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Physiological, biochemical and yield associated traits of chickpea genotypes under moisture stress condition

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Abstract
Chickpea is one of the major *rabi* pulse crops in India popularly called as “gram” being rich in protein. Chickpea accounts for an area of 98.86 lakh ha, and the production of 107.37 lakh tons with the productivity of 1086 kg ha^{-1} annually. The productivity of the crop is constrained by numerous abiotic stresses and among them, drought or moisture stress is the main factor affecting agricultural performance worldwide, accounting 40–50% yield drop. Current study was conducted with a goal to identify, assess, and choose chickpea genotypes with high yield potential under moisture stress. In this context, the experiment was conducted during 2021-22 and 2022-23 at UAS Dharwad, Karnataka, India. Experiment was laid out in split plot design with two moisture stress conditions as main plot (irrigated and rainfed) and 15 chickpea genotypes in subplot, which were replicated thrice. Results of the investigation revealed that, moisture stress condition significantly reduced the yield and yield parameters by significant reduction in physiological and biochemical parameters. Among the genotypes ICCV 4958 (17.67 q ha^{-1}) has bagged maximum yield followed by DIBG 205 (16.93 q ha^{-1}) under rainfed condition and higher yield was due to maximum RWC, Chlorophyll content and proline content and with less membrane injury index.

Keywords: RWC, SPAD, proline, chickpea, yield, moisture stress

Introduction
Pulses are one of the most significant food crops in the India because of high protein content and they are the most accessible and affordable source of eatable protein. India is the world’s leading producer of pulses, accounting for an area of 28.8 million ha and 26.96 million tons global output.
Chickpea is a major *rabi* pulse crop in India popularly called as gram. Accounting an area of 98.86 lakh ha. with a production of 107.37 lakh tons and productivity 1086 kg ha^{-1} (Anon., 2022) [1] contributing of 34% and 45% in area and production respectively in India. Madhya Pradesh is the largest producer of chickpea in India. While Karnataka stands 4th in area and production
Drought or soil moisture stress pose a significant threat to the global success of food production by affecting seed germination, crop stand, photosynthesis and osmotic behaviour of cells. It also changes the physiological and biochemical metabolism in plants such as chlorophyll loss, low water potential (Nayyar *et al.*, 2005) [10], early flowering (Sabaghpour *et al.*, 2006) [11] etc., affecting crop growth that results in lower yield. According to Upadhaya *et al.* (2011) [17], yield loss was calculated to be 10-15% for every 1 °C above the optimal temperature. Similar to this, the yield of chickpea reduced by 38.5 kg/ha for every 0.1 °C increase in temperature when accompanied with a 31% decrease in the yearly rainfall (Dubey *et al.*, 2011) [4].
Chickpea is essentially a rainfed or post monsoon winter crop. The average yield in India is very low, due to the cultivation of this crop on residual soil moisture in cool dry season.it is generally grown on conserved soil moisture and moisture in profile gradually recedes as the crop grows. As a consequence, plant experience progressively increasing degree of terminal moisture stress. Thus, soil moisture stress assumes a major limiting factor determining the growth and yield of chickpea. This demonstrates that the main factor affecting chickpea is drought. In the field and also in controlled situations, Plant's response to stressful environment have been investigated by examining physiological responses in chickpea and screening approaches have been created. In recent years, significant advancements have been made in the chickpea's ability to respond to drought stress.

By keeping the above facts in view, research was constituted with an objective to screen chickpea genotypes under moisture stress condition on phenological, physiological and biochemical basis.

Materials and Methods

Field experiment was conducted during 2021-22 and 2022-23 at UAS Dharwad, Karnataka, India which is located at 15° 49' N latitude and 74⁰ 98' E longitude with an altitude of 678 metres above the mean sea level (MSL).

Fifteen chickpea genotypes were evaluated under two different water stressed conditions for characterization of the physiological and yield attributing characters of chickpea. Genotypes used were BGD 133, BGD 225, BGD 111-1, BGD 103, ICCV 191608, ICCV 191106, ICCV 201111, DBGV 206, NBeG 506, DIBG 205, SA-1, JAKI 9218, A-1, JG 11 and ICCV 4958. Among water stressed treatments, rainfed treatment received no irrigation during crop growth period except at sowing. Whereas, irrigated treatment received 3 irrigations *i.e.,* at sowing, at flower initiation stage (45 DAS) and pod filling stage (70 DAS).

Phenological parameter

The observations on days to initiation of flowering, 50% flowering, days to maturity was recorded from the date of sowing.

Relative water content (RWC)

Relative water content (RWC) was determined according to Bars and Weatherly (1962) [2] at 45 and 60 DAS by using formula.

$$RWC\ (\%) = \frac{\text{Fresh weight - Dry weight}}{\text{Turgid weight - Dry weight}} \times 100$$

Membrane injury index (MII)

Membrane injury index was estimated at 45 and 60 DAS by the procedure given by (Sullivan and Ross, 1979)

Membrane injury index (%) = EC_1/EC_2 x 100

SPAD chlorophyll meter

Chlorophyll concentration was assessed using chlorophyll meter (SPAD-502 plus, Minolta). Measurements were taken at three points (upper, middle and lower parts). Average of these three readings was considered as SPAD reading of the leaf. SPAD reading was carried out at 45 and 60 DAS. The mean SCMR reading was taken out in the end and presented as average SPAD value.

Proline content

Proline content in leaf tissues of both control and drought stress chickpea at 45 and 60DAS was determined using the acid ninhydrin reagent as per the method described by Bates *et al*., (1973) [3]. The proline content was expressed as μmoles per gram fresh weight.

Yield associated parameter

Three plants were randomly chosen from each plot to measure the number of seeds per plant, number of pods per plant, 100-seed weight recorded at the time of harvest.

Results and Discussion

Effect of drought stress on phenological parameters in chickpea genotypes under rainfed and irrigated condition

Days taken to 1st flower initiation was noticed earlier under rainfed condition (42.42 days) as compared to irrigated condition (Table 1). Among the genotypes, genotype A-1 has taken less number of days for 1st flowering (38.83 days) which was significantly earlier as compared to rest of the genotypes except with the genotype ICCV 4958 (39.17 days) under rainfed condition. Among the interactions, genotype A-1 under rainfed condition flowered earlier as compared to rest of the interactions except with ICCV 4958 under rainfed condition (39.75 days).

Days to 50% pod initiation and days to attain physiological maturity was significantly shortened under rainfed condition as compared to irrigated condition. Among genotypes, genotype ICCV 4958 (55.08 and 87.83 days) required minimum no of days to 50% pod initiation and attain physiological maturity, respectively, which was significantly earlier as compared to rest of the genotypes except with genotype A-1 (55.33 and 89.19 days). Genotypes shortened the days taken to 50% pod initiation and days to physiological maturity by 2-10 days under rainfed condition as compared to irrigated condition. Genotype A-1 under moisture stressed condition (52.50 days) required minimum number of days to 50% pod initiation compared to rest of the interactions except JAKI 9218, ICCV 4958 and JG 11 under rainfed condition. However, days taken to attain physiological maturity was significantly lower with the genotype A-1 under moisture stressed condition (86.33 days) which remained on par with ICCV 4958, BGD 111-1, BGD 103 and SA-1. Genotypes BGD 111-1 and BGD 103 shortened their days taken to 50% pod initiation and physiological maturity by 8 and 10 days, respectively which was higher among the compared genotypes. Moisture stress reduced the number of days to flower initiation, 50% pod initiation and days to physiological maturity compared to irrigated condition (Krishnamurthy *et al*., 2013) [8]. This might be due to the fact that sufficient moisture during the growing period lead to higher plant water status which hasten the vegetative growth and water stress condition fasten towards the reproductive growth. Under stress conditions plants tends to have a common senescence mechanism that it finishes its life cycle as early as possible hence it can produce not ample but some of seeds in order to grow the generation of their own. Similar results were found by Ghiabi *et al.* (2013) [5] that under adequate availability of water during growth period encouraged the vegetative growth that led to delay in maturity. Sachdeva *et al.* (2022) [12] was also noticed that the genotypes under water stress mature earlier with a shorter life cycle and pre-flowering moisture stress shortened the days to flowering, but flowering stage stress shortened the seed-filling period.

Effect of drought stress on physiological and biochemical parameters of chickpea genotypes under rainfed and irrigated condition

Relative water content (RWC) was significantly affected by water stressed conditions. Whereas, significantly higher relative water content (83.95 and 81.06%) were recorded under irrigated condition at 45 and 60 DAS, respectively as compared to rainfed condition *i.e.,* water stressed condition.

Among genotypes, ICCV 4958 maintained significantly higher RWC (86.97 and 84.06%) as compared to other genotypes except with the genotype DIBG 205 and A-1. Whereas, ICCV 191608 and ICCV 191106 were recorded significantly lower RWC (69.00 and 70.53%, respectively). Gradual decrease in RWC in all the genotypes was noticed under moisture stress condition. At 45 and 60 DAS, maximum RWC was maintained by JG-11 (89.16 and 86.67%, respectively) and A-1 (88.12 and 86.13%, respectively) genotype which was followed by ICCV 4958 and DIBG 205 under irrigated condition. On the contrary, under rainfed condition, ICCV 4958 (84.80 and 83.05%, respectively) and DIBG 205 (83.80 and 82.23%, respectively) genotypes were found promising for maintaining higher RWC than other genotypes. However, they remained at par with the RWC of the same genotypes under irrigated condition with the minimal reduction of 3.57 and 3.91%, respectively. Genotype IICV 191106 was found susceptible to moisture stress condition by reducing 14.87% of RWC as compared to irrigated condition. Under moisture stress, RWC of all genotypes decreased considerably as compared to irrigated condition. This reduction in RWC indicated that genotypes under rainfed condition suffered from moisture stress to some extent which resulted in reduced uptake of water and nutrients, and loss of water through stomatal regulation lead to lower RWC under rainfed condition. The findings are in line with earlier research which found that water deficit in chickpea cultivars resulted in a considerable drop in chlorophyll content and relative water content (Talebi *et al.*, 2013) [15]. Win *et al.* (2017) [18] also noticed that RWC is significantly reduced under moisture stress condition as compared to well-watered *i.e.*, irrigated condition. Similar results were observed by Ghiabi *et al.* (2013) [5] and Sharma *et al.* (2017) [13] in Chickpea.

Data in Table 3 depicts that significantly higher proline accumulation was observed in rainfed condition (3.74 and 5.35 µmole g_{-1} fresh wt.) than irrigated condition (1.20 and 2.06 µmole g_{-1} fresh wt.) at both 45 DAS and at 60 DAS, respectively. Significantly higher proline content (4.42 and 6.46 µmole g_{-1} fresh wt.) was observed in the genotype ICCV 4958 compared to rest of the genotypes at 45 DAS and at 60 DAS, respectively. Among the interaction between moisture stress condition and genotype, significantly higher proline content was observed in the genotype ICCV 4958 (2.88 and 4.34 µmole g_{-1} fresh wt.) grown under moisture stress condition *i.e.*, rainfed condition at 45 DAS and at 60 DAS, respectively. However, Drought stress increased the proline concentration, this increase served to promote osmotic compatibility and modify osmotic potential, which led to drought stress avoidance in Chickpea. According to Verbruggen and Hermans (2008) [19] proline accumulation is thought to perform adaptive roles in plant stress tolerance. Results are in line with the findings of Mafakheri *et al.* (2010) [9] in chickpea who noticed that moisture stress increased the proline accumulation in all the chickpea genotypes.

Under stressed condition membrane injury index (15.57 and 17.86 %) was significantly higher at both 45 DAS and 60 DAS, respectively. The genotype which showed higher membrane injury index was IICV 201111 (14.82 and 17.82%) at both 45 DAS and 60 DAS, respectively. The interaction of moisture regime and genotype showed that rainfed condition increased the membrane injury index in the all genotype as compared to irrigated condition. Genotype DIBG 205 (12.86 and 14.73 %) grown under moisture stress condition recorded lowest membrane injury index at both 45 DAS and 60 DAS, respectively. Whereas, ICCV 4958 and A-1 genotypes shown least membrane injury index than other genotypes under rainfed condition when compared with irrigated condition. This higher MII might be due to the high temperature and moisture stress which injures the leaf tissue, cellular membrane permeability is increased and electrolytes diffuse out of the cells. The resilient plants create a variety of physiological and biochemical reactions that are adaptive in nature when exposed to water stress. These include modifications to pigment content, osmotic adjustment, photosynthetic activity and water use efficiency. These systems are essential for stopping membrane injury and providing resistance to drought (Talebi *et al.*, 2013) [15].

Irrigated condition recorded significantly higher SPAD values than rainfed condition at 45 and 60 DAS, respectively. Among the genotypes, ICCV 4958 recorded significantly higher SPAD values (41.66 and 45.31) as compared to other genotypes which was followed by DIBG 205 and A-1 genotypes. Among interactions, ICCV 4958 and DIBG 205 genotypes recorded significantly higher SPAD values as compare to other genotypes under both irrigated and rainfed condition than other genotypes. Whereas, all the genotypes showed decline in SPAD values under rainfed condition but the reduction was least under ICCV 4958, DIBG 205 and A-1 genotypes. Higher SPAD value under irrigated condition was due to the greater availability of soil moisture coupled with better soil aeration lead to the adequate availability and uptake of nitrogen, and higher stomatal conductance which might have resulted in the increased chlorophyll content and SPAD value. One of the effects of drought stress, which can be brought on by persistent photoinhibition and photobleaching, is the destruction of chlorophyll leading to reduced SPAD values under moisture stressed condition. Whereas, tolerant genotypes adopted to moisture stress condition by altering the physiological processes and maintain higher RWC and stomatal conductance resulted in maintaining of higher SPAD values even under rainfed condition. Talebi *et al.* (2013) [15] reported that significant decrease in SPAD values was noticed in all genotypes under drought stress, but the reduction was minimum in tolerant genotypes. The results are in line with Sachdeva *et al.* (2020) [12] and Ucak and Arslan (2023) [16] in Chickpea.

Effect of drought stress on yield parameters and yield of chickpea genotypes under rainfed and irrigated condition

Under different moisture regimes, significantly higher number of pods/plant and test weight were observed in irrigated condition (45.34 and 24.39 g, respectively) as compared to moisture stress condition (40.20 and 21.48 g, respectively). Among the genotypes, ICCV 4958 recorded significantly higher number of pods/plant (47.83) and BGD 103 recorded significantly higher test weight (28.15 g) as compared to other genotypes under irrigated condition. The interaction between moisture stress condition and genotypes showed that significantly higher number of pods per plant was recorded under JG 11 (50.77) followed by A-1 (50.67) under irrigated condition. All the genotypes shown significant reduction in number of pods per plant under rainfed condition as compared to irrigated condition except ICCV 4958 and DIBG 205.

Higher test weight was recorded with genotypes BGD 103 (26.52 g) under irrigated condition as compared to rest of the treatments. However, test weight of all the genotypes were significantly reduced under rainfed condition except ICCV 4958. The maintenance of higher RWC through increased water uptake, decreased water loss by closing stomata, increased antioxidant by degrading ROS, increased solute accumulation improve drought-tolerance mechanisms, which increases the accumulation of photosynthates and improves the source sink relation, may be the cause of higher yield parameters, such as the number of pods per plant and test weight. Similar findings were observed by Ulemale *et al.* (2013) [20] in Chickpea.

Significantly higher seed yield was observed in irrigated condition (10.72 g plant^{-1} and 17.31 q ha^{-1}) as compared to moisture stress condition (8.77 g plant^{-1} and 14.40 q ha^{-1}). Among the genotypes, the genotype ICCV 4958 (12.14 g plant^{-1} and 18.19 q ha^{-1}) recorded significantly higher yield per plant and yield per ha as compared to other genotypes which was followed by JG 11 and DIBG 205. This might be due to the presence of significant level of genotypic heterogeneity across the chickpea accessions under drought stress conditions enhanced the drought tolerance which ultimately resulted in higher yield in ICCV 4958, JG 11, DIBG 205 and A-1 genotypes. These findings are in line with Ulemale *et al.* (2013) [20] and Ghaibi *et al.* (2013) [21] in Chickpea. Among interactions, genotype JG 11 (13.43 g plant^{-1} and 20.96 q ha^{-1}) under irrigated condition recorded significantly higher yield as compared to rest of the treatments except A-1 (19.60 q ha^{-1}) which was followed by ICCV 4958 (18.71 q ha^{1}). Average yield reduction due to moisture stress was 14.57%. However, all the genotypes recorded significantly lower yield when compared with irrigated condition which ranged from 3.51–27.7%, among the genotypes. Whereas, ICCV 4958, DBGV 206 and DIBG 205 shown least reduction in seed yield by 3.51, 5.54 and 5.40%, respectively when compared with the seed yield under irrigated condition. Higher yield under irrigated condition was mainly due to higher yield attributing characters *viz.*, seed numbers, test weight and seed yield per plant. However, tolerant genotypes maintained similar yield under moisture stress condition as that of irrigated condition which might be due to the physiological changes (Chlorophyll content, leaf RWC, etc.) and other important metabolic processes under water deficit condition as well as responses of various defence mechanisms by the plant under drought stress resulting in higher yield under rainfed condition as compared to susceptible genotypes. Ghaibi *et al.* (2013) [21] reported that genotypes such as Flip2005-1C, Flip2005-5C and Flip2005-7C exhibited maximum grain yield and its component in both environments. Sharma *et al.* (2017) [13] noticed that susceptible genotypes showed greater reduction in yield and tolerant genotypes showed higher yield under moisture stress condition. These findings are in line with Ulemale *et al.* (2013) [20] revealed that Phule G 0302-26 was found to be promising genotype with least reduction in yield due to moisture stress and found to be stable high yielding by exhibiting higher drought tolerance index, proline content and other physiological processes.

Table 1: Effect of drought stress on days to first flower initiation, days to 50% pod initiation and days to physiological maturity in chickpea genotypes under rainfed and irrigated condition pooled data (2021-22 and 2022-23)

Genotype	Phenological parameters								
	Days to 1st flower initiation			Days to 50% pod initiation			Days to physiological maturity		
	IR	RF	Mean	IR	RF	Mean	IR	RF	Mean
BGD 133	45.42	44.05	44.73	65.17	58.05	61.61	99.67	95.67	97.67
BGD 225	45.03	43.55	44.29	62.28	57.55	59.92	98.68	94.49	96.59
BGD 111-1	41.79	41.46	41.62	63.83	55.46	59.65	95.68	91.44	93.56
BGD 103	41.83	40.83	41.33	64.50	55.83	60.17	96.70	92.74	94.72
ICCV 191608	42.67	40.67	41.67	64.32	54.50	59.41	98.65	91.99	95.32
ICCV 191106	45.67	44.50	45.08	64.31	58.50	61.41	98.69	97.00	97.85
ICCV 201111	46.33	45.31	45.81	65.83	59.31	62.57	99.67	96.00	97.84
DBGV 206	46.67	44.98	45.82	64.83	58.98	61.91	100.66	92.32	96.49
NBeG 506	45.95	44.83	45.39	63.99	58.59	61.29	98.66	92.65	95.66
DIBG 205	46.65	45.85	46.26	63.34	58.83	61.09	100.00	95.33	97.67
SA-1	42.92	41.83	42.38	63.50	55.71	59.61	93.71	88.06	90.89
JAKI 9218	40.80	39.63	40.22	60.83	53.63	57.23	102.72	95.35	99.04
A-1	39.92	38.83	39.02	58.17	52.50	55.33	90.55	86.33	88.44
JG 11	43.50	40.83	42.17	59.50	54.67	57.08	97.63	92.96	95.30
ICCV 4958	40.33	39.17	39.75	56.50	53.67	55.08	89.33	87.82	88.57
Mean	43.70	42.42		62.73	56.39		97.40	92.68	

	S.EM. ±	CD @ 5%	S.EM. ±	CD @ 5%	S.EM. ±	CD @ 5%
T	0.407	2.477	0.601	2.283	0.820	3.362
G	0.451	1.278	0.584	1.653	1.569	4.446
(T×G)	0.638	1.808	0.825	2.338	2.219	6.288

Table 2: Effect of drought stress on relative water content (%) and membrane injury index (%) of chickpea genotypes under rainfed and irrigated condition pooled data (2021-22 and 2022-23)

Genotype	Relative water content (%)						Membrane injury index (%)					
	45 DAS			60 DAS			45 DAS			60 DAS		
	IR	R	mean	IR	R	mean	IR	R	Mean	IR	R	Mean
BGD 133	81.70	74.37	78.03	79.35	72.60	75.98	12.41	15.90	14.15	14.71	19.52	17.11
BGD 225	80.66	73.50	77.08	79.06	69.88	74.47	11.67	16.02	13.84	14.80	18.84	16.82
BGD 111-1	84.52	77.22	80.87	81.35	75.27	78.31	11.06	13.70	12.38	13.37	17.80	15.59
BGD 103	86.98	77.63	82.31	82.52	75.66	79.09	10.84	14.45	12.64	13.16	18.27	15.71
ICCV 191608	76.97	69.00	72.98	74.70	65.53	70.11	11.54	16.03	13.79	15.78	20.03	17.91
IICV 191106	77.59	70.03	73.81	77.28	67.85	72.56	12.14	15.31	13.73	16.40	18.90	17.65
ICCV 201111	77.98	70.53	74.26	74.95	65.03	69.99	12.76	16.88	14.82	15.33	20.31	17.82
DBGV 206	85.67	78.30	81.99	83.73	77.30	80.52	10.65	14.59	12.62	12.80	17.59	15.19
NBeG 506	84.61	76.70	80.66	81.23	74.57	77.90	11.42	14.03	12.72	13.74	16.53	15.13
DIBG 205	88.15	83.80	85.97	84.45	82.23	83.34	10.66	12.86	11.76	13.16	14.73	13.95
SA-1	83.73	75.39	79.56	78.70	72.12	75.41	11.52	14.86	13.19	14.13	19.04	16.59
JAKI 9218	84.28	73.30	78.79	80.77	72.70	76.73	11.52	14.69	13.11	13.55	17.14	15.34
A-1	88.12	81.63	84.87	86.13	80.12	83.13	10.43	13.16	11.80	12.92	16.45	14.68
JG 11	89.16	82.48	85.82	86.67	79.57	83.12	10.40	14.17	12.29	12.62	17.02	14.82
ICCV 4958	89.14	84.80	86.97	85.08	83.05	84.06	10.79	12.93	11.86	13.33	15.73	14.53
Mean	83.95	77.51		81.06	74.30		11.32	15.57		13.99	17.86	

	S.EM. ±	CD @ 5%	S.EM. ±	CD @ 5%	S.EM. ±	CD @ 5%	S.EM. ±	CD @ 5%
T	0.170	0.745	0.240	0.912	0.116	0.440	0.207	0.724
G	1.416	4.011	0.898	2.545	0.305	0.864	0.318	0.900
(T×G)	2.002	5.672	1.270	3.599	0.431	1.222	0.449	1.273

Table 3: Effect of drought stress on Proline content (µmole g_{-1} fresh wt.) and Relative chlorophyll content (SPAD values) chickpea genotypes under rainfed and irrigated condition pooled data (2021-22 and 2022-23)

Genotype	Proline content (µmole g_{-1} fresh wt.)						Relative chlorophyll content (SPAD values)					
	45 DAS			60 DAS			45 DAS			60 DAS		
	IR	R	mean	IR	R	mean	IR	R	Mean	IR	R	Mean
BGD 133	1.08	3.35	2.21	1.95	5.13	3.54	38.17	33.66	35.91	41.22	35.82	38.52
BGD 225	1.10	3.63	2.36	1.97	5.38	3.67	37.20	32.57	34.88	40.61	33.95	37.28
BGD 111-1	1.24	3.85	2.54	2.09	5.72	3.91	41.75	37.70	39.73	44.11	40.53	42.32
BGD 103	1.26	3.80	2.53	2.09	5.49	3.79	40.73	34.47	37.60	43.09	36.93	40.01
ICCV 191608	1.03	3.49	2.26	1.89	4.97	3.43	38.58	32.59	35.59	40.50	32.99	36.75
IICV 191106	1.02	3.26	2.14	1.87	4.94	3.41	37.55	31.17	34.36	38.60	32.13	35.36
ICCV 201111	1.01	3.19	2.10	1.87	4.87	3.37	38.17	31.81	34.99	40.26	32.63	36.44
DBGV 206	1.27	3.83	2.55	2.14	5.51	3.82	42.12	37.58	39.85	44.75	39.33	42.04
NBeG 506	1.17	3.65	2.41	2.03	5.19	3.61	38.92	35.57	37.25	41.88	38.13	40.01
DIBG 205	1.33	4.40	2.86	2.19	6.17	4.18	41.20	40.45	40.82	45.57	43.36	44.46
SA-1	1.20	3.75	2.48	2.08	5.29	3.68	40.43	34.79	37.61	43.27	37.89	40.58
JAKI 9218	1.19	3.73	2.46	2.05	5.20	3.62	39.33	33.82	36.57	42.05	36.84	39.44
A-1	1.36	3.90	2.63	2.24	5.41	3.82	43.27	36.00	39.64	46.73	37.38	42.06
JG 11	1.46	3.90	2.68	2.39	5.69	4.04	43.47	35.86	39.66	47.24	36.48	41.86
ICCV 4958	1.34	4.42	2.88	2.21	6.46	4.34	42.76	40.57	41.66	46.47	44.15	45.31
Mean	1.20	3.74		2.06	5.35		40.24	35.24		43.09	37.23	

	S.EM.±	CD @ 5%	S.EM.±	CD @ 5%	S.EM.±	CD @ 5%	S.EM.±	CD @ 5%
T	0.010	0.042	0.015	0.047	0.110	0.460	0.417	0.543
G	0.051	0.145	0.074	0.210	0.666	1.887	0.657	1.862
(T×G)	0.072	0.205	0.105	0.297	0.942	2.668	0.930	0.572

Table 4: Effect of drought stress on yield parameters and yield of chickpea genotypes under rainfed and irrigated condition pooled data (2021-22 and 2022-23)

Genotype	Yield attributes											
	No of pod/plant			Test seed weight (g)			Seed yield (g $plant^{-1}$)			Seed yield (q ha^{-1})		
	IR	RF	Mean	IR	RF	Mean	IR	RF	Mean	IR	RF	Mean
BGD 133	43.21	35.93	39.57	24.98	21.50	23.24	10.10	8.11	9.10	16.67	13.20	14.93
BGD 225	43.63	36.10	39.86	24.09	20.49	22.29	9.69	7.67	8.68	16.22	13.88	15.05
BGD 111-1	48.31	43.46	45.88	25.73	22.47	24.10	11.91	10.43	11.17	18.67	16.36	17.51
BGD 103	48.17	41.78	44.97	28.15	24.88	26.52	11.05	9.18	10.11	18.27	14.70	16.48
ICCV 191608	41.30	34.92	38.11	24.53	20.50	22.52	9.11	7.02	8.07	15.38	11.84	13.61
IICV 191106	40.46	33.63	37.04	24.55	19.98	22.27	8.87	6.15	7.51	14.84	10.73	12.79
ICCV 201111	42.49	35.77	39.13	24.11	20.49	22.30	8.84	6.69	7.76	16.00	12.44	14.22
DBGV 206	44.79	40.34	42.56	24.58	21.50	23.04	10.68	9.39	10.03	16.98	14.42	15.70
NBeG 506	43.51	37.86	40.68	23.39	20.48	21.93	9.87	8.29	9.08	16.31	14.31	15.31

DIBG 205	47.33	46.33	46.83	25.54	23.97	24.75	11.85	10.89	11.37	17.89	16.93	17.41
SA-1	47.00	42.52	44.76	22.60	20.00	21.30	10.49	8.34	9.41	16.98	13.49	15.23
JAKI 9218	43.16	37.22	40.19	23.34	21.00	22.17	9.78	8.02	8.90	16.13	13.29	14.71
A-1	50.67	43.19	46.93	22.06	19.93	21.00	12.70	9.86	11.16	19.60	16.18	17.76
JG 11	50.77	44.50	47.63	23.50	21.00	22.25	13.43	9.92	11.67	20.96	16.64	18.78
ICCV 4958	48.33	47.33	47.83	24.67	23.96	24.31	12.51	11.77	12.14	18.71	17.67	18.19
Mean	45.34	40.20		24.39	21.48		10.72	8.77		17.31	14.40	

	S.EM.±	**CD @ 5%**	**S.EM.±**	**CD @ 5%**	**S.EM.±**	**CD @ 5%**	**S.EM.±**	**CD @ 5%**
T	0.099	0.604	0.053	0.320	0.042	0.155	0.294	1.117
G	0.722	2.045	0.370	1.049	0.201	0.569	0.278	0.788
(T×G)	1.021	2.892	0.523	1.483	0.284	0.805	0.394	1.115

Conclusion

Different genotypic responses to drought stress in several crops as well as in chickpea were observed (Talebi *et al.*, 2013) [15]. These differential responses of genotypes for drought tolerance features suggested the existence of various drought resistance mechanisms. Combining these traits in breeding programmes for chickpea should boost the crop's ability to withstand drought (Win *et al.*, 2017) [18]. The results of this study demonstrated that combined analysis of variance was significant among the tested genotypes for the majority of the attributes taken into account, indicating the existence of variability among tested genotypes and the potential for selection under moisture stress conditions. All the genotypes recorded significantly lower yield when compared with irrigated condition which ranged from 3.51-27.7%, among the genotypes except ICCV 4958, DBGV 206 and DIBG 205. Whereas, ICCV 4958, DBGV 206 and DIBG 205 shown higher yield under moisture stress condition with least reduction by 3.51, 5.54 and 5.40%, respectively when compared with the seed yield under irrigated condition. It was found that these genotypes exhibited higher RWC, proline content and SPAD chlorophyll meter readings with less membrane injury index under stress condition indicating the tolerant characteristics to moisture stress. Therefore, in future breeding programmes to develop the drought resistant genotypes in chickpea, these genotypes can be employed as potential sources breeding for drought tolerance.

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