Water-Deficit Stress Effects on Polyamine Metabolism of the Cotton Flower and Subtending Leaf Under Field Conditions

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RESEARCH PROBLEM

Water-deficit stress is a major abiotic factor limiting more than one third of the arable land around the world. Polyamines are endogenous plant growth promoters that affect a variety of physiological and metabolic functions, and are particularly involved in the flowering process. Research in other crops has indicated a relationship between changes in polyamine metabolism and drought tolerance. However, no information exists on polyamine metabolism of cotton under conditions of limited water supply. This study was aimed at quantifying the effect of water deficit on polyamine metabolism and resulting changes in their concentrations.

BACKGROUND INFORMATION

Polyamines (PA) are low-molecular-weight organic polycations with two or more primary amino groups $-NH_2$ 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). 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 (Boucehereau et al., 1999).

Drought is a major abiotic factor reducing plant growth and crop productivity around the world (Boyer, 1982). Cotton (*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

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to intensify in the future (IPCC, 2007), tools to help with selection of drought-tolerant genotypes are greatly needed. 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., 2012), polyamine content just prior to rapid fiber elongation (Davidonis, 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 objectives of our study were to monitor and evaluate the alterations caused by water-deficit stress on the polyamine metabolism of the cotton pistil and its subtending leaf under field conditions.

RESEARCH DESCRIPTION

Cotton cultivar ST5288B2F seeds were sown at a density of ten plants per meter in a Captina silt loam (Typic Fragidult) soil on 6 June 2011 at the University of Arkansas Agricultural Experimental Station in Fayetteville, Ark. and in a sandy loam (Typic Amarillo) soil on 30 May 2011 at Texas Tech University Farm in Lubbock, Texas. Plots were 4 m × 7 m with 1-m borders between each plot. To maintain well-watered conditions until stress was imposed, plants in Fayetteville, Ark. were irrigated by furrow irrigation to soil saturation every six days in the absence of saturating rainfall; while in Lubbock, Texas, subsurface drip irrigation was provided daily. Fertilizer application, weed control, and insecticide applications were performed according to Extension center recommendations and practices. Irrigation was withheld when plants reached the flowering stage which was 20 July in Fayetteville, Ark. and 13 July in Lubbock, Texas. First sympodial branch fruiting position white flowers and their subtending leaves were sampled at 1200 h at the end of the first and second week after irrigation was withheld and analyzed for polyamine content according to Bibi et al. (2010). Measurements of soil moisture content and stomatal conductance were taken also at the end of each week from the Arkansas site.

RESULTS AND DISCUSSION

Water-deficit stress resulted in significant decreases in leaf stomatal conductance (Table 1) and soil moisture content (Table 2) in Fayetteville, Ark. In Lubbock, Texas, no significant differences were detected in soil moisture content between control and water-stressed plots (Table 2); however, we speculate that this was due to a sampling mistake since vapor-pressure deficit in this location was consistently higher compared to Fayetteville, Ark. (Table 3).

Polyamine analysis showed that both leaf and ovary metabolism was significantly affected by limited water supply in both locations (Tables 4 and 5). Specifically, water-stressed ovary and leaf PUT concentrations were significantly higher compared to the control at the end of the second week in both locations (Tables

4 and 5), and a similar pattern was observed in water-stressed ovary and leaf SPD concentrations at the end of the second week in both locations (Tables 4 and 5). However, ovary and leaf SPM concentrations remained unaffected under conditions of water stress compared to the control in Fayetteville, Ark. (Table 4); whereas the opposite was observed in Lubbock, Texas with both ovary and leaf SPM levels being significantly higher under conditions of water-deficit stress compared to the control at the end of the second week (Table 5).

PRACTICAL APPLICATION

The results of our study indicated that leaf and ovary polyamine metabolism were affected significantly by limited water supply, suggesting that polyamines have a critical role in cotton protection under adverse environmental conditions. This indicated that polyamine metabolism, PUT and SPD especially, could provide useful tools for drought-tolerant genotype selection. However, more research needs to be conducted in order to elucidate the exact function of each polyamine and the ways polyamines can be used to enhance drought tolerance in cotton.

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Table 1. Effect of water-deficit stress on leaf stomatal conductance in Fayetteville, Ark.

Stomatal Conductance (mmol/m²s)			
---------------Week I---------------		---------------Week II---------------	
C	WS	C	WS
697.1 a[†]	432.2 b	640.7 a	373.1 b

[†]Different letters indicate statistical significance at ***P*** = 0.05.
Notes: Water-deficit stress (WD) and control (C).

Table 2. Effect of water-deficit stress on soil moisture content in Fayetteville, Ark. and Lubbock, Texas.

Soil Moisture Content (%)							
-----------------Fayetteville-----------------				-------------------Lubbock------------------			
-----Week I-----		-----Week II-----		-----Week I-----		-----Week II-----	
C	WS	C	WS	C	WS	C	WS
0.89 b[†]	0.93 a	0.89 b	0.94 a	0.95 a	0.97a	0.97 a	0.98 a

[†]Different letters indicate statistical significance at ***P*** = 0.05.
Notes: Water-deficit stress (WD) and control (C).

Table 3. Vapor pressure deficit in Fayetteville, Ark. and Lubbock, Texas.

Vapor Pressure Deficit	
Fayetteville	Lubbock
27.75	39.46

Table 4. Effect of water-deficit stress on polyamine concentrations of ovary and subtending leaf in Fayetteville, Ark.

Polyamine Content (nmoles/g FW) Fayetteville											
Ovary						Leaf					
PUT		SPD		SPM		PUT		SPD		SPM	
C	WS	C	WS	C	WS	C	WS	C	WS	C	WS
Week I						Week I					
311.0 a[†]	349.1 a	429.6 a	297.1 b	288.1 a	200.5 a	14.0 b	43.3 a	92.63 b	117.6 a	69.0 a	61.5 a
Week II						Week II					
338.2 b	519.5 a	400.5 b	533.4 a	188.6 a	184.5 a	57.1 b	203.7 a	232.9 a	288.6 a	104.0 a	109.4 a

[†]Different letters indicate statistical significance at $P = 0.05$.
Notes: Water-deficit stress (WS), control (C), putrescine (PUT), spermidine (SPD), and spermine (SPM).

Table 5. Effect of water-deficit stress on polyamine concentrations of ovary and subtending leaf in Lubbock, Texas.

Polyamine Content (nmoles/g FW) Lubbock											
Ovary						Leaf					
PUT		SPD		SPM		PUT		SPD		SPM	
C	WS	C	WS	C	WS	C	WS	C	WS	C	WS
Week I						Week I					
275.4 b[†]	666.7 a	89.5 b	131.6 a	89.6 b	578.1 a	14.7 b	125.6 a	104.1 b	198.6 a	93.5 b	131.3 a
Week II						Week II					
516.9 b	1076.7 a	1192.3 b	1354.4 a	131.6 a	506.7 a	58.8 b	990.6 a	144.1 b	241.3 a	72.7 b	97.9 a

[†]Different letters indicate statistical significance at $P = 0.05$.
Notes: Water-deficit stress (WS), control (C), putrescine (PUT), spermidine (SPD), and spermine (SPM).