PHYSIOLOGICAL CHARACTERIZATION OF COTTON GENOTYPES IN RESPONSE TO WATER-DEFICIT STRESS

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RESEARCH PROBLEM

While water-deficit stress is a major limiting factor in cotton *(Gossypium hirsutum* L.) production, the level of drought tolerance among currently-grown commercial cultivars is largely unknown. Plants have evolved novel strategies for tolerating water-deficit stress, however, in agronomically important plants it is not enough to merely survive. In cotton, traditional selection approaches have generally proved unsuccessful in improving agronomic yields due to interactions between genotype and environment, therefore, research efforts need to be directed toward identifying traits associated with maintenance of growth under water-deficient conditions.

BACKGROUND INFORMATION

When water-deficit stress is encountered, a cascade of events is triggered in a plant. One of the first signs of water-deficit stress is decreased turgor pressure (Kramer and Boyer, 1995), which is eventually manifested as wilting. Because cellular expansion is dependent on sufficient turgor pressure, growth can be negatively affected if the stress is prolonged. Insufficient turgor pressure also results in stomatal closure, which decreases carbon fixation via photosynthesis inhibiting growth by diminishing both sink and source components (Bradford and Hsaio, 1982). A decrease in transpiration usually occurs during water-deficit stress in an effort to conserve water and is directly related to stomatal closure. Commonly, water-deficit stressed cotton leaves will exhibit an increase in the waxy cuticular layer of the leaf (Weete et al., 1978; Oosterhuis et al., 1991) for water conservation. It is obvious that water-deficit stress affects a plant at many levels, and a yield reduction is often the ultimate consequence.

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RESEARCH DESCRIPTION

After consulting top cotton breeders in the US and abroad, seven cultivars representative of the major cotton areas in the US were chosen. These included Maxxa (west), Sphinx (southwest), Fibermax (midsouth), Deltapine Nu33B, Stoneville 747, Sure-Grow 474 (Mississippi River Delta), and Paymaster 1218 (east). An Australian cultivar, Siokra L-23, was included for its known level of drought tolerance (Nepomuceno,1998). Studies were performed in Fayetteville, Arkansas, in a growth chamber and in the field. In the growth chamber studies, plants were grown in 2-L plastic pots containing “Sunshine”, a soilless horticultural mix. Plants were arranged in a completely randomized design with three replications, and the study was repeated five times. Plants were given half-strength Hoagland’s nutrient solution to maintain adequate nutrients and water. At four weeks after planting, half the plants were subjected to water-deficit stress past the point of stomatal closure to full wilt. After full rehydration, osmotic adjustment was measured using end-window thermocouple psychrometry. Gas exchange measurements were taken 1, 3, and 7 days after stress recovery with a LI-COR 6200 portable photosynthesis system. Leaf epicuticular wax content was measured at 7 days after rehydration by soaking leaves in chloroform for 30 seconds, followed by evaporation, leaving only the wax. Differential carbon isotope analyses were performed to further elucidate differences in drought tolerance in these cultivars. In the field study, plants were arranged in a split-plot design with six replications. Half the plants were irrigated with in-furrow irrigation, while the other half were unirrigated. At first-flower (FF), FF + 2 and FF + 4 weeks, leaf water and osmotic potentials, relative water content, and gas exchange measurements were collected. All data were analyzed using SAS PROC GLM.

RESULTS

Means of five experiments indicated a narrow range of osmotic adjustment. Several significant differences existed in osmotic adjustment between cultivars (Table 1), with Sphinx (44 %) showing the highest and Maxxa (12 %) the lowest level of osmotic adjustment. Stressed plants of several cultivars showed significant increases in photosynthetic rate at three days after stress cessation compared to control plants, especially Siokra L-23 and Sphinx (Fig. 1). Leaf epicuticular wax content was significantly higher in all stressed plants, and transpiration rates were inversely related to amount of wax (data not shown). Stressed Sphinx plants showed the greatest degree of wax accumulation compared to other cultivars. A highly significant cultivar by water interaction was observed in carbon isotope discrimination (Table 2). Stressed plants in all cultivars discriminated less compared to the well-watered control plants. Generally, cultivars with high levels of osmotic adjustment exhibited less differences in carbon discrimination between stressed and well-watered control plants, indicating that stomates of these cultivars remained open longer when compared to other cultivars.

Under field conditions, osmotic measurements mimicked results from the controlled studies (data not shown). Because adequate amounts of rainfall were received, the degree of water-deficit stress was minimal. No significant differences in yield between cultivars or water regimes were observed in the field study (Table 3) due to the lack of drought stress. Overall, results indicated a limited amount of drought tolerance in current commercial cultivars. However, there was evidence of enhanced photosynthetic recovery from water-deficit stress in several cultivars.

PRACTICAL APPLICATION

Due to the complex nature and far-reaching effects of water-deficit stress, it is essential to characterize the responses at many different levels. Knowledge gained from this research can assist producers in making informed decisions regarding appropriate cultivars in areas prone to drought. Breeding and screening efforts can also be improved based on information arising from this project.

LITERATURE CITED

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Table 1. Osmotic adjustment observed under controlled environmental conditions. These values represent means of five experiments.

Cultivar	Adjustment[z]
	(%)
Sphinx	44 a[y]
Suregrow 747	31 b
Siokra L-23	24 bc
Stoneville 474	23 bc
Paymaster 1218	21 c
DeltaPine Nu33b	19 c
Fibermax 989	18 c
Maxxa	12 d

[z] Percentage adjustment in osmotic potential compared to the well-watered control.
[y] Means followed by the same letter are not significantly different (P=0.05).

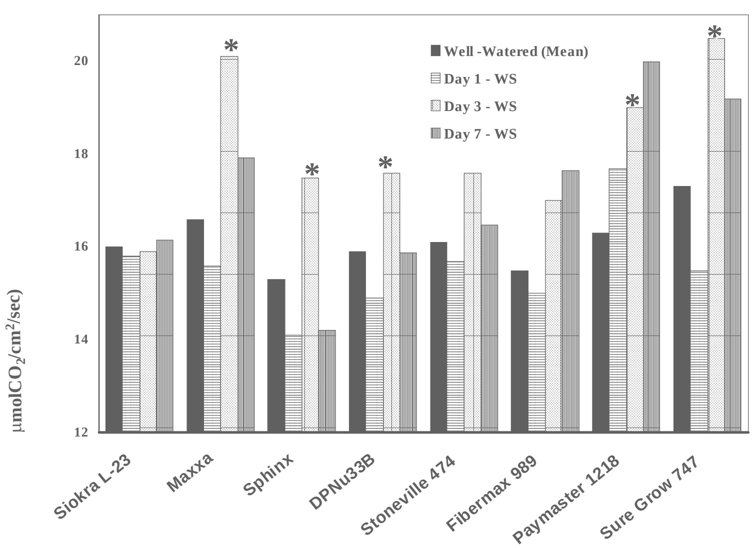

Fig. 1. Photosynthesis of the cotton cultivars after 1, 3, and 7 days of rehydration. Significant differences between cultivars within a given water treatment are denoted by an asterisk.

Table 2. Carbon isotope discrimination observed under controlled environmental conditions. The cultivar by water interaction was highly significant (P=0.0013).

Cultivar	Well-watered	Water-stressed
Sphinx	-31.3	-31.1[z]
Suregrow 747	-31.6	-31.3
Siokra L-23	-31.8	-31.3
Stoneville 474	-31.7	-30.6
Paymaster 1218	-31.2	-30.8
DeltaPine Nu33b	-31.1	-30.1
Fibermax 989	-31.8	-31.0
Maxxa	-32.0	-31.2

[z] A lower value depicts comparatively more discrimination in water-stressed plants, i.e., more drought tolerance.

Table 3. Seedcotton yield results from the field study. No significant differences were observed.

Cultivar	Irrigated	Unirrigated
Sphinx	1635	1751
Suregrow 747	1868	1573
Siokra L-23	1793	1709
Stoneville 474	2231	1798
Paymaster 1218	1910	1537
DeltaPine Nu33b	1793	1705
Fibermax 989	2217	1639
Maxxa	1551	1318
LSD (P=0.05)	NS[z]	NS

[z] NS = non-significant (P=0.05).