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WATER USE EFFICIENCY AND YIELD OF CHICKPEA GENOTYPES AS INFLUENCED BY SOIL MOISTURE AVAILABILITY

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SUMMARY

Six chickpea (*Cicer arietinum* L) genotypes were evaluated under soil moisture stress for morpho-physiological characteristics conferring resistance to drought. The increased moisture stress reduced the maturity duration by 15 and 19 days under mild and severe stress, respectively over irrigated control. The shorter maturity duration resulted in reduced reproductive phase duration. The water use efficiency was higher under irrigated control as compared to both the stress conditions. The plant water status reduced significantly at full bloom stage (110 DAS) under moisture stress. The moisture stress significantly reduced the plant height, number of effective pods per plant, 100 seed weight, seed yield, biological yield and harvest index over irrigated control. The longer maturity duration (r=0.93) has significant positive association with seed yield. The plant water status parameters have significant positive associations with seed yield. Among the yield attributes, pod density has highest significant positive association (r=0.89) with seed yield followed by 100 seed weight (r = 0.78). The genotypes, ICCV 10, BG 364 and C 214 have relatively higher plant water status and maintained their canopy cooler at full bloom and yielded highest as compared to other tested genotypes.

***Key words*: Chickpea, moisture stress, plant water relations, water use efficiency, yield**

INTRODUCTION

Chickpea (*Cicer arietinum* L) is an important pulse crop in India and the third most important pulse crop globally. This crop is largely grown on stored soil moisture making terminal drought stress a primary constraint to productivity. 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, thus limiting pod filling stage. Frequent drought, besides lowering the crop yield also decreases seed quality by reducing seed size. The component traits of drought resistance in pulse crops include drought avoidance, root traits and transpiration efficiency (Serraj *et al*. 2004). The development of moisture stress leads to a wide range of changes in partitioning of plant dry matter like diversion of biomass to undesirable plant parts. Therefore, the improved chickpea genotypes with better water use efficiency and high yield will be suitable for cultivation in drought prone areas and can prove a boon to improve the economy of poor farmers of dryland areas.

MATERIAL AND METHODS

Six chickpea (*Cicer arietinum* L) genotypes viz., IPC 94-132, ICCV 10, BG 364, K 850, ICC 4958 and C 214 were grown in concrete drought plots (30 x 6 x 1.65 m) filled with light textured sand at Crop Physiology Field Lab, Agronomy Research Farm, CCS Haryana Agricultural University, Hisar (29° 10'N latitude, 75° 46'

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E longitude and 215 M altitude), India. Four rows of 1 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 normal irrigated (NI- two post sowing irrigations, one at flowering and another at pod setting), mild stress (MS- one irrigation of 30 mm at flowering) and severe stress (SS- no post sowing irrigation) conditions, laid out in randomized block design with three replications. The 165 cm soil profile retained 15% soil moisture at the time of seeding. There was no rainfall during the growing season. Recommended agronomical practices were adopted to raise the crop.

The soil moisture content of 0-15 cm soil depth was determined by gravimetric method. The soil moisture at 15-45, 45-75, 75-105, 105-135 and 135-165 cm soil depth was recorded by Neutron moisture meter (Model 2651 Troxler laboratories, Releigh, NC, USA). The observations were recorded at sowing and also before and after each irrigation upto harvest. Water use efficiency of different treatments was calculated as percent ratio of economic yield with crop water use. The plant water relation parameters were recorded at full bloom stage (110 DAS). The leaf water potential (Ψ_w) was measured by Pressure Chamber (PMS Instrument Co., Oregon, USA), relative water content (RWC) of leaf (Weatherley 1950) and canopy temperature depression (CTD) using Infra-red thermometer (Model AG-42 Tela-temp Corp.CA). Data presented are mean of four sets of measurements.

The vegetative and reproductive phases were computed as the period in days from sowing to 50 % flowering and 50 % flowering to harvestable maturity, respectively. Yield attributes and seed yield were recorded from representative five plant samples taken from each plot at harvest. The statistical analysis for different parameters and yield were worked out as per standard procedures (Panse and Sukhatme 1985).

RESULTS AND DISCUSSION

The phenological development (Table 1) indicated that severe stress treatment reduced the crop duration by 19 days over irrigated control. The shorter crop duration in severe stress also resulted in reduced reproductive duration by about 27 days over the irrigated control. No marked variation in crop duration of genotypes were noticed. The shortest reproductive phase was observed in C 214 closely followed by K 850 and IPC 94-132 with non-significant difference among genotypes. The similar reduction in maturity duration have been reported earlier (Rehman and Uddin 2000).

The plant water relations recorded at full bloom in different genotypes showed that the severe moisture stress and mild stress environment reduced the relative water content (RWC), leaf water potential (Ψw) and canopy temperature depression significantly over irrigated control (Table 2). The decreased leaf water potential and RWC under water stress have also been reported earlier

Table 1. Effect of water stress environments on phenology (DAS) of chickpea genotypes

Genotypes	Duration of vegetative phase				Duration of reproductive phase				Crop duration (Day after sowing)			
	NI	MS	SS	Mean	NI	MS	SS	Mean	NI	MS	SS	Mean
ICC 4958	55	53	68	59	94	86	64	81	149	139	132	140
BG 364	68	81	73	74	82	58	59	66	151	139	132	141
C 214	85	79	82	82	65	51	48	55	150	130	130	137
IPC 94-132	76	87	82	82	75	50	45	57	150	132	132	138
K 850	80	84	86	83	71	49	48	56	151	134	132	139
ICCV 10	59	81	76	72	91	54	52	66	150	133	130	138
Mean	71	78	78	75	80	58	53	63	150	135	131	139
CD at 5%	E	G	E x G		E	G	E x G		E	G	E x G	
	NS	10.0	NS		7.0	10.0	NS		4.0	NS	NS	

NI = Normal irrigated; MS = Mild stress; SS = Severe stress

(Leport *et al.* 1999, Deshmukh *et al.* 2004). Among the genotypes, the significantly higher RWC, Ψw and transpirational cooling was recorded in ICCV 10. The lowest RWC was observed in BG 364 followed by K 850, whereas lowest Ψw was recorded in C 214 and K 850. The water use efficiency (WUE) decreased drastically from 145 kg ha^{-1} cm^{-1} in irrigated control to 10.8 kg ha^{-1} cm^{-1} in mild stress and 0.65 kg ha^{-1} cm^{-1} in severe stress, respectively. Greater water use efficiency under non stress condition as compared to stress (rainfed) condition have been reported by Zhang *et al.* (2000). The water use efficiency declined due to more utilization of water without proportionate increase in grain production (Gupta *et al.* 2000, Soltani *et al.* 2001). Genotype C 214 recorded highest WUE followed by IPC 94-132. But under mild stress, it was highest in ICC 4958 followed by K 850 and in severe stress it was highest in ICCV 10 followed by IPC 94-132 (Table 2).

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 and 4). Due to terminal moisture stress, the reduction in seed yield was relatively more than the biological yield, which resulted in lowest harvest index under severe stress. Among the yield components, water stress had greater effect on number of pods per plant and had little effect on number of seed per pod. Similar reduction in number of pods per plant, number of seeds per pod and 100-seed weight in chickpea genotypes under rainfed condition have been reported earlier (Rehman and Uddin 2000, Kumar *et al.* 2001). Among the genotypes, the significantly taller plants were observed in BG 364 followed by K 850. The plants of IPC 94-132 were having significantly lower plant height. The highest pod density was recorded in C 214 closely followed by ICCV 10. Significantly lowest 100 seed weight was found in C 214 and a reverse was true in case of ICC 4958. Highest seed yield per plant was observed in ICCV10 followed by BG 364 and C 214, and lowest in IPC 94-132. The biomass accumulation per plant was highest in ICC 4958 followed by ICCV 10 and BG 364. Similar genotypic variation in yield and its attributes under moisture stress has been reported earlier (Kumar *et al.* 2001, Deshmukh *et al.* 2004).

The seed yield has significant positive correlation with longer maturity duration (r=0.93) and longer reproductive phase (r=0.65) under normal soil moisture condition. But under stressed conditions short maturity duration helps crops to escape from drought under terminal moisture stress condition. The plant water status parameters namely RWC and Ψw recorded at full bloom have significant positive association with seed yield (r=0.85 and r=-0.78, respectively). Among the yield attributes, pod density has highest significant positive association (r=0.89) with seed yield followed by 100 seed weight (r

Table 2. Effect of water stress environments on plant water relations and water use efficiency of chickpea genotypes

Genotypes	RWC (%)				Ψw (-MPa)				CTD (°C)				Water Use Efficiency (kg ha^{-1} cm^{-1})			
	NI	MS	SS	Mean	NI	MS	SS	Mean	NI	MS	SS	Mean	NI	MS	SS	Mean
ICC 4958	70.0	61.9	57.3	63.1	1.05	1.70	2.37	1.71	-0.3	6.3	7.5	4.5	89	16.6	0.74	40.3
BG 364	73.7	57.0	49.3	60.0	1.13	1.82	2.57	1.84	-1.1	4.3	8.8	4.0	156	10.2	0.55	70.7
C 214	76.7	57.4	57.2	63.8	1.20	2.23	2.37	1.93	-0.7	4.8	8.1	4.1	178	10.2	0.21	78.2
IPC 94-132	69.3	61.5	58.0	62.9	1.12	2.12	2.33	1.86	-3.0	6.0	8.7	3.9	172	8.5	0.87	73.2
K 850	71.9	65.9	48.6	62.1	1.10	1.92	2.90	1.97	-0.8	5.3	8.7	4.4	127	10.8	0.29	57.2
ICCV 10	73.0	63.6	59.7	65.4	1.04	1.30	1.77	1.37	-0.4	3.9	5.9	3.2	147	8.4	1.25	68.1
Mean	72.4	61.2	55.0	62.9	1.11	1.85	2.39	1.78	-1.1	5.1	8.0	4.0	145	10.8	0.65	64.6
CD at 5%	E	G	ExG		E	G	ExG		E	G	ExG		E	G	ExG	
	2.3	3.2	5.6		0.07	0.1	0.17		0.18	0.25	0.43		6.3	3.5	NS	

NI = Normal irrigated; MS = Mild stress; SS = Severe stress

Table 3. Effect of water stress environments on yield attributes in chickpea genotypes

Genotypes	Plant height (cm)				Number of effective pods plant^{-1}				Number of seeds pod^{-1}				100 seed weight (g)			
	NI	MS	SS	Mean	NI	MS	SS	Mean	NI	MS	SS	Mean	NI	MS	SS	Mean
ICC 4958	44.8	34.2	34.0	37.7	19.0	9.6	7.0	11.9	1.13	1.15	1.13	1.14	42.8	37.6	20.6	33.7
BG 364	47.1	41.1	39.7	42.6	21.1	11.1	6.3	12.8	1.33	1.17	1.22	1.24	32.3	24.7	20.0	25.7
C 214	43.6	38.6	34.7	39.0	35.4	16.5	8.4	20.1	1.63	1.56	1.23	1.48	15.0	11.2	8.3	11.5
IPC 94-132	40.1	36.4	24.7	33.7	20.9	9.1	4.0	11.3	1.25	1.24	1.14	1.21	23.1	15.4	9.1	15.9
K 850	44.4	41.6	39.7	41.9	21.9	10.4	6.2	12.8	1.24	1.17	1.22	1.21	38.3	17.3	10.5	22.0
ICCV 10	42.3	37.0	36.2	38.5	32.9	14.9	9.4	19.1	1.31	1.34	1.17	1.27	27.4	17.3	14.1	19.6
Mean	43.7	38.2	34.8	38.9	25.2	11.9	6.9	14.7	1.32	1.27	1.18	1.26	29.8	20.6	13.8	21.4
CD at 5%	E	G	ExG		E	G	ExG		E	G	ExG		E	G	ExG	
	1.7	2.4	4.2		1.3	1.9	3.2		0.04	0.06	0.11		1.0	1.4	2.4	

NI = Normal irrigated; MS = Mild stress; SS = Severe stress

Table 4. Effect of water stress environments on yield and its attributes and in chickpea genotypes

Genotypes	Seed yield (g plant^{-1})				Biological yield (g plant^{-1})				Harvest index (%)			
	NI	MS	SS	Mean	NI	MS	SS	Mean	NI	MS	SS	Mean
ICC 4958	6.3	3.6	2.3	4.1	25.3	18.5	11.8	18.5	24.9	19.5	19.5	21.3
BG 364	7.6	4.2	1.6	4.5	24.9	15.8	7.8	16.2	30.5	26.6	20.5	25.9
C 214	7.6	3.5	2.0	4.4	21.4	13.4	8.8	14.5	35.5	26.1	22.7	28.1
IPC 94-132	5.6	3.0	0.6	3.1	18.6	11.8	5.9	12.1	30.1	25.4	10.2	21.9
K 850	6.0	3.8	1.6	3.8	21.7	14.3	8.2	14.7	27.6	26.6	19.5	24.6
ICCV 10	8.8	5.2	2.3	5.4	25.6	18.1	10.2	18.0	34.4	28.7	22.5	28.6
Mean	7.0	3.9	1.7	4.2	22.9	15.3	8.8	15.7	30.5	25.4	19.7	25.1
CD at 5%	E	G	ExG		E	G	ExG		E	G	ExG	
	0.8	1.1	NS		2.6	3.7	6.4		1.3	1.9	3.3	

NI = Normal irrigated; MS = Mild stress; SS = Severe stress

= 0.78). The biological yield has the highest significant positive relationship (r = 0.99) followed by HI (r = 0.95) with seed yield in chickpea. Among the various genotypes evaluated, ICCV 10 performed best in terms of yield and yield attributries under terminal moisture stress condition.

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