some combination of the race and 1990 year variables are important in the determination of barrow prices (Table 2). Likewise, some combination of buyer characteristics (specifically group and business categories) seems to be statistically influential in the determination of lamb prices at the fair. These results indicated that prices received in the county fair youth livestock auctions were relatively without prejudice and unaffected by the various exhibitors' sociological, demographic, and personal characteristics modeled. The results also provided reason to believe that the final bid price on animals was not significantly affected by the various buyer attributes analyzed excepting the lamb market (businesses and groups) and same town variable for the rabbit auction. While the overall pricing policy at the youth fair seemed to be largely unaffected by personal characteristics, a possible area for concern is relevant with regard to non-caucasian exhibitors, especially in the barrow contest. Other exhibitor characteristics including age, town of residence, agricultural organization affiliation, and sex were seemingly unrelated to the prices received, with no discernable pattern observed for these attributes. However, the race variable was consistently negative across all regression models. Prices received for non-caucasian exhibitors were consistently lower than for caucasians. Nonetheless, statistical significance was displayed only in the case of the race variable for the barrow auction.

Table 5. Reduced Model Regression Results, by Animal Type.

	Steer	Barrow	Lamb	Chicken	Rabbit
F-value	35.41	21.67	28.54	12.14	11.64
R^2	0.79	0.61	0.67	0.47	0.46
Adjusted R^2	0.77	0.58	0.65	0.43	0.42
Beta Values and Standard Errors†					
Intercept	2633.13*	1359.50*	1301.17*	1047.87*	918.97*
	300.97	159.99	125.09	106.38	86.66
PL	-70.43	4.15	-19.11	-9.92	-6.64
	37.19	17.44	13.63	11.60	9.44
GC	3862.30*	2011.35*	1480.44*	887.05	637.68*
	439.63	253.42	198.13	168.50	137.27
RC	632.73	444.70	599.55	246.97	219.32
	420.88	244.87	191.45	162.82	132.64
LP	331.35	440.72	772.96*	275.95	455.68
	389.45	244.87	191.45	162.82	132.64
F-drop value	1.88	2.33*	3.01*	1.32	0.97

†See Table 1 for legend. Standard Errors are reported below Beta estimates.
* Significant at the $\alpha = 0.05$ level.

SUMMARY AND CONCLUSIONS

The atypical economic environment of a county youth fair livestock auction was modeled using a qualitative characteristic framework. Regression models were used to analyze pricing policies of a county youth fair in Texas by examining both exhibitor characteristics (age, town of residence, agricultural organization affiliation, sex, and race) and buyer attributes (white collar professionals, groups, businesses, and blue collar individuals as well as geographical location and whether buyer and exhibitor are residents of the same town). Models were examined for each of the market livestock auctions: steer, barrow, lamb, chicken, and rabbit. Additional variables were included for placement of the animal, grand champion status, reserve champion status, last place status, and a dummy variable was incorporated for the year of the auction. The regression models performed well overall, but displayed problems of degrading multicollinearity and heteroscedasticity. Corrections for these conditions did not drastically alter the results. The use of an F-drop test conducted from comparisons of the full model to a reduced model showed that only in the case of the barrow and lamb auction did some exhibitor and buyer attributes influence prices with statistical significance. Race was the only exhibitor trait with a consistent sign across models. As the negative valued parameters demonstrate, non-caucasian exhibitors consistently received lower prices than their caucasian counterparts and significantly lower in the case of the barrow market auction. However, overall pricing was largely unaffected by buyer or exhibitor attributes.

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Impact of the 4-H After School Curriculum on Latch-key Children

Randall H. Williams*
Jeff W. Howard
Texas A&M University-Kingsville, Campus Box 156, Kingsville, TX 78363

ABSTRACT

Every day thousands of American children are left at home without adult supervision. Many working American parents cannot afford supervised day care. Their children, known as "latch-key children", often make poor use of their time after school. An early-morning variation of the "4-H After School Curriculum" was used to teach these children how to more effectively use their unsupervised time. Fifteen Cleburne Independent School District students participated in this project while attending Cleburne Community Education's Super Summer School. Ten 4-H members presented the curriculum over a 2-week period. A pre-event survey focusing on after-school supervision was given to the children in June 1992. In December 1992, a personal interview of a portion of the participants showed that none of the participants questioned had changed the way they used unsupervised time after school. However, 83% had changed their overall (supervised and unsupervised) snacking habits.

Care for school-age children is a national problem that affects more and more families each year. The increasing numbers of women in the work force, single parent families and dual wage earner families have resulted in a growing demand for child care for school-age children. Many young children are left unsupervised for extended periods of time because of the lack of caretakers, high costs, and changes in traditional family support structures. Children that are left alone for regular periods of time while their parents work are known as "latch-key" children. It is difficult to obtain an accurate count of latch-key children in Texas. The Texas Department of Human Services reports that 435,000 latch-key children is a conservative estimate of the number of children left alone daily in the state (TDHS, 1989). Nationally, the estimates range between 2 million and 15 million latch-key children. However, there are thousands of other "supervised" school-age children who are considered to be involved in activities that are not appropriate for their age and interest (Baker, 1990). Totals are sometimes underestimated because some parents feel guilty about leaving children unsupervised and consequently do not openly admit it. Others fear that children will be in danger if their latch-key status is known. Whether or not an exact count of latch-key children can be made, experts agree that we can expect the number of school-age children needing care to increase (Coolsen et al., 1985).

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THE LATCH-KEY SITUATION

There are several causes of the current latch-key situation. Single parent families, dual-working parents, and the large number of women now in their child bearing years, especially those in their 30s and 40s, who postponed marriage and childbirth (Calvi et al., 1989). Researchers indicate that families are now smaller and people are having fewer children. They also point out that grandparents are less likely to live with or near the family and in many cases are still in the work force themselves (EPC, 1982). These trends will affect the types of child care arrangements available to the modern family. Having fewer children who are spaced closer together reduces the likelihood of older children caring for siblings. Families are less likely to have other relatives living in the home to provide care. Smaller families also indicate mothers are more likely to be included in the work force (Calvi et al., 1989). The greatest change taking place in the structure of American households is the increase in the proportion of families supported by women. This can be attributed to increases in divorce rates, to increases in birth rates for unmarried women, and to the tendency for single mothers to set up their own home rather than to live with relatives. Today, over half of the mothers with children between the ages of 6 and 17 are working. According to the United States Department of Labor (Bureau of Labor Statistics, Southwest Regional Office, Austin, TX), these trends are expected to increase throughout the decade of the 1990s. There are several other factors contributing to the latch-key situation in America. Affordability is the most significant one. The ability or inability to pay for organized child care influences the decision of many parents to leave their children unattended. After shelter, food and taxes, child care is the fourth largest expense for families today. Many families spend more than 20% of their gross income for child care expenses (Calvi et al., 1989). The effects of unsupervised children are significant. Studies at major corporations have shown that the instability and poor quality of child care is one of the most significant predictors of ill health and stress of men and women with children (Calvi et al., 1989). Parents often experience increased worry and stress regarding their children who are supposed to be getting themselves to the proper location after school has been dismissed. This stress-related problem causes parents to perform less efficiently at work. Parents feel guilty because they cannot be at home with their children. The children will, of course, sense the stress felt by their parents. Communities are also affected by the problem of latch-key children. There will be more situations involving drug abuse, skipping school, vandalism, deliberately or accidently set fires, and other home-related accidents. Students are also unprepared in class because of the lost preparation time after school. These children are experiencing academic failure. The Texas Agricultural Extension Service has addressed this problem by writing and implementing the 4-H After School Curriculum. This curriculum was established for school systems to use in after school programs. The package includes information on establishing the project, recruiting volunteers, staffing and business decisions. The lesson plans are 20 minutes in length and include a list of all materials needed and the approximate cost. The 4-H After School Curriculum was piloted in several counties throughout the state. Through these pilot counties, the curriculum was tested and a final copy of the curriculum was written and distributed to the counties across the state.

METHODS

The purpose of this study was to determine the effectiveness and impact that the 4-H After School Curriculum had on students in relation to their unsupervised time spent after school and on their snacking habits. To determine the effectiveness of the program, the students were issued a pre-event survey and were asked questions in relation to their unsupervised time at home. A post-event survey was issued to determine if the children had used the material presented.

The eastern section of the Cleburne Independent School District is made up mostly of low income families where a great number of children are left alone while their parents work. This community had the potential to be strengthened by implementation of the 4-H After School Curriculum. In May 1992, Cleburne Community Education requested assistance with a summer project. Community Education was trying to establish Super Summer School, a summer program that the school children could elect to attend. Super Summer School would be held for 2 weeks during June. Classes would be offered in the sciences, computers, physical fitness, and other topics that would be interesting to children. The classes would begin at 9:30 a.m. and end at 3:00 p.m. The Super Summer School idea was well received by the community. A problem arose in that parents needed to drop their children off by 8:00 a.m. on their way to work. The 4-H After School Curriculum fit this situation very well as the lesson plans would be used for an hour and a half before the other classes started.

Every two days, the children had a different volunteer staff team made up of two 4-H members. Most of the activities were well received and the children enjoyed the hands-on activities. The curriculum included a lesson plan on maps. The children did not like sitting still and drawing maps. Consequently, this turned out to be a real problem. The children were easily bored, however they expected to be entertained during their one and a half hours. Fortunately, the majority of curriculum selected by the volunteer staff was hands-on type activities. The curriculum taught the children about the state of Texas, its land and its weather. Through the weather curriculum the children were encouraged to watch the news. Each child was responsible for obtaining the weather report from the evening news. Consequently, the children began discussing other events from the area and around the world that were discussed during the news broadcast.

Using the food curriculum, the children prepared nutritious snacks during their morning workshops. The snacks were simple and could be prepared without cooking or cutting. During preparation time, nutritional aspects of the snacks and how they contribute to the child's developing body were discussed. The students' response to this curriculum was very positive.

A wildlife curriculum was also used. One particular activity made the children much more aware of plants growing in their area. A list of plants that they had to find in a field was issued. The plants were species consumed by deer. The children learned the distance deer must travel to consume their daily diet. Other curricula were related to at-home activities so that the children could use them during their unsupervised time after school.

RESULTS

Overall, the at-school portion of the project was successful, as all of the material selected was adequately presented. However, coping with the students' attitudes and lack of discipline was a problem. Disruptions were common.

There were eight male and seven female participants in the program. There were three hispanics, one black and eleven white children. They came from varied economic backgrounds. Three were from very low income families.

Question 1 of the survey was: "Do all of the adults in your house work outside of the home?" Ninety percent of the children responding to Question 1 came from families where all of the adults worked outside of the home. Question 2 asked: "If yes, who do you normally stay with?" During the summer, 40% of the children stayed at a day care facility, 40% stayed with their grandparents, and 20% stayed at home with siblings. During the school year, 70% stayed home alone after school while their parents worked. The other 30% stayed with extended family members or in a day care facility. Question 3 asked: "Do you ever stay home alone while the adults are working?" Of the 70% that stayed alone after school, the time alone ranged from 30 minutes to 4 hours. Question 4 asked: "What do you normally do during your time alone?" One hundred percent indicated watching television or talking on the phone. No one indicated that their time was spent studying or doing homework.

In December six participants along with their parents were interviewed to determine the impact that the 4-H After School Curriculum had on the children. The children were asked: (1) How do you spend your time after-school before your care giver gets home? (2) Have your snacking habits changed since Super Summer School? and (3) Do you use any of the activities you learned during Super Summer School? Of the six students interviewed, all of them still watched television and talked on the phone after school. The parents indicated that they did not object to their children sitting and watching television because it was better than being out on the streets. Five of the six children (83%) indicated that they had changed their snacking habits and ate more nutritious foods after school. The parents were asked the similar questions as they related to their child. Two of the parents indicated that while the children did not think that they used what they had learned at summer school, they had noticed the children taking greater interest in the evening news. One father indicated that his son could explain the weather patterns as a result of the material presented to him the previous summer.

CONCLUSIONS AND RECOMMENDATIONS

If parents or other care givers are not with children, time after school is usually spent watching television or talking on the phone. While the parents may be pleased that the children are not on the streets, grades in school fall because of unsupervised time (Coolsen et al., 1985). Latch-key children are becoming a community problem as fires and other in-home accidents occur in latch-key households. It could be less expensive for the communities to help fund programs such as these rather than spend money repairing damaged property due to vandalism, or on juvenile probation, and correcting other problems attributed to unsupervised time after school. Through after school programs, inappropriate activities could decrease and school grades improve. Parents could be more at ease in the work place knowing that their children are being well cared for and are not engaged in activities that could harm them or others.

A future study is recommended to determine a more accurate impact on children participating in after school programs. A study with a greater number of children in an inner-city, low income neighborhood could give a better indication of the impact that the after school curriculum could have on a diverse audience. This study should be done over a 2 to 3 year period and involve parents or care givers as much as possible. If parents are involved from the start and have an interest in the program, chances of success are greater.

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Changes in Waterfowl and Wetland Abundance in the Chenier Plain of Texas 1970s-1990s

Thomas C. Tacha*
Ann M. Holzem
Darrin W. Bauer
Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Campus Box 218, Kingsville, Texas 78363

ABSTRACT

Trends in numbers of ten species of ducks were analyzed using data from 1976 to 1991 Midwinter Aerial Inventories for seven Texas Chenier Plain transects. Transects were also used as a sampling framework for wetland studies; black and white 1:20,000 aerial photos taken during 1964-66 and 1989-90 were analyzed to estimate changes in numbers and areas of wetlands by type. Ten species of ducks selectively ($P < 0.10$) used Zone A (coastal areas). Numbers of gadwalls (*Anas strepera*), mallards (*A. platyrhynchos*), mottled ducks (*A. fulvigula*), pintails (*A. acuta*), wigeons (*A. americana*), and total ducks declined ($P < 0.10$) during 1976-91. By 1991, numbers of total ducks had declined by 89% from peak populations in the late 1970s. Area of wetlands declined 16% (42,000 ha) between 1964-66 and 1989-90. Major losses occurred in Estuarine Intertidal Emergent (17,000 ha) and Palustrine Emergent Farmed (rice) (50,000 ha) wetlands. Many of these losses were by conversion to open water Palustrine Unconsolidated Bottom (8,000 ha), Lacustrine Limnetic (2,400 ha), and/or diked/impounded/excavated (19,000 ha) wetlands. Losses and degradations appeared primarily in coastal Zone A, and appeared highly associated with declining duck numbers. Management efforts should emphasize halting soil subsidence and saltwater intrusion; and the restoration, enhancement, and/or acquisition of Estuarine and Palustrine Emergent wetlands in Zone A.

KEYWORDS: ducks, Gulf Coast

The Monitoring, Evaluation, and Research Team (MERT) of the Gulf Coast Joint Venture (GCJV) of the North American Waterfowl Management Plan (NAWMP) identified as a priority the need to evaluate losses of various kinds of wetlands in Louisiana and Texas since the early 1970s (MERT meetings, 19 July 1990). This information would aid the MERT in setting habitat objectives for the GCJV by identifying wetland types most seriously impacted since the NAWMP baseline period of the early 1970s.

Wetland losses in the Chenier Plain of Louisiana and Texas were documented from 1952 to 1974 by Gosselink et al., (1979). Over the 22-year period, there was a net loss of nearly 44,000 ha of vegetated wetlands in the Chenier Plain of both

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states, with nearly 68% of the loss to open water. Losses and changes in wetlands in Texas have not been quantified since the early 1970s.

The objectives of this study were to (1) estimate losses and changes in various types of wetlands in the Chenier Plain of Texas since the early 1970s; (2) evaluate changes in relative abundance, species composition, and distributions of waterfowl in the Chenier Plain of Texas since the mid 1970s; (3) relate changes in waterfowl distribution to changes in wetlands within and among zones in the Chenier Plain of Texas; and (4) to develop draft priorities for wetland habitat conservation in the Chenier Plain of Texas.

STUDY AREA

The 2.6-million-ha Chenier Plain Initiative area extends 60-100 km inland from the Gulf of Mexico between Vermillion Bay in Louisiana and Galveston Bay in Texas (Chenier Plain Initiative Team 1990). The Chenier Plain Initiative area in Texas includes all of Chambers, Jefferson, Liberty, and Orange counties; encompassing Texas portions of the Chenier Plain Coastal Ecosystem (Gosselink et al., 1979) plus considerable areas of more interior agricultural lands.

The Chenier Plain Initiative area of Texas (hereafter referred to as Texas Initiative area) has a warm, humid climate with mean annual precipitation of 112 cm near Galveston Bay to about 125 cm near the Louisiana border (Chenier Plain Initiative Team, 1979). Soils are the product of sedimentation from rivers and the Gulf. Beach ridges parallel to the coast (cheniers) were formed by Gulf water currents. From the coast inland, a typical cross section currently contains beaches, cheniers, extensive estuarine to fresh water wetlands, and uplands. Interior upland sites in Texas are dominated by rice fields, while both coastal marsh and interior uplands are commonly used for cattle grazing.

Our 450,000-ha study area included the more coastal 85% of the Texas Initiative area (Fig. 1). Coastal Zone A (229,000 ha) contains most of the Texas parts of the Chenier Plain Coastal Ecosystem dominated by coastal marsh, while inland Zone B (221,000 ha) is dominated by more upland agricultural lands.

METHODS

Waterfowl Data

Midwinter aerial transect surveys have been conducted annually in the Chenier Plain Initiative area of Texas (Fig. 1) since 1976. We computerized waterfowl estimates for Zones A and B of the Texas Chenier Plain as reported by Haskins (1991). Estimates of numbers of 10 species of ducks, and the sum of these numbers (total ducks), were available for each zone (Texas Chenier Plain Zones A and B) and each year except 1979. The 10 duck species included in these survey results were canvasback (*Aythya valisineria*), gadwall, green-winged teal (*Anas crecca*), common mallard, mottled duck, northern pintail, redhead (*Aythya americana*), lesser scaup (*Aythya affinis*), northern shoveler (*Anas clypeata*), and American wigeon.

Midwinter inventories were conducted in early to mid-January each year by flying transects at a standardized altitude and speed in a fixed-wing aircraft (Haskins, 1991), and recording numbers of ducks observed within 200 m (220 yards) on either side of the aircraft. These raw numbers were then expanded to reflect numbers of ducks in each zone by multiplying the raw numbers by a factor representing the ratio of the area in each zone to the area surveyed in each zone. The expansion multiplier was 31.66 for Zone A, and 47.52 for Zone B.

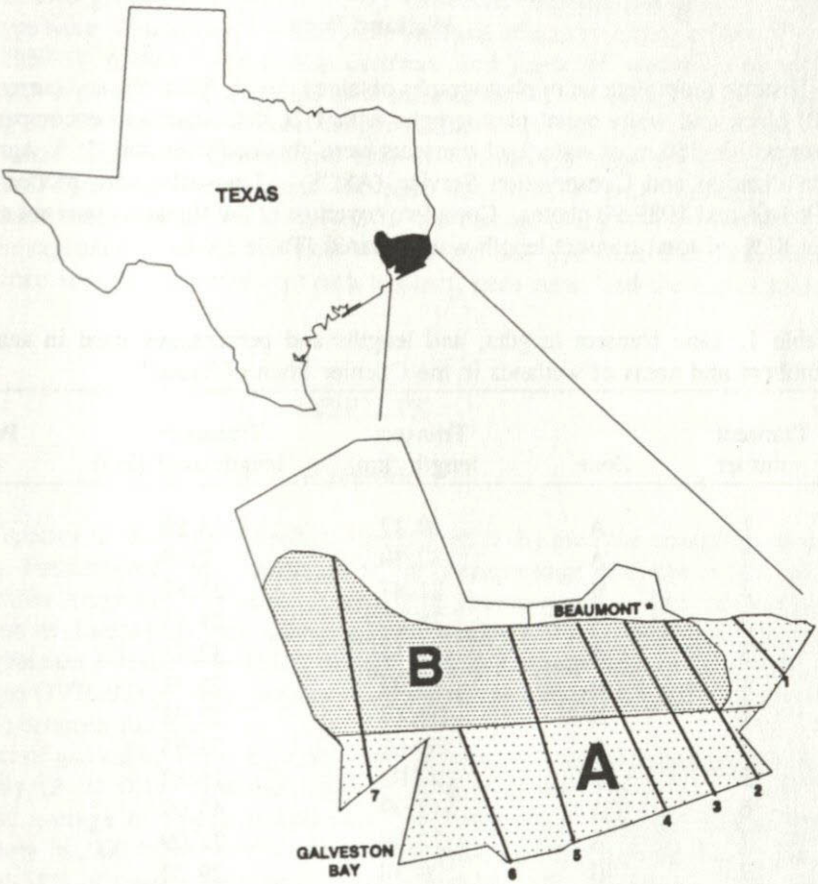

Fig. 1. January waterfowl survey transects and zones in the Chenier Plain of Texas.

Statistical analyses were conducted using the Statistical Analysis System (SAS Institute, 1985). Average proportions of ducks (by species) occurring in Zones A versus B were compared with Z tests to document waterfowl distribution. Estimated numbers of each species and total duck numbers were subjected to simple linear regression analyses (PROC REG of SAS) to delineate significant trends among years (1976-91) for each zone and zones combined. This approach was conservative because of the highly variable estimates of duck numbers that can occur due to variable weather conditions at the time of January surveys, and did not allow particularly low estimates in any one year to bias analyses. For species with significant ($P < 0.10$) trends, average annual rate of change in numbers (regression slope) and percent ($\bar{x}$ number change/year divided by $\bar{x}$ number observed across all years) were calculated; the overall percentage change (of lowest number/highest number X 100) was also calculated.

Wetland Data

Historic (complete set of photographs obtained during 1964-66) and current (1989-90) black and white aerial photographs with 1:20,000 scale and encompassing the area within 250 m of waterfowl transects were obtained from the U. S. Agricultural Stabilization and Conservation Service (ASCS). Transects were plotted on both 1964-66 and 1989-90 photos. Complete coverage of the transects was not available, but 81% of total transect length was acquired (Table 1).

Table 1. Line transect lengths, and lengths and percentages used in analyses of numbers and areas of wetlands in the Chenier Plain of Texas[†].

Transect number	Zone	Transect length (km)	Transect length used (km)	Percent used
1	A	29.87	15.85	53
2	A	32.30	7.19	22
2	B	21.87	21.87	100
3	A	25.71	21.93	85
3	A	32.11	32.11	100
4	A	28.08	25.71	92
4	B	31.13	29.63	95
5	A	39.60	28.95	73
5	B	27.02	16.32	60
6	A	43.99	43.99	100
7	A	22.09	22.09	100
7	B	29.30	29.30	100
Total or average		363.07	294.94	81

[†]Only those parts of transects for which both 1964-66 and 1989-90 aerial photos were available could be used.

Transect lines were flown in a Cessna 182 fixed-wing aircraft (equipped with a Loran Navigation System) at 305 m (1000 feet) above ground level at 100 km hr^{-1} during 26-29 May 1992. All wetlands within 250 m of transect lines were identified on 1989-90 photos, and classified according to Cowardin et al. (1979) with as much detail as possible. Subsequent analyses comparing wetland images on 1989-90 photos allowed delineation of wetlands on 1964-66 photos using the same level of detail in classification. In identifying wetlands on both 1989-90 and 1964-66 photos, only areas showing water or hydrophytic vegetation were considered wetlands; dry wetland basins were not considered wetlands because we could not identify them. Fortunately, conditions at the time of our 1992 aerial surveys, and at the times of all aerial photography, were relatively wet.

Numbers and area of wetlands by type were quantified from surveyed portions of both 1964-66 and 1989-90 photos using an electronic digitizer capable of recording 0.1 ha wetlands given the 1:20,000 scale. Observed numbers and areas of each wetland type were summarized for each zone segment of each transect on both 1964-66 and 1989-90 photos. Observed numbers and areas of wetlands in each zone/transect segment were analyzed in a manner similar to waterfowl data, but accounting for both reduced transect length (Table 1) and the ratio of sampled to available area. Expanded 1964-66 and 1989-90 estimates of numbers and area of each wetland type were summarized for each zone area of each transect, each transect, each zone, and the entire study area. Percentage changes from 1964-66 to 1989-90 in expanded numbers and areas of each wetland type were then calculated for each zone area of each transect, each transect, each zone, and the entire study area.

RESULTS

Waterfowl

All ten species of ducks selectively (Z-tests, $P < 0.01$) used the coastal Zone A (Table 2). Furthermore, the distribution of ducks (percentage of ducks in Zone A) did not differ (regression F-tests, $P > 0.10$) among years. The percentage composition of ducks (e.g., percentage of total ducks that were mallards) did not differ (regression F-tests, $P > 0.10$) among years in the study area or either zone. The average (1976-91) percentage composition of ducks also did not differ (Z-tests, $P > 0.10$) between the zones.

Numbers of gadwalls, mallards, mottled ducks, pintails, wigeons, and total ducks significantly ($P < 0.10$) declined between 1976 and 1991 (Table 3). Pintails declined an average of nearly 16,000 $year^{-1}$, and total ducks declined an average 7.8% (nearly 30,000 birds $year^{-1}$). Overall, numbers of ducks in the study area declined to 11% of peak populations between 1976 and 1991 (Table 3). Only 1% of peak wigeon, 2% of peak pintail, and 5% of peak mallard numbers were present in 1991.

These declines in duck numbers were almost entirely due to declines in Zone A (Table 3). Gadwalls, mallards, mottled ducks, and wigeon significantly ($P < 0.10$) declined in Zone A, while no declines in duck numbers ($P > 0.10$) were detected in Zone B.

Table 2. Average percentages[†] of ducks in Zone A estimated in the Chenier Plain of Texas in January 1976-91.

Species	% in Zone A	Species	% in Zone A
Canvasback	96.4	Pintail	73.9
Gadwall	95.2	Redhead	99.7
Green-winged teal	84.3	Scaup	98.5
Mallard	86.5	Shoveler	72.4
Mottled duck	81.7	Wigeon	96.7
Total ducks	82.5		

[†]Percentages did not change 1976-91, $P > 0.10$.

Table 3. Significant ($P < 0.10$) simple linear regressions showing declines in numbers of ducks in January in the Chenier Plain of Texas 1976-91[†].

Zones[‡]/Variable	F - value[§]	P	$\bar{x}$ change year^{-1} No.	$\bar{x}$ change year^{-1} %[¶]	Overall % decline[#]
Combined zones					
Gadwall	18.4	0.001	-4,724	-10.2	90
Mallard	15.9	0.002	-1,221	-8.7	95
Mottled duck	29.8	0.001	-666	-7.6	74
Pintail	3.9	0.072	-15,925	-11.3	98
Wigeon	3.7	0.079	-1,263	-14.7	99
Total ducks	5.5	0.036	-29,677	-7.8	89
Zone A					
Gadwall	20.9	0.001	-4,886	-11.1	90
Mallard	18.5	0.001	-1,167	-9.6	95
Mottled duck	40.2	0.001	-699	-9.9	77
Wigeon	3.2	0.099	-1,198	-14.4	99

[†]No data were available for 1979.
[‡]No significant ($P > 0.10$) changes occurred 1976-91 in Zone B.
[§]df = 1, 12 for all tests.
[¶]% = $\bar{x}$ number change/year divided by $\bar{x}$ number observed in all years. This is a rate-of-change estimate and not a percentage of peak population numbers that would eventually reach zero.
[#]Percentage change from peak estimates 1976-91; lowest estimates for all species occurred in 1991.

Wetlands

The number of wetlands in the study area declined 12% between 1964-66 and 1989-90 (Table 4). Area of wetlands declined 16% over the same period, from 269,128 ha to 226,887 ha. Nearly 16,000 ha (24%) of Estuarine wetlands were lost or altered, including 49% of Aquatic Bed and 31% of Emergent Intertidal Estuarine wetlands. Estuarine Subtidal Unconsolidated Bottom wetlands increased 69%. Nearly 20,000 ha (15%) of Palustrine wetlands were lost, including 13% of Aquatic Bed and 18% of Emergent classes. Area of Palustrine Emergent diked/impounded, and Palustrine Unconsolidated Bottom wetlands increased 166% and 754%, respectively. Area of Riverine wetlands changed little overall, although area of excavated Riverine wetlands increased 40%. Area of Lacustrine wetlands increased 37%, from 6,226 ha to 8,498 ha. Area of shallow Lacustrine Littoral wetlands declined 17%, while deeper Lacustrine Limnetic wetlands (particularly diked/impounded areas) increased 45%.

The most significant changes in numbers and areas of wetlands occurred in Zone A (Tacha et al., 1992:tables 5,6). In Zone A, declines in area of valuable Estuarine Intertidal, Palustrine, and Lacustrine Littoral wetlands, and increases in generally poorer quality diked/impounded and Unconsolidated Bottom wetlands, follow changes for the entire study area. Flooded rice fields declined in both zones, but a nearly 50% decline occurred in Zone A.

Table 4. Numbers and areas of wetlands in the Chenier Plain of Texas 1964-66 and 1989-90 (wetland classification from Cowardin et al., 1979).

System Subsystem Class Subclass	Numbers[†] 1964-66	Numbers[†] 1989-90	Numbers[†] % change	Area (ha) 1964-66	Area (ha) 1989-90	Area (ha) % change
Estuarine	2,908	3,656	+26	67,989	51,916	−24
Intertidal	2,207	2,650	+21	66,089	48,708	−26
Aquatic bed	312	234	−25	1,320	668	−49
Emergent	791	1,061	+34	55,991	38,854	−31
Uncon. shore	1,104	1,355	+23	8,777	9,186	+5
Diked/impnd	30	30	0	639	590	−8
Subtidal	701	1,006	+44	1,901	3,207	+69
Uncon. bottom	701	1,006	+44	1,901	3,207	+69
Excavated	481	686	+43	1,326	2,987	+25
Lacustrine	483	507	+5	6,226	8,498	+37
Limnetic	368	392	+7	5,362	7,781	+45
Aquatic bed	115	170	+48	2,591	3,191	+23
Diked/impnd	0	55	+++	0	1,041	+++
Uncon. bottom	253	222	−12	2,771	4,590	+66
Diked/impnd	35	127	+263	194	4,252	+2,092
Littoral	115	115	0	863	717	−17
Aquatic bed	115	115	0	863	717	−17
Palustrine	16,257	13,072	−20	188,370	159,928	−15
Aquatic bed	416	746	+79	888	777	−13
Diked/impnd	30	25	−17	22	5	−77
Emergent	13,665	9,946	−27	178,663	146,670	−18
Diked/impnd	502	1,773	+235	12,425	33,022	+166
Farmed rice	10,955	7,116	−35	144,615	99,326	−31
Forested	522	411	−21	7,658	2,554	−67
Uncon. bottom	1,654	1,968	+19	1,162	9,927	+754
Diked/impnd	90	96	+07	57	1,345	+2,260
Excavated	278	511	+84	122	223	+83
Riverine	3,005	2,784	−7	6,543	6,545	+1
Lower perennial	3,005	2,784	−7	6,543	6,545	+1
Uncon. bottom	3,005	2,784	−7	6,543	6,545	+1
Excavated	1,491	2,010	+35	2,781	3,882	+40
Total	22,653	20,019	−12	269,128	226,887	−16

[†]Numbers of estuarine and riverine wetlands may be inflated due to sampling approach.

DISCUSSION AND CONCLUSIONS

Waterfowl

The circa 90% declines in numbers of each species (except mottled ducks with a 74% decline) in the Texas Chenier Plain area far exceeds the more modest declines observed in continental, Central Flyway, Texas statewide or Texas Gulf coastal duck populations (Haskins, 1991; Caithamer et al., 1992). Given that the magnitude of these large declines cannot be attributed to continental, flyway, statewide, or Texas coastal duck population changes, the Texas Chenier Plain waterfowl habitat base has almost certainly declined in quantity and/or quality since 1976.

The Chenier Plain Initiative Team (1990:table 16) listed population baseline (averages of 1984-88 Midwinter Inventories) and objectives for ducks in the Texas Initiative area. Duck populations are currently (1990-92) averaging only about 6% of population objectives. Furthermore, current populations on average are only 20% of the baseline populations. Clearly, massive effort will be required just to stabilize duck population declines, let alone meet Texas Initiative area objectives.

Wetlands

Wetland losses from 1964-66 through 1989-90 in the Texas Initiative area (42,000 ha destroyed) were primarily in Zone A. The largest losses of habitat were Estuarine Intertidal Emergent (17,000 ha) and Palustrine Emergent Farmed (50,000 ha of primarily rice fields) wetlands. Not all of these wetlands were destroyed, but rather many were converted to Palustrine Unconsolidated Bottom (8,000 ha), Lacustrine Limnetic (2,400 ha), and/or were diked/impounded or excavated (19,000 ha). These 1964-66 through 1989-90 losses and conversions are consistent with overlapping similar estimates made for the entire Chenier Plain during 1952-74 by Gosselink et al. (1979). Unfortunately, direct comparisons are not possible due to differences in classification methods, and the fact that Gosselink et al. (1979) did not separately summarize Texas losses.

Losses of Estuarine and Palustrine Emergent wetlands were probably due to subsidence, saltwater intrusion, and continuing disruption of freshwater inflows described in detail by Gosselink et al. (1979). Conversion of these emergent wetlands to open water (all unconsolidated bottom and Lacustrine Limnetic, and most diked, impounded, or excavated wetlands) was probably primarily the result of subsidence and saltwater intrusion in Estuarine areas, and construction of levees and canals in Palustrine areas (Gosselink et al., 1979; Craig et al., 1980). Large-scale pumping of groundwater for use in agriculture and industry, and dredging of large navigation channels, is responsible for much of the subsidence and saltwater intrusion (Chenier Plain Initiative Team, 1990). These degradations are exacerbated by reductions in freshwater inflows caused by interior levees, ditches, pipelines, roads, and canals.

Wetland/Waterfowl Associations

Estuarine and Palustrine Emergent (particularly when salinities are < 5 g L^{-1}) wetlands are generally high quality waterfowl habitat (Palmisano, 1973; Chabreck, 1979; Gosselink et al., 1979; Stutzenbaker and Weller, 1989). Palustrine Emergent

Farmed (rice field) wetlands are particularly valuable (Hobaugh et al., 1989). Losses and conversion of these to less productive open water habitats (Gosselink, 1984; Armstrong, 1987) undoubtedly has had a negative impact on duck numbers in the Texas Initiative area (Gosselink et al., 1979; Briggs and Everett, 1983). Although open-water wetlands are not necessarily less productive or valuable to ducks than emergent wetlands (see Stutzenbaker and Weller, 1983), many of the converted wetlands in this study have greater water depth, and higher salinities, turbidity, or disturbance that render them far less valuable to ducks (Gosselink et al., 1979; Stutzenbaker and Weller, 1989).

Substantial losses and degradation of wetlands have probably directly influenced the decline in duck use of the Texas Initiative area. However, we do not believe the dramatic declines in duck use can be entirely explained by the changes in wetland habitats we have documented. Perhaps declining duck use in the Texas Initiative area is aggravated by less tangible degradation of the entire coastal marsh ecosystem, or by widespread pollution, disturbance, or other less obvious habitat changes. A comprehensive, in-depth field study focused on details of duck habitat, population, and behavioral ecology will be needed to fully understand the precipitous declines in duck use of the Texas Chenier Plain area.

MANAGEMENT IMPLICATIONS

This study documented dramatic declines in duck use, and losses and degradation of wetlands, associated with coastal Zone A of the Texas Chenier Plain area. Wetland management efforts should clearly focus on Zone A. Within Zone A, we specifically recommend (in descending order of priority):

1. Organized state and federal interagency efforts to combat soil subsidence and salt water intrusion via control of dredging, filling, ditching, and draining of wetlands and their water sources. Aggressive enforcement and more restrictive interpretation of regulations associated with Section 404 of the Clean Water Act, and swampbuster provisions of the Food Security Act, may be necessary to have a meaningful effect.
2. Restoration, enhancement, and/or acquisition of Estuarine and Palustrine Emergent wetlands, with emphasis of marsh productivity in general, and early successional seed-bearing annual (moist soil) plants in particular. Priority for ducks should be given to wetlands capable of maintaining < 5 g L^{-1} salinities (fresh and intermediate marshes). Restoration of historic duck use may require addition of as much as 50,000 ha of these high-quality wetlands.

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Effects of Browse Rejuvenation on White-tailed Deer Diets and Nutrition

Timothy E. Fulbright*
J. Paul Reynolds
Samuel L. Beasom
Caesar Kleberg Wildlife Research Institute, Campus Box 218, Texas A&M University-Kingsville, Kingsville, TX 78363

ABSTRACT

We determined the effects of roller chopping (20% of a 1,000-acre area, once per year in separate strips to rejuvenate browse) on white-tailed deer (*Odocoileus virginianus* Raf.) diet composition and nutritional indices in a guajillo (*Acacia berlandieri* Benth.)- and blackbrush acacia (*Acacia rigidula* Benth.)-community in southern Texas. Browse comprised a greater percentage of deer diets in a control area than in the treated area during October 1986, but was similar in deer diets in the control and roller-chopped areas on other sampling dates. Femur marrow fat and kidney fat indices of deer from the roller-chopped and control areas were similar. Rumen crude protein of deer from the control area exceeded that of deer from the roller-chopped area. Based on our results, we suggest that the idea of browse rejuvenation improving deer nutrition should not be accepted as axiomatic without further testing.

KEYWORDS: *Acacia berlandieri*, *Acacia rigidula*, blackbrush acacia, brush management, guajillo, habitat, roller chopping

Browse rejuvenation, or top-growth removal of woody plants to stimulate sprouting, is commonly recommended as a habitat improvement practice to temporarily increase nutritional quality and availability of browse (Scifres, 1980; Vallentine, 1980; Yoakum et al., 1980). This practice has been applied in chaparral in California (Yoakum et al., 1980), bitterbrush [*Purshia tridentata* (Pursh)] (Yoakum et al., 1980) and gambel oak (*Quercus gambelii* Nutt.) stands in the western United States, curlleaf mountain mahogany (*Cercocarpus ledifolius* Nutt. ex. Torr. & Gray) stands in Utah (Vallentine, 1980), and mixed brush in southern Texas (Powell and Box, 1966; Everitt, 1983; Fulbright et al., 1991).

Although browse rejuvenation is a widely accepted management practice, the hypothesis that browse rejuvenation has a positive nutritional impact on large herbivores has not been documented. We tested the hypothesis that stimulating shrub resprouting by top-growth removal would improve the nutritional plane of white-tailed deer (*Odocoileus virginianus* Raf.).

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Based on increases in browse palatability and nutritional quality following top-growth removal reported by Powell and Box (1966) and Everitt (1983), we predicted that (1) browse would compose a greater percentage of deer diets following top-growth removal by roller chopping than on untreated rangeland and (2) indices of deer nutritional status would be greater on roller-chopped than on untreated rangeland. Our specific objectives were to determine effects of annually roller chopping 20% of a 1000-acre area in separate strips on deer diet composition and nutritional indices in a guajillo- (*Acacia berlandieri* Benth.) and blackbrush-acacia- (*Acacia rigidula* Benth.) community in southern Texas.

Roller chopping was done during the summer because (1) crude protein and digestible energy of deer diets in southern Texas reach the lowest levels during late summer (Meyer et al., 1984) and (2) browse is the primary component of deer diets during summer, fall, and early winter in the Rio Grande Plain of Texas. Forbs are preferred as they become available in late winter and spring (Everitt and Drawe, 1974; Meyer et al., 1984; Varner and Blankenship, 1987) and availability of browse regrowth during summer and fall should have a greater impact on deer nutrition than during portions of the year when forbs are available. New strips of brush were roller chopped each year to provide an annual supply of regrowth.

METHODS

Study Area

The study was conducted on a 12,000-acre ranch in Duval County, Texas. Precipitation is bimodal with peaks in May and September. Mean annual rainfall and temperature in Duval County are 23 inches and 73°F, respectively. Annual rainfall at Freer, Texas, about 10 miles from the study area, was 33 inches in 1985, 26 inches in 1986, 25 inches in 1987, and 19 inches in 1988 (NOAA, 1985-1988).

Predominant soil on the ranch is Olmos Loam (USDA Soil Conservation Service, Benavides, TX, unpubl.), a grassland soil (Mollisol) (Sanders et al., 1974). Vegetation on the ranch is predominantly dense, low-growing brush dominated by guajillo, blackbrush acacia, and honey mesquite (*Prosopis glandulosa* Torr.).

Parallel strips of brush 130 feet wide and 0.75 - 1.1 miles long were roller chopped in a 1,000-acre area with a 20-foot-wide (about 60,000 lb.) roller chopper pulled by a crawler tractor in a pattern of alternating roller-chopped and nontreated strips during the summers of 1985-1988. About 20% of the area was roller chopped each year. This produced a repeating series of sequentially roller-chopped strips, with strips roller chopped each year adjacent to each other and each series adjacent to nontreated brush.

An area of similar size, soil, and plant composition about 1.5 miles distant was selected for a control. Estimated deer density in the roller-chopped area was greater than in the control area during 1985-1987, but estimated densities were similar in the two areas during 1988 (Bozzo et al., 1992). Licht (1987) reported that white-tailed deer on the Edwards Plateau of central Texas rarely travel farther than 1.25 miles from the center of their home range, and home range sizes average only 0.4 miles^2 for does and 1.6 miles^2 for bucks. Ellisor (1969) and Inglis et al. (1986) reported home ranges of deer on the Rio Grande Plains in Dimmit County, Texas, to be 0.9 miles^2 and 0.7 miles^2, respectively. Home range sizes of female deer appear less variable than those of males (Inglis et al., 1986). Thus, samples between sites were assumed to be independent.

Deer Diet Composition and Nutritional Status

Three to eight female white-tailed deer were collected with high-powered rifles in the control area and 4-10 in the roller-chopped area each February 1986-1988 and October 1985-1987. Rumen contents were mixed thoroughly and 0.8-ounce samples were removed. One rumen sample from each deer was rinsed with distilled water, dried at 104°F for 2 days, ground in a Wiley Mill over a 20-mesh screen, and analyzed for % organic matter and crude protein. Crude protein values for rinsed rumen samples are closer to true diet values than are samples that are not rinsed (R. D. Brown, Dep. Wildl. and Fish., Miss. State Univ., pers. commun., 1990). Crude protein was determined by the micro-Kjeldahl procedure (AOAC, 1987) and is reported as a percentage of organic matter. Organic matter was determined by ashing duplicate samples in a muffle furnace at 1,112°F for 6 hours and subtracting ash from 100%.

The second rumen sample was preserved in 100% ethanol. Samples were air dried, ground over a 20-mesh screen and sent to the Composition Analysis Laboratory, Range Science Department, Colorado State University, for microhistological analysis. Three slides $sample^{-1}$ (deer) were prepared and relative density (%) of each plant genus was determined using 20 fields $slide^{-1}$ (Hansen and Lucich, 1978).

Deer were aged by tooth eruption and wear (Severinghaus, 1949), and eviscerated carcass mass, kidney fat index, and femur marrow fat (Riney, 1955; Neiland, 1970) were determined. Fetal counts were made for does collected in February.

Statistical Analyses

Data were analyzed by analysis of variance for a completely randomized design with a factorial arrangement of treatments (6 sampling dates X 2 treatments) (SAS Inst., 1985). Orthogonal contrasts were used to compare treatment means for each date when the sampling date by treatment interaction was significant ($\underline{P} \leq 0.05$) (Snedecor and Cochran, 1967). The experiment was not replicated because of the expense of the treatments. Because the experiment was not replicated, treatment effects were possibly confounded with site effects. Statistical inference is valid when treatments are not replicated, but inferences pertain only to specific sites (Steel and Torrie, 1980; Hurlbert, 1984; Guthery, 1987).

RESULTS

There was a sampling date X treatment interaction ($P = 0.01$) for % browse in deer diets. Browse comprised a greater ($P = 0.001$) percentage of deer diets in the control area than in the treated area during October 1986, but was similar ($P > 0.05$) in deer diets in the control and roller-chopped areas on other sampling dates (Table 1). Major shrubs in deer diets included ceniza [*Leucophyllum frutescens* (Berl.) I. M. Johnston], *Acacia* spp., hog plum [*Colubrina texensis* T. & G. (Gray)],

Table 1. Temporal trends in percent browse, forbs, grass, lichens, and mast and seeds (%) in diets of white-tailed deer collected in a control (Con.) and roller-chopped (Trt.) area during October 1985-1986 and February 1986-1987, Duval County, Texas.

		Browse		Forbs		Grass		Lichens†		Mast and seeds†	
	n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Oct 1985											
Con.	3	68	6	28	6	4	1	0	0	2	1
Trt.	4	39	12	56	11	3	1	<1	<1	2	1
P-value‡		0.122		0.087		0.902					
Feb 1986											
Con.	5	56	9	24	8	20	5	0	0	0	0
Trt.	6	74	10	15	5	10	5	1	1	0	0
P-value		0.214		0.500		0.002					
Oct. 1986											
Con.	5	61	9	37	10	2	2	0	0	0	0
Trt.	4	7	2	92	2	1	<1	0	0	0	0
P-value		0.001		0.001		0.810					
Feb 1987											
Con.	7	46	8	36	8	18	4	0	0	<1	<1
Trt.	7	57	11	31	9	10	2	2	1	<1	<1
P-value		0.362		0.652		0.001					
Oct 1987											
Con.	6	43	6	27	6	4	3	<1	<1	25	5
Trt.	6	44	14	7	2	1	<1	0	0	47	13
P-value		0.950		0.115		0.797					
Feb 1988											
Con.	8	22	5	65	8	9	3	1	1	2	<1
Trt.	10	30	10	57	11	3	2	3	2	7	4
P-value		0.498		0.413		0.066					

†Treatment main effect and sampling date X treatment interaction not significant ($P > 0.05$).
‡P-value for control versus treatment comparison within a sampling date.

myrtlecroton [(*Bernardia myricaefolia* (Scheele) Wats.], Texas kidneywood (*Eysenhardtia texana* Scheele), honey mesquite, and spanish dagger (*Yucca treculeana* Carr.).

The sampling date X treatment interaction also was significant for % forbs (P = 0.002) and for % grasses (P = 0.04) in deer diets. Forbs comprised more (P = 0.001) of deer diets in the treated area than in the control area during October 1986, whereas the percentage of forbs in diets was similar (P > 0.05) in the control area and in the treated area on other sampling dates (Table 1). Major forb genera in deer diets included *Croton* spp., *Zexmenia* spp., ratany (*Krameria* spp.), *Chamaesaracha* spp., and *Lesquerella* spp. Grasses composed more of deer diets in the control area than in the roller-chopped area during February 1986 (P = 0.002) and February 1987 (P = 0.001) but the percentage of grasses in deer diets was similar (P > 0.05) between the two areas on other sampling dates.

There was no sampling date X treatment interaction for % lichens (P = 0.96) and percent mast and seeds (P = 0.13) in deer diets. The percentage of lichens (P = 0.24) and mast and seeds (P = 0.08) in deer diets was similar in the control and roller-chopped areas (Table 1).

The sampling date x treatment interaction was not significant (P > 0.05) for age, eviscerated carcass mass, femur marrow fat, kidney fat index, rumen crude protein, and number of fetuses per doe. Age, eviscerated carcass mass, femur marrow fat, and kidney fat index of deer from the control area were similar (P > 0.05) to those of deer from the treated area (Table 2). Rumen crude protein of deer in the control area was greater (P = 0.02) than that of deer in the treated area. The mean number of fetuses per doe for the control (1.1 ± 0.4) ($\bar{x}$ ± SE) and treated (1.6 ± 0.3) areas were similar (P = 0.18) for the 3 February collections.

Table 2. Mean age, eviscerated carcass mass (ECM), femur marrow fat (FMF), kidney fat index (KFI), and rumen crude protein (RCP) of white-tailed deer in a control and roller-chopped area averaged across October 1985-1987 and February 1986-1988, Duval County, Texas.

	Control (n=28)		Roller chopped (n=30)		
	$\bar{x}$	SE	$\bar{x}$	SE	P-value
Age (Years)	4.2	0.4	4.1	0.3	0.8328
ECM (lbs)	69.4	1.9	70.3	1.5	0.1463
FMF (%)	57.7	5.3	55.7	4.7	0.7814
KFI (%)	28.7	4.4	22.8	3.5	0.2733
RCP (%)	13.5	0.6	12.2	0.4	0.0231

DISCUSSION

Our predictions that (1) browse would compose a greater percentage of deer diets on roller-chopped than on untreated rangeland and (2) indices of deer nutritional status would be greater on roller-chopped than on untreated rangeland were not supported by our results. We cannot make definite conclusions regarding the effectiveness of rejuvenating browse to improve nutrition of white-tailed deer because the experiment was not replicated (Guthery, 1987), but based on our results we suggest that the idea of browse rejuvenation improving deer nutrition should not be accepted as axiomatic without further testing.

Reasons for the lack of treatment differences in deer nutritional status are unclear. Treatment effects were possibly confounded by greater deer density in the roller-chopped area than in the control area. Greater deer density in the roller-chopped area may have resulted in depletion of high-quality forages, thus masking treatment effects. On the other hand, improved nutritional conditions in the treated area could have resulted in greater deer density in the treated area without resulting in a net increase in nutritional status of individual deer. Shea et al. (1992) reported that reducing density of a Florida pine flatwood white-tailed deer population resulted in no improvement in physiological indices of individual deer. A third possible reason that browse rejuvenation did not result in increased deer nutritional status is that shrub regrowth may be high in secondary compounds, which may obviate the benefit of increased crude protein and other chemical components by reducing digestibility (Hagerman et al., 1992). Reynolds et al. (1992) found that in vitro organic matter digestibility of blackbrush acacia browse was lower than that of browse from nontreated plants 2 months after roller chopping. A final possible reason for the lack of a response to treatment is that laboratory analyses indicating deer forage in southern Texas is of low nutritional quality during late summer and early fall (Varner et al., 1977; Meyer et al., 1984) are possibly misleading because deer select more nutritious plant parts than researchers who sampled the plants (Karn and Hofmann, 1990). Management strategies that increase forage nutritional quality may have little impact on deer nutritional status if the habitat already meets nutritional needs.

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Effects of Browse Rejuvenation on Selected Blood Serum Characteristics of White-tailed Deer

Timothy E. Fulbright*
J. Paul Reynolds
Samuel L. Beasom
Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, TX 78363

ABSTRACT

The effects of roller chopping brush annually during summer on blood serum characteristics of white-tailed deer (*Odocoileus virginianus* Raf.) were determined from 1985-1988. Blood Ca of deer from the roller-chopped area was higher than that of deer from the control area in fall 1987 and winter 1988 but was lower in winter 1987. Blood P was greater in the roller-chopped area in winter 1986 and winter 1987. Values for other blood characteristics were similar between the roller-chopped area and control area. Blood serum characteristics did not provide conclusive evidence of differences in nutritional status of deer in the two areas.

KEYWORDS: *Acacia berlandieri*, *Acacia rigidula*, blackbrush, brush management, guajillo, *Odocoileus virginianus*, shrubs

Mechanical top growth removal of brush stimulates regrowth which is temporarily higher in crude protein and phosphorus than mature browse (Powell and Box, 1966; Everitt, 1983; Fulbright et al., 1992; Reynolds et al., 1992) and is more accessible to white-tailed deer (*Odocoileus virginianus* Raf.) because of plant height reduction (Everitt, 1983). Everitt (1983) recommended shredding brush in July to temporarily improve white-tailed deer nutrition by providing nutritious sprouts during the late summer and early fall.

Nutritional quality of white-tailed deer diets in south Texas is greatest in spring, late fall, and winter and lowest in late summer and early fall when forbs become scarce. During this period of low forb availability deer become primarily browsers of woody material with lower digestible energy content (Everitt and Drawe, 1974; Meyer et al., 1984; Varner and Blankenship, 1987). Annual availability of nutritious brush resprouts during late summer and early fall should lessen this seasonal fluctuation in nutritional quality of white-tailed deer diets. Thus, we predicted that annually roller chopping a guajillo- (*Acacia berlandieri* Benth.) and blackbrush-acacia- (*A. rigidula* Benth.) community during the summer would result in improved nutritional status of white-tailed deer.

Blood serum characteristic values are commonly used as indices of condition in

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cervids (Kie, 1988). Our objective was to determine the effects of annually roller chopping 20% of a 1,000 acre area on blood total serum protein (TSP), albumin, globulin, calcium (Ca), phosphorus (P), glucose, creatinine, total bilirubin, alkaline phosphatase, and creatinine phosphatase.

MATERIALS AND METHODS

The study was conducted on the 12,000 acre Esperanza Ranch in Duval County, Texas. Climate, soils, and vegetation of the ranch are described in Fulbright et al. (1992). Parallel strips of brush 130 feet wide and 0.75 - 1.1 miles long were roller chopped in a 1,000 acre study area using a 20-foot-wide (about 60,000 lbs.) roller chopper pulled by a crawler tractor in a pattern of alternating roller-chopped and nontreated strips during the summers of 1985-1988. A new strip was roller chopped each year adjacent to each strip roller chopped the previous year. About 20% of the area was roller chopped annually. Our goal was to produce browse regrowth each year while maintaining adequate brush for cover.

An area of similar size, soils, and vegetation about 1.5 miles distant was utilized as a control. Licht (1987) reported that white-tailed deer on the Edwards Plateau of central Texas rarely travel farther than 1.25 miles from the center of their home range, and home range sizes average only 0.4 miles^2 for does and 1.6 miles^2 for bucks. Ellisor (1969) and Inglis et al., (1986) reported home ranges of deer on the Rio Grande Plains in Dimmit County, Texas, to be 0.9 miles^2 and 0.7 miles^2, respectively. Home range sizes of female deer appear less variable than those of males (Inglis et al. 1986). Thus, samples from treated and untreated areas were considered independent of each other.

Three to 6 female white-tailed deer from the control area and 4-6 in the roller-chopped area were shot with high-powered rifles during winter 1986-1988 and fall 1985-1987. Blood samples were collected by cardiac puncture using a heparinized syringe for serum separation. Samples were then centrifuged and the serum was extracted and sent to the Texas A&M Veterinary Medical Diagnostic Laboratory, College Station. Samples were analyzed to determine TSP, albumin, globulin, Ca, P, glucose, creatinine, total bilirubin, alkaline phosphatase, and creatinine phosphatase.

Data were analyzed with analysis of variance (ANOVA) for a completely randomized design with a factorial arrangement of treatments (6 seasons X 2 treatments) (Steel and Torrie, 1980). Orthogonal contrasts were used to compare ($P \leq 0.05$) treatment means for each date when the season X sampling date interaction was significant ($P \leq 0.05$) (Steel and Torrie, 1980). The experiment was not replicated because of the expense of the treatments. Statistical inference is valid when treatments are not replicated, but inferences pertain only to specific sites (Steel and Torrie, 1980; Hurlbert, 1984).

RESULTS AND DISCUSSION

Blood serum characteristic values were similar ($P > 0.05$) between the roller-chopped and control areas except for blood Ca and P. The sampling date X treatment interaction was significant for blood Ca ($P = 0.02$) and P ($P = 0.05$).

Blood Ca of deer from the roller-chopped area was higher than that of deer from the control area in fall 1987 and winter 1988 but was lower in winter 1987 (Table 1). LeResche et al. (1974) stated that depressed blood Ca may indicate range deterioration in certain instances. Blood P was greater in the roller-chopped area in winter 1986 and winter 1987. Decreased inorganic P may result from dietary deficiencies (LeResche et al., 1974).

Total serum protein, albumin, globulin, albumin/globulin ratio, creatinine, total bilirubin, alkaline phosphatase, and creatinine phosphatase varied significantly ($\underline{P} < 0.05$) among sampling dates. Kie et al. (1983) reported that serum creatinine, albumin, and alkaline phosphatase differed with month of collection. In their study, glucose, TSP, and bilirubin did not vary with month of collection.

Blood characteristic values did not provide conclusive evidence of differences in nutritional status of deer in the roller-chopped and control areas. The few blood values that differed between the 2 areas, except for blood Ca in winter 1987, tended to indicate better nutritional status in the roller-chopped area. Lack of differences in blood values may have resulted in part from low sensitivity of blood values to differences in nutritional status, from differences in deer density between the 2 areas, and from similaries in diet composition between the two areas. Kie et al. (1983) concluded that postmortem blood chemistry is of limited value in assessing physical condition in field situations because they found highly significant differences in body weights and fat reserves between deer from a low density and deer from a high-density herd, but few differences in blood values. Body weights and fat reserves of deer in our study were similar in the roller-chopped and control areas, except in fall 1987 when the kidney fat index was higher for deer in the control area (Fulbright et al., in press).

Deer density increased during the study in the roller-chopped area and was higher in the roller-chopped area than in the control area during 1985-1987 (Bozzo et al., 1992). Greater deer density in the roller-chopped area may have resulted in depletion of high-quality forages, thus masking differences in blood characteristics between deer in the two areas.

Browse and forb composition of deer diets was similar in the control and roller-chopped areas on all sampling dates except fall 1986 (Fulbright et al., in press). During fall 1986, browse comprised a greater percentage of deer diets in the control area than in the treated area, whereas forbs comprised more of deer diets in the treated area than in the control area. Our results should be interpreted cautiously because the experiment was not replicated. Although we attempted to select areas that were similar in soils and plant composition, differences in blood serum characteristics between the 2 areas may have resulted in part from inherent differences between the sites rather than from treatment effects.

Table 1. Albumin (Alb), albumin/globulin ratio (AG), alkaline phosphatase (AP), calcium (Ca), creatinine (Creat), globulin (Glo), glucose (Gluc), phosphorus (P), total bilirubin (TB), and total serum protein (TSP), of deer collected from a control (Con) and roller chopped (Trt) area in fall 1985-1987 and winter 1986-1988, Duval County, Texas.

Blood	Fall 1985		Winter 1986		Fall 1986		Winter 1987		Fall 1987		Winter 1988	
Charac.	Con	Trt	Con	Trt	Con	Trt	Con	Trt	Con	Trt	Con	Trt
Deer sampled	3	4	4	4	5	5	5	5	5	6	6	6
Alb (g dL^{-1})	3.1	3.3	3.3	3.7	2.7	2.4	3.9	3.9	2.6	2.5	2.5	2.8
AG	1.1	1.2	1.1	1.3	0.8	0.7	1.3	1.4	0.7	0.7	0.5	0.7
AP (Units L^{-1})	146.7	153.3	60.8	65.5	181.6	231.4	57.0	89.0	33.0	67.5	21.5	43.5
Ca (mg dL^{-1})	7.9	8.8	8.6	8.5	10.1	9.6	9.3	8.2*	9.2	9.7*	8.8	9.4*
Creat (mg dL^{-1})	1.2	1.2	1.3	1.4	1.7	1.4	1.6	1.4	1.3	1.2	1.4	1.6
Glo (g dL^{-1})	3.0	2.8	2.9	2.9	3.2	3.5	3.2	2.8	3.6	3.6	4.5	3.9
Gluc (mg dL^{-1})	90.0	144.2	133.3	118.8	131.8	137.0	126.0	119.0	216.8	127.7	83.5	152.5
P (mg dL^{-1})	14.2	10.4	8.9	13.5*	14.7	10.5	10.6	12.6*	7.9	10.7	8.2	9.2
TB (mg dL^{-1})	0.5	0.5	0.5	0.6	1.5	0.6	0.1	0.1	0.2	0.1	0.1	0.1
TSP (mg dL^{-1})	6.1	6.1	6.2	6.6	5.8	5.9	7.2	6.7	6.2	6.1	6.9	6.7

* Significantly different ($P < 0.05$) according to orthogonal contrasts comparing the two treatments for each date.

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Economics of Pesticide Regulation on Sorghum Production in the U.S. and Texas

Eduardo Segarra*
Department of Agricultural Economics, Texas Tech University, and the Texas Agricultural Experiment Station, Lubbock, TX 79401.
Cris Gwinn
William P. Morrison
John R. Abernathy
Texas Agricultural Experiment Station, Lubbock, TX 79401.

ABSTRACT

Using a national pesticide use survey in sorghum production, a market framework was used to derive the short-run welfare impacts to consumers, and producers (users and non-users) of the removal of pesticides registered for use on sorghum. It was projected that the loss of atrazine would have the largest overall impact, with an estimated loss of $266 million. Users of atrazine in the U.S. would be expected to lose $122 million with users of atrazine in Texas losing $42 million.

KEYWORDS: consumer impacts, producer (user and non-user) impacts, NAPIAP

Grain sorghum is an important crop to U.S. agricultural producers. This crop is generally cultivated in areas that are too dry or too hot for successful corn production (Bennett et al., 1990). Advancements in the chemical industry, tillage practices, and hybrid seed production have played a vital role in the development of sorghum as a major cereal crop in U.S. agriculture. Three areas of concern affecting yields are weeds, insects and diseases. Potential annual yield loss due to these pests is great and their control is important to the economic success of producers. Control or suppression is obtained by efficient use of technological advances. Good cultural practices, including proper selection of hybrids and judicious pesticide use, provides maximum yield potential for producers.

Programs such as the National Agriculture Pesticide Impact Assessment Program (NAPIAP) of the U.S. Department of Agriculture (USDA) have been developed to assess and inform regulatory agencies of the biologic and economic impacts of pesticide use in agriculture. Numerous studies have been and continue to be conducted on chemical use and alternatives in agriculture. Assessments such as the Biologic and Economic Assessment of Ethyl Parathion (USDA, 1989a), Oxydemeton-Methyl (Mayo, 1990), Carbofuran (USDA, 1989b), Chlorpyrifos (Rice, in press), and Phorate and Terbufos (Knutson, 1990) show the impacts of these chemicals to the producer and the environment as well as to the consumers of agricultural commodities.

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The Biologic and Economic Assessment of Oxydemeton-Methyl (Mayo, 1990) showed that use of this insecticide in sorghum was minimal. Registered on sorghum for the control of greenbugs, corn leaf aphid, yellow sugarcane aphid, and Banks grass mites, oxydemeton-methyl cost appears to be the main deterrent for its use. Alternative insecticides were generally considered to be equally effective as oxydemeton-methyl while the cost of this insecticide was 45 to 55% greater than other registered products.

Phorate is labeled on sorghum for the control of greenbugs, chinch bug, and Banks grass mites. Terbufos provides control of southern corn rootworms, wireworms, white grubs, nematodes, and early season greenbugs in sorghum. The Biologic and Economic Assessment of Phorate and Terbufos estimated that sorghum yields would be reduced 0 to 10% on a state-by-state basis should phorate and/or terbufos use be cancelled (Knutson, 1990). Carbofuran and terbufos could be substituted for phorate and the cancellation of terbufos would increase the use of carbofuran, chlorpyrifos, and phorate. Carbofuran was found to be the primary alternative insecticide used by sorghum producers should the registrations of terbufos and phorate be cancelled.

Carbofuran is a vital tool in the control of chinch bug. Kansas, Nebraska, Texas, Mississippi, Louisiana and Oklahoma are the primary users of carbofuran for chinch bug control. Central Texas and Kansas sorghum growers rely heavily on granular carbofuran and report that alternate compounds either are not effective for chinch bug control or are too expensive (USDA, 1989b). The granular carbofuran label was phased-down because of its toxicity to birds although no documented bird kill incidents from grain sorghum use have occurred (Brooks, 1992). The National Grain Sorghum Producers Association recommended that granular carbofuran be retained for use on sorghum in key states of Kansas, Nebraska, Texas, and Oklahoma. The Environmental Protection Agency (EPA) is presently examining the risk versus benefits of its use on sorghum.

Ethyl parathion has been used to control sorghum insects since the 1950s (USDA, 1989a). Methyl parathion is not used on sorghum because it is phytotoxic to most hybrids. Ethyl parathion remains an important compound for control of greenbugs and occasional pests. In the 1970s, Texas reported insecticide resistance in greenbugs to dimethoate and disulfoton (USDA, 1989a). Other alternatives to parathion, such as chlorpyrifos, provide control of greenbugs but are often more expensive.

Chlorpyrifos is registered for use on sorghum to control both below-surface and above-surface insects. Research has shown that chlorpyrifos is one of the most effective insecticides against sorghum pests, but opinions expressed by NAPIAP survey respondents suggest that cancellation of this product would have minimal overall impact on future yields (Rice, in press). Alternatives available for chlorpyrifos include: carbofuran, parathion, dimethoate, carbaryl, and terbufos depending on the targeted pest. Greater expense, shorter residual control, greater human toxicity, and less effectiveness were listed as the greatest constraints of the alternatives of chlorpyrifos by the survey respondents.

These studies and others currently being conducted under NAPIAP, represent a good effort to disentangle the horizontal relationships with respect to the use of a particular pesticide across several crops. That is, most often an assessment examines a specific active ingredient and its uses on all agricultural enterprises. This study examines the use patterns of all herbicides and insecticides on sorghum. Seed treatment, fungicide and post-harvest storage pesticide uses were not included. In particular, the objective of this study was to derive the short-run welfare impacts to consumers, and producers (users and non-users) of the removal of pesticides registered for use on grain sorghum production.

METHODS AND PROCEDURES

With a more environmentally conscious society, a popular approach followed by EPA has been the suspension or cancellation of registered pesticide use in agriculture (Ferguson et al., 1992; and Zilberman et al., 1991). The removal of a pesticide from the market affects the quality of the environment and reduces the associated human health risk while altering the production cost and supply available to the market (Knutson et al., 1990). However, in the decision-making process, policy makers need to consider not only the environmental impacts stemming from the suspension or cancellation of a registered pesticide, but also the associated economic impacts to consumers, and users and non-users of the pesticide.

As Lichtenberg et al. (1988) and Ferguson et al. (1992) showed, the short-run welfare impacts of the removal of a pesticide can be calculated by finding the changes in economic surpluses. Ferguson et al. (1992) developed a market model to estimate the short-run welfare impacts of a pesticide ban. This model was the framework used in this study to derive the short-run welfare impacts of the removal of pesticides registered for use on grain sorghum production, and it takes the following form:

$$D=D(P) \tag{1}$$

$$S^u=y^uA^u \tag{2}$$

$$S^n=y^nA^n \tag{3}$$

$$D=S^u+S^n \tag{4}$$

where D equals the quantity of crop demanded, P equals the crop price, S^u equals the quantity of crop supplied by pesticide users, y^u equals the crop yield per acre among pesticide users, A^u equals the crop acreage of pesticide users, S^n equals the quantity of crop supplied by pesticide non-users, y^n equals the crop yield per acre among pesticide non-users, and A^n equals the crop acreage of pesticide non-users. At equilibrium, crop price, quantity demanded, and quantity supplied by pesticide users and non-user are expressed as P_0, D_0, S_0^u, and S_0^n, respectively.

Given an initial sorghum demand function (D) and an initial sorghum supply function ($S_0^T = S_0^u + S_0^n$), the welfare implications on consumers and producers of the equilibrium price (P_0) and equilibrium quantity (D_0) are illustrated in Figure 1. Given the equilibrium price and the equilibrium quantity, the consumers' welfare measure (or consumers' surplus) is defined as the area above the equilibrium price and bellow the demand curve (area A+B+C+D in Figure 1). The producers' welfare (or producers' surplus) is defined as the area bellow the equilibrium price and above the supply curve (area E+F+G in Figure 1). The sum of these two areas (A+B+C+D+E+F+G) represents the overall welfare measure.

As a result of a pesticide ban, pesticide users' crop yield per acre changes to y_1^u, while production cost per acre changes from C_0^u to C_1^u. This is represented in Figure 1 by the shift of the supply function from S_0^T to S_1^T. In this study, it was assumed that no alternative was selected, thus the change in cost is equal to the reduction in cost due to not using the pesticide. Also, pesticide non-users yield per acre, y^n, and production cost per acre, C^n, were assumed to remain the same. Given these assumptions, the estimated short-run welfare impacts represent an upper bound of the impacts. At equilibrium after the pesticide ban, crop price, quantity demanded, and quantity supplied by pesticide users and non-users are expressed as P_1, D_1, S_1^u, and S_1^n, respectively.

As shown in Figure 1, given this new equilibrium, the consumers' welfare is represented by area A and the producers' welfare is represented by the area B+E. Thus, as a result of the pesticide ban, the overall reduction of welfare to both consumers and producers equals area C+D+F+G in Figure 1. The consumers' welfare loss equals area B+C+D. It is important to note, however, that area B represents a transfer to producers from consumers, and that the loss to producers will be dependent on the relative magnitudes of areas B and F+G. If area B > F+G the ban would represent a gain to producers, but if B < F+G the ban would represent a loss to producers. Furthermore, because not all sorghum producers are users of the banned pesticide, it is important to evaluate what the distributional impacts of this ban would be on both, users and non-users of the pesticide in question. Non-users of the banned pesticide will not be negatively affected by the ban, and in fact they will benefit from it, because of an increase in the price of sorghum. Users of the pesticide being banned will be affected negatively if the impact on the reduction of yields is stronger than the price effect. If the increase in price of sorghum is strong enough, users of the pesticide being banned could benefit.

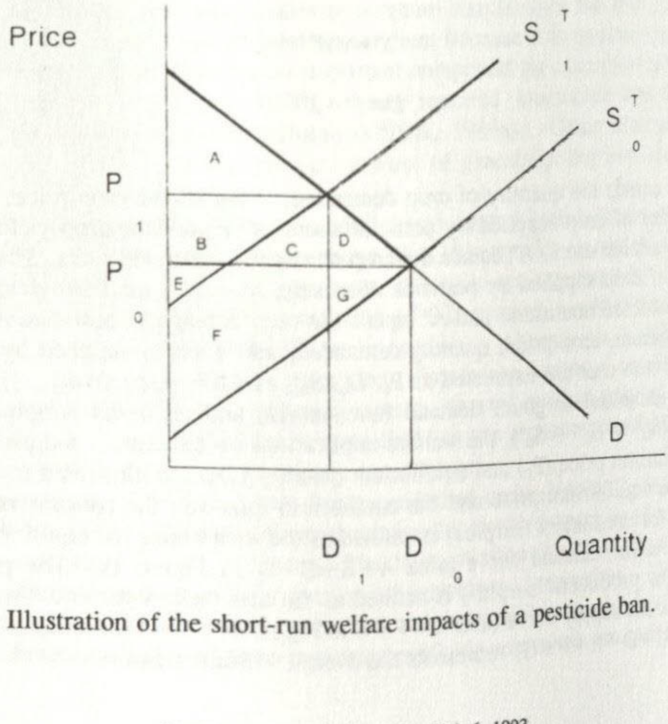

Figure 1. Illustration of the short-run welfare impacts of a pesticide ban.

Given the model above, the consumer, I^c, pesticide users, I^u, and non-users, I^n, short-run welfare impacts were estimated as follows:

$$I^c=-[(P_1-P_0)D_1+.5(P_1-P_0)(D_0-D_1)] \quad (1)$$

$$I^u=[P_1y_1^u-P_0y_0^u]A^u+(C_0^u-C_1^u)A^u \quad (2)$$

$$I^n=[P_1-P_0]y^nA^n \quad (3)$$

Through a pesticide usage survey conducted in 1993 for the crop year 1992, yields per acre, per acre rates, percent of acres treated with a pesticide, and perceived yield loss due to the cancellation of pesticides were obtained from respondents. The number of sorghum acres planted for 1992 was obtained from the USDA Agricultural Statistics (USDA, 1992a). The cost per pound of active ingredient of the pesticides were obtained from Agricultural Resources: Inputs Situation and Outlook Report (USDA, 1992b). The application cost per acre was obtained using Texas Custom Rates Statistics (Texas Agricultural Statistics Service, 1992). This information was applied to the above market model to estimate the economic impact of ban of a given pesticide. Also, the Food and Agricultural Policy Research Institute (FAPRI) national sorghum demand model was used to estimate the change in P_0, crop price at equilibrium before a pesticide ban, and P_1, crop price at equilibrium after a pesticide ban (Adams, 1992).

Survey respondents were asked to provide the top three herbicides and insecticides in their sorghum operations. Along with the top three herbicides and insecticides, respondents provided their perceived yield loss, if the respective chemical was no longer available for sorghum production and the mean of the perceived yield loss was calculated. These perceived yield losses should be considered the upper bound because no alternatives were taken into consideration. It is likely that an alternative pesticide or another means of control could be used instead of the cancelled product. However, due to the lack of information with respect to both the product that could be used and the impact on yields, for this study, three yield losses were used in estimating the economic impacts of a pesticide ban.

The first yield reduction used the mean of the perceived yield loss as reported by the survey respondents. In the second reduction, the mean perceived yield loss was reduced by one-third. The third used a two-thirds reduction of the original perceived yield loss.

After the percentage of yield loss due to the cancellation of a product was established, it was applied to three groups of sorghum yields. The first yield per acre figure used came from the elicited yield per acre of the survey respondents. Survey respondents were asked to provide their 1992 yield per acre for their irrigated and/or non-irrigated fields. Their responses were averaged for both irrigated and non-irrigated categories. Survey respondents' yields per acre for irrigated and non-irrigated were 11 to 31 percent, respectively, higher than the average USDA yield for 1992. The second yield used was the 1992 actual yield per acre for irrigated and non-irrigated farms in Kansas, Nebraska, Texas, and other states as reported by the USDA. Since all other sorghum producing states were grouped together for the purpose of this study, other states yield per acre was estimated by dividing total production of the other states by total acres harvested as reported by the USDA Agricultural Statistics (USDA, 1992a).

The third yield per acre figure used was also elicited from surveyed respondents. Respondents were asked to provide their expected lowest, mostly likely, and highest yield per acre. The mean of these responses (implicitly assuming a triangular probability density function of sorghum yields) can be considered as an estimate of the long-term expected average yield per acre. These calculated long-term yields per acre for irrigated and non-irrigated crops were 6% lower to 29% higher than the average USDA yields for 1992.

Given the three perceived yield losses and the three yield levels used, a total of nine possible scenarios were analyzed in deriving the short-run welfare impacts of the removal of registered pesticides in the production of sorghum. Scenario 1 depicts the short-run welfare impacts by using the survey yields reduced by the full perceived yield loss. Scenario 2 used the USDA yields reduced by the full perceived yield loss. Scenario 3 used the long-term yields reduced by the full perceived yield loss.

In Scenarios 4 to 6, the same survey, USDA, and long-term yields were used, but the perceived yield loss was set at two-thirds of the full perceived loss (medium level of yield loss). In Scenarios 7 to 9, the perceived yield loss was reduced to one-third of the full perceived yield loss (low level of yield loss).

RESULTS

The economic impact of the loss of a pesticide depends upon the percent of acres treated and the expected yield loss due to the absence of the chemical. As pointed out above, in this study no pesticide alternatives were taken into consideration; thus, the resulting impact represents an upper bound estimate of the impact.

Tables 1 to 3 present the economic impacts to consumers, users and non-users of banning herbicides or insecticides in sorghum production in the U.S. Tables 4 to 6 present the economic impacts to user and non-users of banning herbicides or insecticides in sorghum production in Texas. Table 1 shows the impacts on consumers, users, non-users, and the overall impact of the ban of a select group of herbicides and insecticides under Scenarios 1 to 3. The loss of atrazine, the most widely used pesticide in sorghum production, would be expected to have the largest overall impact under the survey, USDA, and long term yields with an overall estimated loss of $266, $217, and $233 million, respectively. The loss to consumers due to the absence of atrazine was estimated to be $443, $269, and $316 million under the survey, USDA, and long term yields, respectively. These losses would be expected to result due to the increase in the price of sorghum.

The loss to users of atrazine was expected to be $122 million under the survey yields, and $130 million under the USDA and long term yields. Non-users of atrazine would be expected to gain $299, $181, and $213 million under the survey, USDA, and long term yield scenarios, respectively.

In evaluating the results in Tables 1 to 3 with respect to the banning of insecticides, it should be noted that the use and the value of using insecticides vary greatly from year to year, due to the outbreak of different pests. The lack of the proper insecticide to control selected pests during severe outbreaks could be devastating to producers and could result in greater than the estimated losses in Tables 1 to 3. Taking this into consideration, the loss of esfenvalerate showed the

Table 1. Short-run welfare impacts of eliminating pesticides registered for use on sorghum in the US, assuming the full reduction of elicited perceived yield loss, 1992.

	Full reduction of survey yields				Full reduction of USDA yields				Full reduction of long-term yields			
	Consumer x1000	User x1000	Non-user x1000	Total x1000	Consumer x1000	User x1000	Non-user x1000	Total x1000	Consumer x1000	User x1000	Non-user x1000	Total x1000
Herbicides												
Atrazine	-443015	-121935	298797	-266154	-268730	-129689	181451	-216968	-315732	-129962	212574	-233120
2,4-D	-97104	-41420	86868	-51656	-59302	-37311	53007	-43606	-68826	-38584	61618	-45791
Metolachlor	-110875	-38055	101562	-47368	-67629	-32294	61916	-38007	-78277	-33846	71772	-40350
Glyphosate	-58625	-24420	55361	-27684	-36145	-21229	34115	-23258	-40774	-21396	38527	-23643
Metolachlor+Atrazine	-57847	-23268	55676	-25439	-35600	-19666	34248	-21018	-40141	-19910	38668	-21383
Alachlor	-56327	-23184	54456	-25055	-34625	-19558	33462	-20721	-39261	-19966	37982	-21245
Bromoxynil	-23059	-9191	22403	-9847	-14305	-7812	13889	-8228	-15795	-7685	15364	-8116
Dicamba	-16156	-7709	15920	-7946	-9881	-6553	9736	-6697	-11400	-6825	11233	-6991
Alachlor+Atrazine	-16215	-5919	15964	-6170	-9918	-4764	9764	-4918	-11383	-4992	11207	-5168
Cyanazine	-6506	-2709	6447	-2768	-4063	-2302	4026	-2339	-4391	-2196	4352	-2235
Insecticides												
Esfenvalerate	-30727	-16698	30303	-17123	-17989	-13800	17750	-14039	-23047	-15995	22711	-16331
Carbofuran	-34550	-15106	33730	-15927	-20870	-12502	20374	-12998	-24791	-13583	24202	-14172
Chlorpyrifos	-25168	-12197	24792	-12573	-14934	-10009	14716	-10227	-18556	-11397	18269	-11684
Terbufos	-23422	-10508	23043	-10887	-13744	-8361	13529	-8576	-17501	-9941	17204	-10238
Parathion	-19763	-9978	19510	-10231	-11885	-8378	11734	-8530	-14277	-9128	14092	-9313
Disulfoton	-1360	-676	1359	-677	-796	-543	795	-544	-1020	-642	1019	-644

Table 2. Short-run welfare impacts of eliminating pesticides registered for use on sorghum in the US, assuming the elicited yield loss at 2/3 of the original value, 1992.

	Medium reduction of survey yields				Medium reduction of USDA yields				Medium reduction of long-term yields			
	Consumer x1000	User x1000	Non-user x1000	Total x1000	Consumer x1000	User x1000	Non-user x1000	Total x1000	Consumer x1000	User x1000	Non-user x1000	Total x1000
Herbicides												
Atrazine	-301660	-55510	199198	-157971	-182977	-65663	120967	-127673	-215005	-64459	141716	-137748
2,4-D	-65011	-24597	57912	-31697	-39703	-22071	35338	-26436	-46078	-22868	41079	-27867
Metolachlor	-74276	-17854	67708	-24423	-45306	-14293	41277	-18322	-52437	-15263	47848	-19852
Glyphosate	-39182	-13584	36907	-15859	-24158	-11531	22744	-12946	-27250	-11632	25684	-13197
Metolachlor+Atrazine	-38662	-12232	37117	-13776	-23793	-9904	22832	-10865	-26826	-10056	25779	-11103
Alachlor	-37643	-12368	36304	-13707	-23141	-10020	22308	-10852	-26237	-10280	25321	-11196
Bromoxynil	-15388	-4824	14936	-5276	-9546	-3916	9260	-4202	-10540	-3830	10243	-4127
Dicamba	-10778	-4589	10613	-4754	-6592	-3824	6490	-3925	-7605	-4004	7489	-4120
Alachlor+Atrazine	-10818	-2792	10643	-2967	-6616	-2028	6509	-2135	-7594	-2179	7472	-2301
Cyanazine	-4339	-1448	4298	-1488	-2710	-1178	2684	-1203	-2928	-1107	2901	-1134
Insecticides												
Esfenvalerate	-20512	-10699	20202	-11010	-12008	-8791	11833	-8966	-15386	-10242	15141	-10487
Carbofuran	-23068	-8459	22486	-9040	-13934	-6750	13583	-7101	-16552	-7462	16135	-7880
Chlorpyrifos	-16797	-7311	16528	-7580	-9967	-5867	9811	-6023	-12385	-6786	12179	-6991
Terbufos	-15630	-5976	15362	-6244	-9172	-4558	9019	-4710	-11680	-5604	11469	-5815
Parathion	-13186	-6140	13006	-6320	-7930	-5083	7823	-5190	-9527	-5579	9395	-5711
Disulfoton	-907	-410	906	-411	-531	-321	530	-321	-680	-387	680	-388

Table 3. *Short-run welfare impacts of eliminating pesticides registered for use on sorghum in the US, assuming the elicited yield loss at 1/3 of the original value, 1992.*

	Low reduction of survey yields				Low reduction of USDA yields				Low reduction of long-term yields			
	Consumer x1000	User x1000	Non-user x1000	Total x1000	Consumer x1000	User x1000	Non-user x1000	Total x1000	Consumer x1000	User x1000	Non-user x1000	Total x1000
Herbicides												
Atrazine	-153988	-1716	99599	-56105	-93400	-9286	60484	-42203	-109761	-7991	70858	-46894
2,4-D	-32643	-8325	28956	-12012	-19936	-7167	17669	-9434	-23136	-7540	20539	-10137
Metolachlor	-37318	1627	33854	-1837	-22763	3268	20639	1144	-26344	2815	23924	395
Glyphosate	-19641	-2947	18454	-4134	-12110	-1957	11372	-2696	-13659	-2002	12842	-2819
Metolachlor+Atrazine	-19379	-1389	18559	-2209	-11927	-261	11416	-772	-13446	-332	12889	-888
Alachlor	-18867	-1735	18152	-2450	-11599	-595	11154	-1040	-13150	-720	12661	-1209
Bromoxynil	-7701	-487	7468	-721	-4778	-39	4630	-187	-5275	4	5121	-149
Dicamba	-5393	-1484	5307	-1570	-3298	-1104	3245	-1157	-3805	-1194	3744	-1254
Alachlor+Atrazine	-5413	320	5321	229	-3311	699	3255	643	-3800	624	3736	560
Cyanazine	-2170	-190	2149	-210	-1355	-55	1342	-68	-1464	-20	1451	-33
Insecticides												
Esfenvalerate	-10270	-4755	10101	-4923	-6012	-3812	5917	-3907	-7704	-4531	7570	-4665
Carbofuran	-11551	-1880	11243	-2187	-6977	-1039	6791	-1225	-8289	-1391	8067	-1612
Chlorpyrifos	-8407	-2461	8264	-2604	-4989	-1747	4905	-1830	-6199	-2203	6090	-2312
Terbufos	-7823	-1475	7681	-1617	-4590	-772	4510	-853	-5846	-1292	5735	-1404
Parathion	-6599	-2325	6503	-2420	-3968	-1801	3911	-1858	-4767	-2047	4697	-2117
Disulfoton	-453	-143	453	-144	-265	-99	265	-99	-340	-132	340	-133

largest overall impact using the survey yields with a loss of $17 million. Consumer and user losses were expected to be $31 and $17 million, respectively, with non-users gaining $30 million under the survey yields scenario. It should be noted that in 1992 esfenvalerate was used predominately by sorghum producers in Texas, whose production of sorghum was up because some, otherwise cotton and/or corn producers, lost their cotton and/or corn crops in 1992.

Under the USDA and long term yield scenarios, esfenvalerate was also found to be the insecticide with the largest associated impact if cancelled. The overall loss in the absence of esfenvalerate was estimated to be $14 and $16 million under the USDA and long term yield levels, respectively. Carbofuran, showed the second largest impact for an insecticide under the survey, USDA, and long term yield levels with estimated total losses of $16, $13, and $14 million, respectively.

Table 2 presents the welfare impacts under the survey, USDA, and long term yield levels with the medium reduction of yields. As expected, the overall estimated impacts are lower under these three scenarios, with the order of the impacts remaining basically the same as the previous three scenarios. Under this yield reduction scenario, the cancellation of atrazine would result in an estimated net loss of $158, $128, and $138 million under the survey, USDA, and long term yield levels, respectively. In these three scenarios, the absence of esfenvalerate was again found to have the largest expected losses for an insecticide with $11, $9, and $10.5 million under the survey, USDA, and long term yields levels, respectively.

The economic impacts presented in Table 3 shows the expected losses assuming the low reduction of yield for the survey, USDA, and long term yields levels. There were few changes in the ranking of the impacts. A ban of atrazine would still be expected to cause an overall loss of $56, $42, and $47 million across yield levels. Esfenvalerate remained the insecticide with the greatest expected loss at $5, $4, and $5 million across yield levels.

The economic impact figures presented above are important in evaluating the overall impacts due to the elimination of selected pesticides registered for use on sorghum production in the U.S. However, it is important to find out what these results mean to important sorghum producing states, Texas in particular. For this reason, in Tables 4 to 6 the impacts to users and non-users of pesticides on sorghum production in Texas are presented.

The economic impacts to users and non-users of pesticides on sorghum production in Texas (Tables 4 to 6), show that when comparing the U.S. figures (Tables 1 to 3) to Texas figures, if pesticides are banned on sorghum production, users (non-users) of herbicides in Texas would tend to bear (capture) roughly a third of the losses (gains). Notice that when looking at the insecticides figures, the users' losses are proportionally higher, and the non-users' gains are proportionally lower. This points to the fact that insecticide availability in Texas seems to be more important than in the rest of the U.S. However, it should be pointed out that although herbicide availability may not be as important in Texas as it is in other sorghum producing states, their economic value on sorghum production in Texas is very significant and in many instances greater than the economic value of insecticides.

Table 4. Short-run welfare user and non-user ($) impacts due to the elimination of selected pesticides registered for use on sorghum in Texas, assuming the full reduction of elicited perceived yield loss, 1992.

	Full reduction of survey yields		Full reduction of USDA yields		Full reduction of long-term yields	
	User x1000	Non-user x1000	User x1000	Non-user x1000	User x1000	Non-user x1000
Herbicides						
Atrazine	-42268	89988	-43482	52578	-48800	67730
2.4-D	-4428	31064	-3773	18276	-4398	23247
Metolachlor	-12919	33779	-10288	19849	-12567	25177
Glyphosate	-1663	18983	-1316	11276	-1626	13938
Metolachlor + Atrazine	-3795	18666	-3025	11067	-3651	13674
Alachlor	-3770	18248	-3007	10807	-3614	13428
Bromoxynil	-457	7553	-349	4514	-434	5463
Dicamba	-1454	5247	-1142	3091	-1382	3909
Alachlor + Atrazine	-1290	5262	-1008	3100	-1227	3900
Cyanazine	335	2118	328	1274	330	1509
Insecticides						
Esfenvalerate	-16698	9570	-13800	5396	-15995	7580
Carbofuran	-7363	11012	-5868	6408	-7015	8344
Chlorpyrifos	-8661	7969	-6968	4555	-8255	6205
Terufos	-10129	7280	-8031	4115	-9628	5744
Parathion	-4425	6385	-3595	3699	-4224	4871
Disulfoton	-682	445	-549	251	-649	352

Table 5. Short-run welfare user and non-user ($) impacts due to the elimination of selected pesticides registered for use on sorghum in Texas, assuming the elicited yield loss at 2/3 of the original value, 1992.

	Medium reduction of survey yields		Medium reduction of USDA yields		Medium reduction of long-term yields	
	User x1000	Non-user x1000	User x1000	Non-user x1000	User x1000	Non-user x1000
Herbicides						
Atrazine	-18352	59992	-21087	35052	-23852	45153
2.4-D	-2614	20709	-2201	12184	-2609	15498
Metolachlor	-6421	22519	-4760	13233	-6244	16785
Glyphosate	-805	12655	-581	7517	-785	9292
Metolachlor + Atrazine	-2080	12444	-1579	7378	-1993	9116
Alachlor	-2108	12166	-1611	7205	-2012	8952
Bromoxynil	-229	5036	-157	3010	-214	3642
Dicamba	-805	3498	-599	2061	-758	2606
Alachlor + Atrazine	-699	3508	-512	2067	-658	2600
Cyanazine	329	1412	325	850	326	1006
Insecticides						
Esfenvalerate	-10699	6380	-8791	3598	-10242	5054
Carbofuran	-4237	7342	-3254	4272	-4013	5562
Chlorpyrifos	-5157	5313	-4039	3037	-4892	4136
Terufos	-5760	4853	-4375	2743	-5433	3830
Parathion	-2726	4257	-2177	2466	-2594	3247
Disulfoton	-416	296	-327	167	-393	235

Table 6. Short-run welfare user and non-user ($) impacts due to the elimination of selected pesticides registered for use on sorghum in Texas, assuming the elicited yield loss at 1/3 of the original value, 1992.

	Low reduction of survey yields		Low reduction of USDA yields		Low reduction of long-term yields	
	User x1000	Non-user x1000	User x1000	Non-user x1000	User x1000	Non-user x1000
Herbicides						
Atrazine	-933	29996	-1397	17526	-2390	22577
2.4-D	-858	10355	-664	6092	-863	7749
Metolachlor	-150	11260	-633	6616	-91	8392
Glyphosate	-36	6328	-145	3759	-44	4646
Metolachlor + Atrazine	-396	6222	-152	3689	-356	4558
Alachlor	-475	6083	-232	3602	-431	4476
Bromoxynil	-2	2518	-34	1505	-5	1821
Dicamba	-158	1749	-57	1030	-137	1303
Alachlor + Atrazine	-111	1754	-18	1033	-91	1300
Cyanazine	324	706	321	425	322	503
Insecticides						
Esfenvalerate	-4755	3190	-3812	1799	-4531	2527
Carbofuran	-1144	3671	-659	2136	-1035	2781
Chlorpyrifos	-1679	2656	-1126	1518	-1549	2068
Terufos	-1422	2427	-736	1372	-1261	1915
Parathion	-1036	2128	-764	1233	-971	1624
Disulfoton	-149	148	-105	84	-138	117

CONCLUSION

The economic impacts derived in this study are short-term in nature and caution must be used in their interpretation. The total long-term effects, of a ban of a pesticide may not be truly known. Many factors are involved in obtaining an accurate assessment of the impacts of a pesticide, some of which cannot be accounted for. Insecticides are a prime example of this fact. As mentioned earlier, the use of an insecticide is a function of the type of target pest and the rate of infestation. Careful considerations must be taken into account in policy-making for pesticide use. Questions such as the possibility of insect resistance to particular chemicals need to be addressed in the policy-making process.

The use of economic impacts estimated in this study must be bound by the limitations imposed by their derivation. That is, these impacts are short-run welfare impacts that ignore the dynamics of both market forces and pests. These estimates can be used as good upper bound short-run levels of the expected impacts of banning certain pesticides; but, the banning of several pesticides at the same time could be significantly underestimated by these results.

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Fungicide Treatment Effects on Cotton (*Gossypium Hirsutum*) Emergence, Establishment and Yield

N.W. Hopper*
Box 42122, Texas Tech University and Texas Agricultural Experiment Station, Lubbock, TX 79409-2122
J. Supak
Texas Agricultural Extension Service, Texas A&M University, College Station, TX 77843

ABSTRACT

Seedling diseases account for major losses in stands of cotton (*Gossypium hirsutum* L.). The use of fungicide treatments may enhance seedling survival. Our objectives were to evaluate the effect of several fungicide treatments on emergence, stand establishment and yield of cotton, and to compare the effectiveness of seed treatment versus in-furrow soil applications. During 1987, four fungicide seed treatments (Captan, Captan + Apron, Captan + Apron + Vitavax, and Nuflow ND + Apron) and three in-furrow fungicide applications (two rates of Ridomil PC and one rate of Terrachlor Super X) were evaluated. Treated seed had higher ($P < 0.05$) emergence rates (97% to 194%) than the control. There were no differences ($P > 0.05$) among in-furrow applications. Stand establishment for the treated seed was higher (140 to 330%) than the control as was the in-furrow treatments of Ridomil PC (high rate) and Terrachlor Super X (150% for each). The seed and in-furrow treatments produced 37 to 84% higher lint yields than the control. The highest emergence and stand establishment resulted from seeds treated with Captan + Apron, and Nuflow ND + Apron. The highest lint yield resulted from seeds treated with Captan + Apron, Captan + Apron + Vitavax, and Nuflow ND + Apron. During 1988, the seed treatments, Captan, Captan + Apron, and Captan + Apron + Demosan were evaluated. Multiple seed treatments (Captan + Apron, and Captan + Apron + Demosan) generally produced 42 to 43% higher seedling emergence and 36% higher stand establishment compared to the control; however, no yield differences among the treatments were observed. Our results show that for improving emergence, establishment and yield of cotton, multiple fungicide seed treatments are generally superior to single seed treatments and to in-furrow treatments.

KEYWORDS: seedling disease, chemical protectants

Diseases account for major losses in cotton yield across the Cotton Belt (Blasingame, 1992; Ridgway et al., 1984). Blasingame (1992) estimated that the major cotton diseases caused the loss of 1.97 million bales during 1991. Of these diseases, the seedling disease complex (*Rhizoctonia solani*, *Pythium* spp., *Thielaviopsis* spp., and *Fusarium* spp.) accounted for the largest number of bales

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lost. In Texas the economic loss was over $28 million. Minton (1988b) reported that tremendous progress has been made in disease control with the introduction and use of inorganic and organic fungicides, and more recently the systemic fungicides. The fungicides used earlier were primarily broad spectrum types; however, recently developed fungicides are more specific for certain organisms (Minton, 1986). Therefore, selection of a certain fungicide or fungicide combination can be implemented to target specific organisms, thus accomplishing better disease control.

A good stand of cotton plants is a prerequisite for a high yield. Good stands are characterized by the following factors: 1) adequate number of plants per hectare, 2) uniform spacing of the plants, 3) uniform growth rate of the plants, and 4) seedlings that are free from disease. Good stands require the planting of high quality seed in a moist and properly prepared seedbed with some form of pesticide protection (Jividen, 1985; Minton, 1986; Minton and Garber, 1983; Waddle, 1985). Pesticide protection may be applied to the seed prior to planting, at planting (planter box treatment), or by the use of an in-furrow soil treatment. A misconception is that planting at higher seeding rates can replace the use of high quality seed and pesticide treatment. A higher seeding rate may produce an adequate plant population; however, it will not ensure uniform spacing and growth of seedlings.

Historically, Captan has been an effective fungicide in disease control for cotton. Minton and Green (1980) reported increased emergence and survival of cotton seedlings from the use of various rates of Captan in both greenhouse and field studies. Later reports have noted the effectiveness of several other compounds such as Ridomil PC, Terrachlor Super X, Apron, Vitavax, TCMTB, and Demosan used alone or in combination (DeVay et al., 1987; DeVay et al., 1988; Minton et al., 1986; Minton, 1988a; Sciumbato, 1987). Seedling survival rates and yield results have been somewhat variable among studies with different fungicides. Undoubtedly, variable results are due in part to the presence and/or virulence of certain organisms and the particular environmental conditions. More recent recommendations have included the use of fungicide combinations for the most effective control of seedling diseases (DeVay et al., 1988; Minton, 1988b; Papavizas et al., 1980).

The purpose of this study was to evaluate several fungicides and fungicide combinations on the emergence, stand establishment, and lint yield of cotton under Texas High Plains conditions. In addition, the effectiveness of seed treatment versus in-furrow applications was evaluated.

METHODS AND MATERIALS

This study was conducted over two growing seasons (1987 and 1988) at the Texas Tech University Research Farm. The soil type at this location is a Pullman clay loam (torrertic Paleustoll). Fungicide preparations for the seed were made by mixing the selected fungicide(s) with water to a final volume of 15 ml kg^{-1} of seed (Tables 1 and 2). One kilogram of seed for each treatment was placed in a laboratory seed treater and rotated as the seed treatment was applied using a syringe. After drying, the seeds were counted into individual packets in preparation for planting with a cone attachment on a field planter. The in-furrow applications were made by directing the selected materials (Table 1) through a tube from pesticide boxes mounted on the planter to the seed furrows where the materials would be in contact with the seed.

Table 1. Seed and in-furrow fungicide treatments evaluated for Experiment 1, 1987.

Treatment	Active ingredient (ai)	Method[†]	Rate[‡]
Control	-	-	-
Captan	captan: N-[(trichloromethyl) thio]-4-cyclohexene-1,2-dicarboximide	S	0.938
Captan	captan: N-[(trichloromethyl) thio]-4-cyclohexene-1,2-dicarboximide	S	0.938
+ Apron	metalaxyl: N-(2,6-dimethylphenyl)-N-(methoxylacetyl) alanine methyl ester	S	0.155
Captan	captan: N-[(trichloromethyl) thio]-4-cyclohexene-1,2-dicarboximide	S	0.469
+ Apron	metalaxyl: N-(2,6-dimethylphenyl)-N-(methoxylacetyl) alanine methyl ester	S	0.155
+ Vitavax	carboxin: 5,6-dihydro-2-methyl-1,4-oxantyiin-3-carboxanilide	S	0.748
Nuflow ND	TCMTB: 2-(thiocyanomethythio) benzothiazole	S	0.322
	chloroneb: (1,4-dichloro-2,5-dimethoxybenzene)	S	0.841
+Apron	metalaxyl: N-(2,6-dimethylphenyl)-N-(methoxylacetyl) alanine methyl ester	S	0.155
Ridomil PC	metalaxyl: N-(2,6-dimethylphenyl)-N-(methoxylacetyl) alanine methyl ester	I	0.056
	PCNB: pentachloronitrobenzene	I	0.560
Ridomil PC	metalaxyl: N-(2,6-dimethylphenyl)-N-(methoxylacetyl) alanine methyl ester	I	0.084
	PCNB: pentachloronitrobenzene	I	0.840
Terrachlor Super X	PCNB: pentachloronitrobenzene	I	1.120
	terrazole: 5-ethoxy-3-(trichloromethyl)-1,2,4-thiadiazole	I	0.280

[†]S denotes seed treatment and I denotes in-furrow application.

[‡]Seed treatment rates expressed as g ai kg^{-1} of seed and in-furrow applications as kg ai ha^{-1}.

Table 2. Fungicide seed treatments evaluated for Experiment 2, 1988.

Treatment	Active ingredient (ai)	Rate[†]
Control	-	-
Captan	captan: N-[(trichloromethyl) thio]-4-cyclohexene-1,2-dicarboximide	0.938
Captan	captan: N-[(trichloromethyl) thio]-4-cyclohexene-1,2-dicarboximide	0.938
+ Apron	metalaxyl: N-(2,6-dimethylphenyl)-N-(methoxylacetyl) alanine methyl ester	0.155
Captan	captan: N-[(trichloromethyl) thio]-4-cyclohexene-1,2-dicarboximide	0.938
+ Apron	metalaxyl: N-(2,6-dimethylphenyl)-N-(methoxylacetyl) alanine methyl ester	0.155
+ Demosan	chloroneb: (1,4-dichloro-2,5-dimethoxybenzene)	1.300

† g ai kg^{-1} of seed.

A 3-meter section of a center row of each plot was delineated for daily stand counts through 28 days after planting. These data rows were selected so they were planted by a common planter unit to avoid any differences in planting depth. The daily emergence counts were used to calculate an Emergence Rate Index (ERI) according to the following equation:

$$ERI = \sum_{i=1}^{y} [E_i((y + 1) - x_i)]$$

where: E_i = total emerged seedlings on day "i"
y = days to final count (28 days)
x_i = assumes the value of "i"

An Establishment Index (EI) was calculated 6 weeks after planting according to the following equation:

$$EI = \frac{\text{number of seedlings / 3m}}{\text{number of seeds planted / 3m}} \times 100$$

Lastly, a 5-meter section of one of the two center rows was harvested and the lint yield determined.

Experiment 1 (1987)

Prior to planting, the study area was fertilized with 90 kg ha^{-1} of N and 40 kg ha^{-1} of P_2O_5. In addition, Treflan or trifluralin [2,6-Dinitro-N,N, dipropyl-4-(trifluoromethyl) benzenamine] at the rate of 0.84 kg ai ha^{-1} was applied for weed control and the area was irrigated to ensure adequate moisture for germination and early season growth. Cotton ('Paymaster 145') was planted on 14 May at a seeding rate of 23.3 seeds per meter of row. Individual plots were 4 rows spaced 1.02 m apart and 12.2 m long. At the time of planting, Temik or aldicarb [2-Methyl-2-(methylthio) propionaldehyde O-(methylcarbamoyl) oxime] (0.51 kg ai ha^{-1}) was applied for early season insect control. Seasonal applications of insecticide were made as needed to control insect infestations. Two irrigations were applied during the growing season to prevent plant moisture stress. Eight treatments were investigated which included a control (no fungicide), Captan, Captan + Apron, Captan + Apron + Vitavax, Nuflow ND + Apron, Ridomil PC (two rates), and Terrachlor Super X (Table 1.)

Experiment 2 (1988)

The study area was fertilized with 87 kg ha^{-1} of N and 38 kg ha^{-1} of P_2O_5. Weeds were controlled with a preplant application of trifluralin (0.84 kg ai ha^{-1}) and a pre-emergence application of metolachlor [2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl) acetamide] (1.92 kg ai ha^{-1}) and prometryne [2,4-bis (isopropylamino)-6-(methylthio)-S-triazine] (1.35 kg ai ha^{-1}). Prior to planting, the area was irrigated. Two seasonal irrigations were applied to minimize plant moisture stress. Plots consisted of four rows spaced 1.02 m apart and 11 m long. The cultivar Paymaster 145 was planted on 17 May at a rate of 26 seeds m^{-1} of row.

Aldicarb (2.8 kg ha^{-1}) was applied for early-season insect control with seasonal insecticide applications as needed. Four treatments (Control, Captan, Captan + Apron, and Captan + Apron + Demosan) were evaluated during 1988 (Table 2).

Both years, the experimental design was a randomized complete block with four blocks. The data were analyzed using analysis of variance and the means were separated using the Duncan's Multiple Range Procedure.

RESULTS AND DISCUSSION

Experiment 1 (1987)

The germinating and emerging seedlings were exposed to more stressful environmental conditions during the first 14 days after planting in 1987 than in 1988. Precipitation was received on 12 of these days in 1987 (trace to 24 mm) and only on 6 days in 1988 (trace to 25 mm). The four seed treatments of Captan (C), Captan + Apron (C+A), Captan + Apron + Vitavax (C+A+V), and Nuflow ND + Apron (NF+A) all had higher ($P < 0.05$) ERI values than the control (Fig. 1). These seed treatments produced ERI increases of 97, 110, 158, and 194% over the control for C+A+V, C, NF+A and C+A, respectively. The in-furrow treatments, Ridomil PC at the low rate [RPC(L)] and high rate [RPC(H)] and Terrachlor Super X (TSX), did not perform significantly better ($P > 0.05$) than the control.

Within the seed treatments, the C+A and NF+A treatments had the highest ERI values; however, the NF+A was not different ($P > 0.05$) than the C or C+A+V treatments. There were no differences ($P > 0.05$) among the in-furrow treatments [RPC(L), RPC(H), and (TSX)] nor were they different from the control. In general, the seed treatments had higher ERI values than the in-furrow treatments, the only exception being that the C+A+V treatment was not significantly different ($P > 0.05$) from the RPC(H) and TSX in-furrow treatments.

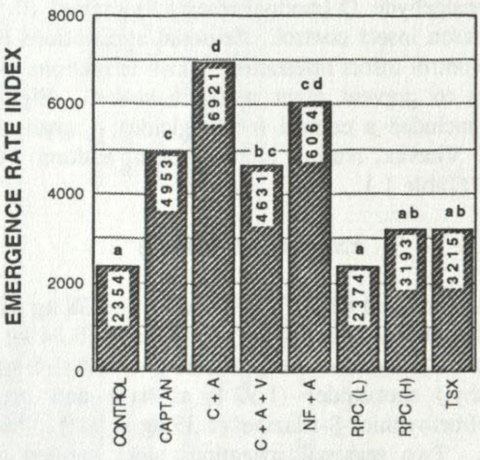

Figure 1. Emergence rate index of cotton as influenced by seed and in-furrow fungicide treatments during 1987. Bars with the same letter are not significantly different ($P > 0.05$).

The establishment index (EI) values represent the percentage of seeds planted that produced established plants 6 weeks after planting (Fig. 2). The EI values ranged from 10 to 43%. Again, the environmental conditions were especially stressful during the spring of 1987. All fungicide treatments, with the exception of RPC(L), produced higher ($P < 0.05$) EI values than the control. Within the seed treatments, both the C+A and NF+A treatments had higher EI values (43 and 40%, respectively) than the C (24%) and C+A+V (30%) treatments. Within the in-furrow treatments, higher ($P < 0.05$) EI values were noted for RPC(H) (25%) and TSX (25%) treatments than for the RPC(L) (14%). The C+A and NF+A seed treatments had the highest ($P < 0.05$) EI values.

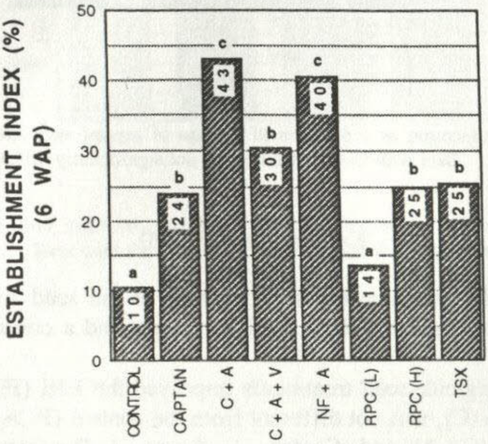

Figure 2. Relationship between the cotton seedling establishment index 6 weeks after planting (6 WAP) and the use of seed and in-furrow fungicide treatments during 1987. Bars with the same letter are not significantly different ($P > 0.05$)

The yield differences were not as pronounced as the ERI and EI values; however, all fungicide treatments produced significantly greater yields ($P < 0.05$) than the control (Fig. 3). The seed treatments of C, C+A, C+A+V, and NF+A caused yield increases over the control of 42, 83, 84, and 84%, respectively. The in-furrow treatments of RPC(L), RPC(H), and TSX generated yield increases over the control of 45, 37, and 38%, respectively.

Within seed treatments, yields from the C+A (936 kg ha^{-1}), C+A+V (938 kg ha^{-1}), and NF+A (940 kg ha^{-1}) treatments were higher ($P < 0.05$) than the C (726 kg ha^{-1}) treatment. However, no differences ($P > 0.05$) were noted among the C+A, C+A+V, and NF+A treatments. In addition, no differences ($P > 0.05$) were noted among in-furrow treatments.

The seed treatments of C+A, C+A+V, and NF+A produced higher ($P < 0.05$) yields than the control and in-furrow treatments.

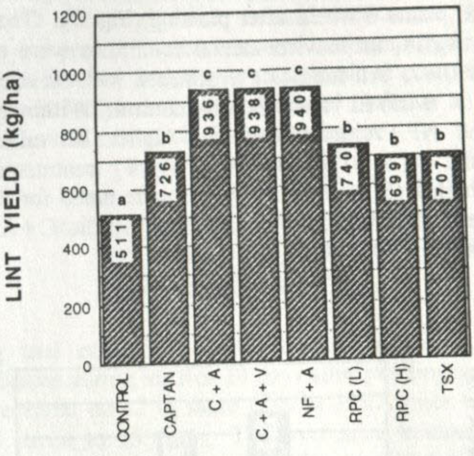

Figure 3. Lint yield of cotton as a function of the use of several seed and in-furrow fungicide treatments during 1987. Bars with the same letter are not significantly different (P> 0.05).

Experiment 2 (1988)

Results from 1987 had indicated an advantage of the seed treatments over the in-furrow applications, so only three seed treatments and a control were evaluated in 1988.

Again, certain fungicide seed treatments improved the ERI (Fig. 4). The single treatment of Captan (C), was not different from the control (P > 0.05). However, Captan + Apron (C+A) and Captan + Apron + Demosan (C+A+D) had significantly greater (P < 0.05) ERI values than the control (10042, 10078, and 7069 units, respectively). This represented an increase over the control of 42 and 43%, respectively, for the C+A and C+A+D treatments. There were no significant differences (P > 0.05) among the C, C+A, and C+A+D treatments.

Similar trends were noted for the EI values (Fig. 5). The C+A and C+A+D seed treatments were significantly better (36% for both) than the control with no difference being noted between the C treatment and the control. Again, no differences (P > 0.05) among the C, C+A, and C+A+D treatments were observed.

Although yields from the various treatments ranged from 571 kg ha^{-1} (Control) to 739 kg ha^{-1} (C+A), no significant differences (P > 0.05) existed among the treatments (Fig. 6). While the yield trends followed that of the ERI and EI parameters, a midseason hail storm (approximately 7 weeks after planting) may have been responsible for masking any potential yield differences. The 1987 data indicated a general advantage for seed treatments over the in-furrow applications. No real differences existed among the in-furrow treatments for ERI or yield.

Based on our findings, multiple seed treatments could be expected to produce higher ERI and EI values than untreated seed (1987 and 1988) and higher yields (1987). In addition, the lower ERI and EI values noted during 1987 were likely due to the greater number of days with precipitation during the first 14 days after planting.

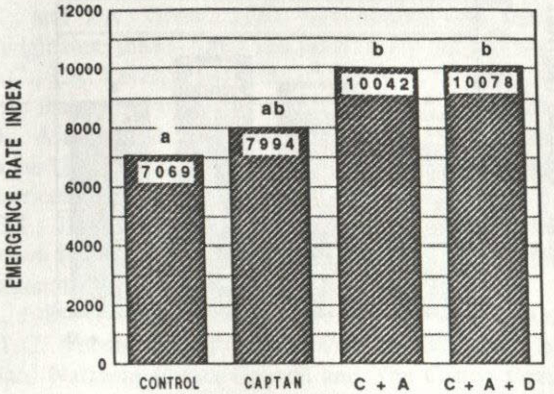

Figure 4. Emergence rate index of cotton as influenced by single and multiple fungicide seed treatments during 1988. Bars with the same letter are not significantly different (P > 0.05).

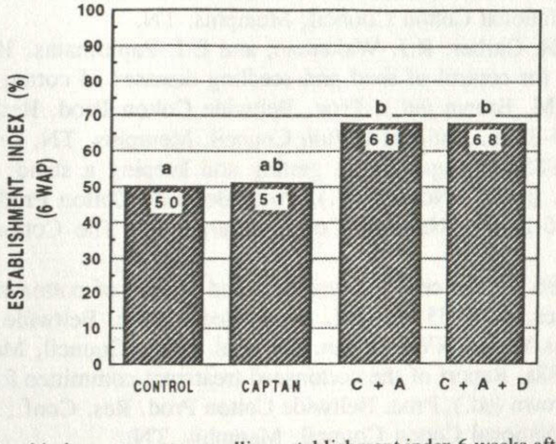

Figure 5. Relationship between cotton seedling establishment index 6 weeks after planting (6 WAP) and use of single and multiple fungicide seed treatments during 1988. Bars with the same letter are not significantly different (P > 0.05).

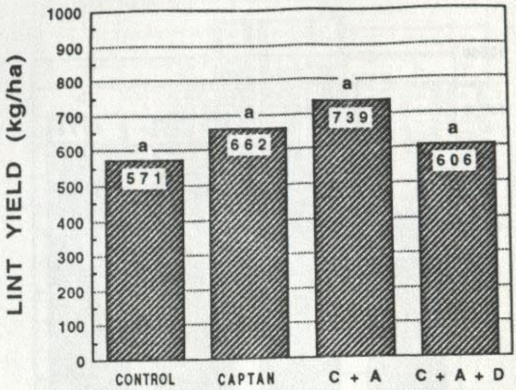

Fig. 6. Lint yield of cotton as a function of the use of single and multiple fungicide seed treatments during 1988. Bars with the same letter are not significantly different ($P > 0.05$).

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Validation and Repeatability of Measurement of Antibody Response to Ovalbumin in Beef Cattle

H.H. Shepard
Texas Tech University, Lubbock, TX 79409
R.D. Green*
Dept. of Animal Sciences, Colorado State University, Fort Collins, CO 80523
R.L. Hennig
M.L. Gibson
Texas Tech University, Lubbock, TX 79409

ABSTRACT

The objectives of this experiment were to evaluate the pattern of antibody response to ovalbumin as a test antigen in beef cattle, and to estimate the repeatability of the measurement of that response. Purebred Angus cows and calves were immunized with ovalbumin and later tested for antibody response. Six animals were sampled 7 d post-initial immunization to characterize primary antibody response and at 3, 5 and 7 d post-secondary immunization to characterize secondary antibody response. Increases in level of IgG specific for ovalbumin were more rapid in calves than in cows but gradually, measured levels became similar. Secondary responses were measurable on all specified dates, but primary response was not evident at d 7. Correlations between successive samples on animals indicated that the measurements were repeatable (R=.73) for secondary response. These data indicate that ovalbumin is an acceptable test antigen for eliciting a humoral immune response in beef cattle and that measurement of secondary response to ovalbumin can be evaluated in beef cattle at 5 or 7 d post-secondary immunization.

KEYWORDS: immune response, antigens

Traditionally in the livestock industry, disease has been combatted through the use of vaccines, antitoxins, antibiotics and other drugs. An alternative to these costly solutions would be to selectively breed animals for increased disease resistance (Templeton et al., 1988).

Most of the research on the genetics of immunocompetence in livestock has been done in pigs and there are relatively few beef cattle studies (Warner et al., 1987). Selecting for disease resistance in a particular species requires identifiable marker traits that characterize general immunocompetence in that species, as well as heritability estimates and genetic correlations for those traits. Because of limited research in beef cattle, reliable measurements of marker traits are still

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being developed. An important aspect of determining an animal's immunocompetence is quantifying its response when challenged with an antigen, because antibody-producing ability is controlled by multiple genes that have been postulated to correlate with resistance to disease (Warner et al., 1987). This ability is our best measurement of humoral immune response. Preliminary research at Texas Tech University (Green, unpublished data) indicated that thrice washed 40% sheep red blood cells (a common test antigen in livestock) do not elicit a satisfactory response in beef cattle. However, ovalbumin (OVA) has been shown to be a foreign and harmless antigen that produces a response in dairy cattle (Burton et al., 1989). Therefore, the objectives of this study were: 1) to evaluate the pattern of antibody response to OVA as a test antigen and 2) to estimate repeatability of measurement of antibody response to OVA in beef cattle.

MATERIALS AND METHODS

Six purebred Angus cows and their calves from the Texas Tech University teaching herd, New Deal, TX, were sampled in this study. The cows ranged in age from 2 to 9 yr and were nursing equal numbers of male and female calves that were from 3 to 5 months old. During most of the preceding year, cows were grazing wheat pasture or a sudan-sorghum hybrid. During the winter months, animals were fed crop residues and supplemented with protein. Cows were fed to meet or exceed NRC requirements.

To prepare the test antigen, crystallized OVA (Grade V,; Sigma Chemical Co., St. Louis, MO.) was dissolved 2:1 in non-sterile phosphate buffered saline and then diluted 1:1 in Freund's incomplete adjuvant in 20 ml syringes. The mixture was then emulsified and stored at 25°F (-4°C) for future immunizations.

Immunization of animals was accomplished by subcutaneous injections of 4 ml of OVA solution as described by Burton et al. (1989). Blood samples (20 ml) were collected via jugular venipuncture into heparinized syringes at the time of immunization (d 0) and at d 7. At d 14, animals were re-immunized with 4 ml OVA solution; then blood samples were collected at d 17, 19 and 21 to measure secondary antibody responses. Additionally, on days 19 and 21, two samples were collected per animal to estimate repeatability of the OVA antibody measurement. Plasma was obtained from each blood sample and stored at 25°F (-4°C) for later antibody content determinations. The antibody (immunoglobulin G specific for OVA, IgG_{OVA}) content of the plasma was measured by an enzyme-linked immunosorbent assay (ELISA) procedure and results were expressed as absorbance units at 405 nm. The OVA antigen (.5 mg ml^{-1} PBS) was attached to solid phase, flat bottomed, 96 well microtiter plates. Plasma samples were then diluted and plated with 3 wells/sample. Plates were incubated for 2 h to allow OVA specific antibodies in plasma to bind to OVA antigen. Plates were washed and anti-bovine IgG alkaline phosphatase (whole molecule; Sigma Chemical Co., St. Louis, MO.) was added to the wells. It should be noted that, since the bovine IgG antisera was whole molecule specific, there was a possibility that it might have cross-reacted with IgM or other immunoglobulins. However, the occurrence of such reactions should have been low because the antisera product had been company-tested for specificity. Plates were incubated for 1 h to allow enzyme-linked antibodies to bind to the "stem" (or F_c portion) of the remaining plasma antibodies. An initially colorless substrate which yields a colored metabolic product upon enzyme degradation, p-nitrophenyl phosphate (Sigma Chemical Co., St. Louis, MO.) was then added. After a 30 minute incubation, NaOH was added to stop the reaction and plates were read at 405 nm using a plate reader (Bio Rad EIA; Richmond, CA.) to obtain relative plasma contents of IgG_{OVA}.

Data were evaluated for variability within replicates of the same sample. If the within sample CV was in excess of 10% (listed as satisfactory assay repeatability; Muggli et al., 1987), the outlying replicate was deleted and the CV was recalculated. Means were then calculated from edited data for each animal, sample and time point. IgG_{OVA} values were determined to be non-normal, thus data were transformed by taking the natural logarithm of each data point. Final data were analyzed by analysis of variance. There was an interaction effect ($P < .01$) of parental status (i.e. cow versus calf) by time, thus analyses were performed on cow and calf data separately with a model including the effect of day of measurement (day). Mean separations were done with least significant difference tests. Repeatability was estimated by pooling data for d 19 and 21 and estimating variation between animals (V_B) and that within animals (V_W) from a mixed model including effects of day and animal. Standard errors of repeatabilities were calculated using the following formula (Falconer, 1989):

$$V(t) = \frac{2[1+(n-1)t]^2(1-t)^2}{n(n-1)(N-1)}$$

RESULTS AND DISCUSSION

Analyses of variance by parental status indicated an increase ($P < .01$) in IgG_{OVA} over the dates measured (Table 1), in agreement with Burton et al. (1989) who followed a similar immunization schedule using OVA as a test antigen in dairy calves. This was true for both cows and calves, with the reason for the significant interaction of parental status X day being that calves increased at a faster rate between d 0 and 17 than cows, and then plateaued (Figure 1).

Table 1. Analyses of variance for measurement of ovalbumin antibody levels by parental status.

	Source of variation	df	Mean square
Cows			
	Day	4	.77**
	Error	25	.03
Calves			
	Day	4	1.08**
	Error	25	.04

** significant at $P < 0.01$.

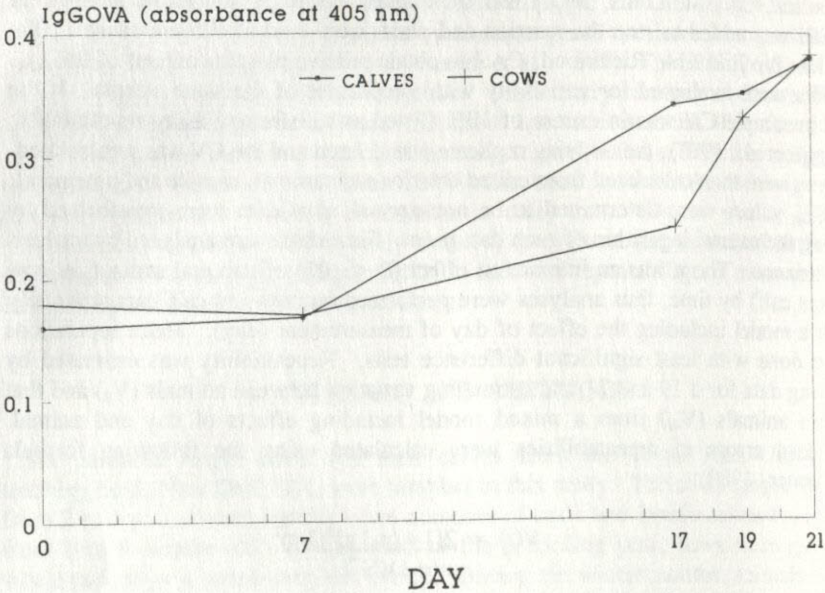

Figure 1. Ovalbumin antibody content by day of measure and parental status. (Standard error of mean = .02).

The changes in antibody content between dates of measurement are presented in Table 2. Cows experienced a larger percentage change after d 17 than calves and appeared to be still increasing at d 21, but the percent changes between d 19 and d 21 for both cows and calves were non-significant. Final differences between cows and calves at d 19 and 21 were small. Since d 19 and d 21 correspond to d 5 and d 7 of secondary response, these data indicate that secondary response to ovalbumin as a test antigen can be measured effectively at either 5 or 7 d post-secondary exposure.

Table 2. Percentage response between days of measurement by parental status.

	Days†						
	0-7	0-17	0-19	0-21	17-19	17-21	19-21
Parental Status							
Cows	0	35.2*	84.0**	116.7**	36.1*	60.3**	17.8
Calves	2.5	113.7**	118.5**	137.7**	2.1	11.2	9.0

†Percentage change in antibody level between two dates of measurement (eg., % change from d 0 to d 7). * $P < .05$, ** $P < .01$.

Differences between d 0 and d 7 as measures of primary response were small and non-significant. This was expected because the ELISA procedure measured IgG specific to ovalbumin and that IgM antibodies make up a major proportion of the primary response, while the secondary response consists almost entirely of IgG (Roitt et al., 1989).

Measures of accuracy and repeatability of IgG_{OVA} are presented in Table 3. Correlations between successive samples on the same animal were relatively high (r=.69 and P<.01 on day 19; r=.74 and P<.01 on day 21). Repeatability of the measure was estimated to be $.73 \pm .14$. Comparisons of sample means within date indicated close agreement (2.2% and 0.4% differences between means on d 19 and 21, respectively).

Table 3. Measures of accuracy of ovalbumin antibody levels.

Correlations between Samples within day
$r_{19} = .69^{**}$
$r_{21} = .74^{**}$
Variance component (V) estimates and degree of repeatability
V (between animals) = .026
V (within animal) = .009
Repeatability = $.73 \pm .14$
Means and Standard errors of IgG_{OVA} by sample and day
Day 19 (sample 1) = $.35 \pm .07$
Day 19 (sample 2) = $.34 \pm .05$
Day 21 (sample 1) = $.39 \pm .08$
Day 21 (sample 2) = $.39 \pm .07$

** P < .01

OVA was used in this study because it has proven useful as a test antigen in experiments with mice, pigs, sheep and dairy cattle (Biozzi et al., 1989; Babinszky et al., 1991; Berggren-Thomas et al., 1987; Burton et al., 1989). Furthermore, Burton et al. (1989) list moderate to high heritabilities for secondary response to ovalbumin in dairy calves, which will be important if response to OVA is to be incorporated into any type of selection program for immune response in beef cattle.

Collectively, the results of this study indicate that ovalbumin can effectively be used as a test antigen to elicit repeatable responses of the humoral immune system in beef cattle. Using this procedure, it appears that the best sampling time is 5 or 7 d post-secondary exposure to the antigen. This latter conclusion agrees with data on dairy calves that peaked at 7 d post-secondary exposure (Burton et al., 1989).

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Pricklypear Control with Fire and Herbicides on the Texas Rolling Plains

Boyd Keith Blair
Carlton M. Britton*
Dept. of Range and Wildlife Management, Texas Tech Univ., Lubbock, TX 79409-2125
Darrell N. Ueckert
Texas Agricultural Experiment Station, Lubbock, TX 79409

ABSTRACT

A fire/herbicide system and the efficacy of picloram compared to triclopyr in this system was evaluated for pricklypear control. The study was initiated in 1987 and repeated in 1988, with control evaluated for 4 and 3 years post-treatment, respectively. Pricklypear response varied depending on year of application. Fire alone in the 1987 experiment did not provide sufficient control after 4 years. Fire plus picloram at 0.25 lb ai ac^{-1} provided 89% reduction of pricklypear canopy cover after 4 years. In 1987 unburned plots receiving the 0.25 lb ai ac^{-1} rate of picloram also provided the best control after 4 years (73% reduction). Fire alone in the 1988 experiment provided substantial control of pricklypear after 3 years (72% reduction). Pricklypear control in 1988 was enhanced by the addition of picloram treatments on burned plots. The addition of triclopyr to burned plots provided little benefit over that of fire alone. In 1987 unburned plots initial canopy cover played an important role in the comparison of pricklypear response to herbicide treatments. Picloram at 0.25 lb ai ac^{-1} applied to 1987 unburned plots generally provided better control than other treatments, but only when initial canopy cover was above specific amounts.

KEYWORDS: picloram, triclopyr, canopy cover, torrential rain, *Opuntia*

Pricklypear (*Opuntia* spp.) occupies about 25.4 million ac of rangeland in Texas (Lundgren et al., 1981). Only 8% of the ranchers in the High and Rolling Plains of Texas consider pricklypear to be beneficial to livestock production (Lundgren et al., 1981). Consumption of pricklypear fruits and cladophylls by livestock, especially sheep and goats, causes severe health problems (Merrill et al., 1980). Cactus spines frequently become imbedded in the tongues of cattle, predisposing the tongue to bacterial infection (Migaki et al., 1969). The discomfort caused by cactus spines can suppress livestock performance. Cactus glochids imbed in the lips, gums, tongues, stomachs, and intestines of sheep and goats causing ulceration and a subsequent decline in body condition, reduced lactation, and loss of young (Merrill et al., 1980).

Pricklypear can reduce forage availability for grazing (Petersen et al., 1988;

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Bement, 1968), compete with desirable forage plants, and interfere with movement and handling of livestock (Ueckert, 1982). Pricklypear can be controlled with herbicides (Wicks et al., 1969; Schuster, 1971; Kitchen et al., 1980; Price et al., 1985). Herbicidal control of brownspine pricklypear (*Opuntia phaecantha* Engelm. & Bigel) in the northern Rolling Plains did not affect total herbaceous forage production, but livestock carrying capacity increased in direct proportion to reduction in pricklypear canopy cover (Price et al., 1985). However, according to Ueckert (1982), aerial application of herbicides is not an economically feasible practice for many ranches. In contrast, the sequential application of prescribed fire and herbicides may significantly increase pricklypear control and thus be economically viable. Ueckert (1980) integrated prescribed fire with picloram (4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid) spray applied at 0.5 lb ai ac^{-1}. He reported 99.6% reduction in canopy cover and 96% mortality of pricklypear the second season after treatment. Presently, a prescribed burn, followed by an application of picloram, is the fastest and most reliable way to control pricklypear. The fire destroys mulch and litter so that nearly all the picloram reaches bare soil (Ueckert, 1986), which may increase the actual amount of herbicide absorbed by the plant. The objectives of this study were to evaluate the use of a prescribed fire/herbicide system and to compare the efficacy of picloram to that of triclopyr {[(3,5,6-trichloro-2-pyridnyl)oxy]acetic acid} for pricklypear control in the northern Rolling Plains of Texas. Pricklypear (*Opuntia* spp.) classification follows Grant and Grant (1979). Other plant classification follows Correl and Johnston (1979).

MATERIALS AND METHODS

The study was conducted in the northern Rolling Plains on the West Fuller Ranch, 17 mi northwest of Snyder, Texas, in Scurry County. Soil is a Stamford clay (fine, montmorillonitic, thermic family of typic Chromusterts) with 0-5% slopes (Dixon et al., 1973). Average annual precipitation for Scurry County is 19.6 inches.

The dominant plant community is a honey mesquite (*Prosopis glandulosa* Torr.)-tobosagrass {*Hilaria mutica* (Buchl.) Benth.} type. Texas wintergrass (*Stipa leucotricha* Trin. and Rupr.), sideoats grama {*Bouteloua curtipendula* (Michx.) Torr.}, Texas grama {*B. rigidiseta* (Steud.) Hitchc.}, and buffalograss {*Buchloe dactyloides* (Nutt.) Engelm.} are subdominant to tobosagrass. *Opuntia edwardsii* was common throughout the site, and had hybridized forming intermediates with *O. phaeacantha major* and *O. lindheimeri*. Agarita (*Berberis trifoliolata* Moric.), Mormon tea (*Ephedra antisyphilitica* C.A. Mey.), and cholla (*Opuntia imbricata* Haw.) also occurred on the site.

The study was initiated March 1987 and repeated in 1988. Prior to burning 12, 0.56-ac plots were arranged in a completely randomized design within a 7-ac grazing exclosure. Three areas were burned each year and three were left unburned. Fire breaks were constructed around each main plot to be burned. Each of three plots was individually ringfired.

Herbicide treatments were randomly assigned to seven 16 by 98 ft subplots within each main plot. Each herbicide treatment was separated by a 16 by 98 ft border. Herbicide treatments included picloram applied at 0.12 and 0.25 lb ai ac^{-1}, and triclopyr applied at 0.12, 0.25, 0.50, and 1.0 lb ai ac^{-1}. One subplot in each main unit was left as an untreated check.

Live canopy cover of pricklypear was measured along four permanently marked 50-ft transects within each subplot. Canopy cover was recorded prior to treatment, and once per year thereafter. A completely randomized design with three replications was used. Analysis of variance was used to compare initial and post-treatment canopy cover within a treatment. Analysis of covariance was used to remove the influence of initial canopy cover and to compare post-treatment canopy cover between treatments.

Fine-fuel load was determined by clipping ten 0.25-m² rectangular quadrats in each main plot prior to burning. Samples were oven dried at 140 °F and weighed. Ten soil cores were taken from each main plot and soil water contents were determined gravimetrically (Black, 1965) (Table 1). Soil samples were collected from the 0 to 6 inch depth the day of the burn. Air temperature, humidity, and wind speed were monitored throughout ignition using a belt weather kit (Table 1). Rainfall data were averaged from the Texas Tech Experimental Ranch near Justiceburg, Texas (12 mi west of the study site) and NOAA 1987-88 Snyder, Texas station (15 mi southeast of study site).

Table 1. Environmental variables recorded at study site during application of fire treatments.

Date of Application	Ambient temperature	Relative humidity	Wind Speed	Soil water† content	Fine fuel‡ load
	(°F)	(%)	($mi\ hr^{-1}$)	(%)	($lb\ ac^{-1}$)
March 1987	64	38	6-14	22.7 ±2.2	2414 ±185
March 1988	63	33	5-9	16.7 ±1.5	1804 ±203

†Soil water content is the average of 30 samples taken at the 0 to 6 inch depth. Standard error is given below the mean.
‡Fine fuel load is the average of 30 samples taken from 3 plots prior to burning. Standard error is given below the mean.

Fire treatments were applied 7 March 1987 and 5 March 1988. Herbicide treatments were applied as foliar sprays 11-15 May 1987 and 23-27 May 1988 using a Solo backpack pump sprayer. Picloram was applied in 43 gal ac^{-1} water with 0.1% (v:v) commercial emulsifier. Triclopyr was applied in 43 gal ac^{-1} of a 1:14 (v:v) diesel fuel/water emulsion with 0.1% (v:v) commercial emulsifier. The amount of diesel used in the triclopyr formulations was higher than normally recommended which may make the triclopyr treatments less comparable to other studies. Herbicide applications were restricted to certain weather conditions. Temperature was between 61 and 81° F, relative humidity was greater than 25% and wind was less than 8 mi hr^{-1}.

RESULTS AND DISCUSSION

Pricklypear had started to resprout in burned plots and new cladophylls with true leaves were present in unburned plots at the time of herbicide application for both years. However, resprouting was less evident in 1988 burned plots and budbreak in 1988 unburned plots was less substantial than experienced in 1987.

Total rainfall was near the long term average in 1987 and 20% above normal in 1988. The study site received 7.4 inches within 2 weeks after herbicide application in 1987, and 2.3 inches within 1 week after herbicide application in 1988. Fine fuel averaged 2414 (S.E.=185) lb ac^{-1} in 1987 and 1804 (S.E.=203) lb ac^{-1} in 1988 (Table 1).

Pricklypear canopy cover in the 1987 experiment was reduced ($P \leq 0.05$) 1, 2, 3, and 4 years after fire plus picloram treatment at 0.25 lb ai ac^{-1} (Table 2). Percent reduction from initial canopy cover increased each year to a high of 89%, 4 years post-treatment. Higher rates of picloram may have provided better and faster control, as shown by Ueckert (1980) where canopy cover was reduced 99.6% the second season after fire plus picloram treatment at 0.50 lb ai ac^{-1}.

Fire alone in the 1987 experiment did not reduce ($P \geq 0.05$) pricklypear canopy cover at any post-treatment period (Table 2). These results are not consistent with those of Ueckert et al. (1982) where canopy cover was reduced 85% 6 months after fire. Bunting et al. (1980) reported only a 20% mortality of brownspine pricklypear 6 months after fire, but mortality was reported to exceed 70% by the end of the third year. Mortality, however, may not be comparable to canopy cover data.

The fire plus 0.25 lb ai ac^{-1} rate of picloram reduced pricklypear canopy cover more consistently than any other treatment in the 1987 experiment. Reduction was greater ($P \leq 0.05$) 3 and 4 years post-treatment than any other treatment, except for fire plus 1.0 lb ai ac^{-1} rate of triclopyr the fourth year post-treatment (Table 2).

Pricklypear canopy cover in 1987 unburned plots was increased ($P \leq 0.05$) from initial canopy cover by the 0.12 lb ai ac^{-1} rate of triclopyr 2, 3, and 4 years post-treatment (Table 3). Post-treatment canopy cover of areas treated with picloram at 0.25 lb ai ac^{-1} did not differ ($P \geq 0.05$) from initial canopy cover at any post-treatment period, although reduction reached 73% after 4 years. Changes in post-treatment canopy cover were apparent even after 4 years and would indicate that long-term monitoring is necessary to fully evaluate treatment effects.

In 1987 unburned plots, different slopes for the response of post-treatment canopy cover to initial canopy cover for some treatments was detected ($P \leq 0.01$). This indicated that some post-treatment responses were influenced by initial canopy cover. Therefore, to test for differences between treatments, the region of significance in initial canopy cover was calculated for all pairwise comparisons of treatments with a separate slopes model (Searle, 1987) (Table 4). For example, the 0.25 lb ai ac^{-1} rate of picloram reduced ($P \leq 0.05$) pricklypear canopy cover more than the untreated check 3 and 4 years post-treatment, but only if initial canopy was greater than 1.5 and 1.3%, respectively. These data suggest that if initial canopy cover is low, then a picloram treatment at rates used in this study may not be appropriate for pricklypear control. If initial canopy cover is low, then a fire treatment may be warranted since fine fuel load may be negatively correlated to pricklypear canopy cover. There also may be an upper range of initial canopy cover when fire alone will not achieve substantial control, and the picloram treatment should be used along with fire. Additionally, areas with very high initial canopy cover may not support

Table 2. Percent initial and post-treatment canopy cover of pricklypear from 1987 burned plots.

Treatment (lb ac^{-1})	Initial	Canopy Cover (%) Years After Treatment 1	2	3	4
Fire plus	2.73	2.54[†]	1.92	1.72	1.60
Picloram		2.95[‡] a	2.16 a	2.00 a	1.82 a
(0.12)		-7[§]	-30	-37	-41
Fire plus	3.45	1.47 *	1.08 *	0.58 *	0.38 *
Picloram		1.32 b	0.99 b	0.47 b	0.30 b
(0.25)		-57	-69	-83	-89
Fire plus	3.83	3.44	2.44 *	3.28	2.49 *
Triclopyr		3.00 a	2.17 a	2.97 ac	2.25 a
(0.12)		-10	-36	-14	-35
Fire plus	3.50	2.74	2.63	3.17	2.91
Triclopyr		2.56 a	2.51 a	3.04 ac	2.81 a
(0.25)		-22	-25	-9	-17
Fire plus	3.10	2.05 *	2.16	2.78	2.55
Triclopyr		2.17 ab	2.23 a	2.87 a	2.62 a
(0.50)		-34	-30	-10	-18
Fire plus	2.83	2.37	1.53	1.95	1.44 *
Triclopyr		2.69 a	1.73 ab	2.18 ac	1.62 ab
(1.0)		-16	-46	-31	-49
Fire only	3.36	2.95	2.67	3.29	2.94
		2.87 a	2.62 a	5.24 c	2.90 a
		-12	-21	-2	-13

†Actual means within a row of post-treatment canopy cover followed by an asterisk are different ($P<0.05$), AOV, from the initial canopy cover.
‡The second number within a row and column are adjusted means based on initial canopy cover as a covariable, ANCOVA. Adjusted means within a column followed by different letters are different ($P<0.05$).
§Percent change is based on initial and the actual post-treatment canopy cover.

Table 3. Percent initial and post-treatment canopy cover of pricklypear from 1987 unburned plots.

Treatment (lb ac^{-1})	Initial	Canopy Cover (%) Years After Treatment 1	2	3	4
Picloram	1.43	1.88[†]	1.54	1.77	1.56
(0.12)		2.33[‡] ab	[¶]abc	ab	ab
		+31[§]	+8	+24	+9
Picloram	1.64	1.32	0.82	0.52	0.44
(0.25)		1.51 a	a	a	a
		-20	-50	-68	-73
Triclopyr	1.26	1.98	2.83 *	3.48 *	3.07 *
(0.12)		2.63 b	b	b	b
		+57	+125	+176	+144
Triclopyr	1.06	1.30	1.43	1.66	1.48
(0.25)		2.20 ab	abc	ab	b
		+23	+35	+57	+40
Triclopyr	2.23	2.96	2.73	3.29	2.64
(0.50)		2.44 b	c	b	b
		+33	+22	+48	+18
Triclopyr	3.21	3.24	5.06 *	5.05 *	4.08
(1.0)		1.54 a	bc	b	b
		+3	+58	+57	+27
Untreated	1.58	1.83	1.92	2.58	1.91
		1.86 ab	c	b	b
		+16	+22	+63	+21

†Actual means within a row of post-treatment canopy cover followed by an asterisk are different ($P<0.05$), AOV, from the initial canopy cover.

‡The second number within a row and column are adjusted means based on initial canopy cover as a covariable, ANCOVA. Adjusted means within a column followed by different letters are different ($P<0.05$).

§Percent change is based on initial and the actual post-treatment canopy cover.

¶Means 2,3, and 4 years post-treatment within a column followed by different letters are different ($P<0.05$), ANCOVA and seperate slopes model, but only at the specified region of significance of initial canopy cover given in Table 4.

Table 4. Regions of significance for 2,3,4 years post-treatment in 1987 unburned plots.

2 year Post-treatment	
Significant treatment Comparisons (lb ai ac^{-1})	Initial % Canopy Cover Regions of Significance
Picloram 0.25 and Triclopyr 0.12	>1.12
Picloram 0.25 and Triclopyr 0.50	>1.56
Picloram 0.25 and Triclopyr 1.0	>2.48
Picloram 0.25 and Untreated	<0.45 or >1.28
Triclopyr 0.12 and Triclopyr 0.50	1.25 to 1.76
Triclopyr 0.12 and Untreated	1.18 to 1.86
3 year Post-treatment	
Significant treatment Comparisons (lb ai ac^{-1})	Initial % Canopy Cover Regions of Significance
Picloram 0.25 and Triclopyr 0.12	1.05 to 2.45
Picloram 0.25 and Triclopyr 0.50	>1.95
Picloram 0.25 and Triclopyr 1.0	>2.07
Picloram 0.25 and Untreated	>1.47
4 year Post-treatment	
Significant treatment Comparisons (lb ai ac^{-1})	Initial % Canopy Cover Regions of Significance
Picloram 0.25 and Triclopyr 0.12	1.12 to 1.79
Picloram 0.25 and Triclopyr 0.25	1.05 to 1.49
Picloram 0.25 and Triclopyr 0.50	>0.91
Picloram 0.25 and Triclopyr 1.0	>1.50
Picloram 0.25 and Untreated	1.29

enough fine fuel for an adequate fire, and higher rates of picloram alone may be needed for sufficient control of pricklypear.

Pricklypear canopy cover in the 1988 experiment was reduced ($P \leq 0.05$) in burned plots after 1, 2, and 3 years for all treatments (Table 5). Canopy cover was reduced 98% by fire plus the 0.12 and 0.25 lb ai ac^{-1} rates of picloram, and 72% by fire alone after 3 years. The 1988 results are more consistent with those found in earlier research (Ueckert et al., 1982; Bunting et al., 1980).

Table 5. Percent initial and post-treatment canopy cover of pricklypear from 1988 burned plots.

	Canopy Cover (%)			
		Years After Treatment		
Treatment (lb ac^{-1})	Initial	1	2	3
Fire plus	4.38	0.80† *	0.17 *	0.09 *
Picloram (0.12)		0.99‡	0.61	0.31 a
		-82§	-96	-98
Fire plus	4.12	0.94 *	0.21 *	0.08 *
Picloram (0.25)		1.19	0.52	0.36 ab
		-77	-95	-98
Fire plus	6.22	0.99 *	1.50 *	1.01
Triclopyr (0.25)		0.78	1.13	0.76 ab
		-84	-76	-84
Fire plus	4.31	0.62 *	1.42 *	0.86 *
Triclopyr (0.50)		0.83	1.64	1.10 ab
		-86	-67	-80
Fire plus	4.19	0.23 *	0.63 *	0.61 *
Triclopyr (0.50)		0.46	0.70	0.87 ab
		-86	-85	-85
Fire plus	6.88	1.12 *	2.11 *	1.59 *
Triclopyr (1.0)		0.76	1.81	1.17 ab
		-84	-69	-77
Fire only	6.59	1.84 *	2.67 *	1.85 *
		1.55	2.30	1.51 b
		-72	-59	-72

†Actual means within a row of post-treatment canopy cover followed by an asterisk are different ($P < 0.05$), AOV, from the initial canopy cover.
‡The second number within a row and column are adjusted means based on initial canopy cover as a covariable, ANCOVA. Adjusted means within a column followed by different letters are different ($P < 0.05$).
§Percent change is based on initial and the actual post-treatment canopy cover.

Adjusted canopy cover means between treatments differed ($P \leq 0.05$) only between fire plus the 0.12 lb ai ac^{-1} rate of picloram and fire alone after 3 years (Table 5). Most of the reduction apparently was due to the fire treatment. Long-term monitoring, however, is needed to determine the longevity of these treatments.

In the 1988 unburned plots, post-treatment canopy cover differed ($P \leq 0.05$) from initial canopy cover after 3 years in areas treated with the 0.25 lb ai ac^{-1} rate of picloram (Table 6). The 0.12 and 0.25 lb ai ac^{-1} rate of picloram provided better control ($P \leq 0.05$), 37 and 64% reduction of canopy cover respectively, than other treatments. Additionally, the effects of picloram treatments on canopy cover probably are not fully manifested after 3 years as other biological factors may continue to influence the weakened plants.

Table 6. Percent initial and post-treatment canopy cover of pricklypear from 1988 unburned plots.

	Canopy Cover (%)			
		Years After Treatment		
Treatment (lb ac^{-1})	Initial	1	2	3
Picloram (0.12)	4.57	4.16†	3.34	2.86
		2.55‡ a	1.51 a	0.31 ac
		-9§	-27	-37
Picloram (0.25)	3.23	4.05	2.21	1.16 *
		3.88 b	2.54 ab	1.04 a
		+25	-32	-64
Triclopyr (0.12)	3.05	3.39	3.85	3.63
		3.41 ab	3.68 abc	3.65 b
		+11	+26	+19
Triclopyr (0.25)	2.26	2.60	3.54	3.22
		3.48 ab	5.27 abc	2.83 b
		+15	+57	+42
Triclopyr (0.50)	1.79	2.01	2.74	2.53
		3.39 ab	4.04 abc	3.47 b
		+12	+53	+41
Triclopyr (1.0)	3.61	4.01	4.19	3.31
		3.42 ab	3.22 abc	2.91 bc
		+11	+16	-8
Untreated	2.99	2.73	3.66	3.06
		2.82 ab	4.31 bc	3.12 b
		-9	+22	+2

†Actual means within a row of post-treatment canopy cover followed by an asterisk are different ($P < 0.05$), AOV, from the initial canopy cover.
‡The second number within a row and column are adjusted means based on initial canopy cover as a covariable, ANCOVA. Adjusted means within a column followed by different letters are different ($P < 0.05$).

CONCLUSIONS

Rainfall appeared to play an important role in the efficacy of treatments for control of pricklypear. Rainfall after herbicide application is critical, especially for picloram which is both foliar and root absorbed. Torrential rains, however, many inhibit lethal concentrations of herbicide from entering plant systems. In the 1987 experiment fire alone did not provide sufficient control of pricklypear after 4 years. Fire plus picloram at 0.25 lb ai ac^{-1} gave the best control after 4 years (89% reduction in canopy cover). In unburned plots, the 0.25 lb ai ac^{-1} rate of picloram also provided the best results after 4 years (73% reduction in canopy cover). This would indicate that certain years would require more than fire alone or treatments other than fire to obtain sufficient control of pricklypear. Higher rates of picloram also may provide quicker and better control.

Fire alone in the 1988 experiment provided substantial control of pricklypear after 3 years (72% reduction in canopy cover). The addition of picloram treatments to burned plots enhanced control over that of fire alone, however, the cost of the additional picloram should be evaluated if it is known that fire alone will give substantial control. Pricklypear response to fire alone appears variable and at this time the addition of the picloram treatment should give more consistent control.

Determining initial canopy cover before treatment application for pricklypear control may provide important insight to which type of treatment should be used. There may be a range of initial canopy cover that can be controlled by fire alone, fire plus picloram, or picloram alone. Further studies are needed to evaluate how initial canopy cover influences treatment efficacy.

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Effects of Clippings and Fertilizers on Warm-Season Turfgrasses

Jerry R. Vernon
Donald L. Cawthon*
Richard G. Dubes
Larry J. Klingbeil
East Texas State University, East Texas Station, Commerce, TX 75429

ABSTRACT

Six warm-season turfgrasses were established on a clay-loam soil to determine the effects of clippings and nitrogen (N) fertilizers on growth and appearance. Ammonium sulfate produced higher clipping yields and tissue N content than Milorganite. Using 0.5 lb. N from ammonium sulfate per 1000 sq. ft. was as effective as 1.0 lb. N from Milorganite per 1000 sq. ft. Recycling clippings increased growth without a reduction in tissue N content or general appearance. Compared with other grasses, 'Prairie' buffalograss and bermudagrass cultivars generally had greater tissue N levels and growth. The growth and quality of 'Georgia Common' centipedegrass declined during the second year of the study. General appearance ratings for 'Emerald' zoysiagrass declined during the second year at higher N rates supplied by ammonium sulfate.

KEYWORDS: mulching mower, Milorganite

Continued population growth, urbanization, and environmental awareness are creating interest in environmentally friendly landscape management practices. Using organic fertilizers and mulching mowers to recycle nutrients may contribute to environmentally sound management practices.

Organic nitrogen (N) carriers are processed from metropolitan sewage sludges and animal residues (Beard, 1973 and Turgeon, 1980). Use of slow-release forms of N reduces thatch accumulation and provides for more uniform growth compared to synthetic sources (Meinhold et al., 1973). English et al. (1974) found leachates to be low in ammonium and nitrate forms of N when the organic fertilizer, Milorganite, was compared to urea and ammonium nitrate. Barrios et al. (1979) found that N from Milorganite generally produced turfgrass of higher quality than equivalent rates of N from synthetic sources in sandy soils.

Turfgrass clippings are also a potentially significant source of organic nutrients (Anonymous, 1989). Recycling clippings may provide up to 25% of the fertilizer needs of a lawn. Grass clippings returned to the turf canopy decompose quickly compared to stem and crown tissues (Beard, 1976) and nutrient recycling can begin within 14 days (Johnson et al., 1987; Soper et al., 1988).

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This study was done to determine the interactive effects of grass clippings and N applications on the growth and appearance of six warm-season turfgrasses.

MATERIALS AND METHODS

Turfgrass species and cultivars used in this project were: 'Common' bermudagrass [*Cynodon dactylon* (L.) Pers.], 'Tifway' bermudagrass [*Cynodon transvaalensis* Burt-Davies x *Cynodon dactylon* (L.) Pers.], 'Georgia Common' centipedegrass [*Eremochloa ophiuroides* (Munro) Hack.], 'Raleigh' St. augustinegrass [*Stenotaphrum secundatum* (Walt.) Kuntze.], 'Emerald' zoysiagrass [Z. *japonica* x Z. *tenufolia*], and 'Prairie' buffalograss [*Buchloe dactyloides* (Nutt.) Engelm.].

The soil used on the East Texas State University Farm was classified as a clay-loam with 8.1 pH and 4% organic matter. The soil was high in phosphorus, potassium, calcium, magnesium, zinc, iron, and copper. Manganese, sodium, sulfur and boron were low. No preplant fertilizers or soil amendments were incorporated.

The experimental design was a randomized split-plot with three replications and with cultivars as main plots. All main plots measured 10.0 ft. by 12.5 ft. and were established by laying sod in May and June of 1990, except buffalograss plots which were established in July, 1990.

Each main plot was subdivided into five subplots measuring 2.5 ft. by 10 ft. for the following fertilizer treatments (expressed in lbs. of actual N per 1000 sq. ft.): control (no fertilizer), milorganite at 0.5 lb., ammonium sulfate at 0.5 lb., milorganite at 1.0 lb., and ammonium sulfate at 1.0 lb. Fertilization treatments were applied by hand on 11 July, 6 August, 14 September, and 12 October in 1990 and on 10 May, 15 June, 28 July, and 19 August in 1991. The fertilizer subplots were further subdivided into 2.5 by 5.0 ft. plots to accommodate mowing treatments using either a traditional bagging mower or a recycling (mulching) mower.

All plots were mowed weekly during the growing season and irrigated as necessary. Once per year, about 2 weeks after a fertilizer application, clipping yields were determined and visual evaluations were conducted. On 15 August, 1990 and 2 July, 1991, hand clippers were used to remove all clippings above the 2-inch height inside a 14-inch diameter template. Clippings were oven-dried at 70° Celsius for about 72 hours and dry weight was measured. Dried samples from the 1991 clipping harvest were analyzed for N content following digestion procedures of Isaac and Johnson (1976) and distillation and titration procedures of Bremner (1965).

On 2 September, 1990 and 6 August, 1991, each plot was visually evaluated by two to four raters. General appearance values were based on turfgrass color, density, vertical shoot growth, and uniformity. Each plot was assigned a value between 1 and 5, with 5 being best and 3 minimally acceptable.

Data were analyzed by analysis of variance and means were separated by the Duncan's multiple range test. Buffalograss data were analyzed separately because of a lack of randomization among the other main plots due to late sod availability and establishment.

RESULTS AND DISCUSSION

When data were pooled, all main effects except year significantly affected clipping

When data were pooled, all main effects except year significantly affected clipping yield (Table 1). The only significant interaction affecting clipping yield was the cultivar by year interaction.

Table 1. Analysis of variance data (main effects and significant interactions) for clipping yield (dry weight) of turfgrasses.

Source	df	SS	F	P
Fertilizer	4	1091.62	43.02	0.0001
Mowing trmt.	1	113.34	17.87	0.0001
Cultivar	4	404.80	15.95	0.0001
Year	1	9.72	1.53	0.2172
Rep	2	57.92	4.56	0.0115
C x Y	4	105.58	4.16	0.0029
Error	198	1256.04		

Ammonium sulfate (AS) at 1.0 lb. of actual N per 1,000 sq. ft. per growing month (1.0 AS) produced the most growth as indicated by clipping yield (Table 2). The same rate of N supplied by Milorganite (1.0 M) produced less clipping yields than the 1.0 AS treatment, but was similar to 0.5 lb. of N per 1,000 sq. ft. supplied by ammonium sulfate (0.5 AS). The 0.5 Milorganite (0.5M) fertilization treatment produced the lowest clipping yield of any of the treatments receiving fertilizer application. The control treatment (receiving no supplemental fertilization) produced the lowest clipping yield and exhibited poorest growth.

The grass did not use N as readily when supplied by Milorganite. This is possibly because the organic source of N from Milorganite was not as readily available to the root system, as suggested by Beard (1973) and Turgeon (1980).

The lack of a significant fertilizer X year interaction suggests that the slow-release rate of N from Milorganite did not have a carry-over effect influencing clipping yields during the second year of this study (Table 1). These results are in conflict with those reported by Barrios et al. (1979).

Recycling clippings produced higher clipping yields across both years compared to the traditional bagging mower (Table 2). This is possibly a result of added N from the recycled clippings that became available to the grass plant. Tifway bermudagrass produced significantly higher clipping yields than any other cultivar, while Common bermudagrass, Georgia Common centipedegrass, and Raleigh St. augustinegrass produced similar, but significantly lower clipping yields (Table 2). Emerald zoysiagrass produced the lowest clipping yield of all five turfgrasses. The growth response of these cultivars in comparison to one another follows established trends previously reported by Beard (1973), Turgeon (1980), and Johnson et al. (1986).

Table 2. Treatment main effects on clipping yield (dry weight), general appearance rating, and tissue N content of turfgrasses.

Main Effect	Clipping yield†	General appearance‡	Tissue N§
	g		%
<u>Fertilizer</u>			
Control	3.2d¶	2.8d	1.3e
0.5 lb.-Milorganite	4.3c	3.7c	1.5d
0.5 lb.-Am. Sulfate	5.7b	4.1b	1.7c
1.0 lb.-Milorganite	5.3b	4.2b	1.9b
1.0 lb.-Am. Sulfate	8.9a	4.5a	2.7a
<u>Mowing Treatment</u>			
Clippings removed	4.9b	3.9a	1.8a
Clippings recycled	6.1a	3.8a	1.8a
<u>Cultivar</u>			
'Common' bermuda	5.5b	3.7bc	2.0a
'Tifway' bermuda	7.6a	3.9b	2.0a
'Georgia Common' centipede	5.1b	4.2a	1.7b
'Raleigh' St. augustine	5.2b	3.9b	1.4c
'Emerald' zoysia	4.0c	3.6c	1.9a
<u>Year</u>			
1990	5.3a	4.0a	—
1991	5.7a	3.7b	—

† Clippings above the two-inch height collected within a fourteen-inch diameter template. 1 g = 0.0022 lb.

‡ Rated on a 1-5 scale with 5=best, 1=poorest, and 3=minimal acceptance. Color, vertical shoot growth, density and uniformity were considered in overall rating. Values are means of two to four evaluators.

§ Percent tissue nitrogen was determined by Kjeldahl procedure.

¶ Means separations within columns and main effects by Duncan's multiple range test. Means followed by the same letter are not significantly different at the .05 level.

The only significant interaction affecting clipping yield was cultivar X year (Table 1). Figure 1 shows that all clipping yields tended to increased the second year of the study except for centipedegrass. Although centipedegrass may be sensitive to higher rates of N, the clipping yield from all centipedegrass plots regardless of fertilizer treatment was lower during the second year of this project as indicated by a nonsignificant fertilizer X cultivar X year interaction, and the actual means (data not shown). A contributing factor to lower clipping yield of centipede during the second year could be due to its poor adaptability to high soil pH conditions as suggested by Beard (1973) and Turgeon (1980).

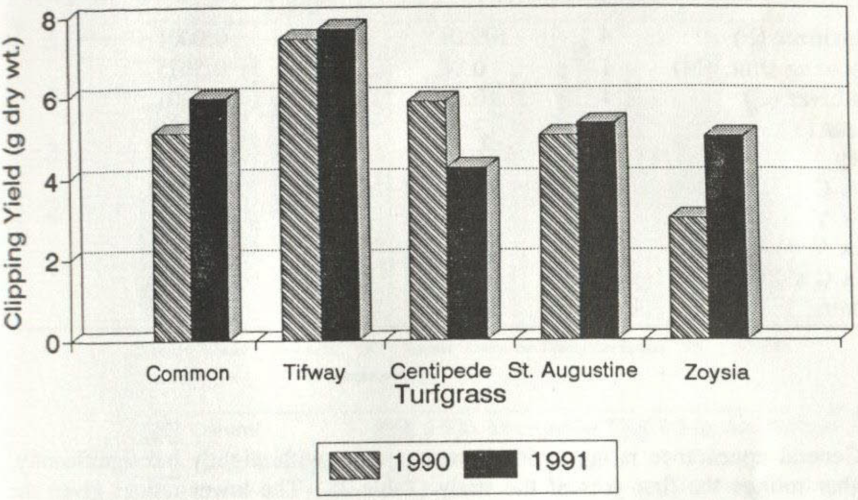

Figure 1. Interactive effects of cultivar x year on clipping yields of turfgrasses. (1 g = 0.0022 lb.)

All main effect treatments, except mowing, significantly affected turfgrass general appearance (Table 3). All interactions, except those with mowing treatments as a factor, also affected general appearance ratings.

The control fertilizer treatment resulted in the poorest (2.8) general appearance rating (Table 2), and was considered unacceptable by the evaluators because a rating of 3.0 was established as minimal acceptability. This treatment had the slowest rate of vertical shoot growth and the least green color. The 1.0 AS fertilizer treatment produced the highest rating, as a result of the vertical shoot growth and greenest color. The 1.0 M and 0.5 AS treatments produced similar general appearance ratings, while 0.5 M produced the poorest acceptable appearance, of any fertilized plot.

Mowing treatments had no significant influence on general appearance (Table 2). Georgia Common centipedegrass received the highest general appearance rating, followed by Raleigh St. augustinegrass, Tifway bermudagrass and Common bermudagrass. Emerald zoysiagrass rated the poorest, although not significantly different than Common bermudagrass.

Table 3. Analysis of variance data (main effects and significant interactions) for general appearance rating of turfgrasses.

Source	df	SS	F	P
Fertilizer (F)	4	109.01	108.35	0.0001
Mowing trmt. (M)	1	0.08	0.33	0.5675
Cultivar (C)	4	10.84	10.77	0.0001
Year (Y)	1	3.96	15.75	0.0001
Rep	2	1.89	3.75	0.0251
F x C	16	10.84	2.69	0.0007
F x Y	4	4.19	4.16	0.0029
C x Y	4	4.45	4.42	0.0019
F x C x Y	16	22.76	5.65	0.0001
Error	198	49.80		

General appearance rating varied between years, with slightly but significantly, higher ratings the first year of the study (Table 2). The lower ratings given the second year of this study is primarily attributable to a slight decline in general appearance of centipedegrass and zoysiagrass (Figure 2). Although clipping yields were not adversely affected, declines in general appearance ratings for these two cultivars the second year occurred at the higher fertilization rates as indicated by the significant fertilizer X cultivar X year interaction (Figure 3). Although 1.0 AS resulted in the highest general appearance ratings for all cultivars the first year, both Emerald zoysiagrass and, to a lesser extent, Georgia Common centipedegrass failed to respond to this N source and rate the second year.

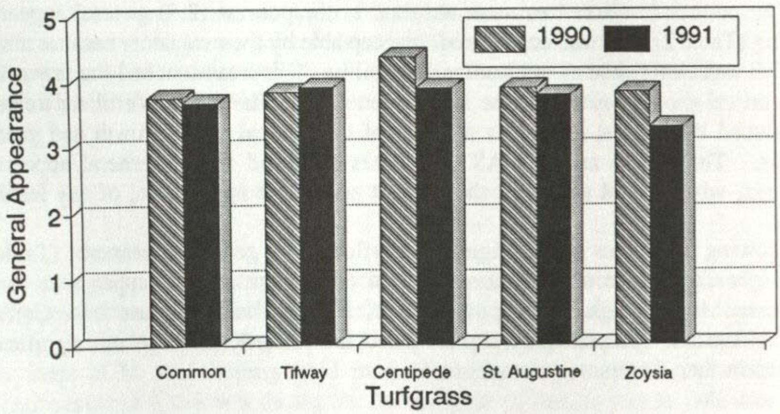

Figure 2. Interactive effects of cultivar x year on general appearance ratings of turfgrasses.

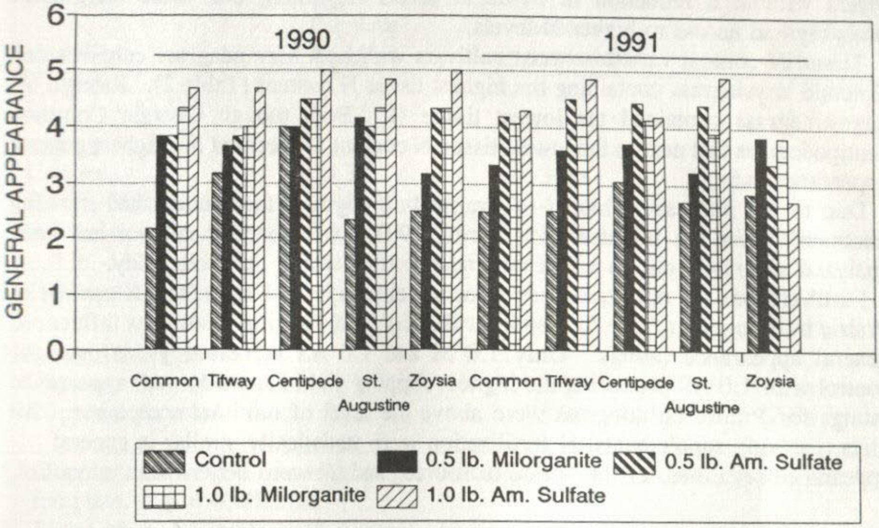

Figure 3. Interactive effects of fertilizer x cultivar x year on general appearance ratings of turfgrasses.

The first year, the general appearance ratings for Emerald zoysiagrass increased with each increase in fertilization rate (Figure 3). However, the second year, any increase in fertilization rate above the 0.5 M treatment either failed to improve or significantly reduced appearance ratings. At equivalent N rates, Milorganite produced higher general appearance ratings for Emerald zoysiagrass than AS.

Only the main effects of fertilizer and cultivar affected tissue N content (1991 data only) (Table 4). No interactions were significant. The control (no fertilization) resulted in lowest tissue N content (Table 2). Each succeeding increase in N rate increased tissue N content. Ammonium sulfate was more effective than Milorganite in increasing tissue N, with 1.0 AS resulting in the highest level.

Table 4. Analysis of variance data for tissue N content of turfgrasses, 1991.

Source	df	ss	F	P
Fertilizer	4	326861.69	121.87	0.0001
Mowing Trmt.	1	114.41	0.17	0.6805
Cultivar	4	81901.96	30.54	0.0001
Rep	2	1710.76	1.28	0.2838
Error	98	65711.24		

Although mowing treatments had no effect on tissue N content (Table 2), clipping yields were increased when clippings were recycled. Recycling clippings increased yields without a reduction in tissue N levels suggesting that these turfgrasses probably had access to higher N levels.

Tissue N content varied between cultivars with both bermudagrass cultivars and Emerald zoysiagrass containing the highest tissue N content (Table 2). Raleigh St. augustinegrass contained the lowest tissue N. Even though Georgia Common centipedegrass had next to the lowest tissue N content, it received the highest general appearance ratings.

Due to the late establishment of Prairie buffalograss, fertilization and mowing treatments were not initiated until Spring 1991. Data on this cultivar has been analyzed separately due to a lack of randomization within the main study.

Fertilizer was the only treatment affecting clipping yield and tissue N content of Prairie buffalograss (Table 5). Both fertilization and mowing treatments influenced general appearance ratings. Only 1.0 M and 1.0 AS increased yields over the control with 1.0 AS producing the highest clipping yield (Table 6). All appearance ratings for Prairie buffalograss were above the level of minimal acceptance. All plots receiving supplemental N fertilization were statistically similar in general appearance regardless of the N rate or source, and all were better than the control.

Table 5. Analysis of variance data for clipping yield (dry weight), general appearance rating, and tissue N content of 'Prairie' Buffalograss, 1991.

Source	df	SS	F	P
Clipping Yield				
Total	29	373.09		
Fertilizer	4	299.55	21.22	0.0001
Mowing	1	2.64	0.75	0.3985
Rep	2	0.58	0.08	0.9209
Error	18	63.53		
General Appearance				
Total	29	2.33		
Fertilizer	4	1.67	18.57	0.0001
Mowing	1	0.10	4.56	0.0468
Rep	2	0.07	1.47	0.2573
Error	18	0.40		
Tissue N				
Total	29	48411.5		
Fertilizer	4	45713.3	100.81	0.0001
Mowing	1	73.6	0.65	0.4308
Rep	2	163.4	0.72	0.4999
Error	18	2040.6		

Table 6. Treatment main effects on clipping yield (dry weight), general appearance rating, and tissue N content of 'Prairie' Buffalograss, 1991.

Main Effect	Clipping yield†	General appearance‡	Tissue N§
	g		%
Fertilizer			
Control	5.3c¶	3.4b	1.6d
0.5 lb.-Milorganite	5.3c	4.0a	1.8c
0.5 lb.-Amm. Sulfate	6.2c	4.0a	1.8c
1.0 lb.-Milorganite	10.3b	3.9a	2.2b
1.0 lb.-Amm. Sulfate	13.2a	4.0a	2.7a
Mowing Treatment			
Clippings removed	7.7a	3.8b	2.0a
Clippings recycled	8.3a	3.9a	2.0a

† Clippings above the two-inch height collected within a fourteen-inch diameter template. 1 g = 0.0022 lb.

‡ Rated on a 1-5 scale with 5=best, 1=poorest, and 3=minimal acceptance. Color, vertical shoot growth, density and uniformity were considered in overall rating. Values are means of two to four evaluators.

§ Percent tissue N was determined by Kjeldahl procedure.

¶ Means separations within columns and main effects by Duncan's multiple range test. Means followed by the same letter are not significantly different at the .05 level.

Supplemental N fertilization increased tissue N concentration (Table 6). The 0.5 M and 0.5 AS treatments produced similar N content but 1.0 AS was superior to the 1.0 M treatment.

Although non-significant, recycling clippings tended to increase clipping yield. Recycling clippings slightly increased general appearance ratings but had no effect on tissue N content (Table 6).

CONCLUSIONS

Milorganite at rates providing 0.5 to 1.0 lb. of N per 1,000 sq. ft. per growing month maintained acceptable turfgrass quality. Higher rates of N from an organic source would probably be required to produce results similar to a synthetic source. The use of mulching (recycling) mowers improved turfgrass growth compared to bagging mowers, and would reduce the amount of supplemental fertilizer required.

Centipedegrass exhibited the best overall general appearance ratings, while Tifway bermudagrass was the most vigorous. Prairie buffalograss did not show a decline in general appearance ratings even at the lowest level of supplemental fertilization.

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The Nutritive Value of Range Grasses in Northern Brewster County, Texas

Davy R. Brown*
Department of Animal Science, University of Wyoming, Laramie, WY 82070
James G. Houston
Department of Chemistry, Sul Ross State University, Alpine, TX 79832

ABSTRACT

Blue grama, sideoats grama, hairy grama, sprucetop grama, silver bluestem, johnsongrass, sand dropseed, tobosa, and big alkali sacaton were randomly collected from one of five sites in northern Brewster County, Texas. Each grass was analyzed for crude protein (CP) content and amino acid (AA) composition for the determination of biological value (BV) using an amino acid index (AAI). Means were compared by ANOVA and separated using Student Newman Keul's multiple comparisons test. The quadratic response in CP content throughout the year was determined using regression analysis. The mean CP content for all grasses throughout 1991 was described by the equation $y = 0.98 - 0.13x^2 + 1.76x$ ($r^2 = 27\%$; $P < 0.001$). Big alkali sacaton contained the highest CP content in the spring (8.3%) and fall (10%); johnsongrass CP was highest in the summer (13.2%) and sprucetop grama in the winter (5.3%) ($P < 0.05$). The grasses had BVs in the mid-to upper 70s except silver bluestem (2%) and johnsongrass (80%). The low BV of silver bluestem was suggestive of an AA imbalance in the plant due to stress before sampling. Barring any factors that may have inhibited digestion and absorption, range grasses in northern Brewster County contained adequate CP to meet CP requirements of dry gestating beef cattle (500 kg) during the summer, fall, and spring of 1991.

Crude protein (CP) content is commonly used to indicate range grass quality (Rodgers and Box, 1967). Studying range grass quality will provide range managers and wildlife biologists access to a greater data base on which to make judgments concerning provision of supplemental feed for their livestock and game animals. Because the species selected for this study occupy approximately 90% of the rangeland in northern Brewster County Texas (Gould, 1975), assessing their nutritive quality will help to form the basis of a valuable management tool in West Texas.

Analyzing CP content in grasses is important but determining the quality of the protein is equally critical. Protein quality can be estimated from amino acid (AA) composition by the equations of Mitchell and Block (1946). This method establishes an amino acid index (AAI) to compare the amino acid composition of the samples to that of a standard. In many cases whole egg is the standard of choice because it is very high in total protein and those proteins have a digestibility coefficient of 96% (Oser, 1959). The ratio established between the standard and the samples is indicative of the digestibility of the proteins in the sample. The objective of this

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study was to determine the seasonal CP content and quality in nine species of range grasses in northern Brewster County, Texas.

MATERIALS AND METHODS

Sample Collection and Analysis

Samples of blue grama (*B. gracilis*), sideoats grama (*Bouteloua curtipendula*), hairy grama (*B. hirsuta*), sprucetop grama (*B. chondrosioides*), silver bluestem (*Bothriochloa laguroides*), johnsongrass (*Sorghum halepense*), sand dropseed (*S. cryptandrus*), tobosa (*Hilaria mutica*), and big alkali sacaton (*Sporobolus wrightii*) were collected from one of five sites in northern Brewster County, Texas. Sites (about 25 m^2) averaged 1624 m in elevation and consisted primarily of rocky hills or sandy loams of creek levies. All sampled pastures were moderately stocked with cattle (about 17 $section^{-1}$) and were not irrigated. The same collection sites were used throughout the study. The description, habitat, and abundance of these species is provided by Gould (1975).

Samples from each species were collected by hand to simulate grazing and composited into sealable plastic bags for transportation to the laboratory. The samples were dried at 50^{0}C for 48 h in a forced-air oven and ground to pass through a 1 mm screen using a standard no. 3 Wiley mill. Duplicate 1 g aliquots of ground material were analyzed for Kjeldahl nitrogen using the Kjeltec Digestion System 6/12 and the associated 1002 Distilling unit (Prabin and Co AB, Klippan). The percent CP was calculated as 6.25 x N%.

The AA composition of each species was determined using HPLC by the Biotechnology Support Laboratory at Texas A&M University (TAMU) using the Bidlingmeyer et al. (1984) method. Pre-treatment was conducted at our laboratory and involved delipidization and decolorization of the samples (Bidlingmeyer et al., 1987). The lyophilization pretreatment was done by TAMU.

Statistical Analysis

Analysis of Variance testing of a completely randomized design was used to determine differences in mean CP content and AA composition between species. Means were separated using Student Newman Keuls' multiple comparisons test where significance was declared when $P < 0.05$. Regression analysis was used to determine the trend of the CP content in the grasses relative to the months of the year. The means for each season were determined by averaging the CP content in each grass over the three months in each season.

RESULTS

Crude Protein Content

The amount of CP in the grasses varied throughout the year. The highest levels occurred in the summer and the lowest levels in the winter ($P < 0.05$; Figure 1). These data fit the quadratic equation, $y = 0.98 - 0.13x^2 + 1.76x$ ($r^2 = .27$; $P <$

0.001). The CP content of grass species peaked at different times of the year (Figure 2). The CP content in hairy grama, for example, peaked in April while blue grama peaked in August and sprucetop grama in July. The maximum and minimum CP contents observed were 14.4% in big alkali sacaton and 1.7% in silver bluestem. Comparisons of the CP content between grasses within a season are summarized in Table 1. Overall, big alkali sacaton, johnsongrass, and sprucetop grama contained the highest CP content whereas sand dropseed, hairy grama, and sideoats grama typically contained the lowest.

Table 1. Seasonal crude protein (CP) content and biological value (BV) of range grasses in northern Brewster County, Texas in 1991.

	CP (%)				
Item	Spring	Summer	Fall	Winter	BV, %
Blue grama	5.75ab	5.62b	3.86b	3.28b	77.55
Sideoats grama	4.33b	5.24b	2.88b	2.33b	77.61
Hairy grama	4.66b	6.68b	4.84b	3.06b	78.70
Sprucetop grama	7.34ab	9.24ab	5.71b	5.33a	78.30
Silver bluestem	3.65b	4.84b	3.01b	2.06b	2.00
Johnsongrass	6.62ab	13.17a	8.06ab	3.81b	80.32
Sand dropseed	3.88b	7.80ab	3.77b	3.00b	75.70
Tobosa	4.48b	4.53b	3.91b	3.64b	74.69
Big alkali sacaton	8.34a	11.37ab	10.03a	5.14a	78.25
Standard deviation	1.58	2.89	2.29	1.06	1.64

Within columns, means followed by different letters differ (P < 0.05).

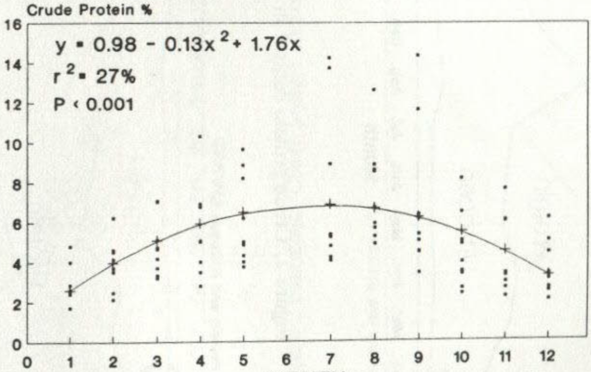
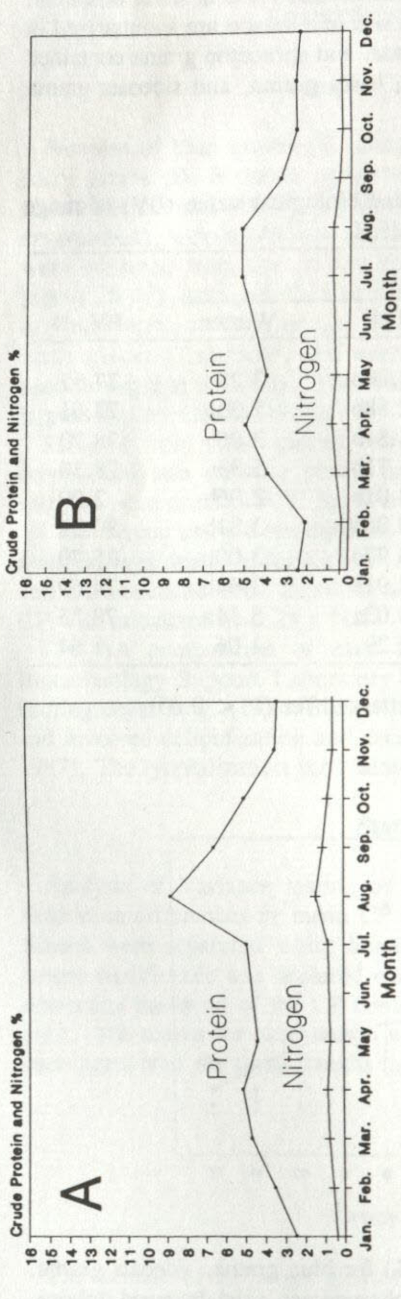


Figure 1. Temporal trends in crude protein (%) for blue grama, sideoats grama, hairy grama, sprucetop grama, silver bluestem, johnsongrass, sand dropseed, tobosa, and big alkali sacaton in northern Brewster County, Texas, 1991.



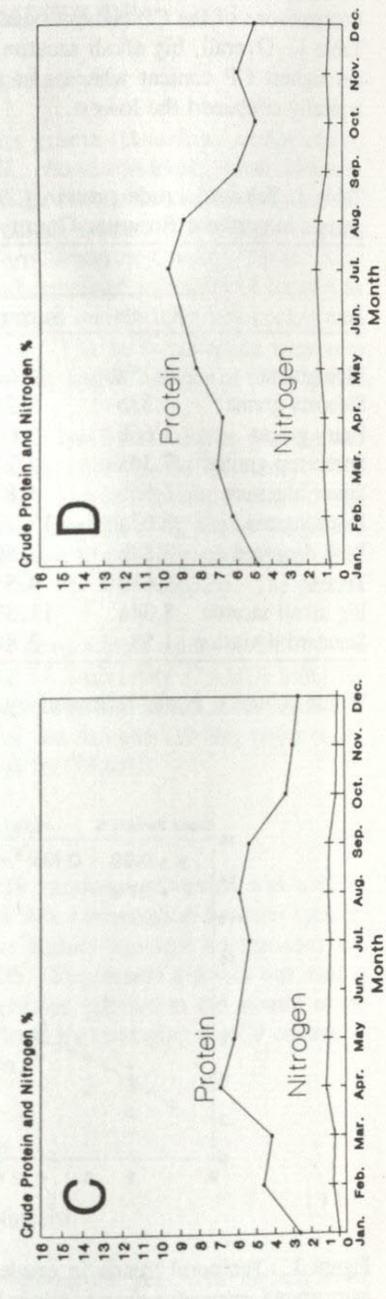


Figure 2. Crude protein content in (A) blue grama, (B) sideoats grama, (C) hairy grama, (D) sprucetop grama.

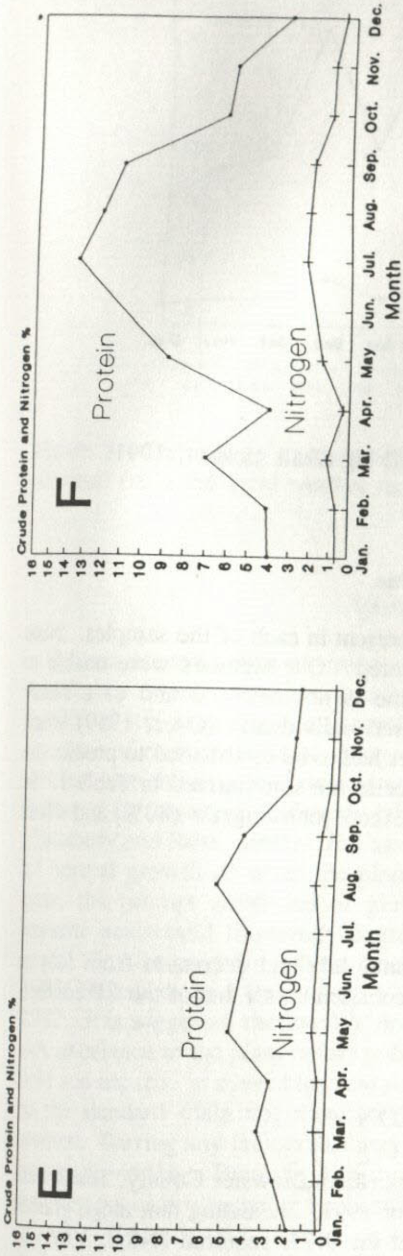
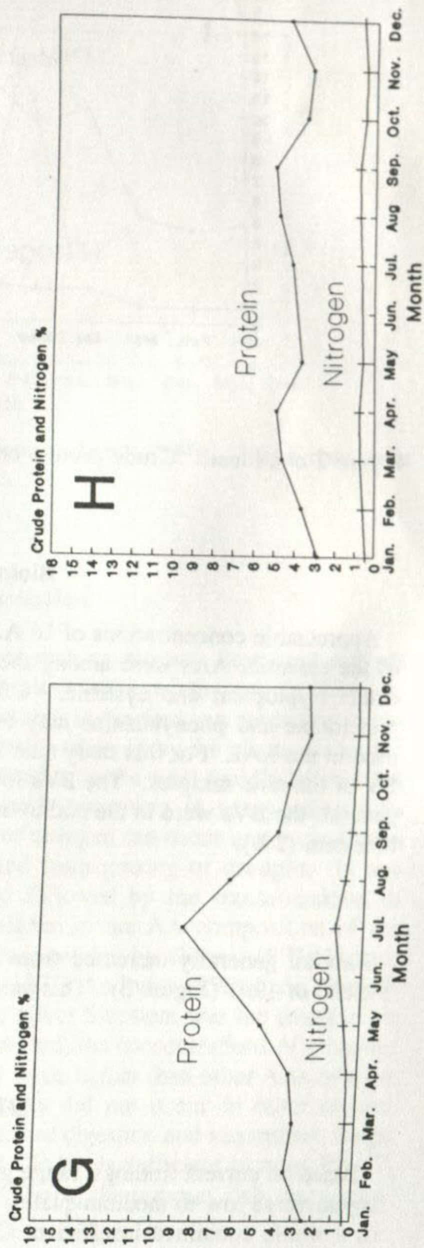


Figure 2 continued. Crude protein content in (E) silver bluestem, (F) johnsongrass, (G) sand dropseed (H) tobosa.



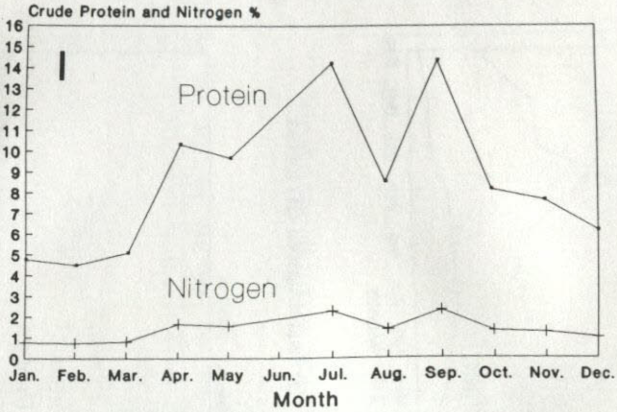


Figure 2 continued. Crude protein content in (I) big alkali sacaton, 1991.

Biological Value

Appreciable concentrations of 16 AAs were present in each of the samples. Nine of the essential AAs were among the 16 measured. Our methods were unable to detect tryptophan and cysteine. Often cysteine is not detected and as a result methionine and phenylalanine may be considered individually (Oser, 1959) when used in the AAI. For this study nine AA indices had to be established to predict the BV of the nine samples. The BVs for each species are summarized in Table 1. In general, the BVs were in the mid to upper 70s except johnsongrass (80%) and silver bluestem (2%).

Rainfall

Rainfall generally increased from January until July and decreased from July to the end of 1991 (Figure 3). This pattern was consistent with that of the CP content.

DISCUSSION

Based on current findings, range grasses in northern Brewster County, Texas were appraised as low to medium quality forages for 1991. Indicating that range grasses as a whole contained insufficient CP to meet the 9.7% required (NRC, 1984) by lactating beef cattle (500 kg) during summer and fall. However, the lower CP requirement of 7% for maintenance of the dry beef cow in early to mid gestation was potentially met during summer, fall, and spring (Table 1). In winter all nine of the grasses studied were suboptimal in protein content.

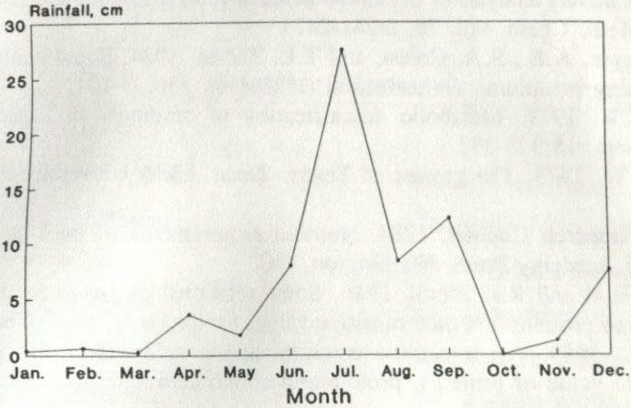


Figure 3. Rainfall in northern Brewster County, Texas, 1991. These data were obtained from the local weather radio station.

Nitrogen Assimilation

Grasses contend with environmental factors such as rainfall, heat, and soil pH which may or may not culminate in adequate microbial populations to facilitate the uptake of soil nitrogen. In general, glutamic acid is the first AA aminated in the presence of certain forms of nitrogen (e.g. nitrate) taken up by the plant. Using N^{15} labeled ammonium, glutamic acid was determined to be the most rapidly labeled AA followed by aspartic acid with N^{15} subsequently appearing in many other AAs (Salisbury and Ross, 1985). The assimilation of nitrogen can occur under conditions of normal growth or when the plant is stressed from grazing or drought. In any case, the prompt amination of glutamic acid followed by the transamination to aspartic acid could transiently cause an imbalance in the AA composition of the plant. Studies regarding these mechanism are provided by Givan, 1979; Runge, 1983; Rajaskhar and Oelmuller, 1987; Pate, 1973; Andrews, 1986; and Stewart 1982. It is suggested the low BV observed for silver bluestem was the result of an AA imbalance in the plant before collection. Indeed, the concentrations of glutamic acid and aspartic in silver bluestem were 3 to 4 times higher than other AAs relative to the standard (data not shown). This anomaly did not occur in other species studied. Barring any factors that may have inhibited digestion and absorption, range grasses in northern Brewster County contained CP levels sufficient to meet the CP requirement of dry gestating beef cattle (500 kg) during the summer, fall, and spring of 1991.

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