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RESEARCH PAPER

Effect of drought stress on morho-physiological and yield components in chickpea genotypes

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Abstract: Chickpea is one of the major *rabi* pulse crops in India popularly called as "gram". Many abiotic stressors limit crop output, among them moisture stress accounts for 40–50% yield loss in chickpea. In order to evaluate, and select chickpea genotypes with high yield potential under moisture stress most prerequisite, the current study was carried out at UAS Dharwad in Karnataka, over the 2021–22 and 2022–23 periods. To study morpho-physiological traits related to drought tolerance and to fix the criteria for reliable screening of drought tolerant chickpea genotypes, 15 chickpea genotypes grown on rainfed and irrigation condition. The effect of drought stress on plant height, number of branches, leaf area, total chlorophyll content, chlorophyll stability index, relative water content and yield attributes were evaluated. Among genotypes, the maximum plant height was recorded in DBGV 206 under rainfed condition and more number of branches per plant was recorded in A-1 under stress condition. Tolerant genotypes like ICCV 4958, DIBG 205 and BGD 111-1 were showed highest yield under rainfed condition with less percent yield reduction compare to irrigated ones. Which was due to maximum RWC, CSI, chlorophyll content with minimum reduction in morphological parameters under rainfed condition.

Key words: Chickpea, Drought, Genotypes, Rainfed, Yeld components

Introduction

Chickpea (*Cicer arietinum* L.) is grown in many parts of the world and yields a total of about 13543.63 thousand tonnes from an area of 10740.10 thousand ha (*Anon* 2022). Despite the high yield potential of chickpea of over 6000 kg ha^{-1}, the actual yields are significantly lower considered to be due to a combination of biotic and abiotic stresses. Among the major chickpea producer countries, India, Pakistan, Turkey and Iran, in these regions, chickpea is generally grown under rainfed conditions either on stored soil moisture in subtropical environments with summer dominant rainfall. In both environments, non irrigated chickpea fields suffer yield losses from terminal drought (Yadav *et al*., 2006; Canci *et al*., 2009). Kumar and Abbo (2001) reported that about 90% of the world's chickpea is grown under rainfed conditions where terminal drought is the major stress, accompanying with high temperature stress. Deleterious responses to drought can include reduction of growth, decrease in chlorophyll increase in proline. It is recognized that resistant plants under water stress conditions developed various physiological responses of adaptive nature. These include changes of water use efficiency, pigment content, osmotic adjustment and photosynthetic activity. Photosynthetic pigments play an important role in light harvesting and dissipation of excess energy. It is known that the content of both chlorophyll a and b changes under drought stress (Farooq *et al*., 2009). As a major crop, wheat has gained special attention with respect to morphological and physiological characters and traits affecting drought tolerance, but there is not enough information for chickpea about the relevant parameters and their relationships with drought susceptibility among chickpea cultivars. As mechanisms of responses to drought stress varies with genotypes and growth stages of individual plants (Ashraf and Harris 2004). Identifying suitable drought tolerant chickpea genotypes is crucial for ensuring chickpea production in drought prone areas. Physiological attributes can provide valuable insights into drought tolerance mechanisms and serves as potential selection criteria for screening large number of genotypes efficiently.

Material and methods

Field experiment was conducted during 2021-22 and 2022-23 at MARS, UAS Dharwad, Karnataka which is located at 15^{o} 49' N latitude and 74^{0} 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 morpho-physiological and yield attributes. 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 regimes 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 (40 DAS) and pod filling stage (70 DAS).

Observation recorded

Morphological and growth parameters-Plant height, Number of branches and Leaf area recorded at 90 DAS

Physiological parameters

Leaf chlorophyll content- Chlorophyll content was determined as given by Hiscox and Israelstam (1979).

$$\text{Leaf total Chlorophyll (mg g}^{-1}\text{ fr.wt.)} = 20.2\,(A_{645}) + 8.02\,(A_{663}) \times \frac{V}{1000 \times a \times W}$$

Chlorophyll stability index- CSI was estimated using the method of Koleyoreas (1958)

$$CSI(\%) = \frac{\text{Total chirophyll content heated}}{\text{Total chirophyll content control}} \times 100$$

Relative water content- Relative water content was estimated by the formula given by Barr and Weatherley(1962).

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

Yield components

Number of pods per plant, test weight and seed yield per ha during harvest.

Results and discussion

Effect of drought stress on morphological and growth parameters

The data on the plant height recorded at 90 DAS was presented in Table 1. Plant height recorded was highest in DBGV 206 (50.30 cm) and lowest was recorded in SA-1 (42.20 cm) under irrigated condition. Under rainfed condition as well, the highest plant height recorded in DBGV 206 (48.56 cm) and lowest plant height recorded in SA-1 (36.44 cm). It was postulated drought stress hinders plant growth by disrupting cell expansion and inhibiting cell division due to reduced cyclin-dependent kinase activity. Similarly, reduction in plant height in response to soil water deficit was has been reported for cowpea by Aderolu (2000) and mung bean by Ahmad *et al*., (2015). There was a significant difference for number of branches among the genotypes and treatment. Among the genotypes the number of branches per plant was recorded was highest in A-1 and SA-1 (16.33) followed by JG -11 (16.31). Drought condition cell elongation of higher plants can be inhibited by interruption of water flow from xylem to the surrounding elongating cells which leads to lowest number of branches (Manivannan *et al.*, 2007). Less reduction in leaf area in rainfed compared to irrigated conditions, which was recorded in ICCV 4958 (14.85%). The highest reduction in leaf area among the genotypes was recorded in ICCV 191608 (33.71%). The highest leaf area was recorded in ICCV 4958 (3.24 dm^2 $plant^{-1}$). Decrease in leaf area also observed in chickpea by Salehpoor *et al.* (2009). Drought stress lowers the production of leaves, higher leaf senescence, decreased leaf size which directly affect vegetative growth (Pagter *et al.,* 2005).

Effect of drought stress on physiological parameters

ICCV 4958, DIBG 205, recorded the highest total chlorophyll content (2.68, 2.66 mg/g fr. wt), respectively, under irrigated conditions. A very less reduction in chlorophyll content was observed in ICCV 4958 and DIBG 205 (1.48 and 2.59%) from rainfed to irrigated conditions (Table 2). The highest per cent reduction in total chlorophyll content was recorded in IICV 191608 and (16.46%). Reduced light-harvesting capacity might mitigate the production of reactive oxygen species, which could be achieved through degradation of absorbing pigments. (Herbinger *et al*., 2002) similar results obtained by Baroowa and Gogoi *et al*. (2014) in black gram and green gram. Under rainfed conditions, the highest CSI was recorded in ICCV 4958 (73.20%). Baroowa and Gogoi *et al*. (2014) postulated that CSI under moisture stress which lead to Plant growth is hindered by excessive cell division and cell wall rupture, which causes the release of pigments and disrupts photosynthesis. Under rainfed conditions, the highest RWC was recorded in ICCV 4958 (83.05%), while the lowest was observed ICCV 201111 (65.03%). Terzi and Kadioglu (2006), observed that drought conditions have negative impact on water balance, and hence

Table 1. Effect of drought stress on morphological and growth parameters in chickpea genotypes under rainfed and irrigated condition pooled data (2021-22 and 2022-23)

Genotypes	90 DAS								
	Plant height (cm)			Number of branches per plant			leaf area (dm^2 $plant^{-1}$)		
	IR	RF	Mean	IR	RF	Mean	IR	RF	Mean
BGD 133	48.30	43.19	45.75	12.17	8.17	10.17	2.84	2.44	2.64
BGD 225	48.35	42.88	45.62	13.17	9.17	11.17	2.93	2.54	2.74
BGD 111-1	43.80	39.59	41.70	16.33	11.67	14.00	3.26	2.94	3.10
BGD 103	48.71	41.58	45.15	17.50	11.17	14.33	2.88	2.30	2.59
ICCV 191608	47.30	40.11	43.71	13.17	8.83	11.33	2.63	2.09	2.36
ICCV 191106	46.50	41.27	43.89	14.83	9.83	12.33	2.80	2.35	2.57
ICCV 201111	48.30	39.87	44.09	13.83	9.17	11.50	2.80	2.32	2.56
DBGV 206	50.30	48.56	49.43	12.81	10.50	11.67	3.43	3.01	3.22
NBeG 506	47.80	41.40	44.60	15.83	11.83	13.83	2.92	2.35	2.63
DIBG 205	46.30	41.81	44.06	15.83	13.82	14.82	3.33	2.93	3.13
SA-1	42.20	36.88	38.54	17.82	14.83	16.33	2.82	2.26	2.54
JAKI-9218	48.77	40.73	44.75	13.83	10.50	11.83	2.87	2.26	2.57
A-1	43.43	37.86	40.65	17.50	15.17	16.33	3.09	2.63	2.86
JG-11	46.64	41.43	45.04	18.83	14.03	16.43	3.30	2.93	3.12
ICCV 4958	44.20	40.36	42.28	16.83	14.33	15.58	3.43	3.04	3.24
Mean	46.72	41.16		15.36	11.51		3.02	2.56	
	S.EM. ±	CD @ 5%		S.EM. ±	CD @ 5%		S.EM. ±	CD @ 5%	
Main plot (A)	0.113	0.429	0.042	0.155	0.018	0.070			
Sub plot (B)	0.643	1.823	0.201	0.571	0.050	0.141			
Interaction	0.910	0.257	0.285	0.807	0.071	0.200			

decrease the water potential of leaves. Results are lined with observed by Singh and Deshmukh *et al.*, (2003) in chickpea.

Effect of drought stress on yield and yield components

Yield attributes include the number of pods per plant, test weight, seed yield /ha. All these attributes showed significant differences among genotypes and treatments mentioned in Table 3. Under rainfed conditions, ICCV 4958 and DIBG 205 (47.33 and 46.33, respectively) recorded the highest number of pods plant with a smaller reduction compared to irrigated conditions (2.06% and 2.11% reduction), while the lowest number of pods per plant was recorded in ICCV 191106 (33.63). Number of pods per plant decreased in rainfed condition similar with earlier findings in chickpea by Khurgami *et al.* (2009). Result of number of pods and percentage reduction in pods due to the abscission of the reproductive structures under stress conditions. Under rainfed conditions, BDG 103 recorded the highest test weight (24.88 g), followed by DIBG 205 and ICCV 4958, with test weights of 23.97 g and 23.96 g, respectively. Results lining with Anbessa *et al.* (2002) in

Table 2. Effect of drought stress on physiological parameters in chickpea genotypes under rainfed and irrigated condition pooled data (2021-22 and 2022-23)

Genotypes	60 DAS								
	Total chlorophyll content (mg g^{-1} fr.wt.)			Chlorophyll stability index			Leaf relative water content		
	IR	RF	Mean	IR	RF	Mean	IR	RF	Mean
BGD 133	2.57	2.16	1.90	69.97	65.01	67.49	79.35	72.60	75.98
BGD 225	2.55	2.15	2.35	70.98	64.43	67.71	79.06	69.88	74.47
BGD 111-1	2.71	2.54	2.62	75.66	71.09	73.37	81.35	75.27	78.31
BGD 103	2.67	2.29	2.48	74.94	70.68	72.81	82.52	75.66	79.09
ICCV 191608	2.43	2.03	2.23	69.89	63.53	66.71	74.70	65.53	70.11
ICCV 191106	2.22	2.14	2.18	68.33	62.60	65.46	77.28	67.85	72.56
ICCV 201111	2.25	2.12	2.18	67.03	60.88	63.96	74.95	65.03	69.99
DBGV 206	2.69	2.59	2.64	76.06	70.55	73.31	83.73	77.30	80.52
NBeG 506	2.58	2.24	2.41	70.92	66.06	68.49	81.23	74.57	77.90
DIBG 205	2.70	2.63	2.66	76.79	74.81	75.80	84.45	82.23	83.34
SA-1	2.61	2.24	2.43	73.19	67.66	70.42	78.70	72.12	75.41
JAKI-9218	2.62	2.21	2.41	71.13	65.75	68.44	80.77	72.70	76.73
A-1	2.74	2.50	2.62	78.31	67.27	72.79	86.13	80.11	83.12
JG-11	2.76	2.52	2.64	77.16	70.29	73.72	86.67	79.57	83.13
ICCV 4958	2.70	2.66	2.68	75.82	73.20	74.51	85.08	83.05	84.06
Mean	2.61	2.32		73.08	67.59		81.06	74.30	
	S.EM. ±	CD @ 5%		S.EM. ±	CD @ 5%		S.EM. ±	CD @ 5%	
Main plot (A)	0.010	0.043	0.105	0.336	0.240	0.912			
Sub plot (B)	0.036	0.101	1.149	3.255	0.898	2.545			
Interaction	0.050	0.142	1.625	4.604	1.270	3.599			

Table 3. Effect of drought stress on physiological parameters in chickpea genotypes under rainfed and irrigated condition pooled data (2021-22 and 2022-23)

	Number of pods per plant			Test weight (g)			Seed yield (q/ha)		
	IR	RF	Mean	IR	RF	Mean	IR	RF	Mean
BGD 133	43.21	35.93	39.57	24.98	21.50	23.24	16.67	13.20	14.93
BGD 225	43.63	36.10	39.86	24.09	20.49	22.29	16.22	13.88	15.05
BGD 111-1	48.31	43.46	45.88	25.73	22.47	24.10	18.67	16.36	17.51
BGD 103	48.17	41.78	44.97	28.15	24.88	26.52	18.27	14.70	16.48
ICCV 191608	41.30	34.92	38.11	24.53	20.50	22.52	15.38	11.84	13.61
ICCV 191106	40.46	33.63	37.04	24.55	19.98	22.27	14.84	10.73	12.79
ICCV 201111	42.49	35.77	39.13	24.11	20.49	22.30	16.00	12.44	14.22
DBGV 206	44.79	40.34	42.56	24.58	21.50	23.04	16.98	14.42	15.70
NBeG 506	43.51	37.86	40.68	23.39	20.48	21.93	16.31	14.31	15.31
DIBG 205	47.33	46.33	46.83	25.54	23.97	24.75	17.89	16.93	17.41
SA-1	47.00	42.52	44.76	22.60	20.00	21.30	16.98	13.49	15.23
JAKI-9218	43.16	37.22	40.19	23.34	21.00	22.17	16.13	13.29	14.71
A-1	50.67	43.19	46.93	22.06	19.93	21.00	19.60	16.18	17.76
JG-11	50.77	44.50	47.63	23.50	21.00	22.25	20.96	16.25	18.60
ICCV 4958	48.33	47.33	47.83	24.67	23.96	24.31	18.71	17.67	18.19
Mean	45.34	40.20		24.39	21.48		17.31	14.37	
	S.EM. ±	CD @ 5%		S.EM. ±	CD @ 5%		S.EM. ±	CD @ 5%	
Main plot (A)	0.099	0.604	0.053	0.185	0.294	1.117			
Sub plot (B)	0.722	2.045	0.370	1.049	0.278	0.788			
Interaction	1.021	2.892	0.523	1.483	0.394	1.115			

chickpea. Decrease in 100 grain weight under drought stress conditions due to lower photosynthetic translocation to reproductive part like grains. Under rainfed conditions, ICCV 4958 showed high yields (17.67 q/ha), while ICCV 191106 had very low yields (14.84 q/ha and 10.73 q/ha) in both irrigated and rainfed conditions. Increased floral and pod abortion, along with CO^2 assimilation disruption due to drought avoidance, led to substantial yield loss.

Conclusion

Drought tolerance traits among chickpea genotypes suggest multiple resistance mechanisms. Breeding programs can be combined with traits to enhance chickpeas drought resilience. Selective breeding under moisture stress lead to climate resilient chickpea varieties (Gunes *et al*., 2006; Talebi *et al*., 2013). Among genotypes ICCV 4958, DIBG 205 shown higher yield under moisture stress with least reduction by 5.55 and 5.39%, respectively. It was found that these genotypes exhibited higher RWC, chlorophyll and CSI indicating the tolerance 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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