Website : www.asthafoundation.in
Frontiers in Crop Improvement
Vol 10 (2) : 141-146 (July-2022) Print ISSN : 2393-8234 Online ISSN : 2454-6011
Astha Foundation, Meerut (U.P.) India

Morpho-Physiological Characterization of Indian Chickpea (*Cicer arietinum* L.) Genotypes Based on Early Drought Stress Response

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Abstract

Moisture stress influences the overall growth and development of chickpea. The tolerance level of genotypes to drought depends on their morpho-physiological and biochemical attributes. Therefore, the pot experiment was conducted in a completely randomized design (CRD) in the Rabi season of 2020-21 and 2021-22 with the objective of morpho-physiological characterization of 40 desi chickpea genotypes in response to early drought stress. Relative water content (RWC), canopy temperature depression (CTD) and chlorophyll content index (CCI) were significantly decreased when stress imposed before the onset of flowering resulted in declined plant height (PH), number of primary branches (NPB), number of secondary branches (NSB), biological yield per plant and seed yield per plant. Data of both seasons were pooled for calculation of summary statistics and cluster analysis for grouping chickpea genotypes. These parametersshowed more potential for utilization in plant breeding programs, *viz*., varietal identification and germplasm characterization for drought tolerance.

Key words : *Chickpea, morpho-physiological, early drought stress, cluster analysis.*

Introduction

Chickpea (*Cicer arietinum* L.) is a self-pollinating, diploid (2n=16) legume crop with a genome size of 738Mbp (1). Chickpea seeds are a good source of dietary proteins for the resource-poor vegetarian population. Globally, it is grown in more than 54 countries, among which India contributes a leading share (75%) to worldwide chickpea production. An all-time highestproduction of chickpea, 12.61 million tons, was recorded in 2020-21 in India to realize the country towards self-sufficiency in pulses as Pulse Revolution (2). However, that production was not enough to meet the domestic pulse demand.

Various biotic and abiotic stresses debar chickpea productivity; among them, drought stress along with heat stress is the major constraining factors. It has been estimated thatonly these two stresses cause more than 50% of yield losses. Chickpea yield loss due to droughtis about 45–50% to total crop failureacross the globe (3).

The concept of drought tolerance of chickpea germplasmis becoming an excellent assignment for the scientific fraternity due to climate change, water shortage and alteration of rainfall patterns (4). Plants react to drought stress through various morpho-physiological, biochemical and gene regulatory mechanisms (5). Moisture stress tolerance of genotypes is linked with high relative water content (RWC) and low saturation water deficit. Thus, the study was conducted to characterize chickpea genotypes based on morpho-physiological responses under early drought stress conditions to select promising early drought-tolerant lines.

Materials and Methods

The experimental chickpea material contained 40 genotypes, including varieties, checks and advanced breeding lines. The details of chickpea genotypesare listed in Table-1. The trial was conducted at Nethouse of Biotechnology Center, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, in a completely randomized design (CRD) with three replications in the Rabi seasons of 2020-21 and 2021-22. Standard agronomical practices were followed to maintain five plants of each genotype in each 20 kg pot.

Drought stress was imposed by stopping irrigation before the onset of flowering for 15 days in the stressed plants, while optimal irrigation continued for the normalplants. Three evocative plants are carefully selected from each pot for the recording of the observations on plant height (PH), number of primary branches (NPB), number of secondary branches (NSB), chlorophyll content index (CCI), biological yield per plant (BYPP) and seed yield per plant (SYPP). RWC was calculated according to Sachdeva et al. (6). SWD was calculated by subtracting RWC from 100. CTD was calculated by subtracting the canopy temperature of the plant from air temperature. Statistical analysis of both seasons' pooled data was done using WindowStat 9.1 software. Genetic diversity was determined using

Received : April-2022; Revised : May-2022; Accepted : May-2022

Table-1 : Details of chickpea genotypes used in the study.

S. No.	Genotype	Source	Pedigree
1.	ICC4958	ICRISAT, Patancheruvu	JGC 4958
2.	JAKI9218	JNKVV, Jabalpur	(ICCC 37 x GW5/7) x ICCV 107
3.	JG6	JNKVV, Jabalpur	(Phule G-5 x Narsinghpur bold) x ICCC 37
4.	JG11	JNKVV, Jabalpur	ICCC 44 × ICCV 10
5.	JG14	JNKVV, Jabalpur	Single Plant selection from JG 62
6.	JG16	JNKVV, Jabalpur	A composite from genetic stock
7.	JG17	JNKVV, Jabalpur	(ICCV10XK850) x (H208XRS11)
8.	JG24	JNKVV, Jabalpur	(GW5/7XP326)XICCL83149
9.	JG28	JNKVV, Jabalpur	BDNG 9-3 x Narsingpur Bold
10.	JG32	JNKVV, Jabalpur	(JG 74 x ICC 4958)-21
11.	JG33	JNKVV, Jabalpur	[(JM – 1 X IPC 9239)X JG 7] – 14-11
12.	JG36	JNKVV, Jabalpur	[(JM – 1 x IPC 4958) x JG 315] – 2
13.	JG42	JNKVV, Jabalpur	[(JM – 1 x IPC 9239) x JG 322] – 30-3
14.	JG63	JNKVV, Jabalpur	JG 12 x JG 16
15.	JG74	JNKVV, Jabalpur	[(JM 1x IPC 9239) JG7] 14-11-2011-42
16.	JG226	JNKVV, Jabalpur	JG 74 x JG315
17.	PG205	JNKVV, Jabalpur	JG 315 x ICC 96029
18.	ICCV15102	ICRISAT, Patancheruvu	ICCV03112 x ICCV10
19.	ICCV15115	ICRISAT, Patancheruvu	ICCV10 x ICCV 96970
20.	ICCV15118	ICRISAT, Patancheruvu	ICCV 05530 x ICCV 88510
21.	ICCV19616	ICRISAT, Patancheruvu	JAKI 9218/ICCV 05103
22.	ICCV181664	ICRISAT, Patancheruvu	ICC 4958 TM/JG 130
23.	JG2003-14-16	JNKVV, Jabalpur	[(JM1 x ICC4929) x ICC4958]-2-14-16
24.	JG2016-44	JNKVV, Jabalpur	(ICC 96029 x ICC11551) 44
25.	JG2016-45	JNKVV, Jabalpur	(JG 74 x ICC11551) 45
26.	JG2016-1411	JNKVV, Jabalpur	JG 14 x JG 11
27.	JG2016-1614	JNKVV, Jabalpur	JG 16 x JG 14
28.	JG2016-9605	JNKVV, Jabalpur	JG 74 x ICC 96029
29.	JG2016-9651	JNKVV, Jabalpur	JG 130 x ICC 96029
30.	JG2016-74315	JNKVV, Jabalpur	[{(JG 74 x WR 315) x JG 74} -2010 -1- 3- 5- 11-15-10-2]
31.	JG2016-634958	JNKVV, Jabalpur	JG 63 x ICC 4958
32.	JG2016-921814	JNKVV, Jabalpur	JAKI 9218 x JG 14
33.	JG2017-48	JNKVV, Jabalpur	(JG 315 x ICC 96029)48
34.	JG2018-51	JNKVV, Jabalpur	JG63 x ICC1205
35.	JG2022-74	JNKVV, Jabalpur	JG12XJG74
36.	JG2016-36	JNKVV, Jabalpur	JG12XJG16-1
37.	JG2022-75	JNKVV, Jabalpur	JG12XICC4958
38.	JG2021-6301	JNKVV, Jabalpur	JG12 X ICCV06301
39.	JG2021-1424	JNKVV, Jabalpur	JG14XJG24
40.	JG2021-1617	JNKVV, Jabalpur	JG16 X JG17

Mahalanobis's D2 (7), and clustering of genotypes was performed according to Tocher's method (8).

Results and Discussion

Chickpea is India's third most prominent legume crop, occupying 45% of the total pulse production. Drought is a severe constraint in chickpea production. The studied characters indicatedthe presence of a considerable amount of variation in the studied chickpea genotypes. Observations on RWC, SWD, CTD, CCI, PH, NPB, NSB, BYPP and SYPP of the forty genotypes were recorded in both seasons. Data of both seasons were pooled for further analysis.

Under normal conditions, the RWC was recorded from 65.2 to 79.5 with a mean of 73.48, SWD from 20.49 to 34.80 with a mean of 26.52, CTD from 2.61 to 4.04 with a mean of 3.26, CCI from 55.46 to 62.63 with 58.82, PH from 40.96 to 57.92 cm with a mean of 47.91, NPB from 2.4 to 3.26 with a mean of 2.84, NSB from 6.08 to 8.75 with a mean of 7.32, BYPP from 21.44 g to 39.60 g with a mean of 26.43 g and SYPP ranged from 7.08 g to 13.37 g with a mean of 26.43 g (Table-2).

Table-2 : Pooled morpho-physiological mean performance of different chickpea genotypes under normal conditions.

S. No.	Genotype	RWC	SWD	CTD	CCI	PH	NPB	NSB	BY	SY
1.	ICC4958	77.35	22.65	3.79	59.33	46.16	2.86	8.38	26.93	9.49
2.	JAKI9218	77.64	22.36	3.63	60.89	49.69	2.95	8.33	27.98	11.45
3.	JG6	75.99	24.01	3.62	58.82	50.29	2.90	7.38	26.66	13.37
4.	JG11	79.32	20.68	4.04	60.87	46.54	2.99	8.75	26.78	10.20
5.	JG14	72.95	27.05	3.48	59.17	49.13	2.40	7.42	24.45	8.34
6.	JG16	77.19	22.81	3.93	60.60	48.75	3.08	8.50	39.60	11.54
7.	JG17	70.84	29.16	3.45	57.38	48.57	2.63	8.04	24.09	7.67
8.	JG24	79.51	20.49	3.33	61.00	57.92	3.00	8.25	28.74	7.66
9.	JG28	75.75	24.25	3.30	59.70	51.73	2.45	7.63	23.47	7.08
10.	JG32	74.45	25.55	3.20	58.51	49.22	2.64	6.88	23.27	8.57
11.	JG33	71.43	28.57	3.89	57.34	51.63	2.91	7.63	26.11	9.19
12.	JG36	75.01	24.99	3.14	60.02	48.17	2.58	7.66	21.44	9.35
13.	JG42	74.90	25.10	2.93	58.59	47.03	2.78	8.04	24.48	9.20
14.	JG63	78.83	21.17	3.66	60.80	49.29	3.09	8.67	22.73	10.41
15.	JG74	77.59	22.41	2.64	60.07	48.44	2.84	7.88	30.53	10.40
16.	JG226	77.14	22.86	3.02	60.31	48.63	2.94	7.13	23.73	9.11
17.	PG205	78.81	21.19	2.70	62.28	48.57	3.21	6.21	38.07	10.87
18.	ICCV15102	73.49	26.51	3.50	57.53	46.83	2.53	6.50	29.54	9.20
19.	ICCV15115	79.19	20.81	3.31	60.60	45.41	3.26	7.75	29.58	9.22
20.	ICCV15118	76.96	23.04	3.00	60.20	50.04	2.81	6.08	29.59	9.07
21.	ICCV19616	67.00	33.00	3.61	56.50	51.17	2.83	7.38	23.39	8.66
22.	ICCV181664	78.76	21.24	2.82	61.29	48.23	2.78	6.71	21.57	8.79
23.	JG2003-14-16	78.51	21.49	3.24	60.33	51.51	2.97	6.69	27.88	9.06
24.	JG2016-44	78.09	21.91	3.26	62.45	50.01	2.92	7.17	27.62	8.68
25.	JG2016-45	68.60	31.40	2.75	55.90	46.07	2.85	7.08	25.15	8.74
26.	JG2016-1411	75.91	24.09	2.87	59.85	50.61	2.90	6.53	23.51	8.93
27.	JG2016-1614	66.18	33.82	3.25	56.17	46.75	2.69	6.58	26.50	8.49
28.	JG2016-9605	67.16	32.84	2.61	56.37	48.94	2.65	6.84	25.61	8.91
29.	JG2016-9651	69.95	30.05	3.28	57.49	43.58	2.75	7.55	23.82	9.08
30.	JG2016-74315	71.97	28.03	3.05	57.11	45.17	3.05	7.04	27.04	8.42
31.	JG2016-634958	75.96	24.04	2.93	62.53	44.96	3.05	6.42	22.53	8.74
32.	JG2016-921814	72.35	27.65	2.95	58.42	43.17	2.68	7.50	28.50	8.69
33.	JG2017-48	66.45	33.55	3.70	56.06	47.97	2.84	6.71	25.41	8.80
34.	JG2018-51	72.13	27.87	3.71	58.16	44.67	3.07	7.58	25.05	9.04
35.	JG2022-74	68.69	31.31	3.44	56.28	44.88	2.81	6.92	26.46	8.79
36.	JG2016-36	65.20	34.80	2.84	56.29	41.75	2.85	6.67	24.74	8.79
37.	JG2022-75	66.10	33.90	3.15	55.46	46.63	2.89	7.13	27.57	8.29
38.	JG2021-6301	69.23	30.77	3.13	57.58	40.96	2.79	7.05	25.24	8.61
39.	JG2021-1424	69.81	30.19	3.36	57.96	51.15	2.65	6.92	26.94	8.26
40.	JG2021-1617	66.92	33.08	2.99	56.55	46.21	2.57	7.25	24.71	8.22
	Min	65.20	20.49	2.61	55.46	40.96	2.40	6.08	21.44	7.08
	Max	79.51	34.80	4.04	62.53	57.92	3.26	8.75	39.60	13.37
	Mean	73.48	26.52	3.26	58.82	47.91	2.84	7.32	26.43	9.13
	SD	4.56	4.56	0.37	2.01	3.13	0.20	0.69	3.68	1.15

Under drought-stressedconditions, RWC ranged from 57.03 to 79.42 with a mean of 68.28, SWD 20.58 to 42.97 with a mean 31.72, CTD was depicted from 1.08 to 2.18 with a mean 1.67, CCI 51.19 to 58.87, PH from 33.37 cm to 47.50 cm with a mean 39.63 cm, NPB from 2.04 to 2.75 with a mean 2.26, NSB 5.67 to 7.63 with a mean 6.23, BYPP 8.53 g to 19.61 g with a mean 10.02 g and SYPP ranged from 2.57 g to 5.21 g with a mean 3.37 g (Table 3).

The genotypic and phenotypic diversity per se is an inferential selection criterion, so it may not be more beneficial for directly selecting the genotypes as parents for the crop breeding program. Different scientists have used several clustering techniques to quantify the genetic

Table-3 : Pooled morpho-physiological mean performance of different chickpea genotypes under drought stressed conditions.

S.No.	Genotype	RWC	SWD	CTD	CCI	PH	NPB	NSB	BY	SY
1.	ICC4958	74.23	25.77	2.11	55.65	39.44	2.38	7.24	10.12	3.53
2.	JAKI9218	74.74	25.26	2.03	56.25	44.46	2.39	6.75	9.54	3.70
3.	JG6	69.72	30.28	1.08	55.04	42.71	2.53	6.28	9.96	3.62
4.	JG11	75.88	24.12	2.02	56.61	37.83	2.48	6.85	10.58	3.82
5.	JG14	64.44	35.56	1.14	54.72	41.71	2.33	6.14	9.20	2.82
6.	JG16	73.80	26.20	2.00	56.44	43.13	2.44	7.52	19.28	4.34
7.	JG17	63.68	36.32	1.99	53.02	41.64	2.16	6.21	9.36	3.11
8.	JG24	77.00	23.00	1.70	57.23	47.50	2.14	6.50	10.63	2.73
9.	JG28	68.50	31.50	1.71	55.20	44.25	2.08	6.33	8.53	2.94
10.	JG32	71.41	28.59	1.66	55.37	43.46	2.18	5.75	9.11	2.99
11.	JG33	67.55	32.45	1.75	53.84	43.88	2.33	5.88	8.65	2.72
12.	JG36	77.16	22.84	1.58	58.55	38.88	2.29	6.72	11.73	5.21
13.	JG42	71.31	28.69	1.39	55.03	38.13	2.21	6.39	8.96	3.05
14.	JG63	77.66	22.34	2.08	57.37	43.33	2.35	7.63	8.75	3.32
15.	JG74	69.09	30.91	1.09	56.13	39.88	2.04	5.67	9.47	2.57
16.	JG226	70.93	29.07	1.11	56.58	38.88	2.10	5.83	10.12	2.75
17.	PG205	77.60	22.40	1.73	58.87	40.71	2.38	5.97	19.61	4.76
18.	ICCV15102	69.72	30.28	1.75	53.75	38.17	2.09	5.79	10.26	2.66
19.	ICCV15115	74.34	25.66	1.38	56.13	39.38	2.23	6.56	9.76	3.38
20.	ICCV15118	72.29	27.71	1.64	56.25	43.04	2.15	5.67	9.86	3.35
21.	ICCV19616	62.21	37.79	2.18	52.78	39.29	2.27	6.38	8.91	2.88
22.	ICCV181664	72.90	27.10	1.75	56.49	40.92	2.08	6.04	8.73	3.14
23.	JG2003-14-16	72.38	27.62	1.61	55.42	43.63	2.29	5.71	9.18	3.23
24.	JG2016-44	79.42	20.58	1.51	58.87	43.54	2.47	6.13	10.21	3.06
25.	JG2016-45	62.92	37.08	1.76	52.04	37.83	2.31	6.33	9.87	4.82
26.	JG2016-1411	73.06	26.94	1.63	56.64	40.63	2.43	5.75	9.35	3.20
27.	JG2016-1614	58.64	41.36	1.58	52.00	38.13	2.27	5.75	9.12	3.36
28.	JG2016-9605	57.63	42.37	1.08	51.84	39.08	2.16	5.67	9.15	3.59
29.	JG2016-9651	62.96	37.04	1.77	53.34	35.50	2.10	6.58	9.98	2.90
30.	JG2016-74315	64.84	35.16	1.91	52.62	36.21	2.22	6.17	8.68	3.07
31.	JG2016-634958	66.85	33.15	1.67	57.47	34.83	2.75	5.83	9.81	3.18
32.	JG2016-921814	65.58	34.42	1.65	54.43	35.92	2.26	6.27	8.93	2.94
33.	JG2017-48	62.36	37.64	2.13	52.56	39.67	2.21	5.79	9.66	4.56
34.	JG2018-51	67.38	32.62	2.14	54.18	36.04	2.32	6.59	9.81	3.33
35.	JG2022-74	62.04	37.96	1.44	52.22	35.58	2.08	6.29	9.72	4.33
36.	JG2016-36	57.03	42.97	1.46	51.97	33.54	2.15	6.08	9.72	4.28
37.	JG2022-75	58.72	41.28	1.24	51.19	34.96	2.24	6.15	9.18	3.12
38.	JG2021-6301	61.44	38.56	1.75	53.52	33.33	2.13	5.98	9.18	2.91
39.	JG2021-1424	62.22	37.78	1.90	53.64	40.63	2.25	5.86	9.07	2.65
40.	JG2021-1617	59.80	40.20	1.80	52.37	35.63	2.08	6.00	9.14	2.89
	Min	57.03	20.58	1.08	51.19	33.33	2.04	5.67	8.53	2.57
	Max	79.42	42.97	2.18	58.87	47.50	2.75	7.63	19.61	5.21
	Mean	68.28	31.72	1.67	54.84	39.63	2.26	6.23	10.02	3.37
	SD	6.34	6.34	0.31	2.11	3.42	0.15	0.48	2.28	0.66

diversity in tested genotypes based on collected data (9, 6). Tocher's clustering grouped all the forty genotypes into ten major clusters (Table 4, Figure 1). Cluster I contained six genotypes (JG74, JG226, JG14, JG6, JG2016-9605 and JG2022-75). Cluster II consisted with 20 genotypes (JG42, ICCV15115, JG2022-74, JG2003-14-16, JG2016-44, ICCV15118, JG2016-1411, JG32, JG2016-1614, JG2016-921814, JG28, JG24, JG33, ICCV181664, JG36, ICCV15102, JG2016-45, JG2016-9651, JG2016-6301 and JG2021-1617). Cluster III comprised 10 genotypes (JAKI9218, JG63, ICC4958, JG11, JG2018-51, JG17, ICCV19616, JG2016-74315 and JG2021-1424). Cluster IV and Cluster V contained with single genotypes (JG2016-36 and JG2016-634958, respectively). Cluster VI consisted with two genotypes (JG16 and PG205).

Clustering could classifythe drought-tolerant chickpea lines from the drought-susceptible chickpea genotypes. In the study, Tocher's clustering differentiated drought-tolerant genotypes into Cluster III (JAKI9218, JG63, ICC4958, JG11, JG2018-51, JG17, ICCV19616, JG2016-74315 and JG2021-1424) and drought-sensitive

Table-4 : Clusters of tested genotypes in early drought stress response.

S. No.	Cluster No.	No. of genotypes	Name of genotypes
1.	Cluster I	6	JG74, JG226, JG14, JG6, JG2016-9605, JG2022-75
2.	Cluster II	20	JG42, ICCV15115, JG2022-74, JG2003-14-16, JG2016-44, ICCV15118, JG2016-1411, JG32, JG2016-1614, JG2016-921814, JG28, JG24, JG33, ICCV181664, JG36, ICCV15102, JG2016-45, JG2016-9651, JG2016-6301, JG2021-1617
3.	Cluster III	10	JAKI9218, JG63, ICC4958, JG11, JG2018-51, JG17, ICCV19616, JG2016-74315, JG2021-1424
4.	Cluster IV	1	JG2016-36
5.	Cluster V	1	JG2016-634958
6.	Cluster VI	2	JG16, PG205

Table-5 : Inter and intra cluster divergence values for different clusters generated by Tocher's method.

	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI
Cluster I	8.91	31.99	54.35	22.91	38.31	48.80
Cluster II	31.99	13.81	26.55	17.58	18.54	25.88
Cluster III	54.35	26.55	11.34	35.85	24.49	22.92
Cluster IV	22.91	17.58	35.85	0.00	20.17	33.05
Cluster V	38.31	18.54	24.49	20.17	0.00	24.14
Cluster VI	48.80	25.88	22.92	33.05	24.14	14.71

Table-6 : ClusterMeans of different traits generated by Tocher's method.

	RWC	SWD	CTD	CCI	PH	NPB	NSB	BY	SY
Group.1	39.53	2.23	5.96	65.09	34.91	1.12	54.25	9.51	3.08
Group.2	39.86	2.21	6.12	69.02	30.98	1.64	54.94	9.54	3.29
Group.3	39.85	2.30	6.55	68.52	31.48	2.05	54.47	9.45	3.40
Group.4	33.54	2.15	6.08	57.03	42.97	1.46	51.97	9.72	4.28
Group.5	34.83	2.75	5.83	66.85	33.15	1.67	57.47	9.81	3.18
Group.6	41.92	2.41	6.74	75.70	24.30	1.86	57.66	19.45	4.55

genotypes into Cluster I (JG74, JG226, JG14, JG6, JG2016-9605, JG2022-75). Rest clusters consisted of moderate drought tolerant genotypes. Similar outcomes obtained by (6) also discriminated drought-tolerant chickpea genotypes from susceptible genotypes based on morpho-physiological traits. They found that Cluster IIa consisted of drought-tolerant genotypes viz., ICC4958, ICCV10, ICCV10313and ICCV97309, while cluster I and Cluster III contained the most susceptible genotypes.

Further, Mahalanobis's D2 values depicted a wide range of intra-cluster distances from 0.00 to 14.71 (Table 5). Cluster VI depicted maximum intra-cluster D2 mean value (D2 = 14.71) followed by Cluster II (D2 = 13.81), Cluster III (D2 = 11.34) and Cluster I (8.91). The remaining two clusters (Cluster IV and Cluster V) depicted zero value for intra-cluster distance because of having a single genotype in each cluster. The highest inter-cluster divergence was demonstrated between genotypes of cluster I and Cluster III (54.35), depicting their highest suitability for use in a breeding program. Outcomes of the cluster distance demonstrated the remarkable opportunities for introgression of allelic resources from these genotypes by using a suitable breeding program. These findings were also approved in earlier studies (10, 11).

Conclusions

The genotypes JAKI9218, JG63, ICC4958, JG11, JG2018-51, JG17, ICCV19616, JG2016-74315 and JG2021-1424, had been identified as early drought tolerant genotypes. These genotypes had lower variability and higher yield in studied characters under drought stress conditions; thus, they are very good drought-tolerant genotypes to be utilized as drought-tolerant donors. Crossing the genotypes of Cluster I with Cluster III would be ideal for creating variation for studied traits. Crosses of these diverse parents would produce various deviations for selecting the desirable characters.

Acknowledgements

The first author is thankful to Indian Council of Agriculture Research, New Delhi, for providing a study fellowship for Ph.D. at JNKVV, Jabalpur, M.P. The authors also acknowledge AICRP on Chickpea, the Department of Plant Breeding and Genetics, and JNKVV Jabalpur for providing research material.

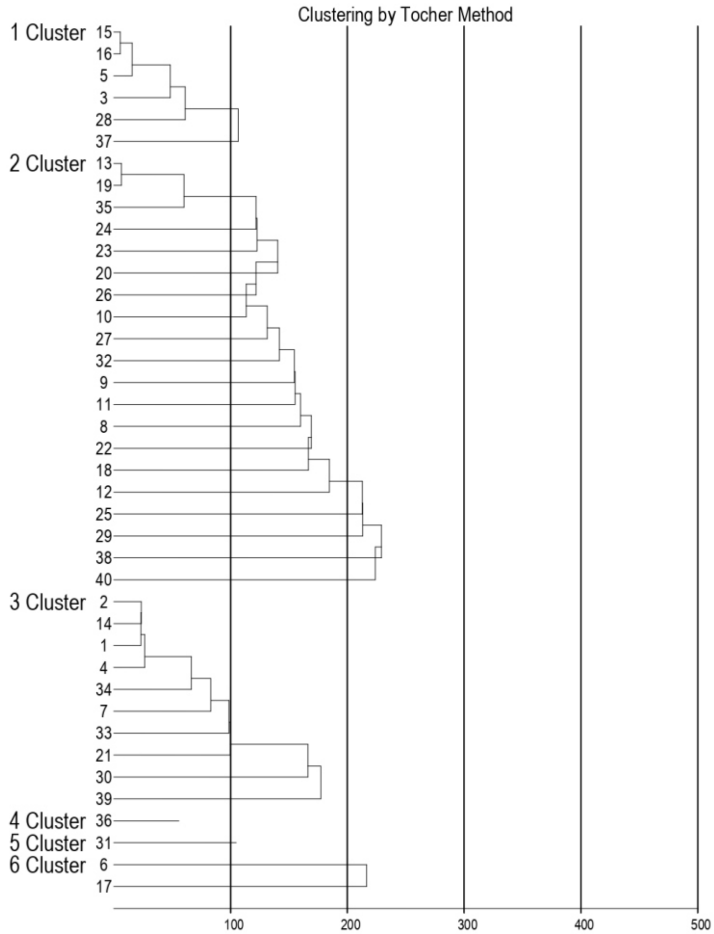

Figure-1 : Clustering of chickpea genotypes in early drought stress response.

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