Effect of Water-Deficit Stress on Polyamine Metabolism of Cotton Flower and Their Subtending Leaf

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RESEARCH PROBLEM

Water-deficit stress is a major abiotic factor limiting more than a third of the arable land around the world. Polyamines are endogenous plant growth promoters that affect a variety of physiological and metabolic functions. Research in other crops has indicated a relationship between changes in polyamine metabolism and drought tolerance. However, no information exist on polyamine metabolism of cotton under conditions of limited water supply. In this study it was hypothesized that limited water supply would significantly affect cotton polyamine metabolism resulting in changes in their concentrations.

BACKGROUND INFORMATION

Polyamines (PA) are low-molecular-weight organic polycations with two or more primary amino groups \(-\text{NH}_2\) and they are present in bacteria, plants and animals. In plants, the diamine putrescine (PUT) and its derivatives, the triamine spermidine (SPD) and the tetramine spermine (SPM) are the most common polyamines and they have been reported to be implicated in a variety of plant metabolic and physiological functions (Kakkar et al., 2000). Additionally, PAs play a significant role in flower induction (Bouchereau et al., 1999) along with flower initiation (Kaur-Sawhney et al., 1988), pollination (Falasca et al., 2010), fruit growth and ripening (Kakkar and Rai, 1993). Furthermore, research in other crops has indicated that changes in PA concentrations is a common plant response to a variety of abiotic stresses, including salinity, high or low temperatures, and drought, as well as biotic stresses (Bouchehereau et al., 1999).

Water deficit is a major abiotic factor limiting plant growth and crop productivity around the world (Boyer, 1982). Cotton \(\text{(Gossypium hirsutum L.)}\) is considered to be relatively tolerant to drought, i.e. by osmotic adjustment (Oosterhuis and Wullschleger 1987). Since projections anticipate that water-stress episodes are going to intensify in the future due to increased greenhouse gas concentrations, tools to help with selection of drought-tolerant genotypes are greatly need-

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Polyamine metabolism is an enticing target; however, despite the extensive research on other crops, limited information on PA metabolism exists for cotton with the only reports being on the distribution of polyamines in the cotton plant (Bibi et al., 2011), polyamine content just prior to rapid fiber elongation (Davidois, 1995), the effect of heat stress on PAs (Bibi et al., 2010), and the occurrences of uncommon polyamines (norspermidine, norspermine, pentamine, and hexamine) (Kuehn, et al., 1990).

The purpose of this study was to investigate the changes in PA concentrations in first day flower ovaries and their subtending leaves under conditions of water-deficit stress by using two cultivars differing in drought tolerance in order to determine whether PAs are involved in drought tolerance.

**RESEARCH DESCRIPTION**

Growth chamber studies were conducted in 2009-2010 in the Altheimer laboratory of the University of Arkansas in Fayetteville. Cotton (*Gossypium hirsutum* L.) cultivars ST5288B2F (drought-sensitive) and Siokra L23 (drought-tolerant) were planted into 1-L pots containing a horticultural mix (Sun-Gro horticulture mix). The growth chambers were set for normal conditions of 30/20°C (day/night), ±60% relative humidity, and 14 h photoperiod, while half-strength Hoagland’s nutrient solution was applied daily in order to maintain adequate nutrients and water. Irrigation was withheld at flowering (approximately 8 weeks after planting) until plants were visually wilted after which water stressed plants received 50% of their daily use of water for ten days. Plants were arranged in a completely randomized block design with 15 replications and the experimental design was a 2 × 2 factorial with the main effects being water-deficit stress and cultivar, with 15 replications in each treatment. Treatments consisted of: 1) ST5288 and Siokra L23 control, where optimum quantity of water was applied throughout the duration of experiment, and 2) ST5288 and Siokra L23 water-stressed, where 50% of daily water use was applied. Measurements of leaf stomatal conductance were taken daily between 11:00 a.m.-1:00 p.m. from the fourth main-stem leaf from each plant using a leaf porometer Decagon SC-1 (Decagon Devices, Inc., Pullman, Wash.). Photosynthetic rates were measured the first and fourth day after spraying, between 11:00 a.m.-1:00 p.m. from the fourth main-stem leaf from each plant using the LI-COR 6200 gas analyzer (LI-COR Biosciences, Lincoln, Neb.) Polyamine content was estimated from white flowers (ovaries) and their subtending leaves that were collected when available from all four treatments. Polyamine analysis was done according to Flores and Galston (1984) with modifications.

**RESULTS AND DISCUSSION**

Water-deficit stress significantly decreased both ST5288 B2F and Siokra L23 stomatal conductance rates compared to the control (Fig.1). Interestingly, well-
watered Siokra L23 had significantly lower stomatal conductance rates compared to well-watered ST 5288. Limited supply of water had a similar effect on photosynthesis, with photosynthetic rates of water-stressed plants of both cultivars being significantly lower compared to control, while water-stressed Siokra L23 had significantly lower photosynthetic rates compared to water-stressed ST 5288 (Fig. 2). Regarding polyamine metabolism, the results of our study (Table 1) indicated that polyamines in cotton accumulate in higher concentrations in the reproductive structures compared to the vegetative tissues. Total polyamine concentrations were not shown to be affected significantly by water-deficit stress conditions however the opposite was observed when each polyamine concentration was analyzed individually. Diamine putrescine was shown to significantly affect stomatal function in cotton, with increasing concentrations inducing stomatal closure. Triamine spermidine levels on the other hand remained unaffected, suggesting that SPD does not play a significant role in cotton defense mechanism under conditions of water-deficit stress. Conversely, SPM levels significantly affected photosynthetic rates since decreases in its concentration resulted in significantly lower photosynthetic rates.

**PRACTICAL APPLICATION**

Polyamine metabolism of cotton reproductive ovaries and their subtending leaves appeared to be significantly affected by water-deficit stress. In addition, changes in polyamine concentrations appeared to affect physiological functions such as photosynthesis and stomatal conductance. We speculate that polyamines play an important role in cotton protection under adverse environmental conditions and changes in their concentrations, especially PUT and SPM, could be used as potential markers for selection of drought-tolerant cultivars.

**LITERATURE CITED**


Table 1. Effect of water-deficit stress on polyamine concentrations of subtending leaf and ovary.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>LEAF</th>
<th>OVARY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>WS</td>
</tr>
<tr>
<td>ST 5288</td>
<td>276.82a</td>
<td>313.5a</td>
</tr>
<tr>
<td>SIOKRA L23</td>
<td>23.8b</td>
<td>61.2a</td>
</tr>
<tr>
<td>ST 5288</td>
<td>146.6a</td>
<td>141.7a</td>
</tr>
<tr>
<td>SIOKRA L23</td>
<td>106.3a</td>
<td>110.7a</td>
</tr>
</tbody>
</table>

1 Numbers within a column followed by the same letter are not significantly different (P = 0.05).
Fig. 1. Effect of water-deficit stress on stomatal conductance rates of ST 5288 and Siokra L23. Points within a sampling day with the same letter are not significantly different ($P = 0.05$).

Fig. 2. Effect of water-deficit stress on photosynthetic rates of ST5288 and Siokra L23. Bars with the same letter are not significantly different ($P = 0.05$).