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Research Article

Physiological Responses of Chickpea (*Cicer Arietinum*) Genotypes to Drought Stress

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Abstract

Chickpea (*Cicer arietinum* L.) is the third most important food legume with total global production of 13.2 million tons from an area of 15.17 million ha. It is an important legume crops because of its low production cost, wide climate adaptation, use in crop production and atmospheric nitrogen fixing ability. The present study was planned to study the various physiological parameters in leaves and roots of drought sensitive (HC-1) and drought tolerant (ICC-4958 and RSG-931) genotypes/cultivars 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. It can be concluded that drought tolerant genotypes acclimated better than sensitive genotype by maintaining higher water relations.

Keywords: Chickpea, drought, genotypes, osmotic, physiological

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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 from an area of 15.17 million ha and productivity of 0.86 tons ha^{-1} [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 chickpea cultivars (susceptible and resistant) to get information on the physiological responses to drought stress.

Material and Methods

Leaves and root samples of drought sensitive (HC-1) and drought tolerant (ICC-4958 and RSG-931) cultivars 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).

Water potential (Ψ_w)

It was measured with the help of Pressure Chamber (Model 3005, Soil Moisture Equipment Corporation, Santa Barbara, CA, USA), between 8 AM to 11 AM.

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 method of Premchandra *et al*. (1990) as modified by Sairam (1994).

Results and Discussions

Drought stress adversely effected plant water status by significantly declining water potential (ψ_w) of leaves (**Table 1**), osmotic potential (ψ_s) of leaves and roots (**Table 2**) and relative water content (RWC) of leaves and roots (**Table 3**) in chickpea genotypes at 50% flowering and 50% podding stages. A significant decline in ψ_w of all the genotypes under stress condition was observed with more decrease in both the drought tolerant genotypes (ICC-4958 and RSG-931) as compared to sensitive one (HC-1) at both the developmental stages.

Table 1 Leaf water potential (-MPa) of chickpea genotypes under drought condition

Cultivars/Genotypes	50% Flowering	50% Podding
Parents	**Irrigated Condition**	
HC-1	0.81±0.050	0.92±0.010
ICC-4958	0.55±0.020	0.82±0.015
RSG-931	0.71±0.005	0.90±0.012
	Drought Condition	
HC-1	1.34±0.030	1.42±0.011
ICC-4958	1.03±0.045	1.63±0.045
RSG-931	1.23±0.040	1.65±0.020

Table 2 Osmotic potential (-MPa) chickpea genotypes 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
RSG-931	1.20±0.025	1.09±0.070	2.04±0.080	1.68±0.020
	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
RSG-931	1.45±0.025	1.35±0.060	2.47±0.080	2.01±0.040

The osmotic potential of leaves under drought stress decreased from -1.16, -1.14 and -1.20 to -1.37, -1.63 and -1.45 MPa for genotypes HC-1, ICC-4958 and RSG-931, respectively, at 50% flowering stage. The decline in osmotic potential of the tolerant genotypes ICC-4958 and RSG-931 was recorded high, since they may accumulate higher amount of solutes under drought as compared to HC-1. The more negative value of ψ_s was also observed in drought tolerant ggenotypes at 50% podding stage. The drought sensitive genotype was observed with smaller reduction in ψ_s as compare to both the tolerant genotypes.

Relative water content (%)

Relative water content (Table 3) 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 and RSG-931, whereas under drought condition it was 72.24%, 82.92% and 78.92%, respectively.

Table 3 Relative water content (%) of chickpea genotypes 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
RSG-931	90.67±0.44	92.95±1.18	74.73±0.48	77.94±1.83
	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
RSG-931	78.92±0.57	82.25±1.00	60.67±0.53	64.38±0.62

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. 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%) and RSG-931 (11.51%).

Relative stress injury (%)

A significant increase in relative stress injury (RSI) was observed in genotypes under drought stress condition (**Table 4**). 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 and RSG-931 upon imposition of drought stress but to a smaller extent than HC-1 at both stages. Among all the genotypes, maximum stress injury was in drought sensitive genotype HC-1 (83.02-93.55%) at both the developmental stages.

Table 4 Relative stress injury (%) of chickpea genotypes 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
RSG-931	11.91±0.13	09.45±0.34	18.93±0.27	16.97±0.29
	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
RSG-931	20.93±1.35	15.76±0.58	35.70±0.35	30.38±0.28

The results obtained are in agreement to previous reports on the effect of drought stress on ψ_s in wheat and melon genotypes [6]. Reports say decline in ψ_s and RWC in drought sensitive and drought tolerant cultivars of groundnut with lower reduction in RWC in tolerant cultivars occurred [7]. Reduction in RWC of leaves and roots to adjust osmotic pressure has also been demonstrated by several workers under drought stress in black gram [8], chickpea [9] and wheat [10]. 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 [11, 12]. 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 [13]. Decline in ψ_s can be a result of either simple passive concentration of solute or net solute accumulation eg. amino acids like proline, betaine, total soluble sugars and ion accumulation[14]. 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

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