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RESEARCH ARTICLE

Assessment of Genetic Diversity of Small Cardamom (*Elettaria cardamomum* M.) in India

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As part of AICRP on Spices, a total of 200 germplasm accessions of small cardamom are being maintained at Cardamom Research Station Pampadumpara as field gene bank repository. Sixty seven cardamom accessions were studied for genetic diversity by evaluating fourteen characters for three years (2006-2009) continuously. Almost all accessions showed significant variability for the biometric and biotic stress characters. The results indicated a great amount of genetic diversity in small cardamom in the evergreen tropical forest of the Western Ghats.

Key Words: Field gene bank, Small cardamom, Western Ghats, Variability

Introduction

Cardamom, *Elettaria cardamomum* Maton, popularly called as 'Queen of Spices', and the economic part of which is the dried fruit of the perennial rhizomatous herb belonging to the family zingiberaceae. It is one of the costliest and most ancient and valuable spice crops since ancient times. The crop is indigenous to south India and Sri Lanka (Purseglove 1981) but Guatemala is the largest producer and exporter of the crop. The natural habitat of the crop used to be in the evergreen rainforests of the Western Ghats of south India at altitudes between 600 and 1500 m above MSL. Cardamom is generally cross-pollinated and propagated by seedlings and suckers; occasionally, selfing also occurs. Considerable variation is encountered in seedling progenies of cardamom (Padmini *et al.,* 2000). At present, the cardamom-growing area in India is concentrated mainly in those regions that are the natural habitat of the spices: between 8°30' and 14°30'N latitude and longitude 75-70'E. The area is an elongated tract from north to south from Sirsi of Karnataka to Thirunelvelli of Tamil Nadu. East to west, it is a narrow belt of highland distributed over the Western Ghats (Madhusoodanan *et al*., 1994).

Elettaria is a small genus having only 3-4 species spread across East and Southeast Asia. Two botanical varieties were distinguished by earlier researchers, one for the wild taxon and the other for the cultivated forms (Wardini and Thomas 1999). *E. cardamomum* var. *major* Thwaites consists of wild cardamoms that are common in Sri Lanka and southern India. *E. cardamomum* var. *cardamomum* (syn var. *minor* Watt. var. *minuscula* Burkill) consists of the cultivated cardamoms, which could be classified and named as cultivar groups. Detailed documentation of cardamom genetic resources was reported by Mayne (1951), Abraham and Tulasidas (1958) and Sudharshan *et al*. (1991). It is essential that sufficient variability for economic traits should exist in the cardamom germplasm for profitable utilization in the crop breeding programmes.

The monoculture farming practices, along with environmental degradation and urban development have contributed to the loss of plant genetic resources (Van Sloten, 1990) and therefore, erosion of these resources poses a severe threat to the world's food security in long term (FAO, 1996). Hence, characterization of genetic divergence for selection of suitable and diverse genotypes should be based on sound statistical procedures, such as D'- statistics and nonhierarchical Euclidean cluster analysis (Mahalanobis 1936; Spark 1973). These procedures characterize genetic divergence using the criterion of similarity or dissimilarity based on the aggregate effect of a number of economically important characters. In view of these, cardamom genotypes were evaluated in this study to determine the magnitude of variability in the population for yield and yield components as well as the grouping pattern of genotypes in different clusters.

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Materials and Methods

The germplasm materials consisting of 67 accessions (Table 1) collected from cardamom growing areas in south India were used in this study. These accessions were evaluated at the Cardamom Research Station, Kerala Agricultural University, Pampadumpara which is located in a medium rainfall zone (1500-2500 mm per annum) at an elevation of 1100 m above MSL.

The experimental field was planted with a spacing of 2m×2m comprising 10 experimental plants per accession. The recommended crop-growing practices (Package of Practices, Kerala Agricultural University, 2006) were followed uniformly to all accessions. Data on 14 characters were recorded from 10 plants based on the IPGRI descriptor of small cardamom during 2006 to 2009 and the average were taken for statistical analysis. The mean and coefficient of variation were calculated as per the standard statistical procedures.

Results and Discussion

Significant differences among germplasm accessions were observed for all traits that indicates the presence of higher variability. Previous authors have also reported the significance difference in various characters of cardamom and other crop genotypes. Korikanthimath *et al*. (2000) reported significant difference among cardamom genotypes particularly for number of capsules per plant, weight of fresh and dry capsule and oleoresin content. Ankegowda and Krishnamurthy (2008) have also showed variability in number of tillers, number of leaves and plant height that were significantly different for six cardamom germplasm accessions under moisture stress condition.

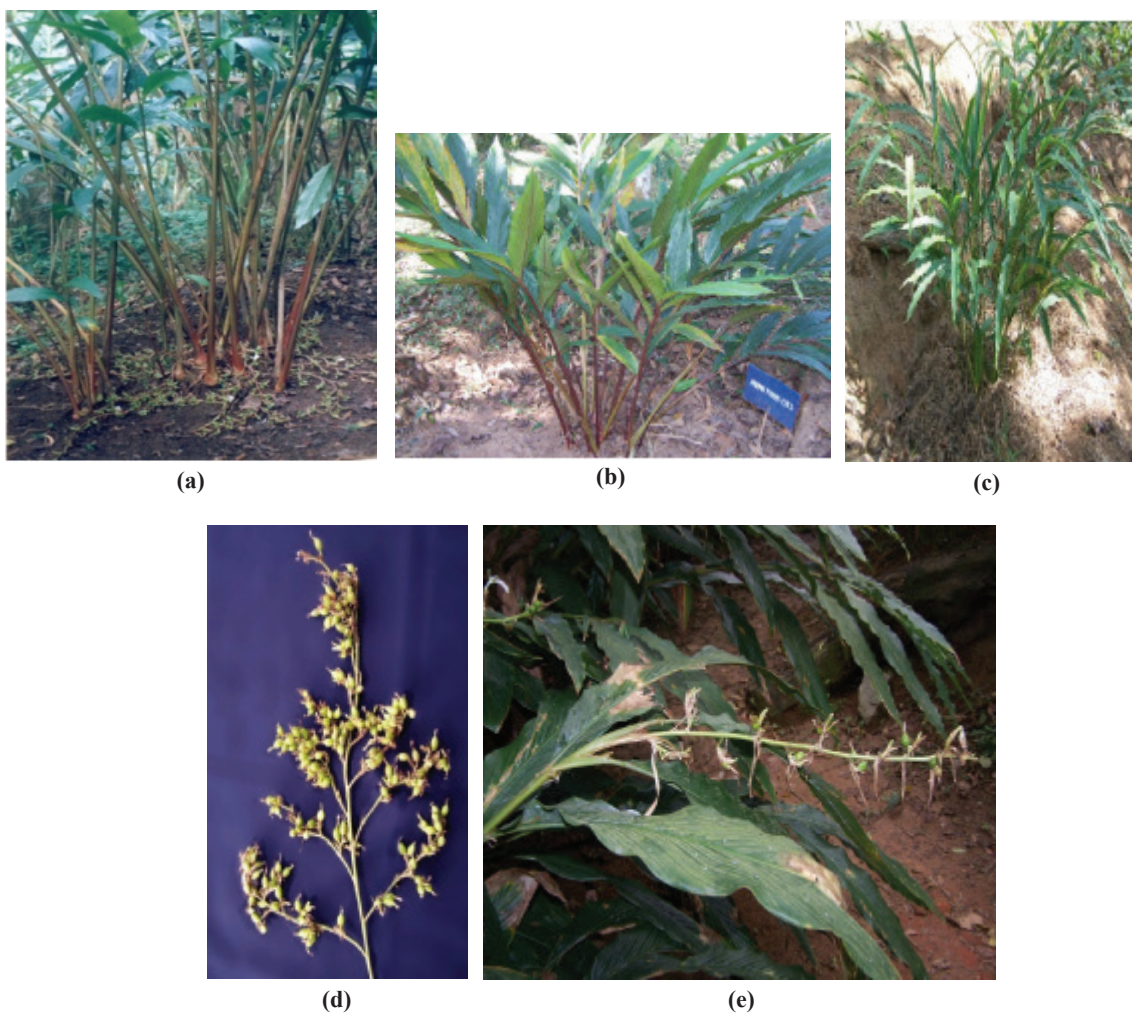

Fig. 1. Some small cardamom correlation- (a) Pink Base; (b) Mini Pink; (c) PV 8 (d) Multi branded panicle of MBP (e) Terminal panicle produced from Alfred clone

Table 1. Details of the cardamom accessions used in the genetic diversity analysis.

Sl. No.	Name of the land race/variety	Type	Source	Remarks
1	ACC 1	Vazhukka		Around 3 panicles per tiller, small globose shaped light green capsules
2	ALFRED CLONE	Malabar	From farmers' field	Presence of both terminal and basal panicle
3	BEP 1	Vazhukka	Selection from farmers' field	Close internodes between raceme
4	BEP 2	Vazhukka		Four panicles per tiller, light green colour capsules
5	CHETTI 1		Selection from farmers' field	Short stature
6	CHETTI 2			Tolerant to pest and diseases
7	CHETTI 3			
8	CLONE 37	Malabar	From IISR Regional Station, Appangala	Released as Appangala 1
9	CLONE 57			Globose light green capsule
10	COM.PAN	Malabar	Collection from Kodagu	Branched panicles
11	GREENGOLD	Vazhukka	Famers variety of Idukki	High yield with enhanced fertilizer response
12	HEMA	Vazhukka		Seventeen seeds per capsule
13	MANJURABAD	Malabar	From Shakleshpur	Three to four panicles per tiller
14	MBP	Malabar	Collection from Kodagu	Multibranched panicles
15	MCC 11		From ICRI Myladumpara	
16	MCC 40	Malabar	From ICRI Myladumpara	High yielder
17	MCC 61	Vazhukka	From ICRI, Myladumpara	Released as ICRI 2
18	MINI PINK	Malabar		Pink colouration at the base of the pseudostem
19	PINK BASE	Malabar		Pink colouration in the pseudostem
20	PPK 1	Vazhukka	Selection from farmers field	Long bold capsules
21	PPK 2	Vazhukka	Selection form green gold , Farmers variety	Extra long panicle but smaller capsules
22	PRO 17			Light green coloured rhizhome
23	PRO 107			Lower surface of leaf is glabrous
24	PS 10	Malabar	Plant selection from CRS	Elongated green colored bold capsules
25	PS 12	Vazhukka	- do -	Three panicles per tiller
26	PS 13	Malabar	- do -	Globose light green capsules
27	PS 14	Malabar	- do -	Round and light green coloured bold capsules
28	PS 16	Vazhukka	- do -	Elongated light green bold capsules
29	PS 17	Malabar	- do -	Light green coloured capsules
30	PS 18	Vazhukka	- do -	Elongated light green coloured capsules
31	PS 19	Vazhukka	- do -	Elongated green capsules
32	PS 2	Malabar	- do -	Bold elongated light green coloured capsules
33	PS 21	Vazhukka	- do -	Elongated light green capsules
34	PS 22	Vazhukka	- do -	Light green coloured bold capsules
35	PS 23	Malabar	- do -	Elongated green capsule
36	PS 24	Malabar	- do -	Green elongated bold capsules
37	PS 25	Malabar	- do -	Elongated light green capsules
38	PS 26	Malabar	- do -	Around fourteen seeds per capsule
39	PS 27	Malabar	- do -	High yielder with bold capsules
40	PS 28	Malabar	- do -	Green elongated capsules
41	PS 29	Malabar	- do -	Green elongated bold capsules
42	PS 30	Malabar	- do -	Bold elongated light green colored capsules
43	PS 31	Vazhukka	- do -	Bold elongated green colored capsules
44	PS 32	Malabar	- do -	Bold elongated green coloured capsules
45	PS 4	Malabar	- do -	Green elongated bold capsules

Sl. No.	Name of the land race/variety	Type	Source	Remarks
46	PS 5	Malabar	- do -	Green elongated bold capsules
47	PS 7	Malabar	- do -	Light green globose shaped capsules
48	PS 8	Vazhukka	- do -	Light green globose shaped capsules
49	PS 9	Vazhukka	Plant selection from CRS	Elongated green capsules
50	PV 10	Mysore	- do -	Light green coloured rhizome
51	PV 11	Vazhukka	- do -	Glabrous leaves
52	PV 12	Vazhukka	- do -	Elongated bold green coloured capsules
53	PV 2	Vazhukka	- do -	Bold elongated light green coloured capsule
54	PV 33	Malabar	CRS Pampadumpara	Light green elongated capsule
55	PV 34	Malabar	CRS Pampadumpara	Higher volatile oil content
56	PV 5	Malabar	- do -	Light green coloured globose shaped capsules
57	PV 6	Malabar	- do -	Dark green coloured capsules
58	PV 7	Malabar	- do -	Poor yielder
59	PV 8	Mysore	- do -	Narrow leaf lamina
60	PV1	Malabar	CRS Pampadumpara	Released variety with long thin capsules
61	S 1	Malabar	Seedling selection from commercial plantation of CRS	Higher yielder with long bold dark green capsules
62	Sinchona sel	Mysore		Light green coloured capsules
63	Type 1	Malabar	Seedling selection from the Malabar types	Around eighteen seeds per capsule
64	Type 103	Malabar	Seedling selection from the Malabar types	Around ten seeds per capsule
65	Type 4	Malabar	Seedling selection from CRS Pampadumpara	Light green coloured rhizome
66	Type 6	Malabar	Seedling selection from CRS Pampadumpara	Globose shaped light green coloured capsules
67	VEERAPUTHRAN	Malabar	From ICRI Myladumpara	Released variety as ICRI 1

Peculiar types in terms of physical appearance

Among all the landraces, morphologically peculiar types identified were Pink Base, Mini Pink, MBP, Alfred clone, Compound Panicle and PV8. Pink Base and mini pink were easily distinguishable from other landraces/ varieties due to their pink coloration in the pseudostem (Fig. 1). However, in the case of Mini Pink, Pink coloration is uniformly spread in the pseudostem and for Pink Base, pink colour is mainly concentrated on the base of the pseudostem. PV 8 could be distinguished by its narrow leaf lamina. All these three land races were poor yielders. MBP and compound panicle types were also categorized under land races that have multi branched panicles. Both of them were higher yielders due to their branched nature of panicles which bear more flowers. Alfred clone produces both basal and occasionally terminal panicles but found to be poor yielders when comparing it with other land races.

Variability in yield and biotic stresses

Almost all the cultivars showed significant differences in fresh capsule yield at 1% and 5% levels. Among cultivars the highest wet weight was reported by PPK 2 (3051 kg/ha) but it was on par with other cultivars like Sinchona Sel, PS 27, PS 10, MBP, BEP 1, BEP 2, CHETTI 1 and PS 28. The ultimate and penultimate lowest yield was reported by Pink Base and PV 6, respectively.

The highest dry yield recorded for PS 28 (560 kg/ha) was on par with PS 10 and PPK 2 and the lowest yield was recorded from the Pink Base. The data on the wet and dry capsule yield showed poor yielding nature of the cultivar. Weight of 100 capsules recorded for clone 57 was maximum (116 g) followed by PS 22 and PPK 1 but they were statistically at par with each other. Capsule weight was minimum for PS 7 (73 g)

Table 2. Pooled analysis (2006-2008) of yield and biotic stress characters.

Name of the cultivar	Wet weight	Dry weight	100 capsule weight	Incidence of thrips	Incidence of borer	Incidence of Azhukal
ACC 1	1373.500	297.000	97.000	21.656	0.707	1.171
ALFRED CLONE	922.500	163.000	92.500	19.358	0.977	0.707
BEP 1	2103.500	456.500	104.000	12.494	0.707	0.707
BEP 2	2034.000	445.000	94.000	25.411	1.171	1.225
CHETTI 1	2074.500	319.000	75.000	27.271	0.977	0.707
CHETTI 2	1137.000	209.000	105.500	20.889	0.977	0.707
CHETTI 3	930.500	172.000	99.000	25.741	1.171	1.171
CLONE 37	421.500	87.500	89.000	16.430	0.707	0.707
CLONE 57	1772.500	90.500	**116.000**	18.787	0.707	1.171
COM.PAN	1610.166	367.500	104.000	13.554	1.331	0.977
GREENGOLD	1865.000	399.000	103.500	25.463	**1.728**	0.707
HEMA	210.300	46.500	76.500	15.105	0.977	0.707
MANJURABAD	1016.500	187.500	98.000	26.176	1.559	1.225
MBP	2001.000	405.500	99.000	20.257	1.225	0.707
MCC 11	1060.500	200.500	100.500	25.411	1.595	0.707
MCC 40	910.500	178.500	94.500	17.171	0.977	0.707
MCC 61	1170.000	185.000	101.500	21.837	1.171	1.171
MINI PINK	289.500	63.000	88.000	23.033	0.977	**1.331**
PINK BASE	**160.500**	**34.625**	95.000	17.948	1.470	0.707
PPK 1	1623.000	334.500	**115.000**	21.898	1.693	0.707
PPK 2	**3051.000**	509.000	81.000	22.396	0.707	1.171
PR 17	456.000	103.000	83.500	16.833	1.171	0.707
PRO 107	259.500	59.000	92.500	22.455	0.707	0.707
PS 10	2635.500	**558.000**	107.000	18.824	0.707	0.707
PS 12	2166.500	454.500	104.000	20.584	0.977	1.171
PS 13	1891.500	411.000	102.500	14.535	1.693	0.707
PS 14	1566.750	319.000	92.500	18.265	1.171	0.707
PS 16	2580.500	194.000	86.000	14.049	0.707	0.707
PS 17	412.150	79.000	85.000	**7.759**	0.977	0.707
PS 18	1383.500	203.500	95.500	19.166	0.707	0.707
PS 19	1022.500	207.500	94.000	33.825	1.331	0.707
PS 2	1571.000	322.350	94.000	19.533	0.707	0.707
PS 21	1208.500	233.500	111.000	12.746	1.581	0.977
PS 22	1655.500	273.500	**115.500**	19.166	1.581	**1.331**
PS 23	1337.333	376.000	104.000	11.477	1.470	0.707
PS 24	887.500	163.000	99.000	25.161	1.331	0.707
PS 25	995.000	184.000	104.000	**45.407**	0.707	0.707
PS 26	1515.000	319.000	101.000	28.308	0.707	0.977
PS 27	2478.500	459.500	98.500	15.956	0.707	0.707
PS 28	**3018.000**	**560.000**	100.000	28.956	0.977	0.707
PS 29	1016.000	201.500	102.500	10.611	1.225	0.977
PS 30	493.500	89.500	87.500	13.481	0.977	0.707
PS 31	630.000	139.000	82.500	15.240	1.331	0.977
PS 32	1175.500	234.000	86.500	18.741	1.171	0.707
PS 4	1321.000	263.500	88.500	10.765	1.559	0.707
PS 5	1488.000	331.500	93.500	15.889	0.977	0.707
PS 7	692.000	113.500	**73.000**	11.021	0.707	0.707

Name of the cultivar	Wet weight	Dry weight	100 capsule weight	Incidence of thrips	Incidence of borer	Incidence of Azhukal
PS 8	676.000	107.000	91.500	14.707	1.693	0.977
PS 9	1011.500	224.500	91.500	20.495	1.171	1.171
PV 10	1643.000	367.500	91.000	14.764	0.977	0.707
PV 11	620.500	131.500	89.000	17.948	0.707	0.707
PV 12	1321.500	266.500	103.500	15.846	**1.728**	0.707
PV 2	918.500	204.000	92.000	25.489	0.707	0.707
PV 33	718.000	139.500	91.000	26.720	0.707	0.707
PV 34	476.000	90.000	96.500	19.680	0.707	0.707
PV 5	407.250	92.500	84.000	16.739	1.559	0.977
PV 6	**161.500**	35.000	83.500	22.384	0.707	0.977
PV 7	249.500	42.166	**74.000**	18.421	1.225	0.707
PV 8	422.500	139.500	**75.000**	17.777	0.707	0.707
PV1	905.000	186.000	90.500	29.374	1.225	0.977
S 1	1291.000	225.900	100.000	18.880	1.171	0.977
Sinchona sel	2516.500	440.500	106.500	23.292	0.707	0.977
Type 1	855.000	155.500	106.000	20.889	1.171	0.707
Type 103	1027.500	203.000	103.000	17.441	0.977	0.707
Type 4	609.000	136.000	100.500	16.078	1.171	0.977
Type 6	256.000	49.500	112.000	18.824	0.707	0.707
VEERAPUTHRAN	655.500	149.000	98.500	14.049	0.707	0.707
CV	50.203	68.197	31.431	32.641	28.704	24.1
CD (1%)	1266.21	350.814	65.540	13.494	0.647	0.425
CD (5 %)	963.42	266.92	49.864	10.267	0.492	0.323

which was at par with PV 7 and PV 8. PPK 2 and PS 28 can be recommended for breeding programmes on the account of their higher yield potential.

None of the cultivars was free from pests and disease incidence however, some of the cultivars showed significant difference in pest and disease infestation both at 1% and 5% level. This indicated that cultivars were susceptible to various biotic stresses at varying levels. Incidence of thrips infestation ranged from 7.759 % in PS 17 to 45.407% in PS 25. In the case of capsule borer incidence, infestation ranged between 0.707 % and 1.728%. Green Gold and PV 12 showed the highest borer incidence. However Green gold was the most popular variety cultivated in Idukki district of Kerala. Varied level of incidence of Azhukal disease among cultivars/landraces was shown, but the highest level of the disease incidence was shown by PS 22 and Mini pink.

Variability in Yield Attributing Characters

The accession Veeraputhran registered highest plant height. Among these characters, the highest variability was noticed for number of capsules/plant (64.40%) followed by panicle length and number of panicles/ plant. According to Padmini *et al*. (2000) the highest variability was noticed in *Malabar* accessions where in the number of panicles per plant varied greatly. MBP recorded the highest number of capsules/plant (3139.2) which was mainly attributed to its branched nature of panicles. The number of panicles per plant was maximum in Veeraputhran (46.66). Moderate variability was reported on the number of internodes per panicle, number of panicles per tiller and number of tillers per plant. Type 103 registered the highest number of internodes per panicle (38) and highest panicle length. The least variability was shown for plant height and number of seeds per capsule. Backiyarani *et al*. (2000) have confirmed least coefficient of variance for the number of seeds per capsule.

Cluster Analysis

Agglomerative hierarchical clustering analysis has been done using the mean values of fourteen characters including the yield attributing and biotic stresses. The accessions studied were grouped into fourteen clusters which show the magnitude of variability. This may have arisen through decades of domestication events occurring

Table 3. Pooled data (2006-2008) of yield attributing characters.

Accession	Plant height(cm)	No. of tillers/ plant	No. of panicles/ plant	No. of capsules/ plant	Panicle length (cm)	No.of panicles / tiller)	Number of internodes/ panicle	No. of seeds /capsule
ACC 1	266.66	28.66	12	466.3	42	3	22	16.1
Alfred clone	152.66	44.66	3.33	501.3	39	3	22	16.7
BEP 1	295.33	27.66	18.33	1355.5	24	4	19	16.5
BEP 2	225	40.33	13	815.6	45	3	21	14.7
CHETTI 1	282	34.33	28.33	1041.3	25	2	19	12.3
CHETTI 2	265.66	19.66	15	1114.7				13.3
CHETTI 3	268.33	32.33	13	954.6	24	3	24	15.8
CLONE 37	256	35	18	1186.6	50	4	25	14.9
CLONE 57	228	41.66	18.33	1067.2	43	2	22	13.1
COM. PAN	329.33	45.33	23	1502.2	85	3	34	14.7
GREEN GOLD	255.33	26.33	8.33	1451.6	19	2	16	15.3
HEMA	269.66	34	16.6	889	71	3	29	16.8
MANJURABAD	220.33	48.66	8.6	924.3	25	3	17	17.1
MBP	328.66	32.33	31	**3139.2**	69	2	34	11.8
MCC 11	266.2	26	21.66	2010.6	34	2	25	14.4
MCC 40	292	29	10	1041.2	19	1	16	11.7
MCC 61	241.33	28.33	5	156.3	12	1	7	13.1
MINI PINK	306.66	21	14.66		43	3	21	11.7
PINK BASE	245	24	9.33	203.3	55	3	1	14
PPK 1	213.66	51	24	739	30	3	14	12.7
PPK 2	261	32.33	31	1050.6		3	18	14.4
PRO107	291	32.66	23.66	1111.6	29	2	19	16.2
PRO17	260	23	23	450.6	14	2	11	16.6
PS 10	301	36	16.33	1637.6	39	3	20	11.5
PS 12	325	22.66	31.33	1895.9	49	3	20	20.3
PS 13	214	26.66	8.66	991.6	28	2	17	14.3
PS 14	210.66	38.33	7.33	790.9	42	4	22	12.8
PS 16	218.33	24	12	1158.6	39	3	20	15.4
PS 17	215	40.33	14.33	298	38	2	21	14.9
PS 18	330	24.66	40.66	783.2	47	2	12	12.9
PS 19	251.66	5.33	27.33		39	4	28	14.1
PS 2	270.66	23.33	3.66	1141.6	43	1	17	13.3
PS 21	274.66	18	5.66	673.3	21	2	20	19.9
PS 22	278.66	18.66	23.66	1207.8	63	1	17	15.4
PS 23	239.66	35	21.66	920	42	2	19	13.5
PS 24	295.33	30	33	1817.9	30	3	20	14.4
PS 25	264.33	35.66	20.66	409.3	63	2	33	13.7
PS 26	229	32	23	1356.9	18			14.3
PS 27	284.33	27.33	17	1433.5	23	3	19	11.3
PS 28	224	37.33	15.33	576.6	17	2	16	13.7
PS 29	265	32	28	1687.6	34	3	21	12.4
PS 30	252.33	31	20.33	779.9	34	2	25	10.4
PS 31	312.66	26	30.33	2050.5	60	2	24	17.3
PS 32	244	24	11	110	30	2	18	12.5
PS 4	290	24	23.33	1852.6	85	4	19	14.8
PS 5	318.33	24.6	15	1188.3	43	3	37	16.4

Accession	Plant height(cm)	No. of tillers/ plant	No. of panicles/ plant	No. of capsules/ plant	Panicle length (cm)	No.of panicles / tiller)	Number of internodes/ panicle	No. of seeds /capsule
PS 7	288.3	31.66	36	1621.9	26	2	16	14.1
PS 8	296.66	31.33	16.66	430.5	30	2	13	10.6
PS 9	358	29	33.66	2674.4	45	2	21	15.6
PV 33	332.33	15.33	17.66	813.6	42	3	24	15.1
PV 34	269	23.33	11	529	20	2	16	12.8
PV1	156.33	31.33	4	474.5	15	2	8	9.6
PV10	234	**46.33**	14.66	132.9	26	2	16	9.4
PV11	207.66	37.66	27	273	19	1	11	12.5
PV12	216.66	62	8.6	261.9	33	2	19	13.5
PV2	220	35	20.3	558.2	40	4	11	12.1
PV5	277.33	43	17	589.2	68	2	23	14.1
PV6	242.33	37	24.33	719.9	50	2	21	15.3
PV7	194	31.33	8		14	2	10	10
PV8	215	44	12.66	281	10	2	9	8.1
S -1	340.66	33.66	37.33	2464	60	4	28	17.3
Sinchona sel.	254.33	20	20	861.6	29	1	14	18.5
TYPE 1	294	53.66	29	602.3	30	2	16	18.5
Type 103	271.66	25	19.66	700.2	**90**	4	**38**	10.6
TYPE 4	282	33.66	16.3	267	24	2	15	11.9
TYPE 6	211	27	5	256.3	44	3	24	10.9
Veeraputhran	**356**	38.33	**46.66**	1936.3	48	3	22	14.8
Mean	263.3679	31.71269	18.86	1005	38.26	2.476	19.630	14.010
SD	43.77519	9.566578	9.5737	647.9	18.21	0.831	6.913	2.46620
CV	16.62131	30.16641	50.737	64.40	47.6	33.55	35.218	17.602

Table 4. Cluster details of landraces/cultivars.

Cluster Number	Accessions included	Number of accessions	Central accession
1	ACC 1, PRO 17	2	ACC 1
2	Alfred clone, BEP 2, Chetti 1, Chetti 3, Hema, MCC 40, PPK 1, PRO 107, PS 14, PS 19, PS 23, PS 30, PS 5, PV 1, PV 6, Sinchona Sel.	16	Sinchona Sel.
3	BEP 1, Chetti 2, Clone 37, Clone 57, Compound panicle, Green gold, Manjuarabad, MBP, MCC 11, Mini pink, PPK 2, PS 10, PS 12, PS 13, PS 16, PS 2, PS 22, PS 24, PS 26, PS 27, PS 29, PS 31, PS 4, PS 7,PS 9, S1, Veeraputhran	27	PS 7
4	MCC 61	1	MCC 61
5	Pink base	1	Pink base
6	PS 17, PS 25, PS 8	3	PS 25
7	PS 18, PS 21, PS 28, PV 33, PV 34, PV 2, PV 5, PV 7, Type 1	9	Type 1
8	PS 32	1	PS 32
9	PV 10	1	PV 10
10	PV 11, PV 8	2	PV 11
11	PV 12	1	PV 12
12	Type 103	1	Type 103
13	Type 4	1	Type 4
14	Type 6	1	Type 6

from different parts of Cardamom Hill Reserve. However there was no definite clustering based on the source from which these accessions were collected. It may be due to the use of seedlings as planting material in the initial years of commercial cultivation of cardamom. No definite clustering was observed for peculiar genotypes. This revealed low correlation between the biometrical and morphoqualitative characters. Accessions from the same cultivar group *(Malabar/Vazhukka/Mysore)* were scattered in different clusters. This indicated the possibilities of a common ancestral type and close relationship of the genotypes of these three groups and also that the geographical origin was not the single factor for genetic divergence in cardamom (Prasath and Venugopal, 2004).

Cluster 3 was the largest one with 27 accessions (Table 4) and showed high level of genetic interrelationship among them. Therefore hybridization between these accessions may not lead to the production of progenies with high hybrid vigour due to their genetic similarity. The cluster consisted of Green Gold, PPK 2, Clone 37, Veeraputhran, PS 27, Mini Pink etc. The central accession in Cluster 3 was PS 7. Pink Base, MCC 61, PS 32, PV 10, PV 12, Type 103, Type 4 and Type 6 have formed separate clusters individually. This indicated that the variability from other cultivars with respect to its yield and yield attributing characters were different. Maximum inter-cluster distance existed between cluster 8 and 3 (1489) followed by cluster 9 and 3 (1466).

Conclusion

The present study focused on intra specific variation in cardamom with respect to yield and yield attributing characters. The accessions collected in South India and conserved at the Cardamom Research Station are an important genetic reservoir of variability. The collected germplasm accessions are now conserved in ex situ as field gene banks. Thus, there is an excellent opportunity to bring about improvement through direct selection and hybridization which can involve crossing of genotypes from different clusters. The cluster analysis showed that there was no definite clustering based on cardamom types or centre of diversification. The information gathered in this study could be used as a guide for further breeding programmes in cardamom.

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Conflict of interest

The authors declare no conflict of interest.

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