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BRIEF COMMUNICATION

Effect of growth regulators on photosynthesis, transpiration and related parameters in water stressed cotton

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Abstract

Gas exchange in *Gossypium hirsutum* L. cv. H-777 as affected by water deficit and growth regulators (IAA, GA_3, BAP, ABA, ethrel) was examined. Sixty days after sowing, growth regulators in concentration 50 μM were applied as foliar spray and irrigation was withheld to get desired (moderate and severe) water deficit. All the parameters were measured on the third leaf from the top between 10:00 and 11:00. Net photosynthetic rate (P_N), transpiration rate (E), stomatal conductance (g_s), carboxylation efficiency (CE), and water potential (ψ_w) decreased significantly with the increasing water stress, however, water use efficiency (WUE) was unaffected. Foliar spray with IAA, GA_3 and BAP partially counteracted the effect of water deficit on the above parameters except ψ_w, which became more negative. ABA and up to some extent ethrel increased WUE and maintained higher ψ_w, however, caused further decrease in P_N, E, and g_s.

Additional key words: *Gossypium hirsutum*, water deficit, water potential, water use efficiency.

Cotton is an important crop grown throughout the world. Water deficit severely limits the photosynthesis and crop productivity (Lawlor and Uprety 1993, Kumar *et al.* 1994). Both stomatal and non-stomatal factors contribute to the effects of water deficit on photosynthesis and water use efficiency (Matthews and Boyer 1984, Bunce 1988, Martin and Ruiz-Torres 1992, Dubey 1997).

Various factors are thought to be involved in decline of plant productivity under water stress, and content of endogenous phytohormones is important one (Cornish 1988). Exogenous application of plant growth regulators (PGRs) has been employed in order to alleviate the harmful effects of water deficit. Although some encouraging results are available in the literature (Gadallah 1995, Cadena and Cothren 1996, Coskuncelebi *et al.* 1997, Zhao *et al.* 1997, Pospíšilová *et al.* 2000), yet, information available regarding role of PGRs under water deficit is inconclusive. So, present study was conducted to see the effects of PGRs on photosynthesis, water use efficiency and related parameters and to see the correlation of these parameters with leaf water potential.

Experiment was conducted in screenhouse in earthen pots during 1998 at CCS Haryana Agricultural University, Hisar, India, using dune sand and Hoagland's nutrient solution. Water stress was imposed at 60 days after sowing (DAS) by withholding irrigation in order to achieve desired stress level: field capacity [soil moisture content (SMC) = 10 ± 0.5 %], moderate stress (SMC = 5 ± 0.5 %), severe stress (SMC = 3 ± 0.5 %). Foliar spray of indoleacetic acid (IAA), gibberellic acid (GA_3), benzylaminopurine (BAP), abscisic acid (ABA), and ethrel in the concentration 50 μM was applied just before withholding the irrigation while distilled water was sprayed on control plants. Water potential was measured using pressure chamber (*Model 3005*, *Soil Moisture Equipment Corporation*, Santa Barbara, USA). Gas exchange parameters were measured using infrared gas analyser (*Ciras-1*, *P.P. Systems Inc.*, Hitchin, U.K.)

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Abbreviations: ABA - abscisic acid, BAP - benzylaminopurine, CE - carboxylation efficiency, DAS - days after sowing, E - transpiration rate, GA_3 - gibberellic acid, g_s - stomatal conductance, IAA - indoleacetic acid, P_N - net photosynthetic rate, SMC - soil moisture content, ψ_w - water potential, WUE - water use efficiency.

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under natural daylight (1000 - 1100 μmol m^{-2} s^{-1}), temperature (32 ± 0.5 %), air humidity (60 ± 5 %) and CO_2 concentration (354 ± 5 cm^3 m^{-3}). Carboxylation efficiency (CE) and water use efficiency (WUE) were calculated using following relationships:

$$CE [\%] = (P_N/c_i) \times 100$$

$$WUE = P_N/E$$

Where, P_N, c_i and E represent net photosynthetic rate, internal carbon dioxide concentration, and transpiration rate, respectively.

All the observations were measured on third leaf from top on main axis between 10:00 to 11:00 in triplicate and data were analysed using factorial CRD.

Net photosynthetic rate (P_N), transpiration rate (E) and stomatal conductance (g_s) were significantly decreased under water deficit (Table 1). Decline in P_N in cotton was observed also by Zhao *et al.* (1991), Ephrath *et al.* (1993), Cadena and Cothren (1996), Faver *et al.* (1996). Drought induced reduction in the rate of transpiration was noted in cotton by Leidi *et al.* (1993), Cadena and Cothren (1996), Van Iersel and Oosterhuis (1996) while decline in stomatal conductance was reported in cotton by Zakaria *et al.* (1993) and Iersel *et al.* (1996). Reduction in CE under water deficit was reported in cotton by Leidi *et al.* (1999). Water use efficiency (WUE) did not change significantly under water deficit because P_N and E decreased proportionately (Table 1). However, Van Rensburg and Krüger (1993) reported that WUE declined significantly in tobacco under drought. At moderate and severe stress, ψ_w of the leaves was -1.37 and -1.70 MPa, respectively, while at field capacity it was -0.98 MPa (Table 1). Reduction in ψ_w of cotton leaves was reported by Ephrath *et al.* (1993) under soil moisture stress.

Foliar spray of IAA, GA_3 and BAP resulted in an increase in P_N, E and g_s at moderate and severe stress as compared to that of control plants at similar stress level (Table 1). Application of ABA did not show any considerable effect at moderate stress but at severe stress it caused a further decrease in P_N (25 %); ethrel was not found effective at either stress level (Table 1). On the other hand, ABA and ethrel caused a significant decrease in E and g_s at moderate and severe stresses.

Table 1. Effect of growth regulators (50 μM) on net photosynthetic rate, transpiration rate, stomatal conductance, carboxylation efficiency, water use efficiency and water potential in cotton under water deficit.

PGR/stress	H_2O	IAA	GA_3	BAP	ABA	Ethrel	$LSD_{0.05}$
	Net photosynthetic rate [μmol(CO_2) m^{-2} s^{-1}]						
Field capacity	7.00	7.13	7.27	6.57	5.83	6.36	PGR 0.44
Moderate stress	4.43	5.93	5.93	5.50	4.30	4.63	stress 0.31
Severe stress	3.03	3.77	3.47	3.70	2.27	3.00	PGR × stress NS
	Transpiration rate [mmol(H_2O) m^{-2} s^{-1}]						
Field capacity	4.41	4.96	5.10	4.56	3.92	4.10	PGR 0.28
Moderate stress	3.03	4.13	4.08	3.83	2.62	2.73	stress 0.20
Severe stress	2.09	2.68	2.75	2.63	1.01	1.80	PGR × stress NS
	Stomatal conductance [mmol(H_2O) m^{-2} s^{-1}]						
Field capacity	431	486	498	455	403	411	PGR 18.0
Moderate stress	306	378	367	350	280	287	stress 12.7
Severe stress	258	288	302	295	172	239	PGR × stress 31.2
	Carboxylation efficiency [%]						
Field capacity	3.27	3.26	3.55	3.15	2.55	3.02	PGR 0.34
Moderate stress	1.69	2.40	2.85	2.25	1.28	1.57	stress 0.24
Severe stress	0.94	1.37	1.23	1.24	0.60	0.91	PGR × stress NS
	Water use efficiency [μmol(CO_2) $mmol^{-1}$(H_2O)]						
Field capacity	1.59	1.44	1.43	1.44	1.49	1.55	PGR 0.17
Moderate stress	1.46	1.43	1.45	1.43	1.64	1.70	stress NS
Severe stress	1.45	1.41	1.26	1.41	2.25	1.66	PGR × stress 0.30
	Leaf water potential [-MPa]						
Field capacity	0.98	0.96	0.97	0.98	0.93	0.97	PGR 0.06
Moderate stress	1.36	1.44	1.45	1.38	1.24	1.32	stress 0.04
Severe stress	1.70	1.81	1.83	1.73	1.56	1.66	PGR × stress NS

Carboxylation efficiency (CE) was improved in response to IAA, GA_3 and BAP but decreased with ABA, and was unaffected with ethrel at moderate stress (Table 1). At severe stress, only IAA was able to improve CE while ABA further declined it as compared to control plants. WUE was not affected by the application of IAA and BAP at either stress level but GA_3 at severe stress caused 13 % decrease in WUE. However, significant increase was observed with ABA and ethrel at moderate as well as severe stress (Table 1). Water potential (ψ_w) of leaves became more negative by application of IAA and GA_3, unaffected by BAP and ethrel, but significantly improved by ABA at both the stress levels (Table 1).

Zhao *et al.* (1997) reported that cotton plants treated with PGR-IV (GA_3, IBA and propriety fermentation broth) showed an increase in P_N and g_s under water deficit. Foliar spray of ABA on cotton plants was found to be beneficial in order to minimize water loss under water deficit condition (Gadallah 1995). Similarly, Goswami and Srivastava (1985) argued that application of ABA resulted in lesser lowering of ψ_w of leaves, and decrease in g_s, E and P_N in sunflower under water deficit. Higher WUE with ABA under water deficit may be ascribed to the role of ABA in stomatal closure (Nilsen and Orcutte 1996) and the fact that E was lowered up to greater extent than P_N with ABA under water deficit (Table 1).

All the parameters (P_N, E, g_s, CE, WUE) showed strong positive correlation with leaves ψ_w in control, IAA and GA_3 treated plants. This is also true in case of BAP and ethrel treated plants except WUE, which showed negative correlation with ψ_w. However, under ABA treatment, WUE showed very strong negative correlation because ψ_w decreased while WUE increased in ABA treated plants.

Results of this experiment led us to interpret that under water deficit, spray of ABA resulted in higher WUE which seems to be a desirable trait under drought condition and such an affect might be due to reduction in stomatal conductance and transpiration rate that ultimately led to maintain better water status of leaves under stress conditions.

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