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BIOCHEMICAL AND PHENOLOGICAL EVALUATION OF CHICKPEA GENOTYPES DIFFERING IN DROUGHT TOLERANCE

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SUMMARY

Field experiment was conducted to study the mechanism of moisture stress tolerance during flowering and grain filling stages in chickpea genotypes, and its impact on seed yield. Eight chickpea genotypes (four tolerant and four susceptible) of different adaptations were taken for the study. Soil moisture extraction pattern showed that chickpea crop drew soil moisture from deeper root zone upto 90-cm depth. Greater accumulation of solutes like sugar, soluble proteins and proline content was observed under moisture stress condition at 105 DAS. However, at the later stage of crop growth (125 DAS) under rainfed condition, the soluble protein and soluble sugar contents decreased below the irrigated-control plants, while proline content was slightly higher than control plants. Under rainfed condition greater accumulation of solutes occurred at comparatively higher osmotic potential at 105 DAS than at 125 DAS, when plants showed much lower osmotic potential. Susceptible chickpea genotypes showed reduced grain filling duration (11-14 days) and greater reduction in seed yield as compared to tolerant genotypes. Thus, it can be concluded that chickpea genotypes have osmoregulation as mechanism of drought tolerance at lower osmotic potential.

Key words: **Chickpea, drought, osmotic potential, proline, seed yield, soluble proteins.**

INTRODUCTION

India is one of the major pulses growing countries in the world, accounting for roughly one third of the total world area under pulses and one fourth of the total world production (Anonymous 1999). Among the pulses, chickpea (*Cicer arietinum)* is the most important crop representing about 27 per cent of the land area under pulse, which contributes 33 per cent of the total pulse production in India (Anonymous 2000). Chickpea is grown across a wide range of environments in India and other countries (Siddique *et al*. 2000) and cultivated as a rainfed crop on residual soil moisture (Saxena *et al*. 1990 and Leoport *et al*. 1999). The chickpea crop experiences moisture stress during flowering and grain filling stages under Northern Indian conditions.

Osmotic adjustment is considered as an important physiological mechanism of drought adaptation in many plants (Subbarao *et al.* 2000) and particularly in chickpea cultivars at lower osmotic potential (Chopra *et al*. 1995, Leoport *et al*. 1998). Osmotic adjustment requires regulation of intracellular levels of several compounds, collectively known as osmolytes (Janardhan and Bhojraja 1999). Leoport *et al*. (1999) observed considerable genetic variation from 0 to –1.3 MPa in osmotic adjustment among chickpea genotypes. Besides causing the accumulation of specified compounds, water stress

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*Corresponding author's present address: Department of Basic Science, GBPUA&T, Hill Campus, Ranichauri, Tehri Garhwal-249 199, E-mail: panks_kr@yahoo.co.in is accompanied by shift in the partitioning of photosynthates (Hare *et al.* 1998). Moisture stress increased total sugar, soluble protein and free amino acid content in chickpea cultivars and was positively correlated with tolerance to moisture stress (Yadav *et al.* 1996). Proline is one of the important osmolytes which accumulates during moisture stress condition. It helps to maintain turgor and promotes continued growth in low water potential soils (Yadav and Khare 1995, Mullet and Whitsitt 1996). Gorbani *et al.* (1998) observed that soluble protein content decreased while amino acids accumulated during moisture stress in chickpea cultivars. Accumulation of soluble proteins leads to osmotic adjustment as a mechanism of dehydration postponement in chickpea (Lecour *et al.* 1992 and Munoz *et al.* 1998).

The present experiment was therefore, designed to study the osmotic adjustment as a mechanism of dehydration tolerance during flowering and grain filling stages and its impact on grain filling duration and seed yield in tolerant and susceptible chickpea genotypes.

MATERIALS AND METHODS

An experiment was carried out at the Division of Plant Physiology, Indian Agricultural Research Institute, New Delhi with eight chickpea genotypes, four tolerant (C-214, K-850, Annegeri and ICC-4958) and four susceptible (BG-362, H-208, Amethyst and Tyson) under field condition. The seeds were obtained from Pulse Research Laboratory, Division of Genetics, IARI, New Delhi. Genotypes C-214, K-850, BG-362 and H-208 are adopted to North Indian conditions, Annegeri and ICC-4958 to South Indian, while Amethyst and Tyson are Australian genotypes. Forty eight plots of 4.0 × 1.2 m were sown in three replications under irrigated and rainfed conditions. The irrigated and rainfed plots were separated by 10m to avoid any seepage of moisture. One presowing irrigation was given under both the conditions to make the soil conducive for proper germination and growth, whereas, second irrigation at the time of flowering was given only to the irrigated treatment as per recommendation.

Soil water content was determined under irrigated and rainfed conditions at 20 days interval from 45 DAS to 125 DAS at the depths of 0-30 cm, 30-60 cm, 60-90 cm and 90-120 cm. Three soil samples were taken at random from each plot at each depth with the help of auger and fresh weight was recorded. The soil was dried in oven at 80ºC for 48 h and its dry weight was recorded. The soil water content (SWC) was calculated by using the following formulae:

$$\text{SWC (\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \times 100$$

Total sugar content was estimated following the method of Dubois *et al.* (1956) and total soluble protein was estimated following the method of Chinard (1952). The osmotic potential was measured with the help of Wescor-5500 Vapour Pressure Osmometer (Wescor, USA). The number of days from flowering to maturity was recorded in chickpea genotypes and expressed as days under both irrigated and rainfed condition. Seed yield per plant was recorded by uprooting five plants from each replication and expressed as g/plant.

RESULTS AND DISCUSSION

Soil moisture depletion pattern shows that the soil water content (SWC) decreased in all layers under study with the age of the crop (Fig. 1). The significant decrease in SWC was observed upto the depth of 60-90 cm. However, maximum decrease in SWC was observed between 0-30 cm depth followed by 30-60 cm depth. It shows that chickpea is a deep rooted crop and draws soil water upto 90 cm depth. Saxena *et al.* (1983) reported that chickpea crop can extract soil moisture upto 150 cm depth.

The total sugar content in leaves was maximum at 105 DAS and decreased thereafter under both irrigated and rainfed conditions (Table 1). The total sugar content was significantly higher under rainfed condition as compared to irrigated control at 105 DAS. Significantly higher sugar was observed in genotype ICC-4958 followed by K-850 and C-214. At 125 DAS the total sugar decreased significantly as compared to 105 DAS and the decrease was more under rainfed condition as compared to irrigated condition. Greater reduction in sugar was observed in susceptible genotypes as compared to tolerant genotypes at this stage. The translocation of soluble sugar from source was faster under rainfed

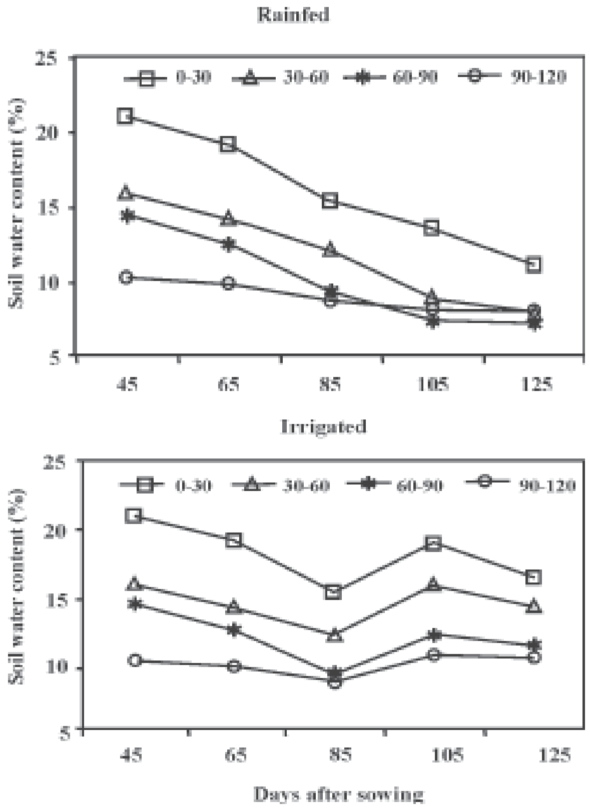

Fig. 1. Soil water extraction pattern of chickpea genotypes under irrigated and rainfed conditions

condition as compared to irrigated condition, which was associated with early maturity and reduced grain filling period. However, lesser impact of moisture stress was observed in tolerant genotypes as compared to susceptible genotypes under rainfed condition. Accumulation of sugars under moisture stress condition in chickpea cultivars has also been reported by Yadav *et al.* (1996) and Leoport *et al.* (1998).

Soluble protein content in leaves was significantly higher at 105 DAS as compared to 125 DAS both under irrigated and rainfed conditions (Table 1). The genotype K-850 possessed highest soluble protein content followed by ICC-4985 under rainfed condition. The soluble protein content at 105 DAS was significantly higher under rainfed condition as compared to irrigated condition in all the genotypes. At 125 DAS, significant decrease in soluble protein content was observed under both the conditions and greater reduction was observed under rainfed condition. Genotype IC-4958 possessed highest soluble protein followed by C-214 and K-850 under irrigated condition whereas, under rainfed condition genotype IC-4958 recorded highest soluble protein content followed by Amethyst. Though all the chickpea genotypes recorded significantly higher soluble protein content in

Table 1. Effect of moisture stress on total soluble sugar (mg g^{-1} dw) and soluble proteins (µg g^{-1} dw) at different growth stages in leaves of chickpea genotypes.

Genotypes	**Total soluble sugar**						**Soluble proteins**					
	105 DAS			**125 DAS**			**105 DAS**			**125 DAS**		
	Irrigated	**Rainfed**	**Mean**	**Irrigated**	**Rainfed**	**Mean**	**Irrigated**	**Rainfed**	**Mean**	**Irrigated**	**Rainfed**	**Mean**
C-214	6.07	10.31	8.19	4.73	4.21	4.47	197	469	333	189	168	179
K-850	6.27	11.31	8.79	5.02	3.78	4.40	217	489	353	186	159	173
Annegeri	6.57	10.00	8.29	5.56	4.97	5.27	179	475	327	165	146	156
ICC-4958	6.63	11.54	9.09	5.10	5.74	5.42	246	484	365	219	185	202
BG-362	6.69	9.42	8.06	4.94	3.91	4.43	193	433	313	182	143	163
H-208	5.91	9.22	7.57	4.35	3.39	3.87	208	380	294	150	130	140
Amethyst	6.35	9.30	7.83	4.85	3.53	4.19	192	401	297	159	150	155
Tyson	6.18	9.66	7.92	4.62	2.99	3.81	178	330	254	164	134	149
Mean	**6.33**	**10.09**		**4.90**	**4.06**		**201**	**433**		**177**	**152**	
	Genotypes	Treatment	G x T	Genotypes	Treatment	G x T	Genotypes	Treatment	G x T	Genotypes	Treatment	G x T
CD at 5%	0.323	0.166	0.502	0.203	0.112	0.296	32.325	16.884	46.594	27.591	13.339	37.513

leaves under moisture stress condition as compared to irrigated control at 105 DAS, but it mobilized very fast from leaves under rainfed condition at 125 DAS. However, not much difference in soluble protein content was observed between 105 DAS and 125 DAS under irrigated condition. The accumulation of soluble protein in leaves of chickpea genotypes under moisture stress condition helps in maintaining turgor (Chopra *et al*. 1995). Besides causing the accumulation of specified compounds, water stress is accompanied by shift in the partitioning of photosynthates (Hare *et al*. 1998).

The proline content in leaves was significantly higher under rainfed condition in all the chickpea genotypes as compared to irrigated control at both the stages of crop growth under study, and significant genotypic differences were also observed (Table 2). The genotype ICC-4958 possessed highest proline content followed by BG-362 under irrigated condition. Whereas, the genotype K-850 possessed the highest proline content followed by ICC-4958 and C-214 under rainfed condition. At 125 DAS, significant decrease in proline content under both irrigated and rainfed conditions were observed. However, relatively lesser decrease in proline content was observed in tolerant genotypes as compared to susceptible genotypes. Unlike, sugars and soluble protein content, the proline content remained higher under rainfed condition as compared to irrigated-control even at 125 DAS. Proline accumulation helps to maintain turgor and promotes continued growth under moisture stress condition (Yadav and Khare 1995, Mullet and Whitsitt 1996).

The osmotic potential was significantly lower under rainfed condition at both the stages as compared to irrigated control (Table 2). This reduction in osmotic potential was 32.00 to 45.78 per cent in tolerant genotypes and 12.62 to 26.48 per cent in susceptible genotypes. Significantly lower osmotic potential was observed in genotype ICC-4958 followed by K-850, Annegeri and C-214 as compared to susceptible genotypes under rainfed condition. The moderate decline in osmotic potential under moisture stress condition at 105 DAS was associated with the accumulation of osmolytes like sugars, soluble proteins and proline, while a further drastic decline at 125 DAS resulted in lowering of sugars, soluble protein and proline contents. Accumulation of these osmolytes leads to lower osmotic potential and helps

Table 2. Effect of moisture stress on proline content (mg g^{-1} fw) and osmotic potential (MPa) at different growth stages in leaves of chickpea genotypes.

Genotypes	Proline content						Osmotic potential					
	105 DAS			125 DAS			105 DAS			125 DAS		
	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean
C-214	2.31	9.45	5.88	1.28	7.02	4.15	-2.00	-2.64	-2.32	-2.33	-3.20	-2.77
K-850	2.36	9.74	6.05	1.85	7.17	4.51	-1.74	-2.77	-2.25	-2.26	-3.42	-2.84
Annegeri	2.17	8.73	5.45	2.00	7.30	4.65	-1.84	-2.60	-2.22	-2.42	-3.23	-2.83
ICC-4958	2.66	9.60	6.13	1.35	8.36	4.86	-1.90	-2.77	-2.33	-2.29	-3.51	-2.90
BG-362	2.51	6.81	4.66	2.14	6.33	4.24	-1.83	-2.23	-2.03	-2.08	-2.79	-2.43
H-208	2.34	6.65	4.50	1.24	5.82	3.53	-1.85	-2.34	-2.10	-2.24	-2.92	-2.58
Amethyst	2.09	6.32	4.21	1.28	5.92	3.60	-1.98	-2.35	-2.16	-2.26	-2.61	-2.43
Tyson	2.38	7.38	4.88	1.01	6.53	3.77	-1.98	-2.23	-2.11	-2.14	-2.75	-2.45
Mean	**2.35**	**8.09**		**1.52**	**6.81**		**-1.89**	**-2.49**		**-2.25**	**-3.05**	
	Genotypes	Treatment	G x T	Genotypes	Treatment	G x T	Genotypes	Treatment	G x T	Genotypes	Treatment	G x T
CD at 5%	0.212	0.115	0.322	0.313	0.154	0.397	0.127	0.064	0.180	0.164	0.082	0.231

in avoiding drought by maintaining leaf turgor and growth in chickpea genotypes (Leoport *et al.* 1998, Munoj *et al.* 1998).

The influence of early mobilization of osmolytes from leaves under moisture stress condition was seen on days to maturity (Fig. 2A). The susceptible genotypes matured (11-14 days) early as compared to tolerant genotypes (1-8 days) under rainfed condition. Days from 50% flowering to maturity decreased in all the genotypes under rainfed condition (Fig. 2B). The reduction in days from 50% flowering to maturity was more in susceptible genotypes as compared to tolerant genotypes. Moisture stress condition reduced the duration of grain filling period in chickpea genotypes by early mobilization of photosynthates from the source, which resulted in reduction in seed yield (Fig. 2C). The decrease in seed yield per plant was more in susceptible genotypes (10.46 to 21.09 %) as compared to tolerant genotypes (2.97 to 5.73%). However, the lowest decrease in seed yield was observed in genotype C-214 (2.97%) followed by ICC-4958 (4.35%) and Annegeri (4.73%). Lopez *et al.* (1996) and Mwanamwenge *et al*. (1999) have reported that moisture stress during flowering or during pod filling stage causes maximum loss in seed yield.

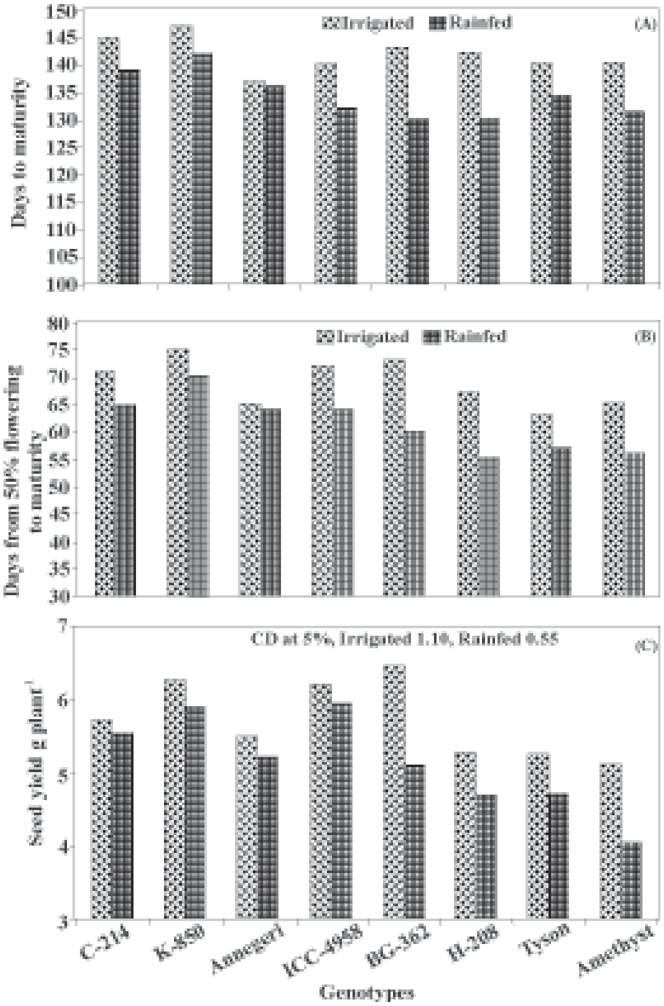

Fig. 2. Effect of moisture stress on days to maturity (A), days from 50% flowering to maturity (B) and seed yield per plant (C) under rainfed and irrigated condition in chickpea genotypes

It can be concluded from the present investigation that chickpea genotypes show greater osmolyte accumulation at moderately low osmotic potential, which helps to tolerate moisture stress and also draw soil moisture from deeper root zone to maintain turgidity. The greater reduction in grain filling duration in susceptible genotypes, which was associated with early mobilization of photosynthates under moisture stress condition resulted in more decline in yield than in tolerant genotypes.

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