Adaptation of photosynthetic components of chickpea to water stress

P.S. Basu, Masood Ali and S.K. Chaturvedi

Indian Institute of Pulses Research (ICAR) , Kanpur- 208 024 (UP), India Email : basups@satyam.net.in

Abstract

Six chickpea genotypes were grown under two distinct soil moisture (rainfed and irrigated) conditions. The relative water content (RWC) of leaves of these genotypes at podding stage decreased to mean value of about 55.7 % in rainfed and 76.5% in irrigated crop. Leaf growth rate and photochemical efficiency (quantum yield,Fv/Fm) of leaves pre-adapted to dark or light did not decrease significantly even RWC declined to about 55% due to water stress. The influence of water stress on steady state minimum fluorescence Fs at various irradiances was also non-significant. This suggested that non-stomatal components associated with photosynthesis were little affected by drought and high irradiance. None of the genotypes showed any significant decrease in the leaf elongation rate under drought. However , the effect of drought on other attributes such as total leaf and secondary branch numbers was prominent which invariably decreased under rainfed. The leaf number had significant association ($r = 0.65^{**}$) with grain yield. The results indicated that photochemical efficiency could be relatively stable and less affected by drought in chickpea. This stability of photosynthetic components could be attributed by maintenance of positive leaf turgor under stress as a result of osmotic adjustment.

Media summary

Photosynthetic components of chickpea involving photochemical efficiency of PS II has been detected as relatively resistant to drought as a result of maintenance of positive leaf turgor and osmoregulation.

Keywords

Leaf water potential, osmotic potential, photosyntheis, photodamage, photoinhibition, drought resistance

Introduction

The chickpea (*Cicer arietinum* L.) is generally grown under conserved moisture condition and the crop usually encounters into terminal drought during pod filling stage. The reduction in the grain yield in chickpea under drought has been reported to be associated with significant decrease in the above ground dry matter or vegetative biomass (Basu & Singh, 2003). Growth of the vegetative biomass in chickpea is highly sensitive to drought stress, which is clearly visible, even the crop experiences moderate stress during vegetative period. The reduction in the biomass could be due to either decrease in the photosynthesis or reduced leaf expansion rate or cumulative effect of both (Turner & Begg, 1981). On the other hand, the decline in photosynthesis in dehydrating leaves may be due to stomatal closure or else changing biochemical and biophysical pathways of photosynthesis (Boyer, 1970). The precise mechanism of reduction in the biomass even under moderate water stress is not known. Very little information is available regarding the effect of water stress on photochemical efficiency of PS II in chickpea, the species known to have for wide range of adaptability under drought condition. It is therefore imperative to analyse the factors at the level of non-stomatal components of photosynthesis influencing biomass in chickpea.

Methods

Six chickpea (*Cicer arietinum* L.) genotypes namely C 214, K 850, Katila, Phule G5, RSG 143-1 and Vijay were selected for physiological studies. The crop was sown under conserved soil moisture during October 2002 last week without any pre-sowing irrigation. Trial was conducted at experimental station of IIPR , Kanpur in Randomized block design (RBD) with three replications, where moisture treatment were kept as main plot and genotypes in the sub-plot. Two treatments involving different soil moisture regimes (i.e.

irrigated and rainfed) were opted for studying the effect of drought. The irrigated treatment received two irrigations to ensure non-limiting conditions through out the crop growth. Rainfed crops were a allowed to grown on residual soil water. There was no rainfall during the season of experimentation. Soil moisture at different depths was monitored with a neutron moisture probe. Number of secondary branches originating from primary stems and leaf numbers were recorded manually. Biomass was estimated by weighing the oven-dried samples. Water relation characteristics such as relative water content (RWC), leaf water potential and osmotic potential were determined by standard methods or as described by Leport *et al.* (1998). Leaf expansion rate was calculated on the basis of measurement of length of tagged leaves at every 24-hour interval. Chlorophyll fluorescence of the leaves was measured by using Pulse Amplified Modulated Fluorometer (FMS 2 Hansatech, U.K.) according to Schreiber *et al.*. (1986). Quantum yield of leaves was measured at different level of PAR (photosynthetic active radiation) from low to high irradiances (about 10-500 ?mol photons $m^{-2}s^{-1}$) using different levels of actinic light. The fluorescence data were analysed using FMS 2 soft wares.

Results

During terminal drought experienced by the rainfed crops in the month of March, the leaf relative water content (RWC) in rainfed situation decreased to about 15-25% lower than irrigated crop (Table 1). The water stress had no significant effect on effective quantum yield (Fv'/Fm') or steady state minimal fluorescence, Fs at various irradiance levels (Table 1 and 2).

Table 1 : Effect of water stress and irradiance on effective quantum yield (Fv/Fm).

Genotype	Treatment	RWC(%)	Effective quantum yield (Fv'/Fm') Irradiance (?mol photons m^{-2} s^{-1}) levels					
			0	10	50	150	300	500
K 850	Irrigated	72.5	0.77	0.76	0.67	0.59	0.47	0.36
	Rainfed	54.1	0.75	0.75	0.72	0.64	0.46	0.32
PG 5	Irrigated	79.7	0.75	0.73	0.66	0.57	0.42	0.24
	Rainfed	54.5	0.76	0.75	0.65	0.57	0.44	0.23
C 214	Irrigated	78.5	0.75	0.75	0.69	0.59	0.42	0.28
	Rainfed	55.2	0.76	0.76	0.73	0.59	0.48	0.33
Katila	Irrigated	76.4	0.75	0.75	0.75	0.67	0.56	0.44
	Rainfed	57.0	0.74	0.77	0.66	0.60	0.52	0.33

RSG 143-1	Irrigated	74.4	0.75	0.75	0.65	0.57	0.45	0.35
	Rainfed	57.3	0.76	0.73	0.65	0.56	0.46	0.33
Vijay	Irrigated	77.8	0.75	0.75	0.70	0.64	0.49	0.38
	Rainfed	56.1	0.75	0.78	0.71	0.62	0.48	0.33

Genotype **(G)** $LSD_{0.05}$ = 0.017 significant; Treatment **(T)**= ns ; Irradiance **(I)** $LSD_{0.05}$ = 0.017 significant ; **G x T (**$LSD_{0.05}$)= 0.024 significant; **G x I** ($LSD_{0.05}$) = 0.042 significant ;**T x I** = ns ; **G x T x I** = ns

Table 2 : Effect of water stress on steady state minimal fluorescence, Fs.

Genotype	Treatment	RWC(%)	Minimal fluorescence (bits) in dark (Fo) and light (Fs)					
			Irradiance (?mol photons m^{-2} s^{-1}) levels					
			0	10	50	150	300	500
K 850	Irrigated	72.5	422	438	481	503	515	533
	Rainfed	54.1	401	416	439	456	467	480
PG 5	Irrigated	79.7	371	394	410	418	429	444
	Rainfed	54.5	445	296	482	493	498	518
C 214	Irrigated	78.5	369	397	417	433	449	465
	Rainfed	55.2	400	436	463	488	508	529
Katila	Irrigated	76.4	387	400	412	423	430	439
	Rainfed	57.0	396	411	431	441	444	449
RSG 143-1	Irrigated	74.4	413	421	441	448	454	463
	Rainfed	57.3	368	372	382	387	390	402

Vijay	Irrigated	77.8	365	390	399	423	440	463
	Rainfed	56.1	409	421	439	454	474	454

Genotype **(G)** $LSD_{0.05}$ =25.96 significant; Treatment **(T)**= ns ; Irradiance **(I)** $LSD_{0.05}$ = 25.96 significant ; **G x T (**$LSD_{0.05)}$ = 36.71 significant ; **G x I** (LSD 0.05) = ns ; **T x I** = ns ; **G x T x I** = ns

There was no indication of any damage in photosynthetic apparatus of water-stressed leaves, as Fs did not significantly change with respect to water regimes (Table 2). However, the decrease in quantum yield due to high irradiance irrespective of water stress was evident which may be attributed to the transient state of photo-inhibition.

The leaf elongation or expansion rate was not reduced significantly in rainfed crops in spite of the fact that leaf elongation is considered to be very sensitive to drought (Table 3). However, the investigation showed that leaf and secondary branch numbers were more adversely affected due to drought than leaf expansion rate and both these traits were highly correlated (P<0.01) with grain yield or pod numbers per plant (Table 4 & 5).

Table 3 : Leaf expansion rate in relation to water status

Traits	C 214		K 850		Katila		Phule G 5		RSG 143-1		Vijay		LSD 0.05
	IR	RF	IR	RF	IR	RF	IR	RF	IR	RF	IR	RF	
RWC(%)	73.2	65.2	75.6	64.5	72.1	69.0	73.9	71.2	74.9	70.2	72	68.1	0.07
Leaf exp rate (mm/day)	6.2	6.4	5.3	4.6	4.8	5.2	6.5	5.7	4.6	4.2	6.0	4.6	1.68
Water pot.ψ_w (M Pa)	-1.3	-1.5	-0.9	-1.3	-0.9	-1.1	-0.9	-1.2	-0.9	-1.2	-0.9	-1.1	0.04
Osmotic pot. .ψs (M Pa)	-1.5	-1.8	-1.0	-1.5	-1.2	-1.4	-1.0	-1.5	-1.0	-1.5	-1.0	-1.3	0.07
Turgor pot. , P (MPa)	0.2	0.3	0.1	0.2	0.3	0.3	0.1	0.3	0.1	0.3	0.1	0.2	0.05

IR= Irrigated ; RF = Rainfed

Table 4 : Leaf and secondary branch numbers per plant at two levels of soil moisture

Traits	C 214		K 850		Katila		Phule G 5		RSG 143-1		Vijay		LSd 0.05
	IR	RF	IR	RF	IR	RF	IR	RF	IR	RF	IR	RF	
Leaf number	220	161	170	114	216	185	227	151	331	208	192	98	37.8
Secondary Branch	21	10	20	8	19	11	21	11	52	15	16	7	3.2

Table 5 : Associations (r) of leaf and secondary branch numbers with pods

	Secondary branch number	Leaf number	Pod number
Secondary branch	1	0.8**	0.76**
Leaf number		1	0.65**
Pod number			1

** Significant at P<0.01

Conclusion

The results showed that neither quantum yield nor minimal fluorescence Fs were affected due to lowering of RWC in chickpea. This finding is not in agreement with other earlier reports that indicated decrease in the quantum yield (Fv'/Fm') as a result of various abiotic stresses such as drought and high light in many plants (Wang et al, 2001; Basu et al, 1998), although crop growth conditions and intensity of drought might be different in different studies. Photochemical damage due to stress was usually reflected in either an increase in original fluorescence Fo/Fs, or decreases in maximum fluorescence (Fm), variable fluorescence (Fv) or quantum yield (Fv/Fm). This indicates the existence of some inherent mechanism that allows the photochemical process involving PS II to function normally in chickpea under water stress. This resistance could be due to inherent ability to maintain positive turgor with decrease in the RWC or leaf water potentials (Table 3). Earlier studies showed that the rates of photosynthesis in chickpea are markedly reduced by water deficits (Leport *et al.,* 1999), which could be due to stomatal closure (Qifu Ma et al., 2001). The present results therefore suggested that non-stomatal components are relatively stable due to turgor maintenance in chickpea under mild drought. The maintenance of positive leaf turgor could be attributed to the osmotic adjustment (Turner and Jones, 1980).

References

Basu PS, Sharma A and Sukumaran NP (1998). Changes in net photosynthetic rate and chlorophyll fluorescence in potato leaves induced by water stress. Photosynthetica 35 ,13-19.

Basu PS and Singh DN (2003). Physiology and abiotic stresses in chickpea. In “ Chickpea Research in India “ (Eds. Masood Ali, Shiv Kumar and NB Singh). pp 137-166 (IIPR, Kanpur, India).

Boyer JS (1970) Differing Sensitivity of photosynthesis to low leaf water potentials in corn and soybean . Plant Physiology 46, 236-239.

Leport L, Turner NC, French RJ, Barr MD, Duda R, Davies SL, Tennant, D, Siddique KHM (1999). Physiological responses of chickpea genotypes to terminal drought in Mediterranean type environment. European Journal of Agronomy 11, 279-291.

Turner NC and Begg JE (1981). Plant-water relations and adaptation to stress. Plant and Soil 58, 97-131.

Turner NC and Jones MM (1980). Turgor maintenance by osmotic adjustment : a review and evaluation. In “Adaptation of plants to water and high temperature stress“ (Eds. Turner NC and Kramer PJ), pp 87-103 (Wiley Interscience, New York).

Qifu Ma MH, Behboudian, Turner NC and Palta JA (2001). Gas exchange by pods and subtending leaves and recycling of CO_2 by pods of chickpea (Cicer arietinum L.) subjected to water deficits. Journal of Experimental Botany 52, 123-131.

Screiber U, Schliwa U, Bilger W (1986). Continuous recording of photochemical and non-photochemical chlorophyll fluorescence quenching with a new type of modulation fluorometer. Photosynthesis Research 10, 51-62.

Wang-YongJian, Zhang-HaiYing , Zhang-Feng; Xu-Yong; Cao-WanHong; Kang-GuoBin; Wang-YJ, Zhang-HY, Zhang-F, Xu-Y, Cao-WH, Kang-GB (2001).Effects of low temperature and low light intensity stress on photosynthesis in seedlings of different cucumber varieties. Acta-Horticulturae-Sinica 28, 230-234.