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CONTENTS

Estimating the Economic Incentive to Adopt FiberMax Cotton Variety

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ABSTRACT

FiberMax is the brand name for cotton varieties marketed by Aventis Crop Science. To estimate profit potential for an individual farmer who might adopt the FiberMax 832 variety, various factors are to be considered such as yield potential, fiber quality, response to management, consistency, crop maturity, disease resistance, insect resistance, stress tolerance, and market acceptance. Introduction of new varieties in the market place increases the complexity of variety selection, but offers opportunity to improve profitability. The approach assumes that farms are in perfect competition. The price per pound of lint was estimated based on the quality parameters of fiber. Budget analysis was done to estimate the net benefit to farmers taking into consideration the variable and fixed costs for a typical cotton farm in Nueces County, Texas. The data analyzed from the four locations (Prince Farms, Kocurek Farms, Meaney Annex Farms, and Perry Foundation) in the coastal bend region indicated that yields of four varieties (FiberMax 832, Deltapine 20B, Deltapine Pearl, and Deltapine 33B) tested for performance, were not statistically different. FiberMax 832 had the highest average yield of 751 lb/acre followed by Deltapine 20, Deltapine Pearl, and Deltapine 33B. The price received by FiberMax 832 per pound of lint was highest in all locations. FiberMax 832 produced exceptionally high fiber quality. FiberMax 832 had the highest mean average price per pound of lint (54.17 cents/lb), followed by Deltapine Pearl, Deltapine 20B, and Deltapine 33B. The net projected returns estimated for these four varieties across the four locations, assuming the same costs of operations, showed that FiberMax 832 had the highest mean value of 23.91 dollars/acre followed by Deltapine 20B (-12.93 dollars/acre), Deltapine Pearl (-17.64 dollars/acre) and Deltapine 33B (-48.17 dollars/acre). FiberMax was the only variety with positive mean returns.

KEYWORDS: FiberMax 832, Deltapine 20B, Deltapine Pearl, Deltapine 33B

Many aspects are considered before the adoption of a new crop variety, these include: 1) price of seed, 2) availability of the seed, 3) estimated yield of the new variety and the expected increase in yield over the locally used variety, 4) cost and labor savings, 5) adaptability of the new variety to local weather conditions, 6) disease and pest resistance, and 7) ecological impacts (Dever 2000). Producers adopt new varieties because of expected revenue increases, this requires producers to analyze expected benefits and costs before deciding to adopt a new variety. Other factors affecting the adoption decision are: time to maturity, herbicide tolerance, fiber quality, and price factors (Stapper 1999).

Benefits to a producer are likely to last for a brief period (short run) as other producers adopt the new technology, causing prices to decrease, any extra normal economic benefits will then be competed away (Cramer et al. 1997). This study determined the supply responses of producers as they adopted a new high quality and high yielding variety of cotton, FiberMax 832, in response to other available varieties. Producers need information to quickly evaluate a situation that will change rapidly. A measure of the expected benefit(s) will be helpful to producers weighing such a decision. This study was done to determine whether or not producers in the Texas coastal bend could profit by adopting a new technology, FiberMax 832 cotton variety, compared to other varieties.

MATERIALS AND METHODS

Information used for this research was procured from the Texas Agricultural Extension Service trial plots conducted across Nueces County for the year 2000 (USDA 2000). Variations in the yield and fiber qualities are the contributing factors for the increase in revenue to producers. The price of inputs and costs for the management practices play an important role in cost benefit analysis. Difference in yield multiplied by the estimated benefit/loss due to fiber quality parameters equals the economic profit to producers. Fiber quality parameters such as micronaire, staple length, strength, uniformity, and color grade can affect the price premiums and discounts by three to five cents per pound or fifteen to twenty five dollars per bale.

Yield and quality parameters for FiberMax 832 were compared to other commercially available varieties: Deltapine 20B, Deltapine 33B, and Deltapine Pearl (Texas A&M Extension 2000). Based on their quality grades, the appropriate price premiums or discounts were calculated using cotton loan information. Gross revenue was determined from lint and seed yields received by the producer and the price received per pound of lint based on quality parameters of lint for a particular variety (Farmers Co-op of El Campo 2000). To determine net revenue, a budget analysis was accomplished considering all variable and fixed costs. The difference between the gross revenue and the total costs would be the net revenue for a particular variety. The difference in net revenue generated by growing different varieties will help with the decision whether to adopt a particular variety.

Analysis of variance was used to test for significance in yield, price received per pound, and net projected income. The data was subjected to analysis of variance using Statistical Analysis Systems software (SAS Institute 1996). The least significant difference (LSD) mean separation test was adopted to find statistical differences among varieties.

RESULTS AND DISCUSSION

Four cotton varieties were evaluated at Prince Farms, Kocurek Farms, Perry foundation, and Meaney Annex in Nueces County (Buehring et al. 2000). Analysis of variance showed no significant yield difference ($P = 0.3878$) among the four varieties tested at the 0.05 level of significance. Locations were treated as blocks in the ANOVA and were therefore not evaluated for significance.

FiberMax 832 had the highest average production for three years (2000, 2001, 2002) as determined on Prince and Kocurek Farms versus DP20B and Delta Pearl;

however, differences were not significant. The price per pound of lint (Table 1) was determined by the quality of the fiber considering various factors such as micronaire, fiber length and uniformity, strength of fiber, and color grade of fiber. Based on the quality characteristics the price premium or discount was determined over the base price. The base price for the year 2000 was 51.92 cents per pound of lint. Analysis of variance showed significant difference (P = 0.0424) between the four varieties tested at the 0.05 level of significance (Table 1).

Table 1. Price in Cents Per Pound of Lint for Four Varieties Tested at Four Locations.

	Variety			
Location	FM 832	DP 33B	DP Pearl	DP 20B
Prince Farms	54.77	52.42	51.92	53.37
Kocurek Farms	54.32	45.62	63.87	51.92
Perry Foundation	52.97	45.62	48.62	48.62
Meaney Annex	54.62	53.72	54.57	53.32
Mean	54.17 a*	49.35 b	52.25 ab	51.86 ab

Within the mean row, values not followed by the same letter are significantly different (LSD .05)

The gross returns per acre of the four varieties were estimated across the four locations. The income from cottonseed is considered to be the same from all varieties at a price of seventy-five dollars per ton. The gross returns per acre is a summation of the incomes from cotton lint and cottonseed. The gross returns for the four varieties across four locations is given in (Table 2). Differences were not significant (p=0.2).

Table 2. Projected Gross Returns in Dollars per Acre for the Four Varieties Tested at Four Locations.

	Variety			
Location	FM 832	DP 33B	DP Pearl	DP 20B
Prince Farms	376.53	374.04	269.06	390.28
Kocurek Farms	554.63	388.32	534.18	474.67
Perry Foundation	338.90	270.16	266.99	276.22
Meaney Annex	508.98	417.78	510.62	468.50
Mean	444.76	362.58	395.21	402.42

Based on yields and prices received for different varieties and their respective fiber quality, the net returns to the farmer growing a particular variety at a particular location were estimated. Calculating the variable and fixed costs for a typical cotton farm in Nueces County completed the estimated budget analysis. The net return per acre of land, considering the costs to be the same for all varieties at different locations, was calculated. The net returns, excluding government payments, at different locations for the varieties as given in (Table 3). Analysis of variance showed no significant difference (P = 0.18) between the four varieties tested.

Table 3. Projected Net Returns in Dollars per Acre for the Four Varieties Tested at Four Locations.

	Variety			
Location	FM 832	DP 33B	DP Pearl	DP 20B
Prince Farms	-30.08	-35.06	-118.86	-20.87
Kocurek Farms	112.05	-34.49	94.84	43.97
Perry Foundation	-62.31	-124.68	-123.75	-116.56
Meaney Annex	75.99	1.57	77.22	41.76

Projected Net Returns for the Four Varieties Across the Four Locations

The economic benefit or loss by adopting a particular variety at the four locations is shown in (Table 4). FiberMax 832 was the best variety in terms of projected net benefits at Kocurek farms with an estimated net profit of 112.05 dollars per acre and at Perry Foundation with an estimated net loss of 62.31 dollars per acre. FiberMax 832 was second best at Prince farms with an estimated loss of 30.09 dollars per acre as compared to a loss of 20.87 dollars per acre by Deltapine 20B. At Meaney Annex farms FiberMax 832 was second best. The net projected returns for Deltapine Pearl was 77.25 dollars per acre and for FiberMax 832 was 75.99 dollars per acre.

Table 4. Net Projected Returns for the Four Varieties at Four Locations.

Location	Variety	Yield	Price	TR	TC	Profit/Loss
Prince Farms	FM 832	619	0.5477	376.53	406.61	-30.09
Kocurek Farms	FM 832	952	0.5432	554.63	448.58	112.05
Meaney Annex	FM 832	863.2	0.5462	508.98	432.99	75.99
Perry Foundation	FM 832	569	0.5297	338.9	401.21	-62.31
Prince Farms	DP 33B	642	0.5242	374.04	409.01	-35.06

Table 4. (Cont'd.)

Location	Variety	Yield	Price	TR	TC	Profit/Loss
Kocurek Farms	DP 33B	769	0.4562	388.32	422.81	-34.49
Meaney Annex	DP 33B	707.9	0.5372	417.78	416.21	1.57
Perry Foundation	DP 33B	510	0.4562	270.16	394.84	-124.70
Prince Farms	DP Pearl	446	0.5192	269.06	387.93	-118.90
Kocurek Farms	DP Pearl	922	0.5387	534.18	439.34	94.85
Meaney Annex	DP Pearl	867	0.5457	510.62	433.40	77.25
Perry Foundation	DP Pearl	472	0.4862	266.99	390.74	-123.80
Prince Farms	DP 20B	661	0.5337	390.28	411.15	-20.87
Kocurek Farms	DP 20B	842	0.5192	474.67	430.70	43.97
Meaney Annex	DP 20B	805.3	0.5352	468.5	426.73	41.76
Perry Foundation	DP 20B	491	0.4862	276.22	392.79	-116.60

Yield = Yield in pounds per acre
Price = Price in dollars per pound of lint
TR = Total Revenue per acre
TC = Total Costs per acre
Profit = Estimated profit in dollars per acre

When taken as an average across four locations, FiberMax 832 was the only variety with positive returns (Table 5). Overall differences were not significant (P= 0.05), so T groupings reflect mean separation from unprotected tests.

Table 5. LSD Mean Separation Test Showing the T Grouping and Means of Net Projected Returns for Four Varieties.

Variety	T Grouping		Mean	N
FiberMax 832		A	23.91	4
Deltapine 20B	B	A	-12.93	4
Deltapine Pearl	B	A	-17.64	4
Deltapine 33B	B		-48.17	4

*Varieties with the same T Grouping are not statistically different at p=0.05 level of significance.

CONCLUSIONS

This study estimates the economic incentive for farmers to adopt a new FiberMax cotton variety. The economic incentive was measured in terms of net returns generated by FiberMax 832 cotton versus other varieties. The results at various research stations show that FiberMax 832 yielded more lint compared to other varieties and the quality of the fiber was superior to other varieties.

The net projected returns estimated for these four varieties across the four locations, assuming the same costs of operations, showed that on average FiberMax 832 had the highest mean value of 23.91 dollars per acre as compared to –12.93 dollars per acre for Deltapine 20B, -17.64 dollars per acre for Deltapine Pearl, and –48.17 dollars per acre for Deltapine 33B.

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Profitability of Short Season Cotton Genotypes on the High Plains of Texas

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ABSTRACT

The short growing season, dry climate, and limited precipitation reduce the yield and quality of cotton grown on the High Plains of Texas. As irrigation water levels decline in the southern counties of the High Plains of Texas, cotton production will probably move northward to areas with greater underground water levels. Freezing temperatures in late spring and early fall in these northern counties require that cotton be planted in late May and mature before mid-October. Developing genotypes that combine early maturity with high lint yield and improved fiber quality will be critical for successful cotton production in these areas. Chemical mutagenesis was used to produce 18 mutant lines, which were compared with seven commercial varieties for lint yield, fiber quality, fiber market price, and gross return when planted at Lubbock, TX on July 3rd of 2000 and 2001. Three mutants, SC 9023-11, Holland 338-6, and GSA 1093-61 produced equivalent lint yields, higher fiber quality, and improved market price than PM 183, the earliest maturing commercial variety in these trials. Economic analyses indicate these mutants could improve the profitability of short season cotton grown on the Texas High Plains.

KEYWORDS: Cotton, Fiber quality, Lint yield, Market price, Gross return, Chemical mutagenesis, Short season

The High Plains of Texas grow nearly four million acres of cotton annually, which provides over 20% of the U.S. total production (Cotton Incorporated 1999). The high altitude, short growing season, dry climate, declining irrigation water, and limited precipitation of the region reduces both the lint yield and fiber quality of this cotton. Fiber length is the trait most often impacted under short season production conditions in this region. In 1999, the average staple length of the 2.36 million bales of cotton evaluated at the USDA classing office in Lubbock, Texas was only 1.02 inches (Cotton Incorporated 1999). In 2000, the 2.1 million bales of upland cotton produced in this region had an average staple length of 1.01 inches and a market price of only $0.514 per pound due to low fiber quality (Cotton Incorporated 2000, TASS 2001). The losses due to poor fiber quality of the cotton grown in this region in both 1999 and 2000 exceeded $60 million (Cotton Incorporated 2001).

As irrigation water levels decrease in the southern counties of the Texas High Plains, cotton production will probably move northward to tap additional underground water reserves of the Ogallala Aquifer. Production in this area will require early maturing cotton cultivars that can produce mature fiber when grown under the limited number of heat units available in the 150 day growing season of this region (Christiansen and Thomas 1969, Gibson and Flowers 1969, and Schulze et al. 1996). Early planting of conventional cotton cultivars ensured good lint yields and fiber quality but increased susceptibility to late spring frosts. Later planting enhanced stand establishment but increased susceptibility to early fall frosts that reduced lint yields and fiber quality. Historically, short season cotton cultivars which minimize the risk of these frosts have had poor fiber quality (Smith 2000). The development of commercial cultivars that produce good lint yields and fiber quality under short season conditions could also allow cotton to be replanted following May and June hailstorms in the southern portions of the Texas High Plains. These same cultivars would allow growers in the Northern counties of the Texas High Plains with better underground water resources to consistently produce successful cotton crops.

The narrow genetic base of upland cotton has limited the ability of breeders to develop cotton cultivars using conventional genetic techniques (Bowman et al. 1996). Chemical mutagenesis has been used to successfully enhance fiber traits while leaving lint yield and adaptation of proven cultivars intact (Auld et al. 2000). Chemically induced mutants do not require the extensive back crossing, regulatory restrictions, and complex property right considerations that currently limit commercialization of transgenic cotton cultivars (Auld et al. 1998). This process was used to develop several mutant lines of cotton, which produce mature cotton fiber in only 90 to 115 days at Lubbock, TX.

In the past, producers have focused on increasing yield to improve farm profitability. Smith (2000) reported that recent developments in the textile industry, particularly in increased rotor and ring spinning speeds and the advent of air-jet spinning, have emphasized the need for cotton varieties with improved fiber traits. As a result of these improvements in processing, the textile industry has encouraged breeders to improve fiber length. Consequently, the value of a short season cotton crop depends not only on its lint yield but also the quality of the fiber it produces.

The objectives of this study were to determine the agronomic and economic performance of 18 mutants selected to mature under short season conditions in comparison with seven commercial cultivars. The factors of lint yield, fiber quality, market price, and gross return were used to measure the potential economic impact of these short season lines in comparison with existing cotton cultivars in the northern counties of the Texas High Plains.

METHODS AND MATERIALS

In 1991, two commercial cultivars (GSA 1054 and GSA 1093) were treated with 3.0% v/v ethyl methanesulfonate (EMS) and advanced to the M_2 generation. In 1992, 135 M_3 plants were phenotypically selected for cold tolerance when seeded in late April at Lubbock, TX. In 1996, six commercial cotton cultivars (Tejas, Holland 338, SC 9023, Sphinx, Explorer and Atlas) were treated with 2.45% v/v EMS and advanced to the M_2 generation. In 1997, these six M_2 populations were planted on 2 July at Lubbock, TX and 62 M_3 plants were selected for ability to mature fiber under short season conditions.

A total of 197 M_3 lines selected in either 1992 or 1997 were evaluated for ability to produce mature fiber when planted on 3 July in both 1998 and 1999.

The 2000 and 2001 trials were planted on 3 July using a randomized block design with two replications in 2000 and four replications in 2001. These trials contained 18 M_5 lines and seven commercial cultivars planted in single rows 18' in length and spaced 40" apart. The trials were provided approximately six inches of supplemental irrigation to complement 10.7 inches of precipitation (May to October) in 2000 and 6.0 inches in 2001. Thirty pounds of nitrogen (32:0:0) was applied in both years. In November of each year, seed cotton from 40 in. of row was harvested from each plot. Samples were ginned to determine lint yield and lint samples were analyzed for fiber quality using High Volume Indexing (HVI) Analysis at the Texas Tech University International Textile Center. HVI filter quality was used to calculate market price for each plot. Market price was multiplied by lint yield to generate estimates of gross return. Data from all indices were subject to analysis of variance. Means were separated with a Fisher's Protected Least Significant Difference Test at the 0.05 level of probability (SAS 1992).

The market prices were estimated using the Daily Price Estimator System (DPES) for West Texas cotton for the 2000/2001 marketing year (Ward et al. 2001). The DPES calculates the market price for cotton lint based on an econometrically estimated hedonic price equation. The price equation estimates premiums and discounts for various lint quality characteristics and adjusts the estimated base price to calculate the market price.

The estimates of gross return and lint yield of the short season lines were used to determine each genotype's profitability as compared to present cotton production in the Northern counties of the Texas High Plains. This comparison provided insight into the possibility of expanding upland cotton production further northward into areas with more irrigation water. The current cotton production data from the northern Texas Panhandle was obtained from the Texas Agricultural Statistics Service (TASS 2000). TASS district 1-N includes all the northern counties in the Texas Panhandle. The average yield for district 1-N was used along with the average price per pound of cotton lint received in Texas.

RESULTS AND DISCUSSION

Average lint yield of the 25 genotypes planted on 3 July in this study ranged from 650 to 167 lbs per acre in 2000 and from 967 to 252 lbs per acre in 2001 (Tables 1 and 2). The cotton trial in 2000 received only 1,723 heat units (60 degree days) from planting to harvest compared to 1,984 heat units in 2001 (Texas Ag Experiment Station 2001). It was interesting to note that the cumulative heat units with a July 3 planting at Lubbock, TX, were less than the average of 2,244 heat units expected at Amarillo, TX, where the last average frost date is May 15 and the average first frost date is October 15. These data would indicate that the short season mutants selected by very late planting at Lubbock, TX may have potential adaptation in the production areas surrounding Amarillo, TX. When the data were analyzed over both test years, three commercial cultivars (Tejas, Paymaster 183, and Paymaster 330) and three mutant lines (SC 9023-11, Holland 338-6, and GSA 1093-61) had the highest lint yields (Table 3).

Table 1. HVI Fiber quality, market value, lint yield, and gross return for 18 mutant lines and seven commercial varieties planted at Lubbock, TX on July 3, 2000.

	HVI Fiber Quality				Market	Lint	Gross
Genotype	Length	Strength	Micronaire	Uniformity	Value	Yield	Return
	inches	g/tex		%	$/lb	lb/acre	$/acre
PM 330	1.02 f-h†	26.8 h-j†	3.7 f-n†	81.4 cd†	0.51 fg†	650 a†	329 a†
GSA 1093-52	1.06 b-h	30.9 a-e	3.8 d-m	82.0 a-d	0.54 a-f	554 ab	298 ab
Atlas -4	1.03 d-h	29.2 c-l	4.2 a-l	83.3 a	0.54 a-f	532 a-d	287 abc
Tejas	1.04 d-h	28.8 c-l	4.0 c-m	83.0 a-d	0.51 efg	527 a-d	271 a-d
GSA 1054-25	1.09 a-f	30.7 a-e	3.6 h-n	82.5 a-d	0.53 a-g	505 a-f	266 a-e
PM 183	0.99 h	28.9 c-l	4.1 a-j	81.7 a-d	0.49 g	518 a-e	255 a-f
Holland 338 -9	1.09 a-f	30.7 a-e	4.3 a-h	83.2 ab	0.56 ab	404 b-g	227 a-f
Holland 338 -6	1.09 a-f	30.9 a-e	4.5 a-d	83.1 abc	0.56 a-d	395 b-g	221 a-f
Explorer -25	1.05 b-h	29.4 b-h	44 a-g	82.9 a-d	0.54 a-f	404 b-g	217 a-g
SC 9023 -11	1.12 ab	29.9 a-g	35 l-n	82.7 a-d	0.56 a	362 b-l	204 a-g
GSA 1093-43	1.06 b-g	29.4 b-l	4.0 a-l;	82.3 a-d	0.52 b-g	391 b-g	203 a-g
GSA 1054-26	1.07 b-f	30.5 a-e	4.3 a-g	81.3 d	0.53 a-g	387 b-g	203 a-g
GSA 1093-41	1.08 a-f	30.8 a-e	4.5 a-e	81.9 a-d	0.54 a-f	382 b-h	201 b-g
GSA 1093-23	1.07 b-f	30.3 a-f	3.8 e-n	82.5 a-d	0.51 efg	395 b-g	201 b-g
Sphinx -4	1.06 b-h	29.4 b-h	4.5 a-e	81.7 a-d	0.53 a-f	365 b-l	194 b-g
SC 9023 -5	1.05 c-h	28.2 e-l	4.2 a-l	82.4 a-d	0.53 a-g	352 b-l	185 b-g
GSA 1093-61	1.15 a	32.2 ab	3.3 mn	81.6 a-d	0.56 abc	316 e-l	178 c-g
Explorer -13	1.04 c-h	32.2 ab	4.7 ab	82.4 a-d	0.52 c-g	338 c-l	173 c-g
Sphinx -20	1.05 c-h	29.5 a-h	4.7 a	82.2 a-d	0.52 a-g	339 d-l	172 b-g
GSA 1093-11	1.06 b-g	29.3 b-l	3.8 d-m	82.2 a-d	0.52 d-g	330 d-l	171 c-g
Sphinx	1.9 a-f	29.9 a-g	3.7 f-n	82.7 a-d	0.54 a-f	299 f-l	162 c-g
GSA 1093-33	1.03 d-h	28.4 d-l	4.1 a-j	81.5 bcd	0.52 a-g	303 f-l	158 d-g
Atlas	1.08 a-f	30.3 a-f	3.5 l-n	82.2 a-d	0.55 a-e	255 g-i	141 efg
Holland 338	1.05 b-h	29.1 c-l	4.2 a-l	81.3 abc	0.55 a-f	237 g-l	130 fg
Explorer	1.12 ab	29.9 a-g	3.3 l-n	83.3 a	0.56 ab	167 l	94 g
Coefficient of Variation	3.3%	4.8%	9.4%	6.7%	4.0%	30.4%	29.8%

†Means within the same column not followed by the same letter differ at the 0.05 level of probability by Fisher's Protected Least Significant Difference Test.

Table 2. HVI Fiber quality, market value, lint yield, and gross return for 18 mutant lines and seven commercial varieties planted at Lubbock, TX on July 3, 2001.

Genotype	HVI Fiber Quality				Market Value	Lint Yield	Gross Return
	Length	Strength	Micronaire	Uniformity			
	inches	g/tex		%	$/lb	lb/acre	$/acre
Holland 338 -6	1.15 f-j†	30.1 c-h†	3.58 a-e†	83.8 d-f†	0.60 c-h†	967 a†	585 a†
GSA 1093-61	1.26 a	29 h,l	3.23 d-g	83.7 e,f	0.65 a	833 a,b	533 ab
SC 9023 -11	1.17 c-g	29.3 e-l	3.7 a-d	84.8 a-c	0.63 a-e	812 a-c	504 abc
Sphinx -4	1.17 c-g	30.9 a-f	3.78 a-c	84.7 a-e	0.63 a-d	785 a-d	493 abc
Sphinx	1.20 b	30.9 a-e	3.45 a-g	85.3 a,b	0.63 abc	774 a-d	486 abc
Tejas	1.13 l.j	29.5 d-l	3.48 a-g	84.6 a-f	0.58 hi	825 a,b	482 abc
PM 183	1.14 h-j	29.3 e-l	3.8 a,b	84.6 a-f	0.60 d-l	783 a-d	465 a-d
Holland 338	1.18 c-f	29.1 g-l	3.35 b-g	84.1 c-f	0.62 a-f	753 a-d	465 a-d
GSA 1093-43	1.22 b	30.4 b-h	3.3 c-g	85.2 a,b	0.63 a-e	749 a-d	465 a-d
GSA 1093-33	1.18 c-d	31.5 a-c	3.38 b-g	84.4 b-f	0.61 c-h	754 a-d	457 a-d
PM 330	1.12 j	28.3 l	3.7 a-d	84.3 b-f	0.59 e-l	760 a-d	451 a-d
Holland 338 -9	1.16 d-h	29.4 d-l	3.9 a	84.8 a-c	0.62 a-f	721 a-d	443 a-d
Explorer	1.17 c-g	30.8 b-h	3.7 a-d	84.8 a-d	0.64 ab	667 a-d	426 a-d
Explorer -25	1.19 b-d	31.3 a-c	3.0 f,g	85.4 a	.61 b-h	671 a-d	406 a-d
Atlas	1.16 e-l	30.2 c-h	3.6 a-e	84.5 a-f	0.62 a-f	660 a-d	406 a-d
GSA 1093-52	1.13 h-j	31.6 a-c	3.5 a-g	85.2 a,b	0.60 e-l	673 a-d	403 a-d
Atlas -4	1.13 l,j	32.4 a	3.6 a-e	84.3 b-f	0.60 d-h	652 b-d	394 bcd
GSA 1093-11	1.18 c-e	30.4 b-h	3.3 c-g	84.3 b-f	0.49 e-l	639 b-d	380 bcd
Explorer -13	1.17 d-g	32.1 a,b	3.6 a-e	85.1 a,b	0.62 a-f	583 b-d	357 bcd
Sphinx -20	1.18 c-e	30.4 c-h	3.1 e,f,g	84.6 a-e	0.62 a-f	574 b-d	337 c-d
GSA 1093-41	1.17 c-g	31.6 a-c	3.4 b-g	83.6 f	0.58 ghi	560 b-e	336 cde
GSA 1054-26	1.15 g-j	31.2 a-c	3.5 a-f	83.8 c-f	0.58 hi	564 b-d	326 cde
SC 9023 -5	1.17 d-g	29.2 f-l	3.5 a-f	84.6 a-f	0.61 b-g	478 d,e	292 de
GSA 1093-23	1.13 h-j	31.1 a-d	3.4 b-g	84.0 c-f	0.57 l	555 c-e	291 de
GSA 1054-25	1.25 a	30.8 a-g	3.0 g	84.6 a-f	0.61 b-h	252 e	151 e
Coefficient of Variation	1.9%	4.0%	10.0%	0.9%	3.7%	32.3%	31.8%

†Means within the same column not followed by the same letter differ at the 0.05 level of probability by Fisher's Protected Least Significant Difference Test.

Table 3. HVI Fiber quality, market value, lint yield, and gross return for 18 mutant lines and 7 commercial varieties planted at Lubbock, TX on July 3, 2000 and 2001.

Genotype	HVI Fiber Quality				Market Value	Lint Yield	Gross Return
	Length	Strength	Micronaire	Uniformity			
	inches	g/tex		%	$/lb	lb/acre	$/acre
Holland 338 -6	1.11 d-h†	30.8 a-d†	4.2 a†	82.9 b-d†	0.59 f†	777 a†	463 a†
GSA 1093-61	1.19 a	30.8 a-d	3.3 f	82.6 cd	0.62 a	661 abc	415 ab
Tejas	1.08 g-j	28.8 e-g	3.9 a-e	83.7 a-c	0.56 lm	726 ab	412 ab
PM 330	1.06 lj	27.8 g	3.9 a-e	82.9 b-d	0.57 jk	724 ab	410 ab
SC 9023-11	1.14 bcd	29.5 d-g	3.7 c-f	83.6 a-d	0.60 b	662 abc	404 ab
PM 183	1.05 j	29.3 d-g	4.1 a-c	83.0 b-d	0.56 k	695 abc	395 ab
Sphinx -4	1.11 c-h	30.3 b-f	4.1 a-c	83.0 bcd	0.60 cde	645 abc	393 ab
Sphinx	1.14 b-e	30.3 b-f	3.6 c-f	83.9 ab	0.60 bc	616 a-d	378 ab
GSA 1093-43	1.13 c-f	30.2 b-f	3.8 a-e	83.9 ab	059 f	630 abc	378 ab
Holland 338 -9	1.11 c-h	29.8 c-f	4.0 a-c	83.8 ab	0.60 bcd	616 a-d	371 ab
GSA 1093-52	1.10 f-h	31.8 ab	3.8 a-e	83.7 a-d	0.58 l	634 abc	368 ab
Atlas -4	1.08 h-j	31.1 a-d	3.9 a-d	83.8 a-c	0.58 gh	612 a-d	358 ab
GSA 1093-33	1.09 f-h	29.8 c-f	3.8 a-e	83.0 b-d	0.58 hi	604 a-d	357 ab
Holand 338	1.11 c-h	29.4 d-g	3.8 a-e	82.6 cd	0.59 e	581 a-d	354 abc
Explorer -25	1.13 c-f	30.6 b-e	3.7 b-e	84.4 a	0.59 fg	583 a-d	343 abc
Atlas	112 c-g	30.5 b-f	3.6 c-f	83.2 b-d	0.60 de	525 a-d	317 abc
Explorer	1.15 bc	30.5 b-e	3.6 d-f	74.0 ab	0.61 a	501 a-d	315 abc
GSA 1093-11	1.12 c-f	30.7 a-d	3.4 ef	83.3 a-d	0.57 j	536 a-d	310 abc
Explorer -13	1.10 e-h	32.5 a	4.1 ab	83.6 a-d	0.58 gh	502 a-d	296 bc
GSA 1093-41	1.13 c-f	31.4 a-c	4.1 a-c	82.6 d	0.57 j	501 a-d	291 bc
GSA 1054-26	1.10 f-l	30.9 a-d	3.8 a-e	82.6 d	0.56 kl	505 a-d	285 bc
Sphinx -20	1.11 d-h	30.3 b-f	3.9 a-e	83.3 b-d	0.57 j	493 bcd	282 bc
GSA 1093-23	1.10 f-h	30.8 a-d	3.7 b-f	83.4 a-d	0.55 m	470 bcd	261 bc
SC 9023 -5	1.10 f-l	28.6 fg	3.8 a-e	83.7 a-d	0.58 gh	436 cd	256 bc
GSA 1054-25	1.17 ab	31.9 ab	3.4 ef	84.0 ab	0.58 gh	336 d	190 c
Coefficient of Variation	2.4%	4.2%	8.8%	1.0%	0.7%	42.4%	42.0%

†Means within the same column not followed by the same letter differ at the 0.05 level of probability by Fisher's Protected Least Significant Difference Test.

The HVI fiber quality traits of length, strength, micronaire, uniformity and estimated market price differed in both years of the study (Tables 1 and 2). Fiber length as probably the most sensitive index ranging from 1.02 to 1.15 inches across the 25 genotypes in 2000 and 1.12 to 1.26 inches in 2001. As with the lint yield, the amount of heat units appeared to have a major impact on fiber length on all genotypes included in this study. Estimated market price was less sensitive across years than fiber length. Market price of the 25 genotypes ranged from $0.49 to $0.56 per lb in 2000 and from $0.57 to $0.65 per lb in 2001. When averaged over both years of the study, the five lines with the highest lint yield had estimated market prices which ranged from $0.56 to $0.62 per lb (Table 3). One of these lines, GSA 1093-61, had the highest fiber length in both 2000 (1.15 inches) and 2001 (1.26 inches). The mutant GSA 1093-61 showed that both good lint yield and superior fiber quality can be combined into a single line that is well adapted to short season production conditions.

As with other indices, estimated gross return had a wide range of differences in both 2000 ($94 to $329 per acre) and in 2001 ($151 to $585 per acre) (Tables 1 and 2). Once again, the relationship with heat units demonstrates the need to optimize the length of the growing season for all cotton production environments. When averaged over both test years, the top six genotypes for lint yield also had the highest gross return per acre (Table 3).

The results of these trials indicate that there could be significant potential gains in lint yield, fiber quality, market price and gross return in the genotypes selected for short season adaptation. The three top M_5 lines (SC 9023-11, Holland 338-6, and GSA 1093-6) were last selected as individual plants in the M_3 generation. Because they have now been advanced to M_7 generation, individual plants selected from these lines should have a high level of homozygosity. Selection within these mutant lines could provide highly inbred lines, which could provide additional advances in the development of short season cotton cultivars.

The reported yield per harvested acre for irrigated cotton in crop reporting district 1-N was 541 lbs per acre for the 2000 crop year and 699 lbs per acre for the 2001 crop year (TASS 2001). The average price received by farmers in Texas for the 2000-2001 marketing year was reported at $0.45 per lb (TASS 2001). The 2000-2001 marketing year price was used to calculate the northern counties of the Texas High Plains estimated gross return per acre for the 2000 and 2001 crop years to be comparable with the market price calculated for the mutant varieties using the 2000 DPES price equation. This allowed a comparison between the predicted gross return of the mutant varieties and the actual gross return of varieties grown in this region.

The average gross return for the mutant Holland 338-6 was $221 per acre in 2000 and $585 per acre in 2001. The projected gross return for irrigated cotton in the northern counties was $243 per acre in 2000 and $315 per acre in 2001. The average estimated gross return over the two years for Holland 338-6 was $463 per acre compared to $279 per acre estimated for commercial production in the northern counties of the Texas High Plains (TASS 2000). Based on its performance in the two trial years, Holland 338-6 and GSA 1093-61 shows the most potential for future development as a short season variety. Future work will focus on selection of highly inbred lines with consistent performance in both lint yield and fiber quality.

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Response of Coastal Bermudagrass to Gypsum Applications

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ABSTRACT

Field studies were conducted from 1998 to 2000 at two locations in Fayette County to evaluate the effects of power plant by-product gypsum in comparison with agricultural gypsum on yield and quality of Coastal bermudagrass [*Cynodon dactylon* (L.)]. By-product gypsum and agricultural gypsum increased yearly coastal bermudagrass yield over the untreated check in only one year at one location over the 3-year test period. No differences in crude protein content of bermudagrass were noted between untreated check and gypsum treatments.

KEYWORDS: Forage, Protein content, Quality, Yield.

Coal is utilized in production of a large portion of the energy produced by the United States. The Clean Air Act of 1990 was designed to reduce sulfur dioxide emissions from coal fired generation power plants. As a result of the scrubbers installed to reduce these emissions, by-product gypsum is produced at many of these power plants. In Texas, by-product gypsum is generated in significant tonnages that create a disposal problem for many power plants (Jason Underbrink, Boral Material Technologies, Inc., personal communication).

Gypsum (calcium sulfate) is a common source of calcium and sulfur for many crops (Grichar et al. 2000; Heath et al. 1985). It has a relatively high solubility and therefore is quickly available to plants. Because gypsum is a neutral salt, it does not increase soil pH. Corn (*Zea mays* L.) and cotton (*Gossypium hirsutum* L.) have responded to gypsum under acid soil conditions (Caldwell et al. 1988, 1990; Toma et al. 1999).

Gypsum is routinely recommended as a source of calcium for peanuts (*Arachis hypogaea* L.) and potatoes (*Solanum tuberosum* L.) (Grichar and Boswell 1990, Grichar et al. 2000, Grichar et al. 2001). High yielding and good quality peanuts require adequate Ca in the top 3 in of soil during pegging and pod filling (Cox et al. 1982, Gascho et al. 1993). Gypsum also has been reported to reduce disease incidence in various crops (Filonow et al. 1988, Hooker 1981, Messenger et al. 2000).

Applications of gypsum significantly reduced root rot in avocado (*Persea americana* Mill.) in California as well as Australia (Broadbent and Baker 1974, Falcon et al. 1984, Messenger et al. 2000). Garren (1964) first reported that high rates of calcium added to soil in the form of gypsum effectively reduced pod rot. Further study (Hallock and Garren 1968) suggested the calcium content of peanut pods was important in suppression of pod rot caused by that *Pythium myriotylum*. Pods containing > 0.20% calcium had less disease than

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those containing < 0.15% calcium. Gypsum has been reported as being effective in reducing the incidence and severity of bacteria potato soft rot (Hooker, 1981; Wright, 1995).

Very little work exists concerning the use of gypsum to increase quality and yield of pasture grasses. Suhayda et al. (1997) reported that gypsum decreased soil pH, electrical conductivity and chloride and sodium levels while water infiltration and calcium levels were increased. They also reported that gypsum increased height and yield of three grass species (*Aneurolepidium chinense, Puccinellia temiflora,* and *Hordeum brevisubulatum*). Improvements in plant growth and survival with calcium appeared to be due to reduced chloride levels and increased calcium availability in the soil, and to changes in soil structure leading to improved water infiltration rates (Suhayda et al. 1997).

Dorsett et al.[1] reported that gypsum obtained from a power plant provided 6 to 30% higher 'Coastal' bermudagrass forage yields than the untreated check depending on harvest date and product. Although soil sulfur levels were not changed, forage sulfur levels increased as gypsum rates increased. The objective of this study was to compare the effects of power plant by-product gypsum with regular agricultural gypsum on coastal bermudagrass yield and quality.

MATERIALS AND METHODS

Field studies were conducted from 1998 through 2000 at two locations in Fayette County to determine the effects of two sources of gypsum on coastal bermudagrass yield and quality. Agricultural gypsum obtained from a local distributor[2] was compared with gypsum obtained as a by-product of a coal-generated power plant[3] located near La Grange, TX. Representative samples of agricultural gypsum and by-product gypsum and soil samples from the 0 to 6-inch depth at each study location were collected prior to study initiation and submitted to the Texas Agricultural Extension Service Soil Test Laboratory for analysis.

Test sites were installed in established stands of coastal bermudagrass at the Cooper Farm Resource Area and Grey Farm for the duration of the study. The Cooper Farm is a 180 acre piece of south-central Texas farmland developed by the Lower Colorado River Authority (LCRA) as a natural science laboratory, in hopes of developing and demonstrating ways to allow wildlife to survive and thrive in an area that is heavily agriculture. The test area was located in one of the Coastal bermudagrass pastures at the site. The Grey Farm is a privately owned ranch. These farms were located approximately four to five miles apart in a radium of about three miles north/northeast of LaGrange.

Soil at the Cooper Farm site was a sandy loam with 69% sand, 19% silt, 12% clay and pH 4.6. The Grey Farm site was a sand with 87% sand, 9% silt, and 4% clay with pH 4.6. Soil nitrate, magnesium, and sodium levels were low at both sites. Phosphorus and potassium levels were low to moderate at both locations. Calcium levels were high at the Cooper Farm but low at the Grey location, while sulphur levels were low at both locations.

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[1]D. J. Dorsett, L. Nickel, and H. D. Pennington. 1995. Evaluation of coal generated by-product gypsum as a soil amendment on improved hybrid bermudagrass. Report for Monex Resources, Inc. (Now Boral Material Technologies, Inc.). San Antonio, TX 78216.

[2]Hoe-Down, Standard Gypsum Corp., 1650 Gypsum Mine Rd., Fredricksburg, TX 78624.

[3]Boral Material Technologies, Inc., San Antonio, TX 78216.

By-product gypsum at 500, 1000, 1500, and 2000 lbs/ac and agricultural gypsum at 500, 1000, and 2000 lbs/ac were hand applied to plots during the spring of each year. An untreated check was included for comparison. Weeds were controlled with Grazon P+D at 3.0 pt/ac applied to plots during the spring at each location. Fertilizer was applied according to soil test recommendations at spring green-up and again after the second cutting. A schedule of events is presented in Table 1 and monthly rainfall received in the study area is shown in Table 2.

Table 1. Schedule of events for gypsum study at two locations in Fayette County, TX.

	Location					
	Cooper			Grey		
Event	1998	1999	2000	1998	1999	2000
First fertilizer application	31 Mar	12 Apr	20 Apr	31 Mar	7 Apr	20 Apr
Second fertilizer application	-	13 Jul	17 May	11 Jun	2 Jun	17 May
Gypsum application	6 Apr	12 Apr	20 Apr	6 Apr	12 Apr	20 Apr
First grass cutting	15 Jul	26 Apr	5 Apr	6 May	24 May	27 Mar
Second grass cutting	-	2 Jun	17 May	11 Jun	24 Jun	11 May
Third grass cutting	-	13 Jul	28 Jun	15 Jul	27 Jul	20 Jun
Fourth grass cutting	-	-	-	6 Dec	10 Nov	-

Table 2. Monthly rainfall for 19982000 and 55 yr average for LaGrange, TX.

Month	1998[a]	1999	2000	Average
	----------inches----------			
January	2.43	0.94	4.52	2.76
February	5.93	0.54	2.24	2.88
March	1.65	3.84	2.31	2.26
April	0.81	9.89	1.70	2.99
May	0.25	5.47	5.38	4.86
June	1.04	4.70	5.75	3.94
July	1.23	3.93	0.50	2.23
August	3.47	0.70	0.85	2.55
September	7.93	0.37	0.29	4.65
October	13.75	0.51	4.06	3.71
November	8.20	0.38	8.84	3.14
December	3.0	1.34	4.13	2.74
Total	49.69	32.61	40.57	38.71

[a/]Studies initiated in April 1998

Plot size was 10 ft wide by 30 ft long. The treatment design was a randomized complete block with four replications. Plots were harvested with a Lawn-Genie forage Harvester.[4] Individual plot weights were obtained at harvest. A subsample (~ 1.0 lb) was

[4]Matthews Co., Crystal Lake, IL 60014

collected to determine weight and then dried in a forced air dryer at 170°F for 96 h. Dry matter weights were then used to calculate forage yield on a per acre basis. Dry forage samples were then sent to the Texas Agricultural Extension Service Soil and Plant Testing Laboratory for analysis of quality and nutrients.

RESULTS AND DISCUSSION

Gypsum composition. Chemical analysis of the two gypsum sources indicated that by-product gypsum contained greater concentrations of boron, chloride, fluoride, magnesium, potassium, and sodium (Table 3). Concentrations of Ca and S were similar for the two products, thus any differences in plant uptake likely would be attributed to variations in solubility. Moisture levels were higher in by-product gypsum compared to agricultural gypsum.

Table 3. Chemical composition of by product gypsum and agricultural gypsum.

Component	By-product gypsum	Agricultural gypsum
	----------mg/kg----------	
Aluminum	<0.05	<0.05
Arsenic	<0.01	<0.01
Barium	0.09	0.06
Boron	0.25	0.12
Calcium	590.0	570.0
Cadmium	<0.005	<0.005
Chromium	<0.01	<0.01
Copper	<0.02	<0.02
Iron	<0.02	<0.02
Lead	<0.005	<0.005
Magnesium	12.00	<0.05
Manganese	<0.01	0.01
Mercury	<0.0002	<0.0002
Molybdenum	<0.02	<0.02
Nickel	<0.02	<0.02
Phosphorus	<1.0	<1.0
Potassium	3.7	<1.0
Selenium	<0.01	<0.01
Silver	<0.01	<0.01
Sodium	41.0	0.92
Vanadium	<0.02	<0.02
Zinc	0.06	0.1
Chloride	40.0	<1.0
Sulfate	1580.0	1500.0
Sulfur (%)	14.3	16.3
pH	7.3	8.0
Moisture (%)	20.0	1.0

Bermudagrass yield. *Grey Ranch*. Four bermudagrass cuttings were obtained in 1998 and 1999 while three cuttings were obtained in 2000. No differences in total bermudagrass yield between the untreated check and gypsum treatments were noted in 1998 and 2000 (Table 4). In 1999, yields in the by-product gypsum plots were significantly greater than those in the untreated check regardless of rate. By-product gypsum yields also were significantly greater than those of ag gypsum applied at 1000 and 2000 lbs, and a similar trend was observed for the 500 lb rate. Although total rainfall for 1999 in the LaGrange area was below normal (Table 2), rainfall during April through July was above average and supported total forage production in excess of > 30,000 lbs/ac.

Table 4. Effect of gypsum on total annual coastal bermudagrass dry matter production at Grey Ranch.

		Yield[1/]		
Treatment	Rate lb/ac	1998(4)	1999(4)	2000(3)
		----------lbs/ac----------		
Check	-	17,552a[2/]	31,667c	21,162a
By-product gypsum	500	21,142a	36,760a	21,878a
By-product gypsum	1000	16,828a	37,404a	23,949a
By-product gypsum	1500	15,312a	37,667a	19,998a
Ag gypsum	500	15,729a	34,285abc	21,884a
Ag gypsum	1000	17,208a	31,963bc	19,290a
Ag gypsum	2000	15,780a	32,306bc	20,265a

[1/] Numbers in parentheses represent the number of cuttings for that year.
[2/] Means within a column followed by the same letters are not significantly different at the 5% probability level by Duncan's New Multiple Range Test.

Cooper Farm. In 1998, only one cutting was obtained while in 1999 and 2000 there were three cuttings per year. In 1998 and 2000 there were no differences in yield between any of the gypsum treatments and the untreated check (Table 5). In 1999, bermudagrass plots which received by-product gypsum at 1500 lbs/ac or ag gypsum at 1000 lbs/ac yielded over 19,900 lbs of bermudgrass on a dry weight basis. Plots which received by-product gypsum at 500 lbs/ac yielded < 16,000 lbs/ac of bermudagrass on a dry weight basis (Table 5).

Table 5. Effect of gypsum on total annual coastal bermudagrass dry matter production at Cooper Farm.

		Yield[1/]		
Treatment	Rate lb/ac	1998(1)	1999(3)	2000(3)
		----------lbs/ac----------		
Check	-	742a	17,961ab	22,064a
By-product gypsum	500	700a	15,722b	21,179a
By-product gypsum	1000	696a	17,740ab	23,141a
By-product gypsum	1500	694a	19,991a	24,531a
Ag gypsum	500	707a	18,667ab	21,196a
Ag gypsum	1000	816a	20,427a	24,370a
Ag gypsum	2000	760a	18,477ab	21,187a

[1/] Numbers in parentheses represent the number of cuttings for that year.
[2/] Means within a column followed by the same letters are not significantly different at the 5% probability level by Duncan's New Multiple Range Test.

Crude protein content. *Grey Ranch*. Only three cuttings resulted in differences in percent crude protein (Table 6). In 1998, the 11 June and 6 December cuttings receiving by-product gypsum at 500 lb/ac produced less crude protein than other gypsum applications. Crude protein contents were extremely low for the December cutting due to harvest delays as a result of heavy rains in October and November (Table 2). At the June 20, 2000 cutting, by-product gypsum at 500 and 1000 lb/ac produced higher crude protein contents than all other treatments (Table 6).

Table 6. Crude protein content of coastal bermudagrass from Grey Ranch.

		Harvest dates [a,b]									
		1998				1999			2000		
Treatment	Rate lb/ac	May 6	June 11	July 15	Dec 6	May 24	July 27	Nov 10	Mar 27	May 11	June 20
		---	---	---	---	%	---	---	---	---	---
Check	-	16a	15a	16a	8a	19a	19a	9a	21a	18a	15b
By-product gypsum	500	15a	14b	15a	7b	18a	18a	9a	21a	17a	16a
By-product gypsum	1000	15a	16a	15a	9a	18a	18a	9a	21a	17a	16a
By-product gypsum	1500	16a	15a	16a	9a	18a	18a	9a	21a	17a	15b
By-product gypsum	2000	17a	15a	16a	9a	18a	18a	9a	21a	18a	15b
Ag gypsum	500	15a	15a	15a	8a	19a	19a	9a	20a	18a	15b
Ag gypsum	1000	17a	16a	16a	9a	19a	19a	9a	20a	17a	15b
Ag gypsum	2000	17a	15a	16a	9a	18a	18a	9a	20a	17a	14b

[2/] Means within a column followed by the same letters are not significantly different at the 5% probability level by Duncan's New Multiple Range Test.
[b]June 24, 1999 harvest date not included.

Cooper Farm. The crude protein content of the 26 April, 1999 cutting was extremely low because of the earliness of the cutting to remove the dead growth from the previous winter (Table 7). Only the 13 July, 1999 and the 5 April, 2000 cuttings resulted in differences in crude protein content. For the 13 July cutting, by product gypsum at 1500 and 2000 lbs/ac and agricultural gypsum at 2000 lb/ac resulted in lower crude protein contents. Similarly, for the 5 April cutting by-product gypsum at 1500 lb/ac and agricultural gypsum at 2000 lb/ac had lower crude protein contents than other gypsum treatments.

Table 7. Crude protein content of coastal bermudagrass from Cooper Farm.

		Harvest dates[a, b]					
		1998	1999			2000	
Gypsum Treatment	Rate lb/ac	July 15	Apr 26	June 2	July 13	Apr 5	June 28
		---	---	%	---	---	---
Check	-	11a	8a	11a	17a	20a	13a
By-product	500	11a	8a	10a	17a	20a	14a
By-product	1000	11a	8a	11a	17a	19a	13a
By-product	1500	10a	7a	10a	16b	18b	13a
By-product	2000	10a	8a	9a	16b	20a	13a
Ag	500	10a	8a	10a	17a	20a	14a
Ag	1000	10a	8a	10a	17a	19a	14a
Ag	2000	11a	8a	10a	16b	18b	13a

[2/] Means within a column followed by the same letters are not significantly different at the 5% probability level by Duncan's New Multiple Range Test.
[b]May 17, 2000 harvest date not included.

Other minerals. Forage calcium and sodium levels were not affected by treatment at either location or any harvest date (data not shown). Dorsett et al.[1] also noted no change in calcium uptake in the hay. However, they found that as the rate of by-product gypsum increased, the sulfur level in the forage increased.

CONCLUSIONS

Application of by-product or ag gypsum did not improve on coastal bermudagrass yield or quality. In addition, although concentrations of several elements were greater in by-product gypsum compared to commercial agricultural gypsum, few differences in tissue concentrations were observed.

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Rooting Ability of Redberry Juniper Sprouts

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ABSTRACT

Redberry juniper (*Juniperus pinchotii* Sudw.; Cupressaceae) sprout rooting ability was evaluated following their mechanical dislodgement from the shrub bases of a random sample of a Rolling Plains population. The objectives of the evaluation were to determine if dislodged sprouts are capable of producing adventitious roots and establishing as individual plants. Twenty-five sprouting shrubs were slashed then top removed with chain saw cuts; random samples of dislodged sprouts from each shrub were placed on gravel and soil and watered monthly on a single bench of the greenhouse. All of the sprouts placed on gravel died within six months after dislodgement. Ninety-eight of the sprouts placed on soil survived and 22 of them produced adventitious roots and established as independent plants. Mechanical manipulation of shrubs can result in their dislodgement. If dislodged sprouts are dispersed to a site with access to soil and water they can establish as independent plants. Best management practices would suggest that mechanical manipulation of redberry juniper be deferred or followed by pyric treatment within one year of slashing or top removal to kill dislodged sprouts.

KEYWORDS: Juniper, *Juniperus*, sprouting

Populations of redberry juniper or cedar (*J. pinchotti* Sudw.) are found within Texas in the Trans-Pecos, Edwards Pleateau, High Plains, and Rolling Plains (Adams 1993). Juniper distribution was reported to have increased in a 65 county area of Texas from 6.3 million acres to 10.1 million acres between 1948 and 1982 (Ansley et al. 1995) with concurrent decreases in herbaceous productivity (Graves 1971) and alterations of precipitation regimes (Hester 1996). The reported increases in juniper distribution within these areas are hypothesized to be the result of seedling establishments in gaps of climax vegetation from either seed banks or dispersed seed (FEIS 1996). Though sprouting may also be a recruitment mechanism for redberry juniper, there are no published accounts of its potential role in the reported increased juniper distribution.

Redberry juniper sprouting (Sudworth 1905, Correl and Johnston 1979) occurs from meristematic tissue in the first leaf area of seedlings and plant canopy base of saplings, juveniles, and adults. Sprouting from this tissue is believed to be related to shrub age (Smith et al. 1975), size (Schuster and George 1976), or position in relationship to soil coverage (Smith et al. 1975). Redberry juniper sprouting has been assumed to be an adaptation to remedy loss of photosynthetic material, i.e., from being browsed or grazed (Adams 1994). Hypothetically, redberry juniper sprouting may also be a reproductive strategy to produce clones that can be dispersed from the shrub by water, wind, or animal transport.

Management techniques employed in an attempt to decrease redberry juniper distribution and density between the 1940's and 1980's decades included dozing (Rechenthin et al. 1964), chaining (Vallentine 1989), mechanical removal (Ueckert and Whisenant 1982), and pyric treatment (Steuter and Britton 1983) with variable success rates related to post-treatment sprouting. Though there are many data reporting the growth rates and numbers of sprouts that are produced after treatment (Ahlstrand 1982, Kittams 1973, McPherson and Wright 1989), no data have been published that describe the behavior of sprouts dislodged from shrubs by mechanical manipulation. If dislodged sprouts are capable of surviving and producing roots, i.e., establishing as independent plants, mechanical manipulation may have contributed to the changes in redberry juniper distribution reported between the 1940's and 1980's decades.

Knowledge of redberry juniper sprout rooting ability would assist in understanding the recent historical changes in distribution and deciding if mechanical treatment alone should be deferred and/or augmented with post-treatment prescription fire or herbicide application. To determine if redberry juniper sprouts are capable of establishing as independent plants, we assessed their rooting ability after they were dislodged from shrub basal areas by mechanical manipulation. The null hypothesis for the study was that no redberry juniper sprout rooting would occur.

METHODS AND MATERIALS

Study material was collected 1 and 3 January, 1999 at the Roy Ranch located 22 miles southeast of Post, Texas in the Rolling Plains. Twenty-five shrubs growing in a Lincoln-Yahola complex, sandy clay loam on the flood plain of Gobbler Creek (33°4'N, 101°8'E) were randomly chosen. The shrubs varied in height from 3 to 6.5 ft but all had sprouts growing from their bases. The shrubs first had their lower limbs removed with a chain saw then were top removed with a cut made as close as possible to ground level. Sprouts that were dislodged from each shrub during the chain saw top removal were gathered, placed in plastic bags, and transported to the Texas Tech University Department of Biology greenhouse facility.

Ten randomly chosen sprouts from each cutting of each shrub were placed on the soil surface of 8 inch diameter plastic pots of either sandy clay loam soil collected at the site of shrub manipulation or gravel. Pots were inspected, rotated on a single greenhouse bench, and watered weekly with a pint dose of tap water for one month, then monthly for 11 months. The total number of sprouts that survived and developed roots was determined at the end of the 11-month period.

RESULTS AND DISCUSSION

All of the sprouts placed on gravel after collection died within six months. One hundred-two of the 250 (40.8%) sprouts placed on soil after collection also died within six months, but roots had developed on 22 (14.9%) of the survivors. A G-test of heterogeneity for sprout root development indicated greater numbers of rooting sprouts than expected by chance along ($G = 15.698$, 1 df; $p<0.05$). The null hypothesis that no rooting of redberry juniper sprouts occurs was rejected.

It appears that redberry juniper sprouting has two functions – maintaining plant occupancy after canopy loss and producing independent plants when sprouts are dispersed from the parent shrub. For the later, the number of sprouts that produce independent plants will be related to their dislodgement, dispersal, and deposition into a suitable habitat for rooting.

Under natural conditions animals may selectively dislodge sprouts and disperse them to areas of suitable habitat: we have documented redberry juniper sprouts incorporated in the entrances of white throated (*Neotoma albigula warreni* Merriam) trade-rat nests. Sprouts may also be naturally dislodged when a shrub falls or basilar branches die back and/or break off. In these scenarios water and wind may also disperse sprouts to suitable microsites. The mechanical manipulation of chain saw top removal in this study also caused sprout dislodgement with dispersal and deposition into microsites that contained shade from slash, soil contact, and increased water access from interception by slash.

The finding that redberry juniper sprouts are capable of establishing as independent plants provides a supplemental explanation for the changes in distribution and density documented during the 1970's to 1990's decades that has been attributed to maximized seed germination and seedling establishment. Mechanical manipulation was used in an attempt to control shrubs prior to and during this time period and doubtlessly dislodged sprouts. If dislodged sprouts were deposited into microsites that included soil contact and water availability, a percentage probably established as independent plants. The total number of plants that established from this pathway would be related to the total number of sprouts dislodged. The observation of seedling densities greater than 800 per acre on sites where mature redberry juniper had been dozed (FEIS 1996) has been attributed to soil seed bank response, but may have been compounded with 'sproutling' establishment.

Until field data for sprout establishment can be collected and analyzed it seems prudent to suggest that dozing, chaining, and top removal manipulations of redberry juniper should either be deterred or a treatment application after manipulation should be used to kill sprouts. Because there are presently no published herbicide trials or recommendations for redberry juniper sprouts, pyric application to slash is the only treatment that could be applied to kill sprouts before they root. This would require that fire treatment be applied to top-removed shrubs and slash within one year of treatment.

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Weed Management in Transgenic and Non-Transgenic Cotton (*Gossypium hirsutum*) in the Texas High Plains

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ABSTRACT

Field experiments conducted at the Texas Agricultural Experiment Station near Lubbock in 1996 and 1997 evaluated Palmer amaranth (carelessweed), devil's-claw, and barnyardgrass control in cotton. Weed management systems included the following soil-applied treatments: Treflan (trifluralin) preplant incorporated (PPI), Caparol (prometryn) preemergence (PRE), or Treflan followed-by (fb) Caparol. Foliar treatments included Roundup Ultra (glyphosate) postemergence (POST) and postemergence-directed (PDIR) in Roundup Ready (Roundup-tolerant) cotton, Buctril (bromoxynil) POST in BXN (Buctril-tolerant) cotton, and Staple (pyrithiobac) POST in conventional (non-transgenic) cotton. Each of these foliar treatments was also used following the soil-applied treatments. In 1996, Roundup Ultra following any soil-applied herbicide treatment provided season-long Palmer amaranth control. Due to multiple Palmer amaranth flushes in 1997, two Roundup Ultra applications were required for control similar to 1996 in all Roundup Ultra-treated plots except for Treflan fb Caparol fb Roundup Ultra, which required only one Roundup Ultra application. Staple following any soil applied herbicide treatment controlled Palmer amaranth at least 96% at the end of the season in 1996, but control was only 75 to 94% at the end of the season in 1997. Neither Buctril nor Staple applied alone controlled Palmer amaranth, but when applied following soil-applied herbicides, control was at least 72% at the end of the season each year. Roundup Ultra or Buctril applied alone controlled devil's-claw at least 92% in both years. Staple applied alone controlled devil's-claw 70% and 92% in 1996 and 1997, respectively. Roundup Ultra was the only POST herbicide that controlled barnyardgrass and was the most consistent POST herbicide in both years. All POST herbicides improved weed control as compared to soil-applied herbicides used alone. Plots treated with Roundup Ultra alone yielded more than plots that received a soil-applied only treatment and yielded similar to plots that received a soil-applied fb foliar treatment.

KEYWORDS: Barnyardgrass, Buctril, BXN cotton, Caparol, Devil's-claw, Palmer amaranth, Roundup Ultra, Roundup Ready cotton, Staple, Treflan

Cotton, the major agronomic crop produced on the Texas High Plains, is planted annually on approximately 3.2 million acres in a 25-county, 100-mile radius surrounding Lubbock. Either Treflan or Prowl is applied to approximately 90% of the acreage planted to cotton in this area (Dotray et al. 1996). Current PPI and PRE herbicides control many small-seeded broadleaf weeds and annual grasses. However, other weeds including devil's-claw [*Proboscidea louisianica* (Mill.) Thellung], common cocklebur (*Xanthium strumarium* L.), morningglories (*Ipomoea spp.*), and silverleaf nightshade (*Solanum eleagnifolium* Cav.) are increasing, and are not controlled by these herbicides.

Staple herbicide, which received a Federal 3 registration for use in cotton in 1996, controls hemp sesbania [*Sesbania exaltata* (Raf.) Rybd. ex A.W. Hill], prickly sida (*Sida spinosa* L.), puncturevine (*Tribulus terrestris* L.), velvetleaf (*Abutilon theophrasti* Medic.), morningglory, and other broadleaf weeds (Holshouser and Chandler 1991, Jordan et al. 1993, Reinhart 1996, Sunderland and Coble 1994). Staple also controls Palmer amaranth (*Amaranthus palmeri* S. Wats) and devil's-claw if applied at appropriate rates and timings (Dotray et al. 1996). Staple applied POST controls weeds in the early seedling stage and has considerable soil residual activity (Crawford 1993). Staple does not control grasses and should be used in conjunction with an effective grass-control herbicide.

The development of herbicide-tolerant cotton varieties may greatly alter weed management strategies on the Texas High Plains. Utilizing Roundup in Roundup Ready cotton in conjunction with traditional herbicides may provide options to economically control a broad spectrum of weeds in conventional and reduced tillage systems (Vidrine et al. 1996). In either conventional or conservation tillage cotton systems, Roundup Ultra applied POST improved weed control over residual herbicides applied alone (Keeling et al. 2000). Using Buctril-tolerant (BXN) cotton allows growers to apply Buctril POST from emergence to 60 days before harvest. Since Buctril will not control grass species or Palmer amaranth, it is recommended for use in conjunction with both a PPI grass herbicide and a PRE broadleaf herbicide (Collins 1996). Buctril controls many annual broadleaf weeds including black and hairy nightshade (*Solanum spp.*), common lambsquarters (*Chenopodium album* L.) and velvetleaf (Vargas et al. 2000).

Traditional PPI and PRE herbicides may still be necessary as a foundation treatment for weed control because neither Roundup Ultra nor Buctril have residual soil activity, and Staple and Buctril do not control grass weeds. The objective of this study was to evaluate weed control systems using Roundup Ultra, Buctril, or Staple applied alone and in combination with standard PPI and PRE herbicides.

MATERIALS AND METHODS

Field experiments were conducted in 1996 and 1997 at the Texas Agricultural Experiment Station near Lubbock on an Amarillo sandy clay loam soil (fine-loamy, mixed, thermic Aridic Paleustalf) with 0.8% organic matter and pH 7.8. Paymaster 2326 Roundup Ready (Roundup-tolerant), BXN 57 (Buctril-tolerant), and Paymaster HS 26 (non-transgenic) cotton varieties were planted at 15 lbs/ac on 40 in. rows on May 22, 1996 and May 23, 1997. Individual four-row plots, 13.3 by 50 ft in length, were arranged in a randomized complete block design with three replications.

Weed management systems included Treflan PPI at 0.75 lb ai/ac, Caparol PRE at 1.2 lb ai/ac, and Treflan PPI fb Caparol PRE at these rates. Sequential applications of

Roundup Ultra POST and PDIR at 0.56 lb ae/ac (in Roundup-tolerant cotton), Buctril POST at 0.5 lb ai/ac (in Buctril-tolerant cotton), or Staple POST at 0.063 lb ai/ac (in non-transgenic cotton) were applied alone or following soil-applied herbicide treatments. All herbicides were applied using a tractor-mounted compressed-air sprayer delivering 10 GPA at 30 PSI. PPI treatments were incorporated 2 to 4 in. deep using a spring-tooth field cultivator within 1 h of application.

Cotton was 3 to 6 in. tall with 3 to 4 leaves when the POST treatments were applied and 16 to 19 in. tall with 9 to 10 leaves when the PDIR (Redball hooded sprayer) treatments were applied. Palmer amaranth height at the POST application was 1 to 6 in. tall with 1 to 8 leaves and 3 to 9 in. tall with 4 to 10 leaves at the PDIR application. Devil's-claw height at the POST application was 1 to 4 in. tall with 1 to 4 leaves and 1 to 4 in. tall with 2 to 4 leaves at the PDIR application. Barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] height at the POST application was 1 to 6 in. tall with 2 to 6 leaves and 2 to 7 in. tall with 2 to 6 leaves at the PDIR application. Row middles of all plots were cultivated three times during the growing season using a sweep cultivator to prevent blowing sand and to prepare the middles for furrow irrigation.

Palmer amaranth, devil's-claw, and barnyardgrass control was estimated visually using a scale of 0% (no weed control) to 100% (complete weed control). Yields were determined by hand-harvesting cotton from 6.6 ft in the center two rows of each plot. Burr cotton was ginned to determine the lint percentage and yields.

All data were subjected to an analysis of variance. Treatment means were separated using Fisher's Protected LSD using a P=0.05. Years were analyzed separately because of environmental differences (Table 1) that affected weed emergence and subsequent POST herbicide inputs.

Table1. Rainfall distribution by month in 1996 and 1997 and a 75-yr average.

Month	1996	1997	75-Year Avg.
	-------------------- inches --------------------		
Jan	0.22	0.25	0.51
Feb	0.02	1.34	0.64
Mar	0.06	0.03	0.79
Apr	0.07	5.78	1.20
May	2.27	2.66	2.59
Jun	2.59	2.74	2.54
Jul	1.60	1.81	2.23
Aug	6.20	1.49	2.03
Sep	0.75	1.59	2.54
Oct	0.39	1.44	2.02
Nov	0.41	0.65	0.64
Dec	0.01	1.92	0.63
Total	14.59	21.70	18.36

RESULTS AND DISCUSSION

Palmer Amaranth Control

1996 Growing Season. All soil applied (residual) herbicides controlled Palmer amaranth at least 90% 16 days after planting (DAP) (Table 2). Roundup Ultra was the only POST herbicide that controlled Palmer amaranth at least 90% 40 DAP. Staple alone controlled Palmer amaranth 78% and Buctril controlled Palmer amaranth 17% 40 DAP. Palmer amaranth control by Treflan, Caparol, and Treflan fb Caparol was 98% at 40 DAP.

Table 2. Palmer amaranth control in cotton weed management systems in 1996 and 1997[a].

Herbicide[b]				1996 Days after planting			1997 Days after planting			
PPI	PRE	POST	PDIR	16[c]	40	120	22	35	61	111
				%						
Treflan				98 a	98 ab	93 ab	75 a-d	67 ef	73 b-e	75 abc
	Caparol			100 a	98 ab	60 c	73 a-d	57 f	55 ef	43 d
Treflan	Caparol			99 a	98 ab	92 ab	93 a	83 bcd	84 abc	72 abc
Treflan		Roundup Ultra	Roundup Ultra[d]	90 b	100 a	95 ab	85 abc	85 a-d	97 a	88 ab
	Caparol	Roundup Ultra	Roundup Ultra[d]	99 a	99 a	93 ab	57 d	72 def	93 ab	86 ab
Treflan	Caparol	Roundup Ultra		100 a	100 a	98 a	87 abc	89 abc	93 ab	97 a
		Roundup Ultra	Roundup Ultra[d]	0 d	93 b	83 b	0 e	67 ef	91 ab	67 bcd
Treflan		Staple[e]		97 a	100 a	96 a	72 a-d	83 bcd	82 abc	88 ab
	Caparol	Staple		100 a	100 a	97 a	60 cd	80 cde	80 a-d	75 abc
Treflan	Caparol	Staple		99 a	100 a	97 a	88 ab	93 abc	100 a	94 a
		Staple		0 d	78 c	40 d	0 e	60 f	45 f	50 cd
Treflan		Buctril		90 b	100 a	93 ab	68 a-d	85 a-d	88 abc	93 ab
	Caparol	Buctril		100 a	100 a	88 ab	85 abc	88 abc	86 abc	72 abc
Treflan	Caparol	Buctril		100 a	99 a	96 a	92 a	95 abc	98 a	88 ab
		Buctril		0 d	17 d	7 e	0 e	60 f	60 def	20 e

[a]Values followed by same letter within a column are not different at P=0.05, according to Fisher's Protected LSD test.
[b]Treflan: 0.75 lb ai/ac PPI, Caparol: 1.2 lb ai/ac PRE; Roundup Ultra: 0.56 lb ae/ac POST or PDIR; Staple: 0.063 lb ai/ac POST; Buctril: 0.5 lb ai/ac POST.
[c]Post treatments were applied 16 DAP in 1996 and 22 DAP in 1997.
[d]Second Roundup Ultra application was applied in 1997 PDIR.
[e]All Staple treatments received crop oil concentrate at 1% v/v.

Treflan and Treflan fb Caparol controlled Palmer amaranth at least 90% 120 DAP. Roundup Ultra was the only POST treatment that controlled Palmer amaranth at least 80% 120 DAP. Treflan or Treflan fb Caparol or fb any other POST herbicide controlled Palmer amaranth 92% 120 DAP. Caparol alone was the only soil residual treatment that benefited from a sequential POST herbicide treatment (Table 2). Roundup Ultra applied following Treflan or Treflan fb Caparol did not increased Palmer amaranth control 40 DAP or 120 DAP as compared to Treflan or Treflan fb Caparol applied alone. These results were different from Goldmon et al. (1996) who reported that residual herbicides did not improve early-season weed control compared to a Roundup Ultra only treatment.

During the 1996 growing season there was only one early-season flush of Palmer amaranth and the few late-emerging Palmer amaranth plants were controlled by cultivation. The lack of rainfall in-season limited differences in Palmer amaranth control among treatments with and without POST herbicides.

1997 Growing Season. In 1997, early-season Palmer amaranth control with Treflan or Caparol applied alone was not as effective as in 1996. In 1996, due to the lack of rainfall and the subsequent lack of multiple weed flushes, both Treflan and Caparol applied alone controlled Palmer amaranth at least 90% 16 DAP. In 1997, these treatments controlled Palmer amaranth 73 to 75% 22 DAP (Table 2). Treflan fb Caparol controlled Palmer amaranth 93% 22 DAP.

At 14 days after the initial POST treatment (35 DAP), Treflan applied alone, Caparol applied alone, or any POST herbicide treatment applied alone provided similar Palmer amaranth control. The sequential treatment of Treflan fb Caparol controlled Palmer amaranth more effectively than any POST herbicide treatment applied alone and did not benefit from a sequential POST application 35 DAP (Table 2). At 35 DAP, Treflan was the only soil-applied treatment that benefited from a sequential POST application of either Roundup Ultra, Staple, or Buctril.

Due to multiple flushes of Palmer amaranth, a second application of Roundup Ultra, which was applied PDIR, was needed to effectively control Palmer amaranth. Treatments that contained soil residual herbicides fb Roundup Ultra did not require a second Roundup Ultra application. This result was similar to that observed by Goldmon (1996).

At 61 DAP, all treatments controlled Palmer amaranth similarly except for Treflan and Caparol applied alone and the POST treatments of Staple and Buctril applied alone. Roundup Ultra applied alone was the only POST treatment that controlled Palmer amaranth $\geq$ 90%. All POST herbicide treatments increased control when applied following Caparol compared to Caparol applied alone.

At 111 DAP, any soil applied treatment fb one or two applications of Roundup Ultra controlled Palmer amaranth at least 86% (Table 2). Treflan fb Caparol fb any POST herbicide treatment controlled Palmer amaranth at least 88% 111 DAP. Caparol was the only soil-applied herbicide that benefited from a POST herbicide treatment at 111 DAP. A sequential POST application used with Treflan or Treflan fb Caparol resulted in similar control.

Devil's-claw Control

1996 Growing Season. Treflan or Caparol applied alone only controlled devil's-claw $\leq$ 27% (Table 3). The sequential treatment of Treflan fb Caparol did not improve control. Poor control of devil's-claw with traditional PPI or PRE herbicides was also observed by Keeling et al. (1999), which indicates the need for an effective POST herbicide for devil's-claw control.

All POST herbicide treatments had good activity on devil's-claw. At 40 DAP, Roundup Ultra and Buctril controlled devil's-claw at least 95% when applied alone or following soil-applied herbicides (Table 3). Staple applied alone did not control devil's claw as effectively as Roundup Ultra or Buctril applied alone.

Table 3. Devil's-claw control in cotton weed management systems in 1996 and 1997[a].

Herbicide[b]				1996 Days after planting			1997 Days after planting		
PPI	PRE	POST	PDIR	16[c]	40	80	22	48	61
				%					
Treflan				25 a-e	0 e	0 e	23 cde	52 d	52 c
	Caparol			27 a-d	47 d	53 g	42 bc	58 d	60 bc
Treflan	Caparol			28 a-d	48 d	72 ef	57 b	70 c	68 b
Treflan		Roundup Ultra	Roundup Ultra[d]	15 e-f	100 a	100 a	18 ef	88 ab	100 a
	Caparol	Roundup Ultra	Roundup Ultra[d]	13 f	98 a	98 a	53 b	95 abc	100 a
Treflan	Caparol	Roundup Ultra		27 a-d	97 a	97 a	85 a	90 ab	92 a
		Roundup Ultra	Roundup Ultra[d]	0 g	95 a	95 a	0 f	85 b	100 a
Treflan		Staple[e]		20 c-f	73 c	73 c	20 ef	90 ab	94 a
	Caparol	Staple		28 a-d	92 ab	92 ab	40 bcd	98 a	97 a
Treflan	Caparol	Staple		35 a	85 b	85 b	48 b	95 abc	100 a
		Staple		0 g	70 c	70 c	0 f	92 ab	92 a
Treflan		Buctril		22 b-f	98 a	98 a	22 de	93 abc	93 a
	Caparol	Buctril		30 abc	97 a	97 a	85 a	96 ab	93 a
Treflan	Caparol	Buctril		33 ab	100 a	100 a	80 a	98 a	98 a
		Buctril		0 g	95 a	92 ab	0 f	98 a	97 a

[a]Values followed by same letter within a column are not different at P=0.05, according to Fisher's Protected LSD test.
[b]Treflan: 0.75 lb ai/ac PPI, Caparol: 1.2 lb ai/ac PRE; Roundup Ultra: 0.56 lb ae/ac POST or PDIR; Staple: 0.063 lb ai/ac POST; Buctril: 0.5 lb ai/ac POST.
[c]Post treatments were applied 16 DAP in 1996 and 22 DAP in 1997.
[d]Second Roundup Ultra application was applied in 1997 PDIR.
[e]All Staple treatments received crop oil concentrate at 1% v/v.

At 80 DAP, all POST herbicides applied alone or sequentially improved devil's-claw control over soil-applied herbicides used alone. POST treatments of Roundup Ultra or Buctril did not benefit from soil-applied herbicides (Table 3). Staple alone or applied sequentially with soil residual herbicides controlled devil's-claw 70 to 92% 80 DAP. This control was not equal to the level obtained with other POST herbicides applied sequentially with soil residual herbicides, but was still more effective than soil residual herbicides applied alone.

1997 Growing Season. Similar to the results recorded in 1996, soil residual herbicides applied alone or sequentially did not effectively control devil's-claw. At 48 DAP, soil residual treatments controlled devil's-claw 52 to 70%, whereas the POST herbicide treatments controlled devil's-claw at least 85% (Table 3). By 61 DAP, all treatments that received a POST treatment alone or sequentially controlled devil's-claw at least 92%. All soil-applied herbicides benefited from a sequential POST treatment. Contrary to 1996, Staple alone controlled devil's-claw equal to that of the other POST treatments. Similar to 1996, POST treatments did not benefit from a soil residual treatment.

Barnyardgrass Control

1996 Growing season. All weed management systems containing Treflan controlled barnyardgrass ≥ 98% 16 DAP (Table 4). Since Roundup Ultra is the only POST herbicide that has grass activity, it was the only POST treatment that effectively controlled barnyardgrass 40 DAP. At 80 DAP, Treflan alone or sequentially treated plots controlled barnyardgrass at least 97% (Table 4.) Roundup Ultra alone controlled barnyardgrass 90% 80 DAP, and was similar to all plots that received Treflan. Treflan applied alone or sequentially with Caparol did not benefit from a sequential POST treatment.

Table 4. Barnyardgrass control in cotton weed management systems in 1996 and 1997[a].

Herbicide[b]				1996 Days after planting			1997 Days after planting		
PPI	PRE	POST	PDIR	16[c]	40	80	35	48	61
				%					
Treflan				99 a	96 ab	97 ab	83 ab	92 a	92 ab
	Caparol			100 a	83 c	80 c	47 c	60 b	73 c
Treflan	Caparol			100 a	98 ab	98 ab	94 a	96 a	94 ab
Treflan		Roundup Ultra	Roundup Ultra[d]	100 a	100 a	100 a	97 a	98 a	100 a
	Caparol	Roundup Ultra	Roundup Ultra[d]	93 a	99 ab	93 ab	57 bc	92 a	100 a
Treflan	Caparol	Roundup Ultra		100 a	100 a	100 a	88 a	93 a	98 a
		Roundup Ultra	Roundup Ultra[d]	0 c	95 ab	90 abc	83 ab	92 a	100 a
Treflan		Staple[e]		100 a	99 ab	100 a	83 ab	92 a	97 a
	Caparol	Staple		100 a	90 bc	87 bc	33 c	65 b	72 c
Treflan	Caparol	Staple		100 a	98 ab	98 ab	87 a	97 a	100 a
		Staple		0 c	30 e	28 d	35 c	37 c	32 d
Treflan		Buctril		98 a	100 a	100 a	93 a	97 a	98 a
	Caparol	Buctril		69 b	97 ab	80 c	50 c	65 b	68 c
Treflan	Caparol	Buctril		100 a	100 a	100 a	93 a	100 a	100 a
		Buctril		0 c	0 f	0 e	0 d	23 c	20 d

[a]Values followed by same letter within a column are not different at P=0.05, according to Fisher's Protected LSD test.
[b]Treflan: 0.75 lb ai/ac PPI, Caparol: 1.2 lb ai/ac PRE; Roundup Ultra: 0.56 lb ae/ac POST or PDIR; Staple: 0.063 lb ai/ac POST; Buctril: 0.5 lb ai/ac POST.
[c]Post treatments were applied 16 DAP in 1996 and 22 DAP in 1997.
[d]Second Roundup Ultra application was applied in 1997 PDIR.
[e]All Staple treatments received crop oil concentrate at 1% v/v.

1997 Growing Season. Barnyardgrass control 61 DAP in 1997 was similar to control achieved in 1996. All plots that contained Treflan controlled barnyardgrass season-long (92 to 100%), and the addition of a sequential POST treatment did not improve control (Table 4). Similar to 1996, Roundup Ultra alone controlled barnyardgrass equal to any treatment that contained Treflan.

Cotton Yield

1996 Growing Season. In 1996, one application of Roundup Ultra applied alone was sufficient to control all weed species in this study and these plots produced yields greater than plots that received Buctril or Staple applied alone. In addition, plots treated with Roundup Ultra only yielded more than plots treated with Treflan or Caparol applied alone (Table 5). The lowest yields were recorded from plots treated with Buctril alone (56 kg/ha).

Table 5. Cotton yields in weed management systems, 1996-1997[a].

Herbicide[b]					
PPI	PRE	POST	PDIR	1996	1997
				----------------lb/ac -----------------	
Treflan				388 c-f	423 b-f
	Caparol			418 c-f	356 def
Treflan	Caparol			550 bcd	475 a-d
Treflan		Roundup Ultra	Roundup Ultra[c]	610 abc	458 a-d
	Caparol	Roundup Ultra	Roundup Ultra[c]	725 ab	453 a-d
Treflan	Caparol	Roundup Ultra		558 bcd	590 a
		Roundup Ultra	Roundup Ultra[c]	714 ab	528 ab
Treflan		Staple[d]		329 def	405 b-f
	Caparol	Staple		684 ab	380 b-f
Treflan	Caparol	Staple		597 abc	496 a-d
		Staple		282 efg	392 b-f
Treflan		Buctril		407 c-f	443 a-e
	Caparol	Buctril		507 b-e	402 b-f
Treflan	Caparol	Buctril		395 c-f	460 a-d
		Buctril		53 g	274 f

[a]Values followed by same letter within a column are not different at P=0.05, according to Fisher's Protected LSD test.
[b]Treflan: 0.75 lb ai/ac PPI, Caparol: 1.2 lb ai/ac PRE; Roundup Ultra: 0.56 lb ae/ac POST or PDIR; Staple: 0.063 lb ai/ac POST; Buctril: 0.5 lb ai/ac POST.
[c]Second Roundup Ultra application was applied in 1997 PDIR.
[d]All Staple treatments received crop oil concentrate at 1% v/v.

1997 Growing Season. Similar to 1996, plots treated with Roundup Ultra only produced yields higher than plots treated with any residual herbicide alone, and equal to plots treated with residual herbicides fb POST herbicides. Plots treated with Treflan fb Caparol fb Roundup Ultra yielded similar to plots that received two applications of Roundup Ultra (Table 5). Similar to 1996, the use of a sequential POST herbicides with soil residual herbicides did not consistently increase yields over plots treated with soil-applied herbicides alone. Plots treated with Roundup Ultra alone produced yields equal to plots that received a soil residual herbicide fb a sequential POST Roundup Ultra application. This is contrary to what had been reported by Murdock and Graham (2000) who found that the Roundup Ultra alone plots produced more cotton than the plots that received a soil residual herbicide fb a sequential POST Roundup Ultra treatment.

Based on the weed species in this study, Roundup Ultra used in Roundup Ready cotton consistently controlled Palmer amaranth, devil's-claw, and barnyardgrass. Although Roundup Ultra applied alone controlled these weeds in both years of this study, a total POST weed control program on the Texas High Plains may be too risky because of unpredictable weather conditions may delay timely POST applications. A PPI herbicide fb Roundup Ultra POST was the most reliable treatment to control Palmer amaranth, devil's-claw, and barnyardgrass.

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Woollyleaf Bursage *(Ambrosia grayi)* Management in Transgenic Cotton on the Texas Southern High Plains

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ABSTRACT

Field studies were established in 1998 and repeated in 1999 to evaluate woollyleaf bursage management in glyphosate- and bromoxynil-tolerant cotton. Glyphosate and bromoxynil, applied three times during the growing season, were evaluated with and without in-season cultivation. Glyphosate alone and in combination with cultivation and bromoxynil with cultivation controlled woollyleaf bursage greater than 70% after one season and greater than 90% after two seasons. Glyphosate treatments reduced woollyleaf bursage density >88% after two years. Weed control systems in both glyphosate- and bromoxynil-tolerant cotton increased yields and net returns over weed control costs compared to cultivation alone for both years of this study.

KEYWORDS: Bromoxynil, Glyphosate, Woollyleaf bursage, *Ambrosia grayi* (A.Nels) AMBGR, Cotton, *Gossypium hirsutum* L., Paymaster HS 200, Paymaster 2200RR, and Stoneville BXN 16

Abbreviations: DAT-1, days after first treatment; DAT-2, days after second treatment; DAT-3, days after third treatment; fb, followed by; PDIR, postemergence-directed; POST, postemergence; PPI, preplant incorporated; PRE, preemergence

Cotton producers have traditionally used preplant incorporated (PPI) and preemergence (PRE) herbicides, spot spraying, cultivation and/or hand-hoeing to control annual and perennial weeds (Newsom and Shaw 1996, Snipes and Mueller 1992). Transgenic glyphosate- and bromoxynil-tolerant cotton provide producers new options to control many annual and perennial weeds. However, most research to date has focused on annual weed control and little information exists on control of most perennial weeds. Effective Palmer amaranth (*Amaranthus palmeri* S. Wats.), ivyleaf morningglory [*Ipomoea hederacea* (L.) Jacq.] and Russian thistle (*Salsola iberica* Sennen and Pau) control has been reported using soil-applied herbicides followed by (fb) glyphosate in-season (Keeton and Murdock 1997, Keeling and Dotray 1997; Keeling et al. 1996). Combinations of trifluralin fb glyphosate, prometryn fb glyphosate, or trifluralin fb prometryn fb glyphosate provided ≥85% control of Palmer amaranth season-long (Asher et al. 1998). Bromoxynil controlled devil's-claw (*Proboscidea louisianica* (Mill.) Thellung), lanceleaf sage (*Salvia reflexa* Hornem.), and red morningglory (*Ipomoea coccinea* L.) ≥95%, but did not control Palmer amaranth (Jones et al. 1994).

Perennial weed species, including woollyleaf bursage [*Ambrosia grayi* (A.Nels.) Shinners], are common on the Texas Southern High Plains. Woollyleaf bursage is an aggressive creeping perennial, common in low-lying areas, in and around playa lakes, and in wet areas throughout the central and southern Great Plains region (Whitson et al. 1996). This weed has become an increasing problem to cotton producers in recent years, with heavily infested areas producing little or no yield. Non-selective herbicides, such as picloram, control woollyleaf bursage in non-cropped areas (Smith et al. 1972). Currie and Thompson (2000) also reported effective control with picloram, but only limited control with glyphosate or 2,4-D. Fall applications of dicamba controlled woollyleaf bursage early-season, but little long-term control was achieved (Chykaliuk et al. 1980, Keeling and Abernathy 1988). Field studies indicated that *Pseudomonas syringae* pv. *tagetis* did infect woollyleaf bursage, but activity was slow and erratic (Sheikh et al. 2001).

Traditional management of woollyleaf bursage, which includes fall applications of dicamba, preplant applications of MSMA, and in-season glyphosate spot spraying, does not provide consistent control, therefore the use of glyphosate and bromoxynil in transgenic cotton provides new opportunities to control this weed. The objectives of this research were: to evaluate woollyleaf bursage control using glyphosate and bromoxynil applied alone or in combination with cultivation; evaluate changes in woollyleaf bursage populations after each season of treatment; and determine effects of woollyleaf bursage control on cotton lint yield and net economic returns with the glyphosate and bromoxynil systems.

MATERIALS AND METHODS

A field experiment was conducted in 1998 and repeated in 1999 at the Texas Agricultural Experiment Station near Halfway, TX at a site containing a dense homogeneous population of woollyleaf bursage. The soil was an Olton clay loam (Fine, mixed, thermic Aridic Paleustolls) with less than 1.0% organic matter and pH 7.4. Trifluralin at 0.8 lb ai/ac PPI and prometryn at 1.2 lb ai/ac PRE were applied over the entire test area to control Palmer amaranth and annual grasses. Paymaster 2200RR (glyphosate-tolerant) was planted in plots receiving glyphosate treatments, BXN 16 (bromoxynil-tolerant) was planted in plots receiving bromoxynil treatments, and Paymaster HS 200 (non-transgenic) was planted in the untreated plots. These varieties were planted on 40 inch rows at the rate of 15 lb/ac. Plots four rows wide by 100 ft in length were arranged in a randomized block design replicated four times. Herbicides were applied with either a tractor-mounted compressed air or CO_2 backpack sprayer calibrated to deliver 10 gpa at 28 psi. Postemergence (POST) bromoxynil applications were made to cotton at the 1-to 2-leaf, 4-leaf, at the mid-bloom stages of growth. Glyphosate postemergence-directed (PDIR) applications were made at the mid-bloom stages of cotton growth. All glyphosate treatments were applied at 0.75 lb ae/ac and included ammonium sulfate at 0.17 lb/gal and all bromoxynil treatments were applied at 0.5 lb ai/ac. Cultivation was performed between the first and second POST applications and between the second and third POST/PDIR applications. Weed species were 1 to 3 inches in height at the time of the initial treatment. Plots received 9 inches of supplemental irrigation in 1998 and 6 inch in 1999 due to differences in rainfall (Table 1). Treatment timing and application dates are summarized in Table 2.

Table 1. Rainfall distribution at Halfway for 1998, 1999, and the 30 year average.

Month	Year		
	1998	1999	30 year Avg.
January	0	1.4	0.5
February	2	3.6	0.6
March	1.5	1	0.8
April	0.3	2.1	1.2
May	0	4.3	2.6
June	1.5	4	2.5
July	0	1	2.2
August	3.6	0.6	2
September	0	3.3	2.5
October	2.4	0.8	2
November	0.8	0	0.6
December	0.6	0	0.6
Total	15.4	22.1	18.1

Table 2. Treatment timing and application dates for 1998 and 1999.

Treatment	Date	
	1998	1999
Postemergence-topical (POST)	May 29	June 7
Postemergence-topical (POST)	June 9	June 28
Postmeregence-topical (POST)	July 7	August 6
Postemergence-directed (PDIR)	July 7	August 6
Cultivations	June17/July 27	July 6/August 27

Percent weed control was estimated visually on a 0 to 100 scale (0 = no control and 100 = complete control) throughout each year. Lint was collected at harvest using a sample area of 44 ft^2. Harvested samples were ginned and fiber quality was evaluated to determine loan price for an economic comparison between systems. Cotton loan price, lint yield, cultivation, herbicide and application costs, as well as seed technology fees associated with herbicide-tolerant varieties, were used to determine net returns over weed control costs. Weed density was recorded on May 5, 1998 (prior to any treatments being applied), on May 19, 1999 (after 1998 treatments and prior to any 1999 treatments), and on April 26, 2000 (after 1998 and 1999 treatments). Weed densities per plot were determined by counts/3 ft^2.

Data were subjected to analysis of variance and means were separated using Fisher's Protected LSD at 0.05 level of significance. Percentage data were arcsine transformed before analysis to stabilize variances and non-transformed data are presented.

RESULTS AND DISCUSSION

Weed Control. In 1998, the first POST herbicide application was applied in late May. At 14 days after first treatment (DAT-1), glyphosate treatments controlled woollyleaf bursage 65 to 72% and was similar to the control achieved with bromoxynil (63%) (Table 3).

Table 3. Effects of POST herbicides on woollyleaf bursage control in cotton, 1998 and 1999[a].

Treatment	Rate	Application timing	1998				1999			
			14DAT-1	14DAT-2	14DAT-3	30DAT-3	14DAT-1	14DAT-2	14DAT-3	30DAT-3
	lb ai or ae/ac									
Untreated	-	-	0	0	0	0	0	0	0	0
Cultivation[b]	-	MID fb LATE	0	38	43	38	0	57	28	38
Glyphosate fb glyphosate fb glyphosate	0.75 fb 0.75 fb 0.75	POST fb POST fb PDIR	65	68	82	72	85	74	92	93
Glyphosate fb glyphosate fb glyphosate fb cultivation[b]	0.75 fb 0.75 fb 0.75	POST fb POST fb PDIR fb MID fb LATE	72	85	91	88	92	89	96	99
Bromoxynil fb bromoxynil fb bromoxynil	0.5 fb 0.5 fb 0.5	POST fb POST fb POST	63	68	66	45	23	55	68	47
Bromoxynil fb bromoxynil fb bromoxynil fb cultivation[b]	0.5 fb 0.5 fb 0.5	POST fb POST fb POST fb MID fb LATE	63	84	87	79	40	84	85	88
LSD (0.05)			8	8	9	13	23	18	13	10

[a] Abbreviation: DAT-1, days after first treatment; DAT-2, days after second treatment; DAT-3, days after third treatment; fb, followed by; Late, late season; MID, mid-season; PDIR, postemergence directed; POST, postemergence.
[b] Two in-season cultivations were made in each year.

At 14 days after second treatment (DAT-2), glyphosate fb cultivation and bromoxynil fb cultivation improved woollyleaf bursage control to 85 and 84%, respectively (Table 3). Glyphosate and bromoxynil without cultivation were less effective at controlling woollyleaf bursage (68%). Cultivation alone provided only 38% control of woollyleaf bursage.

Unlike the findings of Currie and Thompson (2000) who reported limited control of woollyleaf bursage from glyphosate and 2,4-D treatments, glyphosate and glyphosate fb cultivation controlled woollyleaf bursage 82 and 91%, respectively at 14 days after third treatment (DAT-3). Bromoxynil fb cultivation provided similar control (87%). However, bromoxynil without cultivation was less effective at controlling woollyleaf bursage (66%). Cultivation alone controlled woollyleaf bursage only 43%.

At 30 DAT-3, after all herbicide and cultivation treatments were performed, glyphosate fb cultivation controlled woollyleaf bursage 88% (Table 3). Bromoxynil fb cultivation provided similar control (79%), and glyphosate without cultivation controlled woollyleaf bursage 72%. Bromoxynil alone and cultivation alone were less effective (45 and 38%, respectively).

In 1999, glyphosate treatments controlled woollyleaf bursage 85 to 92% at 14 DAT-1 (Table 3). Woollyleaf bursage was not effectively controlled by the bromoxynil treatments (23 to 40%).

At 14 DAT-2, glyphosate fb cultivation controlled woollyleaf bursage 89%, which was similar to control achieved by bromoxynil fb cultivation and glyphosate alone (84 and 74%, respectively) (Table 3). Similar to bromoxynil alone (55%), cultivation controlled woollyleaf bursage 57%.

In early August (14 DAT-3), effective woollyleaf bursage control (85 to 96%) was achieved with glyphosate, glyphosate fb cultivation, and bromoxynil fb cultivation (Table 3). Bromoxynil without cultivation provided less effective woollyleaf bursage control (68%). Cultivation alone provided the least effective control (28%).

In September (30 DAT-3), excellent woollyleaf bursage control (88 to 99%) was achieved with glyphosate, glyphosate fb cultivation, and bromoxynil fb cultivation. Similar to earlier ratings, control was less effective with bromoxynil without cultivation and cultivation alone.

In the spring of 1998, woollyleaf bursage initial density was 80 plants per 3 ft^2. After the treatments in 1998, glyphosate and glyphosate fb cultivation reduced the woollyleaf bursage population 52 and 64% (38 and 29 plants per 3 ft^2), respectively (Table 4). Similarly, bromoxynil fb cultivation reduced the woollyleaf bursage population 41%. Bromoxynil alone had little effect on the population of woollyleaf bursage, only reducing the population density by 17% (66 plants per 3 ft^2). Cultivation alone had no effect on the woollyleaf bursage population.

At the beginning of the 2000 crop season, glyphosate alone and glyphosate fb cultivation were the most effective treatments and reduced woollyleaf bursage population to 18 plants per 3 ft^2 (Table 4). Bromoxynil treatments had less impact on the woollyleaf bursage population, only reducing density 27% and 33% (58 and 53 plants per 3 ft^2, respectively). Two seasons of cultivation had no effect on woollyleaf bursage populations.

Table 4. Effects of herbicides on woollyleaf bursage densities, 1998, 1999, and 2000[a,b].

			Woollyleaf bursage Density	
Treatment	Rate	Application	1998	1999
	lb ai or ae/ac		---------------#/3 ft^2--------------	
Untreated	-	-	80	70
Cultivation[c]	-	MID fb LATE	80	67
Glyphosate fb glyphosate fb glyphosate	0.75 fb 0.75 fb 0.75	POST fb POST fbPDIR	38	18
Glyphosate fb glyphosate fb glyphosate fb cultivation[c]	0.75 fb 0.75 fb 0.75	POST fb POST FbPDIR fb MID fb LATE	29	18
Bromoxynil fb bromoxynil fb bromoxynil	0.5 fb 0.5 fb 0.5	POST fb POST fb POST	66	58
Bromoxynil fb bromoxynil fb bromoxynil fb cultivation[c]	0.5 fb 0.5 fb 0.5	POST fb POST fbPDIR fb MID fb LATE	47	53
LSD (0.05)			16	14

[a]Abbreviation: DAT-1, days after first treatment; DAT-2, days after second treatment; DAT-3, days after third treatment; fb, followed by;LATE, late season; MID, mid-season; PDIR, postemergence directed; POST, postemergence.
[b]Initial populations in May 1998 average 80 weeds per 3 ft^2.
[c]Two in-season cultivations were made in each year.

Cotton Lint Yields and Net Returns. In 1998, cotton lint yield ranged from 100 lb/ac (untreated) to 850 lb/ac (Table 5). No difference in yield was observed between glyphosate fb cultivation, bromoxynil, or bromoxynil fb cultivation. These treatments produced greater yields (730 to 850 lb/ac) than glyphosate alone and cultivation alone. In 1999, yields ranged from 0 lb/ac (untreated) to 1020 lb/ac. The greatest yields were produced with glyphosate and glyphosate fb cultivation. Less yield was produced with the bromoxynil alone treatments, although the addition of cultivation improved yields over bromoxynil treated plots. All other treatments produced greater yields than plots treated with the cultivation alone. In official variety trials conducted at the Texas Agricultural Experiment Station at Halfway in 1998 and 1999, Paymaster 2200RR produced 14% greater lint yields than BXN 16 (Gannaway et al. 1998 and 1999)

Net returns over weed control costs in 1998 ranged from 0 to 330 $/ac (Table 5). Glyphosate and bromoxynil treatments, either alone or in combination with cultivation, produced similar net returns over weed control costs, which were greater than cultivation alone. In 1999, net returns over weed control costs ranged from 0 to 360 $/ac. The greatest net returns were achieved with the glyphosate and glyphosate fb cultivation. Net returns from bromoxynil treatments were greater than with the cultivation alone.

These studies indicate that woollyleaf bursage can be controlled and population densities reduced with the use of glyphosate in-season. Bromoxynil alone was not effective at reducing woollyleaf bursage populations; however, these treatments did reduce weed growth and allowed the cotton to better compete. Glyphosate applied in glyphosate-tolerant cotton provided the most consistent woollyleaf bursage control and greatest overall reduction in population density.

Table 5. Cotton lint yields and net economic returns as a result of woollyleaf bursage, 1998 and 1999[a]

Treatment	Rate	Application Timing	Lint Yields 1998	Lint Yields 1999	Net Returns[b] 1998	Net Returns[b] 1999
	kg ai or ae/ha		-----lb/ac-----		-----$/ac-----	
Untreated	NA	NA	100	0	0	0
Cultivation fb cultivation	NA	MID fb LATE	260	45	90	4
Glyphosate fb glyphosate fb glyphosate	0.84 fb 0.84 fb 0.84	POST fb POST fbPDIR	620	920	240	320
Glyphosate fb glyphosate fb glyphosate fb cultivation(2)[c]	0.84 fb 0.84 fb 0.84	POST fb POST fbPDIR fb MID fb LATE	730	1020	270	360
Bromoxynil fb bromoxynil fb bromoxynil	0.56 fb 0.56 fb 0.56	POST fb POST fb POST	730	490	290	140
Bromoxynil fb bromoxynil fb bromoxynil fb cultivation(2)	0.5 fb 0.5 fb 0.5	POST fb POST fbPOST fb MID fb LATE	850	690	330	220
LSD (0.05)			180	160	100	130

[a]Abbreviation: DAT-1, days after first treatment; DAT-2, days after second treatment; DAT-3, days after third treatment; fb, followed by;LATE, late season; MID, mid-season; PDIR, postemergence directed; POST, postemergence.
[b]Net returns over weed control cost. Based on gross revenue minus seed, herbicide and application and cultivation costs.
[c]Two in-season cultivations were made in each year.

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Comparison of Agricultural and Power Plant By-Product Gypsum for South Texas Peanut Production

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ABSTRACT

Field studies were conducted in 1998 and 1999 at one location in Atascosa and two locations in Wilson County to evaluate the effects of power plant by-product gypsum in comparison with agricultural gypsum applied to peanuts at planting or pegging. The Atascosa County site contained moderate to high calcium (Ca) levels while the Wilson County site was low to moderate in Ca. No differences in southern blight, *Rhizoctonia* pod rot disease control, peanut yield, or grade were noted with each gypsum source. Gypsum reduced disease development at two of three locations but only increased peanut yield or grade at one of three locations.

KEYWORDS: *Arachis hypogaea*, groundnut, *Rhizoctonia solani*, *Sclerotium rolfsii*, southern blight, yield, quality.

High yielding and good quality peanuts (*Arachis hypogaea* L.) require adequate calcium (Ca) in the top 3 in. of the soil during pegging and pod filling. Calcium supplements are frequently required to maintain development. For many years gypsum has been the dominant material used as a Ca supplement for peanuts; although alternative materials have been tested and used by growers on a limited basis. Gypsum has a relatively high solubility and therefore is quickly available to plants. Because gypsum is a neutral salt, it does not increase soil pH.

In runner and Virginia type peanuts calcium is by far the most critical nutrient for achieving high yields and grades. Low levels of calcium cause several serious production problems, including unfilled pods (pops), darkened plumules in the seed and poor germination. Virginia types are less able to take up adequate Ca than runner and Spanish types. This may simply be a matter of pod size, since there is less surface area on larger pods per unit weight of nut (Cox and Sholar 1995). For runner peanut, the critical level is 300 to 500 pounds of Ca per acre while preliminary results with Virginia type peanuts indicate that the critical level should be at least 1500 pounds of Ca per acre (Cox and Sholar 1995).

Since gypsum is a relatively soluble source of Ca (York and Colwell 1951), it is subject to almost complete loss from the soil surface by the time peanuts are harvested (Jones et al. 1976). To offset the leaching loss from the primary pegging zone, gypsum may be applied at planting or pegging to insure that adequate Ca is present in the pegging zone for pod development.

Peanut yields are often limited by a lack of Ca in the fruiting zone (Taylor and Moshrefi 1987). Calcium is passively absorbed and transported almost exclusively in xylem tissue and moves with the transpiration stream. The relationship between Ca and yield occurs as a result of the lack of Ca movement in the developing peg via the phloem. The developing fruit, consequently, depends upon the presence of adequate Ca in the soil solution (Skeleton and Shear 1971, Slack and Morrill 1972).

Another advantage of gypsum would be to aid in the digging process by reducing clod size and improve shedding of soil from peanuts planted in a heavy textured soil (authors personal observation). The reduced cost of by-product gypsum should be an advantage for producers on soils low in Ca and/or S.

Alternative sources of gypsum from power plants have recently come on the market and producers have voiced concerns about heavy metals and other contaminants in addition to plant response to these products. The objective of this study was to compare the effects of power plant by-product gypsum with regular agricultural gypsum on disease development, peanut yield and quality.

MATERIALS AND METHODS

Field studies were conducted during the 1998 and 1999 growing season at one location in Atascosa and two locations in Wilson County to determine the effects of gypsum upon peanut quality and yield.

The location in Wilson County historically had moderate to heavy incidence of the soil-borne disease *Rhizoctonia* pod rot (*Rhizoctonia solani* Kuhn) and pythium pod rot (*Pythium myriotylum*). The Atascosa County location consisted of the soil-borne disease *Rhizoctonia*, southern blight (*Sclerotium rolfsii* Sacc.) and sclerotinia blight caused by *Sclerotium minor* Jagger. Agricultural gypsum obtained from a local distributor[1] was compared with gypsum obtained as a by-product[2] of a coal-generated power plant located near LaGrange, TX. Representative samples of agricultural gypsum and by-product gypsum were collected prior to study initiation and submitted to the Texas Agricultural Extension Service Soil Testing Laboratory for chemical analysis. Soils at the Atascosa County location were a Duval loamy fine sand (fine-loamy, mixed, hyperthermic Aridic Haplustalfs) with $< 1\%$ organic matter and a pH of 7.2.

Soils at the Wilson County location were a Miguel fine sandy loam (fine, mixed, hyperthermic Udic Paleustalfs) with 1.5% organic matter and a pH of 7.0. Initial Ca levels at the Wilson County location were intermediate while Ca levels at Atascosa County were high.

'GK-7' peanut variety was planted at all locations during late May or early June. Peanuts were planted using a vacuum planter[3] set to plant seed 2 in. deep at rate of 80 lbs/ac.

Gypsum was hand applied to plots prior to planting and approximately 60 d after planting when peanut had begun to peg. The gypsum for each plot was pre-weighed, spread over the peanut row (at plant) or spread over the top of the peanut plant within the pegging zone (peg). Irrigation was applied within 5 days of the pegging application to move the gypsum into the pegging zone.

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[1]Hoe-Down, Standard Gypsum Corp., 1650 Gypsum Mine Rd., Fredericksburg, TX 78624.
[2]Boral Material Technologies, Inc., San Antonio, TX 78216.
[3]Monosem pneumatic planter, A.T.I., Inc. Leneka, KS 66219.

Plot size was 4 rows 12 ft wide by 30 ft long. The treatment design was a randomized complete block with four replications. Gypsum treatments included by-product gypsum at 500, 1000,1500, and 2000 lbs/ac applied at planting or 1000 and 2000 lbs/ac applied at pegging. Agricultural gypsum at 1000, 1500, and 2000 lbs/ac was applied at plant or 1000 and 1500 lbs/ac was applied at pegging. An untreated check was included for comparison.

Treatment response data were obtained from the middle two rows of each plot to eliminate edge effects from adjacent plots. Yields were obtained by digging each plot separately, air-drying in the field for 5 to 8 d, and harvesting peanut pods with a tractor pulled combine. Weights were recorded after soil and foreign material were removed from plot samples. Peanut grades were determined from a 7 oz pod sample from each plot following procedures described by the Federal-State Inspection Service (USDA 1998).

Disease incidence were counted immediately after digging. Infection sites (hits) were determined by discolored pods with visual confirmation of the fungus by mycelia or sclerotia production (Rodriguez-Kabana et al. 1975). Maximum length for a target site, if no healthy stems intervened was 12 in. Differences between adjacent infection sites was based on the presence of apparently healthy intervening stems. Since total plot length was 50 ft. (2 row by 25 ft. long), percent disease was determined by dividing the total number of disease sites by 50.

Disease incidence along with peanut yield and grade were evaluated using analysis of variance. Since there was a treatment by location interaction for peanut yield, grade, and disease, the data are presented separately by location. Means were separated using Fisher's Protected LSD test at the 5% level.

RESULTS AND DISCUSSION

Gypsum composition. Chemical analysis of the two gypsum sources indicated that by-product gypsum contained greater concentrations of boron, chloride, magnesium, potassium, and sodium (Table 1). Concentrations of Ca and S were similar for the two products, thus any differences in plant uptake likely would be attributed to variations in solubility. Moisture levels were higher in by-product gypsum compared to agricultural gypsum.

Table 1. Chemical composition of by-product gypsum and agricultural gypsum.

Component	By-product gypsum	Agricultural gypsum
	----------------ppm----------------	
Aluminum	< 0.05	< 0.05
Arsenic	< 0.01	< 0.01
Barium	0.09	0.06
Boron	0.25	0.12
Calcium	590.0	570.0
Cadmium	< 0.005	< 0.005
Chromium	< 0.01	< 0.01
Copper	< 0.02	< 0.02
Iron	< 0.02	< 0.02
Lead	< 0.005	< 0.005
Magnesium	12.0	< 0.5
Manganese	< 0.01	0.01

Table 1. (Cont'd.)

Component	By-product gypsum	Agricultural gypsum
	---------ppm---------	
Mercury	< 0.0002	< 0.0002
Molybdenum	< 0.02	< 0.02
Nickel	< 0.02	< 0.02
Phosphorus	< 1.0	< 1.0
Potassium	3.7	< 1.0
Selenium	< 0.01	< 0.01
Silver	< 0.01	< 0.01
Sodium	41.0	0.92
Vanadium	< 0.02	< 0.02
Zinc	0.06	0.1
Chloride	40.0	< 1.0
Sulfate	1580.0	1500.0
Sulfur (%)	14.3	16.3
pH	7.3	8.0
Moisture (%)	20.0	1.0

Disease development. In 1998, in Wilson County, all gypsum rates except for the by-product gypsum at 500 lbs/ac applied at plant decreased disease development up to 50% when compared with the untreated check (Table 2). Other studies have noted a decrease in pythium disease development when gypsum has been applied. Garren (1964) first reported that high rates of gypsum resulted in a reduction of rotted peanut pods. Walker and Csinos (1980) stated that under severe disease pressure with several cultivars, disease decreased for all cultivars as the rate of gypsum applied was increased.

Table 2. Percent disease development after peanuts were inverted at each location.

Treatment	Rate (lbs/ac)	Application timing	Location[a,b]		
			1998		1999
			---------%---------		
			Atascosa Co.	Wilson Co.	Wilson Co.
Check	-		28	28	20
By-product gypsum	500	plant	30	25	8
	1000	plant	30	18	14
	1500	plant	22	16	10
	2000	plant	24	14	12
	1000	peg	23	18	10
	1500	peg	27	11	15
Ag gypsum	1000	plant	29	19	9
	1500	plant	34	19	10
	2000	plant	37	17	11
	1000	peg	28	15	13
	1500	peg	31	16	12
LSD (0.05)			11	6	9

[a]Disease incidence in Wilson County was 70% Rhizoctonia pod rot and 30% pythium pod rot.
[b]Disease incidence in Atascosa County was 50% southern blight, 40% Rhizoctonia pod and limb rot, and 10% scelrotinia blight.

At the Atascosa County location, no difference in disease incidence was noted between the untreated check and any gypsum treatment (Table 2). Since at this location the primary disease was southern blight, it was hypothesized that no response to gypsum would be noted in disease development (authors personal opinion). However, there have been reports that high levels of Ca may control the pathogen that causes southern blight or that added Ca may increase resistance or productivity of the host plant (Garren and Jackson 1973, Watkins 1961).

In 1999, by-product gypsum at 500 and 1500 lbs/ac applied at plant or 1000 lbs/ac applied at peg and agricultural gypsum at 1000, 1500, and 2000 lbs/ac applied at planting reduced disease incidence (Table 2). Other studies have shown that the readily soluble Ca requires high rates of gypsum be applied to insure adequate Ca was present in the pegging zone for pod development (Jones et al. 1976).

Peanut yield. No increase in peanut yield over the untreated check was noted in either location in 1998 (Table 3). However, in 1999, by-product gypsum at 2000 lbs/ac applied at planting and agricultural gypsum at 1500 and 2000 lbs/ac applied at planting increased peanut yield up to 22% over the untreated check. On light textured soils low in residual Ca, peanut yields have been increased with gypsum applications (Walker and Csinos 1980, Sullivan et al. 1974).

Table 3. Peanut yield with by-product and agricultural gypsum.

			Location[a,b]		
			1998		1999
Treatment	Rate (lbs/ac)	Application timing	-------------------------%-------------------------		
			Atascosa Co.	Wilson Co.	Wilson Co.
Check	-		4195	2654	3325
By-product gypsum	500	plant	4164	3227	3768
	1000	plant	4100	3037	3358
	1500	plant	3946	3016	3783
	2000	plant	4053	3324	3859
	1000	peg	4160	2404	3590
	1500	peg	4363	3008	3456
Ag gypsum	1000	plant	4015	3213	3804
	1500	plant	4011	3042	4011
	2000	plant	3786	3222	4044
	1000	peg	4264	2890	3582
	1500	peg	4102	2913	3619
LSD (0.05)			415	721	514

Peanut Grade. Only in 1998 at the Wilson County location was a significant grade increase noted over the untreated check (Table 4). By-product gypsum at 1500 lbs/ac applied at plant or agricultural gypsum at 1000 lbs/ac applied at peg did not increase peanut grade over the untreated check. Other studies have also reported varying results. Walker and Keisling (1978) reported that gypsum applications did not increase Florunner grade even when residual soil Ca was low while other cultivars responded with higher grades when gypsum was applied. Gascho et al. (1993) found that limestone applied prior to planting was an excellent source of Ca and increased peanut grade.

Table 4. Percent peanut grade with by-product and agricultural gypsum[a].

Treatment	Rate (lbs/ac)	Application timing	Location[a,b] 1998 Atascosa Co.	1998 Wilson Co.	1999 Wilson Co.
			----------%	----------	----------
Check	-		75	65	76
By-product gypsum	500	plant	74	72	77
	1000	plant	74	73	75
	1500	plant	74	69	77
	2000	plant	75	73	76
	1000	peg	74	72	74
	1500	peg	74	72	77
Ag gypsum	1000	plant	76	73	77
	1500	plant	75	73	75
	2000	plant	75	71	77
	1000	peg	74	69	76
	1500	peg	74	72	76
LSD (0.05)			3	2	2

[a]Grade = sound mature kernel and sound splits.

In conclusion, the addition of Ca in the form of by-product or agricultural gypsum was effective for reducing incidence of Rhizoctonia and pythium pod rot. However, peanut yield and grade response was variable and this may be more of a cultivar response.

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Evaluation of Nineteen Zoysiagrass Turfgrass Cultivars on the Texas High Plains

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ABSTRACT

The development of turfgrass quality zoysiagrasses (*Zoysia spp.* Willd.) is dependent upon texture, density, length of growing season, and overall turfgrass quality. Nineteen zoysiagrass cultivars were evaluated for their potential as a high quality turfgrass at Texas Tech University in Lubbock, TX, due to the relatively high elevation (1000m) and latitude (34°N), this area represents one of the most severe environments in which zoysiagrasses have previously exhibited marginal adaptation. Based on turfgrass quality ratings over four-years (1997-2000) the highest rated cultivars were El Toro, Emerald, HT-210, JaMar and Miyako all of which were vegetatively propagated. The highest rated seed propagated cultivars were J-37, Chinese Common, Zenith, Zen-400 and J-36.

KEYWORDS: *Zoysia spp*, cultivar evaluation, turfgrass quality

Zoysiagrasses (Z*oysia spp.* Willd*.*) are perennial warm season grasses with stolons and rhizomes that form a uniform, dense, low growing, high quality turf with a slow rate of growth (Beard 1973). There are three species of zoysiagrass used in the turfgrass industry. These species are Japanese (Korean) lawngrass (*Zoysia japonica)*, manilagrass (*Zoysia matrella)*, and mascarenegrass (*Zoysia tenuifolia)* (Turgeon 2002). Each species is differentiated by leaf texture, vigor and cold hardiness (Duble 1996). All three species are native to tropical, eastern Asia. *Zoysia japonica* has the greatest cold tolerance of the three species, but also has the coarsest leaf texture (Duble 1996). *Zoysia matrella* has a finer leaf texture than *Z. japonica* and grows well in moderate shade (Duble 1996). *Zoysia tenuifolia* has the finest leaf texture, but is intolerant of cold temperatures (Duble 1996).

Zoysiagrasses can make an ideal lawn for use on golf courses, parks, sport fields, commercial lawns, and residential lawns. Zoysiagrasses are adapted across a wide range of environmental conditions found in the Southwestern U.S. However, selection of the appropriate cultivar is relevant to the success of zoysiagrass as a turfgrass

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in this report. Zoysiagrass is intermediate to highly drought resistant depending on cultivar when compared with other C_4 turfgrasses (Huang et al. 1997, White et al. 2001). Numerous studies have shown zoysiagrass cultivars have a wide range of salinity tolerance (Qian et al. 2000, Marcum et al. 1998).

Studies have shown zoysiagrass cultivars also demonstrate differential levels of host resistance to numerous turfgrass pathogens and insects (Brahan and Duncan 2000, Reinert et al. 1992). Previous research has shown that some zoysiagrass cultivars can be maintained in shaded conditions for extended periods of time (Morton et al. 1991, Qian and Engelke 1997).

Zoysiagrass use has been limited because historically turfgrass cultivars had to be vegetatively propagated. *Zoysia japonica* is the only species that can be propagated by seed but has the coarsest leaf texture (Duble 1996). In the tropics, zoysiagrass will remain green year round. However, following extended periods of drought or hard frosts zoysiagrasses turn brown similar to other C_4 grasses

The drought, salinity, shade and pest tolerance of many selected zoysiagrass cultivars make them an important component of the turfgrass industry areas of the southwestern United States. The objective of this study was to evaluate nineteen zoysiagrass cultivars for their potential use as a high quality turfgrass on the Texas High Plains.

MATERIALS AND METHODS

Nineteen zoysiagrass cultivars were planted July 1996 at the Texas Tech University Erskine Research Farm in Lubbock, Texas (Table 1). Two seeded check cultivars, Chinese and Korean common, and three vegetative check cultivars, El Toro, Emerald and Meyer, were included for comparison to fourteen new cultivars. The soil at the test site was an Amarillo fine sandy soil (fine-loamy, mixed thermic, Aridic Paleustalfs). Treatments were arranged as a randomized block design with three replicates. Each cultivar was grown in a 6 ft. x 6 ft. area with a 2 ft. border on all sides. Plots were irrigated with sprinklers during establishment and flood irrigated thereafter. Eight cultivars were established from seed at a rate of 1 lb/1000 ft^2 and the remaining 11 cultivars were established vegetatively with twenty-four plugs per plot (Table 1). Plots were fertilized at a rate of 4-5 lbs. of N/1000ft^2/year, mowed at a height of 2 inches every 7 to 10 days and irrigated weekly to prevent stress during the growing season.

Turfgrass evaluations consisted of leaf texture (1 = coarse to 9 = fine), color (1 = light green to 9 = dark green), density (1 = bare to 9 = maximum density) and percent living ground cover. Turfgrass quality ratings were taken monthly from May through August 1997, April through October 1998, and March through October in both 1999 and 2000. Turfgrass quality ratings are based on a scale of 1 = dead or dormant to 9 = ideal turfgrass. All evaluations were based on standards used by the National Turfgrass Evaluation Program (NTEP). Data were analyzed by analyses of variance and means separated with Fisher's Protected Least Significant Difference Test at the 0.05 level of probability using SAS (SAS 1989).

Table 1. Cultivar, propagation method and sponsor of 19 zoysiagrass cultivars evaluated at Lubbock, TX from 1996 to 2000.

Cultivar	Propagation method	Sponsor
Chinese (Common)	Seeded	Standard Entry
DeAnza	Vegetative	Thomas Bros. Grass Co.
El Toro	Vegetative	Standard Entry
Emerald	Vegetative	Standard Entry
HT-210	Vegetative	Horizon Turfgrass
J-14	Vegetative	Jacklin Seed Company
J-36	Seeded	Jacklin Seed Company
J-37	Seeded	Jacklin Seed Company
JaMar	Vegetative	Bladerunner Farms
Korean (Common)	Seeded	Standard Entry
Meyer	Vegetative	Standard Entry
Miyako	Vegetative	Japan Turfgrass
Victoria	Vegetative	Thomas Bros. Grass Co.
Z-18	Seeded	International Sees, Inc.
Zen-400	Seeded	Finelawn/Turf Merchants
Zen-500	Seeded	Finelawn/Turf Merchants
Zenith	Seeded	Patten Seed Company
Zeon	Vegetative	Bladerunner Farms
Zorro	Vegetative	Texas A&M University

RESULTS AND DISCUSSION

The nineteen cultivars in this experiment were evaluated over a four-year period for leaf texture, color, density, percent ground cover and overall turfgrass quality for growth under high altitudes (3300 ft) and northern latitudes (34°N). Leaf texture was taken in the first year after planting in April 1997 (Table 2). There was a wide range in leaf texture between cultivars with the HT-210 having the finest leaf texture followed by Emerald, J-36, Z-18, Zen-400, Zen-500, Zenith Zeon and Zorro. In national test, Zorro had the finest leaf texture, however the HT-210 likewise had the finest texture at a second Northern test site in Arkansas (Morris 2001). This would indicate that leaf texture may be sensitive to production sites. It is interesting to note that many of the seeded cultivars had finer leaf texture than vegetative propagated cultivars (Table 2).

Turfgrass color is a personal preference with a darker green color preferred by most individuals (Beard 1973). The cultivars that had the darkest green color were Chinese Common, Korean Common, J-37 and Zen-500 all of which are seeded cultivars (Table 2). In contrast, Meyer, Zenith and Emerald had the darkest green color in national test (Morris 2001). Turfgrass color is influenced by fertility, irrigation, disease incidence and mowing (Turgeon 2002). Since the sites in the national test received different cultural practices this could have influenced turfgrass color and impacted the results between the Lubbock site and others across the country.

Turfgrass density data was taken in 1998-99 (Table 2). There were no significant differences in turfgrass density between cultivars in either 1998 or 1999 (Table 2). Percent living ground cover was taken in the fall of 1998 and 1999 (Table 2). In 1998, all cultivars had living ground cover ratings higher than 90%. Only the Zen-400, Korean Common and Z-18 had significantly lower living ground cover ratings of less than 90%. In 1999, Emerald, HT-210, El Toro, Miyako, Victoria, JaMar, Zeon Zorro, Chinese Common, J-37, and Zen-500 had living ground cover ratings of greater than 90%. Zen-400, Meyer and Z-18 had significantly lower living ground cover ratings of 65, 63 and 15%, respectively. The remaining cultivars ranged from 75 to 90% living ground cover.

Table 2. Mean leaf texture, color, density ratings as well as percent living ground cover of 19 zoysiagrass cultivars evaluated at Lubbock, TX from 1996 to 2000.

			Density		Living ground cover	
	Texture	Color	1998	1999	1998	1999
Cultivar	rating[Y]	rating[X]	-------rating[W]-------		------------%------------	
Chinese	6.3bc[Z]	8.3a[Z]	7.7[Z]	7.3[Z]	94.7a[Z]	91.3a[Z]
DeAnza	6.0cd	5.3fg	7.3	7.0	94.7a	85.0ab
El Toro	4.7ef	6.7c-e	8.0	8.3	97.7a	99.0a
Emerald	7.0ab	7.0b-d	9.0	9.0	94.7a	99.0a
HT-210	7.3a	6.7c-e	9.0	9.0	97.7a	99.0a
J-14	6.3bc	6.3d-f	8.0	6.7	94.7a	78.3ab
J-36	7.0ab	5.3fg	8.0	7.0	96.0a	80.0ab
J-37	6.7a-c	7.7a-c	8.0	7.7	97.7a	91.3a
JaMar	4.7ef	6.3d-f	8.0	8.7	99.0a	96.0a
Korean	6.7a-c	8.0ab	6.7	7.3	58.3b	75.0ab
Meyer	5.3de	7.0b-d	7.0	7.3	96.3a	63.3a
Miyako	4.3f	5.0g	8.3	8.0	99.0a	99.0a
Victoria	6.0cd	5.7e-g	8.7	8.3	97.7a	97.7a
Z-18	7.0ab	5.3fg	6.0	6.3	5.0c	15.0c
Zen-400	7.0ab	7.7a-c	5.3	5.7	64.7b	64.7b
Zen-500	7.0ab	5.7e-g	8.0	7.7	91.3a	91.3a
Zenith	7.0ab	5.0g	8.0	6.7	92.7a	78.3ab
Zeon	7.0ab	7.0b-d	8.7	9.0	97.7a	96.0a
Zorro	7.0ab	7.0b-d	8.3	8.3	97.7a	92.7a
LSD (0.05)	0.8	1.3	NS	NS	25.6	25.8
C.V.	7.3%	11.7%	21.5%	20.7%	17.7%	18.6%

[Z] Means within column not followed by the same letter differ at the 0.05 level of probability by Fisher's Least Significant Difference Test.
[Y]Texture rating; 1= coarse to 9 = very fine.
[X]Genetic color rating; 1 = light green to 9 = dark green.
[W]Density rating; 1 = bare to 9 = maximum density.
NS = Non-significant

Turfgrass quality ratings were collected from May through August in 1997 (Table 3). The highest rated cultivars in 1997 were Miyako, El Toro and JaMar with average quality ratings significantly higher than other cultivars. Quality ratings in the first year may be of minimal value as the cultivars were still being established. The Miyako, El Toro and JaMar received the highest quality ratings in the first year. This is an indication of their vigor as compared to other vegetative cultivars.

Table 3. Turfgrass quality ratings of 19 cultivars of zoysiagrass evaluated at Lubbock, TX in 1997.

	Turfgrass quality ratings [Y]				
	May	Jun	Jul	Aug	Avg
Cultivar	---rating---				
Chinese	7.0a-d[Z]	8.0ab[Z]	8.0a-d[Z]	8.7b-d[Z]	7.9bc[Z]
DeAnza	6.0de	6.7cd	7.0de	7.0f	6.7ef
El Toro	8.0a	9.0a	8.3a-c	9.7a	8.8a
Emerald	7.7ab	7.7bc	7.3c-e	8.0ed	7.7cd
HT-210	6.7b-d	7.0b-d	8.0a-d	8.3c-e	7.5cd
J-14	7.0a-d	7.0b-d	7.3c-e	8.0ed	7.3c-e
J-36	7.3a-c	8.0ab	7.7b-e	8.0ed	7.7cd
J-37	6.3c-e	7.7bc	8.0a-d	8.0ed	7.5cd
JaMar	8.0a	9.0a	8.7ab	9.0a-c	8.7ab
Korean	5.3e	6.0d	6.7e	7.0f	6.3f
Meyer	6.7b-d	7.0b-d	7.3c-e	7.0f	7.0d-f
Miyako	8.0a	9.0a	9.0a	9.3ab	8.8a
Victoria	6.0de	7.3bc	7.7b-e	8.0ed	7.3c-e
Z-18	NA	NA	NA	NA	NA
Zen-400	7.0a-d	8.0ab	8.0a-d	8.0ed	7.7cd
Zen-500	7.0a-d	8.0ab	8.0a-d	8.7b-d	7.9bc
Zenith	7.0a-d	8.0ab	8.0a-d	8.3c-e	7.8c
Zeon	6.7b-d	7.0b-d	7.3c-e	7.7ef	7.2c-e
Zorro	6.7b-d	7.3bc	7.7b-e	8.0ed	7.4c-e
LSD (0.05)	1.09	1.06	1.05	0.94	0.82
C.V.	9.5%	8.4%	8.1%	6.9%	6.5%

[Z]Means within column not followed by the same letter differ at the 0.05 level of probability by Fisher's Least Significant Difference Test.
[Y]Turfgrass rating; 1 = dead or dormant to 9 = ideal turfgrass.

In 1998, quality data was taken from April through October (Table 4). The highest rated cultivars were HT-210, JaMar and Miyako. These cultivars had the highest overall average for the entire growing season.

Table 4. Turfgrass quality ratings of 19 cultivars of zoysiagrass evaluated at Lubbock, TX in 1998.

	Turfgrass quality ratings[Y]							
	Apr	May	Jun	Jul	Aug	Sep	Oct	Avg
Cultivar	---rating---							
Chinese	8.0a[Z]	8.3ab[Z]	7.7a-c[Z]	6.7bc[Z]	6.0c-e[Z]	6.3b-d[Z]	3.0bc[Z]	6.6a-c[Z]
Dalz9601	5.7ef	6.7c-e	8.0a-c	8.0ab	7.0a-d	7.7a-c	4.3ab	6.8a-c
DeAnza	5.3f	5.3e	7.0b-d	7.3ab	7.0a-d	7.0a-c	5.0a	6.3a-c
El Toro	7.0a-d	9.0a	7.7a-c	8.3ab	8.0a-c	8.3ab	3.7a-c	7.4ab
Emerald	6.3c-f	7.3bc	8.3a-c	8.0ab	8.0a-c	8.0ab	4.3ab	7.2ab
HT-210	6.0d-f	5.0a-c	9.0a	8.7a	9.0a	8.0ab	4.3ab	7.6a
J-14	7.7ab	7.0b-d	7.3a-d	7.0a-c	6.7b-d	6.7b-d	3.0bc	6.5a-c
J-36	7.3a-c	7.0b-d	7.0b-d	7.0a-c	6.3b-e	7.0a-c	3.0bc	6.4a-c
J-37	7.3a-c	8.0a-c	7.7a-c	7.0a-c	7.7a-d	7.3a-c	4.3ab	7.1a-c
JaMar	8.0a	8.3ab	8.7ab	8.7a	8.0a-c	8.3ab	3.0bc	7.6a
Korean	7.0a-d	6.7c-e	6.7cd	6.7bc	6.7b-d	7.0a-c	3.7a-c	6.3a-c
Meyer	5.7ef	5.7de	6.7cd	6.7bc	7.0a-d	7.0a-c	3.0bc	6.0bc

Table 4. (Cont'd.)

	Turfgrass quality ratings[Y]							
	Apr	May	Jun	Jul	Aug	Sep	Oct	Avg
Cultivar	rating							
Miyako	6.3c-f	5.0a-c	8.0a-c	8.3ab	7.7a-d	9.0a	5.0a	7.5a
Victoria	6.7b-e	7.3bc	8.3a-c	8.0ab	8.3ab	8.0ab	5.0a	7.4ab
Z-18	3.3g	3.7f	4.0e	3.7d	4.3e	4.7d	3.7a-c	3.9d
Zen-400	7.7ab	7.3bc	5.7de	5.3cd	5.7de	5.7cd	2.3c	5.7c
Zen-500	7.3 a-c	7.7 a-c	7.7 a-c	7.0 a-c	7.0 a-d	7.0 a-c	3.0 bc	6.7 a-c
Zenith	7.3 a-c	7.3 bc	7.3 a-d	6.7 bc	6.7 b-d	6.3 b-d	3.7 a-c	6.5 a-c
Zeon	6.3 c-f	7.0 b-d	8.7 ab	7.7 ab	7.7 a-d	7.3 a-c	3.7 a-c	6.9 a-c
LSD (0.05)	1.20	1.48	1.90	1.93	2.25	2.11	1.62	1.47
C.V.	10.9%	12.5%	15.5%	16.2%	19.1%	17.7%	26.1%	13.4%

[Z]Means within column not followed by the same letter differ at the 0.05 level of probability by Fisher's Least Significant Difference Test.
[Y]Turfgrass rating; 1 = dead or dormant to 9 = ideal turfgrass.

In 1999, turfgrass quality ratings were taken from March through October (Table 5). The top rated cultivar was Emerald followed by El Toro, HT-210, JaMar, Miyako, Zeon and Victoria.

Table 5. Turfgrass quality ratings of 19 cultivars of zoysiagrass evaluated at Lubbock, TX in 1999.

	Turfgrass quality ratings[Y]								
	Mar	Apr	May	Jun.	Jul	Aug	Sep	Oct.	Avg
Cultivar	rating								
Chinese	1.7ab[Z]	2.7de[Z]	5.0b-d[Z]	7.0a[Z]	7.0ab[Z]	6.7a-d[Z]	3.7ab[Z]	1.7bc[Z]	4.4a-c[Z]
DeAnza	1.7ab	3.0c-e	6.3a-c	7.0a	7.7a	3.7e	3.3b	1.7bc	4.3a-c
El Toro	2.0ab	4.3ab	6.7ab	8.0a	8.3a	7.3ab	5.3ab	2.0a-c	5.5ab
Emerald	2.3a	4.0a-c	6.7ab	8.0a	8.3a	7.3ab	5.0ab	3.3a	5.6a
HT-210	2.0ab	4.0a-c	6.0a-c	8.0a	8.0a	7.3ab	5.3ab	3.3a	5.5ab
J-14	2.0ab	3.0c-e	5.7a-d	7.0a	7.0ab	5.7a-e	3.3b	1.7bc	4.4a-c
J-36	2.0ab	3.0c-e	4.7cd	7.0a	7.0ab	6.3a-d	3.7ab	1.7bc	4.4a-c
J-37	2.0ab	3.0c-e	6.3a-c	7.3a	7.0ab	6.0a-e	3.7ab	2.0a-c	4.7a-c
JaMar	2.0ab	5.0a	7.0a	8.0a	8.7a	7.3ab	4.7ab	1.7bc	5.5ab
Korean	2.3a	3.0c-e	5.7a-d	6.7ab	7.0ab	5.0b-e	4.0ab	1.7bc	4.4a-c
Meyer	2.0ab	2.7de	4.0de	7.0a	7.0ab	6.3a-d	3.7ab	1.3c	4.3a-c
Miyako	2.0ab	3.7b-d	5.7a-d	7.0a	8.3a	8.0a	5.7a	3.3a	5.5ab
Victoria	1.7ab	3.0c-e	6.3a-c	8.0a	8.0a	7.0a-c	4.7ab	3.0ab	5.2ab
Z-18	1.3b	2.0e	2.3e	4.7c	5.3b	4.7c-e	3.7ab	3.0ab	3.4c
Zen-400	1.7ab	3.0c-e	5.0b-d	5.0bc	5.3b	4.3de	3.3b	1.3c	3.6c
Zen-500	2.0ab	3.0c-e	6.0a-c	7.0a	7.0ab	6.0a-e	4.0ab	1.7bc	4.6a-c
Zenith	1.3b	2.3e	4.0de	6.3a-c	7.0 ab	6.0 a-e	3.7ab	2.7 a-c	4.2 bc
Zorro	1.7ab	2.7de	6.0a-c	7.7a	8.3 a	5.0 b-e	3.7ab	2.0 a-c	4.6 a-c
Zeon	1.7ab	3.7b-d	6.0a-c	8.0a	8.7 a	7.0 a-c	5.0ab	2.7 a-c	5.3 ab
LSD (0.05)	0.69	1.30	1.98	1.87	2.23	2.52	2.06	1.46	1.41
C.V.	22.7%	24.5%	21.6%	15.9%	18.1%	24.7%	29.7%	40.2%	18.1%

[Z]Means within column not followed by the same letter differ at the 0.05 level of probability by Fisher's Least Significant Difference Test.
[Y]Turfgrass rating; 1 = dead or dormant to 9 = ideal turfgrass.

In 2000, cultivars that had the highest average quality ratings were Emerald, Miyako, Zenith, El Toro and HT-210 (Table 6). An infestation of white grubs in the fall of 1999 severely damaged many of the plots and influenced individual turfgrass quality ratings in 2000. In 1999 and 2000, visual quality rating were collected from March through October. In March some cultivars were beginning to green-up and received higher quality ratings compared to other cultivars that were still dormant. Similarly, in October many of the top cultivars were still green when others were already dormant. In some cases, the higher average quality rating was due primarily to an extended growing season rather than a high quality rating during the peak of the growing season.

Table 6. Turfgrass quality ratings of 19 cultivars of zoysiagrass evaluated at Lubbock, TX in 2000.

	Turfgrass quality ratings[Y]								
	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Avg.
Cultivar	rating								
Chinese	2.0a[Z]	3.0ab[Z]	5.0a[Z]	5.7a[Z]	5.7a-c[Z]	4.7a-d[Z]	4.7a-c[Z]	3.7a-d[Z]	4.3ab[Z]
DeAnza	1.0c	1.7bc	2.3d-f	3.3b-d	3.7b-e	3.7c-e	3.7b-d	3.0cd	2.8b-d
El Toro	1.3bc	2.0a-c	4.3a-c	5.3ab	6.3a	6.0ab	5.7a	5.0a	4.5a
Emerald	1.0c	3.0ab	5.0a	5.7a	6.0ab	6.3a	5.7a	4.3a-c	4.6a
HT-210	1.3bc	2.0a-c	4.0a-d	5.3ab	5.7a-c	6.3a	5.7a	4.7ab	4.4a
J-14	1.7ab	2.0a-c	2.7c-f	3.3b-d	3.3c-e	3.0ed	3.0cd	2.3d	2.7cd
J-36	1.7ab	2.3a-c	3.0b-f	4.3a-c	4.7a-e	4.0b-e	4.0a-d	3.3b-d	3.6a-d
J-37	1.7ab	2.7a-c	3.7a-d	4.7a-c	5.0a-d	4.7a-d	4.3a-c	3.7a-d	3.8a-c
JaMar	1.7ab	2.0a-c	4.7ab	5.3ab	6.0ab	5.3a-c	5.0ab	4.7ab	4.3ab
Korean	1.7ab	2.7a-c	4.3a-c	4.7a-c	4.7a-e	4.0b-e	4.0a-d	3.3b-d	3.7a-c
Meyer	1.0c	1.7bc	1.7ef	2.7cd	3.0ed	4.0b-e	3.7b-d	3.3b-d	2.6cd
Miyako	2.0a	2.3a-c	4.3a-c	5.3ab	6.3a	6.0ab	5.3ab	4.7ab	4.5a
Victoria	1.0c	1.7bc	3.0b-f	4.0a-d	4.3a-e	3.7c-e	3.7b-d	3.3b-d	3.1a-d
Z-18	1.0c	1.3c	1.3f	2.0d	2.3e	2.3e	2.3d	2.3d	1.9d
Zen-400	1.3bc	2.0a-c	3.3a-e	3.7a	4.0a-e	3.7c-e	3.7b-d	3.0cd	3.1a-d
Zen-500	1.3bc	2.3a-c	3.3a-e	3.7a	4.0a-e	4.3a-e	3.7b-d	3.3b-d	3.3a-d
Zenith	2.0a	3.3 a	5.0a	5.7a	6.0ab	5.3a-c	4.7a-c	4.0a-c	4.5a
Zeon	1.0c	2.3a-c	3.7a-d	5.0ab	5.0a-d	4.3a-e	4.3a-c	3.7a-d	3.7a-c
Zorro	1.0c	1.7bc	2.7c-f	3.7a-d	3.3c-e	3.0ed	3.0cd	3.0cd	2.7cd
LSD (0.05)	0.62	1.40	1.97	2.08	2.4	2.12	1.94	1.66	1.06
C.V.	26.9%	38.4%	33.5%	28.8%	30.9%	28.7%	27.8%	27.6%	23.5%

[Z]Means within column not followed by the same letter differ at the 0.05 level of probability by Fisher's Least Significant Difference Test.
[Y]Turfgrass rating; 1 = dead or dormant to 9 = ideal turfgrass.

Averaged over a three-year (1998-2000) or four-year period (1997-2000) El Toro, Emerald, HT-210, JaMar and Miyako had the highest overall quality (Table 7). These five cultivars were all vegetatively propagated (Table 7). In national testing, Zorro was the highest rated over the four years of the study, but was not significantly different than Emerald, Zeon and El Toro (Morris 2001). J-37 was the highest rated seeded cultivar over the period of this study, but was not significantly better than Chinese Common, J-36, Korean Common, Zen-500 and Zenith (Table 7). This is similar to national testing except that Zen-400 had the second highest quality rating of the seeded cultivars, but a low turfgrass quality rating in Lubbock (Morris 2001). Over the four-years of this study none of the new seeded or vegetatively propagated cultivars of zoysiagrass had significantly better turfgrass quality ratings than the check cultivars Emerald, El Toro (vegetative) and Chinese Common (seeded).

Table 7. Turfgrass quality ratings of 19 cultivars of zoysiagrass evaluated at Lubbock, TX averaged from 1997 to 2000.

	Turfgrass quality ratings[Y]					
	1997	1998	1999	2000	1997 to 2000	1998 to 2000
Cultivar	rating					
Chinese	7.9bc[Z]	6.6a-c[Z]	4.4a-c[Z]	4.3ab[Z]	5.8a-c[Z]	5.1ab[Z]
DeAnza	6.7ef	6.3a-c	4.3a-c	2.8b-d	5.0c	4.4b
El Toro	8.8a	7.4ab	5.5ab	4.5a	6.5a	5.8a
Emerald	7.7cd	7.2ab	5.6a	4.6a	6.3ab	5.8a
HT-210	7.5cd	7.6a	5.5ab	4.4a	6.2ab	5.8a
J-14	7.3c-e	6.5a-c	4.4a-c	2.7cd	5.2bc	4.5ab
J-36	7.7cd	6.4a-c	4.4a-c	3.6a-d	5.5a-c	4.7ab
J-37	7.5cd	7.1a-c	4.7a-c	3.8a-c	5.8a-c	5.2ab
JaMar	8.7ab	7.6a	5.5ab	4.3ab	6.5a	5.8a
Korean	6.3f	6.3a-c	4.4a-c	3.7a-c	5.2bc	4.8ab
Meyer	7.0d-f	6.0bc	4.3a-c	2.6cd	5.0c	4.3bc
Miyako	8.8a	7.5a	5.5ab	4.5a	6.6a	5.8a
Victoria	7.3c-e	7.4ab	5.2ab	3.1a-d	5.7a-c	5.2ab
Z-18	NA	3.9d	3.4c	1.9d	3.1d	3.1c
Zen-400	7.7cd	5.7c	3.6c	3.1a-d	5.0c	4.1bc
Zen-500	7.9bc	6.7a-c	4.6a-c	3.3a-d	5.6a-c	4.8ab
Zenith	7.8 c	6.5 a-c	4.2 bc	4.5 a	5.7 a-c	5.0 ab
Zeon	7.2 c-e	6.9 a-c	5.3 ab	3.7 a-c	5.8 a-c	5.3 ab
Zorro	7.4 c-e	6.8 a-c	4.6 a-c	2.7 cd	5.4 bc	4.7 ab
LSD (0.05)	0.82	1.47	1.41	1.06	1.12	1.32
C.V.	6.5%	13.4%	18.1%	23.5%	12.1%	16.1%

[Z]Means within column not followed by the same letter differ at the 0.05 level of probability by Fisher's Least Significant Difference Test.
[Y]Turfgrass rating = 1=dead or dormant to 9=maximum turfgrass.

Due to the aggressive growth habit of zoysiagrass many of the cultivars in this study developed extensive thatch layers over the four-years of this study. Dethatching of this accumulation may have led to better quality rating for some of the cultivars tested, although none of the new cultivars performed better than the check cultivars in this study. Many of these cultivars have been developed with improved host resistance to insects and diseases, as well as enhanced shade tolerance, which was not tested for at this location.

CONCLUSION

This study indicates that cultivars El Toro, Emerald, HT-210, JaMar and Miyako produced a high quality turfgrass when grown on the Texas High Plains. These cultivars provide a high quality turfgrass suited for use on golf courses, parks, commercial lawns and residential lawns. The highest quality rated zoysiagrasses were all vegetatively propagated. Although the seeded cultivars J-37, Chinese Common, Zenith, Zen-500 and J-36 produced acceptable turfgrasses. These zoysiagrass cultivars appear to be adapted to the High Plains of West Texas where historically cold temperatures have limited adaptation of zoysiagrasses.

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Response of Herbaceous Vegetation to Winter Burns in the Western South Texas Plains: An Observation

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ABSTRACT

Prescribed fire is becoming a more widely utilized habitat management practice in southern Texas. We examined the effects of winter burns on the abundance and diversity of forbs and grasses on three rangeland sites during the first and second growing seasons postburn in the western South Texas Plains. Forb and grass cover, density, and frequency were estimated in 50, 7.9-x 19.7-in quadrats. Forb and grass species richness and diversity were similar among treatments and growing seasons. Forb cover was greater on burned sites during the first growing season. Burning increased densities of three-seed croton (*Croton lindheimerianus*), rough buttonweed (*Diodia teres*), and spreading sida (*Sida abutifolia*) during the first growing season. Densities of three-seed croton and rough buttonweed were similar among treatments during the second growing season, while increased densities of spreading sida persisted into the second growing season postburn. Most grasses were unaffected by burning. Date of burn influenced herbaceous vegetation response with greatest forb densities on early winter burns and highest grass densities on mid-winter burns. Even with less than optimum growing conditions burning can increase abundance of annual and perennial forbs.

KEYWORDS: prescribed fire, South Texas, herbaceous vegetation, diversity, species abundance

The Rio Grande Plains of South Texas is the southern-most extension of the Great Plains Grasslands. Fire, along with other climatic variables such as drought, presumably maintained the honey mesquite (*Prosopis glandulosa*) savannas and interspersed grasslands of pristine South Texas (Scifres and Hamilton 1993). Frequency of fire appeared to be highly variable and ranged from 5-30 years (Wright and Bailey 1982). Following European settlement, suppression of fire combined with heavy livestock grazing has lead to the current thorn woodlands common throughout southern Texas (Archer et al. 1988, Archer 1994).

Beginning in the mid-twentieth century, South Texas landowners began to convert these thorn woodlands back to grasslands to enhance rangelands for livestock production. Mechanical treatments such as root plowing were commonly utilized methods for achieving this goal. Mechanical brush manipulation practices can significantly reduce woody plant cover while increasing herbaceous vegetation (Scifres et al. 1976, Bozzo et al. 1992). However, once treated rangelands are revegetated by woody species, woody plant diversity can be dramatically reduced (Fulbright and Beasom 1987, Ruthven et al. 1993).

Land ownership and land use practices in South Texas have changed in recent years. The size of individual landholdings has decreased and revenue derived from those properties has become increasingly dependent on wildlife rather than traditional livestock operations. Many wildlife management programs are directed towards game species such as white-tailed deer (*Odocoileus virgininaus*) and northern bobwhite *(Colinus virginianus*). Woody vegetation is a primary component of white-tailed deer diet in South Texas (Drawe 1968, Taylor et al. 1997). In order to maintain woody plant diversity and increase herbaceous vegetation, rangeland managers are beginning to utilize prescribed fire to enhance wildlife habitat. In the southeastern United States, prescribed fire has long been utilized to manage habitat for northern bobwhite by removing decadent growth and debris, recycling nutrients, and stimulating germination of beneficial forb species (Landers and Mueller 1992). Prescribed burning in eastern portions of the Rio Grande Plains can reduce brush cover while maintaining woody plant diversity (Box and White 1969). Prescribed burning in southern Texas has also been shown to increase herbaceous vegetation preferred by wildlife (Box and White 1969, Hansmire et. al 1988, Ruthven et. al, 2000); however, these studies have only investigated herbaceous vegetation response during the first growing season postburn. In addition, little information is available on the effects of fire in the more xeric areas of the western Rio Grande Plains.

Our objective was to determine the effects of fire on the diversity and density of herbaceous vegetation during the first and second growing seasons post-treatment in the western Rio Grande Plains. We hypothesize that prescribe burning South Texas rangelands during the dormant season will enhance germination and establishment of important seed producing annual forbs such as croton (*Croton* spp.) and partridge pea (*Chamaecrista fasciculata*), increase perennial forbs, and increase grass cover.

METHODS

The study area was on the 15,200 acre Chaparral Wildlife Management Area (28° 20' N, 99° 25' W) in the western South Texas Plains (Gould 1975, Scifres 1980, Hatch et al. 1990). The study site was purchased by the state of Texas in 1969, and is managed by the Wildlife Division of the Texas Parks and Wildlife Department (TPWD). Climate is characterized by hot summers and mild winters with an average daily minimum winter (January) temperature of 41° F and an average daily maximum summer (July) temperature of 99° F, with a growing season of 249 to 365 days depending on freezing temperatures (Stevens and Arriaga 1985). Precipitation patterns are bimodal with peaks occurring in late spring (May-June) and early fall (September-October). The 11-year (1989-1999) average is 21 inches (TPWD, unpubl. data).

Three sites subjected to prescribed burns were paired with three untreated sites utilizing a randomized block design. Burned sites were located within larger areas that had been burned. Rangeland fire in southern Texas typically produces a mosaic of burned and nonburned areas as a result of uneven fuel loads (Box and White, 1969). All study sites received 100% coverage by burns. Study sites were burned during winter 1997-1998, with burning dates of 9 December 1997, 9 January 1998, and 3 February 1998. Study sites were approximately 4 acres in size. Burning conditions were similar, with an average relative humidity of 29 ± 4% ($\bar{x}$ ± SE), temperature of 77 ± 2° F, and wind speed of 5 ± 2 mph. Wind direction was variable. Soil moisture was not recorded; however, based on precipitation prior to burns soil moisture was considered low.

Because of variable wind speed and direction during all burns and uneven fuel loads, rate of spread and flame height were highly variable and were not recorded. Fuel loads were not measured as they varied within study sites. Optimum fuel loads for burning in western portions of South Texas are ≥ 1,800 lb/ac (TPWD, unpubl. data) and based on visual estimations study sites met or exceeded these levels. All burns were ignited as head fires with drip torches.

Soils were similar among treatments and consisted of Duval fine sandy loam, gently undulating, Duval loamy fine sand, 0-5% slopes, and Dilley fine sandy loam, gently undulating (Stevens and Arriaga 1985, Gabriel et al. 1994). The Duval series are fine-loamy, mixed, hyperthermic Aridic Haplustalfs and the Dilley series are loamy, mixed, hyperthermic shallow Ustalfic Haplargids. Topography is nearly level to gently sloping and elevation ranges between 580 and 610 feet.

Plant communities belonged to the Mesquite-Granjeno (*Celtis pallida*) association (McLendon l99l). Within this association were 2 primary communities, the Mesquite-Colima (*Zanthoxylum fagara*)/Granjeno community, in which colima and bluewood brasil (*Condalia hookeri*) are the subdominants, and the Mesquite-Granjeno/Hog-plum (*Colubrina texana*) community, in which hog plum is the subdominant. Prominent herbaceous species included Lehmann lovegrass (*Eragrostis lehmanniana*), an introduced perennial, hooded windmillgrass (*Chloris cucullata*), hairy grama (*Bouteloua hirsuta*), partridge pea, and croton.

Domestic livestock have grazed the study area since the 18th century (Lehmann 1969). Cattle have been the major species of livestock since about 1870, whereas sheep were grazed from about 1750 to 1870. Grazing strategies have varied from continuous grazing to various rotational grazing systems (Ruthven et al. 2000). Since 1990, the study area has been grazed utilizing stocker class cattle under a high intensity, low frequency grazing system during the period October through April. Stocking rates were considered low to moderate, and average 30 acres/animal unit/year. Grazing has little affect on the response of forbs to prescribed fire (Ruthven et al. 2000).

Canopy cover of grasses, forbs, litter, and bare ground was visually estimated during late spring and early summer 1998-99 (June-July) in 50, 7.9-x 19.7-in quadrats randomly placed in each study site (Daubenmire 1959). Grass and forb density and frequency were estimated by counting individual plants in quadrats in each site. Grass and forb species diversity was quantified with Shannon's Index (Pielou 1975). Species frequency data were used to calculate the index. Scientific names of plants follow Jones et al. (1997) and common names are from Hatch et al. (1990).

Response of annual forbs and perennial grasses can vary depending on the timing of winter burns (Hansmire et al. 1988), with forbs being more common on sites burned in early winter (December) than late winter (February) and grasses being more productive following late winter than early winter burns. To assess the potential impacts of burning date, total forb and grass densities and dominant annual and perennial forb and perennial grass densities were compared among burning dates. We realize the implications of pseudoreplication (Hurlbert 1984); however, Wester (1992) suggests that pseudoreplication is a matter of scale and that statistical analyses of single treatment studies in which samples are taken within a relatively small area can be useful in assessing treatment impacts. Although conclusions of these analyses are limited to the study site and may not be extrapolated to other populations, they may be helpful in explaining potential effects of temporal factors on the results of this study.

RESULTS AND DISCUSSION

Forb and grass species richness and diversity were similar among treatments and growing seasons (Table 1). There was an interaction with grass diversity being greatest on burned sites during the first growing season and greatest on nonburned areas during the second growing season. Forb species evenness was greatest during the first growing season on both treatments.

Table 1. Herbaceous species richness, diversity, and evenness on burned (n=3) and untreated (n=3) areas during the first (1998) and second (1999) growing seasons following treatment at the Chaparral Wildlife Management Area, Dimmit and LaSalle Counties, Texas, June- July 1998-1999.

	1998				1999			
	Burned		Untreated		Burned		Untreated	
Class/Index	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI
Grasses and Sedges								
Richness	15	7–23	13	11–14	13	8–16	13	10–17
Diversity	2.16	1.86–2.47	2.06	2.00–2.12	2.06	1.90–2.21	2.15	1.87–2.43
Evenness	0.81	0.71–0.92	0.82	0.80–0.84	0.81	0.73–0.89	0.83	0.81–0.86
Forbs								
Richness	15	7–23	14	4–23	15	10–20	15	11–18
Diversity	2.35	1.63–3.07	2.19	1.28–3.10	2.03	1.35–2.72	2.09	1.60–2.58
Evenness	0.88	0.80–0.96	0.84	0.68–1.00	0.75	0.58–0.93	0.78	0.62–0.94

Total forb cover was greater on burned (13 ± 10%, $\bar{x}$ ± 95% CI) than nontreated (4 ± 3%) sites during the first growing season following treatment application. During the second growing season forb cover was similar between burned and nontreated sites (18 ± 14% and 15 ± 20%, respectively). Grass cover did not differ among burned and nonburned treatments or during the first and second growing seasons (59 ± 18% vs. 57 ± 29% and 74 ± 13% vs. 73 ± 23%, respectively). Burning reduced litter during the first growing season following treatment (24 ± 7% vs. 54 ± 27%) and litter accumulation was similar among burned and nonburned sites by the second growing season (30 ± 10% and 36 ± 5%, correspondingly). Bare ground increased on burned sites during the first growing season (62 ± 19% vs. 28 ± 2%) and was similar on burned and nonburned sites by the second growing season (47 ± 20% and 40 ± 17%, respectively). Red lovegrass (*Eragrostis secundiflora*) had greater cover values on burned sites during the first growing season but were similar among treatments during the second growing season (Table 2). Cover values for thin paspalum (*Paspalum setaceum*) did not vary among burned and nonburned sites during the first growing season but were greater on nonburned sites during the second growing season.

Table 2. Foliar cover (%) of common (frequency ≥ 5%) grasses and sedges on burned (n=3) and untreated (n=3) areas during the first (1998) and second (1999) growing seasons following treatment at the Chaparral Wildlife Management area, Dimmit and LaSalle Counties, Texas, June-July 1998-1999.

	1998				1999			
	Burned		Untreated		Burned		Untreated	
Class/Species	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI
Grasses and Sedges								
Aristida purpurea	4	1–7	9	-4–22	3	0–6	3	-3–8
Boutloua hirsuta	19	-26–65	20	-21–62	19	-5–43	23	-20–66
Chloris cucullata	1	0–2	1	-2–4	1	0–2	1	-1–3
Cyperus retroflexus	0	0–0	0	0–0	1	-1–4	1	0–3

Table 2. (Cont'd.)

	1998				1999			
	Burned		Untreated		Burned		Untreated	
Class/Species	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI
Grasses and Sedges (cont.)								
Digitaria cognata	2	-1–4	1	-3–6	2	-4–8	2	-1–6
Eragrostis lehmanniana	18	-8–44	20	-11–51	31	-6–67	17	-14–48
Eragrostis secundiflora	6	1–10	2	-1–5	8	-6–23	7	-3–17
Eragrostis sessilispica	9	-2–19	5	-3–12	1	-2–4	2	-4–7
Paspalum setaceum	2	-5–9	1	-1–3	6	6–7	14	4–24
Setaria firmulum	0	-1–2	1	-1–3	2	-5–9	2	-1–4
Urochloa ciliatissima	2	-2–7	5	-7–17	6	6–7	6	-11–24

Total grass density was similar between burned and nonburned sites and varied by season with greatest density during the second growing season (38 ± 34 plants/yd^2 vs. 47 ± 22 and 74 ± 43 vs. 69 ± 22, respectively). Densities of individual grass species were similar among treatments (Table 3). Oneflower flatsedge (*Cyperus retroflexus*), red lovegrass, tumble lovegrass (*Eragrostis sessilispica*), and purple threeawn (*Aristida purpurea*) varied by growing season, with the former three species having greater densities during the second growing season and the latter decreasing in density from the first to second growing season. Total forb densities were similar among burned and nonburned sites and varied by season with highest densities during the second growing season (19 ± 30 vs. 11 ± 13 and 41 ± 47 vs 24 ± 26, correspondingly). Densities of three-seed croton (*Croton lindheimerianus*), rough buttonweed (*Diodia teres*), and spreading sida (*Sida abutifolia*) were greater on burned areas (Table 3). Three-seed croton densities were greatest during the first growing season. Densities of silky evolvulus (*Evolvulus alsinoides*) and spreading sida were highest during the second growing season. Three-seed croton demonstrated an interaction with greatest densities on burned sites during the first growing season.

Table 3. Density (plants/yd^2) of common (frequency ≥ 5%) grasses, sedges, and forbs on burned (n=3) and untreated (n=3) areas during the first (1998) and second (1999) growing seasons following treatment at the Chaparral Wildlife Management Area, Dimmit and LaSalle Counties, Texas, June-July 1998-1999.

	1998				1999			
	Burned		Untreated		Burned		Untreated	
Class/Species	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI
Grasses and Sedges								
Aristida purpurea	1.3	0.0–3.0	2.8	0.4–5.3	0.9	-0.4–2.2	0.4	-0.6–1.3
Boutloua hirsuta	10.5	-12.1–33.1	10.7	-4.4–25.7	13.0	-9.4–35.3	22.4	-24.7–69.5
Chloris cucullata	0.9	0.1–1.8	0.6	0.0–1.2	0.5	0.2–1.2	0.9	0.3–1.5
Cyperus retroflexus	0.1	-0.2–0.3	0.0	0.0–0.0	2.2	-2.5–6.9	2.0	0.6–3.5
Digitaria cognata	1.8	-1.5–5.1	1.3	-2.8–5.3	1.1	-1.4–3.7	1.6	0.7–2.4
Eragrostis lehmanniana	8.4	1.4–15.3	14.0	-26.2–54.2	22.4	-6.6–51.3	9.7	-4.4–23.9
Eragrostis secundiflora	3.6	-1.7–9.0	1.6	-0.5–3.8	8.0	-4.4–20.5	6.9	-3.3–17.1
Eragrostis sessilispica	2.2	1.3–3.0	1.9	-1.1–4.9	0.5	-0.7–1.8	0.3	-0.6–1.1
Paspalum setaceum	1.8	-2.9–6.5	1.7	-3.3–6.7	4.7	0.4–9.0	7.5	4.5–10.6
Setaria firmulum	0.3	-0.6–1.1	0.3	-0.4–1.0	0.5	-1.6–2.6	1.1	-0.9–3.1
Urochloa ciliatissima	5.0	-9.2–19.3	10.1	-13.9–34.1	16.5	-0.8–33.7	13.4	0.1–26.8
Forbs								
Aphanostephus skirrhobasis	0.2	-0.4–0.8	2.5	-6.5–11.6	0.1	-0.2–0.3	0.0	0.0–0.0
Chamaecrista fasciculata	1.2	-2.2–4.6	2.5	-0.9–5.9	4.3	-2.6–11.2	3.6	-1.5–8.6
Coreopsis nuecensis	0.9	-2.9–4.6	0.0	0.0–0.0	0.0	0.0–0.0	0.0	0.0–0.0
Croton capitatus	2.8	-6.9–12.6	0.0	0.0–0.0	0.0	0.0–0.0	0.0	0.0–0.0

Table 3. (Cont'd.)

	1998				1999			
	Burned		Untreated		Burned		Untreated	
Class/Species	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI
Forbs (cont.)								
Croton lindheimerianus	2.6	-1.4–6.6	0.0	0.0–0.0	0.2	-0.2–0.6	0.1	-0.2–0.3
Dalea nana	0.5	-0.1–1.2	0.6	-0.7–1.9	2.1	-4.4–8.6	0.9	-0.7–2.6
Diodia teres	5.0	-5.5–15.4	0.2	-0.2–0.6	0.9	-0.2–1.9	0.5	-1.8–2.9
Evolvulus alsinoides	1.6	0.6–2.7	0.7	-0.9–2.4	15.6	-15.5–46.7	10.8	-15.9–37.5
Lesqurella argyraea	0.0	0.0–0.0	0.2	0.0–0.5	0.7	-1.0–2.3	0.4	-0.6–1.4
Porttulaca pilosa	0.0	0.0–0.0	0.0	0.0–0.0	10.7	-35.0–56.5	2.6	-6.3–11.6
Sida abutifolia	0.5	-0.7–1.8	0.3	-0.1–0.7	2.1	0.6–3.5	0.9	-0.8–2.5

Percent frequency of grasses was similar among treatments (Table 4). Growing season trends for oneflower flatsedge, red lovegrass, and purple threeawn followed those for density estimates. Tumble lovegrass was more commonly encountered during the first growing season on both treatments. Hooded windmillgrass exhibited an interaction, being more common on burned sites during the first growing season and more frequently encountered on nonburned areas during the second growing season. Three-seed croton was more common on burned sites (Table 4).

Table 4. Percent Frequency of common (frequency ≥ 5%) grasses, sedges, and forbs on burned (n=3) and untreated (n=3) areas during the first (1998) and second (1999) growing seasons following treatment at the Chaparral Wildlife Management Area, Dimmit and LaSalle Counties, Texas, June-July 1998-1999.

	1998				1999			
	Burned		Untreated		Burned		Untreated	
Class/Species	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI
Grasses and Sedges								
Aristida purpurea	13	1–26	30	2–58	9	-3–22	5	-7–16
Boutloua hirsuta	53	-35–142	59	-1–119	61	8–115	62	-30–154
Chloris cucullata	8	3–13	6	1–11	5	0–11	9	2–17
Cyperus retroflexus	1	-2–4	0	0–0	21	-19–61	18	5–31
Digitaria cognata	12	-6–30	10	-16–36	9	-11–29	15	12–18
Eragrostis lehmanniana	56	31–81	56	-26–138	75	50–101	49	-17–115
Eragrostis secundiflora	25	-8–57	16	-6–38	43	10–75	29	12–47
Eragrostis sessilispica	22	13–31	19	-14–52	3	-5–10	3	-7–14
Paspalum setaceum	12	-14–38	14	-21–49	25	2–49	45	42–48
Setaria firmulum	1	-2–4	4	-5–13	5	-18–28	7	-8–23
Urochloa ciliatissima	27	-12–65	31	-17–80	60	17–103	37	9–66
Forbs								
Aphanostephus skirrhobasis	3	-5–10	11	-18–39	1	-2–4	0	0–0
Chamaecrista fasciculata	11	-18–40	21	-3–44	33	-17–82	32	-16–80
Coreopsis nuecensis	6	-20–32	0	0–0	0	0–0	0	0–0
Croton capitatus	11	-16–39	0	0–0	0	0–0	0	0–0
Croton lindheimerianus	20	-2–42	0	0–0	2	-3–7	1	-2–4
Dalea nana	5	0–11	7	-8–21	16	-27–59	7	-5–20
Diodia teres	16	-17–49	2	-3–7	5	3–8	3	-11–18
Evolvulus alsinoides	15	2–27	7	-8–21	61	24–99	41	-10–92
Lesqurella argyraea	0	0–0	3	0–6	8	-12–28	5	-8–17
Portulaca pilosa	0	0–0	0	0–0	14	-42–70	10	-25–45
Sida abutifolia	4	-6–14	4	-1–9	20	7–33	9	-8–27

Silky evolvulus and spreading sida were more commonly encountered during the second growing season. Three-seed croton demonstrated an interaction occurring with greater frequency on burned sites during the first growing season.

Total forb densities varied among burning dates in the following order December (40 ± 10) > January (18 ± 10) = February (12 ± 4). Croton, rough bottonweed, and partridge pea were the most common annual forbs encountered on burn sites during the first growing season and varied among burning dates (Table 5). Densities of the perennial forb, silky evolvulus, were similar between burning dates. Grass densities varied between burning dates in the following order January (62 ± 8) > December (37 ± 8) = February (36 ± 6). Lehmann lovegrass, hairy grama, red lovegrass, and fringed signalgrass (*Urochloa ciliatissima*) were the dominant grasses on burn sites during the first growing season and varied among burning dates (Table 5).

Table 5. Density (plants/yd^2) of dominant (frequency ≥ 25%) grasses and dominant (frequency ≥ 10%) annual and perennial forbs on burned plots (n=50) by date of burn at the Chaparral Wildlife Management Area, Dimmit and LaSalle Counties, Texas, June-July 1998.

	December		January		February	
Class/Species	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI
Grasses						
Boutloua hirsuta	5.8	3.1–8.6	21.3	17.4–25.2	4.8	1.9–7.8
Eragrostis lehmanniana	11.5	7.4–15.6	5.8	3.4–8.3	8.2	6.0–10.3
Eragrostis secundiflora	1.7	0.3–3.1	3.3	1.4–5.3	6.0	3.2–8.8
Urochloa ciliatissima	1.5	0.4–2.6	11.8	5.8–17.8	2.0	0.9–3.1
Annual Forbs						
Chamaecrista fasciculata	0.5	-0.1–1.1	0.3	-0.3–1.0	2.8	1.2–4.4
Croton spp.	12.0	7.0–17.0	1.8	0.4–3.3	2.8	1.4–4.3
Diodia teres	8.7	3.3–14.0	6.2	0.9–11.4	0.3	-0.1–0.8
Perennial Forbs						
Evolvulus alsinoides	1.8	0.1–3.5	2.0	0.8–3.2	1.2	0.4–2.0

Our results indicate that dormant season prescribed fire on South Texas rangelands can increase densities of important seed producing annuals such as croton during the first growing season following burning. The increases of annual forbs on burned sites during the first growing season were similar to those reported along the transition zone between the South Texas Plains and the Gulf Coast Prairies (Box and White 1969, Hansmire et al. 1988). Ruthven et al. (2000) also reported increases in annuals following winter burns in the western South Texas Plains; however densities were dramatically higher than those reported in our study. For instance, croton densities were two-fold greater on burned sites and prairie sunflower (*Helianthus petiolaris*), which was seldom encountered in our study (≤ 3% frequency, ≤ 0.4 plants/yd^2), was 15-times greater on burned sites when compared to our study. These differences may be a result of varying precipitation patterns. Results reported by Ruthven et al. (2000) were from burns conducted in mid- to late winter 1997 in which spring (February-June) precipitation (17.7 in) was 177% of normal and May-June rainfall (10.8 in) was 234% above average. In 1998, spring rainfall (5.1 in) was 49% below normal and May-June precipitation (0.4 in) was 91% below the long-term average. Forb increases during the second growing season on both treatments can also be attributed to precipitation, as spring 1999 precipitation (9.94 in) was 1% below normal and May-June rainfall (6.71 in) was 146% above average compared to 1998. Partridge pea was the most common annual forb encountered and the lack of treatment effects was similar to that previously reported on the study area (Ruthven et al. 2000). This important forb typically increases following winter and spring burns in the southeastern United States (Czuhai and Cushwa 1968, Lewis and Harshbarger 1976). Moisture conditions at the time of burns may have affected germination of partridge pea. Moist heat, which can be common under prescribed burning conditions in the southeastern United States, stimulates germination of partridge pea while dry heat does not increase germination (Cushwa et al. 1968). Controlled laboratory experiments simulating heat produced by prescribed fire have shown no increase in germination of partridge pea seed following exposure to heat of < 600°F (Mitchell and Dabbert 2000). Typical burning conditions on South Texas rangelands are dry with low relative humidity and moderate winds, which are necessary to carry fire through patchy and variable fuel loads. With the exception of spreading sida which increased following burning, perennial forbs appeared to be unaffected by burning. The varied response by perennials to dormant season fire was similar to other studies (Hansmire et al.1988; Ruthven et al. 2000). Ruthven et al. (2000) reported increases of important perennial forbs such as erect dayflower (*Commelia erecta*) and beach groundcherry (*Physalis cinerascens*), which were seldom (≤ 3% frequency, ≤ 0.4 plants/yd^2) encountered in this study. Effect of burning date on forbs, especially annuals such as croton and buttonweed was similar to that reported in eastern portions of the South Texas plains (Hansmire et al. 1988). Our study sites burned in January and February, as opposed to earlier burns, may have dampened the overall increase of forbs in response to burning.

Although burning increased annual forbs during the first growing season postburn, these benefits did not persist into the second growing season. It is unclear whether increases in forb densities in the first growing season result in an increase in availability of seeds for use by wildlife and future forb production. It does appear that additional disturbance is necessary to stimulate a significant increase in germination of annual forbs. The extension of the positive response of some perennials into the second growing season on burned sites is similar to that reported on comparable study sites (TPWD, unpubl. data). Increases in perennials may be explained by the release of nutrients into the soil (Scifres and Hamilton 1993).

Winter burns generally increase overall grass abundance (Box and White 1969; Hansmire et al. 1988), which was not the case in this study, as most grasses appeared unaffected by burning. Individual grass species' response to dormant season burning can be highly variable (Towne and Owensby 1984, Hansmire et al. 1988). Red lovegrass was the only species that responded to burning with an increase in cover. Burning followed by below average precipitation can result in decreases of grass densities (Reynolds and Bohning 1956). Dry conditions following burns may have negated any positive responses by grasses to burning. As with forbs, overall increases in grass during the second growing season may be a result of increased rainfall. In contrast to greatest grass abundance following late winter burns reported by Hansmire et al. (1988), grass densities were higher following application of mid-winter (January) fire.

Invasion of sandy South Texas rangelands by Lehmann lovegrass is a growing concern. This introduced perennial is an aggressive invader that can displace native grasses and quickly become the predominant grass species (Anable et al. 1992). Although hot fires can kill Lehmann lovegrass (Cable 1965), burning may increase germination of Lehmann lovegrass seed (Ruyle et al. 1988). By the second growing season postburn, Lehmann lovegrass densities were not significantly greater on burned than nonburned sites. Burning during December favored Lehmann lovegrass compared to mid- and late winter burning dates. Extended monitoring beyond the second growing season postburn may be necessary to determine the full effects of burning on this species.

MANAGEMENT IMPLICATIONS

Even with less than optimum growing conditions winter burns can increase abundance of annual and perennial forbs. If enhancing annual forbs is a primary goal, then conducting burns during early winter on a biennial schedule may be beneficial. However, grass production must be taken into consideration, as grasses are the primary fine fuels needed to conduct prescribed burns in much of southern Texas. Proper grazing management is crucial in producing adequate fuel loads for burning. The grazing strategy on the study site appears to allow for ample fuel buildups necessary to successfully conduct burns. Multiple prescribed fires have successfully been applied to rangeland sites on the study area over two to four year periods. Short-term periods of drought and highly variable rainfall are typical of the South Texas Plains (Norwine and Bingham 1985). This coupled with the semiarid (annual precipitation $\leq$ 21 in.) nature of western portions of the South Texas Plains may not provide adequate fuel loads on a regular basis to conduct burning on an alternating year schedule. Realistically, burning may be achieved on a three to four year cycle. We concur with Hansmire et al. (1988) that conducting prescribed fires in January may maximize increases in both forbs and grasses. Mid-winter burning may also inhibit Lehmann lovegrass. It is clear that climatic and temporal factors can dramatically affect the impacts of prescribed burning. Further study into these factors and long-term effects of multiple burns on herbaceous and woody vegetation, as well as wildlife, are warranted.

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Root-Zone Refrigeration Delays Budbreak and Reduces Growth of Two Containerized, Greenhouse Grown Grape Cultivars

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ABSTRACT

Following budbreak, grapevines grown in west Texas are particularly susceptible to freeze damage. If deacclimation or budbreak was delayed, damage from spring frosts could possibly be reduced. During spring 1999, two duplicate experiments were undertaken to determine if root-zone refrigeration delayed budbreak of two cultivars of *Vitis vinifera* L. ('Chardonnay' and 'Cabernet Sauvignon'). Under greenhouse conditions, one-year-old grafted vines were planted into containers and placed in water baths. Throughout experiments, thermostats in two water baths were set to maintain temperatures at 35°F and 45°F. In addition, a non-chilled control water bath was maintained. Water and soil temperatures along with greenhouse climatic data were measured. Evaluation of budbreak was performed on a daily basis. At the conclusion of each experiment shoot and root dry mass were measured. Results indicate that when compared to controls, root-zone refrigeration delayed budbreak for both cultivars. Refrigerated grapevines also had a lower percentage of budbreak. Root and shoot mass of control plants were generally greater when compared to refrigerated water treatments. Because prolonged budbreak may allow buds to escape spring frost injury, reductions of root-zone temperature during spring deacclimation could have significant impact on the west Texas viticulture industry.

KEYWORDS: Deacclimation, Frost injury, Viticulture

In 2000, Texas ranked fifth in the United States in vineyard acreage and wine production. During that same period, 1.25 million gallons of wine were produced in Texas with an economic impact of $105 million dollars (Dodd and Hood 2001). Of the six major grape-growing regions in Texas (Figure 1), vineyards in the High Plains region

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account for approximately 40 percent of Texas wine grape production (Dodd and Hood 2001). On the Texas High Plains, the primary risk for grape production is frost injury. Late spring (post-budbreak) temperatures often result in the loss of primary and secondary buds (Lipe et al. 1992).

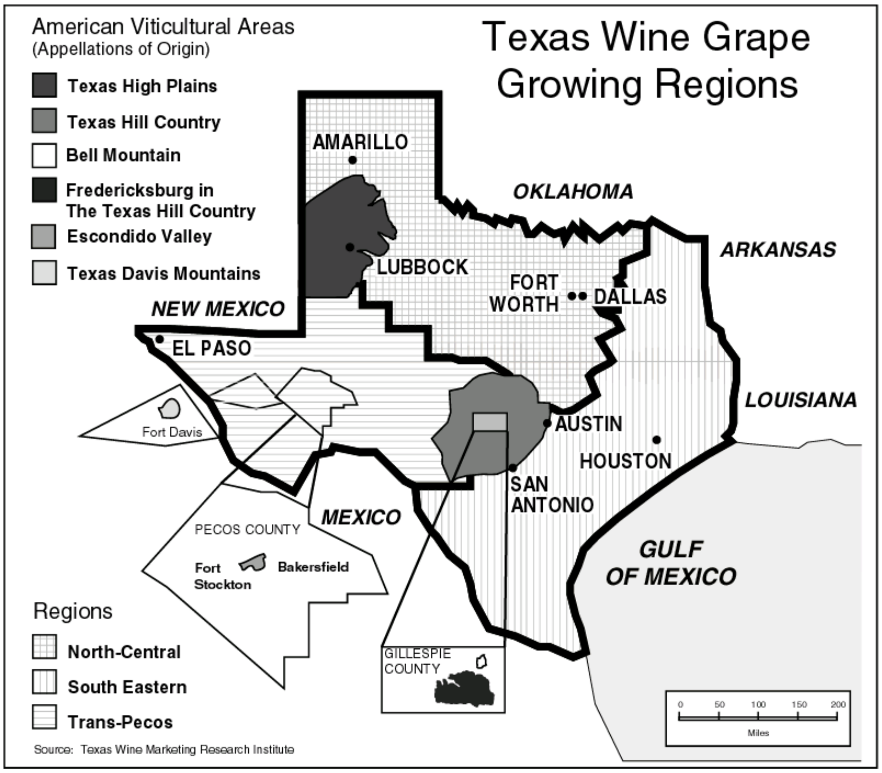

Figure 1. Texas wine grape growing regions (Source: Texas Wine Marketing Research Institute).

Several factors influence hardiness, deacclimation, and budbreak of grapevines. Winter bud survival can be attributed to cane characteristics such as sunlight exposure, periderm color, and cane diameter (Howell and Shaulis 1980). Cultivar differences can also affect bud deacclimation and bud hardiness at any given growth stage (Johnson and Howell 1981). For example, Lipe et al. (1992) reported that on the Texas High Plains, budbreak of 'Cabernet Sauvignon' normally occurs 10 to 15 days after 'Chardonnay'. Bud resistance to cold temperatures decreases with increasing bud moisture (as found during spring deacclimation) and advancing phenological development (Hamman et al. 1990). Air temperature also plays a key role in acclimation and deacclimation of buds (Dokoozlian et al. 1995). Warm air temperatures during spring, which often occur on the Texas High Plains, promote bud growth and decrease bud hardiness (Proebsting 1963). However, unlike many deciduous fruit crops, grapevines can tolerate relatively little chilling exposure to terminate bud dormancy (Dokoozlian 1999).

Suspending budbreak of grapevines has been a goal of viticulture research for many years. Breeding programs have developed several cultivars with improved cold hardiness (Bourne and Moore 1991, Moore 1986), but screening programs are often complicated by sampling considerations of time, tissue type (bud versus stem), and geographical location (Bourne and Moore 1991). Efforts to use wild grapevines as a source of cold tolerance have also been attempted (Becker 1987). However, negative characteristics such as small fruit, undesirable color, and strong taste associated with wild grapes are challenges that breeders have yet to overcome. Several studies have investigated evaporative cooling (misting systems) to delay budbreak of grapevines on the Texas High Plains (Baumhardt et al. 1990, Lipe et al. 1990, 1992). This research has demonstrated that budbreak could be delayed without effecting fruit quality (Lipe et al. 1992). However, limited water supplies and poor water quality may preclude the adaptation of evaporative misting systems in west Texas (Lipe et al. 1977).

Each spring, growth hormones produced in plant roots move to shoots and influence shoot development (Young 1989). The xylem pathway is involved in transporting growth hormones (particularly cytokinin) to developing buds (Belding and Young 1989). Research has demonstrated the importance of cytokinins during budbreak and new shoot growth (Cutting et al. 1991). However, little research has been conducted on the use of soil temperature to delay budbreak of grapevines.

Skene and Kerridge (1967) found 'Thompson Seedless' grapevines grown under greenhouse conditions in an 86°F nutrient solution had greater cytokinin content, shoot elongation, and increased dry-matter accumulation when compared to grapevines grown in an 68°F nutrient solution. Kliewer (1975) found a greater percentage of budbreak and greater shoot growth for greenhouse grown 'Cabernet Sauvignon' grapevines grown at root temperatures of 77°F and 86°F compared to grapevines grown at 52°F or 59°F. Other investigators have reported similar results (Zelleke and Kliewer 1979, 1985). Thus, it appears a reduction of root cytokinin production during periods of low soil temperature and warm air temperature could delay budbreak in grapevines. The relationship between soil temperature, budbreak, and growth has been tested on just a few *Vitis vinifera* L. cultivars. An improved understanding of this relationship would be beneficial for grape producers on the Texas High Plains. Therefore, objectives of this research were to investigate the influence of root-zone chilling on budbreak and vine growth of two *Vitis vinifera* L. cultivars.

MATERIALS AND METHODS

Experiments were performed in greenhouses at the Texas Tech University greenhouse complex. During the spring of 1999, two experiments were conducted. Experiment One began 11 March and concluded 3 April (Julian day 70 to 93). Experiment Two began 25 April and ended 9 May (Julian day 115 to 129). Because of differences in budbreak timing, two species of *Vitis vinifera* L. ('Cabernet Sauvignon' and 'Chardonnay') grafted onto 5BB Kober rootstocks were selected. Dormant plant material was received in February and was placed in a cooler held at 39 °F until initiation of experiments.

Three stainless steel tanks were constructed. Each tank was supported by an individual frame that held the tank two feet above the greenhouse floor. Each tank had a height of 3.2 feet, a width of 2.6 feet, and was 4.2 feet long. To help maintain a constant temperature, R-13 insulation was wrapped around each individual tank. Two tanks were equipped with six horsepower compressor units circulating Freon through 0.25 inch copper tubing. Tubing was placed along the bottom of each tank at 6 inch spacing. A submersible 150-gallon per minute pump circulated water in each of the chilled water tanks. For the duration of the experiment, tanks used for chilling were controlled by thermostats that were set at 35°F and 45°F. A third tank was set up as a non-chilled control (soil temperature dependant upon greenhouse air temperature and incoming solar radiation).

Five-gallon metal pots were selected as containers. To prevent leakage, container seams were sealed with waterproof silicone. To keep containers submerged, the bottom of each container was lined with three inches of pea gravel followed by three inches of coarse sand. Ball Growing Mix #1 (George J. Ball Inc., Pine Bluff, AR) was used as the growing medium. To ensure plants had water, prior to filling containers the growing medium was moistened. Pots were filled with potting medium to within 2 inches of the top of the container. Six containers were placed inside each tank and tanks were filled with water to the level of the potting media. Tank water was then allowed to chill to desired treatment temperatures. After the desired water temperature was obtained, two plants of each cultivar were planted in each container. Throughout the duration of the experiment, plants did not receive supplementary lighting, or additional irrigation.

Each grapevine was pruned to two canes with each cane having five buds. Budbreak was defined as when buds began to swell and new shoot growth was first evident (Zelleke and Kliewer 1989). Experiments concluded when budbreak occurred on a minimum of 50 percent of the buds on each grapevine. Evaluation of budbreak was performed on a daily basis. Each day, the number of new broken buds on each grapevine was recorded. After each experiment was terminated, new shoot growth and roots were harvested. After samples were dried, shoot and root dry mass were measured.

During each experiment, soil temperature was measured with two, type T (copper-constantan) thermocouples in each container (Omega Engineering, Inc., Stamford, CT). Each thermocouple was buried two inches below soil level near the root-zone of one vine. Water temperature was measured by one thermocouple placed in the center of each tank about six inches below the surface. Thermocouples were connected to a datalogger (Model 21X, Campbell Scientific, Inc., Logan, UT) using a multiplexer (Model AM416, Campbell Scientific, Inc.). Inside the greenhouse, incoming shortwave radiation was measured with a pyranometer (Model LI-200SA, LI-COR Inc., Lincoln, NE), and greenhouse air temperature and relative humidity were measured with a combination temperature and humidity sensor (Model CR500, Campbell Scientific, Inc.). Climatic data were recorded with a datalogger (Model CR10X, Campbell Scientific, Inc.). Sensors and thermocouples were scanned every 30 seconds and averages were taken every half-hour.

Each tank contained six pots and each pot contained two vines of each cultivar. For each experiment, 36 plants of each cultivar were evaluated. Data from each experiment were analyzed separately. Total budbreak (%), number of days in treatment until budbreak, and growth data were subjected to analysis of variance using the general linear model procedure appropriate for a split plot design (water temperature = whole plot, cultivar = split plot) (SAS version 8.0, SAS Institute Inc. 1999). If significant differences were found, means were separated by Fisher's least significance difference procedure ($P < 0.10$). Mean daily total shortwave radiation (MJ m^{-2} day^{-1}), greenhouse air temperature (°F), and container media temperature (°F) (± SE) were plotted against Julian day. Total daily shortwave radiation (independent variable) and mean daily greenhouse air temperature (dependent variable) data were analyzed by regression analysis. Linear or quadratic curves were selected according to significance of the equation and coefficient of determination (R^2) value (SAS 1999).

RESULTS

Greenhouse climatic conditions varied between Experiments One and Two (Figure 2). During Experiment One, mean total daily shortwave radiation was about 22 percent less than mean total daily shortwave radiation during Experiment Two. Mean daily greenhouse air temperature followed a similar trend. Due to cloud cover, total daily shortwave radiation and mean daily greenhouse air temperature fluctuated from day to day. During each experiment, container media temperatures were maintained near desired levels (Figure. 2).

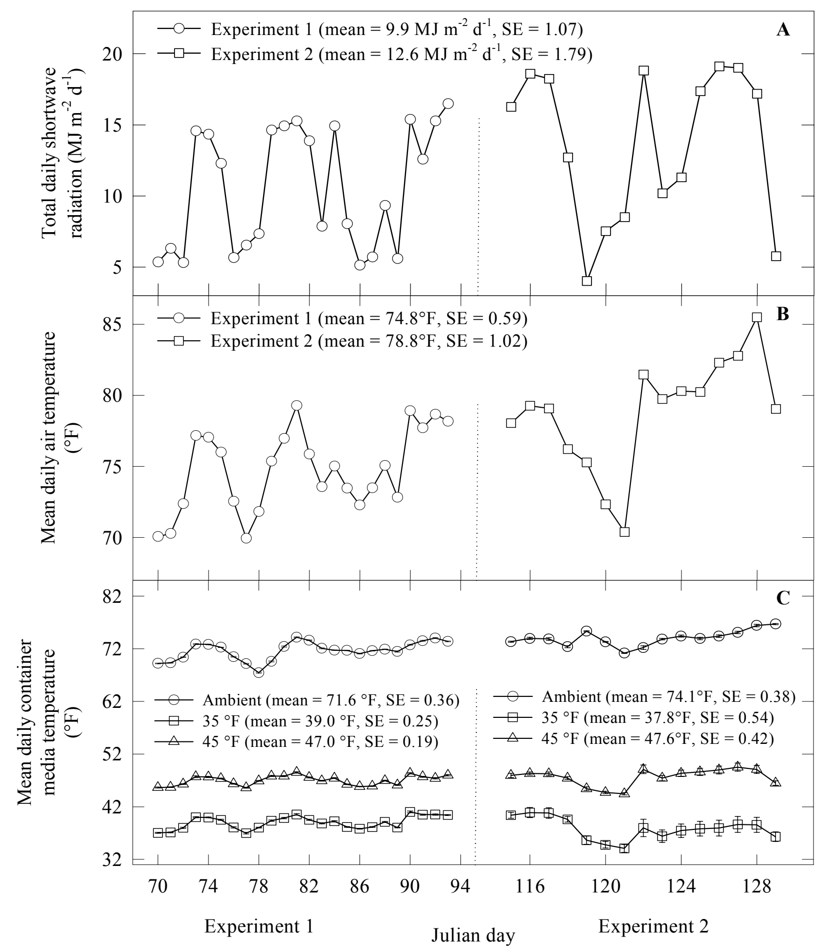

Figure 2. Daily total shortwave radiation (A), mean daily air temperature (B), and mean (± SE) daily container media temperature (C), for two cultivars of containerized *Vitis vinifera* ('Cabernet Sauvignon' and 'Chardonnay'), grown under greenhouse conditions during two experiments (Experiment One Julian day 70 to 93 and Experiment Two Julian day 115 to 129, 1999) in three water temperature treatments (ambient, 35°F, and 45°F).

For Experiment One, percent total budbreak was not different between root-zone temperature treatments ($P < 0.39$), but differences between treatments were present for Experiment Two ($P < 0.02$) (Figure 3). In experiment two, approximately 79 percent of buds on vines exposed to 35 °F water temperature broke dormancy, while about 93 percent of buds on vines exposed to ambient and 45 °F water temperatures broke dormancy. For Experiments One and Two, percent total budbreak between cultivars was different ($P < 0.02$ and $P < 0.07$, respectively). In each experiment, a greater percentage of 'Chardonnay' buds broke when compared to buds of 'Cabernet Sauvignon' (Figure 3).

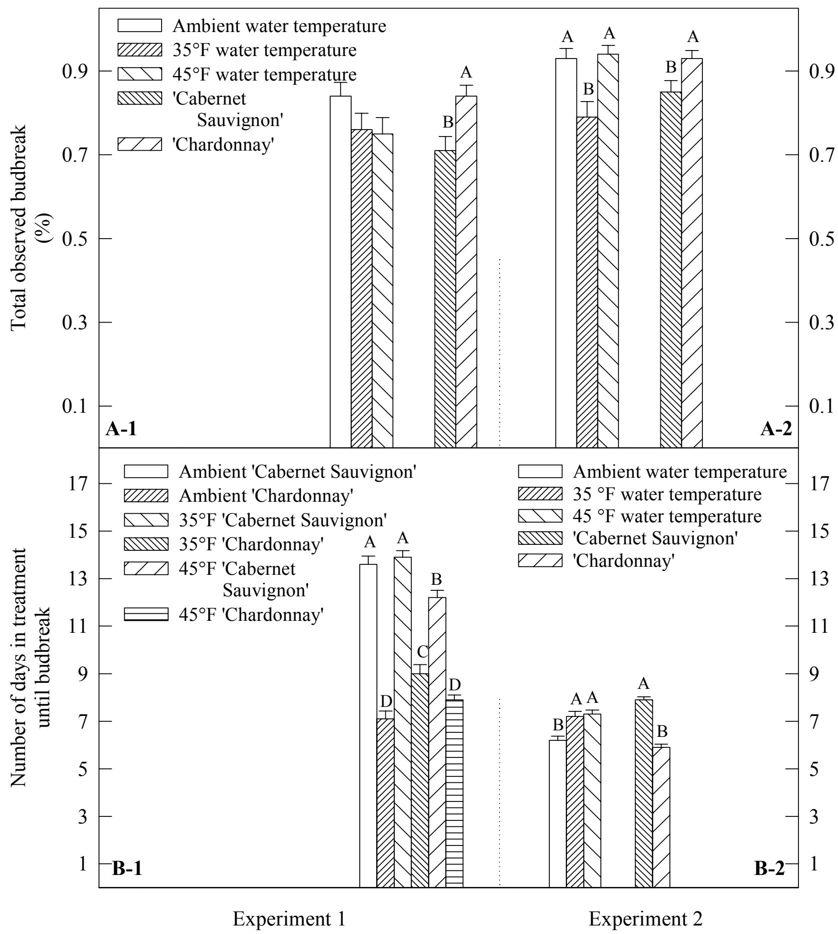

Figure 3. Total observed budbreak (A) and mean number of days in treatment until 50% budbreak (B) for two cultivars of containerized *Vitis vinifera* ('Cabernet Sauvignon' and 'Chardonnay') grown under greenhouse conditions during two experiments (Experiment One Julian day 70 to 93 and Experiment Two Julian day 115 to 129, 1999) in three water temperature treatments (ambient,35°F, and 45°F). Different letters over bars indicate differences among main effects (treatments and genotypes) (A-1, A-2, and B-2), or treatment x genotype interaction (B-1) ($P < 0.10$).

In Experiment One, cultivar and soil treatment had an interactive influence on mean number of days in treatment until budbreak ($P < 0.06$) (Figure 3). Mean number of days until budbreak was greatest for 'Cabernet Sauvignon' exposed to ambient (13.6 days) and 35°F (13.9 days) water temperatures. Mean number of days in treatment until budbreak was least for 'Chardonnay' exposed to ambient (7.1 days) and 45 °F (7.9 days) water temperatures. For Experiment Two, cultivar and soil treatment did not have an interactive influence on mean number of days in treatment until budbreak. However, differences were found between soil temperature treatments ($P < 0.004$) and cultivars ($P < 0.0001$). Grapevines exposed to ambient water temperature broke bud about one day earlier than vines exposed to either 35°F or 45°F water temperatures, and budbreak occurred approximately two days earlier for 'Cabernet Sauvignon' when compared to budbreak for 'Chardonnay' (Figure 3).

Root dry mass was influenced by soil temperature ($P < 0.002$) and cultivar ($P < 0.02$) in Experiment One (Figure 4).

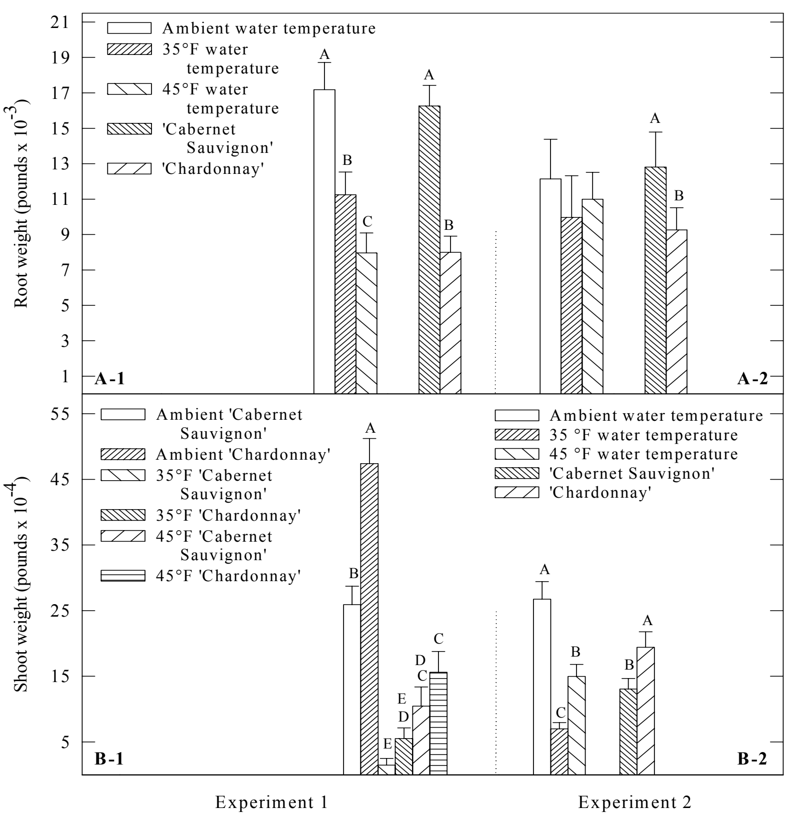

Figure 4. Mean root weight (A) and mean shoot weight (B) (± S.E.) for two cultivars of containerized *Vitis vinifera* ('Cabernet Sauvignon' and 'Chardonnay') grown under greenhouse conditions during two experiments (Experiment One Julian day 70 to 93 and Experiment Two Julian day 115 to 129, 1999) in three water temperature treatments (ambient, 35°F, and 45°F). Different letters over bars indicate differences among main effects (treatments or genotypes) (A-1, A-2, and B-2), or treatment x cultivar interaction (B-1) ($P < 0.10$).

Root dry mass was greatest for plants exposed to ambient water and least for plants exposed to the 45°F water treatment. Root dry mass for 'Cabernet Sauvignon' was over twice that for 'Chardonnay'. Root dry mass was only influenced by cultivar in Experiment Two. Once again, 'Cabernet Sauvignon' had greater root dry mass than 'Chardonnay'.

As was found for the number of days in treatment until budbreak in Experiment One, in Experiment One there was a cultivar and soil temperature interaction on shoot dry mass ($P < 0.02$) (Figure 4). Shoot mass was greatest for 'Chardonnay' grapevines grown in ambient water and least for 'Cabernet Sauvignon' grapevines exposed to 35°F water. However, shoot differences between 'Cabernet Sauvignon' and 'Chardonnay' only occurred in the ambient water treatment. In each of the other water temperature treatments, there were no differences in shoot growth between cultivars. Data from Experiment Two revealed that soil temperature ($P < 0.0001$) and cultivar ($P < 0.01$) influenced shoot growth (Figure 4). Grapevines exposed to ambient water temperature had approximately two times more shoot mass than grapevines exposed to the 45°F water treatment and approximately four times more shoot mass that grapevines exposed to the 35°F water treatment. Shoot mass for 'Chardonnay' was nearly 33 percent greater than shoot mass for 'Cabernet Sauvignon' (Figure 4).

DISCUSSION

Mean greenhouse air temperature was maintained within the optimum range for apical grapevine growth (68°F to 96°F) (Kliewer 1975). Fluctuations in mean daily greenhouse air temperature were closely related to total daily shortwave radiation ($R^2 = 0.71$). This explains the relationship between mean daily greenhouse air temperature and mean greenhouse total daily shortwave radiation (Figure 2). Although water in chilled tanks was maintained near 35°F and 45°F (data not shown), media insulating properties likely increased container media temperature when compared to water temperatures (Figure 2). Zelleke and Kliewer (1979) reported optimal root temperature for 'Cabernet Sauvignon' budbreak and shoot growth is 77°F to 86°F. Results from our research indicate soil temperatures at or near this range for control grapevines and well below this range for water chilled grapevines (Figure 2).

Our research confirms findings of others (Kliewer 1975, Zelleke and Kliewer 1979) that budbreak increases, and shoot and root growth is greater, when grapevines are grown near optimal soil temperatures than when grown at sub-optimal temperatures. Grapevines grown in 35°F and 45°F soil treatments were more likely to break bud later and have a lower budbreak percentage than grapevines grown in the control treatment (Figure 3). Budbreak differences are probably due to the influence of temperature on hormone activities within the root-zone. Plant roots are a primary source of cytokinins (Cutting et al. 1991, Skene and Kerridge 1967) and cytokinins have been shown to hasten budbreak in grapevines (Weaver et al. 1968) and other fruit species (Belding and Young 1989). Low root-zone temperatures appear to reduce cytokinin production and, or translocation and therefore limit budbreak (Young 1989).

Despite identical rootstocks, 'Chardonnay' grapevines had greater budbreak percentage than 'Cabernet Sauvignon' grapevines in each experiment (Figure 3). In addition, in each soil temperature, 'Chardonnay' had fewer days in treatment until budbreak. This agrees with Lipe et al. (1992) that 'Chardonnay' breaks bud prior to 'Cabernet Sauvignon', and therefore 'Chardonnay' will have a greater percentage of buds broken earlier in the growing season. Our data suggest cultivar traits, such as budbreak, may be maintained despite the fact different cultivars are grown on identical rootstocks.

In general, root and shoot mass were dependent upon root-zone temperature (Figure 4). Regardless of root-zone temperature, cultivar differences were apparent in each experiment. Root mass was greatest and shoot mass was least for 'Cabernet Sauvignon'. 'Cabernet Sauvignon' appears to concentrate early spring growth in the root-zone (greater root mass than 'Chardonnay'), and not in budbreak or apical growth (less budbreak and lower shoot mass than 'Chardonnay'). Despite differences in root mass due to treatments in Experiment One (Figure 4), differences due to treatments were not found in Experiment Two. The reason for this is unclear, but may be suggestive of within vine variation found by Howell and Shaulis (1980). Differences in apical growth (shoot mass) between species and treatments are clear in Experiments One and Two. Despite near optimal air temperatures (Figure 2) (Kliewer 1975), shoot growth was limited due to root-zone temperature. Shoot mass differences are most likely attributed to differences in cytokinin production and, or translocation (Young 1989). Unlike previous investigations, (Kliewer 1975, Zelleke and Kliewer 1979) our research was terminated immediately following budbreak. Therefore, the influence of sub-optimal root-zone temperatures on budbreak and plant growth later in the growing season was not investigated. However, Kliewer (1975) and Zelleke and Kliewer (1979) reported reduced post-budbreak growth on grapevines receiving sub-optimal temperature treatments throughout the growing season.

This research demonstrated that root-zone chilling can delay budbreak of greenhouse grown *Vitis vinifera* L. 'Chardonnay' and 'Cabernet Sauvignon' grapevines. For grape producers on the Texas High Plains, and in other regions where freeze damage can eliminate early grapevine growth, reductions of root-zone temperature during spring deacclimation could have significant impact on the viticulture industry. However, the economic value of designing systems to decrease root-zone temperatures has not been evaluated. Cultural practices known to reduce soil temperature, such as organic mulch (Montague et al. 2000), or increased soil moisture (Kliewer 1975) may be viable options. However, additional research is needed to better understand short and long-term effects root-zone refrigeration may have on grapevines. Future research could investigate the effect of root-zone refrigeration on water and nutrient uptake, root and shoot formation, and fruit quality.

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Survival of Plant Species as a Function of Salinity and Slope Position

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ABSTRACT

An experiment was conducted during 1995-1997 at Truscott Brine Lake, Truscott, TX to determine whether any of 38 salt tolerant plant species could survive salt conditions at Truscott Brine Lake and tolerate the summer heat and winter cold of northwest Texas. Little is known regarding survival and growth of species native to salt marsh conditions of southern United States coastal regions with respect to climate which is more xeric and having a wider range of temperature extremes than coastal areas. The objective of this study was to examine the effect of pond salinity and shoreline position (proximity to pond edge) on survival of salt tolerant species and to determine which species may have potential to survive in this environment. Species selection was based on salt tolerance in Gulf and Atlantic coastal areas and in arid western U.S. Species were planted in and around 1-acre circular research ponds, 3 filled with high saline water (termed 'salt water') and 3 filled with less saline water (termed 'fresh water'). Species were planted in spoke arrangements beginning near the center of each pond and radiating outward. Each pond contained a spoke for each species, spokes were spaced uniformly, and species were assigned randomly to spokes within a pond. Three slope positions were designated on each pond spoke to correspond to 3 levels of plant submergence. These levels were position 1: never submerged; position 2: periodically submerged; and position 3: continuously submerged. Water was pumped periodically into each pond to maintain predetermined water levels. Species survival was affected by species genetics, slope position, pond x slope, species x slope, and pond x species x slope interaction. Species survival decreased as the level of submergence increased. In the summer of 1995 there was little effect of slope on species survival, but by the fall of 1997 slope positions 1, 2, and 3 had only 48%, 29%, and 9% survival, respectively. Survival rate decreased by 20% with each slope increment. Based on percentage survival sand cordgrass, saltmeadow cordgrass selection 9067788, and common reed are viable species for use on all slopes in fresh water. Saltmeadow cordgrass var. 'Sharp', 'selection 9067788', and 'Flageo' along with common reed and sand cordgrass are viable species in salt water.

KEYWORDS: Salinity, Slope, Ponds, Plant Species, Survival, Saltmeadow cordgrass

Two primary factors controlling plant establishment in saline soils are seedbed environment and the selected plant materials. Therefore, plant establishment on saline soils is dependent on water and temperature dynamics and plant adaptations which provide avoidance or tolerance to environmental stress. Soluble salts impact growth by limiting water availability (Bernstein 1961). As salt concentrations increase there is a corresponding decrease in osmotic potential of the soil solution, hence, a decline in available water. In arid and semi-arid environments, salinity interacts with temperature and precipitation to limit seed germination and seedling growth (US Salinity Laboratory Staff 1954, Caldwell 1974). A plant's capacity to tolerate, exclude or store specific ions and adjust osmotically to maintain a favorable internal water balance may be a key factor influencing salt tolerance. Some halophytes may dilute accumulated ions by increasing succulence (Caldwell 1974). The U.S. Army Corps of Engineers designed a project to collect and divert water from naturally saline streams in north Texas in an effort to reduce the salt load in downstream rivers and lakes. Truscott Brine Lake was a part of this project, entitled "U.S. Army Corps of Engineers' Red River Chloride Control Project." Truscott Brine Lake was created by capturing salt water flowing from natural springs using an inflatable low water dam, pumping the salt water several miles, and impounding it to form a salt lake near Truscott. During times of low rainfall the dam was inflated and captured water was pumped to Truscott. During periods of significant rainfall runoff, the dam was deflated and water was allowed to move downstream in a normal manner. The salt content of the spring water was thus diluted. As a result of above normal rainfall on the salt lake's watershed, the water level rose faster than anticipated. Useful life of the lake was determined by how much water could be evaporated or transpired from the lake relative to the amount of water which flowed into the lake. The faster than anticipated rise of the water in the lake threatened to shorten the useful life. It was hypothesized that plants growing near the perimeter of the salt lake or in shallow water might increase the amount of water loss from the lake by transpiring water in excess of normal evaporation from the water surface and therefore increase its life (Cox et al. 1996). Higher evapotranspiration from the lake would create a sink for additional water. In addition, any vegetation which could be induced to grow around the salty perimeter of the lake might provide food and habitat for wildlife. The objective discussed in this paper was to screen salt tolerant species that could survive and thrive in water that collected in Truscott Brine Lake.

MATERIALS AND METHODS

The study was conducted on a 7.4 acre area at the U. S. Army Corps of Engineers' Truscott Saline Collection Area ($33^0$52'N, $99^0$52'W, elevation 2450 ft), about 2 miles northwest of the town of Truscott in northwest Texas. The soil parent material consists of sandstone and limestone. The soil type was Vernon clay which is classified as fine, mixed thermic Typic Ustochrept. The long term average annual precipitation of this area is 24.88 inches, occurring mostly between the months of April and October (see Fig. 1 for distribution).

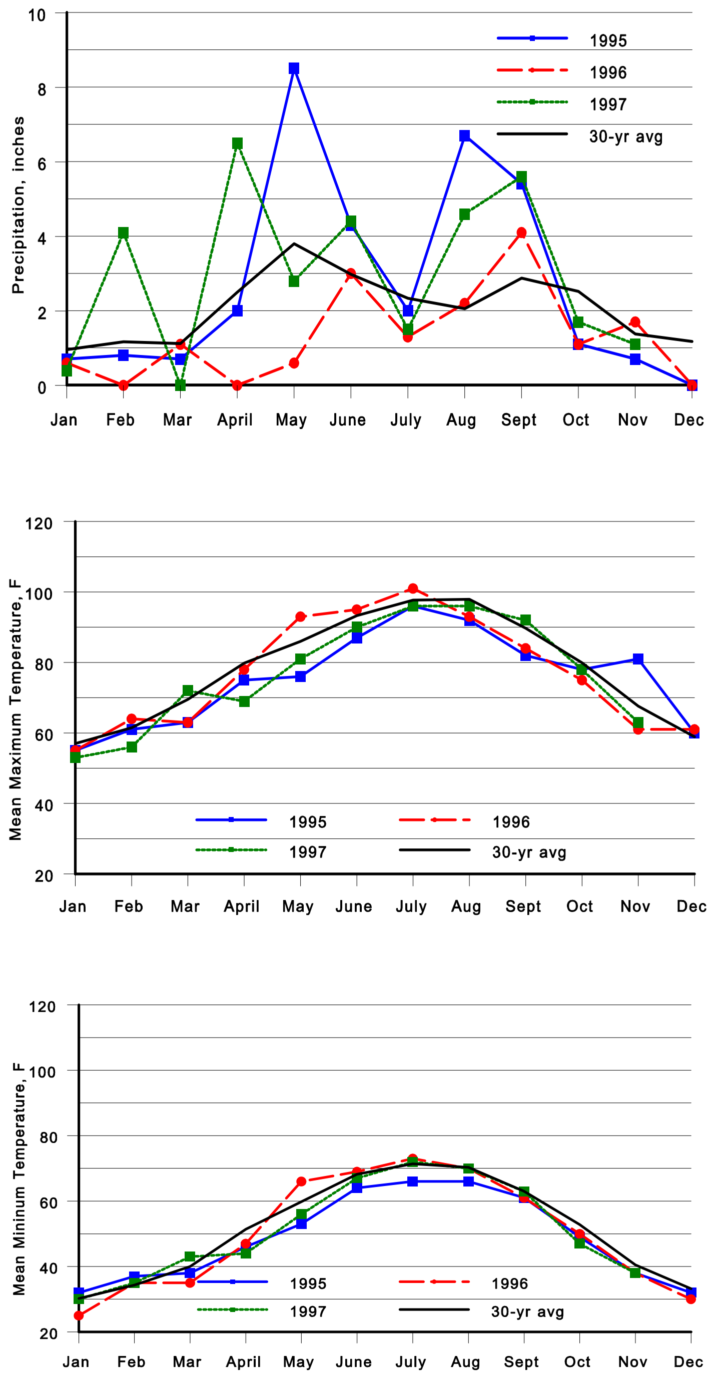

Figure 1. Monthly precipitation, mean maximum and minimum temperatures at Truscott in 1995, 1996, and 1997 and 30 year monthly means from Munday, TX (nearest station).

Pond Construction and Pump Stations

During the spring of 1995, six circular ponds were constructed adjacent to Truscott Brine Lake. Each pond was approximately 100 ft in diameter and 6.5 ft deep in the center. Each was outfitted with a removable stand pipe near the pond center and connected to an underground drain pipe. This allowed ponds to be emptied into a nearby drainage ditch when the stand pipe was removed. The Corps of Engineers constructed an earthen dam to create a fresh water source. Water captured by this dam flowed through natural drainage to an area near the test ponds. A channel from the main body of the salt lake, approximately 600 ft long, was constructed to provide a salt water source near each pond. Two pump stations were established to supply either highly saline water (termed "saltwater") or slightly saline water (termed "fresh water"). Portable pump stations powered by gasoline engines provided water for each pond. Pumps had a 3 inch discharge and were capable of filling an empty pond in less than 4 hours. Water was pumped from each source as needed and was conveyed to each pond using several sections of 4 inch diameter flexible rubber hose equipped with quick connectors. The discharge end of the rubber hoses was attached to a 30 ft long joint of 4 inch PVC pipe. Water was discharged near the center of each pond. The PVC pipe stabilized the discharge line and reduced the amount of erosion and sedimentation in each pond. Prior to planting, ponds were filled twice with fresh water to seal leaks by swelling the clay soil.

Species Selection

Species selection was based on a thorough review of literature to identify species which were tolerant of salt and could be adapted in this hot and dry environment. Species selection was also based on: (1) advice from U.S.D.A. plant material centers' experts located along the Gulf and Atlantic coasts and in arid western states and (2) from commercial businesses involved in shoreline restoration projects. A complete list of species is given in Table 1.

Table 1. Plant species raised in fresh water and salt water ponds.

Common name	No.	Scientific name	Variety
Alkali sacaton	41	*Sporobolus airoides*	Salado
American beachgrass	18	*Ammophila breviligulata*	Cape
Bayberry	9	*Myrica pensylvanica*	Wildwood
Beach plum	8	*Prunus maritina*	Ocean view
Bitter panicum[1]	10	*Panicum amarum*	North PA (from Norwood)
Bitter panicum	39		North PA (from
Coastal panicgrass[2]	24	*Panicum amarum* var.	Atlantic (from Norwood)
Coastal panicgrass	33		Atlantic(from Cape May)
Common reed	37	*Phragmites australis*	ShoreLine
Douglas CWG 94	27		
Glass wort	5	*Salicornia virginica*	
Golden creeper	6	*Ernodea litoralis*	
Gulf cordgrass	21	*Spartin spartinae*	
Hybrid willow	16		Austree
Hycrest #2 CWG 94	26		
Needle/ black rush	2	*Juncus roemerianus*	

Table 1. (Cont'd.)

Common name	No.	Scientific name	Variety
NewHy Miles City 94	25		
Panicum "X"[3]	11		
Prairie cordgrass	38	*Spartina pectinata*	
RS-Hoff natural hybrid E93	29		
RWR Syn A 94	28		
Salt meadow cordgrass	36	*Spartina patens*	Sharp
Saltbush	15	*Atriplex lentiformis*	Playa
Saltmeadow cordgrass	22	*Spartina patens*	Selection 9067788
Saltmeadow cordgrass	34		Avalon
Saltmeadow cordgrass	35		Flageo
Saltwort	7	*Batis maritina*	
Sand cordgrass	30	*Spartina bakerii*	
Sea oats	13	*Uniola paniculata*	
Sea myrtle	12	*Baccharis halimifolia*	
Seas ox-eye daisy	4	*Borrichia frutescens*	
Seashore paspalum	23	*Paspalum vaginatum*	
Seashore saltgrass	31	*Distichlis spicata*	
Seashore dropseed	40	*Sporobolus virginicus*	
Smooth cordgrass	1	*Spartina alterniflora*	Vermilion
Smooth cordgrass	19		Bayshore
Soft rush	42	*Juncus effusus*	
Soft stem bullrush	32	*Scirpus validus*	
Sweet grass	20	*Muhlenbergia filipses*	
Torpedo grass	17	*Panicum repens*	

[1]Species 10 is identical to species 39 but from different sources.
[2]Species 24 is identical to species 33 but from different sources.
[3]A selection made by Mr. Ben Norwood, Norwood Farms, McBee, S.C. from a seed production field. Ancestry and availability are uncertain.

Production of Plants

Plants for several of the species were produced from seeds. These were seeded in small cones approximately 1.6 inches in diameter and 10 inches long. Other species were ordered from commercial nurseries or USDA-NRCS Plant Materials Centers as seedlings or rooted cuttings. Seed, seedlings, and rooted cuttings were grown in a 1:3 mixture of peat moss and field soil. All species were grown in a greenhouse at the Texas Agricultural Experiment Station at Munday in Knox County, TX.

Determination of Slope Divisions

After planting, each spoke was divided into 3 sections, each containing 6 plants of one of the species. Since species had different growth habits water level in each section could not be determined before planting. Water depths which submerged 6 and 12 plants in each slope were determined for each pond. Since the ponds were not identical, these depths varied among ponds. This was done by taking elevation shots with a dumpy level between plants 6 and 7 and between plants 12 and 13 at several locations within each pond. The average of the readings taken between plants 6 and 7 in a given pond became the high water level and the average of the readings taken between plants 12 and 13 became the low water level for the respective ponds. These two elevations were marked on the drain pipe of each pond allowing an easy and quick method to determine whether the pond was low on water and when it was full. Because each pond was not constructed perfectly symmetrical, the number of plants above each water level varied slightly between spokes within a pond. Likewise, the depth of water between the two water marks varied among ponds because of the different side slopes.

Transplanting Species

Each pond was divided into 40 equal sections radiating from the center. One species was planted within each section in a single row. Rows formed a spoke pattern within a pond. Each row consisted of approximately 20 plants spaced 2 ft apart. Because of growing problems in the greenhouse, three species had less than the needed number of plants; therefore, spacing on these was increased in order to have an equal number of plants within each water depth. The exceptions to plant spacing were smooth cordgrass ‘Vermilion’ (4 ft spacing), beach plum ‘Ocean View’ (4 ft spacing), and bayberry ‘Wildwood’ (6 ft spacing). Species were randomly assigned a spoke position within each pond. The three slope sections were designated as the upper slope where plants were never submerged; mid-slope, where plants were periodically submerged; and lower slope where plants were submerged at all times. The 5 ft of each spoke nearest the pond center was not planted. The initial planting was done on May 23 and 24, 1995 with additional species planted on June 27 and 28, 1995. Two species, coastal panicgrass ‘Atlantic’ and bitter panicum ‘North PA’, were duplicated in the planting of each pond; however, plants were obtained from two different sources. Species 3 and 14 were also duplicates from different sources, but were dropped from the study because of insufficient numbers of plants.

Pond Treatment Watering Schedule

Immediately after the May transplanting, ponds were filled with fresh water to provide each species an opportunity to establish. Ponds were filled a second time prior to the June planting. Ponds were drained a few hours after each filling. Ponds were allowed to dry sufficiently to allow foot traffic before making the June planting. Following June planting ponds were again flooded twice with fresh water and drained as before. On August 1, 1995 three ponds were filled with salt water and three were filled with fresh water. Thereafter ponds had water added on a weekly basis during spring, summer and early fall. During the months when freezing was likely, water was added approximately every two weeks. Water was added to ponds as the water level approached the lower mark on a standpipe and filled to near the upper mark. Not all ponds received water at the same time or the same amount of water.

Observations and Data Analyses

The first plant count was taken immediately following each planting in 1995 and the last in October, 1997. Plant counts were recorded twice each year for each spoke. Ponds were drained approximately 10 days prior to counting and refilled after counting. Data regarding plant species survival on each slope section and for each spoke were calculated by the following formula: [(total number of plants surviving in the fall of 1997) x 100] / (Total number of plants initially planted in 1995).

The experimental design was a split-split plot. Ponds were considered main plots and were replicated three times. Species or spokes were considered subplots and slope position within a spoke was considered a sub-subplot. Data were analyzed with SAS computer programming release 6.12 using Proc GLM (SAS Institute 1996). Analyses of variance and probability levels were calculated using appropriate error terms.

RESULTS AND DISCUSSION

The species selected for use in this study were subjected to water with an extremely high salt load, wide fluctuations in annual precipitation, and numerous days with minimum temperatures below freezing. In 1995 and 1997 total annual precipitation (Fig. 1) exceeded average annual precipitation (24.88 inches) by about 8 inches while in 1996 annual precipitation was about two-thirds (16 inches) the annual average. Mean maximum temperatures were highest in 1996 and lowest in 1995. Temperatures fell below freezing (November through March) for 45 and 44 days in 1995-96 and 1996-97, respectively. All of these factors combined to influence the survivability of the species used. No attempt was made to determine which factor or combination of factors made species more susceptible. Overall percentage of plants per spoke that survived for 2.5 years was not affected by water salinity ($P = 0.6799$); about 30% of all plants survived in the fresh water versus 27% in the salt water. However, survival rate among species differed significantly ($P < 0.001$). Survival of species was also affected by species x water type interaction ($P < 0.001$), slope position ($P < 0.001$), slope x species ($P < 0.001$), and salinity x species x slope ($P < 0.001$) interaction. For example, a species may have survived significantly better in fresh water than in salt water on the upper slope.

Saltmeadow cordgrass, selection 9067788, had the highest survival rate (85%), whereas prairie cordgrass had the least survival (< 1%) (Table 2). Species not surviving in both types water included beach plum 'Ocean View', Douglas CWG 94, golden creeper, Hycrest #2 CWG 94, RS-Hoff natural hybrid E93, saltwort, and torpedo grass. Although species survival was significantly affected by slope position, salinity x slope interaction did not affect species survival ($P = 0.1087$). Species survival decreased on the lower portion of the slopes. Upper slope, mid-slope, and lower slope sections had 48, 29, and 9% of the plants surviving when averaged across salinity and species (Table 2). Overall, species survival decreased about 20% per slope increment toward the pond centers. Even though species survival among slope positions differed significantly, saltmeadow cordgrass, selection 9067788, had the highest survival on all slopes. On the upper slope, gulf cordgrass also had 100% survival, but prairie cordgrass had < 3% survival; 9 of 38 species did not survive on this slope. On the mid-slope, 17 species had survival <6%, and on lowest slope, 26 species had survival <3%.

Table 2. Percent of plants surviving 2.5 years after planting at the Truscott Brine Lake by species, salinity, and slope position (1-3), Truscott, TX.

Species	Fresh Water				Salt Water				Average			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Alkali sacaton	88.9	27.8	0.0	38.9	83.3	38.9	0.0	40.7	86.1	33.3	0.0	39.8
American beachgrass, 'Cape'	27.8	0.0	0.0	9.3	0.0	0.0	0.0	0.0	13.9	0.0	0.0	4.6
Bayberry, 'Wildwood'	16.7	0.0	0.0	5.6	0.0	0.0	0.0	0.0	8.3	0.0	0.0	2.8
Beach plum, 'Ocean View'	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bitter panicum, 'North PA' (from Brooksville)	100.0	72.2	16.7	63.0	83.3	16.7	0.0	33.3	91.7	44.4	8.3	48.1
Bitter panicum, 'North PA' (from Norwood)	100.0	55.6	22.2	59.3	77.8	11.1	0.0	29.6	88.9	33.3	11.1	44.4
Coastal panicgrass, 'Atlantic' (from Cape May)	100.0	77.8	0.0	59.3	88.9	33.3	0.0	40.7	94.4	55.6	0.0	50.0

Table 2. (Cont'd)

Species	Fresh Water				Salt Water				Average			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Coastal panicgrass, 'Atlantic' (from Norwood)	100.0	83.3	5.6	63.0	83.3	16.7	0.0	33.3	91.7	50.0	2.8	48.2
Common reed	94.4	77.8	61.1	77.8	94.4	83.3	44.4	74.1	94.4	80.6	52.8	75.9
Douglas CWG 94	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glass wort	0.0	0.0	0.0	0.0	0.0	22.2	0.0	7.4	0.0	11.1	0.0	3.7
Golden creeper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gulf cordgrass	100.0	77.8	16.7	64.8	100.0	88.9	0.0	63.0	100.0	83.3	8.3	63.9
Hybrid willow	38.9	0.0	0.0	13.0	0.0	0.0	0.0	0.0	19.4	0.0	0.0	6.5
Hycrest #2 CWG 94	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Needle/ black rush	61.1	100.0	22.2	61.1	88.9	72.2	22.2	61.1	75.0	86.1	22.2	61.1
NewHy Miles City 94	16.7	11.1	0.0	9.3	0.0	0.0	0.0	0.0	8.3	5.6	0.0	4.6
Panicum "X"1	94.4	55.6	5.6	51.9	88.9	16.7	0.0	35.2	91.7	36.1	2.8	43.5
Prairie cordgrass	0.0	0.0	0.0	0.0	5.6	0.0	0.0	1.9	2.8	0.0	0.0	0.9
RS-Hoff natural hybrid E93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RWR Syn A 94	27.8	0.0	0.0	9.3	22.2	0.0	0.0	7.4	25.0	0.0	0.0	8.3
Salt bush	88.9	11.1	0.0	33.3	100.0	22.2	0.0	40.7	94.4	16.7	0.0	37.0
Saltmeadow cordgrass, selection 9067788	100.0	100.0	50.0	83.3	100.0	100.0	61.1	87.0	100.0	100.0	55.6	85.2
Saltmeadow cordgrass, 'Flageo'	94.4	61.1	22.2	59.3	100.0	100.0	22.2	74.1	97.2	80.6	22.2	66.7
Saltmeadow cordgrass, 'Sharp'	83.3	33.3	22.2	46.3	100.0	100.0	83.3	94.4	91.7	66.7	52.8	70.4
Saltmeadow cordgrass, 'Avalon'	94.4	55.6	33.3	61.1	100.0	100.0	38.9	79.6	97.2	77.8	36.1	70.4
Saltwort	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sand cordgrass	94.4	100.0	50.0	81.5	91.7	72.2	11.1	58.3	93.1	86.1	30.6	69.9
Sea ox-eye daisy	83.3	33.3	0.0	38.9	94.4	16.7	0.0	37.0	88.9	25.0	0.0	38.0
Sea oats	16.7	0.0	0.0	5.6	0.0	0.0	0.0	0.0	8.3	0.0	0.0	2.8
Sea myrtle	83.3	11.1	0.0	31.5	61.1	0.0	0.0	20.4	72.2	5.6	0.0	25.9
Seashore saltgrass	83.3	41.7	0.0	41.7	100.0	94.4	55.6	83.3	91.7	68.1	27.8	62.5
Seashore paspalum	5.6	0.0	0.0	1.9	50.0	11.1	0.0	20.4	27.8	5.6	0.0	11.1
Seashore dropseed	61.1	5.6	0.0	22.2	83.3	5.6	0.0	29.6	72.2	5.6	0.0	25.9
Smooth cordgrass, 'Vermilion'	0.0	0.0	0.0	0.0	0.0	33.3	11.1	14.8	0.0	16.7	5.6	7.4
Smooth cordgrass, 'Bayshore'	27.8	0.0	0.0	9.3	17.8	44.4	16.7	26.3	22.8	22.2	8.3	17.8
Soft stem bullrush	38.9	88.9	16.7	48.1	0.0	5.6	5.6	3.7	19.4	47.2	11.1	25.9
Soft rush	27.8	33.3	0.0	20.4	0.0	0.0	0.0	0.0	13.9	16.7	0.0	10.2
Sweet grass	94.4	27.8	0.0	40.7	0.0	0.0	0.0	0.0	47.2	13.9	0.0	20.4
Torpedo grass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Average	51.1	31.0	8.6	30.3	45.4	27.6	9.3	27.4	48.2	29.3	9.0	28.8

As reported earlier, species survival was affected by salinity x species x slope interaction. On upper slope of both water types, gulf cordgrass and saltmeadow cordgrass, selection 9067788, survived 100%. Bitter panicum (both sources) and coastal panic grass (both sources) had 100% survival in fresh water whereas saltmeadow cordgrass (var. 'Flageo', 'Sharp', and 'Avalon'), salt bush, and seashore saltgrass had 100% survival in salt water. On the mid-slope section, saltmeadow cordgrass, selection 9067788, survived 100% in both water types, sand cordgrass and needle/black rush survived 100% in fresh water, and saltmeadow cordgrass (var. 'Flageo', 'Sharp', and 'Avalon') survived 100% in salt water. No species in either water type had 100% survival on the lower slope. On the lower slope of the fresh water ponds, common reed, saltmeadow cordgrass, selection 9067788, and sand cordgrass had the highest survival (50% or more). On the same slope of the salt water ponds, saltmeadow cordgrass (var. 'Sharp' and 'selection 9067788') and seashore saltgrass had the highest survival (83,61, and 56%, respectively).

CONCLUSIONS

Several of the species chosen for this study flourish naturally in tidal areas along the coast where they are periodically inundated with salt water. In contrast, our study placed them in a situation where they were continually flooded on the lowest slope section and often flooded in the mid-slope section for a significant length of time. Because of this, it was expected that many, if not all, species would not perform well in the lowest slope section and perhaps would not survive in the mid-slope section. Further, it is doubtful that any species capable of growing while fully inundated would be capable of transpiring more water than would be evaporated from a free water surface. Therefore, we concluded that species growing completely inundated probably would not be useful in meeting the eventual project goal of increasing the water lost from the lake.

Transpiration for several of the species was measured to obtain an estimate of water loss. Those results are not the focus of this publication and are not discussed. Vegetation growing at the water's edge would not impede evaporation from the free water surface of the lake and yet would be close enough to the lake to draw water from the lake, thus increasing loss of water from the lake. The benefit to having vegetation growing in the most shallow water would be that as the shoreline receded during times of low runoff and high evaporation and more lake bed became exposed, plants would already be established and would continue to grow and use water. In the event that the lake level increased, plants selected should have the ability to continue to spread up the slope as the water level increased. This could be accomplished through scattering of seeds, rhizomes, or stems which easily root when placed in contact with moist soil. Some of the species requiring less salty water to survive could be established in watershed areas which contribute fresh water to the main lake. Small ponds holding fresh water in the upper reaches of the watershed would also be likely locations for establishment. This will decrease the amount of fresh water entries in the salt lake.

Several species were identified in this study which are capable of surviving around the perimeter of Truscott Brine Lake. These should be successful if grown on areas with relatively flat slopes adjacent to shore lines. These areas with flat slopes will yield larger areas of exposed soil with relatively small drops in water elevation. Several of the species are also capable of sufficient growth to be useful as wildlife habitat.

Additional observations were made with respect to species grown in this study. All varieties/selections of saltmeadow cordgrass, bitter panicum var. North PA, sand cordgrass, panicum "X", gulf cordgrass, and alkali sacaton grew vigorously around the perimeter of salt water. However, these species did not exhibit a great amount of spreading during this study. Other species, such as sea ox-eye daisy and common reed, spread vigorously during the first summer of this study. Sea shore paspalum also spread vigorously the first summer, but was very slow to start regrowth the following spring and never was as vigorous as it had been the first growing season, apparently severely damaged by the winter cold. On the other hand, seashore saltgrass grew rather slowly the first summer but became very vigorous during the second growing season. Sea myrtle grew very well but attracted wildlife that continuously reduced plant numbers. Saltbush spread readily when moisture was present to germinate the abundant seed produced. It was not determined if this seed was useful as a food source for wildlife.

In conclusion, 10 species had 50% or greater survival and tolerated seasonal heat and cold of the Texas Rolling Plains. Common reed, needle/black rush, sand cordgrass, and saltmeadow cordgrass survived on all three slopes in both ponds. Bitter panicum, coastal panic grass, and panicum 'X' survived on the upper slope in both ponds and also on the mid-slope in fresh water ponds. Alkali sacaton, gulf cordgrass, and seashore salt grass survived on both slopes in both ponds; additionally, seashore saltgrass survived on the lower slope in salt water ponds. Saltbush, sea ox-eye daisy, sea myrtle, and seashore dropseed survived on the upper slope in both types of water. Sweet grass survived on the upper slope and soft stem bullrush survived on the mid slope of fresh water ponds. Overall, in salt water ponds saltmeadow cordgrass (all four varieties) had 85% and on the upper two slopes had 100% survival.

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