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.

Genotype	HVI Fiber Quality				Market Value	Lint Yield	Gross Return
	Length	Strength	Micronaire	Uniformity			
	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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