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Full Length Research Paper

Growth and yield of chickpea (*Cicer arietinum* L.) genotypes in response to water stress

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Twenty chickpea genotypes were grown under rainout shelter to investigate the influence of water stress treatments imposed at varied growth stages; T_1; Control, T_2; One pre-sowing irrigation, T_3; withholding irrigation at flower-initiation, T_4; withholding irrigation at pod-initiation stage. The plant height, branches, dry weight of stem, leaves and root plant^{-1}, leaf area, leaf area index were recorded at 120 days after sowing (DAS) which showed significant variation with water stress at varied growth stages. The maximum reduction in height and branches was observed when irrigation was restricted at T_2 stage. Restricted irrigation decreased the biomass of stem, leaves and roots leading to reduced leaf area and leaf area index as well. The yield traits viz. 100 seed weight, total number of pods, percentage filled pods were reduced significantly under stress. The grain yield under restricted conditions was reduced by 40.50 to 55.91% over irrigated control in T_4 to T_2, respectively. Among the tested genotypes, GL28151, RSG963, PDG3 maintained higher growth, yield and yield traits showing their tolerance to water stress, while GL22044, RSG1861 and RVSSG4 were adversely affected most in growth traits and yield as well.

Key words: Water stress, chickpea, growth traits, yield.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is the fourth largest grain legume crop in the world, with a total production of 10.9 million tons from an area of 12.0 million ha and a productivity of 0.91 t ha^{-1}. Major producing countries include India, Pakistan and Iran (FAO, 2010b). About 90% of chickpea in the world is grown under rainfed conditions where drought is one the major constraints, limiting its production. Drought affects various morphological and physiological processes, resulting in reduced growth, development and economic yield of crop. Water stress has prominent effect on leaf number, total leaf area and secondary branches causing invariable reduction under rainfed conditions (Basu et al., 2007). The major characters affecting crop grain yield are number of pods and seeds per plant which reduce under drought stress (Davies et al., 2000) . Several studies have shown that optimum yield can be obtained by irrigation at branching, flowering and pod formation

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stages (Prihar and Sandhu, 1968).

The reactions of plants to water stress vary depending upon intensity and duration of stress as well as plant species and its stage of growth. Stress during vegetative phase reduce grain yield through reducing plant size, restricting leaf area, dry matter accumulation and limiting number of pods (Sadasivan et al., 1988) . However, water deficits at the flowering and the post flowering stages have been found to have greater adverse impact than at the vegetative stage (Cortes and Suidaria, 1986). Present study was conducted to investigate genotypic response towards deteriorative effects of water stress by determination of growth and yield traits in twenty diverse chickpea genotypes and to find most sensitive growth stage in chickpea to water stress by imposition of stress at varied growth stages.

MATERIALS AND METHODS

Twenty chickpea genotypes for studies on moisture stress tolerance (GL21107, GL22044, GL26054, GL26074, GL281137, GL28151, GL28186, GNG1594, GNG1861, DCP 92-3, GG1362, RSG811, RVSSG4, RSG963, RSG957, BGM547, PDG3, PDG4, PBG1, GPF2) were procured from Pulses section, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, Punjab, India and grown in the field area of Department. Ludhiana represents the Indo-Gangetic plains and is situated at 36°-54'N latitude, 25°-48'E longitude and at a mean height of 247 m above sea level. The field was ploughed and leveled properly and divided into 120 plots each measuring 1.8 m^2. Trial was sown in three replications in split plot design. Sowing of seeds was undertaken in the field on 22nd November, 2011 during *Rabi* season 2011 to 2012.

Experimental design included following irrigation treatments. T_1- Without stress (control) given irrigation as and when required; T_2- One pre- sowing irrigation; T_3- Stressed by withholding irrigation at flower initiation; T_4- Stressed by withholding irrigation at pod initiation. The experiment was conducted under rainout shelter to meet the stress levels and data on growth parameters of randomly selected plants were recorded at 120 days after sowing. Plant height, branches, leaf number of randomly selected plants per plot was recorded. Stem dry weight, root dry weight, leaf dry weight of selected plants were derived by chopping the parts of plants and drying in oven at 72°C till a constant weight was derived. Leaf area was measured by leaf area meter CID Inc-213 and expressed as cm^2. Leaf area index was measured by Sun scan canopy analyzer. Yield characteristics viz. 100 seed weight, number of pods, percentage filled pods and yield were recorded at final harvest.

RESULTS

The results showed that the effect of water stress treatments, genotypes and the interactions of genotypes × treatment were significant in all growth traits viz. plant height, branches, leaf number, dry weight of stem, leaves and root, leaf area and leaf area index. Exception was dry weight of root where interaction of genotype × treatment was found to be non significant. Imposed water deficit reduced various growth traits in stressed treatments, in comparison to control. Treatment sown with one presowing irrigation (T_2) was affected most, followed by T_3, where irrigation was with held at flower initiation. Among the genotypes, GL28151 showed least reduction in plant height, number of branches (Table 1) and leaf number (Table 3) under stress treatments, except T_3, where RSG963 performed better with respect to number of branches showing percentage reduction of 2.11%. Effect of water stress was most deteriorative in RVSSG4, reducing plant height under treatments T_2, T_3 and T_4 by 30.32, 17.56 and 8.00%, respectively. GL22044 showed marked reduction in branches and leaf number under all stress treatments, however highest decline was observed under treatment T_2 where branches and leaf number reduced in GL22044 by 50.90 and 52.49%, respectively over control.

Dry weight of stem, leaves and roots decreased under stress treatments in comparison to control in all genotypes. Among genotypes, stem dry weights of GL28151 and PDG3 were recorded with minimum reductions (Table 2) whereas PDG3 recorded least percentage reduction of 13.14% under treatment T_4. GNG1861 and RVSSG4 showed tremendous decline over control under stress treatments, though highest decrease of 42.42% was noticed in GNG1861 under treatment T_2. RSG963 was able to resist drop in leaf dry weight (Table 2) under all stress treatments, though marked reduction in GNG1861 were observed, which showed highest alterations of 39.29% occurred under treatment T_2. Among, genotypes, RSG963 and PDG3 were observed with minimal percentage reductions in root dry weight (Table 3), where least reduction of 8.60% was recorded in RSG963 under treatment T_4. Decrease in root dry weight was high in GL22044 and RVSSG4, with tremendous decline of 38.67% in RVSSG4 under treatment T_2.

Water stress reduced leaf area and leaf area index significantly in all genotypes under water stress treatments in comparison to control (Table 4). Water deficit posed least affect on leaf area of RSG963 showing change of 10.88% under T_4 treatment. Dramatic reduction was noticed in GNG1861 under stress treatments; highest was 49.52% under treatment T_2. GL28151 depicted least alterations in leaf area index among genotypes. Percentage reduction varied between 31.21 to 16.14% under treatment T_2 and T_4, respectively. GL22044 and GNG1861 were observed to show highly deteriorating effects of water stress on LAI, however, maximum change over control was 60.96% observed in GL22044 under treatment T_2.

Drought stress imposed resulted in lower yield and yield traits in all genotypes under stress treatments in comparison to control. Highest reductions were observed under treatment T_2, followed by T_4. Least change in 100 seed weight (Table 5) was noticed in RSG963 under

Table 1. Effect of water stress imposed at pod initiation stage (120 DAS) on plant height (cm) and number of branches of chickpea (*Cicer arietinum* L.) genotypes.

Genotype	Plant height (cm)				Number of branches			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
GL21107	58.33±0.95	45.66±1.61	54.66±1.86	57.00±1.01	23.67±1.25	7.67±0.73	13.33±0.58	15.33±1.47
GL22044	59.09±0.81	45.66±1.20	54.33±1.58	55.09±0.87	37.33±0.70	9.00±0.06	18.33±0.07	19.22±0.59
GL26054	60.00±0.80	51.88±0.91	55.66±0.68	58.33±1.38	20.67±1.14	9.00±0.06	11.33±0.17	19.22±0.23
GL26074	55.00±0.89	50.33±0.93	52.00±1.47	53.66±1.11	22.33±1.61	13.33±0.64	13.89±0.53	15.33±1.24
GL28137	57.33±1.50	53.33±0.95	54.66±2.46	55.00±0.87	32.67±0.70	19.00±0.57	20.33±2.00	23.33±0.99
GL28151	58.00±0.87	56.33±0.62	56.88±0.85	57.00±1.41	25.33±0.90	20.56±0.99	22.67±0.43	24.33±1.05
GL28186	54.80±0.26	47.66±0.85	50.33±0.90	51.66±0.93	19.00±0.13	13.67±0.81	14.44±1.03	17.33±0.73
GNG1594	51.00±0.68	48.00±1.12	48.66±0.97	49.00±0.60	15.67±0.73	9.00±0.04	12.89±1.38	14.99±1.01
GNG1861	55.00±1.33	44.33±0.59	46.33±1.41	51.00±2.97	25.00±0.44	15.67±0.70	17.56±0.54	18.67±1.49
DCP 92-3	56.66±0.76	43.66±1.94	48.66±0.67	52.90±1.46	14.33±0.55	11.00±0.61	12.55±0.83	13.33±1.20
GG1362	62.00±0.94	50.00±0.61	57.661.03	58.66±0.70	26.00±0.61	17.80±0.51	19.00±0.42	20.00±0.59
RSG 811	62.00±1.56	45.00±0.88	52.00±0.87	58.00±1.66	30.00±0.68	12.00±0.72	23.67±0.54	28.00±0.75
RVSSG 4	62.66±0.76	43.66±0.74	51.66±0.83	57.65±0.78	30.67±1.51	15.67±0.35	20.22±0.21	20.22±0.64
RSG 963	60.66±0.86	56.00±0.82	56.33±0.91	57.00±1.76	24.67±1.97	17.89±0.39	20.89±0.73	24.00±1.09
RSG 957	61.66±1.39	47.66±0.57	55.66±0.69	57.33±0.57	30.67±0.93	18.67±0.95	24.44±0.52	27.67±0.84
BGM 547	62.33±0.56	53.44±1.32	58.33±00.42	60.00±0.74	33.00±0.64	18.99±0.13	20.00±0.55	21.33±0.67
PDG3	55.00±0.64	45.34±0.61	46.77±1.93	47.00±0.97	27.66±1.20	20.33±1.80	23.38±0.69	24.00±0.84
PDG4	57.66±1.69	47.00±1.88	48.66±0.99	52.66±1.93	24.00±0.82	18.00±0.65	20.00±1.34	20.67±0.62
PBG1	60.66±1.74	49.33±2.55	55.33±0.78	57.44±0.40	21.67±1.66	13.33±1.05	17.00±0.23	18.22±0.64
GPF2	56.66±0.59	48.00±0.76	49.66±3.27	52.33±1.66	18.96±0.68	12.34±0.58	14.44±0.57	15.32±1.49
	LSD (0.05)G = 0.790, LSD(0.05) T = 1.768, LSD (0.05) G×T = 3.536				LSD (0.05)G = 0.548, LSD(0.05) T = 1.226, LSD (0.05) G×T = 2.452			

*Different values in each column represent mean ±S.E.

stress treatments T_3 and T_4, while GL28151 performed well under stress treatment T_2, with lowest change of 4.17% over control. Highest decrease in 100 seed weight was noticed in GNG1861 under treatment T_3 and T_4, where maximum reduction of 13.07% was shown in GL22044 under treatment T_2. However, effect of stress treatments on total number of pods was recorded least in GL28151 (Table 5), with minimum reduction of 3.53% under stress treatment T_4. Percentage decline in pod number was maximum in RVSSG4 and GNG1861 with highest drop of 52.62% in RVSSG4 under treatment T_2.

Percentage filled pods were least affected in RSG963, PDG3 and GL28151 under varied treatments, with least reduction of 2.13% in PDG3 under treatment T_4 (Table 6). However, stress treatments remarkably altered percentage filled pods in RVSSG4, where maximum decrease of 17.08% noticed under treatment T_2. Yield was less affected in GL28151 under T_2 (13.04%) and T_4 (11.11%) treatments showing its tolerance. Under T_3 treatment, RSG963 performed better showing least reduced yield (8.54%) over control. Yield under stress treatments was determined highly affected in GL22044 under all stress

Table 2. Effect of water stress imposed at pod initiation stage (120 DAS) on dry weight of stem plant^{-1} and dry weight of leaves plant^{-1} of chickpea (*Cicer arietinum* L.) genotypes.

Genotype	Dry weight of stem plant^{-1} (g)				Dry weight of leaves plant^{-1} (g)			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
GL21107	6.01±0.17	4.20±0.07	4.98±0.11	5.11±0.07	4.85±5.70	3.42±0.05	3.90±0.02	4.11±0.09
GL22044	6.33±0.05	3.75±0.12	5.01±0.03	5.08±0.06	6.10±0.267	3.82±0.07	4.10±0.07	4.28±0.02
GL26054	6.26±0.03	4.35±0.07	5.19±0.03	5.25±0.03	5.36±0.07	4.30±0.04	4.54±0.04	4.76±0.06
GL26074	6.44±0.15	4.11±0.01	5.20±0.04	5.23±0.04	5.55±0.07	4.76±0.13	4.85±0.13	4.92±0.12
GL28137	6.27±0.09	4.06±0.02	5.10±0.00	5.20±0.05	5.40±0.11	4.44±0.11	4.67±0.11	4.85±0.04
GL28151	6.20±0.01	5.11±0.05	5.25±0.03	5.38±0.08	6.16±0.04	5.45±0.06	5.50±0.06	5.58±0.24
GL28186	6.19±0.03	4.44±0.11	5.05±0.03	5.14±0.04	5.88±0.11	4.65±0.24	4.90±0.24	5.20±0.06
GNG1594	6.19±0.02	4.06±0.03	5.00±0.06	5.19±0.03	5.07±0.11	4.31±0.13	4.48±0.11	4.52±0.50
GNG1861	6.35±0.11	3.65±0.14	4.76±0.06	5.09±0.02	5.14±0.05	3.12±0.03	3.34±0.11	3.54±0.04
DCP 92-3	6.30±0.09	4.12±0.07	5.02±0.02	5.10±0.05	5.30±0.04	3.76±0.36	4.11±0.18	4.32±0.06
GG1362	6.33±0.12	4.89±0.06	5.06±0.15	5.22±0.06	6.38±0.04	4.88±0.12	5.00±0.11	5.45±0.04
RSG 811	6.38±0.08	4.90±0.01	5.05±0.03	5.17±0.08	6.09±0.04	4.45±0.11	4.66±0.06	4.90±0.02
RVSSG 4	6.48±0.13	3.91±0.11	5.04±0.02	5.11±0.12	5.93±0.01	3.65±0.23	4.00±0.06	4.22±0.07
RSG 963	6.31±0.02	5.18±0.05	5.22±0.06	5.38±0.08	5.98±0.13	5.32±0.10	5.38±0.04	5.44±0.07
RSG 957	6.40±0.10	4.54±0.06	5.26±0.03	5.36±0.13	6.04±0.16	4.75±0.07	5.11±0.09	5.35±0.07
BGM 547	6.45±0.09	4.35±0.06	5.25±0.03	5.31±0.18	4.90±0.21	4.10±0.15	4.23±0.07	4.40±0.07
PDG3	6.02±0.06	4.76±0.04	5.02±0.05	5.22±0.11	6.30±0.07	5.45±0.08	5.60±0.18	5.69±0.05
PDG4	6.11±0.10	4.39±0.08	5.15±0.13	5.18±0.03	4.86±0.09	3.27±0.08	3.88±0.41	4.18±0.05
PBG1	6.47±0.06	4.23±0.07	5.24±0.04	5.32±0.10	5.18±0.52	3.90±0.08	4.25±0.19	4.66±0.07
GPF2	6.45±0.07	4.08±0.02	5.22±0.06	5.29±0.08	5.40±0.04	4.45±0.11	4.68±0.22	4.86±0.03
	LSD (0.05)G = 0.048, LSD(0.05) T = 0.107 , LSD (0.05) G×T = 0.213				LSD (0.05)G = 0.083, LSD(0.05) T = 0.186, LSD (0.05) G×T = 0.372			

*Different values in each column represent mean ±S.E.

treatments (Table 6), though highest reduction of 55.91% under treatment T_2, depicting its lesser adaptive behavior towards water deficit.

Under control conditions (T_1), there were positively non-significant correlations between yield and most of the traits, except significant positive and positive correlation with 100 seed weight (r = 0.3307**) and percentage filled pods (r = 0.2183), respectively (Table 7). However, plant height (r = -0.0307) and dry weight of root (r = -0.0201) were negatively correlated with yield under control.

Under stressed treatments, yield showed positive and highly significant correlation with dry weight of stem, root and leaves, leaf number, leaf area, leaf area index and yield traits viz. 100 seed weight, percentage filled pods and total number of pods.

Number of branches showed non-significant positive correlation (r = 0.2413) with yield under stress treatments T_2 (Table 8), T_3 and T_4, Plant height was found to show non-significant positive correlation (r = 0.1550) under treatment T_3 (Table 9) whereas negative correlation (r = -0.1223) of plant height with yield was observed under treatment T_4 (Table 10).

DISCUSSION

This investigation showed the negative effect of drought on growth traits of chickpea. Treatment T_2 with one pre-sowing irrigation was affected most,

Table 3. Effect of water stress imposed at pod initiation stage (120 DAS) on dry weight of root plant^{-1} and number of leaves plant^{-1} of chickpea (*Cicer arietinum* L.) genotypes.

Genotype	Dry weight of root plant^{-1} (g)				Number of leaves plant^{-1}			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
GL21107	3.10±0.19	2.11±0.07	2.24±0.14	2.52±0.17	164.00±9.72	87.33±5.67	94.34±2.63	112.33±4.96
GL22044	3.16±0.03	2.05±0.04	2.19±0.10	2.28±0.08	258.66±13.69	122.90±6.39	146.50±4.18	160.00±3.18
GL26054	3.21±0.08	2.13±0.02	2.52±0.12	2.64±0.06	206.66±6.84	123.66±7.58	151.00±6.85	167.80±7.20
GL26074	3.27±0.07	2.15±0.20	2.43±0.14	2.68±0.51	193.00±5.31	128.00±8.51	150.66±6.34	172.30±5.21
GL28137	3.10±0.05	2.14±0.09	2.43±0.05	2.53±0.06	208.00±2.64	155.70±11.17	172.30±4.20	182.00±4.38
GL28151	3.13±0.01	2.27±0.11	2.59±0.03	2.59±0.26	255.00±6.97	220.80±5.58	223.40±10.29	36.80±10.10
GL28186	3.22±005	2.11±0.08	2.52±0.06	2.60±0.23	234.66±6.39	151.66±7.94	179.66±2.93	192.50±7.11
GNG1594	3.02±0.05	2.36±0.06	2.37±0.02	2.41±0.20	176.33±4.54	110.90±3.94	144.30±6.95	150.33±3.20
GNG1861	3.18±0.07	2.21±0.01	2.26±0.20	2.32±0.10	187.00±10.50	95.00±4.06	112.00±5.88	126.66±7.55
DCP 92-3	3.12±0.05	1.98±0.10	2.51±0.14	2.56±0.22	172.66±3.91	135.30±11.49	137.90±8.20	150.33±7.15
GG1362	3.16±0.11	2.28±0.09	2.39±0.09	2.46±0.07	269.66±9.63	172.60±4.99	199.00±11.63	211.00±10.64
RSG 811	3.21±0.06	2.46±0.18	2.49±0.21	2.54±0.11	250.66±9.41	172.66±4.31	186.54±11.57	210.80±2.83
RVSSG 4	3.31±0.05	2.03±0.00	2.37±0.09	2.45±0.08	241.00±6.15	102.30±3.58	152.34±4.35	173.00±16.36
RSG 963	3.51±0.05	2.87±0.06	3.12±0.21	3.21±0.07	240.00±6.67	175.30±4.01	192.31±12.80	212.20±5.86
RSG 957	3.45±0.05	2.68±0.18	2.67±0.05	2.75±0.03	247.66±13.39	166.00±3.31	190.00±5.93	210.90±3.73
BGM 547	3.28±0.09	2.58±0.11	2.61±0.06	2.68±0.04	231.33±5.79	145.67±9.90	168.33±6.29	184.33±5.05
PDG3	3.15±0.04	2.58±0.08	2.59±0.07	2.61±0.04	278.00±5.36	167.00±6.63	199.00±11.66	210.00±2.95
PDG4	3.14±0.05	2.44±0.11	2.48±0.10	2.49±0.06	241.00±6.17	169.80±3.26	184.33±4.20	193.33±3.79
PBG1	3.30±0.05	2.47±0.12	2.57±0.28	2.60±0.01	222.00±9.43	131.00±.7.41	161.23±3.49	189.00±7.52
GPF2	3.28±0.05	2.45±0.11	2.55±0.18	2.59±0.10	176.39±4.59	103.28±3.60	140.28±3.21	143.39±6.67
	LSD (0.05)G = 0.078, LSD(0.05) T = 0.175, LSD (0.05) G×T = NS				LSD (0.05)G = 4.572, LSD(0.05) T = 10.222 , LSD (0.05) G×T = 20.445			

*Different values in each column represent mean ±S.E.

followed by stress at flower initiation stage (T_3). Our findings are in agreement with Yaqoob et al. (2012), who suggested that moisture stress at pre flowering stage being harmful and detrimental is the most critical stage for screening chickpea germplasm under drought prone conditions. Significant reductions occurred in plant height and number of branches under varied stress treatments. Similar results were given in chickpea (Shamsi et al., 2010). Reduction in plant height could be attributed to decrease in cell division, cell enlargement under water stress (Manivannan et al., 2007a). Under water deficiency, cell elongation of higher plants can be inhibited by interruption of water flow from xylem to thesurrounding elongating cells leading to reduced number of branches.

In our study, dry weight of stem, root and leaves decreased under stress treatments in all genotypes. The reduction in biomass could be due to either impaired reduced cyclin dependent kinase activity resulted in lesser cell division and vegetative growth reducing dry weight of shoot (Schupper et al., 1998). Decrease in dry weight of root was noticed in chickpea (Millan et al., 2006). It is attributed to reduce partitioning of biomass towards root (Pimratch et al., 2008).

Table 4. Effect of water stress imposed at pod initiation stage (120 DAS) on leaf area and leaf area index of chickpea (*Cicer arietinum* L.) genotypes.

Genotype	Leaf area (cm2)				Leaf area index			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
GL21107	754.39±22.38	483.25±4.32	574.39±8.28	624.39±5.13	4.50±0.30	1.77±0.29	2.47±0.05	2.93±0.12
GL22044	900.34±10.56	490.67±8.35	540.12±2.79	586.55±4.60	5.38±0.13	2.10±0.12	2.64±0.13	2.80±0.07
GL26054	812.67±7.64	592.12±12.71	648.79±11.97	702.34±8.03	7.50±0.21	3.45±0.17	3.93±0.21	4.11±0.03
GL26074	854.44±15.00	678.87±10.90	700.56±10.84	734.56±5.73	6.90±0.10	3.13±0.06	3.73±0.10	4.13±0.22
GL28137	865.39±46.81	644.56±10.65	700.65±10.84	745.56±4.62	8.20±0.04	4.12±0.06	4.45±0.04	4.83±0.06
GL28151	1034.67±44.49	845.67±29.22	865.77±21.42	912.35±6.96	7.56±0.17	5.20±0.09	6.12±0.17	6.34±0.11
GL28186	964.38±74.56	672.34±4.92	734.55±8.88	811.34±16.62	7.44±0.11	4.07±0.05	5.21±0.11	5.64±0.12
GNG1594	812.56±11.55	612.33±9.37	645.56±5.69	700.67±6.20	6.23±0.06	2.65±0.05	3.21±0.06	3.45±0.04
GNG1861	823.45±17.15	415.68±3.42	468.58±1.97	510.45±16.19	8.20±0.07	3.27±0.10	3.55±0.07	3.66±00.06
DCP 92-3	845.78±5.35	534.22±5.70	612.34±6.53	652.34±4.32	7.27±0.09	3.17±0.03	3.66±0.09	3.88±0.13
GG1362	976.54±12.52	678.46±19.00	710.67±9.95	782.34±13.39	6.53±0.21	2.88±0.17	3.24±0.21	3.53±0.15
RSG 811	996.84±31.31	654.33±15.16	702.19±14.09	748.38±9.91	7.13±0.05	2.88±0.06	3.55±0.05	4.12±0.03
RVSSG 4	956.47±6.71	502.45±6.49	572.34±13.56	609.88±15.22	5.43±015	2.12±0.06	2.52±0.15	2.64±0.08
RSG 963	1023.67±50.41	848.78±31.93	880.94±10.93	912.22±6.66	7.50±0.27	4.12±0.06	5.12±0.27	5.33±0.07
RSG 957	995.67±25.52	712.34±13.19	790.67±17.61	834.55±5.71	7.40±0.08	3.37±0.02	3.80±0.08	4.12±0.06
BGM 547	784.34±24.04	573.56±7.54	614.22±14.79	662.34±6.26	6.50±0.09	3.37±0.03	4.10±0.09	4.23±0.02
PDG3	1134.00±56.81	886.56±69.31	942.12±18.01	984.33±34.04	6.37±0.06	3.53±0.21	4.80±0.06	5.12±0.06
PDG4	882.34±56.31	522.34±6.19	645.55±3.50	721.34±6.775	6.23±0.06	3.23±0.12	3.67±0.06	3.81±0.06
PBG1	823.54±5.78	536.67±4.81	600.42±2.78	688.45±7.78	7.45±0.07	3.80±0.08	4.11±0.07	4.20±0.04
GPF2	876.54±10.54	623.35±5.58	682.34±3.22	745.55±11.58	7.49±0.04	3.87±0.06	4.21±0.04	4.33±0.03
	LSD (0.05)G = 13.485, LSD(0.05) T = 30.153 , LSD (0.05) G×T = 60.307				LSD (0.05)G = 0.0721, LSD(0.05) T = 0.161 , LSD (0.05) G×T = 0.322			

*Different values in each column represent mean ±S.E.

Reduced dry weight of leaves was observed in soybean (Silvente et al., 2012). Drought stress inhibits the dry matter production largely through its inhibitory effects on leaf expansion, leaf development and consequently reduced light interception (Nam et al., 2001).

Our results revealed tremendous reduction in the leaf attributes viz. number of leaves, leaf area and leaf area index. Reduced number of leaves and leaf area in response to water deficit was noticed in chickpea (Salehpour et al., 2009). Drought stress leads to lower production of leaves, higher leaf senescence, decreased leaf size which may be attributed to decrease in vegetative growth (Pagter et al., 2005). Drought induced reduction in leaf area is ascribed to suppression of leaf expansion through reduction in photosynthesis (Rucker et al., 1995). Decreased LAI in response to increased water deficit was observed in chickpea (Khamssi et al., 2010). Decrease in leaf area index may be attributed to reduced growth and expansion of leaves (Hall, 2004).

Grain yield and its attributes were reduced significantly due to water stress. Reduction in 100 seed weight, number of pods, percentage filled pods and yield was observed under various

Table 5. Effect of water stress imposed at pod initiation stage (120 DAS) on 100 seed weight and Total number of pods in chickpea (*Cicer arietinum* L.) genotypes.

Genotype	100 seed weight (g)				Total number of pods			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
GL21107	18.23±0.54	16.33±0.40	17.60±0.98	17.23±0.42	40.29±0.95	29.35±1.96	33.54±1.29	30.33±0.53
GL22044	15.12±0.42	13.14±0.35	14.00±0.32	13.78±1.32	40.33±0.47	23.00±0.75	27.45±1.37	25.67±1.39
GL26054	22.34±0.64	19.94±0.26	22.11±0.65	20.66±0.60	51.67±0.78	32.66±0.71	38.34±0.73	35.45±0.77
GL26074	16.93±0.26	15.23±0.55	16.13±0.37	16.00±0.38	55.44±1.36	36.78±0.75	40.00±0.89	37.8±0.69
GL28137	19.11±0.26	17.62±0.68	18.42±0.91	18.26±1.30	43.00±0.62	31.64±0.76	35.43±0.93	32.76±1.25
GL28151	25.85±1.04	24.77±0.35	25.00±0.44	24.90±1.13	48.33±0.69	42.76±0.22	45.34±0.50	43.23±1.25
GL28186	19.22±0.48	18.10±0.36	18.32±1.21	18.25±0.41	42.25±1.07	27.34±0.70	32.90±0.88	30.23±0.45
GNG1594	17.00±0.30	15.80±0.56	16.14±0.68	16.02±0.27	52.45±0.69	34.44±0.67	38.77±0.74	36.78±0.77
GNG1861	16.47±0.39	14.77±0.20	14.92±0.75	14.80±0.66	57.50±1.70	30.33±0.63	37.33±0.47	35.40±0.82
DCP 92-3	16.03±0.41	15.07±0.26	15.45±0.72	15.27±0.10	56.67±1.22	31.22±0.50	38.45±1.33	36.65±0.58
GG1362	22.03±0.83	19.89±0.79	21.00±0.72	20.60±1.45	49.33±0.57	32.00±0.98	37.8±1.24	35.45±1.62
RSG 811	24.82±1.03	22.41±0.40	24.29±0.53	23.24±0.48	50.57±2.25	32.75±0.35	34.00±0.42	33.32±0.95
RVSSG 4	17.61±0.63	15.53±0.61	16.23±0.94	16.10±0.39	44.33±1.08	21.00±0.46	28.99±0.96	25.48±1.27
RSG 963	27.19±0.77	25.80±1.08	26.69±1.65	26.23±1.03	54.67±0.45	46.56±0.72	48.76±1.16	47.44±1.25
RSG 957	25.44±1.16	23.45±0.97	24.34±0.98	23.80±1.06	49.00±1.83	32.23±0.65	36.00±0.40	34.56±0.72
BGM 547	26.03±1.06	23.44±0.55	24.87±0.71	24.63±0.93	34.75±0.77	21.11±0.61	26.77±0.27	25.46±1.27
PDG3	26.54±0.76	24.80±0.69	25.43±0.40	25.15±0.52	50.33±0.80	32.45±0.65	36.67±1.03	34.75±0.80
PDG4	19.04±0.60	17.34±0.55	18.13±0.38	18.00±0.99	51.90±1.25	35.00±0.89	40.00±0.66	36.75±0.86
PBG1	17.03±0.31	15.37±0.53	16.14±0.20	15.90±0.86	43.67±0.89	26.74±0.51	32.00±0.30	30.25±0.60
GPF2	18.94±0.33	17.54±0.68	18.00±0.29	17.95±0.94	32.00±0.79	21.24±1.12	23.45±0.51	22.00±0.44
	LSD (0.05)G = 0.425, LSD(0.05) T = 0.951 , LSD (0.05) G×T = NS				LSD (0.05)G = 0.524, LSD(0.05) T = 1.171, LSD (0.05) G×T = 2.342			

*Different values in each column represent mean ±S.E.

stress treatments. However, water stress affected yield and yield traits maximum under treatment T_2, which was grown with one pre-sowing irrigation followed by T_4, where stress was given at pod initiation stage. Stress at flower-initiation (T_3) had lesser influence on yield attributes in comparison to stress at pod initiation stage (T_4), depicting it as critical stage. This study is supported by investigations of other researchers. The reproductive stage is well known for its sensitivity to drought stress; thus seed yield being the most sensitive traits to water stress treatment imposed at post flowering and pod development stages as observed in mungbean (Uprety and Bhatia, 1989). Results showing reduced number of pods werereported earlier in chickpea (Khurgami et al., 2009). Fertile pods decreased as drought stress was imposed in chickpea (Mcphee and Muehlbauer 2001). Number of pods and percentage filled pods per plant reduction under drought stress may be attributed to the abscission of the reproductive structures. Reduced 100 seed weight and yield losses under drought were reported in chickpea (Shaban et al., 2012). Decrease in 100 grain weight under drought stress conditions might be due to lower photosynthetic translocation in the developing

Table 7. Phenotypic correlation coefficients between grain yield and growth, yield traits under water stress treatment: T_1.

Trait	Plant height	No. of branches	Dry wt of stem	Dry wt of leaves	Dry wt of root	Leaf number	Leaf area	Leaf area index	100 seed weight	Total number of pods	Percentage filled pods	Grain yield
Plant height	1											
No. of branches	0.4927**	1										
Dry wt of stem	0.3310*	0.6031**	1									
Dry wt of leaves	0.2874*	0.2550	0.5560**	1								
Dry wt of root	0.4319**	0.1635	0.0644	0.2530	1							
Leaf number	0.3839**	0.5382**	0.3370*	0.5091**	0.1333	1						
Leaf area	0.1460	0.2567	0.0902	0.4705**	0.2324	0.6797**	1					
Leaf Area Index	-0.0830	-0.1958	-0.9540	0.0992	0.1514	-0.0536	0.1024	1				
100 seed weight	0.3756**	0.2611*	0.1591	0.2756*	0.2885*	0.5297**	0.5242**	0.2021	1			
Total number of pods	-0.2515	-0.2938*	-0.1971	0.0481	-0.0297	-0.0144	0.1586	0.2515	0.0138	1		
Percentage filled pods	0.0375	-0.1222	-0.0553	0.0335	0.1613	0.0759	0.1832	0.2249	0.5341**	-0.0914	1	
Grain yield	-0.0307	0.1201	0.0550	0.0894	-0.0231	0.1169	0.0974	0.0274	0.3307*	-0.0199	0.2183	1

* and ** represent significant correlation at 5% and 1% level of probability respectively.

Table 8. Phenotypic correlation coefficients between yield and growth, yield traits under water stress treatment: T_2.

Trait	Plant height	No. of branches	Dry wt of stem	Dry wt of leaves	Dry wt of root	Leaf number	Leaf area	Leaf area index	100 seed weight	Total number of pods	Percentage filled pods	Grain yield
Plant height	1											
No. of branches	0.3702**	1										
Dry wt of stem	0.4499**	0.4300**	1									
Dry wt of leaves	0.5090**	0.4274**	0.6838**	1								
Dry wt of root	0.3113*	0.3707**	0.4842**	0.3600**	1							
Leaf number	0.4653**	0.6279**	0.7830**	0.6219**	0.3443**	1						
Leaf Area	0.4729**	0.4989**	0.7712**	0.9027**	0.4799**	0.7103**	1					
Leaf Area Index	0.6202**	0.5501**	0.4629**	0.5452**	0.2578*	0.5939**	0.5718**	1				
100 seed weight	0.4723**	0.5871**	0.8277**	0.6917**	0.5700**	0.6890**	0.7690**	0.4949**	1			
Total number of pods	0.4399**	0.2615*	0.6108**	0.4732**	0.2425	0.5678**	0.5868**	0.4186**	0.4512**	1		
Percentage filled pods	0.5352**	0.3602**	0.6542**	0.6734**	0.5304**	0.5523**	0.7377**	0.6034**	0.7088**	0.5910**	1	
Grain yield	0.5790**	0.2413	0.7209**	0.6209**	0.3365**	0.6138**	0.7077**	0.4935**	0.5724**	0.7895**	0.7306**	1

* and ** represent significant correlation at 5% and 1% level of probability respectively.

Table 9. Phenotypic correlation coefficient between yield and growth, yield traits under water stress treatment: T_3.

Trait	Plant height	No. of branches	Dry wt of stem	Dry wt of leaves	Dry wt of root	Leaf number	Leaf area	Leaf area index	100 seed weight	Total number of pods	Percentage filled pods	Grain yield
Plant height	1											
No. of branches	0.1936	1										
Dry wt of stem	0.4041**	0.1631	1									
Dry wt of leaves	0.2667*	0.4113**	0.3514**	1								
Dry wt of root	0.1876	0.2762*	0.3356**	0.4574**	1							
Leaf number	0.2978*	0.6285**	0.4252**	0.6997**	0.4402**	1						
Leaf Area	0.1111	0.4824**	0.3866**	0.8814**	0.4930**	0.7298**	1					
Leaf Area Index	0.1092	0.2838	0.3581**	0.6404**	0.4372**	0.5998**	0.7025**	1				
100 seed weight	0.0370	0.1530	0.0987	0.3590**	0.2619*	0.3500**	0.4791**	0.4063**	1			
Total number of pods	0.3609**	0.6228**	0.4256**	0.6329**	0.4668**	0.6600**	0.7478**	0.5429**	0.3329**	1		
Percentage filled pods	0.2140	0.1963	0.4651**	0.6902**	0.4101**	0.4863**	0.6892**	0.5919**	0.2898*	0.5987**	1	
Grain yield	0.1550	0.2541	0.3192*	0.6422**	0.4750**	0.5574**	0.7466**	0.6553**	0.7261**	0.5793**	0.6298**	1

* and ** represent significant correlation at 5% and 1% level of probability respectively.

Table 10. Phenotypic correlation coefficient between yield and growth, yield traits under water stress treatment: T_4.

Trait	Plant height	No. of branches	Dry wt of stem	Dry wt of leaves	Dry wt of root	Leaf number	Leaf area	Leaf area index	100 seed weight	Total number of pods	Percentage filled pods	Grain yield
Plant height	1											
No. of branches	0.1677	1										
Dry wt of stem	0.2394	0.2469	1									
Dry wt of leaves	0.0538	0.3803**	0.4465**	1								
Dry wt of root	0.1538	0.0331	0.2854*	0.3404**	1							
Leaf number	0.2174	0.6558**	0.3410**	0.7125**	0.2776*	1						
Leaf area	-0.1125	0.4492**	0.4317*	0.8797**	0.4219**	0.7247**	1					
Leaf Area Index	-0.1030	0.2817*	0.3956**	0.6561**	0.3264*	0.5869**	0.7573**	1				
100 seed weight	-0.0548	0.1376	0.1959	0.3649**	0.2917*	0.3731**	0.4837**	0.4571**	1			
Total number of pods	0.2791*	0.5684**	0.4603**	0.6483**	0.4435**	0.6469**	0.7329**	0.5852**	0.3863**	1		
Percentage filled pods	0.0384	0.1062	0.4366**	0.5344**	0.3391**	0.3589**	0.6416**	0.6022**	0.3864*	0.6010**	1	
Grain yield	-0.1223	0.1541	0.3073*	0.5666**	0.3698**	0.4876**	0.6901**	0.5887**	0.7901**	0.5623**	0.5992**	1

* and ** represent significant correlation at 5% and 1% level of probability respectively.

grain. The yield loss caused was mainly due to an increased rate of floral and pod abortion and detrimental effects of drought avoidance on CO_2 assimilation.

As observed in our study, under high moisture stress, high correlation coefficient values were found between seed yield and related traits. It is similar to results observed earlier in chickpea. (Rahman and Uddin, 2000). These traits should be considered in improving yield stability of chickpea under moisture stress conditions. Yield was found positively correlated with plant height, number of branches, 100 seed weight, number of pods per plant (Shamsi et al., 2010), total dry matter (Islam et al., 2008), leaflet number (Farshadfar and Farshadfar, 2008), leaf area (Ali et al., 2010), leaf area index (Khamsi et al., 2010) in chickpea. Significant correlation between fertile pod number and yield in lentil (Azizi-e-Chakherchaman et al., 2009). These traits can be used as reliable criterion in selection of water stress tolerant chickpea cultivars.

Conclusion

An appreciable variation was noticed in all recorded parameters, due to differences in genetic constitution and environmental interactions. All recorded growth traits and yield attributes showed significant reductions under water stress at varied growth stages. These traits showed positively significant correlation with yield, showing that these can be effectively used for field screening of chickpea for drought tolerance. Among twenty genotypes studied, GL28151, RSG963 and PDG3 were more efficient in tolerating the adverse effect of water stress, whereas GL22044, GNG1861 and RVSSG3 showed sensitivity to drought. Effect of stress treatment T_2, grown with one pre sowing irrigation was adverse on growth and yield traits. Treatment stressed at flower initiation (T_3) was affected more in reducing growth traits than pod initiation stage (T_4) stress. However, pod initiation stage was more critical for yield traits than flower initiation.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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