

Effect of Moisture Stress Conditions on Different Varieties of Chickpea and Its Growth and Yield Effect

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Abstract A field experiment was conducted during *rabi* season 2013-14 with the object to evaluate different chickpea genotypes to combat moisture stress situations. The experiment soil is medium black (Vertisols), having 7.88 pH, 0.45% organic carbon, 232 kg/ha available nitrogen, 10.2 kg/ha available phosphorus and 540 kg/ha available potassium. The experiment was conducted in split-plot design replicated 3 times, keeping 3 moisture stress situation viz. S_0 , S_{6L} and S_{FL} . 9 chickpea cultivars were grow in sub plots. Plant population was not varied significantly under different moisture stress situation and chickpea varieties. Days to flower initiation, days to 50% flowering and pod initiation was noted lowest with S_{FL} —Water withheld from flowering under moisture stress situations and with V_9 —KAK 2 under chickpea varieties. Water use efficiency was recorded highest with moisture stress situation S_{FL} —Water withheld from flowering and under various chickpea varieties, it was recorded highest with V_5 —JG 16. Drought susceptibility index was also estimated higher under S_{FL} —

Water withheld from flowering under moisture stress situation and with variety V_4 —JG 6 under chickpea varieties. The relative water content of chickpea under moisture stress situation was recorded highest S_0 —Water withheld after germination at flowering stage, while it was recorded highest under S_{6L} —Water withheld from 6 leaf stage at pod formation stage.

Keywords Moisture stress, Chickpea variety, Water use efficiency, Relative water content, Drought tolerance efficiency.

Introduction

Pulse crops play an important role in Agriculture to sustain the healthy life of human being. Besides being rich in protein, they sustain productivity in cropping system. Their ability to use atmospheric nitrogen through biological nitrogen fixation (BNF) is economically sounder and environmentally acceptable [1]. In Indian context Drought is a major limiting factor in realizing crop productivity. It is known that chickpea thrives well under drought prone conditions. Moisture stress and high temperature during early seedling and seed filling stages are the major constraints of its low productivity. However, there is less variability for yield performance of chickpea. Water stress is an important factor affecting partitioning of biomass [2]. Keeping this view the present study was done to evaluate the effect of moisture stress condi-

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tions on different varieties of chickpea and its growth and yield effect.

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Materials and Methods

The experiment was carried out during *rabi* season 2013-14 with the object to evaluate different chickpea genotypes to combat moisture stress situations. The field experiment was conducted under AICRP on Dryland Agriculture at farm, COA, Indore. The surface soil samples (0–30 cm) were collected randomly from the experimental field and representative composite sample was made for the mechanical and chemical analysis for some important physico-chemical properties. The soil characteristics included: soil solution pH 7.88, EC 0.48 (dSm⁻¹), Organic carbon 0.45%, available-N 232 kg ha⁻¹, available phosphorus 10.2 kg ha⁻¹, available potassium 540 kg ha⁻¹, respectively. The field experiment was carried out in split plot design with twenty seven treatment combinations of three moisture stress situation in main plot and 9 chickpea varieties in sub plots in three replications. The treatment comprises main plot: (3 moisture stress situation) –S₀—Water with held after germination, S_{6L}—Water withheld from 6 leaf stage S_{FL}—Water withheld from flowering. Sub plot: (9 chickpea varieties)-V₁–Ujjain-21, V₂–JAKI-9218, W₃–IG-593, V₄–JG-6, V₅–JG-16, V₆–JG-130, V₇–JG-412, V₈–JG-11, V₉–KAL-2. Nine varieties of chickpea were used in the experiment. Crop was irrigated as per the treatments the details of irrigation are following S₀ (water with held after germination)– Pre-sowing irrigation only, S_{6L} (water withheld from 6 leaf stage)–Irrigations at pre-sowing and 20 DAS crop stage, S_{FL} (water withheld from flowering) Irrigations at pre-sowing, 20 and 35 DAS crop stage.

Relative water content (%)

The RLWC was calculated by the following formula:

$$RLWC\% = \frac{FW-DW}{TW-DW} \times 100$$

Where, FW–Fresh weight (g), TW–Turgid weight (g), DW–Dry weight (g)

Water use efficiency

Crop water use efficiency

It is the ratio of crop yield (Y) to the amount of water depleted by the crop in the process of evapo transpiration.

$$WUE = \frac{Y}{ET}$$

Field water use efficiency

It is the ratio of crop yield (Y) to the total amount of water used in the field (WR)

$$WUE = \frac{Y}{WR}$$

Where, WR–water required / used

Drought tolerance efficiency

$$DRI = (Y_s / Y_n) / (M_s / M_n),$$

$$DTE = \frac{\text{Yield under stress}}{\text{Yield under no-stress}} \times 100$$

Where, Y_s and Y_n are the genotype yields (or biomass) under stress and non-stress respectively and M_s and M_n are the mean yields (or biomass) over all genotypes in the given test under stress and non-stress respectively.

Drought susceptibility index (%)

Drought susceptibility index (DSI) was calculated by using formula given by Fischer and Maurer, 1978.

$$DSI = \frac{(1-Y_0 / Y_1)}{DI}$$

Where, Y₀ = Yield of individual genotype under stress, Y₁ = Yield of individual genotype under no stress, DI = (1–Y_r / Y_i), Y_r = Mean of all the genotypes under

Table 1. Plant height (cm), Number of branches plant⁻¹, Number of pods plant⁻¹ and Number of seeds pod⁻¹ under different moisture stress situation and varieties of chickpea. S₀–Water withheld after germination, S_{6L}–Water withheld from 6 leaf stage and S_{FL}–Water withheld from flowering.

Treatments	Plant population (per meter row)		Plant height (cm)	Number of bran- ches plant ⁻¹	Number of pods plant ⁻¹	Number of seeds pod ⁻¹	Seed index (g)
	Initial (20 DAS)	At har- vest					
Moisture stress situations							
S ₀	12.69	12.08	60.20	8.06	49.73	1.03	28.65
S _{6L}	12.91	12.08	59.52	9.13	53.53	1.01	36.66
S _{FL}	12.37	11.67	46.79	7.17	51.96	1.01	28.11
SEm±	0.15	0.14	1.14	1.04	3.67	0.01	4.64
CD (<i>p</i> = 0.05)	NS	NS	4.47	NS	NS	NS	NS
Chickpea varieties							
V ₁ –Ujjain-21	12.37	11.86	53.98	7.33	48.76	1.00	18.06
V ₂ –JAKI-9218	12.59	11.66	56.51	8.51	46.71	1.00	41.83
V ₃ –IG-593	12.67	11.83	60.36	7.82	39.13	1.02	35.33
V ₄ –JG-6	12.78	12.01	52.24	6.07	38.63	1.04	34.25
V ₅ –JG-16	12.52	11.99	52.89	9.07	52.93	1.02	21.11
V ₆ –JG-130	13.00	12.14	54.89	6.69	54.44	1.04	25.94
V ₇ –JG-412	12.70	12.12	58.44	8.49	62.80	1.00	28.17
V ₈ –JG-11	12.59	11.89	53.56	10.07	50.13	1.00	24.94
V ₉ –KAK-2	12.70	11.99	56.67	9.04	72.11	1.02	50.61
SEm±	0.25	0.27	1.73	0.86	8.57	0.02	8.19
CD (<i>p</i> = 0.05)	NS	NS	4.93	2.44	NS	NS	NS

stress, Yi = Mean of all the genotypes under no stress.

Results and Discussion

Growth and yield

The experimental data of growth and yield parameter is depicted in Table 1. The data reveal that plant population was not affected significantly due to different moisture stress situations as well as due to chickpea varieties at both the stages. However slightly higher plant population was observed in moisture stress situations S_{6L}–Water withheld from 6 leaf stage and chickpea variety V₆–JG 130. It was recorded highest (60.2 cm) with S₀–Water withheld after germination followed by the height under S_{6L}–Water withheld from 6 leaf stage. The lowest plant height of 46.79 cm was recorded under S_{FL}–Water withheld from flowering. Under chickpea varieties, the plant height was recorded significantly higher under V₃–IG 593 (60.36 cm) followed by V₇–JG 412 (58.44 cm) and recorded minimum under V₄–JG 6 (52.24 cm). No significant

differences were noticed in plant. The presented data shows number of branches per plant was found affected significantly only by chickpea varieties. Moisture stress situation and its interaction with chickpea varieties failed to influence the number of branches per plant significantly. However, the number of branches per plant was recorded slightly higher under S_{6L}–Water withheld from 6 leaf stage as compared to the other moisture stress situations. No significant differences were noticed in number of branches per plant due to interaction between moisture stress situations and chickpea varieties. Number of pods per plant was not influenced significantly by moisture stress situations, chickpea varieties or interaction of these two. However the highest numbers of pods per plant were noticed with S_{6L}–Water withheld from 6 leaf stage moisture stress situations. In chickpea varieties, it was recorded highest with V₉–KAK 2 followed by V₇–JG 412. Seed index was not influenced significantly by moisture stress situations, chickpea varieties or interaction of these two. However the highest seed index was noticed with S_{6L}–Water withheld

Table 2. Yield of chickpea as influenced by the interaction of different moisture stress situations and varieties. S₀-Water withheld after germination, S_{6L}-Water withheld from 6 leaf stage, S_{FL}-Water withheld from flowering.

Treatments	Seed yield per plant (g)	Biological yield per plant (g)	Seed yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
Moisture stress situations					
S ₀	15.89	36.93	1024.54	3939.81	26.30
S _{6L}	21.96	45.08	1224.42	4446.76	27.85
S _{FL}	13.90	29.04	1726.04	3953.70	44.28
SEM±	0.79	2.56	26.88	145.21	0.93
CD (<i>p</i> = 0.05)	3.12	10.06	105.52	NS	3.67
Chickpea varieties					
V ₁ -Ujjain-21	15.80	32.86	1374.44	3686.11	34.20
V ₂ -JAKI-9218	15.52	34.63	1294.10	4263.89	30.39
V ₃ -IG-593	14.98	37.51	1184.03	4138.89	30.22
V ₄ -JG-6	13.72	33.53	1103.47	4138.89	27.07
V ₅ -JG-16	18.69	36.04	1656.25	4680.56	35.93
V ₆ -JG-130	23.39	38.93	1573.06	4277.78	38.43
V ₇ -JG-412	16.30	33.38	1130.00	3493.06	33.87
V ₈ -JG-11	11.32	31.18	1463.82	4152.78	35.52
V ₉ -KAK-2	25.50	55.11	1145.83	3888.89	29.68
SEM±	1.73	4.99	77.22	216.63	2.46
CD (<i>p</i> = 0.05)	4.93	NS	219.60	616.08	7.00

from 6 leaf stage moisture stress situations. In chickpea varieties, it was recorded highest with V₉-KAK 2 followed by V₂-JAKI 9218. Number of seeds per pod was not influenced significantly by moisture stress

situations, chickpea varieties or interaction of these two. The highest numbers of seeds per pod were registered with S₀-Water withheld after germination moisture stress situations. In chickpea varieties, it was

Table 3. Phenological observation in chickpea under different moisture stress situation and varieties. S₀-Water withheld after germination, S_{6L}-Water withheld from 6 leaf stage, S_{FL}-Water withheld from flowering.

Treatments	Days to flower initiation	Days to 50% flowering	Phenological observation		
			Days to pod initiation	Days to physiological maturity	Length of reproductive phase
Moisture stress situations					
S ₀	58.56	71.19	79.85	120.30	61.52
S _{6L}	58.56	68.67	73.67	119.56	61.00
S _{FL}	45.15	54.93	57.11	111.04	65.89
SEM±	0.56	1.99	0.93	0.08	0.54
CD (<i>p</i> = 0.05)	2.19	7.82	3.65	0.33	2.12
Chickpea varieties					
V ₁ -Ujjain-21	57.58	67.67	67.22	116.89	59.11
V ₂ -JAKI-9218	56.56	70.78	75.67	118.33	61.78
V ₃ -IG-593	58.33	71.89	75.00	119.56	61.22
V ₄ -JG-6	55.89	68.44	70.00	115.89	60.00
V ₅ -JG-16	57.11	64.78	70.11	116.56	59.67

Table 3. Continued.

Treatments	Days to flower initiation	Days to 50% flowering	Phenological observation		
			Days to pod initiation	Days to physiological maturity	Length of reproductive phase
Chickpea varieties					
V ₆ -JG-130	55.33	57.11	75.44	116.00	59.56
V ₇ -JG-412	51.00	61.11	69.11	113.11	62.11
V ₈ -JG-11	51.44	65.33	72.11	116.67	65.22
V ₉ -KAK-2	43.33	57.22	57.22	119.67	76.56
SEm±	1.10	2.74	2.31	0.41	1.11
CD (<i>p</i> = 0.05)	3.12	7.80	6.57	1.17	3.17

recorded highest with V₄-JG 6 and V₆-JG 130. The data on seed and biological yield per plant (g) were recorded and analyzed statistically. The mean values under different treatments are presented in Table 2. Among different moisture stress situations, the maximum values of seed yield per plant and biological yield per plant S_{6L}-Water withheld from 6 leaf stage (21.96 and 45.08 g) followed by S₀-Water withheld after germination (15.89 and 36.93 g) respectively. The moisture stress situations S_{FL}-Water withheld from flowering resulted into the lowest seed yield per plant and biological yield per plant (13.9 and 29.04 g). Plant height of chickpea was recorded highest with S₀-Water withheld after germination followed by the height under S_{6L}-Water withheld from 6 leaf stage. Number of branches per plant was not affected significantly due to moisture stress situations. The similar result was also reported earlier [3, 4]. Number of pods per plant, seed index and number of seeds per pod were not influenced significantly by moisture stress situations, while pod weight per plant, seed yield per plant and biological yield per plant were affected significantly and was recorded significantly higher with S_{6L}-Water withheld from 6 leaf stage which was at par with pod weight per plant with S₀-Water withheld after germination. The lowest values were recorded with S_{FL}-Water withheld from flowering [5]. Similar finding was also reported earlier [3, 4].

Phenological observation

Days to flower initiation

The data presented to Table 3 shows that the days to flower initiation of chickpea was found to be affected significantly by different treatment of moisture stress

situations. It was recorded highest (58.56 days) under S₀-Water withheld after germination and S_{6L}-Water withheld from 6 leaf stage differed significantly with the S_{FL}-Water withheld from flowering (45.15 days). Significant difference were also noticed due to chickpea varieties treatments on days to flower initiation ; while, it was recorded higher under V₃-IG 593 (58.33 days). Followed by V₁-Ujjain 21 (57.78 days). It was recorded significant lowest with the chickpea variety V₉-KAK 2 (43.33 days) followed by V₇-JG 412 (51 days).

Days to 50% flowering

The days to 50% flowering was recorded significantly higher under moisture stress situations S₀-Water withheld after germination (71.19 days) followed by S_{6L}-Water withheld from 6 leaf stage (68.67 days) and recorded significantly lowest under S_{FL}-Water withheld from flowering (54.93 days). Under various chickpea varieties, days to 50% flowering was recorded lowest in case of V₆-JG 130 (57.11 days) followed by V₉-KAK 2 (57.22 days). Significantly higher values of days to 50% flowering were noticed with V₃-IG 593 (71.89 days) and V₂-JAKI 9218 (70.28 days).

Days to pod initiation

Moisture stress situations and chickpea varieties influenced days to pod initiation significantly. It was recorded highest with moisture stress situations S₀-Water withheld after germination (79.85 days) followed by S_{6L}-Water withheld from 6 leaf stage (73.67 days) and lowest with S_{FL}-Water withheld from

Table 4. Physiological observation of chickpea under different moisture stress situation and varieties. S_0 –Water withheld after germination, S_{6L} –Water withheld from 6 leaf stage, S_{FL} –Water withheld from flowering, RWC=Relative Water Content, WUE=Water Use Efficiency, DTE=Drought Tolerance Efficiency and DSI=Drought Susceptibility Index.

Treatments	RWC (%)		WUE (kg/ha-cm)	DTE (%)	DSI
	At flowering	Pod formation			
Moisture stress situations					
S_0	88.90	78.92	1.67	–	–
S_{6L}	88.13	84.42	2.00	61.39	0.85
S_{FL}	84.16	79.17	2.82	74.14	0.89
SEm±	0.17	0.26	0.04	–	–
CD ($p = 0.05$)	0.67	1.01	0.17	–	–
Chickpea varieties					
V_1 –Ujjain-21	85.09	76.42	2.25	42.50	1.04
V_2 –JAKI-9218	83.06	79.02	2.11	35.50	0.73
V_3 –IG-593	86.77	85.57	1.93	34.21	0.57
V_4 –JG-6	86.39	82.60	1.80	34.81	1.06
V_5 –JG-16	89.67	75.30	2.71	47.91	0.51
V_6 –JG-130	89.75	81.74	2.57	47.47	0.44
V_7 –JG-412	91.00	86.41	1.85	69.68	0.28
V_8 –JG-11	83.94	75.31	2.39	44.99	0.37
V_9 –KAK-2	87.87	85.15	1.87	49.52	0.22
SEm±	0.40	0.37	0.13	–	–
CD ($p = 0.05$)	1.13	1.07	0.36	–	–

flowering (57.11 days). Under various chickpea varieties, the highest days to pod initiation was recorded with V_2 –JAKI 9218 (75.67 days) followed by V_6 –JG 130 (75.44 days). It was noted lowest with V_9 –KAK 2 (57.22 days) followed by V_1 –Ujjain 21 (67.22 days) respectively.

Days to physiological maturity

Days to physiological maturity were influenced significantly by moisture stress situations and chickpea varieties. The significantly lowest period of physiological maturity was registered with S_{FL} –Water withheld from flowering (111.04 days) followed by S_{6L} –Water withheld from 6 leaf stage (119.56 days), while it was recorded highest 120.3 days with S_0 –Water withheld after germination. Under chickpea varieties, this was registered lowest with V_7 –JG 412 (113.11 days) followed by V_4 –JG 6 (115.89 days). Variety V_9 –KAK 2 gave the significantly highest days to physiological maturity (119.67 days). The highest values of days to pod initiation were found to be registered

with V_2 –JAKI 9218 followed by V_6 –JG 130. Days to physiological maturity and length of reproductive phase were recorded significantly higher under V_9 –KAK 2x. The reduction in 50% flowering and relative leaf water content (RLWC) at flowering and post-flowering phases in chick pea was reported [6]. Similar finding was also reported earlier [7, 8].

Efficiency of used water

Relative water content (%)

The relative water content of chickpea under moisture stress situations was recorded highest S_0 –Water withheld after germination (88.9%) at flowering stage, while it was recorded highest (84.42%) under S_{6L} –Water withheld from 6 leaf stage at pod formation stage (Table 4). The lowest values of 84.16% were registered with S_{FL} –Water withheld from flowering at flowering stage and S_0 –Water withheld after germination at pod formation stage (78.92%). Under different chickpea varieties, the higher relative water con-

tent was recorded with V_7 -JG 412 (91 and 86.41%) at both the observation stages respectively followed by V_6 -JG 130 (89.75%) at flowering stage and by V_3 -IG 593 (85.57%) at pod formation stage remaining statistically at par with each other. The lowest values of relative water content were registered with V_2 -JAKI 9218 (83.06%) followed by V_8 -JG 11 (83.94%) at flowering stage and V_5 -JG 16 (75.3%) followed by V_8 -JG 11 (75.31%) at pod formation stage.

Water Use Efficiency

Water use efficiency was recorded highest in moisture stress situations S_{FL} -Water withheld from flowering (2.82 kg/ha-cm) followed by S_{6L} -Water withheld from 6 leaf stage (2 kg/ha-cm). Under various chickpea varieties, it was recorded highest with V_5 -JG 16 (2.71 kg/ha-cm) being at par with V_6 -JG 130 (2.57 kg/ha-cm). The lowest water use efficiency was recorded with V_4 -JG 6 (1.8 kg/ha-cm) which was statistically at par with V_7 -JG 412 (1.85 kg/ha-cm).

Drought Tolerance Efficiency (%)

Under different moisture stress situations, the drought tolerance efficiency was estimated comparatively higher under S_{FL} -Water withheld from flowering (74.14%) as compared to S_{6L} -Water withheld from 6 leaf stage (61.39%). Under different chickpea varieties, variety V_7 -JG 412 shown the highest drought tolerance efficiency of 69.68% followed by V_9 -KAK 2 (49.52%) and it was recorded lowest in case of V_3 -JG 593 (34.21%). Under the interaction between moisture stress situations and chickpea varieties, the treatment combination $S_{FL} \times V_7$ (124.17%) and $S_{6L} \times V_7$ (84.87%) showed highest drought tolerance efficiency, while it was estimated lowest as 43.51% under $S_0 \times V_4$.

Drought Susceptibility Index

Similar to the drought tolerance efficiency, drought susceptibility index was also estimated comparatively higher under S_{FL} -Water withheld from flowering (0.89) as compared to S_{6L} -Water withheld from 6 leaf stage (0.85). Under chickpea varieties, variety V_4 -JG (1.06) shown the highest drought susceptibility index followed by V_1 -Uijain 21 (1.04) and it was recorded low-

est in case of V_9 -KAK 2 (0.22). Treatment combination $S_{6L} \times V_1$ and $S_{6L} \times V_4$ showed highest drought susceptibility index. Several workers studied the performance of different chickpea cultivars under drought conditions at different locations and reported similar effects on these physiological observations [7–12]. Relative water content decreased from the flowering stage to the pod filling stage [13, 14].

Conclusion

It may be concluded from the results obtained from the one season experiment on moisture stress situations and varieties in chickpea that the seed yield of chickpea was obtained highest with moisture stress situation treatment S_{FL} -Water withheld from flowering and the chickpea variety V_5 -JG 16. Thus, the combination of moisture stress situation $S_{FL} \times V_5$ (S_{FL} -Water withheld from flowering in variety V_5 -JG 16) was found better in terms of productivity and profitability.

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