

Effect of bioregulators on canopy photosynthesis, stomatal conductance and seed yield of chickpea, *Cicer arietinum* L under late sown high temperature stress condition

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ABSTRACT

Chickpea being a cool season crop experiences abnormally high temperature during reproductive phase. Therefore terminal high temperature stress is one of the major constraints for its production. Bioregulators play important role in alleviating detrimental effects of high temperature. Therefore in order to test the potential foliar application of some bioregulators viz abscisic acid (ABA), benzyladenine (BA) and salicylic acid (SA) for improving photosynthesis and other physiological parameters under high temperature condition, present investigation was undertaken using Kabuli type chickpea variety (Pusa-1108) and high temperature stress was imposed by delaying the sowing dates (normal sowing and late sowing) to expose the terminal phase of crop to high temperature. Observations were recorded on stomatal conductance and canopy photosynthesis and seed yield. Under high temperature stress interestingly application of bioregulators (ABA, BA and SA) in general maintained the higher value of all physiological parameters. Present findings indicate that the foliar application of ABA, BA and SA improves stomatal conductance and the canopy photosynthesis hence lead to increased seed yield under late sown high temperature condition.

Keywords: Bioregulator; chickpea; late sown; temperature

INTRODUCTION

Chickpea seeds are classified into Desi and Kabuli types. In general Kabuli type are more sensitive to abiotic stress than Desi one (Devasirvatham et al 2012). Chickpea crop frequently experiences

abnormally high temperature (>35°C) during reproductive phase. High temperature has a tremendous effect on the photosynthetic capacity. In photosynthetic machinery carbon metabolism of stroma and light reaction in thylakoid membrane are the primary sites of injury at high

temperature (Wang et al 2009). Bioregulators have been reported to play an important role in imparting adaptation to heat stress by alleviating detrimental effects of high temperature stress (Larkindale and Huang 2004, Wahid et al 2007). It has also been shown that high temperature stress alters the level of endogenous plant hormones (Maestri et al 2002, Wahid et al 2007). A lower concentration of salicylic acid (SA) improves the photosynthetic net CO₂ assimilation in mustard seedlings. As photosynthesis rate increases, carboxylation efficiency, chlorophyll content and the activities of carbonic anhydrase and nitrate reductase are also up-regulated (Fariduddin et al 2003). During the vegetative stage high day temperature can cause damage to compensated leaf photosynthesis reducing CO₂ assimilation rates (Hall 1992).

Increased temperatures curtail photosynthesis and increase CO₂ transfer conductance between intercellular spaces and carboxylation sites. Stomatal conductance (gs) and net photosynthesis (Pn) are inhibited by moderate heat stress in many plant species due to decreases in the activation state of rubisco (Morales et al 2003).

In maize the photosynthesis was inhibited at leaf temperatures above 38°C and inhibition was much more severe when temperature was increased abruptly rather than gradually. However this inhibition was independent of stomatal response to high

temperature (Crafts-Brander and Salvucci 2002).

Under elevated temperature in plants in general the rate of photosynthesis decreases while dark and photorespiration rates increase considerably under high temperatures (Wahid et al 2007).

MATERIAL and METHODS

For the present study a field experiment was conducted in factorial randomized block design with three replications using a Kabuli type chickpea variety Pusa-1108. The seed material was obtained from Division of Genetics, IARI, New Delhi.

High temperature treatment was imposed by delaying sowing dates viz normal (09.11.2012) and late (29.12.2012). Just prior to flowering initiation both sets were treated exogenously with application of different bioregulators viz abscisic acid (ABA, 10 ppm), benzyl adenine (40 ppm), salicylic acid (SA, 100 ppm) and water as control.

Sample collection: High temperature stress treatment was imposed by altering sowing dates viz normal and late sowing. Foliar application was made before flowering under both normal and late sown conditions and plant samples were taken at 0, 10, 20, 30 and 40 days after foliar application of bioregulators. Postharvest observations were recorded at harvest.

Physiological parameters: Observations were recorded on photosynthetic rate, canopy photosynthesis, stomatal conductance, transpiration rate and water use efficiency.

RESULTS

Canopy photosynthesis

There was significant reduction in canopy photosynthesis under late sown high temperature condition as compared to normal sown one. Foliar application of all bioregulators enhanced the canopy photosynthesis under both normal and late sown conditions over their respective controls (water spray). Maximum canopy photosynthetic rate was recorded with foliar application of SA under normal and ABA under late sown conditions (Fig 1, Table 1).

Stomatal conductance

Under late sown high temperature condition, foliar application of BA had the highest value of stomatal conductance followed by control (water spray) and minimum value of stomatal conductance was recorded with ABA. However under normal sown condition foliar spray of ABA showed highest value of stomatal conductance followed by BA and SA under both normal and late sown conditions. Maximum values of stomatal conductance were recorded at 20 days after foliar application under both conditions (Fig 2, Table 2).

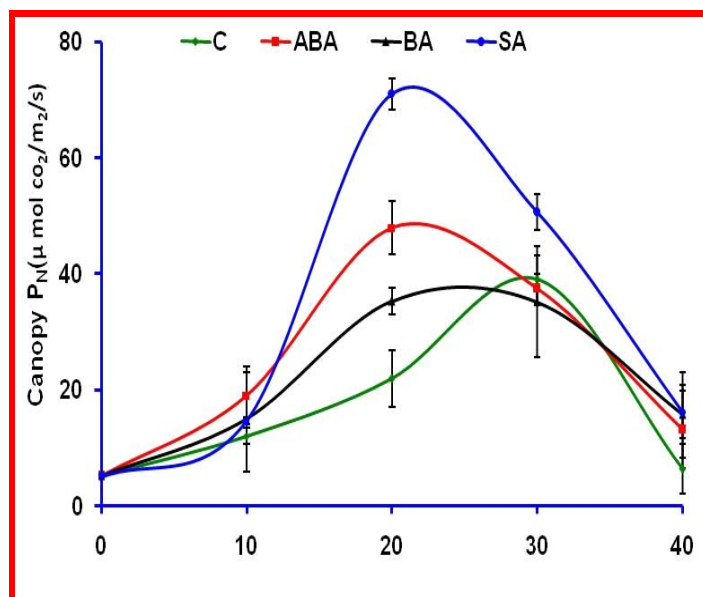
Test weight (1000-seed weight)

As compared to normal sown condition 1000-seed weight was drastically reduced under late sown conditions. In general foliar spray of all bioregulators enhanced the 1000-seed weight and maximum enhancement was recorded with foliar application of BA followed by SA (Fig 3).

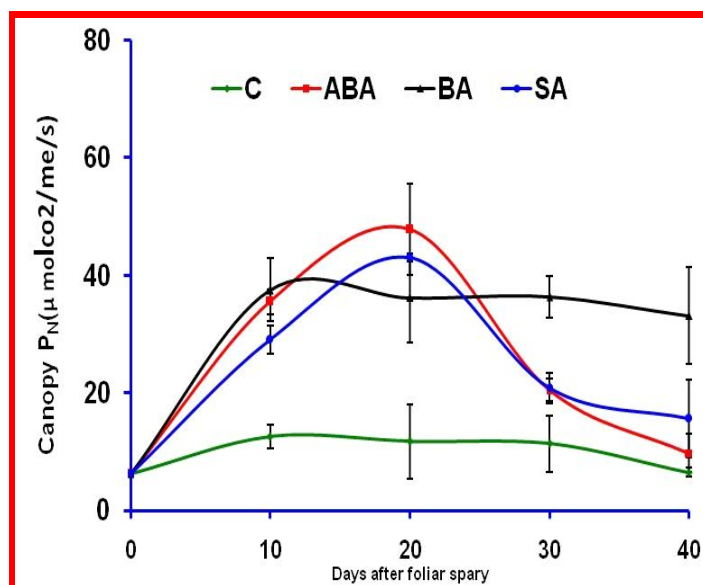
DISCUSSION

Under late sown high temperature condition rate of photosynthesis and canopy photosynthesis, transpiration rate, water use efficiency and Fv/Fm ratio were reduced and bioregulators in general enhanced their values under both normal and late sown conditions. Photosynthetic traits are good indicators of thermo-tolerance in the plants. Photochemical reactions in thylakoid lamellae and carbon metabolism in the stroma of chloroplasts have been suggested as the primary sites of injury at high temperatures (Wise et al 2004). Chlorophyll fluorescence, the ratio of variable fluorescence to maximum fluorescence (Fv/Fm) has been noted to correlate with heat tolerance (Yamada et al 1996).

Exogenous application of SA enhanced the net photosynthetic rate, internal CO₂ concentration, water use efficiency, stomatal conductance and transpiration rate in *Brassica juncea* (Fariduddin et al 2003), maize (Khan et al



(A)

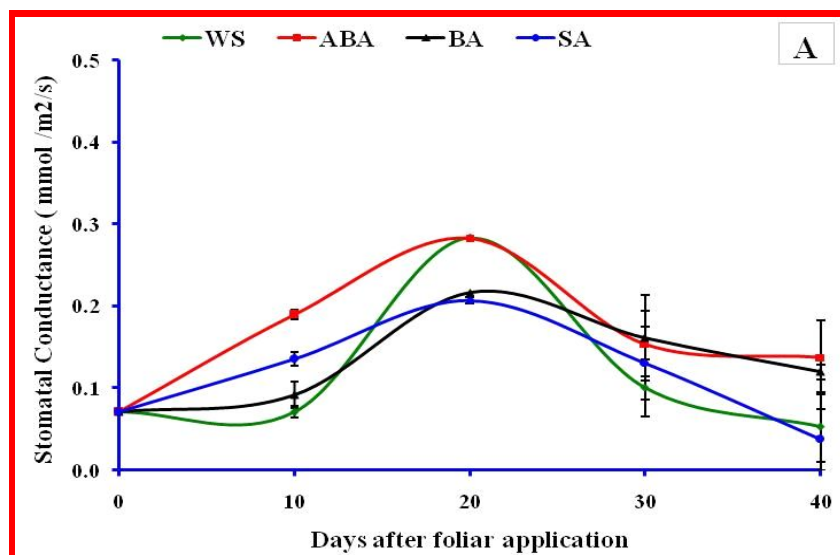


(B)

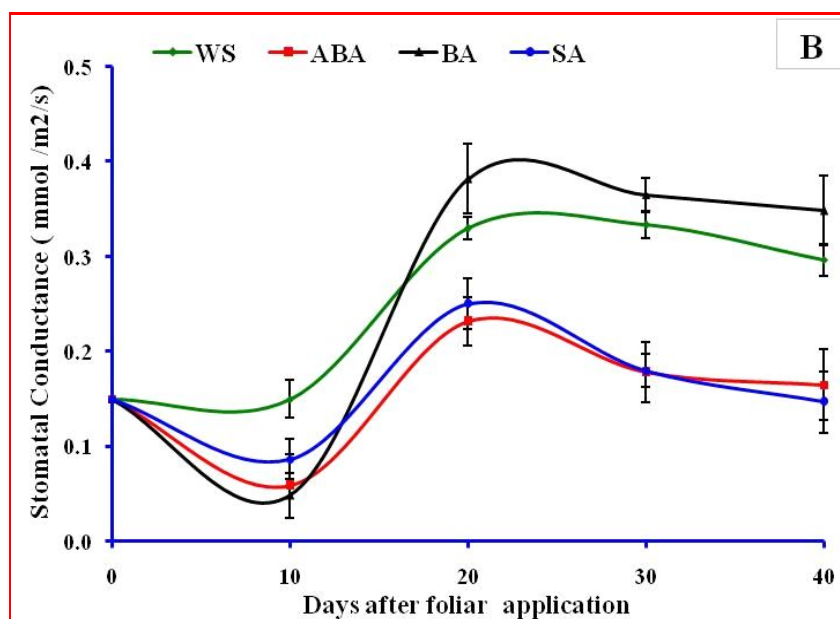
WS- Water spray, ABA- Absciscic acid, BA- Benzyl adenine, SA- Salicylic acid

Fig 1. Effect of foliar application of bioregulators on canopy photosynthesis in Kabuli type chickpea variety under normal sown (A) and late sown condition (B)

Effect of bioregulators on chickpea



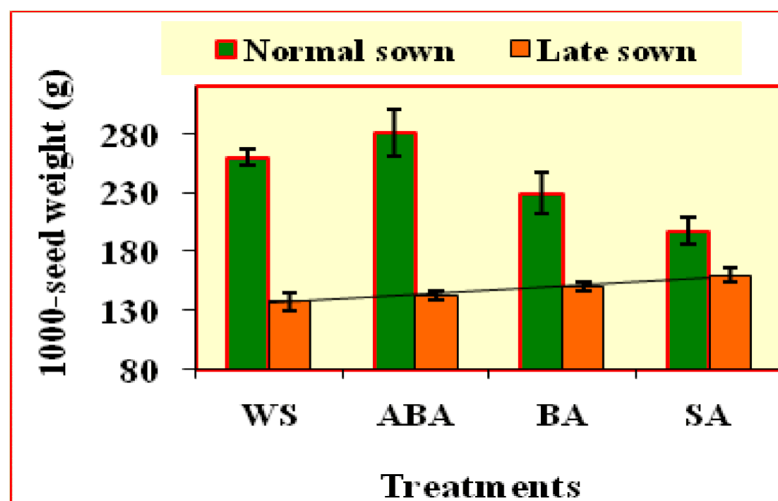
(A)



(B)

WS- Water spray, ABA- Absciscic acid, BA- Benzyl adenine, SA- Salicylic acid

Fig 2. Effect of foliar application of bioregulators on stomatal conductance in Kabuli type chickpea variety under normal sown (A) and late sown condition (B)



WS- Water spray, ABA- Absciscic acid, BA- Benzyl adenine, SA- Salicylic acid

Fig 3. Effect of foliar application of bioregulators on test weight in Kabuli type chickpea variety under normal and late sown condition

Table 1. Effect of foliar application of bioregulators on canopy photosynthesis in Kabuli type chickpea variety under normal sown and late sown condition

Bioregulator	Canopy photosynthesis (μmol CO ₂ /m ² /S) days after foliar application					Mean
	0	10	20	30	40	
Normal sown (A)						
Control	8.84	8.84	21.97	39.06	6.36	8.84
ABA (10 ppm)	8.84	19.06	47.93	38.99	13.13	8.84
BA (40 ppm)	8.84	14.96	35.29	35.20	15.70	8.84
SA (100 ppm)	8.84	14.68	71.03	50.71	16.25	8.84
Mean	8.84	8.84	21.97	39.06	6.36	8.84
Late sown (B)						
Control	12.65	12.65	11.81	6.60		10.93
ABA (10 ppm)	12.65	35.56	47.92	9.86		26.50
BA (40 ppm)	12.65	37.59	36.27	33.22		29.93
SA (100 ppm)	12.65	29.13	33.12	15.70		22.65
Mean	12.65	12.65	11.81	6.60		10.93
CD_{0.05}						
Sowing (A)	0.969	0.177	0.144	0.969		
Treatment (B)	NS	509.9	2049.7	815.250		
A x B	NS	NS	NS	NS		

Effect of bioregulators on chickpea

Table 2. Effect of foliar application of bioregulators on stomatal conductance in Kabuli type chickpea variety under normal sown and late sown condition

Bioregulators	Stomatal conductance (mmol/m ² /s) (days after foliar application)					Mean
	0	10	20	30	40	
Normal sown (A)						
Control	0.071	0.071	0.283	0.100	0.052	0.127
ABA (10 ppm)	0.071	0.190	0.283	0.154	0.137	0.191
BA (40 ppm)	0.071	0.091	0.217	0.161	0.120	0.147
SA (100 ppm)	0.071	0.135	0.207	0.131	0.037	0.128
Mean	0.071	0.12	0.25	0.14	0.09	0.148
Late sown (B)						
Control	0.150	0.150	0.330	0.333	0.297	0.278
ABA (10 ppm)	0.150	0.058	0.232	0.178	0.165	0.158
BA (40 ppm)	0.150	0.048	0.382	0.365	0.348	0.286
SA (100 ppm)	0.150	0.087	0.250	0.180	0.147	0.166
Mean	0.150	0.086	0.298	0.264	0.239	0.222
CD_{0.05}						
Sowing (A)	NS	0.043	0.052	0.053		
Treatment (B)	NS	NS	0.073	0.076		
A x B	0.073	0.085	0.103	0.107		

2003), soybean (Khan et al 2003) and chickpea (Adedipe et al 1971). Salicylic acid pre-treatment in wheat inhibited the decrease in intrinsic photochemical efficiency (Fv/Fm) in cucumber (Sun et al 2006). Cytokinins enhance plant productivity by protecting the photosynthetic machinery from stress (Chernad'ev 2005). Cytokinins regulating multiple functions in plant cells were shown to control the induction and stimulation of synthesis of critical plant proteins and increase the stability of the photosynthetic apparatus during water deficiency and under other unfavorable conditions. Cytokinins can directly affect photosynthetic

parameters like chlorophyll and photosynthetic protein synthesis and degradation, chloroplast composition and ultrastructure, electron transport and enzyme activities (Synkova et al 1997). Moreover ABA treatment markedly decreased heat damage of the chloroplast ultra-structure; an exogenous ABA concentration of 10⁻⁵ molar was found most effective.

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