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Ekta Verma
Department of Biochemistry, COBS & H, CCS Haryana Agricultural University, Hisar, Haryana, India

Jayanti Tokas
Department of Biochemistry, COBS & H, CCS Haryana Agricultural University, Hisar, Haryana, India

HR Singal
Department of Biochemistry, COBS & H, CCS Haryana Agricultural University, Hisar, Haryana, India

Correspondence
Jayanti Tokas
Department of Biochemistry, COBS & H, CCS Haryana Agricultural University, Hisar, Haryana, India

Effect of drought on physiological parameters in chickpea cultivars and their crosses

Ekta Verma, Jayanti Tokas and HR Singal

Abstract
The present study was planned to study the various physiological parameters in leaves and roots of 20 F3 progeny lines of cross HC-1×ICC-4958 (I-1 to I-20) drought sensitive (HC-1) and drought tolerant (ICC-4958) of chickpea. Drought stress adversely affected plant water status of chickpea genotypes. The water potential of leaves and osmotic potential of leaves and roots decreased under drought condition and this was accompanied by significant decline in relative water content (RWC). However, the reduction in RWC was more in drought-sensitive genotype than both the drought tolerant genotypes. Among the progeny lines, I-6, I-7, I-8 and I-16 lines maintained the water status comparable to their respective drought tolerant parent. It can be concluded that drought tolerant genotypes acclimated better than sensitive genotype by maintaining higher water relations.

Keywords: Chickpea, drought, genotypes, osmotic, physiological, progeny

Introduction
Chickpea (*Cicer arietinum* L.), commonly known as gram or Bengal-gram, is an important source of plant-derived edible proteins. It provides approximately 20-30% protein, 41-51% carbohydrates, 3-6% oil and is a rich source of minerals. It is the 3rd largest grain-legume crop in the world, with a total production of 13.1 million tons [1]. It is the most important pulse crop of India and its adjoining countries and accounts for 90% of the total world production [2]. In India, the area under chickpea cultivation is 8.2 million ha and productivity is 895 kg/ha. Chickpea contributes to a share of 50% of total pulse produced in India and that makes India a leading chickpea producing country in the world. Drought stress, like other abiotic stresses, is a major contributor to oxidative stress in the plant cell due to higher leakage of electrons towards oxygen during photosynthesis and respiratory processes leading to increase in reactive oxygen species (ROS)**.** Both qualitative and quantitative changes of proteins have been detected during the stress [3, 4] as exposure of plants to drought stress results in a complex set of gene expression and selective translation of mRNA encoding proteins, thereby enhancing tolerance and improving cellular survival to subsequent water deficit conditions. Keeping in view the above, the present investigation was conducted in 20 F3 progeny lines of cross HC-1×ICC-4958 (I-1 to I-20) drought sensitive (HC-1) and drought tolerant (ICC-4958) of chickpea to get information on the physiological responses to drought stress.

Material and Methods
Leaves and root samples of 20 F3 progeny lines of cross HC-1×ICC-4958 (I-1 to I-20) drought sensitive (HC-1) and drought tolerant (ICC-4958) of chickpea were taken, at 50 percent flowering and 50 percent podding stages. The crop was grown in specially constructed facilities of concrete microplots (6m long, 1m wide and 1.5m deep connected with iron gates and washing tanks) filled with sandy soil and irrigated up to field capacity at Crop Physiology Field Lab, Agronomy Research Farm, CCS HAU, Hisar (29º10'N, 75º46' E, 215 m altitude), Haryana, India. The plots were fertilized at 15kg N ha^{-1} and 40kg P_2O_5 ha^{-1} as basal dose before sowing. The seeds were inoculated with *Rhizobium* culture Ca-181. Each genotype was sown under two environments, irrigated (I: two irrigations of 6 cm depth each at flowering and pod filling) and rainfed (R: one irrigation of 30 mm equal to long-term average seasonal rainfall). The plots were kept weed free by hand weeding and intensive protection measures were taken against pod borer (*Helicoverpa armigera*). The soil moisture content at the time of sowing was 12.8% upto 15cm depth.

The soil moisture content in depth range of 45-135cm in irrigated plots was 9.9% and 6.6% under drought condition at the time of observation (80-120 days).

Osmotic potential (Ψ_s): It was determined using psychrometric technique (Model 5100-B Vapor Pressure Osmometer, Wescor Inc. Logan, Utah, USA).

Relative water content (RWC): The samples were taken at mid day (between 9:00 and 11:00 AM), quickly reeled in humified polythene bags then transported to the laboratory and weighed immediately to take their fresh weight and RWC (%) was calculated [5].

Relative stress injury (RSI): RSI was determined according to the standard method [6, 7].

Results and Discussion

Drought stress adversely effected plant water status by significantly declining water potential (ψ_w) of leaves, osmotic potential (ψ_s) of leaves and roots (Table 1) and relative water content (RWC) of leaves and roots (Table 2) in chickpea genotypes at 50% flowering and 50% podding stages. One progeny line (I-14) of cross HC-1×ICC-4958 had lower ψ_s than their both the parental genotypes at 50% flowering stage, while at 50% podding stage, progeny lines I-6 and I-14 showed the lower ψ_s than their respective parents under drought condition.

Roots maintained higher ψ_s than leaves at both the developmental stages. At 50% podding stage, two progeny lines (I-8 and I-14) of cross HC-1×ICC-4958 had lower ψ_s than both the parents. Five progeny lines (I-1, I-2, I-3, I-4 and I-19) of cross HC-1×ICC-4958 at 50% flowering stage, whereas three progeny lines of cross at 50% podding stage maintained higher ψ_s than their both parental genotypes.

Relative water content of leaves was relatively low under drought stress as compared to irrigated condition in all the parental genotypes at 50% flowering stage. Under irrigated condition, RWC was 89.97%, 92.98% and 90.67% in genotypes HC-1, ICC-4958, whereas under drought condition it was 72.24%, 82.92% and 78.92%, respectively. Most of the progeny lines of cross HC-1×ICC-4958 maintained RWC similar to their both parental genotypes. Maximum RWC was observed in progeny line I-16 and minimum in I-3.

Similarly, at 50% podding stage also decrease in RWC was high in genotype HC-1 (24.47%) as compared to both the tolerant genotypes (15.06-18.81%) under stress condition. Relative water content ranged from 56.18 to 66.26% and 47.30 to 60.89% for F_3 progeny lines of HC-1×ICC-4958 cross. Maximum RWC was observed in progeny lines I-16. None of the progeny lines of cross HC-1×ICC-4958, exhibited lower RWC than sensitive parent.

Roots maintained a better water status in terms of RWC as compared to leaves under stress condition. The reduction in roots RWC was less than that of leaves in all the parental and progeny lines at both the developmental stages. At 50% flowering stage, a significant decline in RWC was observed in all the genotypes under drought stress. Genotype ICC-4958 showed the lowest decrease in RWC (9.39%) than HC-1 (15.97%). Relative water content in F_3 progeny lines of cross HC-1×ICC-4958 varied between 76.33 and 86.53%,. Most of the progeny lines of maintained RWC between the range similar to their respective parental genotypes. However, maximum RWC was recorded in progeny lines I-7, while minimum was recorded in I-10. At 50% podding stage, similar trend of decrease in RWC was shown by parental genotypes. None of the progeny lines of cross HC-1×ICC-4958 had lower RWC than sensitive parent,. Progeny line I-7 had highest RWC.

A significant increase in relative stress injury (RSI) was observed in parental genotypes under drought stress condition. Under irrigated condition, RSI in genotype HC-1 was 12.40 and 21.35%, whereas under stress condition it was recorded as 23.78 and 43.18% at 50% flowering and 50% podding stages, respectively. Similarly, increase in relative stress injury was recorded in both the drought tolerant genotypes i.e. ICC-4958 upon imposition of drought stress but to a smaller extent than HC-1 at both stages. At 50% flowering stage none of the progeny lines of cross HC-1×ICC-4958, exhibited more stress injury than sensitive parental genotype, while at 50% podding stage, four progeny lines I-2, I-3, I-4 and I-10 showed higher stress injury than their sensitive parent.

Among all the parental genotypes, maximum stress injury was in drought sensitive genotype HC-1 (83.02-93.55%) at both the developmental stages. Stress injury in roots was observed to be lower in two progeny lines of each cross with minimum injury in I-6, at 50% flowering stage. At 50% podding stage, highest stress injury was observed in progeny lines I-3, whereas the same was lowest in I-7.

Drought tolerant genotypes showed significantly higher reduction in ψ_w and ψ_s as compared to sensitive genotype. Most of the F_3 progeny lines maintained their water status similar to their both the parental genotypes and progeny lines, I-6, I-7, I-8, I-16 and I-18 maintained water status even better than their tolerant parent. Osmotic potential of leaves showed more '-ve' values as compared to ψ_w at both stages. The results obtained are in agreement to previous reports on the effect of drought stress on ψ_s in wheat and melon genotypes [8]. Reports stated a decline in ψ_s and RWC in drought sensitive and drought tolerant cultivars of groundnut with lower reduction in RWC in tolerant cultivars [9]. Reduction in RWC of leaves and roots to adjust osmotic pressure has also been demonstrated by several workers under drought stress in black gram [10], chickpea [11] and wheat [12]. Decrease in ψ_s and ψ_w under stress conditions has been proposed to play an important role in turgor adjustment and survival of plants under dry conditions [13, 14]. It has also been suggested that high RWC could help the tolerant genotypes to perform physico-biochemical processes more efficiently under stress conditions than susceptible genotypes of chickpea [15]. Decline in ψ_s can be a result of either simple passive concentration of solute or net solute accumulation e.g. amino acids like proline, betaine, total soluble sugars and ion accumulation [16].

Present investigation revealed the more accumulation of proline in leaves and roots under drought stress at 50% flowering and 50% podding stages in drought tolerant genotypes ICC-4958 and RSG-931 than drought sensitive genotype HC-1

Table 1: Osmotic potential (-MPa) in different plant parts of parental chickpea genotypes and F_3 generation of their cross (HC-1×ICC-4958) under drought condition

Cultivars/ Genotypes	50% Flowering		50% Podding	
	Leaves	Roots	Leaves	Roots
Parents	**Irrigated Condition**			
HC-1	1.16±0.080	1.01±0.040	1.79±0.020	1.53±0.017
ICC-4958	1.14±0.100	1.05±0.030	2.16±0.030	1.75±0.070
Drought Condition				
HC-1	1.37±0.050	1.23±0.100	2.09±0.090	1.79±0.020
ICC-4958	1.63±0.070	1.60±0.080	2.68±0.020	2.12±0.030
Progeny lines of cross HC-1×ICC-4958				
I-1	1.30±0.040	1.14±0.015	2.30±0.080	1.80±0.019
I-2	1.20±0.100	1.18±0.020	2.22±0.080	1.46±0.135
I-3	1.02±0.085	0.88±0.060	1.88±0.010	1.43±0.033
I-4	1.12±0.035	1.01±0.045	1.93±0.050	1.53±0.017
I-5	1.38±0.040	1.29±0.040	2.38±0.013	1.82±0.021
I-6	1.43±0.011	1.38±0.009	2.74±0.020	2.01±0.040
I-7	1.39±0.045	1.30±0.026	2.40±0.065	1.89±0.032
I-8	1.48±0.035	1.39±0.055	2.54±0.075	2.16±0.010
I-9	1.43±0.027	1.39±0.010	2.62±0.032	1.97±0.020
I-10	1.40±0.020	1.36±0.100	2.48±0.024	1.85±0.014
I-11	1.42±0.030	1.33±0.018	2.51±0.015	1.93±0.030
I-12	1.40±0.021	1.29±0.012	2.39±0.040	1.85±0.100
I-13	1.39±0.035	1.30±0.052	2.36±0.030	1.83±0.006
I-14	1.74±0.015	1.41±0.040	2.77±0.010	2.15±0.020
I-15	1.37±0.020	1.29±0.030	2.35±0.033	1.82±0.080
I-16	1.47±0.024	1.43±0.012	2.56±0.025	1.93±0.060
I-17	1.37±0.015	1.28±0.040	2.31±0.090	1.81±0.070
I-18	1.42±0.028	1.31±0.040	2.44±0.095	1.85±0.070
I-19	1.14±0.040	1.09±0.025	2.26±0.024	1.80±0.030
I-20	1.39±0.040	1.30±0.020	2.46±0.040	1.82±0.100
CD (5%)	0.14	0.13	0.15	0.16

Table 2: Relative water content (%) in different plant parts of parental chickpea genotypes and F_3 generation of their cross (HC-1×ICC-4958) under drought condition

Cultivars/Genotypes	50% Flowering		50% Podding	
	Leaves	Roots	Leaves	Roots
Parents	**Irrigated Condition**			
HC-1	89.97±0.12	91.31±4.00	73.72±0.51	75.57±1.00
ICC-4958	92.98±1.03	93.96±1.85	75.18±1.17	80.41±2.00
Drought Condition				
HC-1	72.24±0.71	76.73±0.28	55.68±0.32	59.42±0.83
ICC-4958	82.92±2.50	85.14±0.40	63.86±1.46	68.92±1.08
Progeny lines of cross HC-1×ICC-4958				
I-1	77.15±0.15	80.53±2.11	59.34±0.99	61.56±0.75
I-2	76.94±0.27	80.33±1.37	59.97±0.55	62.42±0.37
I-3	75.08±0.35	76.62±1.12	59.45±0.15	62.68±0.57
I-4	76.96±0.36	79.88±0.76	59.26±0.61	60.42±0.37
I-5	79.30±0.49	82.60±0.96	61.04±0.27	66.55±0.45
I-6	79.49±0.51	84.79±1.64	63.58±0.98	67.20±3.94
I-7	83.35±1.17	86.53±0.11	66.25±0.25	70.83±1.73
I-8	81.27±1.36	86.10±0.85	63.58±1.02	70.83±1.64
I-9	79.41±0.50	83.11±1.41	62.46±0.40	67.27±0.73
I-10	76.99±0.54	76.33±1.21	56.18±0.90	59.51±1.09
I-11	78.98±0.81	83.64±1.94	61.66±0.66	65.19±1.63
I-12	81.02±0.92	83.83±0.87	62.24±1.32	67.64±1.95
I-13	77.63±0.48	82.38±2.17	60.87±0.87	65.08±0.84
I-14	79.72±1.19	82.38±1.84	61.81±0.67	67.22±1.35
I-15	77.54±0.27	80.62±2.12	60.56±0.44	64.72±1.16
I-16	84.00±0.20	86.23±0.77	66.26±0.80	67.83±1.14
I-17	77.78±1.25	82.29±0.86	60.70±0.24	64.39±0.50
I-18	82.94±0.21	84.47±0.53	63.78±0.66	68.57±0.72
I-19	77.93±0.07	82.40±0.61	59.99±0.30	64.05±0.79
I-20	79.04±0.81	82.60±0.86	60.63±1.47	64.13±1.00
CD (5%)	2.54	4.46	2.36	4.02

Table 3: Relative stress injury (%) in different plant parts of parental chickpea genotypes and F_3 generation of their cross (HC-1×ICC-4958) under drought condition

Cultivars/Genotypes	50% Flowering		50% Podding	
	Leaves	Roots	Leaves	Roots
Parents	**Irrigated Condition**			
HC-1	12.40±0.33	11.84±0.34	21.35±0.32	18.92±0.02
ICC-4958	09.60±0.68	08.96±0.08	16.58±1.01	15.42±0.05
Drought Condition				
HC-1	23.78±0.46	21.67±0.37	43.18±0.79	36.62±0.58
ICC-4958	15.90±0.66	13.38±0.72	29.12±0.25	25.71±0.35
Progeny lines of cross HC-1×ICC-4958				
I-1	21.79±0.44	18.78±0.22	42.20±0.10	34.53±0.73
I-2	22.67±0.17	21.55±0.25	46.44±0.83	40.57±0.25
I-3	23.16±0.93	22.11±0.13	51.75±0.88	47.16±0.48
I-4	21.51±0.26	20.71±0.10	45.61±0.13	36.00±1.09
I-5	16.85±0.47	14.76±0.84	30.81±0.43	27.59±0.24
I-6	13.53±0.29	11.45±0.29	27.02±0.33	25.71±0.15
I-7	13.71±0.14	11.78±0.72	25.77±0.47	21.45±1.08
I-8	15.49±0.76	13.80±0.61	29.93±0.07	26.66±0.32
I-9	19.10±0.89	16.67±0.19	36.06±0.45	30.50±0.13
I-10	23.39±1.15	22.78±0.64	45.89±0.19	41.50±0.29
I-11	18.98±0.16	17.27±0.15	39.77±0.23	30.62±0.22
I-12	19.04±0.52	17.41±0.24	33.20±0.99	28.89±1.15
I-13	21.95±0.16	19.48±0.29	43.08±1.01	33.53±0.04
I-14	18.97±0.61	16.42±0.12	31.15±0.83	27.50±0.14
I-15	19.65±1.18	17.80±0.18	39.66±0.88	32.62±0.35
I-16	16.34±0.02	15.70±0.40	28.94±0.25	23.44±0.45
I-17	20.30±0.62	18.89±0.06	42.05±0.51	33.24±0.34
I-18	17.22±0.46	16.57±0.25	32.91±0.78	29.84±0.09
I-19	19.08±1.07	18.05±0.58	32.59±0.59	31.61±0.18
I-20	21.31±0.66	17.78±0.56	42.92±0.22	32.72±0.28
CD (5%)	1.81	1.18	1.74	1.41

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