World Journal of Agricultural Sciences 9 (2): 123-131, 2013
ISSN 1817-3047

DOI: 10.5829/idosi.wjas.2013.9.2.1706

Physiological Indices for Drought Tolerance in Chickpea (*Cicer arietinum* L.)

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Abstract: Fourteen chickpea genotypes were evaluated in RCBD with two replications in two separate experiments under moisture stress and non-stress condition to study the physiological indices for drought tolerance. Significant differences exhibited amongst the genotypes for phenology, vegetative growth and source, generative growth and sink capacity, physiological parameters and drought characteristics under moisture stress and non-stress conditions. The genotypes, Phule G 09103, Phule G 2008-74, Digiijay, Phule G 0302-26 recorded minimum percent reduction in yield due to moisture stress. RLWC, membrane injury index, chlorophyll content, chlorophyll stability index, proline accumulation and nitrate reductase activity were found to be the most useful parameters while selecting genotypes for drought tolerance. The genotypes, Phule G 07101, Phule G 2008-74, Digvijay, Phule G 0302-26 under irrigated condition whereas, Phule G 09103, Phule G 2008-74, Digvijay, Phule G 0302-26 under moisture stress condition were promising for yield and yield contributing characters. The genotypes Phule G 09103, Phule G 2008-74, Digvijay exhibited higher values for drought tolerance efficiency, proline content, chlorophyll content and lower values for drought susceptibility index, membrane injury index indicating their drought tolerance behavior. Therefore, these genotypes can be used as sources of drought tolerance in further breeding programme for evolving the drought tolerant genotypes in chickpea.

Key words: Phenology · Physiological parameters · Drought characteristic · Moisture stress · Vegetative growth and source · Generative growth and sink capacity

INTRODUCTION

Grain legumes constitute an important component of drought prone agriculture. The water stress reduces the yield of grain legumes remarkably [1, 2]. Among the different legumes, chickpea is a highly acceptable crop in winter season in drought prone areas of nation as well as in world on receding moisture. More than 85 per cent chickpea is grown as rainfed mostly on residual soil moisture after harvest of *kharif* crops in India [3]. In India, the area under chickpea is 8.2 million hectare with productivity 895 kg/ha and production 7.3 million tones [4]. Despite significant gains in irrigation potential during last three decades, chickpea continued to be a rainfed crop in major parts of the country. Future estimates also indicate that not more than 25 per cent of total chickpea area in India is expected to be under irrigation. Thus, drought is the single most important abiotic constraint limiting the chickpea production. Use of irrigation water, fertilizers, high yielding and drought tolerant varieties are some of the ways to improve the productivity.

Soil moisture stress is a major hazard to successful crop production throughout the world. It reduces the productivity by delay or prevention crop establishment, destruction of established crop, predisposition of crop to insects and diseases, alteration of physiological and biochemical metabolism in plant and quality of grain, forage, fibre, oil and other economically important products. Moisture deficit affects seed germination and its establishment in the field, photosynthetic ability of the plants and osmotic behavior of cells. However, species and genotypes vary in their capacity to tolerate water stress. The improvement in the genotypes is the only alternative for yield stability under water stress environment. Therefore, the improved chickpea genotypes with better water use efficiency and high yield

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will be suitable for cultivation in drought prone areas and can prove a soon to improve the economic status of poor farmers of dry land areas. To achieve this, an understanding of physiological processes associated with drought tolerance is pre-requisite. Therefore, the study was undertaken with the objective to assess and identify morpho-physiological traits for drought tolerance.

MATERIALS AND METHODS

Fourteen genotypes of chickpea were evaluated under moisture stress and non-stress separately in RCBD with two replications at Pulses Improvement Project, MPKV, Rahuri-413722, dist.: Ahmednagar (M.S.), India during *Rabi* 2011-12. The experiment was conducted under rainout shelter condition. The fertilizer dose was applied before sowing @ 25:50:30 and 12.5:25:30, N:P:K kg/ha for non-stress and moisture stress conditions, respectively in the form of Urea, SSP and MOP. The sowing was done by dibbling method with the spacing of 30 x 10 cm and plot size of 1.50 x 0.60 m^2. Gap filling was carried out by 15 days after sowing. At the same time thinning was done by keeping only one healthy plant per hill. One irrigation given to moisture stress trial at the time of sowing for good germination whereas, additional three irrigations at 25 to 30 days interval were given to non-stress trial so as to soil moisture content close to field capacity. Soil samples were collected with the help of screw auger at 0-15 and 15-30 cm depth at 20 days interval starting from sowing before 9.30 A.M. Weights of soil samples before and after drying were taken. Soil samples were dried in hot air oven at 120°C till samples were dried completely.

The percentage of moisture content, stress day factor and available moisture in the soil was calculated by using the formula.

$$\text{Moisture content (\%)} = \frac{\text{Weight of wet soil} - \text{Weight of oven dry soil}}{\text{Weight of oven dry soil}}$$

$$\text{Stress day factor (SDF)} = \frac{\text{Field capacity} - \text{soil moisture content (SMC)}}{\text{Field capacity (F. C.)}}$$

$$\text{Available moisture} = \frac{\text{Soil moisture content (SMC)}}{\text{Permanent wilting point (PWP)}}$$

The observations on days to initiation of flowering, 50% flowering, days to maturity, Plant height, number of primary and secondary branches plant^{-1}, leaf area, dry matter production and it's distribution in component parts of plants, pods plant^{-1}, seeds plant^{-1}, 100 seed weight (g), seed yield plant^{-1}, seed yield^{-ha} and harvest index (%) were recorded.

The relative leaf water content (RLWC) was determined according to the modified method of Bars and Weatherly (5) at 50 % flowering and 50 % podding and by using following formula.

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

Membrane injury index was estimated at 50 % flowering and pod development stage by the following procedure given by Blum and Ebercon (6). The index of total chlorophyll content (SPAD index) of randomly selected leaves was recorded by using the instrument SPAD meter of five at 50 % flowering and pod development. The chlorophyll stability index was computed by using the method proposed by Dhopte [7]. Proline content was determined by using acid ninhydrin reagent as per the method described by Bates *et al.* [8] and expressed in μ moles g^{-1} fresh weight. The *in vivo* nitrate reductase assay under anaerobic conditions was performed with modifications as per the method described earlier by Sawhney *et al.* [9] and Salalakar *et al.* [10]. Harvest index was worked out by formula given by Donald and Hamblin (11).

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \text{x } 100$$

The percent reduction due to moisture stress and drought susceptibility index was calculated by using formula suggested by Fischer and Maurer [12] as below.

$$\text{Percent reduction} = \frac{\text{Yield under non stress} - \text{yield under stress}}{\text{Yield under non stress}} \text{x } 100$$

$$\text{Drought Susceptibility Index (DSI)} = \frac{(1 - Y_d / Y_p)}{D}$$

where,

Y_d = Grain yield of the genotype under moisture stress condition.

Y_p = Grain yield of the genotype under irrigated condition.

$$\text{Drought index (D)} = 1 - \frac{\text{Mean grain yield of all strains under moisture stress condition}}{\text{Mean grain yield of all strains under irrigated condition}}$$

The replicated data for all the character were analyzed in randomized block design (RBD) as per the method given by Panse and Sukhatme [13].

RESULTS AND DISCUSSION

Soil Moisture Status: The data on soil moisture status during course of experiment was collected at 20 days interval from sowing and presented in Table 1. Under non-stress condition, the soil moisture content ranged between 27.40 and 34.40 in 0-15 cm, while, 29.30 and 34.70 in 15-30 cm depth of soil. Under moisture stress condition, the soil moisture content upto 40 days was 26.80 per cent in 0-15 and 26.40 in 15-30 cm depth of soil. Thereafter, it was declined to 21.30% per cent in 0-15 cm and 23.80 in 15-30 cm. In further course of time the soil moisture went down rapidly and recorded 19.80 in 0-15 cm and 21.90 in 15-30 cm depth of soil at 100 DAS. Thus crop under stress plot experiment shortage of water right from 40 DAS till harvesting. At sowing available soil moisture was ranged between 9.56 and 15.56 in 0-15 cm while, 11.46 and 16.86 in 15-30 cm depth under irrigated condition. Under moisture stress condition, available moisture at 40 DAS was 08.96 in 0-15 cm and 08.56 in 15-30 cm depth. Then it was declined upto 1.96 in 0-15 cm and 4.06 to 15-30cm depth of soil. The SDF value was lower under non-stress than the moisture stress condition. It ranged between 0.200 and 0.344 in 0-15 cm, while, 0.169 and 0.368 in 15-30 cm depth of soil. Under moisture stress condition, the SDF value ranged between 0.270 and 0.526 in 0-15 cm while, 0.227 and 470 in 15 to 30 cm depth soil, respectively. The available soil moisture (ASM) upto 75 per cent before sowing gave significantly higher grain yield in Bengal gram [14]. Chickpea crop gave average seed yield 21.2 q ha^{-1} when soil moisture content at 75 per cent of field capacity upto end of seed development stage compared with 15.4 q ha^{-1} without irrigation treatment [15].

Phenological Characters: Early maturity is an important trait to avoid drought stress due to the onset of severe water deficits. Yield potential and early flowering are two major components of drought escape in lentil and chickpea [16, 17]. In the present investigations, days to initiation of flowering, 50% flowering and maturity reduced by 1, 3 and 6 days, respectively (Table 2). The genotype, Vijay required minimum number of days for initiation of flower bud (33.5) and 50% flowering (42.5) under moisture stress. Under non stress Vijay had also recorded minimum number of days for initiation of flower bud (36.0) and for 50% flowering (44.0). Phule G- 07104 is another genotype which required only 38.0 and 39.0 days for initiation of flower bud and 45.5 and 47.0 days for 50 % flowering under moisture stress and non-stress condition, respectively. The genotypes Phule G 2008-74 and Phule G 07102 required minimum number of days to maturity under non-stress (101.50) and moisture stress conditions (98.00), followed by genotypes Digvijay under non-stress (104.50) and moisture stress condition (101.00).

Vegetative Growth and Source: The vegetative phase governs the overall phenotypic expression of the plant and prepares the plant for next important reproductive phase. The plant height, branches and leaves, all these parts constitute vegetative phase and perform specific functions. On an average, the per cent reduction due to moisture stress for plant height, primary and secondary branches and leaf area was 30.96, 27.69, 34.23 and 38.22, respectively (Table 3). The reduction in morpho-physiological traits in chickpea due to moisture stress was recorded by Kuhad *et al.* [18]and Jirali *et al.* [19]. The genotypes, Phule G 2008-10 (81.90 cm) and Phule G-2008-

Table 1: Soil moisture content, available moisture and SDF during crop growth period

Stages		Soil moisture content (%)		Available moisture (%)		Stress day factor (SDF)	
0-15 cm depth	DAS	I_1	I_0	I_1	I_0	I_1	I_0
1	0	33.40	30.50	15.56	12.66	0.200	0.270
2	20	32.30	29.10	14.46	11.26	0.227	0.303
3	40	34.40	26.80	16.56	8.96	0.176	0.358
4	60	29.20	21.30	11.36	3.46	0.301	0.490
5	80	28.80	20.90	10.96	3.09	0.310	0.499
6	100	27.40	19.80	9.56	1.96	0.344	0.526
15-30 cm depth							
1	0	34.70	32.30	16.86	14.46	0.169	0.227
2	20	33.60	30.70	15.76	12.86	0.195	0.265
3	40	29.30	26.40	11.46	8.56	0.368	0.368
4	60	29.90	23.80	12.06	5.96	0.284	0.43
5	80	30.40	24.40	12.56	6.56	0.272	0.416
6	100	30.60	21.90	12.76	4.06	0.267	0.475

I_1 -Irrigated Condition, I_0 – Moisture stress condition

Table 2: Days to flowering and maturity influenced by chickpea genotypes due to moisture stress condition

	Days to initiation of flowering		Days to 50% flowering		Days to maturity	
Genotype	I_1	I_0	I_1	I_0	I_1	I_0
Phule G- 0302-26	48.0	45.5	56.0	55.5	108.5	102.0
Phule G -0204-4	43.5	43.5	51.5	49.0	105.0	100.0
Phule G- 07102	45.0	44.0	53.0	51.5	101.5	98.0
Vishal	40.0	39.5	48.5	47.0	110.5	103.5
Phule G- 2008-10	49.0	49.0	56.5	54.0	104.5	101.5
Phule G-07101	43.5	42.0	51.5	50.5	112.0	106.0
Vijay	36.0	33.5	44.0	42.5	105.5	99.5
Phule G-07104	39.0	38.0	47.0	45.5	114.5	109.5
Phule G-09103	50.5	49.5	58.5	55.5	104.0	99.5
Phule G -2008-19	44.0	42.5	53.0	49.0	102.5	99.0
Phule G-2008-74	47.5	47.0	56.5	53.0	101.5	98.0
Phule G-0204-16	48.0	47.5	56.0	52.0	107.0	102.5
Digvijay	50.5	49.0	57.0	54.5	104.5	101.0
Phule G-6102	46.0	45.5	55.0	53.0	101.5	98.0
Mean	45.0	44.0	53.1	50.9	105.6	101.3
S.E. ±	0.50	0.32	0.28	0.30	0.623	0.327
CD at 5%	1.52	0.98	0.85	0.91	1.906	1.000

Table 3: Vegetative growth and source parameters influenced by chickpea genotypes due to moisture stress condition

	Plant height (cm)		Primary branches plant^{-1}		Secondary branches plant^{-1}		Leaf area (dm^2)	
Genotype	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0
Phule G- 0302-26	60.8	46.4	11.0	9.9	18.5	11.7	6.58	4.07
Phule G -0204-4	50.0	33.4	12.7	9.7	19.7	11.5	6.33	5.19
Phule G- 07102	53.9	40.8	10.2	6.3	14.5	9.6	7.61	4.88
Vishal	54.9	30.8	13.3	6.5	18.1	12.5	9.01	4.76
Phule G- 2008-10	81.9	39.4	11.0	10.5	14.1	10.4	6.01	4.07
Phule G-07101	42.7	33.8	13.1	9.8	14.8	11.0	8.26	5.05
Vijay	33.3	28.9	13.6	9.5	13.8	9.3	7.50	3.53
Phule G-07104	43.4	42.6	11.6	10.0	17.6	11.0	8.68	4.21
Phule G-09103	53.9	28.1	10.9	8.0	13.8	9.2	8.21	3.90
Phule G -2008-19	74.7	48.3	14.5	9.1	15.5	9.8	6.01	2.75
Phule G-2008-74	49.9	36.7	12.5	10.4	18.8	9.2	6.70	3.67
Phule G-0204-16	48.9	32.5	12.8	7.0	14.5	7.7	6.65	5.24
Digvijay	52.9	31.9	12.2	9.5	11.5	8.4	7.11	5.11
Phule G-6102	45.9	28.6	14.0	8.0	13.6	11.0	6.25	5.09
Mean	53.4	35.9	12.4	8.9	15.6	10.2	7.21	4.39
S.E. ±	0.155	1.176	0.650	0.225	0.611	0.489	0.412	0.268
CD at 5%	0.473	3.593	1.988	0.689	1.869	1.495	1.260	0.821

19 (74.70 cm) under non-stress condition and Phule 2008-19 (48.30 cm) and Phule G-0302-26 (46.40 cm) under moisture stress recorded maximum plant height, respectively. The genotypes Phule G 2008-10 maintained maximum number of primary branches plant^{-1} under moisture stress (10.50) and non-stress (14.50) condition followed by genotypes Phule G-6102 under non-stress (14.00) and Phule G-2008-74 under moisture stress condition (10.40). The genotype Phule G 0204-4 (19.70), Phule G-2008-74 (18.80) recorded highest number of secondary branches^{-1} under non-stress condition whereas, genotypes Vijay (12.50) and Phule G 0302-26 (11.70) recorded highest number of branches^{-1} under moisture stress condition. The genotypes Vishal (9.01dm^2), Phule G 0714 (8.68 dm^2) recorded maximum leaf area under non-stress while under moisture stress condition, genotypes Phule G-0204-16 (5.24 dm^2) and Phule G-0204-4 (5.19 dm^2) recorded highest leaf area.

Dry Matter Production and It's Distribution in Component Parts of the Plants: The physiological processes results into a net balance and accumulation of dry matter and hence, the biological productivity of plant is judged from their actual ability to produce and

Table 4: Dry matter production and it's distribution in component parts of plant (g/ plant) influenced by chickpea genotypes due to moisture stress condition

	Root		Stem		Leaves		Pods		Total	
Genotype	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0
Phule G- 0302-26	0.50	0.48	6.78	4.01	3.22	1.47	21.39	15.60	31.89	21.55
Phule G -0204-4	0.56	0.53	9.05	3.53	1.47	0.50	20.80	10.75	31.87	15.31
Phule G- 07102	0.52	0.50	6.93	3.36	3.95	2.35	29.13	22.54	40.53	28.76
Vishal	0.64	0.59	8.88	4.10	0.84	0.56	15.69	12.65	26.05	17.90
Phule G- 2008-10	0.66	0.64	7.67	3.65	2.33	1.27	22.88	16.75	33.53	22.31
Phule G-07101	0.68	0.61	7.71	2.92	3.55	1.93	27.88	24.83	39.82	30.28
Vijay	0.59	0.50	6.85	4.21	3.59	2.39	25.70	21.02	36.73	28.11
Phule G-07104	0.65	0.63	8.72	4.02	3.06	1.32	21.95	14.50	34.38	20.47
Phule G-09103	0.70	0.63	9.57	4.11	3.14	1.59	23.00	20.44	36.42	26.76
Phule G -2008-19	0.51	0.46	6.39	4.66	2.39	2.29	27.10	18.60	36.39	26.01
Phule G-2008-74	0.45	0.42	6.49	3.63	1.66	0.50	16.55	15.28	25.15	19.82
Phule G-0204-16	0.76	0.62	7.69	5.30	2.39	0.89	20.48	15.92	31.32	22.73
Digvijay	0.64	0.55	8.26	3.58	3.51	1.61	26.95	18.28	39.36	24.02
Phule G-6102	0.50	0.45	8.64	4.19	2.34	1.35	22.42	15.55	33.91	21.54
Mean	0.60	0.54	7.83	3.95	2.67	1.43	22.99	17.33	34.09	23.25
S.E. ±	0.013	0.017	0.53	0.23	0.34	0.18	0.521	1.015	0.287	0.989
CD at 5%	0.042	0.053	1.61	0.71	1.05	0.55	1.593	3.102	0.877	3.024

Table 5: Proline content and nitrate reductase activity influenced by chickpea genotypes due to moisture stress and irrigated condition

	Proline content		NR activity	
Genotype	I_1	I_0	I_1	I_0
Phule G- 0302-26	0.841	6.261	2.18	1.81
Phule G -0204-4	1.003	4.927	2.40	1.66
Phule G- 07102	0.697	6.578	2.62	1.49
Vishal	0.867	8.173	2.28	1.40
Phule G- 2008-10	0.597	7.717	2.09	1.75
Phule G-07101	0.784	5.707	2.28	1.15
Vijay	0.656	6.758	2.42	1.31
Phule G-07104	0.966	4.555	2.20	1.58
Phule G-09103	0.840	4.708	2.11	1.46
Phule G -2008-19	0.735	5.257	2.21	1.25
Phule G-2008-74	0.813	6.641	2.40	1.25
Phule G-0204-16	1.132	6.103	2.13	1.30
Digvijay	0.623	6.688	1.26	1.18
Phule G-6102	0.567	5.897	1.91	1.26
Mean	0.794	6.141	2.17	1.42
S.E. ±	0.031	0.383	0.120	0.101
CD at 5%	0.097	1.172	0.369	0.309

accumulate dry matter. In the present experiment, dry matter production in roots, stem, leaves and pods was reduced by 8.91, 48.69, 47.02 and 24.27%, respectively (Table 4). Kumar *et al.* [20] reported the percent reduction due to moisture stress for biomass production in chickpea. The genotypes, Phule G-2008-10 (0.643 g) and Phule G-07104 (0.829 g) under moisture stress and Phule G-0204-16 (0.761g) and Phule G 09103 (0.703 g) under non-stress recorded highest dry matter accumulation in roots plant^{-1}. The genotypes Phule G-09103 (9.570 g) and Phule G-0204-G(9.046 g) recorded maximum dry weight of stem plant^{-1} under non stress condition whereas genotypes Phule G-0204-16 (5.300 g) and Phule-G 2008-19 (4.656 g) recorded maximum dry weight of stem plant^{-1} under moisture stress condition. The genotype Vijay recorded maximum dry weight of leaves plant^{-1} under stress (2.389 g) as well as non-stress (3.591 g) condition followed by Phule G-07102 under stress (2.350 g) and non-stress condition (3.954 g). The highest dry matter accumulation in pods plant^{-1} recorded by Phule G 07102 (29.13 g) under non-stress while Phule G 07101 (24.83 g) and Phule G 07102 (22.54 g) recorded highest dry matter in pods under moisture stress condition. The genotypes, Phule G 07102 (42.03 g) and

Phule G 07101 (39.80 g) under non-stress condition while, Phule G 07101 (31.82 g) and Digvijay (30.13 g) under moisture stress conditions recorded maximum total dry matter plant^{-1}.

Biochemical Parameter: The Proline accumulation provides protection against desiccation. Several investigations indicated positive relationship between free proline content of leaves with drought tolerance in chickpea [21], pigeonpea [22] and soybean [23]. Nitrate reductase, amino-N and sugar contents increased in stressed nodules as compared with controls [24]. In the present study, the highest accumulation of proline and reduction in NR activities was observed (Table 5). Sairam and Dube (25) studied the effect of moisture stress on the NR activity in rice in relation to drought tolerance and observed that leaf NR activity decreased under moisture stress. The genotypes Phule G 0204-16 (1.32), Phule G 0204-4 (1.003) accumulated higher Proline content under irrigated while genotypes Vishal (8.173) and Phule G 2008-10 (7.717) accumulated higher proline content under moisture stress condition. The genotype phule G 07102 (2.62) and Vijay (2.42) recorded maximum nitrate reductase activity under non-stress while, genotypes Phule G 0302-26 (1.81) Phule G 0204-4 (1.66) recorded highest nitrate reductase activity under moisture stress condition.

Physiological Parameters: Several quick method have been employed for screening of drought tolerant varieties such diffusion pressure deficits [26], relative water content [5], membrane injury index [6], chlorophyll stability index [27], epicuticular wax content [28], osmotic potential [29] and plastocron index [30]. The ability of plant to maintain the turgor and related physiological processes even under water stress condition has a great practical significance and it is related with drought resistance in terms of osmoregulatory activities. In the present study, the relative leaf water content (RLWC) was relatively low under moisture stress as compared to non-stress condition (Table 6). The genotype, Phule G-6102 maintained maximum RLWC at 50% flowering under stress (61.81%) and non-stress (61.87%) and at pod development stage under non-stress condition (70.16%). In addition to this, Phule G 07102 under moisture stress at 50% flowering (58.17%) and pod development stage (69.82%) and Vishal under non-stress condition (59.40%) at 50% flowering were found promising for maintaining higher RLWC.

The membrane injury index (MII) evaluates plant tolerance to high temperature by measuring thermostability. The test is based on the observation that when high temperatures injure leaf tissue, cellular membrane permeability is increased and electrolytes diffuse out of the cells. The amount of electrolyte leakage from the heat injured tissue can be estimated by bathing the tissue in deionized water and then measuring the electrical conductance of the water. The genotypes, Phule G 6102 (0.479) and Phule G 07102 (0.473) recorded maximum MII under moisture stress condition whereas, the genotype Phule G 07102 (0.406) and Phule G 0302-26 (0.374) recorded maximum MII under non-stress condition.

The ratio of chlorophyll content in heated plant sample to that an ambient temperature is denoted as chlorophyll stability index (CSI). According to Ali et al (1986), the chlorophyll stability index is inversely related to drought tolerance. Vijay (0.338) and Phule G 07101 (0.342) had minimum chlorophyll stability index under non-stress condition while, genotype Phule G 07104 (0.222) and Vijay (0.229) showed minimum chlorophyll stability index under moisture stress condition. It is to note that, the membrane injury index was higher and chlorophyll stability index was lower under moisture stress condition in all the genotype which confirms the utility of these tests for screening the genotypes for drought tolerance.

As Bently Glass (31) has aptly stated that, “Life is a photochemical phenomenon.” The chemical compounds most important in this conversion of light energy to chemical energy are the pigments that exist within the chloroplast/ chromatophores of plants. The reduction in chlorophyll content was observed due to moisture stress condition (Table 6). Total chlorophyll index recorded by using the instrument SPAD meter at 50% flowering and pod development stage showed that the genotypes, the genotype Phule G 0302-26 (36.55) and Phule G 0204-16 (36.15) under non-stress and Phule G 0302-26 (31.10) and Phule G-09103 (38.05)under moisture stress under moisture stress recorded minimum chlorophyll index at 50% flowering. At pod development stage, Phule G 07101 (17.85) and Phule G 09103 (23.50) under moisture stress and Phule G 07101 (25.55) and Phule G 2008-74 (32.00) under non-stress condition recorded minimum chlorophyll index.

Yield and Yield Contributing Character: The generative growth and sink capacity relates with final produce of the plant. It can reduce by soil moisture deficit condition. The genotypes, Vishal (47) and Phule G 0204-4 (51) under

Table 6: Physiological parameters related to drought characteristics as influenced by chickpea genotypes due to moisture stress and irrigated condition

	RLWC (%)				Membrane injury index		Chlorophyll stability index (CSI)		Total Chlorophyll index (SPAD index)			
	50% flowering		50% pod development		50% flowering		50% flowering		50% flowering		50% pod development	
Genotypes	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0
Phule G- 0302-26	56.32	43.59	69.26	59.74	0.374	0.441	0.464	0.300	36.55	31.10	34.93	29.80
Phule G -0204-4	43.97	43.19	55.70	53.37	0.257	0.447	0.406	0.258	56.20	47.37	49.70	45.25
Phule G- 07102	61.29	58.17	69.82	64.03	0.406	0.473	0.378	0.330	49.95	54.25	51.30	54.15
Vishal	59.40	56.74	68.73	63.05	0.178	0.350	0.438	0.291	56.80	56.65	56.50	52.55
Phule G- 2008-10	43.12	41.09	57.66	54.09	0.294	0.388	0.497	0.274	68.70	51.20	51.40	41.30
Phule G-07101	58.59	54.44	69.27	64.67	0.221	0.461	0.342	0.399	48.65	48.91	25.55	17.85
Vijay	54.68	54.46	65.49	62.66	0.179	0.380	0.338	0.229	42.25	49.80	41.85	28.90
Phule G-07104	46.98	42.39	64.35	62.36	0.321	0.457	0.362	0.222	49.40	53.55	38.00	46.00
Phule G-09103	52.85	49.11	61.60	59.75	0.150	0.289	0.411	0.410	41.50	38.05	41.50	23.50
Phule G -2008-19	50.51	46.22	61.62	55.86	0.235	0.462	0.359	0.346	47.30	49.30	52.05	33.40
Phule G-2008-74	47.28	46.22	61.86	59.60	0.210	0.315	0.412	0.343	53.85	47.60	32.00	38.60
Phule G-0204-16	52.39	44.77	69.67	59.92	0.321	0.322	0.443	0.386	36.15	55.10	43.95	55.00
Digvijay	53.79	40.36	66.45	63.73	0.219	0.331	0.393	0.351	52.25	46.60	52.00	46.25
Phule G-6102	61.87	61.81	70.16	54.27	0.331	0.479	0.412	0.342	51.15	53.09	43.15	47.60
Mean	52.93	48.75	65.11	59.79	0.264	0.399	0.404	0.320	49.34	48.75	43.85	40.01
S.E. ±	1.160	1.380	2.110	1.380	0.0004	0.007	0.009	0.0008	3.82	2.863	0.957	0.731
CD at 5%	3.570	4.230	6.470	4.220	0.0010	0.021	0.029	0.0024	11.67	8.748	2.924	2.235

Table 7: Yield and yield contributing characters influenced by chickpea genotypes under moisture stress and non-stress condition

	Pods / plant		Seeds/ plant		100 seeds weight (g)		Yield/ plant (g)		Yield/ ha (q)		Harvest index (%)	
Genotype	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0
Phule G- 0302-26	49.2	38.0	64.2	42.0	32.2	30.3	12.95	9.45	15.22	11.55	41.39	38.88
Phule G -0204-4	51.0	30.2	71.7	38.5	24.2	22.4	14.85	9.40	17.22	7.44	48.10	45.41
Phule G- 07102	91.5	73.2	113.8	86.5	21.4	20.1	16.55	14.35	12.99	7.99	41.09	38.37
Vishal	47.0	30.0	55.0	38.0	26.8	25.1	13.79	8.96	16.44	11.33	52.42	50.36
Phule G- 2008-10	55.0	35.6	60.2	40.5	19.1	19.0	13.05	10.62	15.77	9.99	48.72	45.05
Phule G-07101	68.3	32.4	81.0	42.9	24.0	22.1	14.80	14.27	23.33	9.11	48.14	41.70
Vijay	82.6	56.0	122.0	85.2	20.3	18.2	14.00	10.07	16.77	10.44	40.56	36.67
Phule G-07104	73.0	48.2	91.5	53.0	25.3	23.3	12.20	9.77	13.66	7.44	49.07	38.64
Phule G-09103	53.8	37.2	64.9	42.2	21.7	19.7	14.31	10.60	19.11	16.88	40.67	35.42
Phule G -2008-19	54.9	27.4	69.0	31.9	22.1	21.1	13.83	10.44	15.22	7.54	42.33	42.05
Phule G-2008-74	60.8	23.3	78.8	31.3	29.8	28.7	14.37	8.82	22.66	14.66	53.51	46.06
Phule G-0204-16	62.0	49.3	68.7	50.5	31.0	29.3	14.17	10.91	16.33	8.66	51.56	48.20
Digvijay	80.7	61.5	91.5	73.7	24.5	23.0	17.25	11.85	19.44	12.99	52.58	48.54
Phule G-6102	72.1	57.2	87.0	64.0	21.5	20.2	13.67	7.69	12.99	6.11	42.48	37.29
Mean	64.4	43.4	80.0	51.4	24.5	23.0	14.27	10.51	16.94	10.15	46.61	42.33
S.E. ±	1.26	4.06	1.30	1.18	0.23	0.15	0.63	0.54	0.95	0.79	1.19	1.89
CD at 5%	3.86	12.40	64.2	42.0	0.7	0.45	1.92	1.65	2.96	2.27	3.64	5.78

moisture stress and Vijay (82.60) and Phule G 07102 (91.50) under non-stress conditions recorded maximum number of pods respectively. Phule G 07102 (86.50) and Vijay (85.20) under moisture stress condition and Vijay (122) and Phule G 07102 (113.80) under non-stress condition were found promising for maintaining higher number of seed plant^{-1}. The genotypes, Phule G 0204-16 (31.00 & 29.25 g 100 seed^{-1}) and Phule G 0302-26 (32.15 & 30.30 g100 seed^{-1}) were bold seed size under non-stress and moisture stress condition, respectively. The genotypes, Digvijay (17.25 g) and Phule G (16.55 g) under non-stress and Phule G 07102 (14.35 g) and Phule G 07101 (14.27g) under moisture stress condition maintained maximum yield plant^{-1}. Phule G 09103 (16.88 q) and Phule G 2008-74 (14.66 q) under moisture stress and Phule G 2008-74 (22.66 q) under non-stress condition recorded highest seed yield ha^{-1}. Nanda and Saini (1992) reported reduction in yield by 17 per cent due to limited moisture available at critical

Table 8: Per cent reduction and drought susceptibility index for yield and yield contributing characters influenced by chickpea genotypes due to moisture stress

	Pods / plant		Seeds/ plant		100 seeds weight (g)		Yield/ plant (g)		Yield/ ha (q)		Harvest index (%)	
Genotype	Red	DSI	Red	DSI	Red	DSI	Red	DSI	Red	DSI	Red	DSI
Phule G- 0302-26	22.76	0.70	34.58	0.97	5.75	0.93	27.03	1.03	24.11	0.93	6.05	0.66
Phule G -0204-4	40.78	1.22	46.30	1.30	7.44	1.20	36.70	1.39	56.79	1.41	5.59	0.61
Phule G- 07102	20.00	0.60	23.99	0.67	6.07	0.98	13.29	0.50	38.49	0.96	6.52	0.72
Vishal	36.17	1.08	30.91	0.87	6.36	1.02	35.06	1.33	31.08	0.77	3.92	0.43
Phule G- 2008-10	35.27	1.05	32.72	0.92	0.58	0.09	18.62	0.71	36.65	0.91	7.53	0.82
Phule G-07101	52.56	1.57	47.04	1.32	8.13	1.31	3.58	0.14	60.95	1.52	13.39	1.46
Vijay	32.20	0.96	30.16	0.85	10.12	1.63	28.07	1.07	37.75	0.94	9.59	1.04
Phule G-07104	33.97	1.01	42.08	1.18	7.72	1.24	19.93	0.76	45.53	1.13	21.26	2.31
Phule G-09103	30.86	0.92	34.98	0.98	9.01	1.45	25.90	0.98	11.67	0.29	12.92	1.41
Phule G -2008-19	50.09	1.49	53.77	1.51	4.31	0.69	24.55	0.93	50.39	1.25	0.66	0.07
Phule G-2008-74	61.68	1.84	60.28	1.69	3.74	0.60	38.66	1.47	35.30	0.88	13.91	1.51
Phule G-0204-16	20.48	0.61	26.49	0.74	5.65	0.91	23.01	0.87	46.97	1.17	6.52	0.71
Digvijay	23.79	0.71	19.45	0.55	6.12	0.99	31.30	1.19	33.18	0.82	7.67	0.84
Phule G-6102	20.67	0.62	26.44	0.74	6.28	1.01	43.76	1.66	52.96	1.32	12.23	1.33
Mean	34.38	1.03	509.19	1.02	6.23	1.00	26.39	1.00	40.13	1.03	9.13	0.91

stages in chickpea. The genotype, Vishal (50.36%) and Digvijay (48.54%) under moisture stress and Phule G 2008-74 (53.51%) Digvijay (52.58%) under non-stress condition recorded maximum harvest index conditions. Rahangadale *et al.* (1994) in the field experiment on chickpea genotypes under soil moisture deficit reported that, under water stressed condition; there was decrease in net assimilation rate (40.4%), dry matter production (31.8%), pod number (26.2%) and seed yield (15.2%) as compared to irrigated conditions.

The genotypes Phule G 0204-16 recorded minimum per cent reduction (20.48) due to moisture stress and minimum DSI (0.61) for pods plant^{-1} (Table 8). The genotype Digvijay (19.45) recorded minimum reduction due to moisture stress and minimum DSI (0.55%) for number of seeds plant^{-1}. The genotype Phule G 2008-10 had minimum per cent reduction (0.58) due to moisture stress condition and minimum DSI (0.09) for 100 seed weight. The genotype Phule G 07101 maintained minimum per cent reduction (3.58) due to moisture stress condition and minimum DSI (0.14) for yield plant^{-1}. The genotype Phule G 09103 maintained minimum per cent reduction (11.67) due to moisture stress and minimum DSI (0.29) for seed yield ha^{-1}. The genotype Vishal maintained minimum reduction (3.92%) due to moisture stress and minimum DSI (0.43%) for harvest index.

CONCLUSIONS

In general, the genotypes Phule G 07101, Phule G 2008-74, Digvijay, Phule G 0302-26 found promising under irrigated condition and Phule G 09103, Phule G 2008-74, Digvijay, Phule G 0302-26 found to be under moisture stress condition. The genotype Phule G-09103, Phule G 2008-74, Digvijay and Phule G 0302-26 have indicated less yield reduction due to moisture stress and such found to be stable the high yielding. Therefore, it was found that genotypes Phule G 09103, Phule G 2008-74, Digvijay, Phule G 0302-26 exhibited higher values for drought tolerance efficiency, proline content, chlorophyll index and lower value for drought susceptibility index. Therefore, these genotypes can be used as sources of drought tolerance in further breeding programme for evolving the drought tolerant genotypes in chickpea.

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