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Potential for Using Leaf Turgidity to Select Drought Tolerance in Cotton[1]

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ABSTRACT

Variability in leaf turgidity has been observed among cotton (*Gossypium hirsutum* L.) strains grown under water deficit field conditions. Two photoperiodic (long-night) strains were identified as having extreme phenotypic expressions of leaf turgidity. Under water deficit conditions T25 retained turgid leaves, while T169 wilted severely. The objective of this research was to determine the potential utility of using the leaf turgidity trait to select germplasm with enhanced drought tolerance. Three types of studies were conducted on these two strains: (i) growth evaluations in wet and dry field conditions and in glass house pots, (ii) evaluations of physiological responses in wet and dry field conditions, and (iii) seed cotton yield evaluations in dry field conditions on germplasm that was introgressed with genes for the day-neutral flowering habit. Under irrigated field conditions, shoot biomass did not differ between T25 and T169, but the interaction between tests and entries was significant. Compared under water-deficit field conditions, the nonwilting T25 strain produced significantly more shoot biomass than did T169. In glass house studies, T25 produced more root and shoot biomass with significantly higher water-use efficiency than did T169. Physiological evaluations showed that under irrigated field conditions, T25 maintained higher leaf water potential, lower leaf conductance, and equal gross photosynthetic rates compared to T169. Under dry (rainout shelter) conditions, T25 always had higher water potential than did T169. At 70 to 80 days after planting (DAP), T25 had higher leaf conductance and photosynthetic rates than did T169. Seed cotton yield was higher for the T25 germplasm than for the T169 germplasm in either population or selected line comparisons. Observed variability in leaf turgidity of cotton under water-deficit field conditions may be useful in selecting germplasm with enhanced drought-tolerance.

***Additional index words:* *Gossypium hirsutum* L., Leaf water potential, Leaf conductance, Gross photosynthesis, Shoot biomass, Seed cotton yield, Leaf wilting, Water-use efficiency.**

IN the past, environmental factors, other than water, have determined the yield of cotton (*Gossypium hirsutum* L.) grown in the southern Great Plains. However, with the gradual depletion of the water from the Ogallala aquifer coupled with the steadily rising cost of energy to pump the remaining water, more cotton is being grown under limited water conditions. These conditions require that the existing water supplies be used efficiently. One approach is to develop cotton germplasm that either uses available water supplies more efficiently or can better withstand the effects of short periods of water stress. In an attempt to identify such cotton germplasm, we observed differences in the leaf turgidity among cotton strains (12).

Cotton leaves wilt when leaf turgor pressure is lost. Turgor is lost when the atmospheric demand exceeds the ability of the plant to compensate, through increased root absorption, for water lost through transpiration. Leaf turgor is maintained through nonlimiting root uptake of soil water, decreased osmotic potential through either active or passive accumulation of cell solutes, or stomatal regulation of transpiration (10). Leaf wilting has been suggested as a mechanism whereby plants reduce the atmospheric heat load associated with water deficits (6). Leaf wilting reduces the amount of leaf area exposed to direct solar radiation. We have observed that transpiration, although greatly reduced, can continue from wilted cotton leaves (12).

The purpose of this research was to compare growth rates, physiological responses, and seed cotton yield under water stressed field conditions between cotton strains that differed in ability to maintain leaf turgidity under dry field conditions.

MATERIALS AND METHODS

In 1973, over 100 photoperiodic (long-night) nonflowering cotton strains were planted in the field to observe their response to water stress. The strains were from the World Collection of cotton germplasm maintained by USDA-ARS scientists at College Station, TX. Two strains were observed to have extreme responses in their ability to maintain leaf turgidity. In this test, T25 (P.I. 154035) maintained turgid (nonwilted) leaves while the leaves of T169 (P.I. 163689) wilted severely. Additional observations on many strains from the World Collection and among many cultivars showed that variabliity exists for leaf turgidity in response to water stress. In these many observations of leaf characteristics over a 10-year-period, T25 remained at one extreme while T169 remained at the other.

The T25 strain was collected originally in Teran, Chiapas, Mexico in 1946 by Richmond and Manning (1). The T169 strain was collected in Santa Elena, Chiquimula, Guatamala in 1948 by Ware and Manning (1). Both locations have a semiarid climate, and we assume that both cotton strains are adapted for growth in these rather dry, harsh conditions. The leaves of T25 are parahelionastic and tend to track the sun from dawn to dark while the leaves of T169 have only a minor parahelionastic response. Both the wilted and nonwilted leaves have a potential advantage in reducing the atmospheric heat load associated with dry, hot atmospheric conditions. By wilting, T169 reduces the leaf area exposed to direct solar radiation while the more erect leaves of the T25 may accomplish the same function through their vertical orientation.

Three types of studies were conducted on these two strains: (i) water stressed and nonstressed growth evaluations, (ii) physiological responses to wet and dry soil water conditions, and (iii) yield evaluations under nonirrigated conditions. All studies were planted on either an Amarillo loam (fine-loamy, mixed, thermic Aridic Paleustalf) or an Acuff loam (fine-loamy, mixed, thermic Aridic Paleustoll) and were irrigated with 15.2 cm of water prior to planting. Routine cultural and tillage practices were used to control weeds and to maintain soil fertility levels.

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Growth Studies Six irrigated and six nonirrigated studies were conducted from 1978-1983. In all studies, plants were spaced 15.2 cm apart and shoot biomass was determined at 80 ± 2 days after planting (DAP). The six irrigated studies were:

1. 1978—Big Spring, TX, 40 cm water applied, plots 1 × 11 m, shoot biomass harvested on 17 August.
2. 1981—Lubbock, TX, 15 cm water applied, plots 1 × 11 m, biomass on 13 August.
3. 1981—Big Spring, 40 cm water applied, plots 1 × 11 m, biomass on 19 August.
4. 1982—Rainout shelter, Lubbock, 45 cm water applied, plots 0.7 × 3 m, biomass on 17 August.
5. 1982—Lubbock, 20 cm water applied, plots 1 × 11 m, biomass on 9 August.
6. 1983—Lubbock, 38 cm water applied, plots 1 × 11 m, biomass on 3 August.

Water was applied to the irrigated plots when tensiometer readings fell below −0.05 MPa at a soil depth of 46 cm.

The six nonirrigated studies were:

1. 1978—Big Spring, plots 1 × 11m, biomass on 17 August.
2. 1980—Rainout shelter, Lubbock, plots 0.7 × 3 m, biomass on 15 August.
3. 1981—Rainout shelter, Lubbock, plots 0.7 × 3 m, biomass on 11 August.
4. 1982—Rainout shelter, Lubbock, plots 0.7 × 3 m, biomass on 17 August.
5. 1982—Rainout shelter, Lubbock, plots 0.5 × 3 m, biomass on 11 August.
6. 1983—Rainout shelter, Lubbock plots 0.5 × 3 m, biomass on 3 August.

In each of the nonirrigated studies, no additional precipitation occurred on the plots after the initial application of 15.2 cm of water.

Since water use data was not obtained from these field studies, a glass house study was conducted during the winter (January to March) of 1984 to obtain transpirational water use and total biomass (shoot and root). Plastic pots (volume = 37.8 L, weight = 1 kg) were filled with exactly 56.4 kg air dried Amarillo fine sandy loam. Water was added until it ran out of the small holes in bottom of the pots. At this point, the surface was sealed with plastic and 3 days later all pots weighed 67.0 kg. The small holes in bottom of the pots were sealed with tape to reduce water loss through evaporation.

Three seed of each strain (T25 and T169) were planted under the plastic surface. The seed for T25 averaged 85 mg per seed and T169 averaged 111 mg per seed. Three pots of both strains were planted in paired plots. At 14 DAP, small cuts were made in the plastic surface to allow the hypocotyl and cotyledons to emerge above the plastic surface. Tape was used to seal around the hypocotyls. Two of the three seedlings were harvested for biomass at 14 DAP. Observational notes were taken on the plants during the study. The date when leaf wilting occurred was recorded for each plant. When leaves dropped from the plants, they were saved and included in the total biomass. The study was terminated at 67 DAP. The pots were weighed to determine total water used. The shoots were divided into leaves, stems, and hypocotyl and dried at 80°C. The roots were washed out of the soil and separated into tap and fibrous components and dried at 80°C. During the entire study, glass house temperatures were maintained at 30°C ± 5°C. Light transmission was greater than 85% of the outside. No control was exercised over relative humidity and it ranged from 50 to 90%. Air movement within the glass house was minimal. The increased humidity and reduced air movement should have increased the leaf boundary layer resistance.

Physiological Studies. Leaf water status (water potential, osmotic potential, and turgor pressure), leaf conductances, and gross photosynthesis were measured on paired wet-dry plots in 1981 to 1983 (irrigated growth studies no. 2, 4, 5, 6 and nonirrigated studies no. 3, 4, 5, 6). All measurements were made on the same uppermost, fully expanded leaf. All data were collected between 1000 and 1600 h and when photosynthetic photo flux densities (PPFD) were greater than 1500 μ mol $m^{-2}s^{-1}$. Leaf water status was measured with Merrill[3] leaf cutter psychrometers (14). Each psychrometer was calibrated with NaCl solutions at 30°C in a water bath controlled to ± 0.1°C. All readings were made in the 30°C water bath. Leaf samples were punched from intact leaves, immediately sealed in the psychrometer chambers, and equilibrated for 4 h prior to measuring water potential. After water potential was determined, the psychrometer chambers were placed in liquid N for about 1 min, allowed to reequilibrate for 1 h, and osmotic potential was estimated. Turgor pressure was estimated as the difference between leaf water potential and osmotic potential.

Leaf conductances, photosynthetic photo flux densities, and leaf temperatures were measured with a Li-Cor 1600 steady state porometer. Leaf temperatures were also determined by a hand-held infrared thermometer immediately prior to making other readings.

Gross photosynthetic rates were determined with a modified $^{14}CO_2$ technique (9). After an 18 exposure to $^{14}CO_2$, the leaf disc were placed in glass scintillation vials and digested in 0.2 mL of 70% (v/v) $HClO_4$ and 0.2 ml of 30% (v/v) H_2O_2 at room temperature. After 24 h, 15 mL of scintillation cocktail was added to each vial and they were counted in a Beckman LS 7000 Liquid Scintillation Spectrometer[3]. The scintillation cocktail consisted of toluene (75% (v/v) by volume), Triton X-100 (25% (v/v) by volume), 6.0 g of PPO, and 0.2 g of POPOP L −1.

Seed cotton Yield Evaluations Since both T25 an T169 are photoperiodic and will not flower at Lubbock, crosses were made with Lubbock Dwarf (13) to introgress day-neutral flowering genes into the two strains. Flowering plants were selected from the F_2 populations of these crosses. The flowering plants were backcrossed to either T25 or T169 and flowering plants were again selected from the BC_1 F_2 population. These flowering plants were again backcrossed to either T25 or T169 and flowering plants were selected from the BC_2 F_2 generation. The flowering plants from each germplasm source (T25 and T169) were used to form flowering populations. These populations were grown for two seasons and selection pressure was placed on early crop maturity and general adaptation to the Lubbock growing conditions.

After two growing seasons, seventy plants were selected from both the T25 and T169 populations in 1980. These selections were based on phenotypic similarity (primarily leaf turgidity) with the respective parental strains. In 1981, seed from each of the selected plants were planted in paired plots with 'Paymaster 303' for a comparison with a widely grown commercial cultivar. An irrigation prior to planting of 15.2 cm of water was applied with no post-planting irrigation water applied. Twenty-eight cm of rainfall occurred during the growing season. The paired plots were each 1 × 11 m and separated by 2 m between plots. Seed cotton yield was determined for both Paymaster 303 and

[3] Mention of a trademark or proprietary product does not infer any endorsement of preferential treatment of the product by the USDA.

the selected strain and the ratios between their seed cotton yields were used to select strains for additional testing.

In 1982, the five strains with the highest ratios from each germplasm source (T25 and T169) were planted at Big Spring and Lubbock. Irrigation water was not applied to either location and rainfall during the growing season consisted of 36 cm at Lubbock and 29 cm at Big Spring. Two planting patterns were used at Big Spring - solid plant and plant two rows skip two rows (2 × 2). All seedling stands were adjusted to 81 000 plants ha^{-1}. Comparisons were made between the two germplasm sources for seed cotton yield in kilograms per hectare.

RESULTS AND DISCUSSION

The most obvious phenotypic difference between T25 and T169 was the degree of leaf turgidity under dry field conditions. A comparison between the strains for turgor pressure over a wide range of leaf water potentials confirmed the observed differences in leaf turgidity (Fig. 1). T169 reached zero turgo pressure at a leaf water potential of about −1.9 MPa while T25 reached zero turgor pressure at a leaf water potential of −2.5 MPa. The relationships showed that at high water potentials, lower osmotic potentials were maintained in T25 than in T169.

Growth Studies Previous studies of shoot biomass in cotton have shown that differences in dry matter accumulation may be associated with seed size (2). Prior to planting, seed size averaged 100 mg for T25 and 99 mg for T169. Under irrigated conditions, there were no differences between the two strains in shoot biomass production at 80 DAP (Table 1). The interaction between the tests and the two strains was significant. In the two tests, where the biomass production was the highest, T169 produced the most biomass, while in the other four tests T25 produced the most biomass. In the nonirrigated tests, differences between the two strains did occur and the interaction between tests and entries was not significant (Table 1). In each of the six tests, T25 produced more biomass at 80 DAP than did T169. T25 produced an average of 20% more shoot biomass and this advantage ranged from 13 to 37%. Rainout shelters were used in five of the six nonirrigated tests. These shelters produced very consistent data within a test, but changes in spacing between plots (1.0 to 0.5 m) for different tests caused significant differences between tests.

The results of the glass house study on the relationship between transpirational water use and biomass showed that at 14 DAP, the T169 seedlings weighed 0.11 g and the T25 seedlings weighed 0.07 g. Between 40 and 50 DAP, the T169 plants appeared to be larger than the T25 plants. At 45 DAP, the T169 plants wilted and were permanently wilted (did not recover early in the morning) by 56 DAP. The T25 plants wilted at 53 DAP and were permanently wilted by 64 DAP. At 67 DAP, T25 produced 12.5% more total biomass than did T169 while using exactly the same amount of water (Table 2). All pots weighed 57.7 kg at 67 DAP. This difference resulted in a significantly greater water-use efficiency for T25. Both shoot and root biomass was significantly larger for T25 than for T169. The root to shoot ratio was larger for T25 (41%) than for T169 (37%), but the difference was not statistically different.

Physiological Studies The relationship between leaf water potential and leaf conductance (only leaf sur-

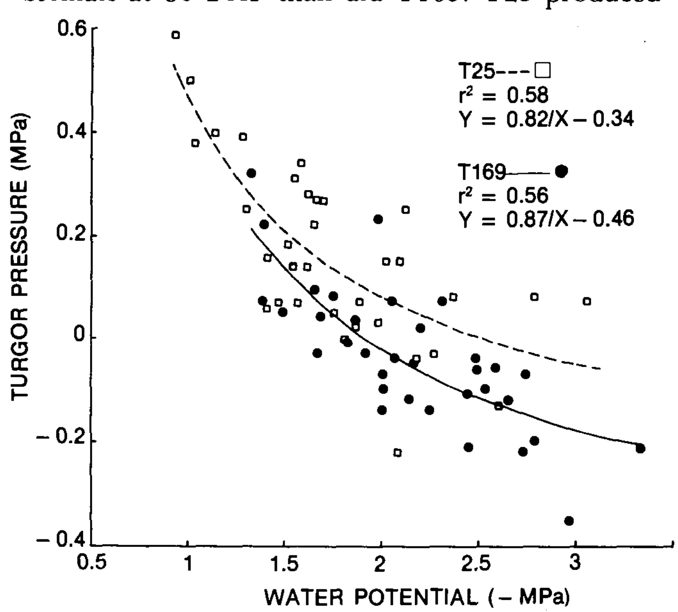

Fig. 1. Comparison of the relationship between turgor pressure and leaf water potential for two cotton strains.

Table 1. Weighted mean squares from analysis of variance and mean comparisons for shoot biomass of two cotton strains at 80 days after planting (DAP) in six irrigated and six nonirrigated tests, 1979–1983.

Source	df	Mean squares: Irrigated	Mean squares: Nonirrigated
Tests (T)	5	1460.3**	191.3**
Entries (E)	1	25.9	56.1**
T × E	5	70.8**	1.2
Error	16	16.7	1.9
CV %		13.2	10.6
		Mean per plant	
		g	
T25		30.3	14.3
T169		31.8	11.4

** Significant at the 0.01 probability level.

Table 2. Comparison of biomass, root to shoot ratio, and water use and water-use efficiency at 67 DAP for T25 and T169 cotton plants grown in 37.8 L pots in a glass house during the winter of 1984.

Traits	Units	Entries: T25	Entries: T169	T169/T25
				%
Total biomass	g	22.76 a*	19.91 b	87.5
Shoot biomass	g	16.13 a	14.52 b	90.0
Leaves	g	10.74 a	9.85 b	91.7
Stem	g	3.91 a	3.05 b	78.0
Hypocotyl	g	1.48 a	1.62 a	109.5
Root biomass	g	6.63 a	5.39 b	81.3
Tap	g	1.28 a	0.87 b	68.0
Fibrous	g	5.35 a	4.52 a	84.5
Root to shoot ratio	$g\ g^{-1}$	0.410 a	0.371 a	90.5
Water use	g	9298.8 a	9298.8 a	100.0
Water-use efficiency	$mg\ g^{-1}$	2.45 a	2.14 b	87.3
Transpiration ratio	$g\ g^{-1}$	408.6 b	467.0 a	114.3

* Means followed by different letters are statistically different at the 0.05 probability level based on a paired *t-test.*

face measured) showed that T25 maintained lower leaf conductances at lower water potentials compared to T169 (Fig. 2). The lower leaf conductances associated with T25 may partially explain the higher turgor pressure and reduced leaf wilting of T25.

Comparisons for leaf water potential, leaf conductance, and gross photosynthesis between T25 and T169 were made hourly (1000 to 1600 h) on 10 to 15 plants strain $^{-1}$ on certain days in 1981 to 1983 on paired wet and dry plots (Table 3). In 1981, data collected at 96 DAP showed that water potential in both the wet and dry plots was higher in T25 compared to T169 while leaf conductance was lower in T25 in the wet plots. Leaf conductance in the dry plots and gross photosynthesis in both the wet and dry plots were equal between the two strains. To evaluate the significance of the lower leaf conductance in the 1981 wet plots, data were collected in 1982 at 76 and 91 DAP. At 76 DAP, water potential was higher in T25 compared to T169 in both the wet and dry plots. Leaf conductance was higher in T169 in the wet plots and higher in T25 in the dry plots. Gross photosynthesis was equal between the strains in the wet plots, and higher for T25 in the dry plots. The results at 91 DAP were the same as those recorded at 96 DAP in 1981.

In 1983, data were collected at 50, 66, 77, and 98 DAP to further define the potential significance of the reduced leaf conductance of T25 under conditions of nonlimiting soil water. Water potential was higher in T25 compared with T169 at all four sampling dates and at both water levels. Leaf conductance was lower in T25 than in T169 at all sampling dates in the wet plots. In the dry plots, leaf conductance was equal between the two strains at 50 and 66 DAP and higher in T25 at 77 DAP. At 81 DAP, 15 cm of water was applied to the dry plots. At 98 DAP, the leaf conductances were again higher in T169 compared to those of T25. In the wet plots, gross photosynthesis was higher in T169 than in T25 at 50 DAP while at 66, 77, and 98 DAP photosynthesis was equal between the strains. In the dry plots, photosynthesis was equal between the strains at 50, 66 and 98 DAP, but higher in T25 at 77 DAP.

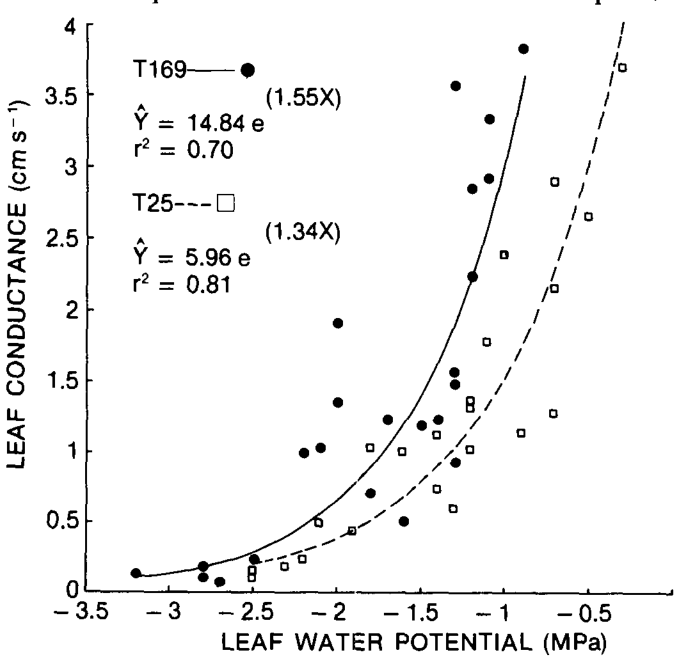

Fig. 2. Comparison of the relationship between leaf conductance and leaf water potential for two cotton strains.

In general, T25 had higher leaf water potential, lower leaf conductances, and equal gross photosynthetic rates compared to T169 in the irrigated (wet) plots. Leaf temperatures of T25 were consistently about 1°C higher than those of T169 in these plots. Because photorespiration in cotton increases with increasing leaf temperature (11), the net photosynthetic rate of T25 may have been slightly lower than in T169. Total leaf area was equal between the two strains, with T25 having more but smaller leaves.

In the rainout shelter (dry) comparisons, T25 always had higher leaf water potential than did T169. At 70 to 80 DAP, T25 had higher leaf conductance and gross photosynthetic rates than did T169. Total leaf area was greater in T25 than in T169.

It is interesting to note the recovery of the two strains at 98 DAP in 1983 after the dry plots had been watered at 81 DAP. Leaf water potentials and leaf conductances increased in both strains, while gross photosynthetic rates did not change. These data were taken on new leaves that developed after the application of water.

Previous studies have shown that the number of stomates per millimeters^2 and per epidermal cell are the same in the two strains (17) and that the leaf size of T25 is 20 to 30% smaller than in T169, while the leaf petiole vascular bundle area is about equal (4, 8). Additional studies have shown that the number of root vascular bundles and the number of lateral roots are larger in T25 than in T169 (7, 15). These results suggest that the ratio of leaf size to petiole vascular

Table 3. Comparisons of leaf water potential, leaf conductance, and gross photosynthesis for two cotton strains in 3 years and two water levels.

		Field irrigated (Wet)					
		Leaf water potential		Leaf conductance		Gross photosynthesis	
Year	DAP	T25	T169	T25	T169	T25	T169
		MPa		cm sec^{-1}		mg m^{-2} s^{-1}	
1981	96	−1.7a*	−1.9b	0.51b	0.79a	0.79a	0.78a
1982	76	−1.0a	−1.4b	1.50b	1.83a	0.73a	0.73a
	91	−1.4a	−1.6b	1.09b	1.78a	0.60a	0.60a
1983	50	−1.1a	−1.2a	0.78b	0.95a	0.70b	0.78a
	66	−1.0a	−1.3b	0.55b	0.72a	0.74a	0.70a
	77	−0.7a	−1.1b	1.28b	1.44a	0.75a	0.83a
	98†	−0.8a	−1.4b	1.03b	1.39a	0.73a	0.76a
		Rainout shelter (Dry)					
1981	96	−2.3a	−2.9b	0.12a	0.09a	0.31a	0.33a
1982	76	−1.6a	−2.3b	0.64a	0.48b	0.64a	0.50b
	91	−2.2a	−2.6b	0.49a	0.47a	0.42a	0.40a
1983	50	−0.9a	−1.4b	0.62a	0.69a	0.67a	0.69a
	66	−1.3a	−1.7b	0.38a	0.31a	0.68a	0.62a
	77	−1.5a	−2.3b	0.45a	0.30b	0.61a	0.50b
	98	−0.7a	−1.2b	1.15b	1.55a	0.56a	0.57a

* Means within years, days after planting (DAP), and water levels followed by different letters are statistically different at the 0.05 probability level based on a LSD test. In 1981 and 1983, leaf conductance was measured on the bottom of the leaf and in 1982 it was measured on the top and the bottom of the leaf. All data were collected between 1000 and 1600 h and with PPFD greater than 1500 $\mu mol\ m^{-2}\ s^{-1}$.

† Irrigation water (15 cm) was applied to the rainout shelter at 81 DAP.

Table 4. Descriptive statistics for seed cotton yield of 70 day-neutral lines derived from T25 and T169 and compared with Paymaster 303 in 1981.

	Population statistics	
	T25 lines	T169 lines
Number of lines (no.)	70	70
Average seed cotton yield (kg ha^{-1})	1139	1036
Mean (%)	90.8	82.5
Variance	481.0	571.9
Standard deviation	29.9	23.9
Standard error of the mean	2.6	2.9
Coefficient of variation (%)	24.2	28.9
Minimum value (%)	41.0	40.0
Maximum value (%)	149.0	146.0
F test for equality of variances	0.84, P = 0.47	
t-test for equality of means	2.13, P = 0.02	

Table 5. Mean squares from analysis of variance and mean comparisons for seed cotton yield for five selected strains of T25 and T169 germplasm tested at two locations in 1982.

	Big Spring			Lubbock	
Source	df	Solid planting	2 × 2† planting	df	Solid planting
Replications (R)	4	35 625	129 515	2	34 496
Germplasm (G)	1	762 365**	572 236*	1	405 305**
Strains/G	8	22 902	56 780	8	19 545
G × R	4	20 130	133 401*	2	9 078
S/G R	32	12 380	46 987	16	9 922
Coefficient of variation %		14.0	20.2		8.6
		Mean seed cotton yield			
		kg ha^{-1}			
T25		872	1 180		1 276
T169		625	965		1 043

*,** Statistically significant at the 0.05 and 0.01 probability levels, respectively.
† Two rows planted and two rows not planted.

area, the amount of root water-conducting tissue, and rooting density may account for part of the observed differences between the two strains in leaf water potential.

If the results of both the wet and dry tests are combined, they suggest that T25 reduced water loss through reduced leaf conductances when water was available. This reduction in transpirational water loss made soil water available longer and allowed more time for the production of photosynthate and, thus, the greater biomass. Farquhar and Sharkey (3) have suggested that the role of stomata is to minimize plant water loss while only marginally limiting carbon gain. Hutmacher, et al. (5) have shown that nonstomatal factors exert a significant influence on photosynthetic rates and that a curvelinear relationship exists between conductance and photosynthetic rates in cotton. Roark and Quisenberry (16) have shown further that leaf conductance in cotton is under genetic control.

Seed cotton Yield Evaluations Statistics for the 70BC$_2$ F$_6$ selected lines from the T25 and T169 populations are shown in Table 4. The T25 lines produced 90.8% (1139 kg ha^{-1}) as much seed cotton as did Paymaster 303, while the T169 lines produced 82.5% (1036 kg ha^{-1}) as much as Paymaster. The *F-test* for equality of variances showed that the variances for the two populations were not significantly different. The *t-test* for comparing the population means demonstrated that the T25 population had a higher seed cotton yield than did the T169 population. The majority of the T25 lines did not show leaf wilting while the leaves of the T169 lines wilted since the lines within the two populations were selected to be phenotypically similar to the parental strains.

Five BC$_2$ F$_7$ lines from each population with the highest 1981 seed cotton yield ratio were tested at two locations in 1982 (Table 5). At both locations and in both row spacings at Big Spring, the difference between germplasm source was statistically significant. The advantage for the T25 germplasm ranged from 19 to 28% depending upon location and row spacing.

We can conclude from these studies that the observed variability in leaf turgidity among cotton germplasm is potentially useful in the development of drought tolerant germplasm. In this series of studies, we have shown that the nonflowering, nonwilting T25 strain produced more shoot biomass than did the nonflowering, wilting T169 strain under water deficit field conditions, and that under glass house conditions, T25 produced more biomass per unit of transpired water than did T169. When genes for the day-neutral flowering response from Lubbock Dwarf were introgressed into the two strains, populations and selected lines showed a significant yield advantage for the T25 germplasm over the T169 germplasm under water deficit field conditions. Our physiological data suggest that T25 reduces water loss under optimal water conditions through reduced leaf conductances which allows T25 to use this saved water to keep its stomata partially open longer and thus fix C and grow longer when seasonal soil water is limited.

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