Genetic Divergence under Three Environments in a Minicore Collection of Chickpea (*Cicer arietinum* L.)

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Two hundred and three germplasm lines of minicore collections obtained from ICRISAT, Hyderabad were evaluated for eight quantitative traits under three environments viz. E1 (rainfed 2004–05), E2 (rainfed 2005–06) and E3 (irrigated 2005–06). Mahalanobis' D2 statistic was applied. These genotypes were grouped into 20, 16 and 25 clusters in E1, E2 and E3, respectively. In the present study in all the three environments, the genotypes of different geographic origin were randomly distributed in the clusters. Thus, there is no parallelism between the genetic distance and geographical diversity. The formation of 16, 10 and 18 distinct solitary clusters in E1, E2 and E3, respectively may be due to intensive natural or human selection for diverse adaptive gene complex. The pairs of clusters revealing maximum genetic diversity were identified for all the three environments. It has been suggested that for varietal improvement the hybridization among the genotypes of divergent clusters should be done rather than depending on those genotypes of the cluster having minimum divergence. Genotypes of cluster XIX (ICC13124) had the highest mean value for pod number and earliness in E1. In E2, the genotypes of cluster XV (ICC12654) and XVI (ICC9848) were superior in respect of plant height, pods/plant and 100 seed weight, respectively. In E3, the genotype of cluster XVI (ICC13124) had the highest mean value for seed yield. Cluster XXIII (ICC6279) had the early maturing genotype and cluster XVIII (ICC5879) was superior in respect of pod number and tertiary branches/plant and cluster V(ICC 6816), cluster XI (ICC10341 and cluster XIII (ICC5504) had the tall genotypes. Therefore, these genotypes may be involved in multiple crossing programme to recover transgressive segregates.

Key Words: Chickpea, Genetic divergence, Minicore collection, Quantitative traits

Introduction

The germplasm is the reservoir of genetic diversity, which is base to meet the changing need for developing improved crop varieties. It is also important that considerable variability for economic traits must exist in the germplasm for better exploitation following recombination breeding or selection. The need of parental diversity in optimum magnitude to obtain superior genotypes to recover transgressive segregates has also been repeatedly emphasized (Murthy and Anand, 1966; Arunachalam, 1981). Earlier workers considered genetic distance in the place of origin as index of genetic diversity and used it for selection of parents for hybridization. However the genetic diversity of selected parents is not always based on factors such as geographical diversity/ place of release (Murthy and Arunachalam, 1969; Bhatt, 1970; Gupta *et al*., 1972). Hence, characterization of genetic divergence for selection of suitable and diverse genotypes should be based on sound statistical procedures, such as D^2 statistic and cluster analysis. These procedures characterize genetic divergence using the criterion of similarly or dissimilarly based on the aggregate effect of a number of agronomically important characters. Genetic diversity is considered to be important for realizing heterotic response in F_1 and a broad spectrum of variability in segregating generations (Arunachalam, 1981). Genetic relationship among genotypes can be measured by similarity or dissimilarity of any number of quantitative characters assuming that the difference between characters of genotypes reflects the divergence of genotypes. In heterosis breeding programme the diversity of parents is always emphasized. More diverse the parent within a reasonable range, better the chances of improving economic characters under consideration in the resulting offspring. Mahalanobis's (1936) D^2 Statistic is a very sensitive tool for measuring genetic divergence based on quantitative traits and is widely used by many geneticists and breeders for selecting divergent parents for hybridization aiming at yield improvement in chickpea. The present investigation was conducted to identify diverse genotypes for yield and yield component traits

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for their use in chickpea improvement programme. In view of this fact, 203 chickpea minicore collections were evaluated for this study. (i) to determine the magnitude of variability among the germplasm collection for yield and other morpho-physiological traits, (ii) to determine the grouping pattern of genotypes in different clusters and (iii) to identify genetically divers and agronomically desirable genotypes for exploitation in a breeding programme aimed at seed yield potential in chickpea.

Materials and Methods

The experimental material for the present study comprised of 203 chickpea germplasm lines from the minicore collection (Upadhyay and Ortiz, 2001) obtained from ICRISAT, Hyderabad (Andhra Pradesh). These lines were evaluated for assessing genetic diversity under three environments (E_1, E_2 and E_3) for agronomic traits. The sources of these lines are given in Table 1. Experiments were conducted during *rabi* 2004–05 and 2005–06 under rainfed and irrigated situation at GPB garden, College of Agriculture, Dharwad (Karnataka) in medium black soils in Randomized Complete Block Design with two replications. Each genotype was grown in a single row of 4 m length with 30 cm spacing between rows and 10 cm within the row. Recommended agronomic practices were followed during the period of crop growth in both the situation. The crop was maintained free from weeds, diseases and pests by adopting appropriate plant protection measures. In irrigated situation, two irrigations were provided one at flowering and other at pod formation stage. Observations were recorded for days to 50% flowering (DFF) on line basis. While plant height (PLHT) (cm), number of primary branches per plant (PB), number of secondary branches per plant (SB), number of tertiary branches per plant (TB), number of pods per plant (PPP), seed yield per plant (YPP) and 100-seed weight (SDWT) on five randomly selected plants. Adjusted mean values for all the characters of test genotypes (203) and the estimates of error mean squares were obtained following Federer (1956) and used for subsequent statistical analyses. The Mahalanobis' D^2 statistic analysis was conducted to estimate the intra and inter-cluster distances and to group the genotypes into different clusters. The appropriate number of clusters to group 203 genotypes was determined following the sequential pseudo F-ratio tests.

Results and Discussion

The clustering procedure used in grouping the 203 germplasm lines included in the study comprise the minicore collections of chickpea which represents the whole range of variation of cultivated species for the assessment of genetic diversity considering eight quantitative characters in three environments. Statistical distance (D^2 value) indicated the index of genetic diversity among the clusters. It would, therefore, be logical to effect crosses between genotypes belonging to clusters separated by the estimates of statistical distances. Based on D2 values 203 genotypes were grouped into twenty, sixteen and twenty-five clusters in E1, E2 and E3, respectively (Table 2) indicating the presence of appreciable amount of diversity among the genotypes under study. This suggested ample scope for selection of superior and diverse genotype for use in programme aimed at enhancing genetic yield potential of chickpea.

The maximum number of genotypes (157) were grouped into cluster II followed by cluster V with 22 genotypes and cluster XI with 5 genotypes. Remaining clusters (III, IV, VI, X and XII to XX) were all solitary, each containing a single genotype. The intra-cluster D^2 values ranged from 140.54 to 212.24 (Table 3–5). The average inter-cluster D^2 value between cluster II, XIII, XI, XV and cluster XX was maximum followed by descending order between these with cluster XIX, XVIII, XIV and XII suggesting that genotypes in cluster XX were relatively more diverse than genotypes in the above selected clusters.

In E2, the largest clusters were II, III, IV and IX which comprised of 105, 58, 15 and 10 genotypes, respectively while cluster I and X had 3 and 2 genotypes. The remaining clusters (V, VI, VII, VIII and XI to XVI) were all solitary each containing single genotype. In E3, the clusters II, IV and III were the largest comprising 88, 44 and 34 genotypes, respectively. Clusters VI and VIII had 8 and 5 genotypes, respectively while clusters XIX and III had 3 genotypes each. However remaining 18 clusters were solitary clusters. In the present study in all the three environments, the genotypes of different geographic origin were randomly distributed in the clusters. It was observed that clusters having more than one genotype included the genotypes originating from different eco-geographical regions and that the genotypes belonging to the same eco-geographical region were included in different clusters suggesting that geographical diversity does not necessarily represents genetic diversity. This was in agreement with the results obtained earlier in chickpea by various workers (Ramanujam, 1975; Singh and Bains, 1982; Arora, 1992; Jeethava *et al.*, 2000; Jeena and Arora,

Table 1. The sources of chickpea minicore germplasm collections

Sl. No.	ICC No.	Source country	Sl. No.	ICC No.	Source country	Sl. No.	ICC No.	Source country
01	16207	Myanmar	62	7184	Turkey	123	11627	India
02	13523	Iran	63	12654	Ethiopia	124	7819	Iran
03	637	India	64	3325	Cyprus	125	12155	Bangladesh
04	14831	India	65	6802	Iran	126	3631	Iran
5	16903	India	66	8195	Pakistan	127	283	India
06	4639	India	67	11498	India	128	4657	India
07	8261	Turkey	68	3218	Iran	129	4418	Iran
08	6816	Iran	69	11584	India	130	7668	Russia and CISs
09	11764	Chile	70	5845	India	131	3230	Iran
10	9895	Afghanistan	71	11944	Nepal	132	6874	Iran
11	13357	Iran	72	7308	Peru	133	13219	Iran
12	5613	India	73	5878	India	134	15294	Iran
13	8058	Iran	74	14402	ICRISAT	135	13461	Iran
14	1083	Iran	75	10945	India	136	16487	Pakistan
15	10341	Turkey	76	8855	Afghanistan	137	13187	Iran
16	3761	Iran	77	3362	Iran	138	7441	India
17	8607	Ethiopia	78	1915	India	139	9643	Afghanistan
18	15612	Tanzania	79	15610	India	140	2629	Iran
19	9002	Iran	80	9755	Afghanistan	141	15868	India
20	13599	Iran	81	13441	Iran	142	3421	Israel
21	12916	India	82	2277	Iran	143	1180	India
22	16915	India	83	16261	Malawi	144	4182	Iran
23	15406	Morocco	84	4872	India	145	8522	Italy
24	1230	India	85	13764	Iran	146	14077	Ethiopia
25	2969	Iran	86	13863	Ethiopia	147	12537	Ethiopia
26	6279	India	87	13892	Ethiopia	148	2884	Iran
27	5434	India	88	2072	India	149	2720	Iran
28	2242	Algeria	89	15802	Syria	150	12866	Ethiopia
29	5504	Mexico	90	456	India	151	6877	Iran
30	1194	India	91	13283	Iran	152	867	India
31	11664	India	92	8621	Ethiopia	153	12299	Nepal
32	4918	India	93	15333	Iran	154	Annigeri 1	India
33	13124	India	94	11879	Turkey	155	708	India
34	9942	India	95	15888	India	156	2990	Iran
35	95	India	96	14595	India	157	14098	Ethiopia
36	791	India	97	12851	Ethiopia	158	15264	Iran
37	440	India	98	9862	Afghanistan	159	1164	Nigeria
38	506	India	99	16524	Pakistan	160	KAK 2	India
39	12307	Myanmar	100	12726	Ethiopia	161	12328	Cyprus
40	4814	Iran	101	12037	Mexico	162	6537	Iran
41	4841	Morocco	102	14815	India	163	15618	India
42	1923	India	103	2919	Iran	164	3776	Iran
43	6579	Iran	104	16796	Portugal	165	1392	India
44	2210	India	105	12947	India	166	15606	India
45	15518	Morocco	106	10755	Turkey	167	2580	Iran
46	16269	Malawi	107	1422	India	168	2263	India
47	11378	India	108	1098	Iran	169	5879	India
48	2065	India	109	11284	Russia and CISs	170	10393	India
49	11121	India	110	8350	India	171	1161	Pakistan
50	12824	Ethiopia	111	13077	India	172	1356	India
51	14799	India	112	14051	Ethiopia	173	5383	India
52	7315	Iran	113	1398	India	174	5639	India
53	1882	India	114	G 130	India	175	4463	Iran
54	4495	Turkey	115	1397	India	176	1431	India
55	14669	India	116	7571	Israel	177	9848	Afghanistan
56	11198	India	117	1510	India	178	2507	Iran
57	4593	India	118	1205	India	179	1715	India
58	14778	India	119	9402	Iran	180	6571	Iran
59	12028	Mexico	120	13524	Iran	181	12492	ICRISAT
60	15567	India	121	3512	Iran	182	13816	Russia and CISs
61	3946	Iran	122	15435	Morocco	183	67	India

contd

Table 1 contd....

Sl. No.	ICC No.	Source country	Sl. No.	ICC No.	Source country	Sl. No.	ICC No.	Source country
184	7867	Iran	191	1052	Pakistan	198	4533	India
185	L 550	India	192	7272	Algeria	199	6811	Iran
186	8384	India	193	8318	India	200	JGK 1	India
187	1710	India	194	12928	India	201	7255	India
188	5135	India	195	4567	India	202	762	India
189	6293	Italy	196	10399	India	203	7554	Iran
190	16374	Malawi	197	6263	Russia and CISs			

Table 2. Distribution of 203 minicore germplasm collection of chickpea in different clusters under three environments (E1, E2 & E3)

	No. of genotypes			Serial No. of genotypes		
Clusters	E1	E2	E3	E1	E2	E3
I	3	3	3	1, 3, 2	74, 104, 84	16, 38, 57
II	157	105	88	170, 179, 141, 117, 165, 181, 200, 62, 53, 111, 10, 186, 160 ,118, 95, 167, 51, 195, 156, 120, 39, 148, 152, 104, 105, 203, 145, 108, 172, 194, 76, 157, 153, 190, 135, 55, 193, 132, 198, 75, 114, 81, 55, 50, 34, 43, 199, 124, 188, 18, 103, 57, 83, 14, 92, 121, 134, 93, 20, 126, 61, 159, 63, 94, 48, 197, 52, 35, 136, 17, 131, 183, 122, 149, 12, 79, 123, 161, 74, 158, 102, 25, 45, 90, 140, 192, 201, 26, 44, 37, 98, 171, 8, 89, 58, 129, 196, 22, 176, 100, 41, 59, 67, 130, 60, 90, 175, 21, 110, 174, 115, 106, 27, 127, 9, 78, 80, 96, 139, 133, 69, 73, 162, 202, 113, 71, 187, 23, 77, 173, 42, 168, 169, 40, 16, 38, 64, 185, 68, 163, 87, 137, 184, 128, 140, 91, 177, 116, 7, 189, 182, 36, 49, 109, 178, 66, 84.	1, 124, 65, 183, 100, 71, 25, 203, 44, 131, 3, 105, 60, 142, 51, 68, 6, 120, 175, 52, 174, 24, 13, 177, 133, 129, 172, 42, 61, 64, 162, 50, 48, 19, 185, 96, 7, 66, 108, 44, 59,168,10,118,170, 81, 137, 176, 157, 126, 171, 196, 21, 143, 55, 57, 54, 92, 43, 101, 201, 20, 103, 5, 114, 46, 178, 156, 128, 17, 160, 152, 166, 198, 26, 70, 180, 190, 153, 37, 191, 18, 197, 113, 161, 82, 132, 192, 73, 138, 136, 28, 188, 91, 130, 134, 56, 9, 99, 116, 107, 106, 112, 49, 125, 18	1, 85, 105, 71, 146, 189, 114, 106, 127, 83, 25, 183, 61, 12, 200, 111, 182, 80, 178, 47, 58, 44, 41, 135, 75, 53, 48, 26, 59, 129, 163, 79, 101, 77, 116, 143, 65, 88, 176, 64, 132, 100, 181, 39, 22, 96, 174, 168, 120, 73, 6, 131, 145, 84, 104, 63, 126, 91, 144, 72, 175, 78, 122, 28, 98, 62, 156, 36, 110, 35, 23, 103, 137, 166, 67
III	1	58	34	54	97, 146, 2, 167, 80, 147, 148, 47, 67, 110, 135, 145, 75, 95, 195, 14, 35, 23, 63, 127, 140, 121, 199, 189, 194, 202, 38, 115, 62, 111, 149, 102, 173, 98, 30, 88, 39, 94, 155, 85, 186, 181, 179, 182, 90, 72, 45, 34, 22, 8, 119, 83, 32, 77, 109, 123, 19, 36.	3, 43, 21, 117, 192, 30, 196, 94, 107, 14, 24, 60, 20, 19, 17, 69, 118, 37, 32, 34, 119, 161, 43, 113, 140, 92, 142, 151, 46, 87, 133, 86, 74, 149
IV	1	15	44	47	53, 58, 41, 117, 150, 76, 151, 169, 40, 15, 154, 11, 93, 69, 87	102, 97, 188, 2, 115, 177, 136, 54, 90, 95, 147, 169, 159, 141, 130, 18, 13, 134, 50, 164, 10, 81, 158, 193, 157, 198, 5, 7, 194, 108, 66, 180, 42, 139, 152, 185, 187, 199, 170, 150, 49, 153, 171, 203
V	22	1	1	13, 82, 85, 144, 151, 143, 72, 112, 138, 65, 142, 154, 101, 80, 180, 97, 15, 147, 150, 32, 24, 19	184	8
VI	1	1	8	191	139	52, 172, 162, 197, 184, 191, 179, 190
VII	1	1	1	31	31	82
VIII	1	1	5	164	127	124, 155, 202, 121, 123
IX	1	10	1	166	12, 31, 29, 79, 78, 163, 159, 86, 158, 4	9
X	1	2	1	28	164, 165	138
XI	5	1	1	88, 119, 6, 30, 155	33	15
XII	1	1	1	125	141	165
XIII	1	1	1	99	16	29
XIV	1	1	1	46	122	148
XV	1	1	1	56	200	11
XVI	1	1	1	29	104	33
XVII	1		1	33		70
XVIII	1		1	11		125
XIX	1		3	107		186, 195, 173
XX	1		1	4		76
XXI			1			109
XXII			1			163
XXIII			1			27
XXIV			1			4
XXV			1			154

E1 (rainfed 2004–05); E2 (rainfed 2005–06); E3 (irrigated 2005–06)

Table 3. Average intra- (diagonal) and inter-cluster distances in chickpea minicore in E_1 (Rainfed 2004–05)

Clusters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Cluster IX	Cluster X	Cluster XI	Cluster XII	Cluster XIII	Cluster XIV	Cluster X V	Cluster X VI	Cluster XVII	Cluster XVIII	Cluster XIX	Cluster XX
Cluster I	**140.54**	232.04	223.09	239.07	237.5	236.78	227.77	222.97	288.26	469.76	255.94	629.77	245.78	700.76	214.61	247.28	283.26	910.02	661.01	1516.19
Cluster II		**0**	410.6	425.76	594.14	414.48	19.55	473.42	659.53	678.26	115.62	1211.56	108.15	1354.35	405.65	201.37	377.34	1554.12	1262.23	2401.47
Cluster III			**0**	16.12	271.73	46.52	364.76	141.28	296.43	157.79	299.41	277.41	332.99	360.64	363.96	237.58	324.12	405.78	343.52	976.35
Cluster IV				**0**	329.66	29.96	367.77	96.57	296.71	138.28	325.54	266.05	396.11	348.17	426.12	240.03	292.7	377.48	390.92	890.5
Cluster V					**0**	347.38	607.89	298.32	168.24	590.98	617.32	373.03	532.46	383.05	210.74	564.58	538.18	648.61	272.94	1133.11
Cluster VI						**0**	338.81	109.27	313.68	158.56	293.81	353.2	411.63	385.39	403.41	256.3	306.65	421.6	402.28	936.67
Cluster VII							**0**	404.04	639.24	592.09	76.8	1147.57	130.99	1257.01	443.3	186.69	337.4	1453.93	1200.04	2230.66
Cluster VIII								**0**	198.17	230.36	368.89	283.5	457.9	341.96	372.84	234.28	137.65	476.15	490.05	795.94
Cluster IX									**187.86**	509.08	632.24	329.78	616.1	354.81	308.19	502.34	393.32	572.42	392.74	927.69
Cluster X										**212.24**	467.3	383.84	575.81	473.59	639.96	349.95	390.99	445.28	565.38	912.72
Cluster XI											0	1036.81	64.46	1156.15	343.45	84.94	232.03	1288.22	1133.62	2065.44
Cluster XII												0	1047.94	43	716.77	778.71	659.4	90.79	158.32	298.12
Cluster XIII													0	1226.52	256.89	97.05	273.78	1388.6	1138.55	2249.81
Cluster X IV														0	792.36	960.42	805.15	87.13	94.45	222.35
Cluster XV															0	298.13	319.16	990.8	717.88	1679.22
Cluster XVI																0	77.38	1038.45	1028.43	1710.84
Cluster XVII																	0	948.56	989.28	1389.43
Cluster XVIII																		0	208.96	213.62
Cluster XIX																			0	525.5
Cluster XX																				0

Table 4. Average intra- (diagonal) and inter-cluster distances in chickpea minicore in E_2 (Rainfed 2005–06)

Clusters	Cluster I	Cluster I I	Cluster I I I	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Cluster IX	Cluster X	Cluster X I	Cluster X I I	Cluster XIII	Cluster X IV	Cluster XV	Cluster XVI
Cluster I	**131.28**	473.87	360.6	288.77	232.55	632.86	236.31	211.51	351.12	873.28	266.65	313.78	266.55	207.18	573.55	1203.21
Cluster II		**144.44**	645.7	286.02	372.42	467.6	561.68	837.02	581.29	1304.03	809.68	265.78	598.43	723.47	400.2	1003.62
Cluster III			**274.13**	738.3	729.97	600.22	488.24	668.02	518.72	670.63	525.54	691.3	636.67	416.97	559.12	1170.95
Cluster IV				**0**	48.57	708.34	466.76	356.17	650.68	1457.7	553.3	201.56	335.73	587.37	753.2	1293.86
Cluster V					**0**	787.96	314.44	218.14	504.14	1408.71	439.97	149.31	204.3	397.45	702.27	1372.35
Cluster VI						**269.07**	497.17	1179.04	437.58	628.42	593.3	533.95	613.21	814.6	599.72	401.43
Cluster VII							**0**	384.73	52.59	591.77	119.81	221.69	90.56	142.17	500.86	744.93
ClusterVIII								**0**	608.63	1347.43	378.14	482.36	361.06	233.09	960.77	1864.85
Cluster IX									**0**	533.8	194.83	268.83	241.19	226.96	433.19	612.49
Cluster X										**237.55**	504.94	1155.72	831.02	809.88	1094.19	572.18
Cluster XI											**0**	407.58	154.06	267.76	860.01	814.1
Cluster XII												**0**	250.08	444.89	380.84	962.24
ClusterXIII													**0**	260.43	755.07	942.59
ClusterXIV														**0**	588.1	1328.12
Cluster XV															**183.38**	1144
ClusterXVI																**0**

Table 5. Average intra- (diagonal) and inter-cluster distances in chickpea minicore in E_3 (Irrigated 2005–06)

Clusters	Cluster I	Cluster I I	Cluster I I I	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Cluster I X	Cluster X	Cluster X I	Cluster X I I	Cluster X I I I	Cluster X IV	Cluster X V
Cluster I	**95.9**	246.4	199.5	468.47	376.57	404.46	523.8	147.86	135.6	150.08	370.34	142.56	146.91	425.58	154.65
Cluster II		**143.32**	540.47	210.71	173.72	180.65	252.42	180.92	267.41	306.18	178.67	253.48	186.45	208.77	211.02
Cluster III			**141.76**	886.77	774.95	804.46	892.28	298.97	252.09	259.41	759.86	270.22	313.95	791.92	290.54
Cluster IV				**0**	169.79	99.71	300.97	387.94	431.3	474.36	118.74	410.9	350.91	44.02	449.9
Cluster V					**0**	72.41	286.27	246.85	382.17	386.7	27.58	304.14	207.8	202.86	350.25
Cluster VI						**0**	256.57	262.79	297.34	323.58	46.12	260.02	189.68	107.62	375.32
Cluster VII							**157.57**	282.51	511.05	569.7	296.88	482.93	331.63	286.88	309.54
Cluster VIII								**0**	147.22	125.71	259.8	86.56	37.57	301.58	72.15
Cluster IX									**0**	83.43	306.69	114.31	69.53	405.83	148.43
Cluster X										**0**	356.46	29.63	98.02	370.69	225.99
Cluster XI											**0**	300.52	181.37	182.41	318.97
Cluster XII												**0**	68.73	293.82	218.99
Cluster XIII													**0**	305.98	92
Cluster XIV														**0**	442.19
Cluster XV															**0**

contd

Table 5 contd...

Clusters	Cluster XVI	Cluster XVII	Cluster XVIII	Cluster XIX	Cluster XX	Cluster XXI	Cluster XXII	Cluster XXIII	Cluster XXIV	Cluster XXV
Cluster I	287.94	239.23	292.19	471.14	418.55	548.35	754.7	591.11	453.41	830.25
Cluster II	546.74	253.03	579.73	422.25	192.46	282.83	604.28	788.26	273.05	621.12
Cluster III	260.66	418.44	259.8	618.69	847.96	975.55	934.55	528.72	813.59	1096.8
Cluster IV	693.29	337.56	868.34	738.05	138.49	87.6	821.94	1293.35	117.3	954.43
Cluster V	768.05	334.29	837.14	658.32	233.3	257.65	912.71	1187.92	298.67	912.79
Cluster VI	780.79	275.45	760.42	725.44	166.27	79.23	905.5	1232.59	206.92	953.54
Cluster VII	842.45	400.97	889.32	328.26	307.24	341.9	397.52	805.68	359.31	412.1
Cluster VIII	364.08	166.96	346.38	265.49	422.25	422.82	498.32	469.23	414.33	615.55
Cluster IX	279.88	189.47	374.49	578.65	407.71	388.87	830.93	727.86	350.88	979.2
Cluster X	414.68	215.59	231.85	660.41	458.87	416.85	984.27	777.58	477.81	1105.44
Cluster XI	659.67	296.56	863.03	688.64	213.52	190.97	910.87	1232.21	172.51	984.87
Cluster XII	425.12	176.64	183.09	594.62	443.25	395.19	893.15	728.99	466.29	1009.74
Cluster XIII	343.94	147.24	393.62	414.42	397.27	359.65	666.44	649.18	328.67	802.49
Cluster XIV	704.44	286.71	647.95	688.26	188.89	84.59	780.2	1141.62	230.71	917.58
Cluster XV	256.28	217.66	481.38	171.42	421.64	535.79	373.43	390.42	323.45	488.96
Cluster XVI	**0**	401.24	569.93	577.63	869.6	899.01	749.4	643.91	522.09	1152.41
Cluster XVII		**233.76**	428.44	505.21	404.76	370.19	689.11	740	346.84	850.36
Cluster XVIII			**0**	771.77	820.21	871.7	1062.41	626.47	937.62	1155.17
Cluster XIX				**0**	688.07	887.21	78.38	225.18	656.04	146.81
Cluster XX					**0**	148.22	837.67	1185.16	212.1	729.07
Cluster XXI						**0**	980.65	1407.78	218.78	1068.38
Cluster XXII							**0**	354.35	740.87	145.82
Cluster XXIII								**176.1**	1193.85	453.37
Cluster XXIV									**0**	922.19
Cluster XXV										**0**

Table 6. Contribution of individual character in the divergence among 203 accessions of chickpea minicore collections under three environments

	Times ranked first			% contribution towards diversity		
Characters	E_1	E_2	E_3	E_1	E_2	E_3
Days to 50% flowering	5775	8733	10528	28.17	42.59	51.35
Plant height (cm)	1606	608	1334	7.83	2.97	6.51
Primary branches/plant	66	133	213	0.32	0.65	1.04
Secondary braches/plant	1083	190	2069	5.28	0.93	10.09
Tertiary branches/plant	566	859	477	2.76	4.19	2.33
Pods/plant	161	100	842	0.79	0.49	4.11
100-seed weight (g)	8254	4852	3921	40.26	23.66	19.12
Yield/plant	2992	5028	1119	14.59	24.52	5.46

2002). This means that geographic diversity, though important, may not be the only factor in determining the genetic divergence. The genetic diversity is the out come of several factors including geographical diversity. Therefore selection of varieties for hybridization should be based on genetic diversity rather than the geographic diversity. The clustering of genotypes from different eco-geographic locations into one cluster could be attributed to the frequent exchange of breeding material from one place to another and it's further selection in different geographic regions which could result in genetic drift or due to unidirectional selection pressure by the breeders of different locations (Murty and Arunachalam, 1969; Singh and Bains, 1982). Hybridization among diverse parents is likely to produce heterotic hybrids and desirable transgressive segregants in advanced generations. Therefore, a hybridization programme may be initiated involving the genotypes belonging to diverse clusters with high mean for almost all component traits. Shinde *et al.* (1997) felt that even the temperature and rainfall pattern, respectively could influence crop characters of the same races. Similar results were also reported in chickpea by Arora (1992), Jeethava *et al.* (2000), Sivakumar and Muthiah (2001) and Jeena and Arora (2002). In the present investigation, 16, 10 and 18 solitary clusters were observed in E1, E2 and E3, respectively. The formation of such a large number of distinct solitary clusters may be due to intensive natural or human selection for diverse adaptive gene complex.

Contribution of Characters to Divergence

The contribution of individual character towards genetic divergence has been worked out in terms of number of times it appeared first (Table 6). Over three environments studied, it is observed that days to 50% flowering (42.59% and 51.35%) contributed maximum to the genetic diversity in E2 and E3 environments while 100-seed weight (40.26%) was contributed maximum towards genetic divergence in E1 followed by days to 50% flowering (28.17%) and seed yield/plant (14.59%). The remaining characters contributed very low to this parameter. Several researchers have reported different characters contributing for genetic diversity in chickpea. Katiyar (1978) concluded that pod number/plant contributed maximum towards divergence. Study by Anil Kumar *et al.* (1993); Sarvaliya and Goyal (1994); and Kumar (1997) indicated that test weight was the major contributor towards diversity. Days to 50% flowering was the major contributor to diversity in the present study as also reported by Shinde *et al.* (1997). A study on genetic diversity by Jeethava *et al.* (2000) has revealed that seed yield/plant, pods/plant and test weight contributed maximum to genetic diversity. Thus contributing characters differ in respect of their contributions to the genetic diversity. Mostly expression of these characters differs due to environmental influence on the genotypes studied, besides the nature of genetic material under investigation.

The genetic diversity is directly related to the success of hybridization for developing varieties/releasing variability. The choice of parents is of paramount importance in any breeding programme. Selection based on extent of genetic divergence has been successfully adopted in pulses (Ramanujam, 1975) and has been used in planning hybridization programme by Rao and Chopra (1989).

In the present investigation it was observed that the genotypes of cluster XIX (ICC13124) had the highest mean value for pod number and earliness in E1. In E2, the genotypes of cluster XV (ICC12654) and XVI (ICC9848) were superior in respect of plant height, pods/plant and 100-seed weight, respectively. In E3, the genotype of cluster XVI (ICC13124) had the highest mean value for seed yield. Cluster XXIII (ICC6279) had the early maturing genotype and cluster XVIII (ICC5879) was superior in respect of pod number and tertiary branches/

plant and cluster V(ICC6816), cluster XI (ICC10341 and cluster XIII (ICC5504) had the tall genotypes. The clusters differed with respect to their *per se* performance.

A close look at Table 7 indicated that the clusters excelled in respect of different characters in 2004–05 rainfed experiment. The clusters XIX, XII, IX can be used as source of genes for high pod number, clusters XX and XVIII used as source of genes for higher 100 seed weight. The clusters XIX, V, XX, XIV can be used as good source of genes for earliness. The genotypes from these clusters may be accordingly selected as parents in crossing programme to incorporate genes for characters for which they excelled in performance during 2004–05 rainfed condition. During 2005–06 rainfed conditions, the clusters XV, XII, IX and XI can be used as source of genes for high pod number, clusters XVI, cluster X and VI used as source of genes for higher seed weight. The clusters VIII, XI and XIV can be used as good source of genes for earliness. From the irrigated experiment, the clusters XXIII and III appeared to be as good source of genes for earliness, clusters XVIII, XIV and cluster XII as source of genes for higher pods number. The clusters XXV, XXII, XXIII, and XIX can be used as good source of genes for bold seeded types. The genotypes of these clusters may be accordingly selected as parents in crossing programme to incorporate genes for characters for which they excelled in performance during their respective environments. Therefore, these genotypes may be involved in multiple crossing programme to recover transgressive segregates.

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Table 7. Cluster means for eight characters in chickpea minicore in three environments

				PLHT (cm)			PB			SB			TB			PPP			SDWT (g)			YPP (g)		
Clusters	E1	E2	E3	E1	E2	E3	E1	E2	E3	E1	E2	E3	E1	E2	E3	E1	E2	E3	E1	E2	E3	E1	E2	E3
I	60.70	49.31	53.58	35.88	38.60	46.42	2.56	3.54	3.69	14.41	8.35	9.09	19.00	15.80	18.50	41.06	77.02	70.71	14.05	15.88	16.39	16.92	17.82	19.07
II	78.00	68.47	65.37	32.50	42.33	48.19	2.90	3.92	3.56	15.00	9.46	8.69	19.00	16.86	19.09	36.00	67.52	62.01	9.25	14.83	18.85	12.65	14.24	19.47
III	63.50	56.48	43.68	37.50	40.13	47.31	2.50	3.96	3.86	13.00	9.88	10.21	17.00	17.95	21.18	40.50	81.67	91.98	22.80	18.16	17.36	13.30	28.16	21.92
IV	67.00	55.50	75.00	32.00	32.30	49.05	2.25	2.35	3.65	13.50	4.75	10.00	18.50	7.00	20.40	39.00	31.50	100.50	23.20	12.95	14.50	16.10	9.00	32.20
V	39.50	50.50	72.00	35.00	33.85	63.75	3.15	3.00	3.25	12.50	6.25	7.00	16.00	16.20	14.35	29.50	39.50	52.00	16.50	13.00	15.25	12.50	8.00	12.75
VI	66.00	67.03	73.50	38.50	38.00	55.70	3.00	3.93	4.85	18.00	8.71	12.50	24.50	15.68	24.10	40.50	65.86	70.00	22.75	24.53	14.00	16.15	18.23	15.85
VII	79.00	48.50	70.18	34.50	41.90	52.79	2.75	3.90	4.26	18.50	9.75	11.66	20.00	29.95	21.31	36.00	70.00	64.00	11.05	21.60	26.64	13.95	13.30	21.20
VIII	63.00	38.00	57.00	37.50	41.05	59.40	2.50	2.85	3.30	15.25	6.05	12.45	18.50	15.25	18.75	33.50	68.00	88.50	20.35	12.45	22.00	24.65	14.45	17.55
IX	47.58	52.00	55.00	34.60	49.45	48.05	2.51	5.05	5.15	12.82	12.95	15.20	18.14	32.00	27.80	44.93	125.00	40.00	18.18	23.40	13.95	22.85	13.70	21.55
X	69.55	53.38	55.00	44.95	39.77	49.25	2.55	3.22	4.00	14.15	7.63	15.80	18.93	20.29	17.90	38.55	65.94	99.50	25.78	31.19	13.10	17.90	26.78	13.20
XI	76.50	43.00	72.00	58.00	33.15	62.70	2.25	2.85	4.50	17.50	8.05	9.65	20.00	16.35	16.90	32.00	111.50	44.50	13.25	23.55	13.85	13.50	14.15	20.05
XII	46.50	57.00	57.00	31.50	41.75	54.15	2.00	2.95	4.60	8.75	6.70	13.75	13.00	26.30	21.40	45.50	136.00	127.50	29.10	16.70	14.70	22.05	8.35	12.05
XIII	72.00	47.00	58.50	57.00	25.10	60.95	2.50	3.05	5.05	11.00	9.40	13.65	14.50	24.50	23.20	41.50	27.50	67.50	11.20	19.90	17.95	12.80	9.80	17.75
XIV	40.50	44.00	72.50	32.00	48.10	48.75	2.25	3.80	2.90	14.50	15.50	11.50	17.50	29.25	22.35	44.00	67.00	146.00	29.90	17.00	15.85	21.45	18.05	27.00
XV	49.00	66.67	55.00	62.00	54.80	53.85	2.25	4.43	5.00	10.50	8.73	12.20	22.75	40.27	17.00	40.00	145.00	39.50	11.50	16.35	23.85	16.10	21.85	25.70
XVI	76.50	67.00	47.00	57.50	45.50	57.40	2.50	3.60	4.50	10.75	6.20	10.90	17.25	14.80	22.80	40.50	25.00	90.00	15.10	34.05	18.45	20.55	13.55	49.30
XVII	71.00		60.00	58.00		53.08	2.25		4.90	12.00		13.11	17.00		25.07	43.50		100.81	15.35		17.82	29.60		24.18
XVIII	47.50		48.00	35.50		38.85	2.00		5.35	11.50		12.65	21.50		26.30	40.00		199.50	33.80		16.85	18.70		10.20
XIX	35.00		55.00	32.00		52.60	3.50		3.75	15.35		10.00	18.50		16.25	49.50		59.00	28.55		35.70	13.00		28.55
XX	40.50		73.00	31.50		29.85	2.25		3.85	15.50		9.25	19.00		17.35	41.50		32.50	37.90		14.85	31.25		17.30
XXI			75.50			42.65			3.70			15.65			26.75			82.00			12.80			23.35
XXII			58.00			49.25			4.15			11.40			24.35			77.50			39.75			40.90
XXIII			42.38			45.99			3.64			10.99			22.81			92.50			36.25			25.09
XXIV			71.00			48.20			7.25			13.50			18.40			56.50			15.80			39.75
XXV			61.00			36.10			4.00			7.80			19.85			26.50			39.90			20.55

E_1 (Rainfed 2004–05), E_2 (Rainfed 2005–06) and E_3 (Irrigated 2005–06)

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