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Response of chickpea genotypes to plant water relations and yield under soil moisture stress

K. D. SHARMA *, R.K. PANNU, P.K. TYAGI, B.D. CHAUDHARY and D.P. SINGH
Crop Physiology Field Lab, Department of Agronomy,
CCS Haryana Agricultural University,
Hisar 125 004, India

ABSTRACT

Six chickpea (*Cicer arietinum* L) genotypes were evaluated under moisture stress for morpho-physiological characteristics conferring resistance to drought. The increased moisture stress reduced the duration of reproductive phase and also total maturity duration over irrigated control. The water use efficiency was higher under rainfed followed by irrigated conditions and lowest in rainout shelters (ROS). Moisture stress significantly reduced the plant water status, plant height, number of effective pods per plant, 100 seed weight, seed yield, biological yield and harvest index over irrigated control. The maturity duration had significant positive association with seed yield (r=0.73). The plant water status parameters had significant positive association with seed yield and soil water use during the crop season. The total water use showed significant association with seed yield (r=0.71). The genotypes, Annegeri and Tyson had relatively higher relative water content (RWC), water use efficiency and seed yield compared to other genotypes tested.

Key words : Plant water relations, moisture stress, water use efficiency, chickpea, yield

Chickpeas are an important source of protein in the Indian sub-continent and Middle East and are increasingly important as a high value export crop and a source of nitrogen for subsequent cereal and oilseed crops. Major constraints to chickpea production are drought and high temperature occurrence during the grain filling stage of crop development. Early maturing varieties that escape terminal drought and heat stress have been developed (Kumar and Abbo, 2001) but early maturity places a ceiling on the potential yield and limits the crop ability to exploit extended growth period. However, the major components associated with seed yield are biological yield and harvest index that are regulated by water use pattern from the soil profile in water deficit environment (Silim and Saxena, 1993). The greater water use from top soil (0-90 cm) during vegetative

* For correspondence: Room No 112, New wing, College of Agriculture, CCS HAU, Hisar 125 004, E-mail: kamald@hau.ernet.in

phase improves the length of pod bearing branches, and more water use from sub-soil (90-180 cm) during reproductive phase of growth increases the pod density and harvest index (Zhang et al,2000). Medium degree of osmotic adjustment has provided similar benefits in long maturing genotypes of chickpea. The development of moisture stress leads to a wide range of changes in plant processes like diversion of biomass to undesirable plant parts. Therefore, the chickpea genotypes with better water use efficiency and high yield will be suitable for cultivation in these stress- prone areas where chickpea is cultivated as rainfed crop.

MATERIAL AND METHODS

Six chickpea (*Cicer arietinum* L) genotypes viz., Tyson, K 850, Ammethyst, Annigeri, ICC 4958 and C 214 were grown during two consecutive rabi seasons (1999-2000 and 2000-2001) in concrete drought plots (dimension 30 x 6 x 2 m) filled with light textured dunal sand at Crop Physiology Field Lab, Agronomy Research Farm, CCS Haryana Agricultural University, Hisar (29° 10'N latitude, 75°46' E longitude and 215 M altitude), India. Four rows of 3 m length with row to row and plant to plant spacing of 30 x 10 cm of each genotype were sown under three environments, namely irrigated (two irrigations at flowering and pod filling each), rainfed (one irrigation of 30 mm, equal to long term average seasonal rainfall) and rainout shelter ROS, (no post sowing irrigation) conditions adopting Randomized Block Design with three replications. The available soil moisture in the 105 cm soil profile was 127 mm at the time of seeding. There was 19 mm rainfall during the growing season (80- 90 DAS) in the first year and there was no rainfall during second year crop season. Recommended agronomic practices were followed to raise the crop.

The soil moisture studies were carried out to find the water use and water use efficiency. Soil moisture of 0-15 cm soil depth was determined by gravimetric method. The soil moisture in 15-45, 45-75, 75-105, 105-135, 135-165 cm soil layers were recorded by Neutron Moisture Meter (Model 2651 Troxler laboratories, Releigh, NC, USA). Observations were recorded at 30 days interval from sowing and also before and after each irrigation upto harvest. Crop water use was computed from soil water content as described by Singh *et al* (1960). Water use efficiency of different treatments was calculated as percent ratio of economic yield with crop water use.

Early vigour was recorded in terms of dry matter accumulation at 35 DAS (about 600° days). Plant water relation parameters along with canopy temperature were recorded at full bloom stage (110 DAS) between 1400 to 1500 h. Leaf water potential (Ψw) was measured by Pressure Chamber (PMS Instrument Co., Oregon, USA), leaf osmotic potential (Ψs) by Vapour Pressure Osmometer (Wescor Inc., Utah, USA) and relative water content (RWC) of leaf as described by Weatherley (1950). The canopy temperature measurements were made using a hand-held Infrared thermometer (Model AG-42 Tela-temp Corp.CA). Measurements were taken by pointing the infrared thermometer at the crop canopy cover at an appropriate angle and distance from the plot, avoiding the effect of soil surface temperature. Data presented are mean of four sets of measurements.

Yield attributes were recorded from five plant samples taken from each plot at harvest. Seed and biological yields were recorded from individual plots and expressed in kg ha^{-1}. The statistical analysis for different parameters and yield were worked out as per standard procedures.

RESULTS AND DISCUSSION

Phenological development

The phenological development (Table 1) indicated that increased moisture stress initiated early flowering and pod formation. Moisture stress in ROS treatment reduced the maturity duration by 15 days over irrigated control, which also resulted in reduced reproductive phase over the irrigated control. Among the genotypes, the ICC 4958 had a significantly greater early vigour over other tested genotypes and also had the shortest maturity duration closely followed by K 850 with non-significant difference among themselves. The earliness (50% flowering) was recorded in genotype ICC 4958 followed by genotypes Annigeri and Tyson. But, the reproductive phase of ICC 4958 was significantly shorter than in C 214. Similar reduction in maturity duration due to moisture stress and higher transpirational losses has been reported earlier by Rehman and Uddin (2000).

Plant water relations

The plant water relations recorded between 1400-1500 h at full bloom in different genotypes showed that severe moisture stress in ROS and mild stress in rainfed environment reduced the relative water content, leaf water potential (Ψw), osmotic potential (Ψs) and increased canopy temperature significantly over irrigated control (Table 2). The decreased leaf water potential and RWC under water stress were also reported by Deshmukh *et al* (2004). Water use efficiency was recorded highest (68.7 kg ha^{-1}-cm) in rainfed environment followed by irrigated condition (61.8 kg ha^{-1}-cm) and was minimum under rainout shelter (57.2 kg ha^{-1}-cm). Evidences in literature reveal that both total water use and water use efficiency are generally higher under non stress conditions as compared to stress (rainfed) conditions (e.g. Silim and Saxena 1993), however, the water use efficiency declines due to more utilization of water without proportionate increase in grain production (Gupta *et al*, 2000, Soltani *et al*, 2001). Among the genotypes, the highest Ψw, Ψs and transpirational cooling were recorded in Amethyst closely followed by K 850, ICC 4958 and Annigeri. Genotype

Table 1 : Early vigour (35 DAS) and phenology (Days after sowing) in chickpea genotypes under moisture stress

Treatments	Early Vigour g plant^{-1}	50% Flowering	50% Podding	Flowering Cessation	Maturity
Environment					
Irrigated	-	98	122	137	150
Rainfed	-	91	121	136	141
ROS	-	88	125	132	140
CD at 5%	NS	4.1	3.0	NS	2.5
Genotypes					
Amethyst	0.19	101	123	136	143
Annigeri	0.24	92	121	135	144
C214	0.22	109	126	140	148
ICC4958	0.44	61	121	133	140
K850	0.30	99	122	137	142
Tyson	0.16	93	124	135	144
CD at 5%	0.05	7.2	NS	NS	4.0

ROS = Rainout Shelter

Table 2 : Effect of moisture stress on plant water relations, water use and water use efficiency of chickpea genotypes.

Treatments	Water potential (-MPa)	Osmotic potential (-MPa)	Relative water content (%)	Canopy temperature (°C)	Water Use (cm)			Water Use Efficiency (kg ha^{-1}-cm)
					Vegetative	Reproductive	Total	
Environment								
Irrigated	2.35	2.51	59.8	31.4	9.89	10.22	20.11	61.81
Rainfed	2.70	2.85	56.6	32.1	10.90	5.78	16.69	68.71
ROS	2.83	3.02	52.4	32.9	9.62	5.75	15.36	57.23
CD at 5%	.013	.062	1.71	0.34	-	-	-	-
Genotypes								
Amethyst	2.45	2.65	54.3	29.7	9.91	7.60	17.51	61.03
Annigeri	2.69	2.95	59.3	31.8	9.53	7.57	17.10	70.40
C214	3.00	3.28	58.8	32.3	10.98	6.62	17.60	64.50
ICC4958	2.68	2.87	52.1	31.8	9.98	7.16	17.15	57.82
K850	2.55	2.69	56.9	31.8	10.36	7.28	17.64	51.53
Tyson	2.57	2.75	54.7	32.4	10.08	7.25	17.33	69.81
CD at 5%	.024	.113	3.12	0.61	-	-	-	-

ROS = Rainout shelter.

Table 3 : Effect of different soil moisture environments on yield attributes and yield in chickpea genotypes.

Treatments	Plant Height (cm)	No. of Effective pods plant^{-1}	No. of Seeds pod^{-1}	100 Seed weight (g)	Biomass Yield (kg ha^{-1})	Seed Yield (kg ha^{-1})	Harvest index (%)
Environment							
Irrigated	65.2	17.0	1.30	15.12	5697	1306	23.1
Rainfed	55.4	14.7	1.31	15.47	4744	1134	24.2
ROS	63.2	8.7	1.55	18.2	4338	871	20.1
CD at 5%	2.9	0.9	0.12	1.65	324	80	1.8
Genotypes							
Amethyst	64.3	17.1	1.45	13.73	4833	1074	22.2
Annigeri	61.3	13.4	1.37	14.85	5199	1213	23.5
C214	56.5	16.4	1.39	10.87	4694	1125	24.2
ICC4958	63.3	10.4	1.15	23.8	4847	991	20.5
K850	67.7	10.9	1.22	22.54	5051	917	18.5
Tyson	60.3	18.8	1.46	10.5	4879	1218	25.0
CD at 5%	5.2	1.7	0.22	3.01	NS	146	3.3

ROS = Rainout shelter

Annigeri recorded highest RWC followed by C 214. However, WUE was highest in Annigeri followed by Tyson.

Seed yield and its attributes

Moisture stress significantly reduced the plant height, number of effective pods per plant, number of seeds per pod, 100 seed weight, seed yield, biological yield and harvest index over irrigated control (Tables 3). Due to terminal moisture stress, the seed yield was reduced by 33.3 and 13.2 percent in severely stressed ROS and mildly stressed rainfed treatment over irrigated control. The per cent reduction in seed yield was relatively more than the biological yield, which resulted in lowest harvest index under ROS. Among the yield components, moisture stress primarily affected number of pods per plant and had little effect on number of seeds per pod. Reduction in number of pods per plant, number of seeds per pod, 100-seed weight and average seed weight in chickpea genotypes under rainfed conditions was also reported by Rehman and Uddin (2000) and Kumar *et al* (2001).

Among the genotypes, significantly tallest plants were observed in K 850 followed by Amethyst. The plants of C 214 were the dwarfest (56.5 cm) than all the tested genotypes. Significantly highest pod density was recorded in Tyson closely followed by Amethyst. Pod density was the lowest in ICC 4958 with non-significant difference with K 850. The genotypes Amethyst and Tyson had higher number of seeds per pod while 100 seed weight was recorded highest in cv. ICC 4958 followed by K 850. The highest seed yield and harvest index was recorded in Tyson (1218 kg ha^{-1}) followed by Annigeri (1213 kg ha^{-1}). The biomass accumulation was recorded highest in Annigeri followed by K 850 but with non significant differences.

The rainfed treatment with the highest HI and WUE indicated that mild degree of stress is beneficial for the chickpea crop. Among all the genotypes, Tyson and Annigeri are most productive with highest WUE.

The associations worked out among important morpho-physiological characters indicated that the early vigour (r=0.57), longer maturity duration (r=0.73) and longer reproductive phase (r=0.56) have significant positive association with seed yield. Also the plant water status had significant positive association with seed yield (r=0.65). Seed and biological yield were highly positively correlated with water use (r=0.61) during reproductive phase of growth and these associations were even greater with water use during the entire crop season (r=0.71). Seed yields and biological yields also showed significant positive association to each other (r= 0.67).

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