A STUDY OF VARIABILITY, PERFORMANCE AND ADAPTABILITY OF SOME ELITE LANDRACES AND HYBRIDS OF SMALL CARDAMOM (*Elettaria cardamomum* Maton)

Thesis submitted in part fulfilment of requirements for the Degree of Doctor of Philosophy in Botany of the University of Calicut

By

T.K.HRIDEEK

GENETICS AND PLANT BREEDING DIVISION
DEPARTMENT OF BOTANY
UNIVERSITY OF CALICUT
KERALA, INDIA
2007

UNIVERSITY OF CALICUT
GENETICS AND PLANT BREEDING DIVISION
DEPARTMENT OF BOTANY
Calicut University (P.O.), 673635 Kerala India

Phone: 0494 2401144*406 Fax: 0494 2400269 E mail: drkvmohanan@rediffmail.com

Dr.K.V.Mohanan
Reader & Research Guide

CERTIFICATE

Certified that this thesis entitled **'A STUDY OF VARIABILITY, PERFORMANCE AND ADAPTABILITY OF SOME ELITE LANDRACES AND HYBRIDS OF SMALL CARDAMOM (*Elettaria cardamomum* Maton)'** embodies the results of a piece of bona fide research work carried out as part fulfilment of requirements for the degree of Doctor of Philosophy in Botany of the University of Calicut by Mr. T.K.Hrideek under my guidance and supervision and that no part of the thesis has been submitted for any other degree.

I further certify that such helps or sources of information availed of in this connection have been duly acknowledged.

Calicut University
22 March 2007

UNIVERSITY OF CALICUT
UNIVERSITY DEPARTMENT OF BOTANY

(Dr.K.V.MOHANAN)

DECLARATION

I, T.K.Hrideek, hereby declare that this thesis entitled **'A STUDY OF VARIABILITY, PERFORMANCE AND ADAPTABILITY OF SOME ELITE LANDRACES AND HYBRIDS OF SMALL CARDAMOM (*Elettaria cardamomum* Maton)'** being submitted in part fulfilment of the requirements for the award of Ph.D. Degree in Botany of University of Calicut embodies the results of a bona fide research work done by me under the guidance of Dr.K.V.Mohanan, Reader and Research Guide, Genetics and Plant Breeding Division, Department of Botany, University of Calicut and that no part of it has been submitted for any other degree.

Calicut University
22 March 2007

T.K.Hrideek

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to my
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and those who make all the things possible

PREFACE

Small cardamom is a very important spice crop of the world and popularly it is known as the queen of spices. It originated in the hilly tracts of the Western Ghats of South India. Now it is cultivated in other countries like Guatemala, Sri Lanka, Papua New Guinea and Tanzania besides India. It is valued for its flavour and medicinal properties. Even through it earns a considerable amount of foreign exchange, there are problems related to productivity, production and marketing. Small cardamom (*Elettaria cardamomum* Maton) has three natural morphotypes, *Malabar, Vazhukka* and *Mysore* based on the nature of panicles. Most of the farmers propagate cardamom clonally. Even though about twelve improved varieties have been released in India, many of the farmers depend on native elite landraces for their planting materials. Hence it is important that efforts are made to study the variability among such land races so as to select superior genotypes from them. Only a few cardamom hybrids have been released till date for cultivation. Hence hybridization and screening of hybrid germplasm to select superior plants is also important. Cardamom is highly habitat specific and hence screening varieties suitable for different agro climatic zones should be carried out so as to come out with genotypes suitable for each location. The present study is a humble effort in these directions.

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Chapter I

INTRODUCTION

Small cardamom, often referred to as the 'queen of spices' is the commercial product obtained from the Zingiberaceous, perennial, rhizomatous plant *Elettaria cardamomum* Maton. It is grown extensively in the Western Ghat region of South India at an elevation of 800-1300 m as an undercrop in forest lands. It is also grown in countries like Guatemala, Sri Lanka, Papua New Guinea and Tanzania.

Cardamom is native to the moist evergreen forests of Western Ghats of South India (Ravindran, 2002). The genus *Elettaria* is represented in India by only one species, *Elettaria cardamomum* Maton. However, other species of *Elettaria* have been described from other parts of the world (Mabberley, 1987; Sakai and Nagamasu, 2000).

The cardamom growing region of South India lies within 8^0 and 30^0 N latitudes and 75^0 and $78^0 30'$ E longitudes. Cardamom is cultivated in India in an area of 73,000 ha out of which Kerala occupies 60%, Karnataka 30% and Tamil Nadu 10% (Thomas, 2006). Cardamom production in India during 2005-06 was 12540 MT (Anonymous, 2006). Presently Guatemala is the largest producer of cardamom with about 20,000-22,000 MT of production annually (Thomas, 2006).

Known as *Ela* in Sanskrit, cardamom is known to be used in India from ancient times, even from the *vedic* period. However, collection of cardamom fruits from naturally growing plants was the major practice in India till 19^{th} century and organized cultivation started only later (Ridley, 1912). Cardamom was a very important product of commercial trade in the British India and buyers were mainly the Muslim merchants (Watt, 1872).

Elettaria cardamomum Maton is represented in nature by three varieties namely var. *Malabar*, var. *Mysore* and var. *Vazhukka* based on the nature of

panicles. Var. *Malabar* is characterized by prostrate panicles; var. *Mysore* by erect panicles and var. *Vazhukka* by semi erect panicles. Var. *Vazhukka* is considered a natural hybrid between var. *Malabar* and var. *Mysore* (Madhusoodanan *et al.*, 2002).

Cardamom is a major flavouring agent used in food products, beverages and medicines. It is used in Indian systems of medicine like Ayurveda, Siddha and Unani. Cardamom is carminative, diuretic and stomachic. It is used to prevent nausea, vomiting due to morning sickness and also bad smell of mouth. It is used to increase urination and to control palpitation of heart. The use of capsules with honey improves eye sight and strengthens nervous system. Cardamom powder mixed with ghee and honey is used against dry cough. Cardamom oil and cardamom powder paste are effective against skin diseases. It is used in more than 110 ayurvedic preparations. Green bold capsules are considered of premium quality both in export and domestic markets. However, bleached and half bleached cardamom is also being traded.

Systematic research on cardamom was initiated in India in 1944. Much information on scientific management of cardamom plantations has been generated. Primary mandates of cardamom research in India are crop improvement, development of agro techniques and development of strategies for integrated nutrient and pest and disease management. Twelve improved varieties of cardamom have been released in India so far (Thomas, 2006).

Even though the improved varieties of cardamom are being used by farmers to some extent, many of them still depend on promising landraces for planting materials. Being a crop that is mainly propagated clonally using suckers; screening of such landraces so as to select promising genotypes from them has immense potential in crop improvement of cardamom. Till date only a few hybrids have been released in cardamom and hence hybridization and selection of promising genotypes from the resultant segregating populations also can be used as an important tool in cardamom improvement.

Cardamom strains are highly niche specific and hence screening suitable strains adaptable to different growing regions is also necessary. The present experiments have been designed with the above objectives.

The experiments consist of analysis of ten elite landraces of cardamom collected from the Idukki district of Kerala, India in comparison with a released variety ICRI-2 based on genetic variability, heritability, genetic divergence, interrelationship of characters, character association and relationship between genotypes; screening of certain hybrid populations of cardamom for selecting the most promising hybrids from them and a study of adaptability of certain pipeline hybrids and landraces of cardamom to Wayanad conditions.

Chapter II

REVIEW OF LITERATURE

2.1. Small cardamom

The small cardamom plant is botanically known as *Elettaria cardamomum* Maton and it belongs to the monocotyledonous family Zingiberaceae. It is believed to have originated in the moist ever green forests of the Western Ghats of South India (Ravindran, 2002). The name of the genus is derived from the Tamil root *elettari*, meaning cardamom seed (Mabberley, 1987). Burtt and Smith (1983) have provided the taxonomic description for *Elettaria cardamomum.* Small cardamom is perennial and rhizomatous and usually perennating by rhizomes. The essential feature of the inflorescence of *Elettaria* is a prostrate axis bearing two ranked sheaths with a cincinnus in the axil of each. The inflorescence is a racemose panicle of cincinni.

Sakai and Nagamasu (2000) have described six species of *Elettaria* (*Elettaria stolonifera, Elettaria kapitensis, Elettaria surculosa, Elettaria linearicrista, Elettaria longipilosa and Elettaria brachycalyx*). The Sri Lankan wild cardamom *Elettaria ensal* (Gaertn.) Abheywickrama (*Elettaria major* Thawaites) is morphologically similar to the true cardamom, but more robust, bearing erect panicles and much elongated fruits (Abheywickrama, 1959). However, Burtt (1980) as well as Burtt and Smith (1983) did not treat this as a separate species, but they included it under *Elettaria cardamomum.* Holttum (1950) is of opinion that Malaysian and Indian species of *Elettaria* represent parallel developments from different points of origin in the *Alpinia stock.* Small cardamom is a perennial rhizomatous herb with under ground rhizome.

According to the nature of panicle orientation, cardamom plants have been divided in to three natural varieties namely var. *Malabar* with prostrate panicles, var. *Mysore* with erect panicles and var. *Vazhukka* the natural hybrid of the above two with semi erect panicles (Sastri, 1952).

According to Gregory (1936) cardamom is tetraploid with a basic chromosome number of x =12 and 2n = 48. Ramachandran (1969) and Sudharshan (1989) have also reported the tetraploid nature of small cardamom with 2n = 48.

The aerial stem of the leafy shoot has the typical monocot structure. Rhizome is sharply differentiated in to an outer cortex and central core (Tomlinson, 1969 and Mercy *et al.*, 1977).

Tillers emerge from the axils of underground stem and from their bases vegetative buds emerge almost throughout the year. However, majority of the vegetative buds are produced during January-March. The linear growth of tillers increases with the onset of south west monsoon and growth rate slows down with the cessation of rains. It takes about ten months for a vegetative bud to develop and one year for a panicle to emerge from the newly formed tillers (Sudharshan *et al.*, 1988). Kuruvilla *et al.* (1992) have carried out a round the year study on the phenology of tillers and panicles in the three natural varieties of cardamom. It takes about 90-110 days for the first flower in a fresh panicle to open irrespective of the variety.

Kulandaivelu and Ravindran (1992) studied the photosynthetic activity of three cardamom genotypes, measured as the rate of O_2 liberated by isolated chloroplasts. Results showed drastic reduction in photosynthetic rates in plants exposed to warm climate. As much as 60-80 per cent decreases in the level of total chlorophyll was noticed in all the three varieties tested. Light requirement for cardamom nursery is about 55 per cent of the normal (Ranjithakumari *et al.*, 1993) and at this light intensity, growth and tiller production are the best.

2.2. Germplasm collection, conservation and evaluation in cardamom

The monoculture practices, environmental degradation and urban development have contributed to loss of plant genetic resources (Van Sloten, 1990) and erosion of these resources poses a severe threat to the world's food security in long term (FAO, 1996). The need to protect and conserve these resources more

long term (FAO, 1996). The need to protect and conserve these resources more systematically is getting recognised now more and several programmes are presently operating for the purpose (Van Sloten, 1990).

Among the eighteen biodiversity hotspots identified in the world two are in India, the Eastern Himalayas and the Western Ghats (Khoshoo, 1996). The hill chain of Western Ghats has been recognized as a region of high levels of biodiversity under threat of rapid loss. The Western Ghats harbour a large number of endemic species. Inventorying, monitoring and conserving the biodiversity of Western Ghats is therefore an important concern (Gadgil, 1996).

2.2.1. Genetic resources of cardamom

The most essential prerequisite in plant breeding is to have good collection of germplasm consisting of all sorts of variants available. In 1950s two surveys were conducted in India in the cardamom growing areas to record the practice of tapping the resources from wild populations (Mayne, 1951) and to understand geographical distribution and environmental impact on cardamom (Abraham and Thulasidas, 1958). Indian Cardamom Research Institute (ICRI) also conducted surveys for conservation and exploitation of cardamom genetic resources (Madhusoodanan *et al.*, 1999). Besides, numerous exploration missions have been carried out by Indian Institute of Spices Research leading to the collection of about 310 accessions of cardamom (Prasanth and Venugopal, 2004).

The collected germplasm accessions are conserved *ex situ* in *in vivo* and *in vitro* germplasm repositories. Accessions with distinct morphological marker characters such as compound panicle types, terminal panicle bearing, narrow leaf types, pink pseudostem types, dark green and bold capsule types and high yielding biotic stress tolerant types are conserved in the repositories besides others. *Ex situ* collections in cardamom has been mainly maintained as field gene banks and they are used for characterization and evaluation. Many variations in morphological and chemical characters and yield have been recorded in these collections (Zachariah and Lukose, 1992 and Zachariah *et al.*, 1998).

Efforts to conserve cardamom genetic resources *in situ* are scanty even though natural populations occur in protected forest areas. In the Silent Valley National Park of Kerala State of India a sizeable population of cardamom plants exist under natural conditions. *Ex situ* germplasm is always at risk due to a variety of reasons, mainly biotic and abiotic stress factors. The prevalence of viral diseases is a serious threat to *ex situ* conservation of cardamom germplasm. An alternative is *in vitro* conservation and establishment of *in vitro* gene banks (Madhusoodanan *et al.*, 2002). Indian Institute of Spices Research, Calicut, India is maintaining *in vitro* conserved cardamom germplasm (Babu *et al.*, 1999).

2.2.2. Studies on variability and selection

Pattanshetti *et al.* (1973) described cardamom selection for early and high yield. In their study the dry capsule yield from 3 cardamom selections in three year old plants was about 450 kg/ ha. Capsule weight showed a maximum of 807 mg. Recovery percentage was 26.6 on the average. In a study by Parameswar and Haralappa (1980) the highest average yield over three seasons was observed as 487.6 kg/ ha.

In a collection of more than 280 wild and cultivated accessions of small cardamom, the range of reproductive structures and breeding systems was observed by Dandin *et al.* (1981). For example, one clone produced no panicles, another had only rudimentary flower like structures and another exhibited female sterility. Some clones were self compatible. George *et al.* (1981) measured twelve characters in 180 accessions of wild and cultivated cardamom under uniform conditions and found that panicle characters were the most variable.

Yield components of cardamom in Sri Lanka were subjected to correlation and path analysis by Sritharan *et al.* (1993). The data on vegetative and reproductive characteristics of cv. *Vazhukka* were analyzed. This study revealed that plant characteristics such as number of pseudostems per plant, leaf length, number of panicles per plant, length of a fully developed panicle and number of capsules in a panicle had a higher association with yield than other parameters. These characters

could be used as selection criteria in a crop improvement programme for maximizing yield. Correlation studies revealed highly significant and positive correlation of yield with number of panicles, length of panicles and number of suckers (Avadhani *et al.*, 1993).

Seventy two cardamom accessions were evaluated for five years at Pampadumpara, Kerala, India for vegetative and economic characters and susceptibility to insect pests by Miniraj *et al.* (2000). Prasanth and Venugopal, (2004) evaluated three hundred and ten accessions of cardamom germplasm for sixteen characters. Nine of the characters showed high variability. Following non hierarchical Euclidean cluster analysis the genotypes were grouped into three clusters with a variable number of genotypes in each cluster. Accessions of three cultivar groups were often grouped together in the same cluster, suggesting some degree of common ancestry between the three groups.

In a preliminary evaluation of 34 cardamom accessions, panicle number per plant, panicle length, percentage fruit set and mean yield per plant were found to be significantly greater in prostrate panicle types than in semi erect or erect panicle types. Of the 19 prostrate forms, 8 produced yields exceeding 500g/ plant (Sudharshan *et al.*, 1989). Three natural varieties (*Malabar*, *Mysore* and *Vazhukka*) and the high yielding clone PV1 were grown during 1986 and data on 13 yield components measured by Gopal *et al.* (1990). Panicles per plant, capsule fresh weight per plant, nodes per panicle and internodal length within the panicle were useful characters in selecting for yield improvement.

Eight cultivars of cardamom were planted in 1984 and evaluated for eight yield and three morphological characters during two seasons (1986-88) by Kuriakose and Sadhankumar (1990). Variability was observed between the cultivars for most of the characters but consolidated data showed that PV1, a *Malabar* type was significantly superior to all the others. In cardamom cultivation under high production technology, the highest yield 1625 kg/ ha (dry) was recorded during the fourth year after planting by Korikanthimath (1995).

Twelve cardamom genotypes were studied for yield correlations at Thadiyankudisai, Tamil Nadu, India by Patil *et al.* (1996) during 1991-94. Results suggested that capsules per panicle, racemes per panicle, tillers per clump, panicles per clump and panicle length were the main contributors to yield and can be used as selection criteria in the genetic improvement of cardamom. Patil *et al.* (1996; 1997) also suggested the utility of traits like panicles per bearing tiller, panicles per clump, recovery ratio and capsules per panicle as criteria for selection for yield in cardamom. In a study using twelve genotypes these workers found that yield per clump had significant and positive correlation with capsules per panicle, cincinni per panicle, tillers per clump, panicle length, panicles per clump, bearing tillers per clump, vegetative buds per clump and recovery ratio. The above workers concluded that capsules and cincinni per panicle, bearing tillers and panicles per clump, panicle length and vegetative buds per clump are significant attributes primarily responsible for high yield in cardamom, and selection for improvement should be based on these attributes.

During 1989, twelve elite clones of cardamom were assessed for yield and yield components at Appangala, India, in a clonal nursery. Three clones were selected for their higher number of panicles and capsules per plant, higher wet weight of capsules per plant and higher dry capsule yield per hectare (Korikanthimath *et al.*, 1997a). Kuruvilla *et al.* (2000) reported that cardamom genotypes varied each other with regard to yield and morphological attributes. However no significant variation was encountered in quality aspects like colour and shape of the capsules.

Forty nine accessions of cardamom were assessed for growth and panicle characters and considerable variations were observed for number of tillers, number of bearing tillers, number of panicles per plant and number of branches per panicle by Korikanthimath *et al.* (1998). The number of panicles per plant ranged from 12 to 148 and number of branches ranged from 17 to 31 per panicle. High variability for total yield and Bartlet Index of earliness for yield was observed by Korikanthimath

et al. (1999a) in high yielding lines of cardamom seedling progenies. Yield per clump varied from 325g to 7555g wet capsules per clump.

Fifteen promising lines of cardamom along with local *Malabar* were studied for yield, recovery percentage and essential oil content in Karnataka by Korikanthimath *et al.* (2000a). Treatment differences were significant for number of capsule and wet and dry weight of capsules per plant.

Elite cardamom landraces native to specific agroclimatic regions often provide immense potential to farmers and researchers in the form of superior planting material and unique raw material for selection. Koshy John (2002) has reported four such elite landraces from Idukki District of Kerala.

The correlation of yield contributing characters with number of capsules per plant and weight of capsules per plant in 16 accessions of cardamom was assessed in an experiment conducted in Karnataka by Korikanthimath *et al.* (2000). The number of tillers per plant, number of bearing tillers per plant and number of panicles per plant showed positive and significant correlation with number of capsules per plant whereas the correlation between plant height with number of capsules per plant was non significant. The total number of tillers per plant and number of bearing tillers per plant was significant and positively correlated with fresh weight of capsules per plant. The number of bearing tillers per plant and plant height were positively correlated with fresh weight of capsules per plant but the differences were nonsignificant.

The estimates of combining ability in some cardamom cultivars were studied by Prasanth and Venugopal (2002). Analysis of variance for combining ability effects of different traits showed that gca and sca were highly significant for all the traits indicating that both additive and non additive gene action played an important role in the expression of all the characters. A study by Backiyarani *et al.* (2003) showed that plant height, tiller number, panicle number, panicle length and recovery

percentage showed high correlation with yield. Therefore, selection programmes based on these characters would lead to significant improvement in the yield of small cardamom.

Twelve cardamom clones with higher yields were assessed for panicle and capsule characters in a field experiment conducted in Karnataka, India during 1993-94 by Korikanthimath and Ravindra Mulge (2005). Length of panicle, number of nodes per panicle, total number of capsules per panicle and wet weight of capsules per panicle were higher in local control compared to clones. Compact panicles with more number of capsules per node influenced the yielding ability of the clones. Length of the panicles, total number of capsules per panicle and wet weight of capsules per panicle were positively correlated with dry capsule yield per plant.

Performance assessment of fourteen cardamom genotypes namely MCC-21, MCC-40, MCC-73, MCC-85, MCC-200, MCC-346, MHC-10, MHC-13, MHC-18, MHC-22, MHC-23, MHC-24, MHC-26 and MHC-27 with regard to growth, yield and quality traits was made in comparison with released clones ICRI-1 and ICRI-2 and also with the popular landrace MCC-260 by Radhakrishnan *et al.* (2005).

The genetic relationship between the elite cardamom genotypes ICRI-1, ICRI-2, MCC-12, MCC-16, MCC-21, MCC-40, MCC-73, MCC-89, MCC-260, MCC-346, MHC-18, MHC-24, MHC-26 and MHC-27 was studied by molecular method by Radhakrishnan and Mohanan (2005). The highest similarity was observed between ICRI-1 and ICRI-2 (95%). At 71% similarity, the genotypes could be grouped into 2 groups, ICRI-1 and ICRI-2 forming the first group and the remaining genotypes forming the second group. Five major clusters of genotypes were obtained in the study: ICRI-1 and ICRI-2 in the first cluster; MCC-12 and MCC-40 in the second cluster; MCC-16, MCC-73, MHC-24, MHC-18, MCC-85, MCC-260 and MCC-346 in the third cluster; MCC-21 and MHC-27 in the fourth cluster and MHC-26 in a separate cluster.

Ninety cardamom accessions were evaluated for genetic diversity available in the accessions by Radhakrishnan *et al.* (2006). D^2 analysis showed wide diversity for growth and yield attributes among the accessions and they could be grouped into eight clusters. Inter cluster distance values indicated wide genetic divergence among the accessions.

A study was undertaken to develop a model for forecasting the yield of cardamom under intensive management by Menon *et al.* (2003). Thirteen biometrical characters examined exhibited a precision of about 82%. Step down regression resulted in the retention of only four characters namely, number of panicles per clump, number of racemes per panicle, number of capsules per raceme and leaf breadth with which yield can be estimated with 77% precision.

Pooled factor analysis of 17 variables representing morphological, yield contributing and qualitative characters of 90 genotypes of cardamom was carried out in 1996 at Myladumpara, Kerala, India to identify marker characters which accommodate the inheritance of associated characters. Among the 17 characters subjected to the analysis, 6 factors were identified as having maximum influence on growth, yield and quality of cardamom. Among the 6 factors identified, 3 factors controlled yield and yield contributing characters, 2 factors controlled qualitative characters and one factor controlled growth characters. The characters identified with maximum factor loadings in each group include bearing tillers per clump, seeds per capsule, internodal length, racemes per panicle, leaf breadth and capsules (dry) per kg. The six principal components or factors accounted for 78.09% of the total variance (Radhakrishnan *et al.*, 2004).

2.2.3. Studies on quality traits in cardamom

The quality of commercial cardamom product is related to moisture level, cleanliness, content of sub standard product, extraneous matter, appearance and colour. The processor also values the extractives, volatile oil and specific ingredients (Zachariah, 2002).

2.2.3.1. Physical quality traits

Kumara *et al.* (1985) reported the effect of maturity on the appearance (including chlorophyll content) of the capsule and its essential oil content and composition. All these parameters were altered with increasing maturity, the most notable effects being increased volatile oil and chlorophyll contents. The main effects on oil composition were an increase in 1, 8-cineole and a fall in alpha-terpinyl acetate contents.

According to Korikanthimath *et al.* (1999b) physical parameters such as seeds in capsules, husk percentage and seed: husk ratio were influenced by fertilizer application rates. Mathai (1985) analyzed eighteen export grades of Indian cardamom for physical and chemical (moisture, essential oil, oleoresin) composition. Grades with larger and heavier capsules were poorer in flavour constituents than medium grade capsules. Export grade cardamom from India, Guatemala and Sri Lanka were evaluated based on the physical quality traits by Sasikumar *et al.* (2005). Indian cardamom was found to be superior to the produces from Sri Lanka and Guatemala for the physical quality parameters such as weight of hundred capsules, seed: husk ratio, bulk density (litre weight), circumference and length.

2.2.3.2. Volatile oil and oleoresins

Volatile oil steam distilled from cardamom and analysed by GLC showed several significant variations. Yield of essential oil was determined and data tabulated on the percentage of terpenes, sesquiterpenes and oxygenated compounds in the oil by Lewis *et al.* (1976). The chemistry and technology of essential oils and oleoresins of cardamom was reviewed by Shankarikutty (1982), Lawrence (1986), Zachariah (2002) and Ravindran (2005). Volatile oil extracts of green capsules of cardamom were analysed by GC-MS by Noleau *et al.* (1987). Of the 122 constituents found, 56 represented over 99% of the total volatile fraction.

According to Narayanan and Mathew (1985) the oil of commercial grades of Alleppey and Coorg cardamom differed in physical properties and composition.

Alleppey Green Superior grade oil was considered the best quality, with the lowest 1, 8-cineole content (24.4%) and highest ester content (49.8%).

The chemical composition, physicochemical properties and antimicrobial activity of dried fruits of cardamom were investigated to assess the potential usefulness of cardamom oil as a food preservative by Badei *et al.* (1991b). The antimicrobial effect of the oil was tested against nine bacterial strains, one fungus and one yeast; the oil was 28.9% as effective as phenol. The minimal inhibitory concentration (MIC) of the oil was 0.7 mg/ml and it was concluded that cardamom oil could be used at an MIC range of 0.5-0.9 mg/ml without any adverse effect on food flavour.

Badei *et al.* (1991a) found that nine chemical groups were represented in the volatile components in the essential oil of cardamom. These were cyclic and aliphatic terpenes, terpene oxides and esters, aromatic hydrocarbons, aliphatic and cyclic terpene alcohols, sesquiterpenes and sesquiterpene alcohols. The oil was effective as an antioxidant for cotton seed oil, as assessed by stability, peroxide number, TBA value, refractive index, specific gravity and rancid odour.

Thirty three cardamom accessions were evaluated for the volatile oil content and its major constituents over three years by Zachariah *et al.* (1996). APG221 gave >7% oil consistently for three years. Its oil had a high concentration of alpha-terpinyl acetate and linalyl acetate and low concentrations of ethers such as 1, 8-cineole. APG223 followed by APG221 gave a consistently higher yield of oil per plant.

Information on yield and essential oil components provided for 12 cardamom clones selected on the basis of their yield performance in the field during 1982-87 by Korikanthimath *et al.* (1999c) showed that significant differences occurred among the clones.

The bound aroma compounds from fresh green cardamoms were isolated and analyzed by adsorption on Amberlite XAD-2 by Menon *et al.* (1999). The free volatiles were eluted with ether pentane (1:1) and the bound compounds with methanol. After hydrolysis of the latter fraction with beta-glucosidase, the aglycones were identified by GC and GC-MS. The major compounds in this fraction were 3-methyl pentan-2-ol, linalol and the cis and trans isomers of nerolidol and farnesol.

The original aroma compounds present in cardamom were isolated by Amberlite XAD-2 column chromatography from fresh green cardamom and termed as OFFC (original flavour of fresh cardamom), distilling fresh green cardamom DOFC (distilled oil of fresh cardamom) and DOCC (distilled oil of commercial cardamom) by Menon (2000). They were analysed by HRGC and GC-MS techniques. The concentrations of major compounds (1, 8-cineole [eucalyptol] and alpha -terpinyl acetate) did not exhibit much variation between samples. Many sesquiterpene hydrocarbons were present in DOFC and not in OFFC, and there were marked differences in the contents of other components.

The volatile oil of cardamom seeds was obtained by supercritical CO_2 extraction (SC-CO_2). The effect of the extraction conditions on the yield and composition of the resulting cardamom volatile oil was examined by testing two pressure values, 9.0 and 11.0 MPa; two temperatures, 40 and 50 degrees C; two flow rate values, 0.6 and 1.2 kg/h and two particle size values, 250-425 and >850 micro m. The main components were as follows: alpha-terpinyl acetate 42.3%; 1, 8-cineole 21.4%; linalyl acetate 8.2%; limonene 5.6%; and linalool 5.4%. A comparison with the hydrodistilled oil, obtained at a yield of 5.0%, did not reveal any consistent difference. In contrast, the extract obtained using hexane, Y=7.6%, showed strong composition differences. Indeed, the volatile fraction of the extract was made up mainly of the following: limonene 36.4%; 1, 8-cineole 23.5%; terpinolene 8.6%; and myrcene 6.6% (Marongiu *et al.*, 2004).

2. 2.4. Studies on biochemical traits in cardamom

Study of biochemical traits is very important in cardamom since seed chemistry determines the quality of it. Several studies have been carried out by different workers in the direction.

The effect of light intensity on the growth and yield of cardamom was studied on 5 year old plants of the cultivar PVI Malabar, grown in Tamil Nadu, India. The light regimes were full, medium and low light. The number of suckers per plant, length of suckers, number of leaves per sucker, number and length of panicles per clump, number of capsules and fresh weight and dry weight of capsules showed maximum values under medium light. There was about 40% reduction in growth parameters and 60% reduction in yield parameters in plants exposed to full light compared to those exposed to medium light. Plants under low light had growth and yield values intermediate between those in medium and full light (Ravindran and Kulandaivelu, 1998a).

In a study at Chettalli, Karnataka, India, 12 selected cardamom clones were evaluated and compared with a local cultivar (Malabar local) for yield, dry matter distribution and harvest index by Korikanthimath and Ravindra-Mulge (1998). Clones differed significantly with regard to dry matter content and percentage of dry matter distribution to roots, rhizomes, leaves, tillers, panicles and capsules. There were significant differences in harvest index (capsule dry weight/ total dry weight) among the clones. The highest percentage of dry matter distribution towards economic parts (capsules) was observed in the clones Sel.9, Sel.7, Sel.12, Sel.4 and Sel.10 and the lowest was observed in the local cultivar showing the different yielding abilities and superiority of the selections. The clones had a high harvest index compared to the local cultivar.

A nursery study was undertaken to know the uptake pattern of nutrients in different parts of cardamom of one year old and prepotent plants by Korikanthimath *et al.* (2000b). The N, P and K uptake increased with increase in dry matter production. Of the various nutrients, the total K uptake was the highest, followed by

N and P in both stages of crop, and it suggests that the crop requires more of K than N and P. Among the different plant parts, the highest contribution to the total N uptake was by green leaves (44.69%) and tillers (29.6%) in one year old and prepotents, respectively. The highest P and K uptake was by roots and grown up tillers in one year old plants, and green leaves and tillers in prepotent plants, respectively. The broad nutrient uptake ratio per plant was 9: 1: 17 (N: P: K).

2.2.4.1. Chlorophyll content

Studies on leaf scorching in nursery seedlings of cardamom grown at Thadiyankudisai (Tamil Nadu, India) indicated that total biomass, chlorophyll and protein contents and photochemical activities were adversely affected in scorched seedlings grown under full light (100% of total sunlight), when compared to healthy seedlings grown under medium light (45-55% of total sunlight) (Ravindran and Kulandaivelu, 1998b).

Twelve clones selected for high yield of capsules and a local standard were sown in a field at Appangala in July 1990 and evaluated in 1992-93 for boldness (100 capsule weight), chlorophyll content of capsule husk and content of essential oil and its components, 1, 8-cineole [eucalyptol] and alpha- terpinyl acetate. Clones were not significantly superior to the local standard for boldness, but five clones had significantly higher husk chlorophyll content, indicating their superiority with respect to green capsule colour. All the clones yielded significantly more essential oil per hectare than the local standard, and nine clones were superior for essential oil content of the capsule, three of them significantly so (Korikanthimath *et al.*, 1997b). Chlorophyll content was found to be higher in cardamom plants treated with 400 ppm and 800 ppm of ethephon (Joseph *et al.*, 2001).

The effect of maturity of cardamom on the appearance (including chlorophyll content) of the capsule and its essential oil content and composition has been worked out by Kumara (1985). All these parameters were altered with increasing maturity, the most notable effects being increased volatile oil and chlorophyll contents. The main effects on oil composition were an increase in 1, 8-cineole and a fall in alpha terpinyl acetate contents. Neither oil content nor oil

composition varied significantly during storage (at 27^0-30^0 C) of dried capsules but chlorophyll loss was retarded by the presence of silica gel.

2.2.4.2. Proximate composition

Proximate composition provides information about the contents of crude protein, crude fat, crude fibre, ash and Nitrogen Free Extractives (NFE) or total crude carbohydrates (Muller and Tobin, 1980). The crude protein content based on nitrogen determination involves the mixture of different nitrogen compounds. Along with protein, there are free amino acids, amines, complex lipids, purine and pyrimidine bases, nucleic acids and alkaloids. All these compounds are classified as Non Protein Nitrogen (NPN) compounds (Earle and Jones, 1962). Lipids are a heterogeneous group, which include fatty acids; mono-, di- and tri-acyl glycerols; phospholipids; sterols; stero esters; glycolipids and lipoproteins (Pattee *et al.*, 1982). Crude fibre, also known as roughage, consists of cellulose and hemicellulose, a heterogeneous group in which pentosans usually predominate over lignin, pectic and cutin substances (Salunkhe *et al.*, 1982).

A study revealed that the nonsaponifiable lipid fraction of cardamom consisted mainly of waxes and sterols. The waxes identified were n-alkanes and n-alkenes. In the sterol fraction, beta-sitosterone and gamma-sitosterol are newly reported. Phytol and traces of eugenyl acetate were also identified in cardamom for the first time (Gopalakrishnan *et al.*, 1990). The total lipid content of cardamom seeds was found to be 3.4%. Cardamom seeds contained 8.7% glycolipids and 1.9% phospholipids, whereas pods contained 29.3% and 4.4%, respectively (Kataoka *et al.*, 1987).

A study showed that the total fat content in cardamom was 3.2%. Palmitic, oleic, linoleic and linolenic acids are the major fatty acids in most spices (Chandrasekhar *et al.*, 1995). Moisture, oil, starch, carbohydrate, reducing sugar, phenolics, protein, crude fibre, ash, acid insoluble ash and GC profile of volatile oil of export grade cardamoms from three countries namely India, Guatemala and Sri Lanka were evaluated by Sasikumar *et al.* (2005).

2.2.4.3. Mineral composition

An experiment was conducted to determine the mineral content (Mn, Ca, Mg, Fe, Co, Cu, Zn, Ni, Pb, Cl, Na, K and Cd) of cardamom collected from different parts of Pakistan by Shahnaz-Akhtar *et al.* (2005). The study showed the occurrence of geographic difference in mineral content of cardamom.

2.2.4.4. Total free phenolics and tannins

Tannins are considered to play a role in the plant's ability to cope with environmental stresses, such as predation by rodents and birds and infestation by microorganisms, including moulds. Phenolics, the aromatic compounds with hydroxyl groups seem to be wide spread in plant kingdom. They occur in all parts of plants. Phenolics are said to offer resistance to pathogens and pests in plants. Grains containing high amounts of polyphenolics are found to be resistant to bird attack (Salunkhe *et al.*, 1990).

Phenolic acids in cardamom, obtained from local markets, were quantified by HPLC using an external standard method by Singh *et al.* (2004). The major phenolic acids in cardamom seeds were caffeic acid + vanillic acid (Variyar and Bandyopadhyay, 1995). HPLC analysis was performed to estimate the phenolic acids in 21 spices commonly used in India in different forms. In all, 7 phenolic acids *viz.*, tannic, gallic, caffeic, cinnamic, chlorogenic, ferulic and vanillic acids could be identified on the basis of their retention time with standard compounds and co-chromatography. The spices are known to significantly contribute to the flavour, taste and medicinal properties of food because of the phenolics.

2.2.4.5. Proline content

The humid tropical climate of Kerala with well defined dry and wet spells causes moisture stress effect to plantation crops. Water intake rate and the movement, storage and availability of water depend on the hydro-physical characteristics of the soils. The drought conditions that cause reduction in productivity are basically due to soil moisture deficit in the root zone of the crop. Though cardamom tracts receive heavy rainfall (1500-4500 mm), the availability of

soil water during summer months is a limiting factor due to undulating topography of the plantation areas (Hegde and Korikanthimath, 1999).

Though considerable efforts are being made to identify high yielding clones, an equal thrust is not endowed for identifying and propagating drought tolerant varieties. Cultivars/ varieties exhibit variations in their capacity for drought tolerance. They respond variedly to the differences in the quantum of irrigation received. Their performance is generally poor under rain fed condition. Identification and propagation of drought tolerant varieties therefore would go a long way in increasing cardamom production (Gurumurthy *et al.*, 1996).

Much attention has been given to accumulation of proline, which has been regarded as providing energy and nitrogen after the stress ends, stabilizing membranes, and acting as a neutral osmoticum. Proline accumulation is indicative of stress and has been suggested as a criterion for selecting drought tolerant crops (Singh *et al.*, 1973). Hence selection of cultivars with higher proline content is very important in the development of a drought resistant variety. However, proline accumulates only with severe stress (Lawlor and Fock, 1977).

2.3. Hybridization in cardamom

Since cardamom is amenable to both sexual and vegetative propagation, hybridization is a very useful tool for crop improvement. The natural cardamom variety namely *Vazhukka* possibly originated as a natural hybrid between var. *Malabar* and var. *Mysore*. As only one species occurs in India, crossing in cardamom is confined to intraspecific level. Because of its perennial, cross heterozygous nature, the conventional methods for evolving homozygous lines in cardamom are time consuming. Small cardamom has been successfully crossed as female parent with a species of *Hedychium* that is resistant to Katte disease. Small cardamom has also been crossed with *Alpinia* sp. and *Amomum* sp.; both crosses resulted in fruit set. Seed germination was evident only in the cross *Alpinia* sp. x *Elettaria cardamomum* (Anonymous, 1976).

Crosses were made between a prostrate variety of *Elettaria cardamomum* (used as female parent) and *Alpinia nutans*, *Amomum subulatum*, *Hedychium flavescens* and *Hedychium coronarium* by Parameswar (1977). Following emasculation the evening before or the morning after anthesis, the stigmatic surface was treated with one drop of 5, 10 or 15% sucrose solution prior to dusting with freshly collected pollen. The cross *Elettaria cardamomum* x *Alpinia nutans* set fruits containing 6-10 seeds.

All other intergeneric crosses involving *Amomum, Alpinia, Hedychium* and *Aframomum* were found to be sterile (Krishnamurthy *et al.*, 1989; Madhusoodanan *et al.*, 1990). Intervarietal and intercultivar level hybridizations have been carried out for producing high yielding heterotic recombinants. A diallele cross involving six selected types with characters like early bearing, bold capsule, high yield, long panicle, leaf rot resistance and multiple branching was carried out and 30 cross combinations were made by Krishnamurthy *et al.* (1989) . All the hybrids were more vigorous compared to the parental lines. In another study, intervarietal hybridization has been carried out using different varieties of cardamom. This resulted in cross combinations of 56 F_1 hybrids. Evaluation of these hybrids led to the isolation of a few high yielding heterotic recombinants with an average yield of 470kg to 610kg per ha under moderate management.

In a diallele cross, bold capsules x long inflorescence, bold capsules x early bearing, long inflorescence x early bearing and early bearing x leaf rot resistant hybrids recorded higher yield (Anonymous, 1977). Padmini *et al.* (2000a) conducted an experiment using six virus resistant genotypes, one rhizome rot tolerant line, one high yielding line plus their open pollinated progenies as well as 54 random cross hybrids of the inbreds. Observations were recorded four months after transplanting. Plant height was the greatest in the hybrids (mean 18.51 cm) followed by the open pollinated progenies (mean 12.04 cm) and inbred lines (mean 10.52 cm). For number of leaves, the highest means were in the order: hybrids (8.35), inbred lines (8.13) and open pollinated progenies (7.99). A similar situation was

noted for leaf length and breadth. Hybrid performance was regarded as superior, followed by the performance of open pollinated progenies and inbred lines.

An 8 x 8 set of crosses including reciprocals were made between elite *Malabar* selections of cardamom namely, CCS-1 and RR-1 and six cardamom mosaic virus (katte) resistant lines (NKE-12, NKE-27, NKE-34, NKE-9, NKE-3 and NKE-19) to incorporate desirable characters in the hybrids by Venugopal and Padmini (1999). All the elite selections were compatible with each other; however, the degree of compatibility varied with the parents selected for hybridization. Crossability was the highest and significant in the cross NKE-19 x NKE-34 (92%) followed by NKE-12 x NKE-19 (77%) and NKE-12 x RR-1 (69%). The crossability in CCS-1 x RR-1, NKE-27 x CCS-1, NKE-12 x RR-1, NKE-9 x RR-1 and NKE-3 x RR-1 was high (>50%) indicating scope for combining yield and disease resistance in these crosses.

Chandrappa *et al.* (1998) carried out studies on the impact of selection in a polycross progeny population. Promising clonal selections of Malabar type cardamom (including the ruling variety Mudigere-l) were grown in isolation, and open pollinated varieties of these selections were evaluated. In the case of 34 per cent of the progenies the average yield was found to be significantly higher than the average of the control variety (Mudigere-l). This yield increase varied from 1-149 per cent, and certain clones were found to be more promising than others. The above workers found that improvement of yield in cardamom could be more effectively achieved through a polycross breeding programme.

A study was conducted to assess the nature and extent of relative heterosis, heterobeltiosis and economic heterosis in cardamom hybrids under nursery conditions by Padmini *et al.* (2000b). Among the 54 cardamom hybrids evaluated for seedling characters, NKE-9 x NKE-34, NKE-19 x NKE-12, NKE-3 x RR-1 and NKE-34 x NKE-12 were the best for plant height, number of leaves per plant, leaf length and leaf breadth respectively. No positive and significant economic heterosis was observed in the hybrids for number of leaves per plant. Nine hybrids exhibited

significantly higher and positive heterobeltiosis and economic heterosis for all the characters studied except number of leaves per plant. A promising inter varietal hybrid was developed by Kuruvilla *et al.* (2006) which has been envisaged to be useful in augmenting production and productivity in cardamom.

2.4. Adaptability of cardamom

As in the case of any other crop, cardamom varieties also show location specific adaptability. Studies on adaptability of cardamom to different agro climatic region have been carried out by different workers. The development and potential of cardamom as a crop in the south-western Ethiopian lowlands has been discussed by Etissa (1995). Promising accessions of cardamom belonging to *Malabar* and *Mysore* types available in Sri Lanka were screened to compare their performance under different vegetation types, *i.e.*, natural forest and *Hevea* rubber plantations, altitudes (1000 m and 50-150 m above MSL) and agroclimatic conditions by Dharmaparakrama *et al.* (2002). Overall better growth and reproductive performances were observed under natural forest conditions at high altitude than in rubber plantations in low altitude. The conversion percentage of ovules into seeds of these accessions was over 80% in low altitude while it was over 75% in all the high altitude accessions. Size of the clump, colour of the leaflets and capsules, length of the panicle, number of flower stalks per cincinnus and flowering frequency were also affected by environmental conditions.

An experimental plot (0.4 ha) of cardamom (2900 bushes/ha) was established under *Pinus* (about 10 years old and at a density of 1000 trees/ha) in Kegalle District, Sri Lanka, in 1980. The yield under *Pinus* was higher than the yield under natural forest; this is attributed to differences in plant competition in the two systems. No major pests or diseases were recorded in cardamom under *Pinus* (Wickremasinghe and Kularatne, 1998).

Ten high yielding small cardamom accessions were collected from RRS Mudigere; ICRI Sakleshpur and CRS Pampadumpara and evaluated for their suitability in Idukki District, Kerala, India, during 1994-2000 by Backiyarani and

coworkers (Backiyarani *et al.*, 2003). M-1 and PV-1 recorded the highest yield consistently for four consecutive years and M-1 was relatively tolerant to thrips infestation.

Nair *et al.* (1989) carried out screening of five cardamom cultivars during 1982-85 for its suitability to North Wayanad, Kerala, India. There were significant differences between clones in the growth traits studied, such as number of shoots, height of the tallest shoot and number of inflorescences. Maximum number of shoots and inflorescences occurred in the natural variety *Malabar*, while the tallest was *Mysore*. *Malabar* gave a significantly higher yield than the other cultivars in all the crop seasons.

Raghupathi and Chandrappa (1998) studied the extent of adoption and the yield potential of an improved cardamom cultivar, Mudigere 1, in the hill zones of Karnataka during the period 1991-95. During the period of study, the percentage area for Mudigere 1 increased from 4 to 7%. Mean yields of Mudigere 1 increased from 70 to 75 kg/ha over this period, while those of local varieties decreased from 52.5 to 45 kg/ha. The results encouraged more farmers to adopt this cultivar.

A field trial was conducted at Hakathur, Coorg, Karnataka to study the scope of cardamom cultivation in valley bottoms under evergreen forest shade by Korikanthimath *et al.* (2002). The highest yield of 1473 kg dry capsules/ha was recorded during the third year after planting as against an average seven crop seasons yield of 735 kg/ha.

The performance of cardamom under low elevation, partial shade and assured irrigation conditions in Karnataka, India, was evaluated from 1993-94 to 1997-98 by Korikanthimath *et al.* (1999). An economic analysis was conducted to assess the feasibility of the high production technology utilized in this research. Early yield (172.9 kg/ha) was observed in 1994-95. A peak yield of 1679.60 was obtained in 1995-96. An average yield of 829 kg/ha was observed from 1994-95 to 1997-98.

In a trial conducted during 1991-93, cardamom was cultivated in an area of 0.05 ha under controlled shade in homesteads at Chettalli (Karnataka, India) and within 30 months, a yield of 103 kg of dry cardamom was achieved, (Korikanthimath and Ravindra Mulge, 1998). Murugan *et al.* (2000) studied the changes in climatic elements and their impact on production of cardamom in the Cardamom Hills of Kerala, India. The rainfall parameters had positive correlation with production of cardamom with significant relationship for number of rainy days.

Kuruvilla *et al.* (2005) compared the performance of tissue culture derived cardamom plants with open pollinated seedlings. It was observed that tissue culture plants of cardamom were uniform and superior over open pollinated seedlings, which showed wide variability. Further, the findings also supported the concept that tissue culture plants are true to type unlike open pollinated seedlings in cardamom.

The above literature on the study of variability, hybridization and adaptability of cardamom provides a bird's eye view of the works that have been carried out and the major gap areas. The present experiments have been designed in order to screen certain elite landraces of cardamom so as to select the most promising ones from them, to study certain hybrid populations of cardamom so as to identify the superior hybrids from them and also to study the adaptability of some pipeline hybrids and landraces of cardamom to Wayanad region so as to select the most suitable varieties for the area.

Chapter III

MATERIALS AND METHODS

The present experiments were designed to analyze the variability, performance and adaptability of some elite landraces and hybrids of small cardamom. The investigations were carried out in the experimental farm of Indian Cardamom Research Institute, Myladumpara, Idukki, Kerala, India and farmers' field at Kalpetta, Wayanad, Kerala during 2002-2006. The experimental farm at Myladumpara is located at an altitude of 1,068 m above MSL at 9^0 53'N latitude and 77^0 09' E longitude. The experimental field at Kalpetta is located at an altitude of 1000m above MSL at 14^0 latitude and 72^0 E longitude. Both the locations enjoyed humid tropical climate. The soils are forest loam with a pH of 5-6. The experiments carried out presently are described below under appropriate heads

3.1. Study of variability of certain elite landraces of cardamom

The experiment was designed to study the variability of some promising landraces identified by farmers and to study their comparative performance. The experiment was laid out in randomized block design with three replications and 12 plants per plot with a spacing of 3 m x 3 m. The materials used for the study included ten landraces and ICRI-2, a released variety as control. Package of practice recommendation of the Spices Board, India was followed for cultivation. The details of the landraces studied and the control are furnished in table 3.1.

Table 3.1. Description of the landraces and control used for the study of variability of landraces.

Landrace/ control	Description
1. Panikulangara-1	This was collected from the field of Mr. Joy Peter, Panikulangara House, Kallar, Adimaly, Idukki, Kerala. It is a *Vazhukka* type cardamom with oval shaped and green coloured capsules. This plant performs well under rain fed conditions.
2. Panikulangara-2	This landrace is a *Vazhukka* type cardamom collected from the field of Mr. Joy Peter, Panikulangara House, Kallar, Adimaly, Idukki, Kerala. The plants are bushy in nature with

	vigorous growth. Branched panicles are also seen in this type. The capsules are oblong and deep green in colour.
3. Njallani Green Gold	This landrace was collected from the field of Mr. Sebastian Joseph, Njallani, Kattappana, Idukki, Kerala who identified this. It is a *Vazhukka* type cardamom. The plants are robust in nature with tall tillers with purple coloured swollen base. It has simple unbranched inflorescence. Capsules are extra bold, dark green and thick skinned.
4. Vali Green Gold	This landrace was collected from the field of Mr. Jose T. Valley, Valiaplackal Estate, Meppara, Kattappana, Idukki, Kerala. It is a *Vazhukka* type cardamom. The plants are robust in nature and the rhizome is fleshy and very stout with the nodes and internodes crowded. Panicles are unbranched and capsules are extra bold and dark green.
5. Palakkudi	This landrace was collected from the field of Mr. Thomas, Palakkudi House, Vellaramkunnu, Kumili, Kerala who identified this. It is a *Malabar* type cardamom. Plants are robust in nature and rhizomes stout and fleshy. Each tiller has 2-3 unbranched panicles. Capsules are round bold and deep green in colour.
6. PNS Vaigai	This landrace was collected from the field of Mr. P.N. Surulivel, P.N.S. Estate, Sasthanodai, Idukki. It is a *Vazhukka* type cardamom. Plants are robust in nature with tall tillers. The dark green coloured non-pubescent leaves and the prominent ligules with light pale green colour are the striking features of this landrace. It has simple unbranched inflorescence. Capsules are extra bold with parrot green colour and thick skin.
7. Wonder cardamom	This landrace was collected from the field of Mr. Sabu Varghese. Vanderkunnel, Valiyathovala, Idukki, Kerala. It is a *Vazhukka* type cardamom. Plants are robust and bushy in nature with very long shoots and deep green foliage. Branched panicles are also seen in this plant. The capsules are extrabold in size and deep green in colour.
8. Ela Rani 1	This landrace was collected from the field of Mr. Jojo Kadamakuzhi, Kattappana, Idukki, Kerala. It is a *Vazhukka* type cardamom. Plants are robust and bushy in nature with very stout pseudostem base. Capsules are round oblong and pale green in colour.
9. Ela Rani 2	This landrace was collected from the field of Mr. Jojo Kadamakuzhi, Kattappana, Idukki, Kerala. It is a *Vazhukka*

	type cardamom. Plants show only average growth and size with average sized tiller base. Capsules are round, slightly oblong and pale green in colour.
10. Ela Rani 3	This landrace was collected from the field of Mr. Jojo Kadamakuzhi, Kattappana, Idukki, Kerala. It is a *Vazhukka* type cardamom. Plants are robust and bushy in nature with vigorous growth and strong tiller base. Capsules are medium sized, round oblong in shape with light green colour.
11. ICRI-2 (control)	This variety was released by Indian Cardamom Research Institute (ICRI), Myladumpara, Idukki, Kerala. It is a *Mysore* type cardamom. Plants are robust in nature. Capsule is oblong and bold with parrot green colour.

3.1.1. Characters observed and methods of observation

Sixty three characters including seven growth characters, nine yield characters, sixteen quality characters and twenty one biochemical characters were studied presently (Table 3.2) and the data were subjected to statistical analysis as detailed below.

Table 3.2. Characters studied for the analysis of variability and the modes of observation.

Character	Mode of observation
I. Growth characters	
1. Tillers per clump	The total number of tillers excluding the vegetative buds was observed.
2. Tiller height (cm)	In clump, the tallest tiller was marked and its height was measured from the ground level to the pseudo stem tip.
3. Leaves per tiller	Number of leaves in the marked tallest tiller was counted and recorded.
4. Leaf length (cm)	Seventh leaf from the top of the pseudostem was observed for leaf length.
5.Leaf breadth (cm)	The middle portion of the seventh leaf from the top of the pseudostem was observed.
6. Number of vegetative buds per clump	The total number of vegetative buds per clump either without leaves or with one leaf was recorded.

7. Number of bearing tillers.	Tillers with panicles were counted from each marked clump and recorded as number of bearing tillers per clump.
II. Yield characters	
1.Panicles per clump	Number of panicles per clump was counted and recorded
2.Panicle length (cm)	In each selected clump three panicles were marked and panicle length was measured from the base of the panicle to the tip and averaged.
3. Racemes per panicle	Number of racemes in three selected panicles of each clump was recorded.
4. Capsules per raceme	In each selected panicle, three racemes were marked and their numbers of capsules were counted and averaged.
5. Fruit set %	The percentages of flowers that set fruits in three panicles per plant were observed and mean calculated.
6. Seeds per capsule	Total numbers of seeds in three capsules per raceme were counted and mean value calculated.
7. Inter nodal length of panicles (cm)	The length between two nodes on a panicle was measured. Three measurements were taken and averaged.
8. Yield per plant-fresh (kg)	Yield per plant in each round of harvest was observed and the values were added up at the end of the crop season to get the total yield per clump.
9. Yield per plant- dry (kg)	Turn out ration of dry capsule per plant was calculated and multiplied with yield per plant (fresh) to get yield per plant dry.
III. Quality characters	
1. Recovery percentage	It was worked out in each round of harvest and percentage of the mean value calculated.
2. Percentage of 7 mm and above sized capsules	From each round of harvest, the percentages of 7 mm and above sized capsules were determined by sieving through a 7 mm mesh. Mean value was worked out at the end of the crop season.
3. Seed weight- fresh (g)	Six fresh capsules were selected per plant at random, their husks removed, the seeds of each capsule were weighed separately and values averaged.
4. Husk weight- fresh (g)	The husks of the six fresh capsules in the case of the above observation were weighed separately and averaged.

5. Seed weight- dry (g)	Six dry capsules were selected per plant at random, their husks removed, the seeds of each capsule were weighed separately and values averaged.
6. Husk weight- dry (g)	The husks of the six dry capsules in the case of the above experiment were weighed separately and averaged.
7. Seed: Husk ratio- fresh capsule	Three well ripe capsules were randomly selected from the third round of harvest and seeds and husks were separated. Weight of the seeds and husk were separately averaged. Seed: husk ratio was calculated from the weights of seeds and husk per capsule.
8. Litre weight of fresh capsules (g)	A cylinder of one litre capacity made of aluminium alloy was filled with fresh cardamom capsules. The measure was shaken horizontally three times and filled again as much as possible to the brim. The measure was taped on a level and hard surface three times changing the position each time and filled again as much as possible to a little over the brim. By moving a thin strip of straight metal sheet, the excess material was removed. Weight of the capsules was taken using a balance. The values of three determinations were averaged to get one litre weight.
9. Number of capsules per litre (fresh)	Counted the number of fresh capsules in a litre and the average value of three determinations was recorded.
10. Litre weight of dry capsules (g)	A cylinder of one litre capacity made of aluminium alloy was filled with dry cardamom capsules. The measure was shaken horizontally three times and filled again as much as possible to the brim. The measure was taped on a level and hard surface three times changing the position each time and filled again as much as possible to a little over the brim. By moving a thin strip of straight metal sheet, the excess material was removed. Weight of the capsules was taken using balance. The values of three determinations were averaged to get one litre weight.
11. Number of capsules per litre- dry	Counted the number of dry capsules in a litre and the average value of three determinations was recorded.
12. 100 capsule weight- fresh (g)	100 fresh capsules per plant were taken randomly and weighed.
13. 100 capsule weight- dry (g)	100 dry capsules per plant were taken randomly and weighed.

14. Volatile oil content (%)	Took 10 g of powdered sample and transferred it in to 1000 ml R.B. flask, to which 500 ml of deionised water was added. Set the apparatus and placed in suitable electric heating mantle and heated the flask to boiling. Refluxing rate was adjusted to 1 drop per second by adjusting the regulator of the mantle. Refluxed until two consecutive readings taken at one hour interval showed no change of oil volume in the trap. Then the apparatus was cooled to room temperature by allowing it to stand in air. Oil drops sticking to the sides of the condenser were pulled down to the trap using a steel rod. Finally recorded the amount of oil collected in the trap in millilitre. Calculated the percentage of volatile oil as follows: $\text{Percentage of volatile oil (v/w)} = \frac{\text{Volume of oil (ml)}}{\text{Weight of the sample}} \times 100$
15. Oleoresin content (%)	2 g of capsule flour was taken in a thimble (prepared from Whatman No. 1 filter paper) and placed it in a Soxhlet apparatus. A dry solvent flask was connected beneath the apparatus and required volume of solvent [Ethylene dichloride (EDC)] was added. Then the condenser was connected to the apparatus. Extraction was done for 20 h. After extraction, the ethylene dichloride extract was evaporated under fume hood. Then transferred the extract to a tared beaker and placed the beaker on a water bath to evaporate the ethylene dichloride. When last traces of ethylene dichloride disappeared, placed the beaker in a hot air oven at 110 ± 2^0C for 30 min. Then the beaker was cooled in a desiccator and its weight was recorded. Calculated the percentage of oleoresin as follows: $\text{Percentage of oleoresin} = \frac{\text{Weight of residue}}{\text{Weight of sample}} \times 100$
16. Moisture content of capsule (%) (OAMASSTA, 1997)	10 g of powdered sample was transferred to distilling flask and sufficient toluene (moisture free) was added to cover the sample completely. Dean and Stark Water Estimation Apparatus was assembled, and the trap was filled with toluene, pouring it through top of the condenser. A loose non-absorbing cotton plug was inserted into the top of the condenser to prevent condensation of atmospheric moisture into the condenser. Distillation was done slowly, approximately 2 drops per second, until most of the water was collected in the trap, and then the reflux rate was increased to about 4 drops per second. When all water was apparently collected, washed down the condenser by pouring toluene at the top, continuing refluxing for 3 to 5

	min. Then the heating source was put off and the trap was cooled to room temperature, the volume of the water was recorded in ml and moisture percentage was calculated as follows: $\text{Moisture (\%)} = \frac{\text{Volume of water (ml)}}{\text{Weight of sample (g)}} \times 100$ The average value of triplicate experiments was expressed as percentage of moisture.
IV. Biochemical characters	
1. Chlorophyll content a, b, total and a/b ratio - leaf (mg g^{-1} fresh tissue) (Arnon, 1949)	In the marked tallest tiller, third leaf from the top was removed and immediately taken to laboratory. 1g of leaf material was taken from the leaf of each landrace and was ground separately with a chilled pestle and mortar in diffuse light with the addition of 20 ml of 80% (v/v) cold acetone and the homogenate was centrifuged at 5000 rpm for 5 minutes. Transferred the supernatant to a 100 ml volumetric flask. Again ground the residue with 20 ml of 80% (v/v) cold acetone. Centrifuged and transferred the supernatant to the same volumetric flask. Repeated this procedure until the residue was colourless. The mortar and pestle were thoroughly washed with 80% (v/v) cold acetone and collected the clear washings in the volumetric flask. Made up the volume to 100 ml with 80% (v/v) cold acetone. The absorbance of the solution was taken at 645 nm, 663 nm and 652 nm against the solvent (80% cold acetone) blank. Calculated the amount of chlorophyll present in the extract by using the following formula and expressed in mg chlorophyll per g tissue. mg chlorophyll a/ g tissue = $12.7 (A\ 663) - 2.69 (A\ 645) \times \frac{V}{1000 \times W}$ mg chlorophyll b/ g tissue = $22.9 (A\ 645) - 4.68 (A\ 663) \times \frac{V}{1000 \times W}$ mg chlorophyll c/ g tissue = $20.2 (A\ 645 + 8.02 (A\ 663) \times \frac{V}{1000 \times W}$ Where, A = Absorbance at specific wavelength. V = Final volume of chlorophyll extract in 80% acetone. W = Fresh weight of tissue extract.
2. Chlorophyll content a, b, total and a/b ratio – fresh and dry	Well ripe/dry capsules of the third round harvest of each landrace were uniformly mixed and three capsules selected out of them at random and wet weight per capsule was

capsules (mg g^{-1} tissue) (Arnon,1949)	recorded. Weighed capsule was ground as such with a chilled pestle and mortar in diffuse light with the addition of 20 ml of 80% (v/v) cold acetone and the homogenate was centrifuged at 5000 rpm for 5 minutes. Transferred the supernatant to a 100 ml volumetric flask. Ground the residue with 20 ml of 80% (v/v) cold acetone, centrifuged and transferred the supernatant to the same volumetric flask. Repeated this procedure until the residue was colourless. Washed the mortar and pestle thoroughly with 80% (v/v) cold acetone and collected the clear washings in the volumetric flask. Made up the volume to 100ml with 80% (v/v) cold acetone. Read the absorbance of the solution at 645, 663 and 652 nm against the solvent (80% cold acetone) blank. Calculated the amount of chlorophyll present in the extract as mg chlorophyll per g tissue using the following formula mg chlorophyll a/g tissue = $12.7 (A\ 663) - 2.69 (A\ 645) \times \frac{V}{1000 \times W}$ mg chlorophyll b /g tissue = $22.9 (A\ 645) - 4.68 (A\ 663) \times \frac{V}{1000 \times W}$ mg chlorophyll c/g tissue = $20.2 (A\ 645 + 8.02 (A\ 663) \times \frac{V}{1000 \times W}$ Where, A = Absorbance at specific wavelength. V = Final volume of chlorophyll extract in 80% acetone. W = Fresh weight of tissue extract.
3. Relative water content (RWC) of leaves (%) (Barrs and Weatherly, 1962)	At random three leaf discs of 4 cm diameter were punched throughout the leaf let excluding the mid rib portion. The initial weight of the three discs (fresh weight) was recorded and floated on distilled water for 24h at 25°C in the dark. After 24h, the turgid weight was recorded. Then the leaf discs were kept in a hot air oven at 80°C for 48h for drying. After 48h, the dry weight of the leaf discs was also recorded. The RCW was calculated by the following formula: $RCW\ (\%) = \frac{\text{Fresh weight - Dry weight}}{\text{Turgid weight - Dry weight}} \times 100$
4. Stomatal frequency (Sreekala and Jayachandran, 2001)	Stomatal frequency was taken by smearing nail polish on the lower and upper surfaces of the leaves. It was then peeled and the peel was observed under a microscope using a 40x objective and 10x eye piece and counted the

	number of stomata and the mean number per microscopic field was calculated and tabulated.
5. Stomatal index (Sinha, 2004)	Smeared nail polish on the upper and lower surface of the leaves. It was then peeled and the peel was observed under a microscope using a 40x objective and 10x eye piece. Counted the number of stomata in the upper and lower surface of the leaf and also in the same microscopic field counted the number of total epidermal cells. The stomatal index was calculated by the following formula: $I = \frac{S}{E+S} \times 100$ Where, I = stomatal index S = number of stomata per unit area E = number of epidermal cells per unit area
6. Leaf proline content (μ moles g^{-1} tissue) (Bates *et al.*, 1973)	**Extraction of proline:** 500 mg (0.5 g) of leaf tissue was homogenized in 10 ml of 3% aqueous sulphosallicylic acid. The homogenate was filtered through Whatman No.2 filter paper and the filtrate was saved and used for proline estimation. **Estimation of proline:** 2 ml of the sample filtrate was taken in a test tube. A blank was maintained with 2 ml distilled water. To each test tube, 2 ml glacial acetic acid followed by 2 ml acid ninhydrin [acid ninhydrin: warm 1.25 g ninhydrin in 30 ml glacial acetic acid and 20 ml 6M phosphoric acid, with agitation until dissolved. Store at 4^0C and use within 24h] was added. The tubes were kept in boiling water bath for 1h. The reaction was terminated by placing the tubes in ice bath. Then, to each tube 4 ml of toluene was added, mixed well and warmed to room temperature. The toluene layer was separated by using UV visible spectro photometer. The amount of proline present in the sample was calculated from a standard curve prepared with pure proline and expressed the proline content on fresh weight basis as follows. $\mu \text{ moles per g tissue} = \frac{\mu \text{ g proline/ ml} \times \text{ml toluene}}{115.5} \times \frac{5}{\text{g sample}}$ Where, 115.5 is the molecular weight of proline.
7. Epicuticular wax (ECW) content (μ g cm^{-2})	The ECW was extracted from the third (from top downwards) leaf of three tillers per clone following the method of Ebercon *et al.* (1977). Segments of 3 cm x 3 cm

	were cut from the leaflet and three such segments were plunged into conical flask containing 15 ml chloroform and vigorously shaken for 15 to 20 seconds and decanted solution into another conical flask and evaporated in a hot water bath. Then, 5 ml of potassium dichromate reagent (5 g of potassium dichromate was added to 10 ml of distilled water and mixed vigorously with the addition of 250 ml of conc. H_2SO_4 and heated till a clear solution was obtained) was added to the dry sample. The samples were placed in boiling water for 30 min. After cooling, the volume was made up to 17 ml with distilled water. The absorbance of the colour solution was taken at 590 nm on Perkin Elmer Spectrophotometer and expressed the ECW content in ug/ cm^2. Polyethylene glycol (PEG) 4000 in chloroform was used for preparing standards.
8. Reducing sugar content in leaf (g 100 g^{-1} fresh tissue)	**Extraction:** 500 mg of leaf tissue was taken and ground in a pestle and mortar with 5 ml of hot 80% ethanol and the homogenate was centrifuged at 500 rpm for 5 min. The supernatant was collected in a 50 ml conical flask. Re-extracted the residue with 5 ml of hot 80% ethanol and centrifuged as above and collected the supernatant. The conical flask containing supernatant was kept on a boiling water bath (80^0C) to evaporate the ethanol. After evaporation, 10 ml of distilled water was added and shaken well. **Estimation:** Pipetted out 0.5 ml of the extract in to a test tube to which, 3 ml of dinitrosallicylic acid reagent [dissolve by stirring 1g dinitrosallicylic acid, 200 mg crystalline phenol and 50 mg sodium sulphate in 100 ml 1% NaOH and store it at 4^0C] was added and the contents were heated in a boiling water bath for 5 min. When the contents of the tube were still warm, 1ml of 40% potassium sodium tartrate solution was added. After cooling the tube, the absorbance of the solution was taken at 510 nm. Calculated the amount of reducing sugar present in the sample using the standard graph prepared with glucose.
9.Soluble and insoluble protein content in leaf (Lowry *et al.* 1951) (g 100 g^{-1} fresh tissue)	**Extraction of protein:** 100 mg of leaf tissue was homogenized in 10 ml of distilled water using mortar and pestle. The extract was centrifuged at 5000 rpm for 20 minutes and the supernatant and precipitate were taken separately for the estimation of soluble and insoluble protein.

	Estimation of soluble protein: Equal volume of 10% trichloroacetic acid (TCA) (w/v) was added to the supernatant and centrifuged at 5000 rpm. Discarded the supernatant and the precipitate was dissolved in 0.1N NaOH. After complete solubilization, 0.2 ml of the dissolved protein solution was taken in a test tube and then added 3 ml of alkaline copper reagent (Solution A: 2% sodium carbonate in 0.1 N sodium hydroxide. Solution B: 0.5% copper sulphate in 1% potassium sodium tartarate. Mix 50 ml of solution A and 1ml of solution B, prior to use) and incubated for 10 minutes. Then, 0.5 ml Folin-Ciocalteau reagent was mixed and kept at room temperature in dark for 30 minutes. The blue colour developed was read at 660 nm using double beam spectrophotometer. A standard graph was prepared using Bovine Serum Albumin as the standard. From the standard graph the soluble protein was estimated and expressed in g 100 g^{-1} fresh tissue. **Estimation of insoluble protein:** The left out precipitate after the extraction of soluble protein was dissolved in 0.1N NaOH. After complete solubilization, 0.2 ml of the dissolved protein solution was taken in a test tube and then added 3 ml of alkaline copper reagent (solution A: 2% sodium carbonate in 0.1N NaOH. Solution B: 0.5% copper sulphate in 1% potassium sodium tartarate. Mix 50 ml of solution A and 1 ml of solution B prior to use) and incubated for 10 minutes. Then, 0.5 ml Folin-Ciocalteau reagent was mixed and kept at room temperature in dark for 30 minutes. The blue colour developed was read at 660 nm using double beam spectrophotometer. A standard graph of the insoluble protein was used to estimate insoluble protein content and expressed in g 100 g -1 fresh tissue.
10. Crude protein content of capsule (g 100 g^{-1} capsule flour) (AOAC, 1970)	**Digestion:** The nitrogen content of the sample was determined by Kjeldahl method. 0.5 g of cardamom powder was taken into a Kjeldahl tube. To this, 2 g of digestion mixture [100 g potassium sulphate, 20 g copper sulphate and 1 g selenium dioxide (100:20:1)] and 10ml of concentrated sulphuric acid were added. The contents of the tube were digested using Kelplus-Supra LX (Pelican, Chennai, India) Equipment's digestion blocks until a light bluish green residue was obtained. Later the contents were cooled. **Distillation:** Distillation was done using Kelplus-Supra LX (Pelican

	Chennai, India) Equipment. About 25 ml of 4% boric acid solution containing 3 drops of mixed indicator (0.1 g bromocresol green and 0.07 g methyl red dissolved in 100 ml of 95% ethanol) was taken in a conical flask. Then the conical flask was fixed in such a way that the delivery tube was dipped into boric acid solution. After that Kjeldahl tube containing the digestion sample was loaded into the distillation equipment. After dilution with distilled water, the alkali (40 ml of 40% NaOH) solution was added using control panel. Distilled and collected the liberated ammonia on boric acid. Distillation was done for 6 min. After completion of distillation, the distilled solution in the receiving conical flask was titrated against 0.02N HCl (normality of the HCl should be checked with known concentration of sodium carbonate solution) until the first appearance of pink colour, the end point. The nitrogen content of the sample was calculated using the following formula: Nitrogen (%) = Titre value of HCl x Normality of HCl x 0.014 x100 ---------- Weight of the sample (g) The crude protein content was calculated by multiplying the per cent nitrogen content of the sample with the factor 6.25. The average value of triplicate determinations was expressed as percentage of crude protein content on dry weight basis.
11. Crude lipid content of capsule. (g 100 g^{-1} capsule flour) (AOAC, 1970)	Two gram of capsule flour was taken in a thimble (prepared from Whatman No. 41 filter paper) and placed in a Soxhlet apparatus. Connected a dry pre-weighed solvent flask ('a'g) beneath the apparatus and added the required volume of solvent (petroleum ether, boiling point 40-60°C) and connected to condenser. Adjusted the heating rate to give a condensation rate of 2-3 drops per second and extracted for 16h. After that removed the thimble and retained ether from the apparatus. The ether was evaporated from the solvent flask on a hot water bath and dried the flask at 105°C for 30 min. Then the flask was cooled in desiccator and recorded the weight ('b' g). The quantity of ether extract was calculated from the following formula: Ether extract in sample (% dry weight basis) = (b – a) ---------- x 100 Weight of the sample (g) The average value of triplicate experiments was expressed as percentage of ether extract or total crude lipid content

	on dry weight basis.
12. Crude fibre content of capsule (g 100 g^{-1} capsule flour) (AOAC, 1970)	After extraction with ether, the left out residue was boiled with 200 ml of 0.225N H_2SO_4 solution for 30 min with bumping chips. After that filtered the boiled material through muslin cloth and then washed it with boiling distilled water until the washings were free of acid. Again boiled the residue with 200 ml of 0.313N NaOH solution for 30 min. Again filtered the boiled material through muslin cloth and then washed it with 25 ml of boiling 1.25% H_2SO_4, then with 50 ml portions of boiling distilled water and 25 ml of alcohol. Then the residue was removed from the cloth and transferred it to pre-weighed ashing dish ('W_1'g). The contents of the dish were dried at 130 ± 2°C. Cooled the dish in a desiccator and then took the weight ('W_2'g) and ignited in an electric muffle furnace for 30 min at 600°C. After cooling the dish in a desiccator, the contents were reweighed ('W_3' g). The percentage of crude fibre was calculated by using the formula given below Crude fibre content = Loss in weight on ignition $(W_2 - W_1) - (W_3 - W_1)$ ---------- x 100. Weight of the sample (g)
13. Ash content of capsule (g 100 g^{-1} capsule flour) (AOAC, 1970)	2 g of capsule flour was weighed into a pre weighed porcelain crucible. The crucible with the seed flour was placed in an electric muffle furnace set at 600°C and maintained for 6h. The contents of the crucible were cooled in desiccator and weighed immediately. Ash content was calculated by using the formula given below Weight of the ash (g) Ash (%) = ---------- x 100. Weight of the sample (g) The ash content was expressed as percentage on dry weight basis.
14. Acid insoluble ash content of capsule (g 100 g^{-1} capsule flour)	After total ash determination the ash was used for determination of acid insoluble ash. To the ash contents 25 ml of the HCl solution (HCl solution – 1:2.5; dilute 100 ml of concentrated HCl with 250 ml of distilled water) was added and boiled for 5 minutes. Covered the dish with a watch glass to prevent spattering. The digested ash was filtered through an ash less filter paper quantitatively. Then, the contents were washed with hot water until the washings were acid free. After that transferred the filter paper and its contents to the silica crucible, dried and ignited in a muffle furnace at 600°C ± 20°C until the ash was carbon free. When carbon free ash was obtained, transferred the crucible to a desiccator, cooled to room

	temperature, weighed immediately and recorded the weight. Weight of acid insoluble ash (g) Acid insoluble ash % = ---------- x 100 Weight of the sample (g)
15. Nitrogen Free Extractives (NFE) content of capsule (total crude carbohydrate content) (g 100 g^{-1} capsule flour) (Muller and Tobin, 1980)	Percentage of NFE was calculated as given below: % NFE = 100 - (CP% + EE% + CF% + Ash %) Where CP = Crude protein EE = Ether extract CF = Crude fibre
16. Calorific value of capsule (kJ 100 g^{-1} DM) (ICMR, 1992)	The calorific value of the seeds was determined in kJ by multiplying the percentage of crude protein, crude lipid and NFE by the factors 16.7, 37.7 and 16.7 respectively.
17. Total free phenols and tannins in capsules (g 100 g^{-1} capsule flour)	**Extraction (Maxon and Rooney, 1972):** 1g of capsule flour was taken in a 100 ml flask, to which was added 50 ml of 1% (v/v) HCl in methanol. The samples were shaken on a reciprocating shaker for 24h at room temperature. The contents were centrifuged at 10000 rpm for 5 min. The supernatant was collected separately and used for further analysis. **Estimation of total free phenolics (Sadasivam and Manickam, 1992):** 1 ml aliquots of the above extract were pipetted into different test tubes to which 1 ml of Folin-Ciocalteu's reagent followed by 2 ml of 20% (w/v) Na_2CO_3 solution were added and the tubes were shaken and placed in a boiling water bath for exactly 1 min. The test tubes were cooled under running tap water. The resulting blue solution was diluted to 25 ml with distilled water and the absorbance was measured at 650 nm with the help of a UV-visible spectrophotometer. If precipitation occurred, it was removed by centrifugation at 5000 rpm for 10 min, before measuring the absorbance. The amount of phenolics present in the sample was determined from a standard curve prepared with catechol. A blank containing all the reagents minus plant extract was used to adjust the absorbance to zero. Average value of triplicate estimations was expressed as g $100g^{-1}$ of the seed flour on dry weight basis.

	Estimation of tannins (Burns, 1971): From suitable aliquots of the above extract tannin content was quantified by the Vanillin-HCl method of Burns (1971) using phloroglucinol as a standard at 500 nm with a UV-visible spectrophotometer. The average values of triplicate estimations of all samples were expressed as g $100g^{-1}$ seed flour on dry weight basis.
18.Total free amino acids of capsule (g 100 g^{-1} capsule flour)	**Extraction:** Ground 500 mg capsule flour in a pestle and mortar with a small quantity of acid-washed sand. To this homogenate, added 10 ml of 80% ethanol. Centrifuged the contents at 5000 rpm for 10 min and saved the supernatant in a 50 ml conical flask. Repeated the extraction twice and pooled all the supernatants. Reduced the collected supernatant volume to known volume by evaporation and used the extract for estimation of free amino acids. **Estimation:** Took 0.1 ml of extract in a test tube and to each tube added 1 ml of ninhydrin reagent [dissolve 0.8 g stannous chloride ($SnCl_2.2H_2O$) in 500 ml of 0.2M citrate buffer (pH 5.0). Added this solution to 20 g of ninhydrin in 500 ml of methyl cellosolve) and mixed it well. Then made up the volume to 2 ml with water. Heated the contents in a boiling water bath for 20 min to which added 5 ml of the diluents (mix equal volume of water and *n*-propanol) while still on the water bath and mixed it well. After 15 minutes of boiling, cooled the tubes under running tap water and read the absorbance of the purple colour against a reagent blank at 570 nm. Calculated the amount of total free amino acids present in the sample using the standard graph prepared with leucine.
19. Reducing sugar content of capsule (g 100 g^{-1} capsule flour)	**Extraction:** 500 mg of capsule flour was taken and ground in a pestle and mortar with 5 ml of hot 80% ethanol and the homogenate was centrifuged at 5000 rpm for 5 min. The supernatant was collected in a 50 ml conical flask. Re-extracted the residue with 5 ml of hot 80% ethanol and centrifuged as above and collected the supernatant. The supernatant containing conical flask was kept on a boiling water bath (80°C) to evaporate the ethanol. After evaporation, 10 ml of distilled water was added and shaken well. **Estimation:** Pipette out 0.5 ml of the extract in a test tube to which, 3

	ml of dinitrosallicylic acid reagent was added [dissolve by stirring 1 g dinitrosallicylic acid, 200 mg crystalline phenol and 50 mg sodium sulphite in 100 ml 1% NaOH and store it at 4°C] and the contents were heated in a boiling water bath for 5 min. When the contents of the tubes are still warm, 1 ml of 40% potassium sodium tartrate solution was added. After cooling the tubes, read the absorbance at 510 nm. Calculate the amount of reducing sugar present in the sample using the standard graph prepared with glucose.

3.1.2. Analysis of variance

Analysis of variance (ANOVA) was carried out to test the significance of variations between the accessions. Test of significance was done with reference to standard F table (Fisher and Yates, 1963).

3.1.3. Variability analysis

3.1.3.1. Phenotypic and genotypic variance

Phenotypic and genotypic variances for the different characters studied were estimated as per Singh and Choudhary (1985).

$$\text{Genotypic variance } (\sigma^2 g) = \frac{\text{MSS for treatment - MSS for error}}{\text{Number of replications}}$$

Phenotypic variance $(\sigma^2 p) = \sigma^2 g + \sigma^2 e$ where $\sigma^2 e$ is error variance.

3.1.3.2. Coefficients of variation

Phenotypic and genotypic coefficients of variation were estimated following Burton and Devane (1953).

$$\text{Genotypic coefficient of variation (GCV)} = \frac{\sigma g \times 100}{\overline{X}}$$

where σg = genotypic standard deviation and

$\overline{X}$ = grand mean for the character.

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{\sigma p \times 100}{\overline{X}}$$

Where σp = the phenotypic standard deviation and $\overline{X}$ = grand mean for the character.

3.1.4. Study of heritability (broad sense)

Heritability (broad sense) is the fraction of the total variance that is heritable and is estimated as the percentage of genotypic variance over phenotypic variance (Jain, 1982).

$$H^2 = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

3.1.5. Study of Genetic advance

Genetic advance under selection was calculated using the following formula proposed by Abraham (2000).

$$GA = \frac{KH^2 \sigma p}{\overline{X}}$$

Where H^2 = heritability in the broad sense; σp = phenotypic standard deviation;

K = selection differential which is 2.06 at 5% intensity of selection in large samples (Allard, 1960);

$\overline{X}$ = grand mean of the character.

3.1.6. Study of correlation of characters

Correlation of the characters has been found out as given by Rangaswamy (1995).

3.1.7. Study of character association

Biometric study of growth, yield and quality characters of the genotypes has been used to analyze character association in the cardamom land races studied. Factor analysis by means of principal component analysis was carried out for the purpose with the help of the software STATISTICA.

3.1.8. Study of genetic divergence

The statistically significant variability observed between different genotypes of a species can be grouped into different clusters of genetically closer accessions based on genetic divergence studies. The eleven genotypes studied above have been subjected to cluster analysis using the software STATISTICA, following UPGMA procedure (Unweighted Pair Group Mathematical Average procedure) (Sneath and Sokal, 1973) to find out the affinities between them, based on growth, yield and quality characters.

3.2. Study of performance of certain elite landraces of cardamom under high range conditions

Comparative analysis of overall performance under high range conditions at Myladumpara, Idukki, Kerala of the ten landraces and one control (Table 3.1) studied above has been carried out presently based on thirty two growth, yield and quality parameters (Table 3.3). The experiment was laid out in the experimental garden of Indian Cardamom Research Institute, Myladumpara in randomized block design with three replications and 12 plants per plot with a spacing of 3m x 3m. The materials used for the study included ten landraces and ICRI-2, a released variety as control. Package of practice recommendation of the Spices Board, India was followed for cultivation. Performance index has been calculated as suggested by Hrideek *et al.* (2002) and Ramasubramanian (2005) by attributing grades to the accessions based on the performance and working out overall rank of performance.

Table 3.3. Characters observed for the study of performance of the cardamom land races under high range conditions.

1. Growth characters
1. Tillers per clump
2. Tiller height (cm)
3. Leaves per tiller
4. Leaf length (cm)
5. Leaf breadth (cm)
6. Number of vegetative buds

7. Number of bearing tillers
II. Yield characters
1. Panicles per clump
2. Panicle length (cm)
3. Racemes per panicle
4. Capsules per raceme
5. Fruit set percentage
6. Seeds per capsule
7. Internodal length (cm)
8. Yield per plant- fresh (kg)
9. Yield per plant- dry (kg)
III. Quality characters
1. Recovery percentage
2. Percentage of 7mm and above sized capsules
3. Seed weight- fresh capsule (g)
4. Seed weight- dry capsule (g)
5. Husk weight- fresh (g)
6. Husk weight- dry (g)
7. Seed: Husk ratio- fresh capsule
8. Litre weight- fresh capsules (g)
9. Number of fresh capsule per litre
10. Litre weight of dry capsules
11. Number of dry capsules per litre
12. Hundred capsule weight- fresh (g)
13. Hundred capsule weight- dry (g)
14. Volatile oil content (%)
15. Oleoresin content (%)
16. Moisture content of capsules (%)

3.3. Performance evaluation of certain hybrids of cardamom in relation to their parents

The comparative performance of two single cross hybrids, two double cross hybrids and two F2 lines detailed below evolved at Indian Cardamom Research Institute, Myladumpara, Idukki, Kerala, India has been studied presently in relation to their parents. Package of practice recommendation of the Spices Board was followed for cultivation. The details of the hybrids and their parentage are shown below.

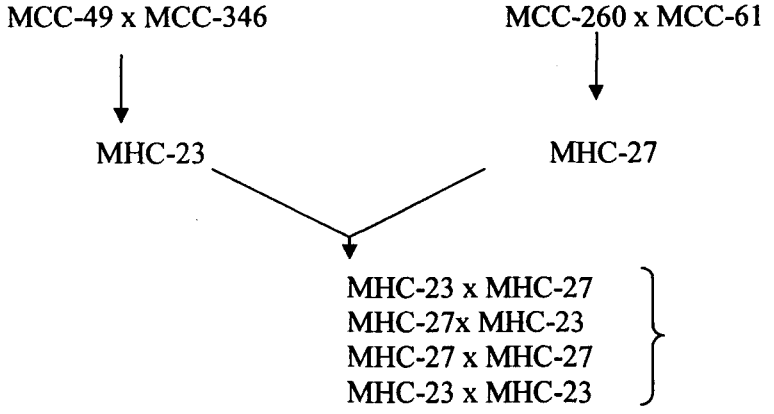


Table 3.4. Details of the hybrids and their parents studied for performance evaluation

Parent/ hybrid	Description
Parent 1: MCC-49 (ICRI-1)	A *Malabar* type variety with round bold and dark green capsules released by Indian Cardamom Research Institute, Myladumpara, Kerala.
Parent 2: MCC-345	A *Vazhukka* type germplasm selection from the accessions collected from Vandiperiyar in Idukki district of Kerala.
Parent 3: MCC-260	This *Vazhukka* type plant is a land race popularly known as Njallani Green Gold. Extra bold capsules with good colour is the special character of this plant.
Parent 4: MCC-61 (ICRI-2)	It is a *Mysore* type variety developed by Indian Cardamom Research Institute, Myladumpara, Kerala. Plants are robust in nature .Capsule is oblong and bold with parrot green colour.
F1: MHC-23 (MCC-49 x MCC-346)	A hybrid of MCC-49 and MCC-345. Panicles are pendent type with round bold and deep green capsules.
F1: MHC-27 (MCC-260 x MCC-61)	A hybrid of MCC-260 and MCC-61. Panicles are pendent type with long angular bold and parrot green capsules.
Double cross: MHC-23 x MHC-27	A Double cross hybrid of MHC-23 and MHC-27. The plants are of *Vazhukka* type.

Double cross: MHC-27 x MHC-23	A Double cross hybrid of MHC-27 and MHC-23. The plants are of *Vazhukka* type.
F2: MHC-27 x MHC-27	F2 hybrid of MHC-27 x MHC-27. The plants are of *Vazhukka* type.
F2: MHC-23 x MHC-23	F2 hybrid of MHC-23 and MHC-23. The plants are of *Vazhukka* type plant.

Twenty two characters including seven growth characters, nine yield characters and six quality characters of the above hybrids and their parents were studied as described elsewhere to evaluate their comparative performance (Table 3.4). The double cross hybrid progeny and F2 hybrid progeny have been analyzed for improvement in characters. Percentages of progeny showing positive heterosis and heterobeltiosis have been calculated. Plants showing heterobeltiosis have been ranked based on overall performance and selected for further studies.

Table 3.5. Characters studied in the case of the evaluation of hybrids

1. Growth characters
1. Tillers per clump
2. Tiller height (cm)
3. Leaves per tiller
4. Leaf length (cm)
5. Leaf breadth (cm)
6. Number of vegetative buds
7. Number of bearing tillers
II. Yield characters
1. Panicles per clump
2. Panicle length (cm)
3. Racemes per panicle
4. Capsules per raceme
5. Fruit set %
6. Seeds per capsule

7. Internodal length (cm)
8. Yield per plant- fresh (g)
9. Yield per plant- dry (g)
III. Quality characters
1. Recovery percentage
2. Percentage of 7 mm and above sized capsules
3. Seed weight- dry (g)
4. Husk weight- dry (g)
5. Litre weight of dry capsules (g)
6. Number of capsules per litre (dry)

3.4. Study of adaptability of some elite landraces and hybrids of cardamom to the Wayanad agro climatic region of Kerala

The performance of nine elite landraces/ hybrids of cardamom in the traditional cardamom tract of Wayanad district of Kerala, India has been analyzed presently keeping the released variety ICRI-2 and a local landrace as control. Data on growth, yield and quality characters were observed at the end of third year. The experiment was started in 2002 in RBD with three replications and 12 plants per plot at a spacing of 3 m x 3 m. The descriptions of the landrace /hybrids and controls used in the study are given in Table 3.5.

Table 3.6. Description of the landraces/ hybrids used for the study of their adaptability to Wayanad agro climatic region

Landraces/ hybrids/ controls	Description
MHC-10	A hybrid of cardamom produced by crossing MCC-34 and MCC-4. The plant has angular bold and deep green capsules. Found to be suited to Idukki and Nelliampathi Hills of Kerala and Nilgiris of Tamil Nadu.
MHC-13	A hybrid of MCC-62 and MCC-3 with medium long capsules. Found to be suited to Idukki and Nelliampathi Hills of Kerala and Nilgiris of Tamil Nadu.
MHC-18	A hybrid of MCC-12 and MCC-35 with angular bold and deep green capsules. Found to be suited to Idukki and Nelliampathi Hills of Kerala
MCC-21	Popularly known as *Vazhukka* LBC (Long Bold Capsule). The

	capsules are long and angular bold. Collected from Kalthotti in Idukki district of Kerala.
MCC-40	Popularly known as *Walayar*. *Malabar* type with short panicles. Early bearing with elongated long capsule. Relatively tolerant to drought. Collected from Mavadi in Idukki.
MCC-73	A *Malabar* type cardamom collection with profuse bearing. Collected from Santhanpara in Idukki. Capsules angular bold.
MCC-200	Collected from Koombanpara of Idukki. A collection with angular bold capsules.
MCC-260	This is a *Vazhukka* type land race popularly known as Njallani Green Gold. Extrabold capsules and good colour are the special characters of this clone. Collected from Njallani, Kattappana, Idukki, Kerala.
MCC-346	This is a *Vazhukka* type plant with good performance and adaptability. Collected from Vandiperiyar in Idukki district of Kerala.
ICRI-2 (control)	A *Mysore* type variety released by Indian Cardamom Research Institute, Myladumpara, Idukki. The variety has long, bold and parrot green capsules. Highly suited to Idukki and Nelliampathi Hills of Kerala and Anamalais of Tamil Nadu.
Local (Clone-37)	It is a clonal selection made by Cardamom Research Centre (Indian Institute of Spices Research) Appangala, Karnataka for its desirable characters such as yield and bold capsule. The capsules are pale green in colour.

Twenty characters including seven growth characters, seven yield characters and six quality characters were observed for the present experiment (Table 3.6). The data were subjected to analysis of variance and comparative performance analysis as described elsewhere to find out relative performance of the landraces, hybrids and controls in the Wayanad geographical area.

Table 3.7. Characters observed for the study of adaptability of the cardamom land races and hybrids to Wayanad agro climatic conditions

1. Growth characters
1. Tillers per clump
2. Tiller height (cm)
3. Leaves per tiller
4. Leaf length (cm)
5. Leaf breadth (cm)

6. Number of vegetative buds
7. Number of bearing tillers
II. Yield characters
1. Panicles per clump
2. Panicle length (cm)
3. Racemes per panicle
4. Capsules per raceme
5. Seeds per capsule
6. Internodal length (cm)
7. Yield per plot- dry (kg)
III. Quality characters
1. Recovery percentage
2. Percentage of 7 mm and above sized capsules
3. 100 capsule weight – dry (g)
4. Volatile oil content (%)
5. Oleoresin content (%)
6. Moisture content (%)

Chapter IV

RESULTS AND DISCUSSION

Small cardamom is a very important commercial product. Studies on its genetic improvement and adaptability of its genotypes to specific cardamom tracts will result in the development of varieties and genotypes suitable for different agroclimatic regions. The present experiments were designed to study variability and performance of certain elite landraces and hybrids of small cardamom so as to select the superior genotypes from them and also to screen genotypes that are suitable to different cardamom growing areas. The major findings of this study are presented below under appropriate heads and discussed in the light of available literature.

4.1. Study of variability of certain elite land races of cardamom

Cardamom breeding in India has resulted in the release of 12 varieties suitable for different agro climatic regions (Thomas *et al.*, 2006). However, many of the farmers prefer local elite landraces due to their high productivity and adaptability. Hence the present study has been designed so as to make a comparative analysis of ten elite landraces of cardamom collected from the cardamom growing areas of Idukki District, Kerala State, India (Table 3.1) in comparison with the released variety ICRI-2 as described elsewhere. Observations on seven growth characters, nine yield characters, sixteen quality characters and thirty one biochemical characters were made for the purpose (Table 3.2). Out of the seven growth characters studied presently, tillers/clump, tiller height, leaf length and leaf breadth showed statistically significant variation among the accessions studied (Table 4.1). Out of the nine yield characters studied, six showed statistically significant variation, out of the sixteen quality characters studied, fourteen showed statistically significant variation and out of the thirty one biochemical characters studied, twenty seven showed statistically significant variation (Table 4.1). The above statistical analysis showed significant difference in the case of most of the characters between the different elite landraces indicating significant levels of genotypic differences between them.

Table 4.1. Characters of the landraces and control studied

1. Growth characters													
Character	Landraces / Control												
	Panikulangara-1	Panikulangara- 2	Njallani	Vali green gold	Palakkudi	PNS Vaigai	Wonder cardamom	ICRI-2	Ela Rani-1	Ela Rani-2	Ela Rani-3	F-value	CD
Tillers per clump	88.94 ±10.06	90.39 ±3.89	70.28 ± 1.13	77.83 ± 10.48	81.56 ± 9.33	66.06 ± 6.22	62.06 ± 5.48	80.39 ± 6.7	95.22 ± 1.06	99.67 ± 5.37	93.01 ± 3.79	10.72 **	11.16
Tiller height (cm)	326.67 ± 18.00	390.44 ± 11.48	341.05 ± 3.02	313.95 ± 44.64	364.94 ± 24.67	347.89 ± 28.33	352.06 ± 10.36	309.16 ± 13.00	305.83 ± 10.36	338.66 ± 5.86	366.83 ± 16.85	5.08 **	34.75
Leaves per tiller	19.22 ±0.58	20.94 ±1.01	21.00 ±1.33	19.82 ±1.34	21.49 ±1.09	20.45 ±1.80	21.44 ±3.36	18.28 ±1.67	20.61 ±0.38	20.72 ±0.58	20.89 ±0.19	1.31	NS
Leaf length (cm)	61.06 ±0.96	69.00 ±2.02	64.94 ±1.84	69.60 ±1.53	61.83 ±1.42	63.72 ±1.45	52.27 ±1.72	61.17 ±2.29	53.61 ±0.48	62.39 ±1.93	59.61 ±3.42	18.55 **	3.19
Leaf breadth (cm)	12.02 ±1.73	11.33 ±0.93	10.61 ±0.35	15.56 ±0.82	12.33 ±1.59	11.55 ±0.63	10.00 ±0.88	12.22 ±0.97	8.49 ±0.54	11.83 ±0.17	10.61 ±0.38	5.01 **	1.61
Number of veg. buds	4.94 ±1.78	4.50 ±1.88	4.06 ±1.29	3.5 ±1.33	4.56 ±0.10	3.50 ±0.76	4.22 ±0.25	2.72 ±1.11	3.28 ±0.19	3.67 ±0.34	3.28 ±0.35	1.20	NS
Number of bearing tillers	46.5 ±9.69	52.22 ±9.48	38.78 ±5.17	43.39 ±6.56	49.28 ±12.00	39.67 ±5.51	38.89 ±2.11	44.78 ±14.14	45.50 ±0.50	58.17 ±0.29	51.17 ±1.17	1.95	NS

2. Yield characters													
Character	Landraces / Control												
	Panikulan gara-1	Panikulan gara-2	Njallani	Vali green gold	Palakku di	PNS Vaigai	Wonder cardamom	ICRI-2	Ela Rani-1	Ela Rani-2	Ela Rani-3	F-value	CD
Panicles per clump	91.94 ±20.15	104.66 ±21.46	84.78 ±12.62	87.00 ±13.07	102.72 ±30.00	83.84 ±15.04	80.39 ±7.86	76.78 ±17.68	95.00 ±0.50	112.83 ±10.00	63.00 ±0.5	2.46 *	26.55
Panicle length (cm)	78.17 ±19.40	81.45 ±22.01	69.83 ±5.09	76.78 ±6.71	97.39 ±11.67	95.39 ±24.09	83.83 ±6.76	69.33 ±9.21	60.66 ±0.29	101.62 ±0.82	70.55 ±0.28	3.18 *	21.66
Racemes per panicle	26.61 ±2.99	24.39 ±0.42	25.89 ±1.99	25.72 ±3.45	28.94 ±0.92	28.21 ±2.46	27.77 ±1.57	18.95 ±0.48	21.44 ±0.20	26.89 ±0.07	25.89 ±0.19	8.35 **	3.04
Capsules per raceme	8.44 ±0.35	8.34 ±0.59	7.89 ±0.49	9.06 ±0.54	7.05 ±0.35	8.44 ±0.20	7.89 ±1.06	7.00 ±0.93	8.17 ±1.19	7.66 ±0.08	8.55 ±0.01	4.17 **	0.91
Fruit set %	73.29 ±4.98	71.30 ±9.73	72.86 ±5.74	63.06 ±4.32	69.93 ±5.47	59.30 ±2.28	61.78 ±3.19	65.67 ±13.92	81.94 ±2.52	75.37 ±4.64	67.85 ±0.80	3.32 **	10.75
Seeds per capsule	18.33 ±2.08	19.67 ±4.04	19.67 ±0.57	19.67 ±2.08	16.33 ±1.53	17.33 ±3.79	21.33 ±0.57	16.33 ±0.57	21.33 ±0.57	19.67 ±0.57	19.67 ±1.53	2.21	NS
Internodal length (cm)	4.14 ±0.76	4.22 ±0.75	3.72 ±0.25	3.94 ±0.51	4.17 ±0.50	4.39 ±0.35	4.05 ±0.63	4.61 ±0.85	3.68 ±0.12	6.17 ±0.29	4.96 ±0.34	5.12 **	0.91
Yield per plant- fresh (kg)	4.05 ±1.82	4.82 ±1.7	3.96 ±0.75	4.81 ±0.77	4.48 ±1.10	5.04 ±0.82	3.51 ±0.30	3.19 ±0.57	4.08 ±0.17	4.00 ±0.37	4.17 ±1.37	1.06	NS
Yield per plant- dry (kg)	0.850 ±0.39	0.940 ±0.30	0.806 ±0.14	1.030 ±0.14	1.043 ±0.28	1.078 ±0.14	0.737 ±0.09	0.639 ±0.10	0.856 ±0.03	0.840 ±0.6	0.879 ±0.9	1.44	NS

3. Quality characters													
Character	Landraces / Control												
	Panikulan gara-1	Panikulan gara-2	Njallani	Vali green gold	Palakkudi	PNS Vaigai	Wonder cardamom	ICRI-2	Ela Rani-1	Ela Rani-2	Ela Rani-3	F-value	CD
Recovery %	21.00 ±0	19.65 ±1.00	20.33 ±0	21.51 ±1.73	22.79 ±0	21.43 ±1.03	20.97 ±0.99	20.04 ±0.30	21.00 ±0	20.98 ±1.00	21.10 ±0	3.17 *	1.37
% of 7 mm & above capsules	78.00 ±0	60.22 ±1.00	71.31 ±1.00	80.04 ±1.24	76.06 ±0	76.51 ±1	83.72 ±0	62.91 ±1.00	73.98 ±1.34	72.03 ±0	73.00 ±0	280.8 **	1.21
Seed wt.- fresh capsules	0.43 ±0.06	0.37 ±0.06	0.40 ±0.10	0.43 ±0.06	0.43 ±0.12	0.43 ±0.06	0.47 ±0.06	0.43 ±0.06	0.50 ±0	0.50 ±0	0.43 ±0.60	1.07 **	0.11
Seed wt.- dry capsules	0.19 ±0.02	0.19 ±0.06	0.20 ±0.05	0.17 ±1.82	0.21 ±0.03	0.21 ±0.02	0.18 ±0.02	0.26 ±1.17	0.26 ±1.17	0.24 ±0.01	0.25 ±1.01	4.63 **	0.01
Husk wt.- fresh	0.90 ±0	0.80 ±0.10	1.07 ±0.06	1.03 ±0.23	0.80 ±0.10	1.10 ±0.10	1.07 ±0.06	0.73 ±0.06	0.90 ±0	0.87 ±0.06	0.87 ±0.06	5.23 **	0.16
Husk wt.- dry	0.06 ±1.82	0.05 ±1.82	0.07 ±1.82	0.06 ±2.94	0.06 ±1.82	0.06 ±1.82	0.07 ±1.82	0.07 ±0.01	0.08 ±0.01	0.07 ±0.01	0.08 ±1.82	2.28	NS
Seed : husk ratio- fresh capsules	48:1 ±6.42	46.82:1 ±12.2	37.27:1 ±7.77	42.45:1 ±3.45	55.75:1 ±19.93	39.34:1 ±2.71	43.94:1 ±6.99	59.52:1 ±10.91	55.66:1 ±0	57.87:1 ±4.00	50.00:1 ±5.56	2.18	NS
Litre wt.- fresh capsules (g)	546.67 ±15.27	566.67 ±5.77	566.67 ±5.77	533.33 ±5.77	573.33 ±11.54	560.00 ±10.00	556.67 ±5.77	566.67 ±11.54	555.00 ±5.0	575.00 ±8.66	568.67 ±2.30	3.13 *	14.87
No. of fresh capsules per litre	571.33 ±24.82	646.00 ±44.22	590.67 ±56.12	539 ±16.37	562.00 ±12.76	515.67 ±19.75	505.00 ±21.65	535.33 ±21.36	551.67 ±2.06	560.67 ±8.14	563.33 ±4.16	6.36 **	44.64

Character	Landraces / Control												
	Panikulan gara-1	Panikulan gara-2	Njallani	Vali green gold	Palakkudi	PNS Vaigai	Wonder cardamom	ICRI-2	Ela Rani-1	Ela Rani-2	Ela Rani-3	F-value	CD
Litre wt of dry capsule (g)	340 ±0	340 ±0	340 ±0	340 ±0	360 ±0	344.33 ±4.04	320 ±0	340 ±0	350 ±0	356.67 ±5.77	356.67 ±5.77	50.41 **	4.67
No of dry capsule per litre	2166.67 ±6.1	2505.33 ±21.58	2308.33 ±38.78	2104 ±78.79	2243.67 ±40.50	2281 ±29.30	2015 ±16.82	2041.33 ±18.90	1984.33 ±10.59	1984.67 ±21.45	2104 ±89.83	4.45 **	228.08
100 capsule wt.- fresh (g)	133.86 ±9.3	116.98 ±1.38	126.09 ±0.72	137.76 ±2.61	117.9 ±1.35	132.23 ±1.91	134.35 ±1.15	121.92 ±0.80	133.33 ±2.88	139.49 ±1.3	137.86 ±7.52	12.76 **	6.69
100 capsule wt.- dry (g)	20.21 ±1.02	20.24 ±1.80	19.58 ±3.13	20.36 ±3.67	20.63 ±3.12	22.56 ±1.93	17.24 ±1.10	26.84 ±1.11	22.47 ±0.13	23.17 ±0.37	23.52 ±0.50	4.84 **	3.41
Volatile oil content (%)	8.79 ±0.69	9.08 ±0.24	9.04 ±0.24	9.85 ±0.95	8.49 ±1.19	8.45 ±0.77	8.99 ±0.24	8.99 ±1.30	8.69 ±1.82	8.94. ±0.04	8.61 ±0.01	2.28	NS
Oleoresin content (%)	6.72 ±0.75	6.31 ±0.38	5.75 ±0.30	7.66 ±0.17	7.33 ±0.27	6.38 ±1.26	7.17 ±0.13	6.26 ±0.09	7.09 ±0.37	7.20 ±0.27	6.97 ±0.47	3.64 **	0.88
Moisture content (%)	10.67 ±0.48	9.33 ±0.14	10.07 ±0.51	12.43 ±0.10	10.87 ±0.81	10.5 ±0.26	12.43 ±0.10	11.04 ±0.10	10.57 ±0.05	10.83 ±0.5	11.00 ±0.1	21.48 **	0.58

4. Biochemical characters													
Character	Landraces / Control												
	Panikul angara- 1	Panikul angara- 2	Njallani	Vali green gold	Palakkudi	PNS Vaigai	Wonder cardamom	ICRI-2	Ela Rani-1	Ela Rani-2	Ela Rani-3	F-value	CD
Chlorophyll a -leaf (mg g^{-1} fresh tissue)	2.77 ±0.03	2.41 ±0.12	1.95 ±0.32	2.21 ±0.22	2.08 ±0.28	2.59 ±0.11	2.70 ±0.03	1.47 ±0.19	1.33 ±0.28	1.57 ±0.19	1.60 ±0.14	21.96 **	0.33
Chlorophyll b–leaf (mg g^{-1} fresh tissue)	0.70 ±0.26	0.39 ±0.11	0.44 ±1.02	0.41 ±0.11	0.41 ±0.06	0.41 ±0.16	0.47 ±0.03	0.29 ±0.06	0.38 ±0.08	0.35 ±0.04	0.38 ±0.07	2.62 *	0.09
Total chlorophyll - leaf(mg g^{-1} fresh tissue)	1.84 ±0.04	1.52 ±0.15	0.88 ±0.23	1.38 ±0.24	1.28 ±0.27	1.58 ±0.25	1.74 ±0.02	2.39 ±0.19	2.28 ±0.46	2.64 ±0.03	2.61 ±0.08	18.60 *	0.40
Chlorophyll a/ b ratio- leaf (mg g^{-1} fresh tissue)	4.28 ±1.36	6.37 ±1.48	3.64 ±0.87	5.60 ±0.92	5.22 ±1.10	4.49 ±0.17	5.53 ±0.20	5.19 ±0.81	3.04 ±0.26	4.45 ±0.33	4.31 ±1.11	3.31 *	1.55
Chlorophyll a- fresh capsule (mg g^{-1} fresh tissue)	1.29 ±0.24	1.47 ±0.22	1.40 ±0.10	1.46 ±0.16	1.36 ±0.48	1.32 ±0.20	1.42 ±2.1	1.60 ±0.03	0.97 ±0.35	0.95 ±0.37	1.08 ±0.04	2.2	NS
Chlorophyll b- fresh capsule (mg g^{-1} fresh tissue)	1.11 ±0.89	1.05 ±0.04	0.79 ±0.07	1.19 ±0.08	1.04 ±0.06	1.29 ±0.25	1.05 ±0.06	1.20 ±0.06	0.61 ±0.25	0.39 ±0.25	0.70 ±0.18	10.89 **	0.25
Total chlorophyll- fresh capsule (mg g^{-1} fresh tissue)	1.03 ±0.04	0.95 ±0.05	0.71 ±0.06	1.08 ±0.07	1.08 ±0.15	1.32 ±0.05	0.98 ±1.02	1.21 ±0.08	0.56 ±0.22	0.37 ±0.22	0.65 ±0.15	17.66 **	0.21
Chlorophyll a/b ratio- fresh capsule (mg g^{-1} fresh tissue)	1.13 ±0.02	1.40 ±0.20	1.78 ±0.03	1.24 ±0.18	1.31 ±0.44	1.16 ±0.26	1.36 ±0.02	1.24 ±0.20	1.63 ±0.10	3.45 ±0.36	1.62 ±0.53	2.35 **	1.26

Character	Landraces / Control												
	Panikulan gara-1	Panikulan gara-2	Njallani	Vali green gold	Palakkudi	PNS Vaigai	Wonder cardamom	ICRI- 2	Ela Rani-1	Ela Rani-2	Ela Rani-3	F-value	CD
Chlorophyll a- dry capsule (mg g^{-1} fresh tissue)	2.40 ±0.05	2.95 ±0.11	3.19 ±0.10	2.79 ±0.1	2.78 ±0.05	3.07 ±0.05	3.15 ±0.04	2.94 ±0.06	2.44 ±0.38	2.56 ±0.33	3.04 ±0.72	3.15 **	0.46
Chlorophyll b- dry capsule (mg g^{-1} fresh tissue)	1.90 ±0.09	2.77 ±0.05	3.14 ±0.21	2.81 ±0.06	2.62 ±0.07	3.14 ±0.10	2.95 ±0.07	2.73 ±0.08	2.01 ±0.41	2.44 ±0.18	2.84 ±0.57	8.80 **	0.40
Total chlorophyll- dry capsule (mg g^{-1} fresh tissue)	1.70 ±0.08	2.47 ±0.05	2.79 ±0.18	2.48 ±0.04	2.44 ±0.25	2.79 ±0.10	2.62 ±0.06	2.43 ±0.07	1.82 ±0.36	2.09 ±0.22	2.72 ±0.87	4.34 **	0.53
Chlorophyll a/ b ratio- dry capsule (mg g^{-1} fresh tissue)	1.26 ±0.03	1.07 ±0.04	1.02 ±0.10	0.99 ±0.03	1.06 ±0.01	0.97 ±0.07	1.07 ±0.10	1.08 ±0.02	1.20 ±0.60	1.05 ±0.17	1.07 ±0.90	3.91 **	0.13
Relative water content (%)- leaf	78.80 ±2.22	65.77 ±0.82	56.67 ±2.03	72.48 ±1.93	59.36 ±5.57	80.22 ±2.98	83.25 ±5.69	72.20 ±2.47	72.22 ±5.66	66.94 ±10.20	76.03 ±17.29	4.42 **	11.83
Stomatal frequency	24.67 ±1.15	27.67 ±4.16	25.67 ±2.08	32.33 ±2.08	26.67 ±2.31	25.67 ±1.53	21.33 ±1.53	27.00 ±3.61	28.67 ±2.31	27.67 ±1.15	28.00 ±1.17	4.07 **	3.98
Stomatal index	4.58 ±0.49	5.41 ±0.79	4.85 ±0.48	5.79 ±0.32	5.05 ±0.41	4.84 ±0.28	3.98 ±0.24	5.07 ±0.79	5.06 ±0.51	4.99 ±6.83	5.42 ±0.37	2.64	NS
Leaf proline (µ moles g^{-1} tissue)	2.10 ±0.02	1.38 ±0.03	2.46 ±0.37	2.04 ±0.02	1.37 ±0.35	1.72 ±0.30	2.52 ±0.05	2.35 ±0.34	1.38 ±0.31	2.46 ±0.37	2.04 ±0.02	23.33 **	0.28

Character	Landraces / Control												
	Panikulangara-1	Panikulangara-2	Njallani	Vali green gold	Palakkudi	PNS Vaigai	Wonder cardamom	ICRI- 2	Ela Rani-1	Ela Rani-2	Ela Rani-3	F-value	CD
Epicuticular wax (μ g/cm^2)	9.62 ±0.24	9.64 ±0.22	7.62 ±0.08	10.77 ±0.22	10.84 ±0.17	9.23 ±0.80	9.28 ±0.14	8.29 ±0.32	9.78 ±0.71	9.87 ±1.00	8.42 ±0.83	13.19 **	0.81
Reducing sugar – leaf (g 100 g^{-1} fresh tissue)	5.43 ±0.81	4.34 ±0.10	4.62 ±1.82	4.74 ±0.30	4.19 ±0.33	5.66 ±0.10	2.18 ±1.82	4.75 ±0.02	4.53 ±2.80	4.89 ±0.75	4.12 ±1.73	5.88 **	0.58
Soluble protein-leaf (g 100 g^{-1} fresh tissue)	6.10 ±0.31	5.76 ±0.42	6.14 ±0.09	8.49 ±0.26	6.73 ±0.26	9.71 ±0.16	8.37 ±0.12	11.79 ±0.56	5.76 ±0.42	6.14 ±0.09	8.49 ±0.26	165.02 **	0.45
Insoluble protein-leaf (g 100 g^{-1} fresh tissue)	20.72 ±0.77	19.28 ±0.44	18.89 ±0.96	16.91 ±0.72	16.59 ±0.33	15.26 ±0.11	10.41 ±0.39	15.12 ±3.68	19.28 ±0.14	18.89 ±0.96	16.91 ±0.72	15.73 **	2.12
Crude protein - capsule (g 100 g^{-1} capsule flour)	11.31 ±0.01	11.66 ±0.18	10.96 00	12.30 ±0.03	11.64 ±0.23	11.43 ±0.23	12.98 ±0.17	13.32 ±0.26	10.61 ±0.30	10.38 ±1.74	10.52 ±0.11	90.30 **	0.30
Crude lipid-capsule (g 100 g^{-1} capsule flour)	3.54 ±1.00	2.58 ±0.35	3.8 ±1.47	2.75 ±0.04	3.52 ±0.58	2.94 ±0.02	2.67 ±0.04	3.03 ±1.49	3.06 ±0.35	2.29 ±0.36	3.39 ±0.56	1.39	NS
Crude fibre- (g 100 g^{-1} capsule flour)	20.84 ±2.38	22.35 ±1.99	27.04 ±1.59	24.50 ±0.64	23.67 ±2.04	21.56 ±0.36	25.07 ±0.17	27.90 ±1.31	21.81 ±0.71	21.26 ±0.65	25.01 ±0.45	9.55 **	2.28
Ash content- (g 100 g^{-1} capsule flour)	8.53 ±0.39	8.55 ±0.43	10.32 ±0.26	8.83 ±0.04	8.36 ±0.33	8.85 ±0.54	9.30 ±0.53	9.19 ±0.36	8.80 ±0.04	7.82 ±0.04	8.27 ±0.04	11.60 **	0.57

Character	Landraces / Control												
	Panikulan gara-1	Panikulan gara-2	Njallani	Vali green gold	Palakkudi	PNS Vaigai	Wonder cardamom	ICRI-2	Ela Rani-1	Ela Rani-2	Ela Rani-3	F-value	CD
Acid insoluble ash (g 100 g^{-1} capsule flour)	0.18 ±0.07	0.27 ±0.02	0.23 ±0.3	0.43 ±0.01	0.70 ±0.01	0.19 ±0.03	0.48 ±0.01	0.44 ±0.08	0.33 ±0.03	0.27 ±0.02	0.25 ±0.01	33.13 **	0.06
Carbohydrate (g 100 g^{-1} capsule flour)	58.37 ±1.60	56.43 ±2.81	50.96 ±2.07	54.89 ±0.59	55.66 ±2.87	57.68 ±0.58	53.52 ±0.49	50.06 ±1.78	50.28 ±1.47	53.13 ±2.69	52.32 ±1.16	7.37 **	3.16
Calorific value (Kcal 100 g^{-1} DM)	307.27 ±6.88	295.08 ±10.65	278.43 ±9.81	290.54 ±2.60	292.24 ±10.27	299.36 ±3.23	287.05 ±1.43	274.41 ±49.34	272.37 ±8.38	287.23 ±13.44	282.66 ±3.30	1.12	NS
Phenol capsule (g 100 g^{-1} capsule flour)	0.33 ±0.01	0.31 ±0.01	0.31 ±0.06	0.20 ±0	0.27 ±0	0.21 ±1.85	0.33 ±0.01	0.26 ±1.85	0.23 ±0.02	0.21 ±0	0.25 ±0	22.04 **	0.03
Tannins capsule (g 100 g^{-1} capsule flour)	0.13 ±1.82	0.15 ±1.82	0.14 ±0.02	0.17 ±1.82	0.20 ±0.02	0.2 ±0	0.20 ±0.01	0.18 ±1.82	0.27 ±0.01	0.28 ±0.02	0.24 ±0.1	56.44 **	0.01
Amino acids (g 100 g^{-1} capsule flour)	0.23 ±0.02	0.24 ±0.02	0.31 ±0.01	0.25 ±1.85	0.21 ±0.02	0.19 ±1.02	0.21 ±0.01	0.26 ±0.01	0.24 ±1.85	0.23 ±0.01	0.23 ±0.01	17.34 **	0.05
Reducing sugar-capsule (g 100 g^{-1} capsule flour)	7.55 ±0.39	5.34 ±0.02	7.61 ±0.44	5.81 ±0.25	3.24 ±0.12	3.29 ±0.47	4.37 ±0.47	7.05 ±0.33	5.38 ±0.53	4.99 ±0.42	4.80 ±0.27	58.43 **	0.59

*: Significant at 5% level; **: Significant at 1% level

Among the growth characters, highest GCV and PCV were shown by tillers per clump; highest heritability was shown by leaf length and highest genetic advance by tillers per clump. This shows that tillers per clump is the most important growth character with the highest GCV, PCV and genetic advance. This character shows 75.42 percentage of heritability (broad sense) also. Among the yield characters studied, the highest GCV and genetic advance were shown by internodal length, highest PCV by panicles per clump and the highest heritability by racemes per panicle. Among the quality characters, GCV and PCV were the highest in dry seed weight, highest heritability was in the case of percentage of 7 mm and above sized capsules and highest genetic advance in the case of percentage of 7 mm and above capsules, seed weight- dry and husk weight- fresh (Table 4.2).

Among the biochemical characters, acid insoluble ash content showed the highest GCV. Highest PCV was shown by chlorophyll b content of leaf. Highest heritability was shown by acid insoluble ash content in capsule followed by soluble protein in leaf, crude protein in capsule, tannin in capsule and reducing sugar in capsule. In all the characters that were statistically significant, PCV was found to be higher than GCV indicating polygenic control of characters and additive gene action. Differential variability of quantitative characters has been reported by earlier workers in cardamom (Radhakrishnan *et al.*, 2006), rice (Mini, 2006), coffee (Nikhila *et al.*, 2002; Raghu *et al.*, 2003), medicinal plants (Misra *et al.*, 1998; Jayasree *et al.*, 2006) and vanilla (Umamaheswari and Mohanan, 2004). Study of variability of the genetic resources of a crop is the first step towards the understanding of the genetic diversity of the genetic stock so as to use them in crop improvement programmes.

Most of the agronomic characters of the crop plants are polygenic and cardamom is no exemption. Polygenic characters show different levels of heritability based on their response to environmental factors. Among the growth characters heritability (broad sense) was found to be the highest in the case of leaf length followed by tillers per clump (Table 4.2). Among the yield characters, racemes per panicle showed the highest heritability. In the case of quality characters the highest

heritability was shown by percentage of 7 mm and above sized capsules which is a very desirable phenomenon. In the case of biochemical characters, the highest heritability was shown by acid insoluble ash, soluble protein- leaf, crude protein- capsule and reducing sugar- capsule in that order.

Highest heritability of characters indicates the limited influence of environment on these characters. Characters like panicles per clump, panicle length, fruit set percentage, fresh seed weight, litre weight of fresh capsules, oleoresin content, chlorophyll b content of leaf and chlorophyll a/ b ratio of leaf and capsules show heritability below 50%, where as all other statistically significant characters show above 50% of heritability. The reason for low heritability in the case of some characters is the influence of environment on them as suggested by earlier workers (Tripathy *et al.*, 2000; Radhakrishnan, 2003).

Genetic advance of characters in percentage of mean is a very effective indicator of the characters that could be utilized in selection programmes. It is a measure derived from heritability. Statistically significant characters analyzed presently showed genetic advance ranging from 0.006 to 0.58. Total chlorophyll content- fresh capsule showed the maximum genetic advance and this is a very desirable condition since green colour of capsules is determined by their chlorophyll content and green dry capsules are preferred highly in the internal and international markets. Total chlorophyll content in leaf showed high genetic advance also. Among the growth characters, total tillers per clump showed the highest genetic advance and among the yield characters internodal length of panicles and racemes per panicle showed the highest genetic advance in that order. Among the quality characters percentage of 7 mm and above sized capsules, dry seed weight and fresh husk weight showed the highest genetic advance. Characters with highest genetic advance could be utilized for selection programmes as reported by earlier workers in cardamom (George *et al.*, 1981; Radhakrishnan *et al.*, 2006) and other crops (Jayasree *et al.* 2006). Studies by Korikanthimath *et al.* (1998) and Korikanthimath *et al.* (2000) showed significant treatment differences for yield and morphological characters.

Table 4.2. Genotypic variance, phenotypic variance, GCV, PCV, heritability (broad sense) and genetic advance of the characters studied in the case of the landraces of cardamom analyzed presently

Sl. No	Characters	Genotypic variance	Phenotypic variance	GCV	PCV	Heritability (broad sense) (%)	Genetic advance
I	**Growth characters**						
1	Tillers/ clump**	139.2	182.14	14.33	16.38	75.42	0.19
2	Tiller height **	565.77	981.87	7.00	9.17	57.80	0.11
3	Leaves/ tiller^{NS}	0.23	2.40	-	-	-	-
4	Leaf length **	20.64	24.17	7.30	7.91	85.00	0.14
5	Leaf breadth **	1.19	2.07	9.71	12.81	57.00	0.15
6	Number of vegetative buds^{NS}	0.08	1.19	-	-	-	-
7	Number of bearing tillers^{NS}	18.56	76.17	-	-	-	-
II	**Yield characters**						
1	Panicles per clump*	118.31	361.25	12.17	21.30	32.75	0.14
2	Panicle length *	117.64	279.4	13.48	20.77	42.10	0.18
3	Racemes per panicle**	7.79	10.96	10.93	12.95	71.00	0.19
4	Capsules per raceme**	0.30	0.59	6.58	9.57	50.85	0.10
5	Fruit set % **	30.76	70.59	8.01	12.12	43.58	0.11
6	Seeds/ capsule^{NS}	1.67	5.82	-	-	-	-
7	Inter nodal length **	0.39	0.68	14.19	18.76	57.00	0.22
8	Yield per plant fresh ^{NS}	0.02	0.91	-	-	-	-
9	Yield per plant dry ^{NS}	0.01	0.04	-	-	-	-
III	**Quality characters**						
1	Recovery %*	0.47	1.12	3.29	5.05	51.09	0.05
2	% of 7 mm & above capsules**	47.29	47.81	9.38	9.43	98.93	0.19
3	Seed wt.- fresh**	0.0001	0.0043	7.18	14.90	2.32	0.006
4	Seed wt.- dry**	0.0008	0.0015	12.85	17.60	53.3	0.19

5	Husk wt.- fresh*	0.013	0.022	12..39	16.12	59.09	0.19
6	Husk wt- dry *	0.0543	0.0544	-	-	-	-
7	Seed : Husk ratio fresh^{NS}	31.64	111.76	-	-	-	-
8	Litre wt. of fresh capsules *	54.07	130.31	1.306	2.03	41.49	0.017
9	Number of fresh capsules per litre**	1226.57	1913.60	6.27	7.83	64.09	0.103
10	100 capsule wt.- fresh**	60.6	76.03	5.98	6.69	79.71	0.11
11	Litre wt of dry capsules**	124.26	131.81	3.23	3.33	94..27	0.064
12	Number of dry capsules per litre**	20610.24	38543.54	6.65	9.09	53.47	0.10
13	100 capsule wt dry**	5.12	9.12	10.5	14.04	56.14	0.16
14	Volatile oil content (%)^{NS}	0.083	0.28	-	-	-	-
15	Oleoresin content (%)**	0.23	0.50	7.05	10.30	46.00	0.10
16	Moisture content (%)**	0.81	0.92	8.24	8.78	88.04	0.14
IV	**Biochemical characters**						
1	Chlorophyll a content- leaf **	0.25	0.29	24.27	26.14	86.21	0.46
2	Chlorophyll b content- leaf *	0.007	0.019	19.05	33.33	36.84	0.23
3	Total Chlorophyll-leaf*	0.32	0.37	30.76	33.23	85.67	0.58
4	Chlorophyll a/ b ratio Leaf*	0.63	1.46	16.67	25.53	43.15	0.23
5	Chlorophyll a content fresh capsule^{NS}	0.027	0.089	-	-	-	-
6	Chlorophyll b- fresh capsule**	0.07	0.09	30.68	34.1	77.78	0.05
7	Total Chlorophyll fresh capsule**	0.08	0.09	31.1	33.3	88.00	0.61
8	Chlorophyll a/ b ratio- fresh capsule**	0.25	0.8	31.21	56.69	31.25	0.36
9	Chlorophyll a - dry capsule**	0.053	0.123	8.07	12.30	43.00	0.11
10	Chlorophyll b- dry capsule**	0.14	0.20	14.16	16.66	72.00	0.24

11	Total Chlorophyll- dry capsule**	0.10	0.20	12.92	18.75	50.00	0.19
12	Chlorophyll a/ b ratio- dry capsule**	0.01	0.01	6.48	9.26	50.00	0.01
13	Relative water content- leaf**	54.94	103.20	10.39	14.25	53.24	0.16
14	Stomatal frequency**	5.59	11.04	8.80	12.37	50.63	0.47
15	Stomatal index^{NS}	0.16	0.45	-	-	-	-
16	Leaf proline**	0.20	0.23	22.73	24.24	86.96	0.43
17	Epicuticular wax**	0.91	1.13	10.11	11.28	80.53	0.19
18	Reducing sugar- leaf**	0.68	1.09	18.26	23.16	62.39	0.30
19	Soluble protein- leaf**	3.80	3.87	25.69	25.96	98.19	0.52
20	Insoluble protein- leaf**	7.63	9.18	16.13	17.71	83.12	0.30
21	Crude protein- capsule**	0.94	0.97	8.39	8.48	96.91	0.17
22	Crude lipid- capsule^{NS}	0.06	0.53	-	-	-	-
23	Crude fibre(%)- capsule**	5.12	6.19	9.54	11.08	74.10	0.17
24	Ash- capsule (%)**	0.39	0.50	7.79	8.82	78.00	0.14
25	Acid insoluble ash- capsule**	0.02	0.02	48.76	48.76	100.00	0.14
26	Carbohydrate- capsule**	7.30	10.74	5.0	6.07	67.97	0.08
27	Calorific value of capsule^{NS}	12.29	312.99	-	-	-	-
28	Phenol- capsule**	0.0020	0.0023	17.2	18.44	86.86	0.32
29	Tannins- capsule**	0.0023	0.0024	23.97	24.49	95.83	0.46
30	Amino acids- capsule**	0.0008	0.001	11.78	13.18	80.00	0.21
31	Reducing sugar- capsule**	2.27	2.38	27.9	28.6	92.43	0.54

**: significant at 1% level; *: significant at 5% level.

4.2. Correlation of characters

Selection of appropriate genotypes based on characters that show good heritability and genetic advance is a very important tool in crop improvement since selection could not be carried out based on all characters. Study of interrelationship of characters is essential to identify the variables which show maximum relationship with others.

Sixty two characters of the eleven genotypes of cardamom studied presently were subjected to correlation analysis (Tables 4.3 and 4.4). The study revealed that tillers per clump showed significant positive correlation with number of bearing tillers and fruit set percentage. Tiller height was positively correlated with leaves per tiller and number of dry capsules per litre. Leaf length showed significant positive correlation with leaf breadth and number of dry capsules per litre. Number of bearing tillers showed significant positive correlation with tillers per clump and inter nodal length of panicles. Panicle length was found to show significant positive correlation with racemes per panicle and racemes per panicle significantly correlated with leaves per tiller also.

Yield per plant- fresh and yield per plant- dry were positively correlated and number of fresh capsules per litre and number of dry capsules per litre also showed significant positive correlation. Recovery percentage and percentage of 7 mm and above sized capsules also showed significant positive correlation. Biochemical characters of the genotypes studied showed significant positive correlations at different levels.

Characters that show significant positive correlation are considered to be inter related and thus can be jointly considered in selection programmes. Similar approaches have been used by earlier workers in different crops including cardamom (Radhakrishnan, 2003; Ramasubramanian, 2005 and Raghu, 2005). Yield components of cardamom have been subjected to correlation and path analysis by Sritharan *et al.* (1993). Yield correlation studies in cardamom by Patil *et al.* (1996) suggested that capsules per panicle, racemes per panicle, tillers per clump, panicles

per clump and panicle length were the main contributors to yield. Patil *et al.* (1997) suggested the utility of traits like panicles per bearing tiller, panicles per clump, recovery ratio and capsules per panicle as criteria for selection for yield in cardamom. They have further concluded that capsules and cincinni per panicle, bearing tillers and panicles per clump, panicle length and vegetative buds per clump are significant attributes responsible for high yield in cardamom. Correlation of yield contributing characters has been attempted in cardamom by Korikanthimath *et al.* (2000) also. Number of tillers per plant, number of bearing tillers per plant and number of panicles per plant showed positive and significant correlation with number of capsules per plant. A study by Backiyarani *et al.* (2003) showed that plant height, tiller number, panicle number, panicle length and recovery percentage showed high correlation with yield.

Table 4.3. Correlation of characters in the eleven genotypes of cardamom studied

	Tillers/ clump	Tiller height	Leaves/ tiller	Leaf length	Leaf breadth	No. of veg.buds	No. of bearing tillers	Panicles/ clump
Tillers/ clump	1							
Tiller height	-0.02615	1						
Leaves/ tiller	-0.10915	0.652893*	1					
Leaf length	0.036857	0.220183	-0.16947	1				
Leaf breadth	-0.094	-0.13473	-0.39237	0.717276*	1			
No. of veg. buds	-0.06294	0.485751	0.378928	0.114635	0.018271	1		
No. of bearing tillers	0.868198**	0.299497	0.077407	0.175559	0.075407	0.05964	1	
Panicles/ clump	0.227886	-0.24052	-0.24857	0.121715	-0.11253	-0.132	0.095922	1
Panicle length	-0.09818	0.423311	0.336994	0.208567	0.304828	0.352279	0.321777	-0.16803
Racemes/ panicle	-0.30234	0.516182	0.624033*	0.094592	0.162575	0.60518	-0.01558	-0.29857
Capsules/ raceme	0.027209	0.008796	0.024643	0.287519	0.192298	0.052819	-0.12993	0.429097
Fruit set %	0.732295*	-0.17429	0.093817	-0.19033	-0.4522	0.143279	0.463223	0.230073
Seeds / capsule	0.119412	-0.01381	0.426379	-0.33219	-0.43666	0.030042	-0.03609	0.531061
Internodal length	0.476301	0.144392	-0.04194	0.053997	0.110818	-0.24165	0.725722*	0.207326
Yield/ plant-fresh	0.012599	0.383204	0.30669	0.604505	0.344071	0.234816	0.091346	-0.02863
Yield/ plant-dry	-0.03265	0.327079	0.360296	0.483814	0.379185	0.253037	0.070829	-0.26887
No. of fresh capsules/ litre	0.489728	0.490587	0.160213	0.514907	-0.05164	0.426051	0.477436	0.181771
No of dry capsules/ litre	-0.172	0.662404*	0.238031	0.644218*	0.109306	0.496837	-0.04205	-0.0801
Recovery %	-0.10035	-0.00808	0.322161	-0.1417	0.25137	0.169666	-0.0008	-0.69371

%of 7mm and above capsules	-0.3911	-0.21652	0.264277	-0.38872	0.089474	0.225542	-0.40092	-0.21313
Seed wt. – fresh	0.245624	-0.50356	0.064598	-0.68385	-0.30793	-0.31403	0.149507	0.157715
Seed wt. - dry	0.521586	-0.27328	-0.21839	-0.39485	-0.44497	-0.66931	0.365094	-0.02588
Husk wt. - dry capsule	-0.42886	0.057337	0.005408	0.083752	-0.0231	-0.20281	-0.36012	0.035312
Husk wt.- fresh capsule	-0.67403	-0.08994	0.304966	-0.03566	-0.01849	0.075774	-0.69073	0.201399
Litre weight of fresh capsules	0.220596	0.509403	0.35946	-0.10503	-0.40956	-0.04173	0.453427	-0.25092
100 capsule wt.- fresh	0.126226	-0.37943	-0.03089	-0.27165	0.02233	-0.26719	0.01785	0.395174
Litre wt. of dry capsules	0.592261	-0.4283	-0.15948	-0.05734	0.184973	-0.34352	0.451308	0.096668
100 capsule wt.- dry	0.419373	-0.34067	-0.58822	0.035349	0.045185	-0.75271	0.339003	0.024257
Volatile oil (%)	-0.09872	-0.29558	-0.2611	0.473158	0.606897	-0.08904	-0.1095	0.385737
Oleoresin (%)	0.237505	-0.14601	0.190312	-0.21316	0.304064	0.002469	0.29409	-0.22149
Moisture content (%)	-0.35866	-0.38434	-0.08565	-0.30379	0.360292	-0.21622	-0.29998	-0.17598
Chlorophyll a - leaf	-0.5471	0.348961	0.123972	0.172257	0.232377	0.69771*	-0.38325	0.008578
Chlorophyll b -leaf	-0.10388	-0.01122	-0.06271	-0.0856	0.026162	0.73846**	-0.21602	0.053578
Total chlorophyll- leaf	0.619359*	-0.22534	-0.29126	-0.43714	-0.25848	-0.5273	0.549769	0.257901
Chlorophyll a/ b ratio- leaf	-0.21361	0.463839	-0.00184	0.423242	0.529035	0.235157	0.131759	-0.10756
Chlorophyll a - fresh capsule	-0.63268	0.076235	-0.31989	0.390857	0.450277	0.12775	-0.4965	-0.21061
Chlorophyll b- fresh capsule	-0.62993	0.008262	-0.38001	0.295197	0.473171	0.135427	-0.55021	-0.2568
Total chlorophyll - fresh capsule	-0.62536	0.008553	-0.37336	0.250128	0.446647	0.083238	-0.51925	-0.34255
Chlorophyll a/ b ratio- fresh capsule	0.496424	0.004166	0.243565	-0.02512	-0.12903	-0.13111	0.61708*	0.3877
Chlorophyll a- dry capsule	-0.69933	0.452533	0.293691	0.128724	-0.05318	-0.14675	-0.47606	-0.20145
Chlorophyll b- dry capsule	-0.68533	0.402419	0.29344	0.316013	0.152705	-0.20759	-0.41231	-0.16983
Total chlorophyll- dry capsule	-0.63735	0.463585	0.334685	0.267223	0.107369	-0.20817	-0.38053	-0.29678
Chlorophyll a/ b ratio- dry capsule	0.491033	-0.28295	-0.27407	-0.47957	-0.392	0.301167	0.178725	0.130137
Stomatal frequency	0.482386	-0.26443	-0.22515	0.544682	0.500346	-0.426	0.354958	0.091407
Stomatal index	0.350727	0.055628	-0.02746	0.592058	0.402969	-0.47043	0.348755	-0.04873
Leaf proline	-0.2808	-0.2789	-0.23833	-0.1331	0.103448	-0.16972	-0.19718	0.288806
Epicuticular wax	0.223895	-0.00331	0.160161	0.141034	0.439569	0.31455	0.31875	-0.18548
Relative water content- leaf	-0.20798	-0.19411	-0.27026	-0.44115	-0.08429	-0.16877	-0.26879	0.240683
Reducing sugar- leaf	-0.03038	-0.42257	-0.76406	0.00092	0.156242	-0.55748	-0.06621	-0.03635
Soluble protein- leaf	-0.44622	-0.2575	-0.52191	-0.03305	0.289236	-0.64455	-0.35894	-0.18908
Insoluble protein- leaf	0.70065*	-0.07998	-0.15764	0.404931	0.02864	0.229632	0.47239	0.300839

Crude protein-capsule	-0.58738	-0.16046	-0.38915	-0.01403	0.348863	-0.09295	-0.46089	-0.17034
Crude lipid-capsule	-0.14654	-0.04015	-0.02837	-0.0623	-0.14512	0.217816	-0.34388	-0.54052
Crude fibre - capsule	-0.43018	-0.11892	-0.17079	0.003881	0.084867	-0.39372	-0.40627	-0.30506
Ash content-capsule	-0.69374	-0.21704	-0.04382	-0.02659	-0.17461	-0.05807	-0.82785	0.025667
Acid insoluble ash- capsule	-0.19955	0.012373	0.184184	-0.17349	0.229242	0.040284	-0.02728	-0.71855
Carbohydrate content-capsule	-0.12129	0.399853	0.06381	0.379585	0.391509	0.65590*	0.056342	-0.05078
Calorific value- capsule	-0.09589	0.362663	0.007667	0.359101	0.401173	0.68621*	0.080932	0.000834
Phenol content-capsule	-0.23582	0.355457	0.127162	-0.19773	-0.31927	0.67529**	-0.21955	-0.07104
Tannins-capsule	0.442966	-0.12164	0.288737	-0.4947	-0.37495	-0.49397	0.438226	0.039753
Amino acids-capsule	0.043788	-0.28402	-0.21955	0.292968	0.019689	-0.14313	-0.15305	0.234241
Reducing sugar- capsule	0.133529	-0.46793	-0.603	0.171119	0.079191	0.00117	-0.13777	0.41562

	Panicle length	Racemes/ panicle	Capsules/ raceme	Fruit set%	Seeds/ capsule	Internodal length	Yield/ plant-fresh	Yield/ plant- dry	No fresh capsules /litre
Racemes/ panicle	0.71001*	1							
Capsules/ raceme	-0.21989	0.190237	1						
Fruit set %	-0.29116	-0.3012	-0.1392	1					
Seeds / capsule	-0.34291	-0.00548	0.48109	0.315392	1				
Internodal length	0.52031	0.103477	-0.21333	0.036629	-0.12694	1			
Yield/ plant fresh	0.351167	0.4581	0.57501	-0.16255	-0.07398	-0.13145	1		
Yield/ plant dry	0.45024	0.5786	0.44033	-0.18696	-0.18228	-0.12542	0.9509**	1	
Number of fresh capsules/ litre	-0.11653	-0.10192	0.07877	0.51315	0.070091	-0.02659	0.271101	0.099919	1
No. of dry capsules/ litre	0.156121	0.243632	0.148725	-0.11504	-0.25295	-0.30475	0.59457	0.45922	0.68038*
Recovery %	0.45942	0.60559	-0.06168	-0.14557	-0.27332	-0.02214	0.319036	0.59359	-0.43558
% of 7 mm and above capsules	0.190449	0.6049	0.303245	-0.26473	0.265903	-0.20546	0.058989	0.243844	-0.65026
Seed wt-fresh capsule	0.09607	-0.03699	-0.15231	0.302499	0.352692	0.3416	-0.36145	-0.22845	-0.58278
Seed wt-dry capsule	-0.26395	-0.57109	-0.41507	0.412452	-0.13126	0.418175	-0.40218	-0.37133	-0.09404
Husk wt-dry capsule	0.35524	0.285132	0.202742	-0.48816	-0.30436	0.019529	0.472172	0.46365	-0.39587
Husk wt.-fresh capsule	0.062579	0.490301	0.504125	-0.38936	0.392882	-0.33012	0.25223	0.250347	-0.41497

Litre weight - fresh capsules	0.330347	0.036741	-0.68119	0.212968	-0.2645	0.514768	-0.21581	-0.18963	0.281516
100 capsule wt- fresh	-0.01793	0.201609	0.539801	-0.03205	0.498332	0.330722	-0.03911	-0.0112	-0.48772
Litre wt. of dry capsules	-0.33141	-0.42235	-0.01978	0.45108	0.322814	0.217532	-0.29329	-0.25571	0.055126
100 capsule wt - dry	-0.15102	-0.61699	-0.30432	0.080534	-0.47109	0.480729	-0.21926	-0.22864	-0.10702
Volatile oil (%)	-0.21874	-0.19893	0.364874	-0.16675	0.309227	-0.14381	0.02502	-0.07778	0.07746
Oleoresin (%)	0.250434	0.279719	0.17843	-0.02234	0.225219	0.165281	0.140516	0.305852	-0.37796
Moisture content (%)	0.028209	0.15431	0.114243	-0.48841	0.174777	-0.02004	-0.2548	-0.10374	-0.75993
Chlorophyll a content- leaf	0.367744	0.60444	0.344205	-0.50278	-0.04683	-0.32879	0.354039	0.327063	-0.0416
Chlorophyll b -leaf	0.011588	0.422396	0.343085	0.073815	0.076547	-0.3236	0.058545	0.081254	0.062365
Total chlorophyll - leaf	-0.10091	-0.40361	-0.10441	0.237195	0.112753	0.67037*	-0.41296	-0.42035	-0.20683
Chlorophyll a/ b ratio- leaf	0.360449	0.126603	-0.02402	-0.55701	-0.20552	0.05336	0.198794	0.139588	0.146098
Chlorophyll a- fresh capsule	-0.0636	-0.1249	-0.15527	-0.60003	-0.42231	-0.4457	-0.04618	-0.09192	0.015558
Chlorophyll b- fresh capsule	0.055494	0.045287	0.098214	-0.71978	-0.51603	-0.47814	0.232684	0.228621	-0.22631
Total Chlorophyll - fresh capsule	0.136611	0.058339	-0.01948	-0.72776	-0.62454	-0.4062	0.216068	0.243571	-0.29015
Chlorophyll a/ b ratio- fresh capsule	0.353313	0.091069	-0.19533	0.44838	0.28782	0.76626**	-0.16629	-0.17347	0.128345
Chlorophyll a- dry capsule	-0.00156	0.156433	-0.05111	-0.65415	-0.03846	-0.14834	-0.01293	-0.06582	-0.09098
Chlorophyll b dry - capsule	0.174209	0.248693	0.006133	-0.70558	-0.10436	-0.04101	0.172722	0.133039	-0.13221
Total chlorophyll - dry capsule	0.120623	0.257999	0.009406	-0.69003	-0.12847	-0.06476	0.18182	0.162727	-0.11298
Chlorophyll a/ b ratio - dry capsule	-0.39392	-0.29864	-0.02693	0.6317*	0.161661	-0.16744	-0.36238	-0.35728	0.16959
Stomatal frequency	-0.20433	-0.31768	0.351288	0.185556	-0.00755	0.078487	0.434546	0.393944	0.226914
Stomatal index	-0.14212	-0.2797	0.225495	0.020723	-0.07051	0.112931	0.46054	0.396645	0.314865
Leaf proline	-0.02109	0.00922	-0.11801	-0.24284	0.147674	0.334594	-0.63594	-0.63596	-0.34396
Epicuticular wax	0.45857	0.332572	0.139852	0.04695	-0.03422	-0.00467	0.48949	0.60191	-0.05821

Relative water content - leaf	-0.06119	0.021559	0.406162	-0.45083	0.18376	0.02315	-0.09926	-0.11668	-0.60907
Reducing sugar-leaf	-0.27428	-0.73431	-0.53142	-0.16811	-0.5407	0.1236	-0.55706	-0.57386	-0.18471
Soluble protein-leaf	-0.06518	-0.29539	-0.16405	-0.74358	-0.46409	0.096654	-0.25174	-0.21897	-0.62017
Insoluble protein-leaf	-0.17253	-0.15488	0.220982	0.7427**	0.007759	0.054581	0.284916	0.191784	0.7049*
Crude protein - capsule	-0.05419	-0.24256	-0.26117	-0.63302	-0.27922	-0.29453	-0.32231	-0.30917	-0.37715
Crude lipid-capsule	-0.37322	0.06578	-0.11248	0.158094	-0.30627	-0.47281	-0.10088	0.005399	0.124601
Crude fibre-capsule	-0.43127	-0.3617	-0.35061	-0.32773	-0.13761	-0.2044	-0.52279	-0.50274	-0.14038
Ash content - capsule	-0.4751	-0.19462	-0.07347	-0.17232	0.109571	-0.64179	-0.28996	-0.33904	-0.08478
Acid insoluble ash-capsule	0.192905	0.059955	-0.54533	-0.17714	-0.26863	-0.17047	-0.16181	0.046509	-0.26945
carbohydrate - capsule	0.57431	0.6342*	0.372733	-0.32036	-0.28079	-0.04003	0.6511**	0.6456*	0.120792
Calorific value - capsule	0.56915	0.6431*	0.359054	-0.2952	-0.26717	0.030844	0.54628	0.54092	0.119161
Phenol - capsule	-0.17472	0.091304	-0.18126	0.074378	0.102361	-0.37748	-0.36508	-0.41418	0.348154
Tannins-capsule	0.151278	-0.05231	-0.14101	0.294879	0.286946	0.53947	-0.10688	-0.01825	-0.32867
Amino acids - capsule	-0.59558	-0.46748	-0.0607	0.352816	0.161012	-0.23583	-0.32315	-0.4277	0.419684
Reducing sugar - capsule	-0.61387	-0.52225	0.053052	0.331013	0.076581	-0.19276	-0.45211	-0.57344	0.312915

	No of dry capsules/ litre	Recovery %	% of 7 mm and above capsule	Seed wt-fresh capsule	Seed wt - dry capsule	Husk wt-dry capsule	Husk wt.-fresh-capsule	Litre weight of fresh capsules	100 capsule wt - fresh capsules
No of dry capsules/ litre	1								
Recovery %	-0.20493	1							
% of 7 mm and above capsules	-0.42337	0.66735*	1						
Seed wt - fresh capsule	-0.87191	0.310708	0.45145	1					
Seed wt – dry capsule	-0.45151	-0.10907	-0.41468	0.431623	1				
Husk wt-dry	0.21165	0.181656	0.136338	-0.03496	-0.00709	1			
Husk wt.-fresh	0.010529	0.147471	0.650782	0.073788	-0.52464	0.47369	1		

Litre weight of fresh capsules	0.162845	-0.0859	-0.51193	-0.0217	0.5133	-0.01128	-0.44293	1	
100 capsule wt- fresh	-0.64831	0.174513	0.6041	0.61836*	0.052256	0.113649	0.47183	-0.40705	1
Litre weight of dry capsules	-0.58001	0.016196	-0.03744	0.422493	0.321353	-0.72662	-0.39257	-0.14161	0.288367
100 capsule wt -dry	-0.28981	-0.16734	-0.54138	0.146506	0.8293**	0.155328	-0.55945	0.324715	-0.01635
Volatile oil (%)	-0.05946	-0.28181	0.031074	-0.15646	-0.47682	-0.40703	0.179248	-0.58327	0.162282
Oleoresin (%)	-0.53834	0.65491*	0.5932	0.5573	-0.09391	-0.24326	-0.02492	-0.33938	0.46596
Moisture content (%)	-0.66243	0.40832	0.7144*	0.435874	-0.23565	-0.12928	0.328889	-0.50671	0.52554
Chlorophyll a content- leaf	0.45433	0.10558	0.406694	-0.38491	-0.85359	0.302509	0.46811	-0.39587	-0.05939
Chlorophyll b -leaf	0.13442	0.140643	0.48828	-0.11349	-0.54754	-0.05126	0.287949	-0.46045	0.186036
Total chlorophyll - leaf	-0.6534	-0.15425	-0.17307	0.58355	0.7513**	-0.11215	-0.46713	0.234834	0.442973
Chlorophyll a/ b ratio- leaf	0.362648	-0.0971	-0.18206	-0.46402	-0.50968	-0.12656	-0.21239	-0.0514	-0.39388
Chlorophyll a- fresh capsule	0.434195	-0.23005	-0.18787	-0.67783	-0.5048	-0.00382	0.018061	-0.20729	-0.58832
Chlorophyll b- fresh capsule	0.377421	0.061498	0.078765	-0.54211	-0.51047	0.369176	0.145938	-0.43398	-0.37041
Total chlorophyll - fresh capsule	0.343556	0.140544	0.064074	-0.48504	-0.4063	0.44324	0.095835	-0.32339	-0.40206
Chlorophyll a/ b ratio- fresh capsule	-0.33336	-0.07915	-0.11979	0.51233	0.346523	-0.19391	-0.10212	0.47152	0.367815
Chlorophyll a - dry capsule	0.362291	-0.21555	-0.09774	-0.48891	-0.21954	0.268496	0.371511	0.249825	-0.24723
Chlorophyll b- dry capsule	0.365016	-0.09196	-0.06026	-0.44691	-0.26478	0.380375	0.438915	0.207462	-0.17249
Total chlorophyll- dry capsule	0.371897	-0.02391	-0.05416	-0.47502	-0.20413	0.351098	0.374544	0.245629	-0.19146
Chlorophyll a/ b ratio- dry capsule-	-0.25276	-0.10836	0.027397	0.261	0.215707	-0.40901	-0.37725	-0.17188	0.051986
Stomatal frequency	-0.02623	0.078535	-0.23751	-0.04699	0.173765	-0.14685	-0.23551	-0.26542	0.116938
Stomatal index	0.18124	-0.00726	-0.42428	-0.25365	0.205142	-0.07503	-0.27429	0.019346	-0.10556
Leaf proline	-0.43844	-0.2812	0.199322	0.194554	-0.0584	-0.17575	0.295607	-0.01374	0.433524

Epicuticular wax	-0.06293	0.61347*	0.356008	0.243594	-0.32121	-0.08109	-0.11322	-0.33335	0.049773
Relative water content-leaf	-0.40154	-0.00482	0.441153	0.308026	-0.05367	0.364453	0.288085	-0.4678	0.54754
Reducing sugar-leaf	-0.22009	-0.37423	-0.51796	-0.08026	0.47006	-0.06395	-0.50464	0.149298	-0.33156
Soluble protein - leaf	-0.25378	-0.041	-0.04372	-0.05913	0.207516	0.370474	-0.00048	-0.06971	0.015534
Insoluble protein-leaf	0.280924	-0.16489	-0.36876	-0.15796	0.139222	-0.22545	-0.30673	-0.00073	-0.04548
Crude protein - capsule	-0.0563	-0.13415	0.018485	-0.21056	-0.3125	-0.06008	-0.03236	-0.27874	-0.33104
Crude lipid - capsule	0.216491	0.220553	0.09382	-0.34155	0.037389	-0.07033	0.029524	0.038336	-0.24133
Crude fibre-capsule	-0.07854	-0.24613	-0.18722	-0.29013	0.090916	-0.28754	-0.02386	0.125426	-0.26853
Ash content-capsule	0.175777	-0.34219	0.015175	-0.3113	-0.24402	0.030453	0.488644	-0.16018	-0.23658
Acid insoluble ash-capsule	-0.18659	0.529669	0.192726	0.11892	-0.06714	-0.33061	-0.27769	0.089164	-0.38506
Carbohydrate - capsule	0.50384	0.307552	0.250891	-0.34406	-0.63187	0.387027	0.16473	-0.27008	-0.0501
Calorific value - capsule	0.443333	0.263735	0.272801	-0.31774	-0.63363	0.320404	0.164247	-0.26739	0.020937
Phenol - capsule	0.346573	-0.33449	-0.04871	-0.40183	-0.3869	-0.38301	-0.04316	0.083397	-0.40995
Tannins – capsule	-0.62758	0.273429	0.112181	0.80175**	0.6655*	0.061045	-0.13303	0.338337	0.45758
Amino acids - capsule	0.10564	-0.52664	-0.38623	-0.30045	0.046982	-0.48452	-0.02082	-0.00985	-0.17277
Reducing sugar - capsule	-0.03024	-0.60159	-0.28102	-0.22679	-0.00873	-0.46129	-0.10238	-0.27067	-0.01084

	Litre weight of dry capsules	100 capsule wt.- dry	Volatile oil (%)	Oleoresin (%)	Moisture content (%)	Chloro phyll a-leaf	Chloro phyll b – leaf	Total Chlorophyll- leaf	Chloro phyll a/ b ratio- leaf
Litre weight of dry capsules	1								
100 capsule wt -dry	0.240272	1							
Volatile oil (%)	0.48650	-0.22306	1						
Oleoresin (%)	0.55231	-0.16009	0.206293	1					
Moisture (%)	0.343193	-0.18584	0.419006	0.6809*	1				
Chlorophyll a content-leaf	-0.6602	-0.6915	0.068587	-0.0428	0.111209	1			

Chlorophyll b -leaf	-0.31131	-0.5679	-0.0609	0.00654	0.029463	0.6882*	1		
Total Chlorophyll- leaf	0.432339	0.6567*	-0.23554	0.250395	0.098159	-0.55982	-0.29576	1	
Chlorophyll a/ b ratio- leaf	-0.08135	-0.20526	0.409582	0.158119	0.193568	0.443564	-0.12548	-0.21863	1
Chlorophyll a - fresh capsule	-0.31914	-0.16005	0.391675	-0.34413	0.11668	0.444945	0.023489	-0.57139	0.65045*
Chlorophyll b- fresh capsule	-0.51605	-0.12149	0.154652	-0.15169	0.187316	0.6376*	0.22831	-0.48052	0.5424
Total chlorophyll - fresh capsule	-0.55111	-0.02538	0.030163	-0.15135	0.166722	0.57652	0.156944	-0.43004	0.50429
Chlorophyll a/ b ratio-fresh capsule	0.401662	0.1785	0.009581	0.14091	-0.10989	-0.46913	-0.30512	0.438314	-0.25486
Chlorophyll a -d ry capsule	-0.46163	-0.16015	0.039618	-0.43674	0.052606	0.192688	-0.31488	-0.37037	0.31435
Chlorophyll b -dry capsule	-0.41588	-0.11623	0.140735	-0.33001	0.093421	0.172972	-0.40851	-0.41471	0.344933
Total chlorophyll - dry capsule	-0.40271	-0.09032	0.046987	-0.29831	0.082292	0.132153	-0.40383	-0.37965	0.315725
Chlorophyll a/ b ratio -dry capsule	0.200303	-0.00516	-0.25122	0.06046	-0.16061	-0.03621	0.55605	0.333024	-0.36015
Stomatal frequency	0.6176*	0.382813	0.46432	0.325776	0.003556	-0.48353	-0.41517	0.109997	0.01692
Stomatal index	0.452206	0.399272	0.354339	0.154374	-0.11566	-0.49839	-0.64756	0.044946	0.184806
Leaf proline	0.114226	-0.01026	0.330823	-0.13654	0.432025	-0.00686	0.076657	0.162722	-0.06665
Epicuticular wax	0.268918	-0.25424	0.1755	0.7849**	0.287039	0.214455	0.118551	-0.09939	0.338964
Relative water content-leaf	-0.21396	0.004461	-0.07544	0.243112	0.47954	0.368045	0.292046	0.399369	0.052179
Reducing sugar-leaf	0.127921	0.7205*	0.068366	-0.33321	0.024541	-0.38189	-0.40808	0.318627	0.133495
Soluble protein-leaf	-0.14207	0.51741	0.05294	-0.08714	0.426737	-0.06356	-0.38539	0.216675	0.256305
Insoluble protein - leaf	0.23066	0.144783	-0.00094	-0.18383	-0.64497	-0.22811	0.245846	0.015839	-0.38027
Crude protein - capsule	-0.09742	-0.05431	0.381191	-0.00265	0.48658	0.314502	-0.08657	-0.20282	0.64171
Crude lipid capsule-	-0.20896	-0.06101	-0.34935	-0.35003	-0.21901	-0.0065	0.388957	-0.3623	-0.46511
Crude fibre-capsule	0.149951	0.150544	0.292739	-0.30172	0.263514	-0.28377	-0.38885	-0.15662	0.130717
Ash content-capsule	-0.27535	-0.277	0.229428	-0.5865	0.011408	0.114869	0.044171	-0.57674	-0.17145

Acid insoluble ash - capsule	0.278561	-0.11069	0.069524	0.49880	0.46039	-0.08778	-0.27723	-0.18121	0.401471
Carbohyd rate- capsule	-0.54314	-0.39062	-0.10033	0.120249	-0.1001	0.8193**	0.5951	-0.3509	0.399813
Calorific value - capsule	-0.51379	-0.39195	-0.07658	0.098289	-0.07383	0.8251**	0.675*	-0.30225	0.363766
Phenol- capsules	-0.3339	-0.53917	-0.08902	-0.40101	-0.1973	0.47834	.560981	-0.33797	0.181299
Tannins- capsule	0.411712	0.376847	-0.32696	0.48151	0.155449	-0.62434	-0.50801	0.6955*	-0.37196
Amino acids- capsule	0.341336	0.048966	0.47043	-0.48329	-0.2238	-0.38011	-0.11257	-0.24234	-0.24473
Reducing sugar capsule	0.25607	0.091013	0.427763	-0.45174	-0.1503	-0.12428	0.300801	-0.03644	-0.23001

	Chloro phyll a content- fresh capsule	Chloro phyll b- fresh capsule	Total Chlor ophyll - fresh capsule	Chloro phyll a/ b ratio- fresh capsule	Chlorop hyll a- dry capsule	Chlor ophyll b- dry capsule	Total chloro phyll - dry capsule	Chloro phyll a/ b ratio- dry capsule	Stomatal frequency
Chloroph yll a content- fresh capsule	1								
Chloroph yll b- fresh capsule	0.8278**	1							
Total Chloroph yll - fresh capsule	0.7884**	0.9843**	1						
Chloroph yll a/ b ratio- fresh capsule	-0.63981	-0.83294	-0.79746	1					
Chloroph yll a- dry capsule	0.51474	0.30985	0.305527	-0.24841	1				
Chloroph yll b- dry capsule	0.47555	0.305484	0.312853	-0.12972	0.9472**	1			
Total Chloroph yll- dry capsule	0.435841	0.290919	0.304232	-0.19459	0.9556**	0.9811**	1		
Chloroph yll a/ b ratio- dry capsule	-0.30632	-0.19084	-0.22021	-0.10328	-0.7014	-0.88884	-0.84297	1	
Stomatal frequency	-0.15064	-0.13716	-0.16254	0.11829	-0.30721	-0.11732	-0.10418	-0.19569	1
Stomatal index	-0.01643	-0.09841	-0.10559	0.085415	0.055574	0.216773	0.252192	-0.45054	0.9024**
Leaf proline	0.108579	-0.13905	-0.16614	0.344725	0.272814	0.24722	0.170103	-0.1503	-0.33344
Epicuticul ar wax	-0.12271	0.109258	0.112392	-0.00294	-0.55032	-0.3875	-0.39763	0.062934	0.360012
Relative water content- leaf	-0.05247	0.3173	0.297317	-0.30899	-0.03094	-0.10612	-0.10376	0.210745	-0.29569

Reducing sugar-leaf	0.45178	0.29884	0.352559	-0.16425	0.083243	0.033113	0.011606	0.017462	0.047566
Soluble protein-leaf	0.47128	0.54156	0.59682	-0.36024	0.445857	0.45271	0.45395	-0.39337	-0.02098
Insoluble protein-leaf	-0.37647	-0.37835	-0.41294	0.262092	-0.60497	-0.5554	-0.54945	0.425019	0.448838
Crude protein-capsule	0.83631**	0.73439**	0.7173**	-0.53982	0.354118	0.297625	0.250043	-0.17711	-0.22391
Crude lipid-capsule	0.105038	0.104377	0.116738	-0.4178	0.087497	-0.03699	0.070553	0.257274	-0.16169
Crude fibre-capsule	0.556417	0.177371	0.169206	-0.22318	0.64666*	0.55475	0.57646	-0.35338	-0.04251
Ash content-capsule	0.522708	0.270012	0.220846	-0.35811	0.56209	0.46616	0.419606	-0.19241	-0.29969
Acid insoluble ash-capsule	0.318129	0.207185	0.260826	-0.19637	0.051508	0.064515	0.10258	-0.14883	0.021038
carbohydrate - capsule	0.168886	0.506412	0.488714	-0.30141	-0.14372	-0.06591	-0.0774	0.010278	-0.13993
Calorific value - capsule	0.148658	0.456716	0.432587	-0.23351	-0.17187	-0.10724	-0.12511	0.068236	-0.19802
Phenol-capsule	0.388326	0.182501	0.115844	-0.31657	0.208166	-0.04231	-0.02489	0.413237	-0.69783
Tannins-capsule	-0.79269	-0.68591	-0.59919	0.60896	-0.27585	-0.20837	-0.18042	-0.00813	0.18645
Amino acids - capsule	0.21068	-0.22555	-0.29856	0.119839	0.14286	0.104007	0.069337	-0.00921	0.242634
Reducing sugar - capsule	0.227711	-0.03081	-0.12161	-0.03115	-0.16747	-0.26317	-0.30938	0.402764	0.064099

	Stomatal index	Leaf proline	Epicutic ular wax	Relative water content-leaf	Reducing sugar leaf	Soluble protein leaf	Insoluble protein leaf	Crude protein capsule	Crude lipid capsule
Stomatal index	1								
Leaf proline	-0.36984	1							
Epicuticular wax	0.184399	-0.50118	1						
Relative water content-leaf	-0.40047	0.173597	0.006003	1					
Reducing sugar - leaf	0.086666	0.250461	-0.36533	0.026827	1				
Soluble protein-leaf	0.092329	0.301456	-0.28722	0.439378	0.706163	1			
Insoluble protein-leaf	0.263266	-0.31136	0.081625	-0.45772	-0.18406	-0.64358	1		
Crude protein-capsule	-0.1581	0.227986	0.017344	0.280239	0.56971	0.65062*	-0.67166	1	

Crude lipid - capsule	-0.16742	-0.06506	-0.36137	-0.28619	-0.00345	-0.09363	0.246682	-0.18239	1
Crude fibre-capsule	0.152873	0.462201	-0.56794	-0.22528	0.548335	0.534608	-0.43608	0.51935	0.303913
Ash content-capsule	-0.2194	0.3412	-0.5948	-0.16407	0.182419	0.167126	-0.23801	0.347248	0.415254
Acid insoluble ash-capsule	0.093277	-0.17635	0.47319	-0.23477	0.169577	0.17873	-0.47394	0.507424	-0.00281
Carbohyd rate-capsule	-0.20307	-0.3259	0.49265	0.249009	-0.41851	-0.17144	0.115329	-0.00084	-0.0631
Calorific value - capsule	-0.28886	-0.18159	0.425594	0.267533	-0.397	-0.1831	0.143256	-0.01537	-0.03697
Phenol – capsule	-0.62394	0.163791	-0.31578	-0.03323	-0.05999	-0.27392	-0.0511	0.245662	0.365259
Tannins capsule	0.175859	-0.07664	0.172028	0.113645	-0.11642	-0.03713	-0.09503	-0.43383	-0.39678
Amino acids - capsule	0.232157	0.351759	-0.51883	-0.57478	0.254126	-0.14947	0.3798	-0.04375	0.349451
Reducing sugar capsule	-0.11	0.445139	-0.46357	-0.15857	0.373658	-0.0783	0.448991	0.074519	0.323555

	Crude fibre-capsule	Ash content-capsule	Acid insoluble ash-capsule	Carboh ydrate-capsule	Calorific value - capsule	Phenol - capsule	Tannins-capsule	Amino acids - capsule	Reducing sugar-capsule
Crude fibre-capsule	1								
Ash content-capsule	0.64775*	1							
Acid insoluble ash-capsule	0.333742	-0.04334	1						
Carbohyd rate-capsule	-0.62448	-0.36582	-0.136	1					
Calorific value - capsule	-0.60325	-0.35894	-0.19692	0.98382**	1				
Phenol-capsule	0.185205	0.387878	-0.00177	0.136946	0.200306	1			
Tannins-capsule	-0.26302	-0.51275	0.086835	-0.4074	-0.43454	-0.60494	1		
Amino acids - capsule	0.57793	0.6232*	-0.18282	-0.5731	-0.51636	0.199264	-0.35292	1	
Reducing sugar-capsule	0.330052	0.45208	-0.37939	-0.29471	-0.18504	0.363405	-0.504	0.79989**	1

Table 4. 4. Details of characters showing significant positive correlation in cardamom

Sl. No.	Character	Characters to which significant positive correlation is observed
1	Tillers/ clump	No. of bearing tillers, fruit set %, total chlorophyll- leaf, insoluble protein- leaf
2	Tiller height	Leaves/ tiller, no of dry capsules/ litre
3	Leaves/ tiller	Tiller height, racemes/ panicle
4	Leaf length	Leaf breadth, no of dry capsules/ litre
5	Leaf breadth	Leaf length
6	No. of vegetative buds	Chlorophyll a- leaf, chlorophyll b–leaf, carbohydrate content- capsule, calorific value- capsule, phenol content- capsule
7	No. of bearing tillers	Tillers/ clump, internodal length, chlorophyll a/ b ratio- fresh capsule
8	Panicles/ clump	Nil
8	Panicle length	Racemes/ panicle
10	Racemes/ panicle	Panicle length, leaves/ tiller, carbohydrate -capsule , calorific value - capsule
11	Capsules/ raceme	Nil
12	Fruit set%	Tillers/ clump, Chlorophyll a/ b ratio - dry capsule, insoluble protein- leaf
13	Seeds/ capsule	Nil
14	Inter nodal/ length	No of bearing tillers, total chlorophyll - leaf, chlorophyll a/ b ratio- fresh capsule
15	Yield /plant- fresh	Yield/plant- dry, carbohydrate -capsule
16	Yield /plant- dry	Yield /plant- fresh, carbohydrate -capsule
17	No. of fresh capsules /litre	No. of dry capsules/ litre, insoluble protein- leaf
18	No of dry capsules/ litre	Tiller height, leaf length, No. of fresh capsules/ litre
19	Recovery percentage	% of 7 mm and above sized capsule, oleoresin, epicuticular wax
20	% of 7 mm and above sized capsules	Recovery percentage, moisture content
21	Seed wt.- fresh capsule	100 capsule wt.- fresh, tannins– capsule
22	Seed wt.- dry capsule	100 capsule wt.- dry, total chlorophyll- leaf, tannins– capsule
23	Husk wt.- dry capsule	Nil
24	Husk wt.- fresh capsule	Nil
25	Litre weight of fresh capsules	Nil
26	100 capsule wt.- fresh	Seed wt.- fresh capsule
27	Litre weight of dry capsules	Stomatal frequency
28	100 capsule wt.- dry	Total Chlorophyll- leaf, reducing sugar- leaf

29	Volatile oil	Nil
30	Oleoresin	Moisture content, Epicuticular wax
31	Moisture content	Oleoresin
32	Chlorophyll a- leaf	No of veg. buds, chlorophyll b– leaf, chlorophyll b- fresh capsule, carbohydrate-capsule, calorific value -capsule
33	Chlorophyll b- leaf	No of veg. buds, Chlorophyll a- leaf, Calorific value-capsule
34	Total Chlorophyll- leaf	Tillers/ clump, internodel length, seed wt.- dry capsule,100 capsule wt. dry, tannins- capsule
35	Chlorophyll a/ b ratio-leaf	Chlorophyll a content- fresh capsule
36	Chlorophyll a content-fresh capsule	Chlorophyll a/b ratio-leaf, chlorophyll b- fresh capsule, total chlorophyll- fresh capsule, crude protein- capsule
37	Chlorophyll b- fresh capsule	Chlorophyll a- leaf , chlorophyll a content-fresh capsule, Total chlorophyll- fresh capsule, crude protein- capsule
38	Total chlorophyll- fresh capsule	Chlorophyll a content- fresh capsule, chlorophyll b- fresh capsule, crude protein
39	Chlorophyll a/ b ratio-fresh capsule	Inter nodal length, No. of bearing tillers
40	Chlorophyll a- dry capsule	Chlorophyll b- dry capsule, total chlorophyll-dry capsule, crude fibre- capsule
41	Chlorophyll b- dry capsule	Chlorophyll a- dry capsule, total chlorophyll-dry capsule
42	Total chlorophyll- dry capsule	Chlorophyll a- dry capsule, chlorophyll b- dry capsule
43	Chlorophyll a/ b ratio- dry capsule	Fruit set %
44	Stomatal frequency	Stomatal index, litre wt. of dry capsules
45	Stomatal index	Stomatal frequency
46	Leaf proline	Nil
47	Epicuticular wax	Recovery %, oleoresin
48	Relative water content-leaf	Nil
49	Reducing sugar- leaf	Soluble protein- leaf,100 capsule wt.- dry
50	Soluble protein- leaf	Crude protein- capsule, reducing sugar- leaf
51	Insoluble protein leaf	Tillers per clump, fruit set %
52	Crude protein capsule	Chlorophyll a- fresh capsule, chlorophyll b-fresh capsule, total chlorophyll- fresh capsule, soluble protein- leaf
53	Crude lipid- capsule	Nil
54	Crude fibre-capsule	Ash content- capsule ,chlorophyll a- dry capsule
55	Ash content- capsule	Amino acids – capsule, crude fibre- capsule

56	Acid insoluble ash- capsule	Nil
57	Carbohydrate- capsule	No of veg. buds, racemes/ panicle, yield/ plant- fresh, yield/ plant dry, chlorophyll a- leaf, calorific value -capsule
58	Calorific value-capsule	Chlorophyll a- leaf, chlorophyll b- leaf, racemes/ panicle, no. of veg. buds
59	Phenol - capsule	No. of veg. buds
60	Tannins- capsule	Seed wt.- fresh capsule, seed wt.- dry capsule, total chlorophyll- leaf
61	Amino acids -capsule	Reducing sugar- capsule, ash content- capsule
62	Reducing sugar- capsule	Amino acid- capsule

4.3. Character association

Agronomic characters of crop plants show different levels of association since they are polygenic. Grouping of characters based on factor loading by factor analysis is an effective measure to reduce the number of variables based on which selection could be practiced. Presently factor analysis has been carried out in the case of growth, yield and quality characters of cardamom under study by principal component analysis (Sneath and Sokal, 1973) using the software STATISTICA (Tables 4.5, 4.6, 4.7, 4.8, 4.9, 4.10, 4.11, 4.12 and 4.13).

The seven growth characters of cardamom studied presently could be grouped in to two based on factor loading with number of bearing tillers showing maximum factor loading in the first group and leaves per tiller showing maximum factor loading in the second group. Out of the two factors identified among the growth characters the first factor with four characters contributed 33.79% of variance exhibited by the growth characters studied and the second factor consisting of three characters contributed 31.08% of variance. Characters with the highest factor loadings can be considered as lead characters based on which selection could be practiced. The analysis has shown that number of bearing tillers and leaves per tiller are the most important characters to be considered when selection is practiced for growth characters of cardamom.

The yield characters also could be grouped into two factors based on factor loading. The first group consisted of five characters and the second group consisted of four characters. Seeds per capsule could not be grouped in to any of these groups. The first factor contributed 34.9% of variation contributed by yield characters and second factor contributed 23.68% of variability. Dry yield per plant was found to be the lead character in the case of the first group of variables and internodal length was found to be the lead character in the second group of variables.

Factor analysis of eleven quality characters resulted in the grouping of the characters in to three groups based on factor loading. The first group consisted of five characters, second group consisted of three characters and the third group consisted of one character. However, the rest of the variables could not be grouped in to any of these factor groups. The three factors together contributed 74.80% of cumulative variance. The percentage of variance contributed by the first factor is 40.71, that contributed by second factor is 20.64 and that contributed by the third factor is 13.46. The lead character in the case of the first group is moisture content followed by percentage of 7 mm and above sized capsules. In the second factor group, volatile oil content is the lead character and in the third factor group 100 capsule weight- dry is the only factor involved.

Factor analysis is a very efficient tool used to find out character association and to group the variables in to different groups and also to effect data reduction by identifying the lead variables of each group and the technique has been utilized by earlier workers in crops like rubber (Abraham *et al.*, 2002), cardamom (Radhakrishnan, 2003), tea (Ramasubramanian, 2005), rice (Mini, 2006), coconut (Abdulkadher *et al.*, 2007) and chillies (Hrideek *et al.*, 2006). A study of character association in cardamom by Sritharan *et al.* (1993) revealed that number of pseudostems per plant, leaf length, number of panicles per plant, panicle length and number of capsules in a panicle had higher association with yield than other parameters. Pooled factor analysis resulted in the grouping of 17 characters of cardamom in to six factors in an experiment carried out by Radhakrishnan *et al.* (2006).

Table 4.5. Factor analysis of growth characters in the eleven cultivars of cardamom studied- percentage of variance contributed by each factor and cumulative percentage of variance

Factor	Eigen value	Percentage of variance	Cumulative eigen value	Cumulative percentage of variance
1	2.365475	33.79250	2.365475	33.79250
2	2.175556	31.07937	4.541031	64.87187

Table 4.6. Factor analysis of growth characters in the eleven cultivars of cardamom studied- factor loadings

Sl. No.	Characters	F1	F2
1	Tillers per clump	**0.809195**	-0.288217
2	Tiller height	0.628600	**0.635518**
3	Leaves per tiller	0.237894	**0.857640**
4	Leaf length	**0.554993**	-0.476761
5	Leaf breadth	**0.322677**	-0.700081
6	Number of vegetative buds	0.434252	**0.473839**
7	Number of bearing tillers	**0.811317**	-0.105454

Table 4.7. Factor analysis of growth characters in the eleven cultivars of cardamom studied- factor groups and the characters in each group

Factor	Characters
1	**Number of bearing tillers,** tillers per clump, length, leaf breadth
2	**Leaves per tiller,** tiller height, number of vegetative buds

Table 4.8. Factor analysis of yield characters in the eleven cultivars of cardamom studied- percentage of variance contributed by each factor and cumulative percentage of variance

Factor	Eigen value	Percentage of variance	Cumulative eigen value	Cumulative percentage of variance
1	3.140609	34.89566	3.140609	34.89566
2	2.130817	23.67574	5.271426	58.57140

Table 4.9. Factor analysis of yield characters in the eleven cultivars of cardamom studied- factor loadings

Sl. No.	Characters	F1	F2
1	Panicles / clump	0.367683	**0.433825**
2	Panicle length	**0.752460**	0.608896
3	Racemes/ panicle	**0.786796**	0.064932
4	Capsules / raceme	**0.337043**	-0.819825
5	Fruit set %	-0.320631	**0.096428**
6	Seeds per capsule	-0.204170	-0.505149
7	Internodal length of panicles	0.127113	**0.654656**
8	Yield /plant- fresh	**0.854444**	-0.369032
9	Yield / plant- dry	**0.903247**	-0.257480

Table 4.10. Factor analysis of yield characters in the eleven cultivars of cardamom studied- factor groups and the characters in each group

Factor	Characters
1	**Yield / plant dry**, yield /plant fresh, racemes/ panicle, panicle length
2	**Internodal length of panicles**, panicles / clump, fruit set %

Table 4.11. Factor analysis of quality characters in the eleven cultivars of cardamom studied- percentage of variance contributed by each factor and cumulative percentage of variance

Factor	Eigen value	Percentage of variance	Cumulative eigen value	Cumulative percentage of variance
1	4.477351	40.70865	4.477951	40.70865
2	2.269908	20.63553	6.747859	61.34418
3	1.480318	13.45744	8.228178	74.80162

Table 4.12. Factor analysis of quality characters in the eleven cultivars of cardamom studied- factor loadings

Sl. No.	Characters	F1	F2	F3
1	Recovery %	**0.522628**	-0.530923	-0.581043
2	% of 7 mm & above capsules	**0.872938**	0.037928	-0.353847
3	Litre wt. of fresh capsules	-0.593038	-0.534259	-0.021103
4	No. of fresh capsules per litre	-0.730373	**0.228948**	-0.274044
5	Litre wt. of dry capsules	-0.219835	-0.815976	-0.164549
6	No. of dry capsules per litre	-0.688611	**0.345673**	-0.500525

7	100 capsule wt.- fresh	**0.693381**	-0.108926	0.283440
8	100 capsule wt.- dry	-0.268909	-0.568193	**0.685706**
9	Volatile oil content	0.299027	**0.672405**	0.216237
10	Oleoresin content	**0.755718**	-0.264196	-0.226625
11	Moisture content-capsule	**0.906379**	0.082447	0.125215

Table 4.13. Factor analysis of quality characters in the eleven cultivars of cardamom studied- factor groups and the characters in each group

Factor	Characters
1	**Moisture content- capsule**, % of 7 mm & above sized capsules, oleoresin content, 100 capsule wt.- fresh, recovery %
2	**Volatile oil content**, number of dry capsule per litre, number of fresh capsule/ litre
3	**100 capsule wt -dry**

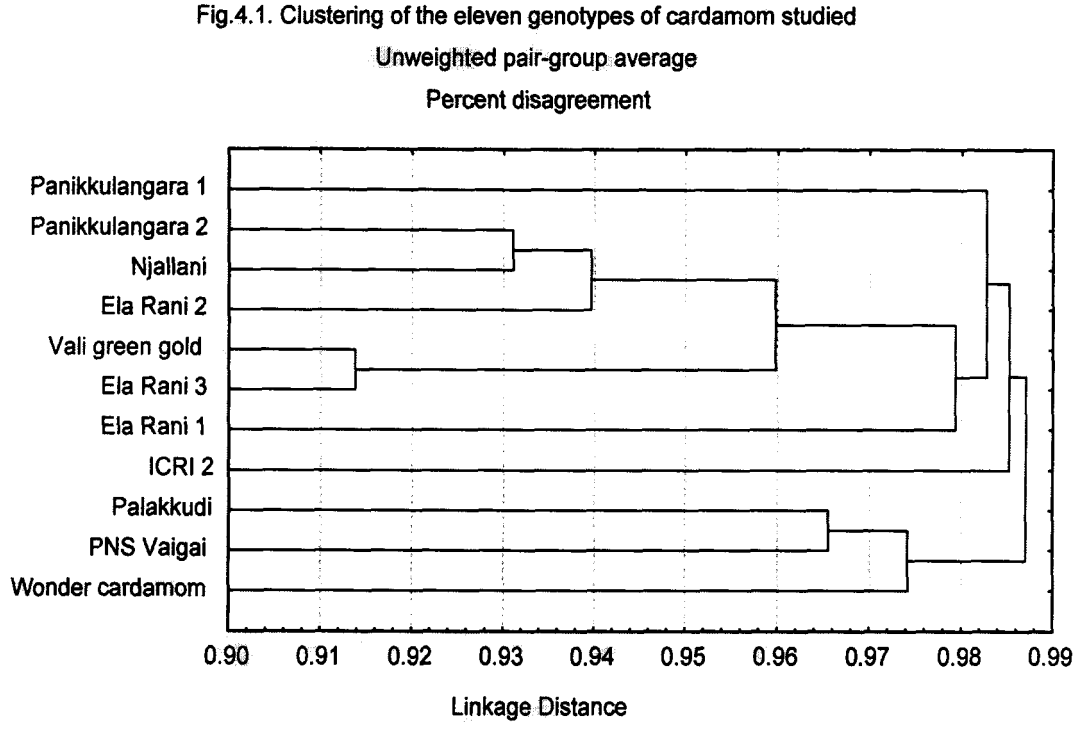
4.4. Genetic divergence

Different genotypes of any crop plants show different levels of genetic distance between them. Study of genetic divergence has been carried out presently in the case of eleven genotypes of cardamom under study using principal component analysis with the help of the software STATISTICA following UPGMA procedure. The study showed that the genotypes could be grouped in to two clusters at a genetic distance of 0.99. The first cluster consisted of eight genotypes and second cluster consisted of three genotypes. Palakkudi, PNS Vaigai and Wonder cardamom formed the smaller cluster while Panikulangara-1, Panikulangara-2, Njallani, Ela Rani-2, Vali green gold, Ela Rani-3, Ela Rani-1 and ICRI-2 formed the second cluster. However, ICRI-2 formed a different cluster at linkage distance of 0.985. Vali green gold and Ela Rani 3 revealed to be the closest genotypes. Panikulangara-2 and Njallani also were found to be closely related (Fig 4.2).

Genotypes belonging to different clusters can be considered to be genetically divergent and such genotypes could be used for hybridization programmes. Earlier workers like Misra *et al.* (1990), Indira (1994), Srivastava *et al.* (2000), Radhakrishnan (2003), Ramasubramanian (2005), Mini (2006) and Prasanth (2006) have carried out studies on cluster analysis in dahlia, capsicum, coriander, cardamom, tea, rice and coconut respectively. Prasanth and Venugopal (2004)

applied cluster analysis to group cardamom accessions based on their phylogenetic relationships and observed common ancestry in the case of the three cultivar groups, *Malabar*, *Mysore* and *Vazhukka*. Clustering of cardamom genotypes both using molecular and morphological parameters has been carried out by Radhakrishnan and coworkers (Radhakrishnan and Mohanan, 2005; Radhakrishnan *et. al.*, 2006). The results indicated the possibility of exploiting the genetic relationship of cardamom genotypes by cluster analysis.

Fig.4.1. Clustering of the eleven genotypes of cardamom studied



4.5. Study of performance of certain land races of cardamom under high range condition

A comparative study of the overall performance of ten landraces of cardamom in comparison with one control has been carried out presently as described elsewhere (Tables 3.1 and 3.3). Observations on 32 characters including seven growth parameters, nine yield parameters and sixteen quality parameters are presented and discussed below (Tables 4.14, 4.15 and 4.16).

The study showed that based on the analysis of over all performance in relation to growth, yield and quality, Ela Rani-2 performed the best followed by Ela Rani-3, Palakkudi and Vali green gold in that order (Table 4.16 and Fig 4.2). Ela Rani- 2, the best performer produced around 100 tillers per clump on the average and 58 bearing tillers. Mean number of panicles per clump was 112.83 and panicle length 101.62 cm. Dry yield per plant was 840 g and recovery percentage was 20.98. Percentage of 7 mm and above sized capsules was 72.03 and seed: husk ratio 57.87:1.

A comparative study of Ela Rani-2, Ela Rani-3, Palakkudi, Vali green gold and ICRI-2 has been provided in Table 4.17. It shows that Ela Rani-2, Ela Rani-3 and Palakkudi produced higher number of tillers per clump when compared to ICRI-2, the control. Tiller height, leaves per tiller and number of vegetative buds were higher in all the four selections when compared to the control. Number of bearing tillers was higher than the control in Ela Rani-2, Ela Rani-3 and Palakkudi. Panicles per clump, panicle length and fruit set percentage were the highest in Ela Rani-2. Dry yield per plant amounted to 840 g in Ela Rani-2 which is considerably high when compared to ICRI-2. Recovery percentage and percentage of 7 mm and above sized capsules were higher in all the four selected landraces when compared to ICRI-2, the control. Litre weight of capsules was higher in Ela Rani-2, Ela Rani-3 and Palakkudi. Number of dry capsules per litre was the highest in ICRI-2 indicating that capsule size was higher in all the four landraces selected. Out of the 32 characters compared 23 characters showed statistically significant variation among

the genotypes and even in the case of other characters there was considerable variation among the landraces.

The present finding indicates the potential of selecting genotypes like Ela Rani- 2, Ela Rani- 3, Palakkudi and Vali green gold for further trials and evaluation protocols so that varieties with significantly superior characters could be developed.

Selection of superior genotypes based on variability and performance analysis has been carried out in several crops including cardamom by earlier workers (Radhakrishnan, 2003; Ramasubramanian, 2005; Mini, 2006; Jayasree *et al.*, 2006 and Kuruvilla *et al.*, 2006). Korikanthimath *et al.* (1997a) conducted a comparative study of yield and yield components in cardamom and selected three superior clones for their higher number of panicles and capsules per plant, higher wet weight of capsules per plant and higher dry capsule yield. Performance assessment of fourteen cardamom genotypes has been carried out by Radhakrishnan *et al.* (2005) and it has resulted in the selection of certain promising selections and hybrids.

Table 4.14. Performance evaluation of genotypes of cardamom in high ranges- character means

Characters	Pani kulan gara-1	Panikulan gara-2	Njallani	Vali green gold	Palakkudi	PNS Vaigai	Wonder cardamom	ICRI- 2	Ela Rani-1	Ela Rani-2	Ela Rani-3	CD
Tillers/ clump**	88.94	90.39	70.28	77.83	81.56	66.06	62.06	80.39	95.22	99.67	93.01	11.16
Tiller height (cm) **	326.67	390.44	341.05	313.95	364.94	347.89	352.06	309.16	305.83	338.66	366.83	34.75
Leaves/ tiller	19.22	20.94	21.00	19.82	21.49	20.45	21.44	18.28	20.61	20.72	20.89	NS
Leaf length (cm)**	61.06	69.00	64.94	69.60	61.83	63.72	52.27	61.17	53.61	62.39	59.61	3.19
Leaf breadth (cm)**	12.02	11.33	10.61	15.56	12.33	11.55	10.00	12.22	8.49	11.83	10.61	1.61
No. of veg. buds	4.94	4.50	4.06	3.5	4.56	3.50	4.22	2.72	3.28	3.67	3.28	NS
No. of bearing tillers	46.5	52.22	38.78	43.39	49.28	39.67	38.89	44.78	45.50	58.17	51.17	NS
Panicles/ clump*	91.94	104.66	84.78	87.00	102.7	83.84	80.39	76.78	95.00	112.83	63.00	26.55
Panicle length (cm)*	78.17	81.45	69.83	76.78	97.39	95.39	83.83	69.33	60.66	101.62	70.55	21.66
Racemes/ panicle**	26.61	24.39	25.89	25.72	28.94	28.21	27.77	18.95	21.44	26.89	25.89	3.04
Capsules/ raceme**	8.44	8.34	7.89	9.06	7.05	8.44	7.89	7.00	8.17	7.66	8.55	0.11

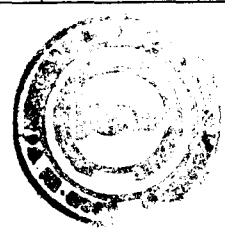
Fruit set % **	73.29	71.30	72.86	63.06	69.93	59.30	61.78	65.67	81.94	75.37	67.85	10.75
Seeds/ capsule	18.33	19.67	19.67	19.67	16.33	17.33	21.33	16.33	21.33	19.67	19.67	NS
Inter nodal length (cm)**	4.14	4.22	3.72	3.94	4.17	4.39	4.05	4.61	3.68	6.17	4.96	0.91
Yield/ plant-fresh (kg)	4.05	4.82	3.96	4.81	4.48	5.04	3.51	3.19	4.08	4.00	4.17	NS
Yield/ plant dry (kg)	0.850	0.940	0.806	1.030	1.043	1.078	0.737	0.639	0.856	0.840	0.879	NS
Recovery % *	21.00	19.65	20.33	21.51	22.79	21.43	20.97	20.04	21.00	20.98	21.10	1.37
% of 7 mm & above capsules**	78.00	60.22	71.31	80.04	76.06	76.51	83.72	62.91	73.98	72.03	73.00	1.21
Seed wt.- fresh capsule (g)**	0.43	0.37	0.40	0.43	0.43	0.43	0.47	0.43	0.50	0.50	0.43	0.11
Seed wt dry-capsule (g)**	0.19	0.19	0.20	0.17	0.21	0.21	0.18	0.26	0.26	0.24	0.25	0.01
Husk wt- fresh (g)**	0.90	0.80	1.07	1.03	0.80	1.10	1.07	0.73	0.90	0.87	0.87	0.16
Husk wt- dry (g)	0.06	0.05	0.07	0.06	0.06	0.6	0.07	0.07	0.08	0.07	0.08	NS

Seed: husk ratio- fresh capsule	48:1	46.82:1	37.27:1	42.45:1	55.75:1	39.34:1	43.94:1	59.52:1	55.66:1	57.87:1	50.00:1	NS
Litre wt.- fresh capsules (g)*	546.67	566.67	566.67	533.33	573.33	560.00	556.67	566.67	555.00	575.00	568.67	14.87
No. of fresh capsules/ litre**	571.33	646.00	590.67	539	562.00	515.67	505.00	535.33	551.67	560.67	563.33	44.64
Litre wt of dry capsules (g)**	340	340	340	340	360	344.33	320	340	350	356.67	356.67	4.67
No of dry capsule/ litre**	2166.67	2505.33	2308.33	2104	2243.67	2281	2015	2041.33	1984.33	1984.67	2104	228.08
100 capsule wt.- fresh (g)**	133.86	116.98	126.09	137.76	117.9	132.23	134.35	121.92	133.33	139.49	137.86	6.69
100 capsule wt .-dry g)**	20.21	20.24	19.58	20.36	20.63	22.56	17.24	26.84	22.47	23.17	23.52	3.41
Volatile oil (%)	8.79	9.08	9.04	9.85	8.49	8.45	8.99	8.99	8.69	8.94.	8.61	NS
Oleoresin (%)**	6.72	6.31	5.75	7.66	7.33	6.38	7.17	6.26	7.09	7.20	6.97	0.88
Moisture content- capsule %)**	10.67	9.33	10.07	12.43	10.87	10.5	12.43	11.04	10.57	10.83	11.00	0.58

Table 4.15. Performance evaluation of genotypes of cardamom in high ranges- value points attributed to genotypes in relation to charcters

Characters	Panikulan gara-1	Panikulan gara-2	Njallani	Vali green gold	Palakkudi	PNS Vaigai	Wonder cardamom	ICRI -2	Ela Rani-1	Ela Rani-2	Ela Rani-3
Tillers/clump	7	8	3	4	6	2	1	5	10	11	9
Tiller height	4	11	6	3	9	7	8	2	1	5	10
Leaves tiller	3	8	9	4	11	2	10	1	5	6	7
Leaf length	4	10	9	11	6	8	1	5	2	7	3
Leaf breadth	8	6	4	11	10	5	3	9	2	7	4
No. of veg. buds	11	9	7	5	10	5	8	3	4	6	4
No. of bearing tillers	7	10	1	4	8	3	2	5	6	11	9
Panicles/ clump	7	10	5	6	9	4	3	2	8	11	1
Panicle length	6	7	3	5	10	9	8	2	1	11	4
Racemes/ panicle	8	4	6	5	11	10	7	2	3	9	6
Capsules/ raceme	9	8	6	11	2	9	6	3	7	4	10
Fruit set %	9	7	8	3	6	1	2	4	11	10	5
Seeds/ capsule	9	10	10	10	6	8	11	7	11	10	10

NB 5324 584.39 HRI/S



Inter nodal length	5	7	2	3	6	8	4	9	1	11	10
Yield /plant-fresh	5	10	3	9	8	11	2	1	6	4	7
Yield / plant-dry	5	8	3	9	10	11	2	1	6	4	7
Recovery %	7	3	5	10	11	9	6	4	7	7	8
% of 7 mm & above capsules	9	1	3	10	7	8	11	2	6	4	5
Seed wt.- fresh capsule	9	7	8	9	9	9	10	9	11	114	9
Seed wt.- dry capsule	6	6	7	4	8	8	5	11	11	9	10
Husk wt.- fresh	8	6	10	9	6	11	10	5	8	7	7
Husk wt.- dry	8	7	9	8	8	11	9	9	10	9	10
Seed: husk ratio- fresh capsule	6	5	1	3	9	2	4	11	8	10	7
Litre wt.- fresh capsules	4	8	8	3	10	7	6	8	5	11	9
No. of fresh capsules/ litre	9	11	10	4	7	2	1	3	5	6	8

Litre wt of dry capsules	7	7	7	7	11	8	6	7	9	10	10
No. of dry capsules/ litre	8	11	10	7	8	9	5	6	3	4	7
100 capsule wt.- fresh	7	1	4	9	2	5	8	3	6	11	10
100 capsule wt.- dry	3	4	2	5	6	8	1	11	7	9	10
Volatile oil	6	10	9	11	3	2	8	8	5	7	4
Oleoresin	5	3	1	11	10	4	8	2	7	9	6
Moisture content- capsule	6	2	3	11	8	4	11	10	5	7	9

Table 4.16. Performance evaluation of genotypes of cardamom in high ranges- performance indices and relative ranks of performance

Characters	Panikulan gara-1	Panikulan gara-2	Njallani	Vali green gold	Palakkudi	PNS Vaigai	Wonder cardamom	ICRI -2	Ela Rani-1	Ela Rani-2	Ela Rani-3
Tillers/ clump	0.64	0.73	0.27	0.36	0.55	0.18	0.09	0.45	0.91	1.00	0.82
Tiller height	0.36	1.00	0.55	0.27	0.82	0.64	0.73	0.18	0.09	0.45	0.91
Leaves/ tiller	0.27	0.73	0.82	0.36	1.00	0.18	0.91	0.09	0.45	0.55	0.64
Leaf length	0.36	0.91	0.82	1.00	0.55	0.73	0.09	0.45	0.18	0.64	0.27
Leaf breadth	0.73	0.55	0.36	1.00	0.91	0.45	0.27	0.82	0.18	0.64	0.27
No. of veg. buds	1.0	0.82	0.64	0.45	0.91	0.45	0.73	0.27	0.36	0.55	0.36
No. of bearing tillers	0.64	1.00	0.09	0.36	0.73	0.27	0.18	0.45	0.55	1.00	0.82
Panicles/ clump	0.64	1.00	0.45	0.55	0.82	0.36	0.27	0.18	0.73	1.00	0.09
Panicle length	0.55	0.64	0.27	0.45	0.91	0.82	0.73	0.18	0.09	1.00	0.36
Racemes/ panicle	073	0.36	0.55	0.45	1.00	0.91	0.64	0.18	0.27	0.82	0.55
Capsules/ raceme	0.82	0.73	0.55	1.00	0.18	0.82	0.55	0.27	0.64	0.36	0.91
Fruit set %	0.82	0.50	0.73	0.27	0.55	0.09	0.18	0.36	1.00	0.91	0.45
Seeds/ capsule	0.82	0.91	0.91	0.91	0.55	0.73	1.00	0.94	1.00	0.91	0.91
Inter nodal length	0.45	0.64	0.18	0.27	0.55	0.73	0.36	0.82	0.09	1.00	0.91

Yield/plant-fresh	0.45	0.91	0.27	0.64	0.91	1.00	0.18	0.09	0.55	0.36	0.64
Yield/ plant-dry	0.45	0.73	0.27	0.64	0.91	1.00	0.18	0.09	0.55	0.36	0.64
Recovery %	0.64	0.27	0.45	0.91	1.00	0.82	0.55	0.36	0.64	0.64	0.73
% of 7 mm & above capsules	0.82	0.9	0.27	0.914	0.64	0.73	1.00	0.18	0.55	0.36	0.45
Seed wt.- fresh capsule	0.82	0.64	0.73	0.82	0.82	0.82	0.91	0.82	1.00	1.00	0.82
Seed wt.- dry capsule	0.55	0.55	0.64	0.36	0.73	0.73	0.45	1.00	1.00	0.82	0.91
Husk wt.- fresh	0.73	0.55	0.91	0.82	0.55	1.00	0.91	0.45	0.73	0.64	0.64
Husk wt.- dry	0.73	0.55	0.91	0.82	0.55	1.00	0.91	0.45	0.73	0.64	0.64
Seed: husk ratio- fresh capsule	0.55	0.45	0.09	0.27	0.82	0.18	0.36	1.00	0.73	0.91	0.64
Litre wt.- fresh capsule	0.36	0.73	0.73	0.27	0.91	0.64	0.55	0.73	0.45	1.00	0.82
No. of fresh capsules/ litre	0.82	1.00	0.91	0.37	0.64	0.18	0.9	0.27	0.45	0.55	0.73
Litre wt. of dry capsules	0.64	0.64	0.64	0.64	1.00	0.73	0.55	0.64	0.82	0.91	0.91
No of dry capsules/ litre	0.73	1.00	0.91	0.64	0.73	0.82	0.45	0.55	0.27	0.36	0.64

100 capsule wt.- fresh	0.64	0.09	0.36	0.82	0.18	0.45	0.73	0.27	0.55	1.00	0.91
100 capsule wt.- dry	0.27	0.36	0.18	0.45	0.55	0.73	0.09	1.00	0.64	0.82	0.91
Volatile oil	0.55	0.91	0.82	1.00	0.27	0.18	0.73	0.73	0.45	0.64	0.36
Oleoresin	0.45	0.27	0.09	1.00	0.91	0.36	0.73	0.18	0.64	0.82	0.55
Moisture content- capsule	0.55	0.18	0.27	1.00	0.73	0.36	1.00	0.91	0.45	0.64	0.82
Total value points	5.56	5.63	5.00	6.46	6.74	4.63	6.09	6.28	5.45	7.65	7.29
Rank of performance	8	7	10	4	3	11	6	5	9	1	2

Table 4.17. Comparative performance of the four elite genotypes selected presently and the control- character means

Characters	Ela Rani-2	Ela Rani-3	Pala kkudi	Vali green gold	ICRI -2	CD
Tillers/ clump **	99.67	93.01	81.56	77.83	80.39	11.16
Tiller height (cm) **	338.66	366.83	364.94	313.95	309.16	34.75
Leaves/ tiller NS	20.72	20.89	21.49	19.82	18.28	NS
No. of veg. buds NS	3.67	3.28	4.56	3.5	2.72	NS
No. of bearing tiller NS	58.17	51.17	49.28	43.39	44.78	NS
Panicles per clump *	112.83	63.00	102.7	87.00	76.78	26.55
Panicle length (cm)*	101.62	70.55	97.39	76.78	69.33	21.66
Racemes per panicle **	26.89	25.89	28.94	25.72	18.95	3.04
Capsules per raceme **	7.66	8.55	7.05	9.06	7.00	0.91
Fruit set % **	75.37	67.85	69.93	63.06	65.67	10.75
Yield per plant-dry (kg) NS	0.840	0.879	1.043	1.030	0.639	NS
Recovery % *	20.98	21.10	22.79	21.51	20.04	1.37
% of 7 mm & above capsules **	72.03	73.00	76.06	80.04	62.91	1.21
Seed: husk ratio-fresh capsule NS	57.87:1	50.00:1	55.75:1	42.45:1	59.52:1	NS
Litre wt. of dry capsules *	356.67	356.67	360	340	340	3.13
No of dry capsules per litre **	1984.67	2104	2243.67	2104	2041.33	44.64
Volatile oil (%) NS	8.94.	8.61	8.49	9.85	8.99	NS
Oleoresin (%) **	7.20	6.97	7.33	7.66	6.26	0.88
Moisture content-capsule (%) **	10.83	11.00	10.87	12.43	11.04	0.58

Fig. 4.2 Elite genotypes of cardamom selected based on performance evaluation

4.6. Performance evaluation of certain hybrids of cardamom in relation to their parents

Comparative performance of two single cross hybrids, two double cross hybrids and two F2 lines as detailed elsewhere has been analyzed presently so as to select he superior genotypes from the hybrid populations.

4.6.1. Study of heterosis and heterobeltiosis

4.6.1.1. Cross 1: MCC 49 x MCC 345

A study of the F1 progeny of the above cross with reference to seven growth characters, nine yield characters and six quality characters showed that the hybrid line exhibited different levels of positive heterosis and heterobeltiosis. The percentage of plants showing heterosis and heterobeltiosis varied in the case of different characters (Table 4.18). The plants that showed positive heterosis and heterobeltiosis could be selected and used for further screening trials so that superior hybrids could be developed and released. The selected F1 plants have been subsequently named MHC-23.

4.6.1.2. Cross 2: MCC- 260 x MCC- 61

This cross also resulted in plants with different levels of heterosis and heterobeltiosis (Table 4.18). Plants that showed positive heterosis and heterobeltiosis could be subjected to further selection procedure. The F1 plants of this cross have been further subjected to selection and subsequently named MHC-27.

4.6.1.3. Cross 3: MHC- 23 x MHC- 27

This is a double cross since it is the cross between two F1 plants selected clonally (Table. 4.18). In this case also the resultant progeny showed different levels of positive heterosis and heterobeltiosis showing the possibility of further screening to select and clonally propagate the best performing plants.

4.6.1.4. Cross 4: MHC- 27 x MHC- 23

It is the reciprocal of the above cross (Table 4.18). Here also majority of the progeny plants showed heterobeltiosis in the case of most of the characters showing the possibility of clonal selection of superior plants from the population.

4.6.1.5. Cross 5: MHC- 23 x MHC- 23

MHC- 23 x MHC- 23 is the production of F2 from the F1 MHC-23. In the case of this progeny also majority of the plants showed positive heterosis and heterobeltiosis. Here also there is very high selection potential for the plants so that improved hybrid lines could be developed clonally.

4.6.1.6. Cross 6: MHC- 27 x MHC- 27

This is the production of F2 from the hybrid MHC-27 and this cross also has proved to be promising since here also the percentages of progeny plants showing positive heterosis and heterobeltiosis are very high (Table.4.18).

Table. 4.18. Hybridization studies in cardamom- parental values and hybrid values of characters and percentages of plants showing positive heterosis and heterobeltiosis

Cross 1: MCC-49 x MCC-345							
Characters	Parents/ hybrids			Better parent value	Mid parent value	% of plants showing positive heterosis	% of plants showing heterobelti osis
	MCC- 49 (Parent)	MCC- 345 (Parent)	MHC-23 (Hybrid)				
1. Growth characters							
Tillers/ clump	46.17	53.33	47.67	53.33	49.75	33.00	33.00
Tiller height (cm)	250.00	254.17	292.00	254.17	252.09	100.00	100.00
Leaves per tiller	14.00	13.00	19.33	14.00	13.50	100.00	100.00
Leaf length (cm)	60.00	63.17	65.00	63.17	61.59	100.00	83.33
Leaf breadth (cm)	9.67	8.33	12.83	9.67	9.00	100.00	100.00
Number of veg. buds	4.67	4.67	3.50	4.67	4.57	0	0

Number of bearing tillers	19.83	22.00	27.33	22.00	20.92	100.00	100.00
2. Yield characters							
Panicles per clump	39.67	43.67	44.33	43.67	41.67	66.67	66.67
Panicle length (cm)	53.17	54.67	58.17	54.67	53.92	83.33	83.33
Racemes per panicle	20.67	20.17	22.00	20.67	20.42	83.33	83.33
Capsules per raceme	5.33	6.83	6.00	6.83	6.08	33.33	33.33
Fruit set %	61.77	63.39	64.61	63.39	62.58	66.67	66.67
Seeds per capsule	17.00	18.00	18.33	18.00	17.50	100.00	100.00
Internodal length (cm)	4.17	4.00	4.33	4.17	4.09	33.33	33.33
Yield per plant fresh (g)	2738.33	2865.00	2926.67	2865.00	280.67	66.67	66.67
Yield per plant dry (g)	541.38	563.86	543.83	563.86	552.62	33.33	33.33
3. Quality characters							
Recovery percentage	19.79	19.65	18.96	19.79	19.72	50.00	50.00
% 7mm and above sized capsules	65.19	68.12	70.15	68.12	66.66	100.00	83.00
Seed wt - dry	0.20	0.20	0.19	0.20	0.20	50.00	50.00
Husk wt dry	0.06	0.06	0.06	.06	.06	66.66	66.66
Litre weight of dry capsules (g)	359.5	355.5	367.00	359.5	357.50	66.66	66.66
Number of capsules per litre-dry	2142.33	2177.17	2124.67	2177.17	2159.75	6.00	6.00

Cross II- MCC-260 x MCC-60							
Characters	Parents/ Hybrids			Better parent value	Mid parent value	% of plants showing positive heterosis	% of plants showing heterobeltiosis
	MCC-260 (Parent)	MCC-61 (Parent)	MHC-27 (Hybrid)				
1.Growth characters							
Tillers/ clump	62.67	74.67	66.83	74.67	68.67	33.00	16.67
Tiller height (cm)	337.83	306.83	292.83	337.83	322.33	16.67	16.67
Leaves per tiller	19.67	17.00	20.17	19.67	18.34	66.67	66.67
Leaf length (cm)	62.83	63.17	62.17	63.17	63.00	33.33	33.33
Leaf breadth (cm)	10.33	13.37	9.67	13.67	12.00	0	0
Number of veg. buds	3.67	3.67	3.37	3.67	3.67	33.33	33.33
Number of bearing tillers	29.67	40.50	25.67	40.50	35.09	0	0
2. Yield characters							
Panicles per clump	62.50	79.50	44.33	79.50	71.0	0	0
Panicle length (cm)	75.00	76.00	76.00	53.83	75.5	0	0
Racemes per panicle	24.50	19.50	22.50	24.50	22.00	83.33	0
Capsules per raceme	7.83	7.83	6.00	7.83	6.92	0	0
Fruit set%	69.03	65.25	68.22	69.03	67.14	50.00	33.33
Seeds per capsule	17.67	17.33	18.50	17.67	17.50	100.00	100.00
Internodal length (cm)	4.00	5.33	3.83	5.33	4.67	16.67	0
Yield per plant- fresh (g)	3256.33	3038.33	3051.00	3038.33	3147.33	33.33	16.67
Yield per plant- dry (g)	671.95	584.40	577.02	671.95	628.18	50.00	50.00

3. Quality characters							
Recovery percentage	20.67	19.50	18.91	20.67	20.09	33.33	0
% of 7mm and above capsules	70.92	63.11	70.19	70.92	67.02	83.00	66.67
Seed wt.-dry (g)	0.20	0.21	0.21	0.21	0.20	50.00	50.00
Husk wt.-dry (g)	0.06	0.06	0.06	0.06	0.6	50.00	50.00
Litre weight of fresh capsules (g)	362.50	350.00	383.17	367.00	364.75	83.33	8333
Number of capsules per litre	2203.83	2303.83	2216.33	2203.83	2303.83	6.00	0
Cross III- MHC-23x MHC-27							
Characters	Parents/Hybrids			Better parent value	Mid parent value	% of plants showing positive heterosis	% of plants showing heterobeltiosis
	MHC-23 Parent)	MHC-27 (Parent)	MHC-23 X MHC-27 (Hybrid)				
1. Growth characters							
Tillers/ clump	47.67	66.83	65.00	66.83	57.25	61.11	44.45
Tiller height (cm)	292.00	292.83	290.61	292.83	292.42	61.11	61.11
Leaves per tiller	19.33	20.17	19.06	20.17	19.75	44.44	16.67
Leaf length (cm)	65.00	62.17	64.61	65.00	63.59	66.67	55.50
Leaf breadth (cm)	12.83	9.67	12.22	12.83	11.25	77.78	38.89
Number of veg. buds	3.50	3.37	3.70	3.50	3.44	50.00	50.00
Number of bearing tillers	27.33	25.67	27.73	27.33	26.50	55.56	55.56
2. Yield characters							
Panicles per clump	51.33	44.33	55.44	51.33	47.83	55.56	55.56
Panicle length (cm)	58.17	53.83	77.80	58.17	56.00	77.78	77.78

Racemes per panicle	22.00	22.50	24.10	22.50	22.25	55.56	55.56
Capsules per raceme	6.00	6.00	7.17	6.00	6.00	94.44	94.44
Fruit set %	64.61	68.22	69.62	68.22	66.42	66.66	55.00
Seeds per capsule	19.00	18.50	17.83	19.00	18.75	50.00	50.00
Internodal length (cm)	4.33	3.83	4.39	4.33	4.07	33.33	33.33
Yield per plant fresh (g)	2926.67	3051.67	3049.44	3050.67	2989.17	50.00	50.00
Yield per plant dry (g)	543.83	577.01	603.40	577.01	560.42	55.56	55.56
3. Quality characters							
Recovery percentage	18.96	18.91	19.58	18.96	18.96	72.22	72.22
% of 7mm and above capsules	70.15	63.11	68.35	70.15	66.63	66.67	50.00
Seed wt.-dry (g)	0.19	0.21	0.22	0.21	.020	72.22	72.22
Husk wt .-dry (g)	0.06	0.06	0.05	0.06	0.06	55.56	55.86
Litre weight of fresh capsules (g)	367.00	383.17	382.44	383.17	375.09	83.33	55.56
Number of capsules per litre	2124.67	2216.33	2072.11	2216.33	2170.50	38.89	27.78
Cross IV- MHC-27x MHC-23							
Characters	Parents/ Hybrids			Better parent value	Mid parent value	% of plants showing positive heterosis	% of plants showing heterobeltiosis
	MHC-27 (Parent)	MHC-23 (Parent)	MHC-27 X MHC-23 (Hybrids)				
1. Growth characters							
Tillers/ clump	66.83	47.67	80.89	66.83	57.25	100.00	83.33
Tiller height (cm)	292.83	292.00	302.94	292.83	292.42	61.11	61.11

Leaves per tiller	20.17	19.33	18.78	20.17	19.75	33.33	33.33
Leaf length (cm)	62.17	65.00	57.50	65.00	63.59	22.22	16.67
Leaf breadth (cm)	9.67	12.83	11.78	12.83	11.25	61.11	33.33
Number of veg. buds	3.37	3.50	3.11	3.50	3.44	44.44	44.44
Number of bearing tillers	25.67	27.33	36.83	27.33	26.50	88.89	88.89
2. Yield characters							
Panicles per clump	44.33	51.33	69.78	51.33	47.83	88.89	94.44
Panicle length (cm)	53.83	58.17	72.94	58.17	56.00	88.89	94.44
Racemes per panicle	22.50	22.00	22.44	22.50	22.25	55.56	55.56
Capsules per raceme	6.00	6.00	7.06	6.00	6.00	83.33	83.33
Fruit set %	68.22	64.61	68.15	68.61	68.22	72.22	72.22
Seeds per capsule	18.50	19.00	18.28	19.00	18.75	27.78	27.78
Internodal length (cm)	3.83	4.33	3.78	4.33	4.07	16.67	16.67
Yield per plant fresh (g)	3051.67	2926.67	3032.22	3051.67	2989.17	44.44	44.44
Yield per plant dry (g)	577.01	543.83	610.58	577.01	560.42	50.00	50.00
3. Quality characters							
Recovery percentage	18.91	18.96	19.15	18.96	18.94	61.11	61.11
% of 7mm and above capsules	63.11	70.15	68.34	70.15	66.63	66.67	50.00
Seed wt.-dry (g)	0.21	0.19	0.21	0.21	0.20	50.00	50.00
Husk wt.-dry (g)	0.06	0.06	0.15	0.06	0.06	72.22	72.22

Litre weight of fresh capsules (g)	383.17	367.00	378.33	383.17	375.09	72.22	44.44
Number of capsules per litre	2216.33	2124.67	2174.61	2216.23	2170.50	50.00	38.39
Cross V- MHC-23 x MHC-23							
Characters	Parents/ Hybrids			Better parent value	Mid parent value	% of plants showing positive heterosis	% of plants showing heterobeltiosis
	MHC-23 (Parent)	MHC-23 (Parent)	MHC-23 X MHC-23 (Hybrid)				
1. Growth characters							
Tillers/ clump	47.67	47.67	48.94	47.67	47.67	55.57	55.57
Tiller height (cm)	292.00	292.00	286.61	292.00	292.00	61.11	61.11
Leaves per tiller	19.33	19.33	19.50	20.00	19.33	44.44	44.44
Leaf length (cm)	65.00	65.00	65.67	65.00	65.00	50.00	50.00
Leaf breadth (cm)	12.83	12.83	13.39	12.83	12.83	77.78	77.78
Number of veg. buds	3.5	3.5	3.22	3.5	3.5	38.89	38.89
Number of bearing tillers	27.33	27.33	22.22	27.33	27.33	16.67	16.67
2. Yield characters							
Panicles per clump	51.33	50.33	45.17	44.33	44.33	50.00	50.00
Panicle length (cm)	58.17	58.17	55.22	58.17	58.17	50.00	50.00
Racemes per panicle	22.00	22.00	21.28	22.00	22.00	44.44	44.44
Capsules per raceme	6.00	6.00	6.22	6.00	6.00	61.11	61.11
Fruit set %	64.61	64.61	67.50	64.61	64.61	72.22	72.22
Seeds per capsule	19.00	19.00	17.44	19.00	19.00	27.78	27.78

Internodal length (cm)	4.33	4.33	4.39	4.33	4.33	38.89	38.89
Yield per plant fresh (g)	2926.67	29.26.67	2973.89	2926.67	2926.67	39.89	38.89
Yield per plant dry (g)	543.83	543.83	584.20	543.83	543.83	50.00	50.00
3. Quality characters							
Recovery percentage	18.96	18.96	19.42	18.96	18.96	66.67	66.67
% of 7mm and sized capsules	70.15	70.15	69.73	70.19	70.19	56.67	50.00
Seed wt.-dry (g)	0.19	0.19	0.22	0.19	0.19	72.22	72.22
Husk wt.-dry (g)	0.06	0.06	0.06	0.06	0.06	66.67	66.67
Litre weight of fresh capsules (g)	367.00	367.00	383.67	367.00	367.00	100.00	100.00
Number of capsules per litre	2124.67	2124.67	2226.01	2124.67	2124.67	61.11	61.11
Cross VI- MHC-27x MHC-27							
Character	Parents/ Hybrids			Better parent value	Mid parent value	% of plants showing positive heterosis	% of plants showing heterobeltiosis
	MHC-27 (Parent)	MHC-27 (Parent)	MHC-27 X MHC-27 (Hybrid)				
1. Growth characters							
Tillers/ clump	66.83	66.83	75.17	66.83	66.83	72.22	72.22
Tiller height (cm)	292.83	298.83	308.50	292.83	292.83	66.67	66.67
Leaves per tiller	20.17	20.17	20.11	20.17	20.17	50.00	50.00
Leaf length (cm)	62.17	62.17	60.83	62.17	62.17	38.89	38.89
Leaf breadth (cm)	9.67	9.67	11.28	9.67	9.67	88.89	88.89
Number of veg. buds	3.37	3.37	3.22	3.37	3.37	50.00	50.00

Number of bearing tillers	25.67	25.67	22.94	25.67	25.67	55.56	55.56
2. Yield characters							
Panicles per clump	44.33	44.33	46.39	44.33	44.33	55.56	55.56
Panicle length (cm)	53.83	53.83	59.00	53.83	53.83	61.11	61.11
Racemes per panicle	22.50	22.50	23.17	22.50	22.50	55.56	55.56
Capsules per raceme	6.00	6.00	7.33	6.00	6.00	100.00	100.00
Fruit set %	68.22	68.22	69.53	68.22	68.22	77.78	77.78
Seeds per capsule	18.50	18.50	17.50	18.50	18.50	33.33	33.33
Internodal length (cm)	3.83	3.83	3.30	3.83	3.83	38.89	38.89
Yield per plant fresh (g)	3051.67	3051.67	2724.44	3051.67	3051.67	27.78	27.78
Yield per plant dry (g)	577.01	577.01	621.84	577.01	577.01	72.22	72.22
3. Quality characters							
Recovery percentage	18.91	18.91	18.23	18.91	18.19	50.00	50.00
%of 7mm and sized capsules	63.11	63.11	69.60	63.11	63.11	66.67	50.00
Seed wt.-dry (g)	0.21	0.21	0.25	0.21	0.21	66.67	66.67
Husk wt.-dry (g)	0.06	0.06	0.06	0.06	0.06	72.22	72.22
Litre weight of fresh capsules (g)	383.17	383.17	383.06	383.17	383.17	50.00	50.00
Number of capsules per litre	2216.33	2216.33	2266.50	2216.33	2216.33	55.56	55.56

4.6.2. Performance analysis in the case of the double cross / F2 progeny

Further evaluation for the selection of superior plants from the double cross/ F2 progeny has been carried out presently so as to identify superior progeny plants for their further screening, clonal propagation and release to farmers. Eighteen plants each of two double crosses and two F2 crosses described elsewhere have been subjected to performance evaluation based on 22 characters including seven growth characters, nine yield characters and six quality characters (Table 4.19, 4.20 and 4.21).

The best performing progenies have been identified based on total performance index of the plants (Table 4.21). The best performing genotypes in the case of the four crosses have been compared with their parents (Table 4.22 and Figs. 4.3 & 4.4). The study showed that the best performing hybrid of MHC-23 x MHC-27 double cross excelled in seven characters out of 22 characters under study including number of vegetative buds, panicles per clump, racemes per panicle, yield per plant- fresh and dry, litre weight of fresh capsules and number of capsules per litre indicating the superior performance of the genotype in comparison to the parents and F1.

The progeny of MHC-27 x MHC-23 (double cross reciprocal) excelled in the case of six characters, the F2 progeny produced from MHC-23 x MHC-23 excelled in the case of two characters and F2 progeny produced from MHC-27 x MHC-27 excelled in the case of five characters. The above analysis shows that the hybrid progeny performed superior to the parents and the F1 in the case of 20 out of 22 characters studied. Dry yield per plant was high in the case of three out of the four hybrids selected. The above findings emphasize the suitability of the selected hybrids for further evaluation and release to farmers.

Programmes to evolve hybrid cardamom varieties have been initiated by different agencies in India and MHC-26, a superior hybrid selected by Indian Cardamom Research Institute, Myladumpara, Kerala, India has been released recently as ICRI-5 for commercial cultivation in Kerala. Some other hybrids are

presently under evaluation trials (Thomas, 2006; Kuruvilla *et al.*, 2006). Padmini *et al.* (2000b) carried out an experiment to assess the nature and extent of relative heterosis, heterobeltiosis and economic heterosis in cardamom hybrids under nursery conditions. Hybrids exhibiting significantly higher and positive heterobeltiosis and positive heterosis could be isolated. The hybrid genotypes presently identified could be released for commercial cultivation after subjecting to appropriate screening protocols.

Table 4.19. Characters of the double cross hybrids/ F2 progeny in the case of the crosses of cardamom studied

Characters	Genotypes/ mean values																	
	MHC 23 x MHC 27																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Tillers/ clump	80.00	43.00	53.00	54.00	72.00	58.00	77.00	55.00	51.00	55.00	60.00	74.00	64.00	58.00	76.00	80.00	81.00	79.00
Tiller height (cm)	215	328	245	250	339	312	330	265	260	290	316	300	300	321	268	300	294	298
Leaves per tiller	11	20	20	19	21	18	20	22	20	19	18	19	20	21	19	19	18	19
Leaf length (cm)	63	65	64	66	63	72	58	58	69	69	60	64	61	65	69	68	65	64
Leaf breadth (cm)	15	13	13	13	11	13	9	14	12	12	13	12	12	12	11	11	12	12
Number of veg. buds	6	4	5	6	3	3	2	2	3	3	4	3	3	5	4	4	2	5
Number of bearing tillers	20	17	22	23	32	17	34	10	16	18	30	34	33	29	40	41	43	40
Panicles per clump	42	34	44	45	64	33	68	20	32	36	61	68	67	58	80	80	86	80
Panicle length (cm)	29	60	55	88	80	68	38	67	125	55	100	98	88	74	90	86	111	89
Racemes per panicle	21	24	20	33	25	21	17	24	26	20	29	26	23	21	19	27	29	29
Capsules per raceme	5	6	8	8	7	6	7	8	7	7	8	8	8	6	8	8	6	8
Fruit set %	58.95	68.05	77.00	78.26	69.98	68.26	65.00	68.00	69.87	76.68	59.89	66.98	68.00	70.12	78.00	79.02	66.02	65.00
Seeds per capsule	19	18	20	21	19	18	18	16	15	17	19	21	19	19	14	13	19	16

Internodal length (cm)	4	4	3	3	5	4	4	4	5	4	4	3	5	7	7	4	4	5
Yield/plant fresh (g)	1560	2740	3590	2290	2450	3850	4100	2350	2260	1670	2530	3730	3760	2620	3300	3730	3980	4380
Yield/plant dry (g)	294.40	539.23	721.59	460.39	492.25	808.51	824.10	473.06	435.78	367.40	531.30	634.10	589.90	600.00	715.44	759.43	720.40	876.00
Recovery percentage	19.00	19.68	19.99	20.10	20.10	21.00	20.10	20.13	19.98	22.00	21.00	17.00	15.69	21.68	20.36	18.00	17.69	19.00
% of 7mm and above sized capsules	62.90	61.91	61.19	69.00	63.00	69.00	79.93	73.30	72.30	72.00	73.21	69.36	62.00	72.96	71.66	70.00	69.00	62.90
Seed wt.-dry (g)	0.24	0.25	0.25	0.22	0.24	0.19	0.23	0.24	0.26	0.24	0.10	0.26	0.19	0.23	0.27	0.17	0.17	0.23
Husk wt.-dry (g)	0.06	0.07	0.5	0.7	0.6	0.06	0.06	0.07	0.08	0.08	0.05	0.06	0.06	0.05	0.04	0.04	0.08	0.08
Litre weight of dry capsules (g)	368	355	355	405	376	390	378	386	400	395	368	376	370	398	386	395	385	398
Number of capsules per litre-dry	2100	2000	2150	2356	2389	2178	2100	2000	2059	2048	2158	2369	2578	2300	2150	2100	278	1985
MHC-27 x MHC-23																		
Tillers/ clump	9.00	110	102	89	82	88	88	62	87	88	100	79	64	85	84	87	90	62
Tiller height (cm)	276	270	344	391	305	313	261	258	300	316	306	320	214	291	318	280	308	382
Leaves per tiller	21	17	18	25	16	16	18	15	21	21	16	19	17	21	21	17	19	20

Leaf length (cm)	64	68	59	57	56	60	59	51	54	62	64	65	59	48	48	48	59	54
Leaf breadth (cm)	13	13	11	9	12	11	11	10	11	12	12	14	10	13	12	12	13	13
Number of veg. buds	4	4	2	1	2	3	2	3	1	4	4	3	5	3	4	4	4	3
Number of bearing tillers	26	28	38	28	42	42	25	38	34	42	40	38	32	45	45	45	40	35
Panicles per clump	32	64	75	57	54	84	50	69	67	83	81	78	60	88	80	90	80	64
Panicle length (cm)	38	68	98	75	94	88	57	65	66	107	65	87	58	65	68	71	73	70
Racemes per panicle	19	21	22	23	30	24	22	21	23	25	19	25	19	16	24	23	25	23
Capsules per raceme	7	9	9	8	8	8	7	5	6	7	6	8	3	3	9	8	8	8
Fruit set %	66.59	66.00	57.00	59.00	56.35	72.00	76.00	78.00	69.98	68.96	65.22	66.69	73.00	78.05	58.00	79.00	67.89	69.00
Seeds per capsule	18	21	21	18	17	13	18	18	15	17	19	21	20	18	18	19	20	18
Internodal length (cm)	3	3	3	4	4	4	4	5	4	4	5	5	3	4	3	3	4	3
Yield per plant-fresh (g)	1670	3300	3780	3690	2630	2820	2330	3660	2730	2950	1860	1600	3490	3560	2620	2580	3630	5680
Yield per plant- dry (g)	336.17	693.10	831.60	774.90	540.00	445.29	468.33	735.66	491.40	619.50	490.00	460.00	704.67	747.67	462.62	404.80	762.30	1022.40
Recovery percentage	20.13	19.98	22.00	21.00	17.00	15.79	20.10	20.10	18.00	16.59	21.00	20.19	21.00	17.98	15.69	19.83	20.35	18.00

% of 7mm and above capsules	63.936	63.92	63.92	62.90	63.00	71.30	67.00	71.00	69.00	71.96	73.00	71.98	72.00	68.96	66.38	72.34	66.00	71.69
Seed wt.-dry (g)	0.26	0.24	0.18	0.16	0.19	0.23	0.21	0.24	0.17	0.17	0.17	0.23	0.26	0.27	0.15	0.15	0.15	0.27
Husk wt.-dry (g)	0.04	0.08	0.08	0.07	0.5	0.7	0.6	0.06	0.08	0.08	0.05	0.06	0.05	0.04	0.05	0.07	0.06	0.06
Litre weight of fresh capsules (g)	405	398	370	378	350	398	403	360	389	390	370	378	350	355	355	368	403	390
Number of capsules per litre	2150	2013	2189	2089	2076	2056	2389	2368	2256	2159	1986	2035	2300	2300	2326	2211	2222	2018
MHC-23 x MHC-23																		
Tillers/ clump	56	58	54	42	44	62	61	48	44	39	40	54	44	29	44	49	52	61
Tiller height (cm)	276	265	298	293	305	247	300	249	287	298	301	310	305	253	278	296	300	298
Leaves per tiller	21	19	19	18	19	18	19	20	20	21	19	20	19	19	21	19	20	20
Leaf length (cm)	70	78	66	69	64	67	63	65	62	66	63	62	62	64	63	63	69	66
Leaf breadth (cm)	14	15	16	13	13	15	13	13	14	11	12	10	15	13	136	12	14	15
Number of veg. buds	2	4	3	3	2	4	2	3	4	5	2	5	2	3	3	5	2	4
Number of bearing tillers	22	24	254	26	22	30	22	13	16	19	21	22	24	16	20	24	25	29

Panicles per clump	50	48	50	52	44	60	44	26	32	38	42	44	48	36	41	47	51	60
Panicle length (cm)	60	54	59	62	64	61	65	60	48	56	44	51	53	66	47	36	47	61
Racemes per panicle	23	21	21	25	23	20	23	23	19	21	19	21	23	24	18	20	16	23
Capsules per raceme	5	7	7	5	6	7	5	8	4	8	5	4	5	6	6	8	8	8
Fruit set %	56.35	72.00	76.00	78.00	58.96	69.25	58.95	68.05	77.00	78.26	69.98	68.26	65.00	68.98	65.00	59.68	59.00	66.23
Seeds per capsule	18	18	18	18	20	20	17	15	18	19	17	17	19	20	16	18	14	12
Internodal length (cm)	4	4	5	4	4	5	4	4	4	4	5	4	4	5	5	5	4	5
Yield per plant- fresh (g)	1990	2930	2400	2410	4230	2650	3730	2360	4150	2390	2350	2610	3990	3560	2280	2700	4350	2450
Yield per plant- dry (g)	400.59	615.35	528.00	380.54	846.00	530.00	497.30	475.01	830.00	406.36	465.30	548.10	798.00	747.60	433.20	504.67	913.50	596.00
Recovery percentage	20.13	21.00	22.00	15.79	17.00	20.10	20.10	20.13	18.00	22.00	19.98	17.00	21.00	18.00	19.36	17.00	21.00	20.00
% of 7mm and above capsules	62.90	61.91	72.96	69.00	69.36	69.00	73.93	73.21	72.30	69.89	63.59	67.00	72.68	73.00	71.00	69.00	72.33	72.00
Seed wt.- dry (g)	0.22	0.22	0.23	0.15	0.18	0.18	0.24	0.25	0.23	0.19	0.26	0.25	0.18	0.24	0.22	0.22	0.28	0.17
Husk wt.- dry (g)	0.06	0.07	0.05	0.07	0.08	0.08	0.07	0.05	0.07	0.06	0.08	0.08	0.05	0.06	0.06	0.05	0.04	0.04

Litre weight of fresh capsules (g)	395	368	376	401	376	390	378	376	400	395	368	376	370	398	376	400	395	368
Number of capsules per litre	2100	2150	2013	2189	2089	2389	2178	2100	2369	2578	2300	2389	2368	2076	2056	2389	2035	2300
MHC-27 x MHC-27																		
Tillers/ clump	70	83	87	109	58	52	68	76	124	68	66	91	83	77	52	82	41	66
Tiller height (cm)	340	347	337	305	300	288	300	324	340	238	292	364	2858	286	300	340	225	342
Leaves per tiller	23	23	23	23	18	16	18	25	17	15	23	23	22	20	20	21	16	16
Leaf length (cm)	64	59	55	58	60	67	54	70	70	54	54	60	61	64	63	58	57	67
Leaf breadth (cm)	10	10	10	11	12	13	9	13	13	15	10	10	10	12	11	8	11	15
Number of veg. buds	3	3	5	4	4	4	5	4	4	2	4	4	3	1	1	3	2	2
Number of bearing tillers	15	26	26	28	30	10	15	27	32	22	18	37	30	15	15	27	8	32
Panicles per clump	30	52	53	56	60	21	36	54	64	45	35	74	60	30	32	54	15	64
Panicle length (cm)	41	54	45	60	76	61	51	57	46	75	86	72	54	46	60	42	36	100
Racemes per panicle	22	27	25	26	21	28	24	13	25	19	31	26	21	21	25	20	18	25

Capsules per raceme	6	6	7	9	6	7	6	9	7	8	6	8	8	8	7	8	8	8
Fruit set %	56.35	72.00	76.00	78.00	69.98	68.96	56.35	72.00	76.00	69.98	68.26	65.00	68.00	69.87	78.00	69.98	68.96	67.89
Seeds per capsule	13	15	14	18	19	20	21	17	17	18	17	17	17	19	17	18	19	19
Internodal length (cm)	3	3	4	4	3	3	4	5	3	3	4	4	3	2	2	2	3	5
Yield per plant fresh (g)	1820	2900	3520	3460	2410	2600	2230	3490	2980	2180	2400	3520	2130	2000	2100	2920	3580	2800
Yield per plant dry (g)	363.64	582.90	707.52	695.46	433.80	468.00	450.23	704.63	506.60	704.00	716.00	749.65	743.21	689.98	698.99	752.36	489.69	736.54
Recovery percentage	19.98	20.10	20.10	16.59	21.00	18.00	20.10	20.19	18.26	17.00	19.25	18.26	21.00	20.00	18.00	14.02	18.00	19.00
%of 7 mm and above capsules	61.91	62.00	63.00	73.30	72.00	71.66	73.00	69.36	71.68	71.33	72.33	72.00	73.21	69.36	62.00	72.96	68.96	72.68
Seed wt.-dry (g)	0.22	0.22	0.22	0.22	0.26	0.25	0.24	0.15	0.15	0.8	0.19	0.18	0.22	0.26	0.24	0.18	0.25	0.26
Husk wt.-dry (g)	0.07	0.06	0.08	0.08	0.05	0.06	0.06	0.05	0.04	0.08	0.05	0.06	0.05	0.04	0.06	0.06	0.07	0.08
Litre weight of fresh capsules (g)	376	400	395	368	390	395	398	376	398	376	390	378	376	400	395	368	376	370
Number of capsules per litre	2150	2356	2389	2178	2158	2369	2578	2300	2211	2222	2018	2100	2369	2578	2300	2076	2056	2389

Table 4.20. Study of performance of the double cross/ F2 progeny in the case of the crosses of cardamom studied- value points

Characters	Genotypes/ values																	
	MHC 23 x MHC 27																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Tillers/ clump	17	4	6	7	12	9	15	8	5	8	10	13	11	9	14	17	18	16
Tiller height	3	16	4	5	18	13	17	7	6	9	14	12	12	15	8	12	10	11
Leaves per tiller	13	16	16	15	17	14	16	18	16	15	14	15	16	17	15	15	14	15
Leaf length	12	14	13	15	12	18	9	9	17	17	10	13	11	14	17	16	14	13
Leaf breadth	18	16	16	16	14	16	13	17	15	15	16	15	15	15	14	14	15	15
Number of veg. buds	18	16	17	18	14	14	13	13	14	14	16	14	14	17	16	16	13	17
Number of bearing tillers	8	6	9	10	13	6	15	4	5	7	12	15	14	11	16	17	18	16
Panicles per clump	9	7	10	11	14	6	16	4	5	8	13	16	15	12	17	17	18	17
Panicle length	3	6	5	12	10	8	4	7	18	5	16	15	12	9	14	11	17	13
Racemes per panicle	11	13	10	18	14	11	8	13	15	10	17	15	12	11	9	16	17	17
Capsules per raceme	15	16	18	18	17	16	17	18	17	17	18	18	18	16	18	18	16	18

Fruit set %	3	9	15	17	12	10	5	9	11	14	4	7	8	13	16	18	6	5
Seeds per capsule	16	15	17	18	16	15	15	13	12	14	16	18	16	16	11	10	16	13
Internodal length	16	16	15	15	17	16	16	16	17	16	16	15	17	18	18	16	16	17
Yield /plant fresh	2	10	12	5	7	14	17	6	4	3	8	13	15	9	11	13	16	18
Yield per plant dry	1	8	14	4	6	16	17	5	3	2	7	11	9	10	12	15	13	18
Recovery percentage	9	10	12	13	13	16	13	14	11	18	16	6	5	17	15	8	7	9
% 7mm and above sized capsules	7	5	4	9	8	9	18	17	14	13	16	10	6	15	12	11	9	7
Seed wt.-dry	14	16	16	12	14	11	13	14	17	14	9	7	11	13	18	10	10	13
Husk wt.-dry	13	14	16	18	17	13	13	14	15	15	12	13	13	12	11	11	15	15
Litre weight of dry capsules	8	7	7	18	9	14	11	13	17	15	8	10	9	16	13	15	12	16
Number of capsules per litre dry	10	7	11	15	17	13	10	7	9	8	12	16	18	14	11	10	5	6
MHC-27 X MHC -23																		
Tillers/ clump	5	18	17	14	9	13	13	6	12	13	16	8	7	11	10	12	15	6
Tiller height	5	4	16	18	9	12	3	2	8	13	10	15	1	7	14	6	11	17

Leaves per tiller	17	13	14	18	12	12	14	11	17	17	12	15	13	17	17	13	15	16
Leaf length	16	18	13	12	11	14	13	9	10	15	16	17	13	8	8	8	13	10
Leaf breadth	17	17	15	13	16	15	15	14	15	16	16	18	14	17	16	16	17	17
Number of veg. buds	17	17	15	14	15	16	15	16	14	17	17	16	18	16	17	17	17	16
Number of bearing tillers	10	11	15	11	17	17	9	15	13	17	16	15	12	18	18	18	16	14
Panicles per clump	3	8	11	6	5	16	4	10	9	15	14	12	7	17	13	18	13	8
Panicle length	4	9	17	13	16	15	5	7	8	18	7	14	6	7	9	11	12	10
Racemes per panicle	12	13	14	15	18	16	14	13	15	17	12	17	12	11	16	15	17	15
Capsules per raceme	16	18	18	17	17	17	16	13	15	16	14	17	12	12	18	17	17	17
Fruit set %	7	6	2	4	1	13	15	16	12	10	5	8	14	17	3	18	9	11
Seeds per capsule	15	18	18	15	14	12	15	15	13	14	16	18	17	15	15	16	17	15
Internodal length	16	16	16	17	17	17	17	18	17	17	18	18	16	17	16	16	17	16
Yield per plant- fresh	2	11	17	16	7	9	4	15	8	10	3	1	12	13	6	5	14	18
Yield per plant- dry	1	11	17	16	9	3	5	13	8	10	7	6	12	14	4	2	15	18
Recovery percentage	14	12	18	17	9	7	13	13	10	8	17	15	17	9	6	11	16	10

% of 7mm and above capsules	6	5	5	3	4	12	11	10	14	18	15	10	6	10	9	17	8	13
Seed wt.-dry	17	16	12	11	13	15	14	16	12	12	12		17	18	10	10	10	18
Husk wt.-dry	11	15	15	14	16	18	17	13	15	15	12	13	12	11	12	14	13	13
Litre weight of fresh capsules	18	16	12	13	8	16	17	10	14	15	12	13	8	9	9	11	17	15
Number of capsules per litre	9	4	11	8	7	6	18	17	14	10	3	5	15	15	16	12	13	14
MHC-23 X MHC-23																		
Tillers/ clump	15	16	14	9	10	18	17	11	10	7	8	14	10	6	10	12	13	17
Tiller height	9	8	14	12	17	5	15	6	11	14	16	18	17	7	10	13	15	14
Leaves per tiller	18	16	16	15	16	15	16	17	17	18	16	17	16	16	18	16	17	17
Leaf length	17	18	14	16	12	15	11	13	10	14	11	10	10	12	11	11	16	14
Leaf breadth	15	16	17	14	14	16	14	14	15	12	13	11	16	14	18	13	15	16
Number of veg. buds	15	17	16	16	15	17	15	16	17	18	15	18	15	16	16	18	15	17
Number of bearing tillers	12	13	18	14	12	17	12	7	8	9	11	12	13	8	10	13	15	16
Panicles per clump	15	14	15	17	12	18	12	6	7	9	11	12	14	8	10	13	16	18

Panicle length	12	9	11	14	16	13	17	12	6	10	4	7	8	18	5	3	5	13
Racemes per panicle	16	15 15	18	16	14	16	16	13	15	13	15	16	17	12	14	11	16	
Capsules per raceme	15	17	17	15	16	17	15	18	14	18	15	14	15	16	16	18	18	18
Fruit set %	2	14	15	17	4	12	3	9	16	18	13	10	7	11	7	6	5	8
Seeds per capsule	16	16	16	16	18	18	15	13	16	17	15	15	17	18	14	16	12	11
Internodal length	17	17	18	17	17	18	17	17	17	17	18	17	17	18	18	18	17	18
Yield per plant fresh	1	12	6	7	17	10	14	14	16	5	3	9	15	13	2	11	18	8
Yield per plant dry	2	13	9	1	17	10	7	6	16	3	5	11	15	14	4	8	18	12
Recovery percentage	16	17	18	9	10	15	15	16	11	18	13	10	17	11	12	10	17	14
% of 7mm and above capsules	4	3	15	7	8	7	18	17	12	9	5	6	14	16	10	7	13	11
Seed wt.-dry	13	13	14	9	11	11	15	16	14	12	17	16	11	15	13	13	18	10
Husk wt.-dry	16	17	15	17	18	18	17	15	17	16	18	18	15	16	16	15	14	14
Litre weight of fresh capsules	15	10	12	18	12	14	13	12	17	15	10	12	11	16	13	17	15	10
Number of capsules per litre	10	11	5	13	9	17	12	10	16	18	14	17	15	8	7	17	6	14

MHC-27 x MHC-27																		
Tillers/ clump	10	14	15	17	7	6	9	11	18	9	8	19	14	12	6	13	5	8
Tiller height	14	16	13	11	10	8	10	12	14	6	9	17	18	7	10	14	5	15
Leaves per tiller	17	17	17	17	13	11	13	18	12	10	17	17	16	14	14	15	11	11
Leaf length	16	12	9	11	13	17	8	18	18	8	8	13	14	16	15	11	10	17
Leaf breadth	14	14	14	15	16	17	13	17	17	18	14	14	14	16	15	12	15	18
Number of veg. buds	16	16	18	17	17	17	18	17	17	13	17	17	16	12	12	16	13	13
Number of bearing tillers	10	13	13	15	16	9	10	14	17	12	11	18	16	10	10	14	8	17
Panicles per clump	8	12	13	15	16	6	10	14	17	11	9	18	16	8	7	14	5	17
Panicle length	5	10	7	12	16	13	9	11	8	15	17	14	10	8	12	6	4	18
Racemes per panicle	12	16	14	15	11	17	13	7	14	9	18	15	11	11	14	10	8	14
Capsules per raceme	15	15	16	18	15	16	15	18	16	17	15	17	17	17	16	17	17	17
Fruit set %	9	16	17	18	15	14	9	16	17	15	13	10	12	14	18	15	14	11
Seeds per capsule	11	13	12	15	16	17	18	14	14	15	14	14	14	16	14	15	16	16
Internodal length	16	16	17	17	16	16	17	18	16	16	17	17	16	15	15	15	16	18

Yield per plant- fresh	2	12	17	15	9	10	7	16	14	6	8	17	5	3	4	13	18	11
Yield per plant- dry	1	7	13	9	2	4	3	12	6	11	14	17	16	8	10	18	5	15
Recovery percentage	14	16	16	8	18	10	16	17	11	9	13	11	18	15	10	7	10	12
%of 7 mm and above capsules	4	5	6	18	12	10	16	8	11	9	13	12	17	8	5	15	7	14
Seed wt.- dry	15	15	15	15	18	17	16	12	12	11	14	13	15	18	16	13	17	18
Husk wt.- dry	17	16	18	18	15	16	16	15	14	18	15	16	15	14	16	16	17	18
Litre weight of fresh capsules	13	18	16	11	15	16	17	13	17	13	15	14	13	18	16	11	13	12
Number of capsules per litre	10	15	17	12	11	16	18	14	13	13	6	9	16	18	14	8	7	17

Table 4.21. Study of performance of the double cross/ F2 progeny in the case of the crosses of cardamom studied- performance indices in relation to characters

Characters	Genotypes/ values																	
	MHC 23 x MHC 27																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Tillers per clump	0.94	0.22	0.33	0.39	0.67	0.50	0.83	0.44	0.28	0.44	0.56	0.72	0.61	0.50	0.78	0.94	1.00	0.89
Tiller height	0.17	0.89	0.22	0.28	1.00	0.72	0.94	0.39	0.33	0.50	0.78	0.67	0.67	0.83	0.44	0.67	0.56	0.61
Leaves per tiller	0.72	0.89	0.89	0.83	0.94	0.78	0.89	1.0	0.89	0.83	0.78	0.83	0.89	0.94	0.83	0.83	0.78	0.83
Leaf length	0.67	0.89	0.89	0.83	0.94	0.78	0.89	1.00	0.89	0.83	0.78	0.83	0.89	0.94	0.83	0.83	0.78	0.83
Leaf breadth	1	0.89	0.89	0.89	0.78	0.89	0.72	0.94	0.83	0.83	0.89	0.83	0.83	0.83	0.78	0.78	0.83	0.83
Number of veg. buds	1.00	0.89	0.94	1.00	0.78	0.78	0.72	0.72	0.78	0.78	0.89	0.78	0.78	0.94	0.89	0.89	0.72	0.94
Number of bearing tillers	0.44	0.33	0.50	0.56	0.72	0.33	0.83	0.22	0.28	0.39	0.67	0.83	0.78	0.61	0.89	0.94	1.00	0.89
Panicles per clump	0.5	0.39	0.56	0.61	0.78	0.33	0.89	0.22	0.28	0.44	0.72	0.89	0.83	0.67	0.94	0.94	1.00	0.94
Panicle length	0.17	0.33	0.28	0.67	0.56	0.44	0.22	0.39	1.00	0.28	0.89	0.83	0.67	0.50	0.78	0.61	0.94	0.72
Racemes per panicle	0.61	0.72	0.56	1.00	0.78	0.61	0.44	0.72	0.83	0.56	0.94	0.83	0.67	0.67	0.50	0.89	0.94	0.94
Capsules per raceme	0.83	0.89	1.00	1.00	0.94	0.89	0.94	1.00	0.94	0.94	1.00	1.00	1.00	0.89	1.00	1.00	0.89	1.00
Fruit set %	0.17	0.5	0.83	0.94	0.67	0.56	0.28	0.50	0.61	0.78	0.28	0.39	0.44	0.72	0.89	1.00	0.33	0.28
Seeds per capsule	0.89	0.83	0.94	1.00	0.89	0.83	0.83	0.72	0.67	0.78	0.89	1.00	0.89	0.89	0.61	0.50	0.89	0.72
Internodal length	0.89	0.89	0.83	0.83	0.94	0.89	0.89	0.89	0.94	0.89	0.89	0.83	0.94	1.00	1.00	0.89	0.89	0.94

Yield per plant- fresh	0.11	0.56	0.67	0.28	0.39	0.78	0.94	0.33	0.22	0.17	0.44	0.72	0.83	0.50	0.61	0.72	0.89	1.00
Yield per plant- dry	0.06	0.44	0.78	0.22	0.33	0.89	0.94	0.28	0.17	0.11	0.39	0.61	0.50	0.56	0.67	0.83	0.72	1.00
Recovery percentage	0.44	0.56	0.67	0.72	0.72	0.89	0.72	0.78	0.67	1.00	0.89	0.39	0.61	0.50	0.56	0.67	0.83	0.72
% of 7mm and above sized capsules	0.39	0.56	0.67	0.72	0.72	0.89	0.72	0.78	0.61	1.00	0.89	0.33	0.28	0.94	0.83	0.44	0.39	0.50
Seed wt.- dry	0.78	0.89	0.89	0.67	0.78	0.61	0.72	0.78	0.94	0.78	0.50	0.94	0.61	0.72	1.00	0.56	0.56	0.72
Husk wt.- dry	0.72	0.78	0.89	1.00	0.94	0.72	0.72	0.78	0.83	0.83	0.67	0.72	0.72	0.67	0.61	0.61	0.83	0.83
Litre weight of dry capsules	0.44	0.39	0.39	1.00	0.50	0.78	0.61	0.72	0.94	0.83	0.44	0.56	0.56	0.89	0.72	0.83	0.67	0.89
Number of capsules per litre- dry	0.56	0.39	0.61	0.83	0.72	0.56	0.39	0.50	0.44	0.67	0.89	1.00	0.78	0.61	0.56	0.33	0.28	0.33
Total performance index	12.5	14.12	15.23	16.27	16.49	15.45	16.07	14.10	14.37	14.66	16.07	16.53	15.78	16.32	**16.72**	16.70	**16.72**	**17.30**
MHC 27 x MHC 23																		
Tillers per clump	0.28	1.00	0.94	0.78	0.50	0.72	0.72	0.33	0.67	0.72	0.89	0.44	0.39	0.61	0.56	0.67	0.83	0.33
Tiller height	0.28	0.22	0.89	1.00	0.50	0.67	0.17	0.11	0.44	0.22	0.56	0.83	0.06	0.39	0.78	0.33	0.61	0.94
Leaves per tiller	0.94	0.72	0.78	1.00	0.67	0.67	0.78	0.61	0.94	0.94	0.67	0.83	0.72	0.94	0.94	0.72	0.83	0.89
Leaf length	0.89	1.00	0.72	0.67	0.61	0.78	0.72	0.50	0.56	0.83	0.89	0.94	0.72	0.44	0.44	0.44	0.72	0.56

Yield per plant- fresh	0.11	0.56	0.67	0.28	0.39	0.78	0.94	0.33	0.22	0.17	0.44	0.72	0.83	0.50	0.61	0.72	0.89	1.00
Yield per plant- dry	0.06	0.44	0.78	0.22	0.33	0.89	0.94	0.28	0.17	0.11	0.39	0.61	0.50	0.56	0.67	0.83	0.72	1.00
Recovery percentage	0.44	0.56	0.67	0.72	0.72	0.89	0.72	0.78	0.67	1.00	0.89	0.39	0.61	0.50	0.56	0.67	0.83	0.72
% of 7mm and above sized capsules	0.39	0.56	0.67	0.72	0.72	0.89	0.72	0.78	0.61	1.00	0.89	0.33	0.28	0.94	0.83	0.44	0.39	0.50
Seed wt.- dry	0.78	0.89	0.89	0.67	0.78	0.61	0.72	0.78	0.94	0.78	0.50	0.94	0.61	0.72	1.00	0.56	0.56	0.72
Husk wt.- dry	0.72	0.78	0.89	1.00	0.94	0.72	0.72	0.78	0.83	0.83	0.67	0.72	0.72	0.67	0.61	0.61	0.83	0.83
Litre weight of dry capsules	0.44	0.39	0.39	1.00	0.50	0.78	0.61	0.72	0.94	0.83	0.44	0.56	0.56	0.89	0.72	0.83	0.67	0.89
Number of capsules per litre- dry	0.56	0.39	0.61	0.83	0.72	0.56	0.39	0.50	0.44	0.67	0.89	1.00	0.78	0.61	0.56	0.33	0.28	0.33
Total performance index	12.5	14.12	15.23	16.27	16.49	15.45	16.07	14.10	14.37	14.66	16.07	16.53	15.78	16.32	**16.72**	16.70	**16.72**	**17.30**
MHC 27 x MHC 23																		
Tillers per clump	0.28	1.00	0.94	0.78	0.50	0.72	0.72	0.33	0.67	0.72	0.89	0.44	0.39	0.61	0.56	0.67	0.83	0.33
Tiller height	0.28	0.22	0.89	1.00	0.50	0.67	0.17	0.11	0.44	0.22	0.56	0.83	0.06	0.39	0.78	0.33	0.61	0.94
Leaves per tiller	0.94	0.72	0.78	1.00	0.67	0.67	0.78	0.61	0.94	0.94	0.67	0.83	0.72	0.94	0.94	0.72	0.83	0.89
Leaf length	0.89	1.00	0.72	0.67	0.61	0.78	0.72	0.50	0.56	0.83	0.89	0.94	0.72	0.44	0.44	0.44	0.72	0.56

Leaf breadth	0.94	0.94	0.83	0.72	0.89	0.83	0.83	0.78	0.83	0.89	0.89	1.0	0.78	0.94	0.89	0.89	0.94	0.94
Number of veg. buds	0.94	0.94	0.83	0.78	0.83	0.89	0.83	0.89	0.78	0.94	0.94	0.89	1.00	0.89	0.94	0.94	0.94	0.89
Number of bearing tillers	0.56	0.61	0.83	0.61	0.94	0.94	0.50	0.83	0.72	0.94	0.89	0.83	0.67	1.0	1.0	1.0	0.89	0.78
Panicles per clump	0.17	0.44	0.61	0.33	0.28	0.89	0.22	0.56	0.50	0.83	0.78	0.67	0.39	0.94	0.72	1.0	0.72	0.44
Panicle length	0.22	0.50	0.94	0.72	0.89	0.83	0.28	0.39	0.44	1.00	0.39	0.78	0.33	0.39	0.50	0.61	0.67	0.61
Racemes per panicle	0.67	0.72	0.78	0.83	1.00	0.89	0.78	0.72	0.83	0.94	0.67	0.94	0.67	0.61	0.89	0.83	0.94	0.83
Capsules per raceme	0.89	1.00	1.00	0.94	0.94	0.94	0.89	0.72	0.83	0.89	0.78	0.44	0.78	0.94	0.17	1.00	0.50	0.61
Fruit set %	0.39	0.33	0.11	0.22	0.06	0.72	0.83	0.89	0.67	0.56	0.28	0.44	0.78	0.94	0.17	1.00	0.50	0.61
Seeds per capsule	0.83	1.00	1.00	0.83	0.78	0.67	0.83	0.83	0.72	0.78	0.89	1.00	0.89	0.94	0.89	0.89	0.94	0.89
Internodal length	0.89	0.89	0.89	0.94	0.94	0.94	0.94	1.00	0.94	0.94	1.00	1.00	0.89	0.94	0.89	0.89	0.94	0.89
Yield per plant- fresh	0.11	0.67	0.94	0.89	0.39	0.50	0.22	0.83	0.44	0.56	0.17	0.06	0.67	0.72	0.33	0.28	0.78	1.00
Yield per plant- dry	0.06	0.61	0.94	0.89	0.50	0.17	0.28	0.72	0.44	0.56	0.39	0.33	0.67	0.78	0.22	0.11	0.83	1.00
Recovery percentage	0.78	0.67	1.00	0.94	0.50	0.39	0.72	0.72	0.56	0.44	0.94	0.83	0.94	0.50	0.33	0.61	0.89	0.56
% of 7mm and above capsules	0.33	0.28	0.28	0.17	0.22	0.67	0.44	0.61	0.61	0.83	0.11	0.83	0.89	0.56	0.50	0.94	0.44	0.72
Seed wt.- dry	0.94	0.89	0.67	0.61	0.72	0.83	0.78	0.89	0.67	0.67	0.67	0.83	0.94	1.00	0.56	0.56	0.56	1.00

Husk wt.-dry	0.61	0.83	0.83	0.78	0.89	1.00	0.94	0.72	0.83	0.83	0.67	0.72	0.67	0.61	0.67	0.78	0.72	0.72
Litre weight of fresh capsules	1.00	0.89	0.67	0.72	0.44	0.89	0.94	0.56	0.78	0.83	0.67	0.72	0.44	0.50	0.50	0.61	0.94	0.83
Number of capsules per litre	0.50	0.22	0.61	0.44	0.39	0.33	1.00	0.94	0.78	0.56	0.17	0.28	0.83	0.83	0.89	0.67	0.72	0.22
Total performance index	13.22	15.37	**17.09**	15.81	13.88	16.16	14.64	15.15	14.98	**16.70**	14.31	15.63	15.12	16.41	13.78	15.77	**16.85**	16.26
MHC 23 x MHC 23																		
Tillers per clump	0.83	0.89	0.78	0.50	0.56	1.00	0.94	0.61	0.56	0.39	0.44	0.78	0.56	0.33	0.56	0.67	0.72	0.84
Tiller height	0.50	0.44	0.78	0.67	0.94	0.28	0.83	0.33	0.61	0.78	0.89	1.00	0.94	0.39	0.56	0.72	0.83	0.78
Leaves per tiller	1.00	0.89	0.89	0.83	0.89	0.83	0.89	0.94	0.94	1.00	0.89	0.94	0.89	0.89	1.00	0.89	0.94	0.94
Leaf length	0.94	1.00	0.78	0.89	0.67	0.83	0.61	0.72	0.56	0.78	0.61	0.56	0.56	0.67	0.61	0.61	0.89	0.78
Leaf breadth	0.83	0.89	0.94	0.78	0.78	0.89	0.78	0.78	0.83	0.67	0.72	0.61	0.89	0.78	1.00	0.72	0.83	0.94
Number of veg. buds	0.83	0.94	0.89	0.89	0.83	0.94	0.83	0.89	0.94	1.00	0.83	1.00	0.83	0.89	0.89	1.00	0.83	0.94
Number of bearing tillers	0.67	0.72	1.00	0.78	0.67	0.94	0.67	0.39	0.44	0.50	0.61	0.67	0.72	0.44	0.56	0.72	0.83	0.89
Panicles per clump	0.83	0.78	0.83	0.94	0.67	1.00	0.67	0.33	0.39	0.50	0.61	0.67	0.78	0.44	0.56	0.72	0.89	1.00
Panicle length	0.67	0.50	0.61	0.78	0.89	0.72	0.94	0.67	0.33	0.56	0.22	0.39	0.44	1.00	0.28	0.17	0.28	0.72

Racemes per panicle	0.89	0.83	0.83	1.00	0.89	0.78	0.89	0.89	0.72	0.83	0.72	0.83	0.89	0.94	0.67	0.78	0.61	0.89
Capsules per raceme	0.83	0.94	0.94	0.83	0.89	0.94	0.83	1.00	0.78	1.00	0.83	0.78	0.83	0.89	0.89	1.00	1.00	1.00
Fruit set %	0.11	0.78	0.83	0.94	0.22	0.67	0.17	0.50	0.89	1.00	0.72	0.56	0.39	0.61	0.39	0.33	0.28	0.44
Seeds per capsule	0.89	0.89	0.89	0.89	1.00	1.00	0.83	0.72	0.89	0.94	0.83	0.83	0.94	1.00	0.78	0.89	0.67	0.61
Internodal length	0.94	0.94	1.00	0.94	0.94	1.00	0.94	0.94	0.94	0.94	1.00	0.94	0.94	1.00	1.00	1.00	0.94	1.00
Yield per plant- fresh	0.06	0.67	0.33	0.39	0.94	0.56	0.78	0.22	0.89	0.28	0.17	0.50	0.83	0.72	0.11	0.61	1.00	0.44
Yield per plant- dry	0.11	0.72	0.50	0.06	0.94	0.56	0.39	0.33	0.89	0.17	0.28	0.61	0.83	0.78	0.22	0.44	1.00	0.67
Recovery percentage	0.89	0.94	0.11	0.50	0.56	0.83	0.83	0.89	0.61	1.00	0.72	0.56	0.94	0.61	0.67	0.56	0.94	0.78
% of 7mm and above capsules	0.22	0.17	0.83	0.39	0.44	0.39	1.00	0.94	0.67	0.50	0.28	0.33	0.78	0.89	0.56	0.39	0.72	0.61
Seed wt.- dry	0.22	0.17	0.78	0.78	0.50	0.61	0.61	0.83	0.89	0.78	0.67	0.94	0.89	0.61	0.83	0.72	0.71	0.56
Husk wt.- dry	0.89	0.94	0.83	0.94	1.00	1.00	0.94	0.83	0.94	0.89	1.00	1.00	0.93	0.89	0.89	0.83	0.78	0.78
Litre weight of fresh capsules	0.83	0.56	0.67	1.00	0.67	0.78	0.72	0.67	0.94	0.83	0.56	0.67	0.61	0.89	0.72	0.94	0.83	0.56
Number of capsules per litre	0.56	0.61	0.28	0.72	0.50	0.94	0.67	0.56	0.89	1.00	0.78	0.94	0.83	0.44	0.39	0.94	0.33	0.78
Total performance index	14.54	16.21	16.32	16.44	16.39	**17.49**	16.76	14.98	16.54	16.34	14.38	16.11	13.24	16.10	14.14	15.65	**16.85**	**16.95**

MHC-27 x MHC-27																		
Tillers/ clump	0.56	0.78	0.83	0.94	0.39	0.33	0.94	0.61	1.00	0.94	0.44	0.89	0.78	0.67	0.33	0.72	0.28	0.44
Tiller height	0.78	0.89	0.72	0.61	0.56	0.44	0.56	0.67	0.78	0.33	0.50	0.94	1.00	0.39	0.56	0.78	0.28	0.83
Leaves per tiller	0.94	0.94	0.94	0.94	0.72	0.61	0.72	1.00	0.67	0.56	0.94	0.94	0.89	0.78	0.78	0.83	0.61	0.61
Leaf length	0.89	0.67	0.50	0.61	0.72	0.94	0.44	1.00	1.00	0.44	0.44	0.72	0.78	0.89	0.83	0.61	0.56	0.94
Leaf breadth	0.78	0.78	0.78	0.83	0.89	0.94	0.72	0.94	0.94	1.00	0.78	0.78	0.78	0.89	0.83	0.67	0.83	1.00
Number of veg. buds	0.89	0.89	1.00	0.94	0.94	0.94	1.00	0.94	0.94	0.72	0.94	0.94	0.89	0.67	0.67	0.89	0.72	0.72
Number of bearing tillers	0.55	0.72	0.72	0.83	0.89	0.50	0.56	0.78	0.94	0.67	0.61	1.00	0.89	0.56	0.56	0.78	0.44	0.94
Panicles per clump	0.22	0.67	0.72	0.83	0.87	0.33	0.56	0.78	0.94	0.61	0.50	1.00	0.89	0.44	0.39	0.78	0.28	0.94
Panicle length	0.28	0.55	0.39	0.67	0.89	0.72	0.50	0.61	0.44	0.83	0.94	0.78	0.56	0.44	0.67	0.33	0.22	1.00
Racemes per panicle	0.67	0.89	0.78	0.83	0.61	0.94	0.72	0.39	0.78	0.50	1.00	0.83	0.61	0.61	0.78	0.56	0.44	0.78
Capsules per raceme	0.83	0.83	0.89	1.00	0.83	0.89	0.83	1.00	0.78	0.94	0.83	0.94	0.94	0.89	0.94	0.94	0.94	0.94
Fruit set %	0.50	0.89	0.94	1.00	0.83	0.78	0.50	0.89	0.94	0.83	0.72	0.56	0.67	0.78	1.00	0.83	0.78	0.78
Seeds per capsule	0.61	0.72	0.67	0.83	0.89	0.94	1.00	0.78	0.78	0.83	0.78	0.78	0.78	0.89	0.78	0.83	0.78	0.78
Internodal length	0.89	0.89	0.94	0.94	0.89	0.89	0.94	1.00	0.89	0.89	0.94	0.94	0.89	0.83	0.83	0.83	0.89	1.00
Yield per plant- fresh	0.11	0.67	0.94	0.83	0.50	0.56	0.39	0.89	0.78	0.33	0.44	0.94	0.28	0.17	0.22	0.72	1.00	0.61

Yield per plant- dry	0.06	0.39	0.72	0.50	0.11	0.22	0.17	0.67	0.33	0.61	0.78	0.94	0.89	0.44	0.56	1.00	0.28	0.83
Recovery percentage	0.78	0.89	0.89	0.44	1.300	0.56	0.89	0.94	0.61	0.50	0.72	0.61	1.00	0.83	0.56	0.39	0.56	0.62
%of 7mm and above capsules	0.22	0.28	0.33	1.00	0.67	0.56	0.89	0.44	0.61	0.50	0.72	0.67	0.94	0.44	0.28	0.83	0.39	0.78
Seed wt.- dry	0.83	0.83	0.83	0.83	1.00	0.94	0.89	0.67	0.67	0.61	0.78	0.72	0.83	1.00	0.89	0.72	0.94	1.00
Husk wt.- dry	0.94	0.89	1.00	1.00	0.83	0.89	0.89	0.83	0.74	0.89	0.83	0.89	0.83	0.78	0.89	0.89	0.94	1.00
Litre weight of fresh capsules	0.72	1.00	0.89	0.61	0.83	0.89	0.94	0.72	0.94	0.72	0.83	0.78	0.72	0.91	0.89	0.61	0.72	0.67
Number of capsules per litre	0.55	0.83	0.94	0.67	0.61	0.89	1.00	0.78	0.72	0.72	0.33	0.50	0.89	1.00	0.78	0.44	0.39	0.94
Total performance index	13.60	16.89	17.36	17.68	16.77	15.70	16.05	17.33	17.22	14.97	15.79	**18.09**	**17.73**	15.30	15.02	15.98	13.27	**18.15**

Table 4.22. Characters of the parents, F1 and the best performers of double crosses/ F2 in the case of the hybrids studied.

Characters	Genotypes									
	MCC 49	MCC 345	MCC 260	MCC 61	MHC 23 (MCC49 x MCC 345)	MHC 27 (MCC 260 x MCC 61)	MHC 23 x MHC 27 (double cross)	MHC 27 x MHC 23 (double cross-reciprocal)	MHC 23 x MHC 23 (F2)	MHC 27 x MHC 27 (F2)
Tillers/ clump	46.17	53.33	62.67	74.67	47.67	66.83	79.00	**102**	62	66
Tiller height (cm)	250.00	254.17	337.03	306.83	292.00	292.83	298	**344**	247	342
Leaves per tiller	14.00	13.00	19.67	17.00	19.33	**20.17**	19	18	18	16
Leaf length (cm)	60.00	63.17	62.83	63.17	65.00	62.17	64	59	**67**	**67**
Leaf breadth (cm)	9.67	8.33	10.33	13.67	12.83	9.67	12	11	**15**	**15**
Number of veg. buds	4.67	4.67	3.67	3.67	3.50	3.37	**5**	2	4	2
Number of bearing tillers	19.83	22.00	29.67	**40.50**	27.33	25.67	40	38	30	32
Panicles per clump	39.67	43.67	62.50	79.50	51.33	44.33	**80**	75	60	64
Panicle length (cm)	53.17	54.67	75.00	76.00	58.17	53.83	89	98	61	**100**
Racemes per panicle	20.67	20.17	24.50	19.5	22.00	22.50	**29**	22	20	25

Capsules per raceme	5.33	6.83	7.83	7.83	6.00	6.00	8	**9**	7	8
Fruit set %	61.77	63.39	69.03	65.25	64.61	68.22	65.00	57.00	**69.25**	67.89
Seeds per capsule	17.00	18.05	17.67	17.33	18.50	18.502	16	**21**	20	19
Internodal length (cm)	4.17	4.00	4.00	5.33	4.33	3.83	5	**3**	5	5
Yield per plant- fresh (g)	2738.33	2865.00	3256.33	3038.33	2926.67	3051.67	**4380**	3780	2650	2800
Yield per plant- dry (g)	541.38	563.86	671.95	584.40	543.83	577.01	**876.00**	831.60	530.00	736.54
Recovery percentage	19.79	19.65	20.67	19.50	18.96	18.91	19.00	**22.00**	20.10	19.00
%of 7mm and above capsules	65.19	68.12	70.92	63.11	70.15	63.11	62.90	63.92	69.00	**72.68**
Seed wt.- dry (g)	0.20	0.20	0.20	0.21	0.19	0.21	0.23	0.18	0.18	**0.26**
Husk wt.- dry (g)	0.06	0.06	0.06	0.06	0.07	0.06	0.08	0.08	0.08	0.08
Litre weight of fresh capsules (g)	359.5	355.5	362.50	350.00	367.00	383.17	**398**	370	390	370
Number of capsules per litre	2142.33	2177.17	2293.83	2303.83	2124.67	2216.33	**1985**	2189	2389	2389

Fig. 4.3. Parents and F1 in the case of the crosses of cardamom studied

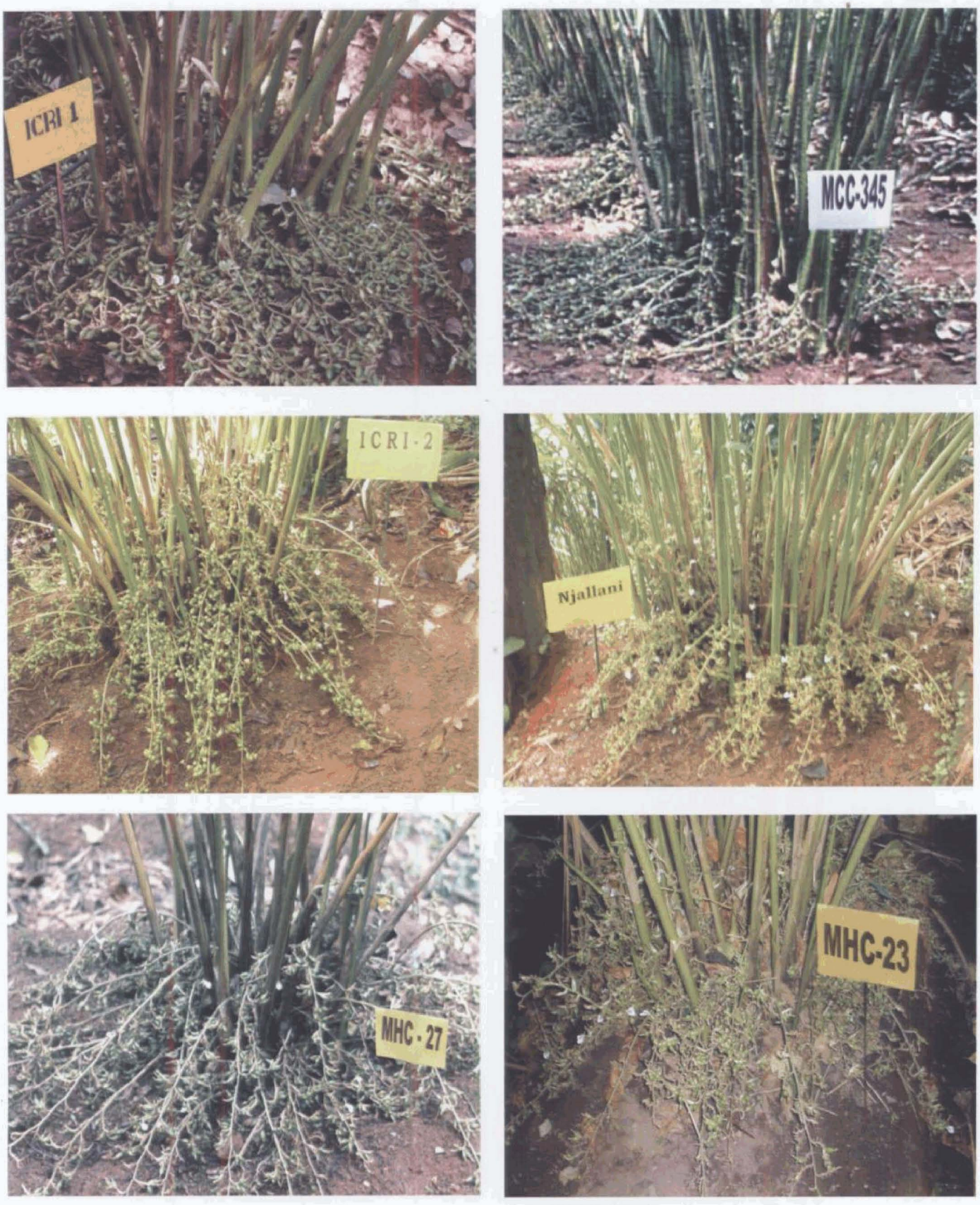


Fig.4.4 Double cross/F2 progeny (best performing) in the case of the crosses of cardamom studied

4.7 Study of adaptability of some elite landraces and hybrids of cardamom to Wayanad agro climatic region of Kerala

Wayanad, one of the richest agro biodiversity centres of Western Ghats is a traditional cardamom growing area. An experiment was conducted to study the adaptability of three pipe line hybrids and six landraces of cardamom to this area in comparison with two controls, ICRI-2 and a local clone Clone-37. The results of the experiment are presented in Table 4.23 and discussed below with the help of performance analysis. The study showed that out of the seven growth characters four differed significantly, out of the seven yield characters three differed significantly and all the six quality characters differed significantly in the case of the eleven genotypes under analysis (Table 4.23).

Performance analysis of the genotypes in relation to the twenty growth/ yield/ quality characters showed that MHC-18 and MCC-73 (Fig. 4.5) were the most suitable for Wayanad region (Tables 4.24, 4.25). The above two genotypes can be subjected for further evaluation trials and recommended to farmers. Even though other genotypes suitable to Kerala can be successfully grown in the Wayanad region also, varieties recommended after specific evaluation trials are scanty. However, Nair *et al.* (1989) had carried out an experiment to screen cardamom varieties suitable to Wayanad. They observed that *Malabar* varieties were more suited to the region when compared to others. It is hoped that the new materials selected could be successfully grown in the region helping to boost the production and productivity of cardamom in the area.

Table 4.23. Characters of the genotypes studied for adaptability analysis in Wayanad

1. Growth characters													
Character	Genotypes												
	MHC-10	MHC-13	MHC-18	MCC-21	MCC-40	MCC-73	MCC-200	MCC-260	MCC-345	ICRI-2	Local	F-value	CD
Tillers/ clump	33.77 ±5.48	27.55 ±1.21	35.55 ±0.58	28.72 ±2.5	31.78 ±2.06	28.89 ±5.02	32.55 ±3.06	24.44 ±4.71	30.27 ±2.28	31.27 ±8.58	33.22 ±1.7	1.84	NS
Tiller height (cm)	379.27 ±23.28	376.00 ±11.72	388.94 ±3.49	392.39 ±1.87	343.77 ±11.78	355.27 ±33.28	347.00 ±18.35	363.44 ±15.79	377.61 ±46.08	350.83 ±14.22	351.72 ±15.41	1.97	NS
Leaves per tiller	18.00 ±2.29	17.38 ±1.27	15.9 ±1.35	15.33 ±1.53	17.38 ±1.13	18.39 ±1.33	19.00 ±2.53	17.66 ±1.21	21.17 ±1.76	19.11 ±3.01	17.17 ±1.04	2.38*	3.04
Leaf length (cm)	63.00 ±1.76	60.83 ±2.19	60.41 ±0.71	58.78 ±2.46	61.84 ±1.66	64.22 ±1.95	59.7 ±1.35	61.04 ±1.91	60.89 ±0.38	57.88 ±2.54	63.08 ±2.52	3.02*	8.65
Leaf breadth (cm)	11.83 ±0.73	11.01 ±0.38	13.06 ±0.42	11.90 ±0.69	10.23 ±0.52	11.02 ±0.78	12.95 ±0.48	11.83 ±0.58	10.63 ±0.06	12.38 ±0.10	12.72 ±0.24	10.63**	0.87
Number of veg. buds	5.33 ±0.58	4.67 ±0.58	4.67 ±1.53	4.00 ±0	3.33 ±1.15	5.67 ±0.58	2.67 ±0.58	4.67 ±1.53	4.33 ±0.58	4.67 ±1.15	3.33 ±1.53	2.36*	1.73
Number of bearing tillers	19.21 ±1.92	18.33 ±1.02	23.88 ±2.60	19.44 ±1.02	21.44 ±1.69	20.05 ±3.29	19.39 ±4.55	16.61 ±3.21	19.12 ±4.04	19.67 ±3.61	20.76 ±2.57	1.20	NS

2. Yield characters													
Character	Genotypes												
	MHC-10	MHC-13	MHC-18	MCC-21	MCC-40	MCC-73	MCC-200	MCC-260	MCC-345	ICRI-2	Local	F-value	CD
Panicles / clump	25.61 ±1.35	26.72 ±0.67	35.50 ±1.88	28.94 ±2.65	28.38 ±1.93	27.77 ±2.67	25.33 ±7.37	22.94 ±5.09	25.55 ±9.24	25.72 ±3.13	28.96 ±2.22	1.71	NS
Panicle length (cm)	61.67 ±4.51	57.33 ±2.08	70.33 ±4.01	61.33 ±4.16	52.00 ±3.00	63.67 ±4.51	56.33 ±1.53	57.67 ±2.52	61.67 ±6.35	61.00 ±5.29	56.67 ±2.08	4.38**	6.75
Racemes/ panicle	15.26 ±3.03	16.09 ±0.23	20.33 ±0.92	18.26 ±1.17	13.50 ±3.49	20.79 ±3.56	18.31 ±3.78	19.80 ±4.57	16.52 ±3.08	15.60 ±0.99	18.47 ±0.70	2.16	NS
Capsules / raceme	9.17 ±1.86	10.07 ±0.77	10.38 ±0.46	10.41 ±0.43	9.14 ±0.26	9.40 ±0.86	9.57 ±0.27	9.42 ±0.50	10.22 ±0.39	9.48 ±0.20	8.59 ±0.79	1.75	NS
Seeds per capsule	18.00 ±2.29	17.39 ±1.27	15.90 ±1.35	15.33 ±1.53	17.39 ±1.13	18.39 ±1.33	19.00 ±2.53	17.67 ±1.21	21.17 ±1.76	19.11 ±3.01	17.17 ±1.04	2.38*	3.04
Inter nodal length (cm)	5.00 ±1.00	4.33 ±0.58	5.33 ±0.58	3.67 ±0.58	5.00 ±00	5.0 ±1.0	5.00 ±0	5.67 ±0.58	5.33 ±0.58	5.0 ±1.0	6 ±0	2.74*	1.01
Yield / plot- (12 plants) dry (kg)	9.79 ±4.16	7.15 ±1.22	11.5 ±0.92	9.58 ±1.45	6.10 ±1.31	9.67 ±1.33	7.28 ±0.58	7.07 ±1.85	7.45 ±3.37	6.48 ±0.42	6.67 ±0.98	2.29	NS

3. Quality characters													
Character	Genotypes												
	MHC-10	MHC-13	MHC-18	MCC-21	MCC-40	MCC-73	MCC-200	MCC-260	MCC-345	ICRI-2	Local	F-value	CD
Recovery %	19.96 ±0.07	20.11 ±0.14	22.24 ±1.26	19.65 ±0.59	18.79 ±0.92	20.41 ±0.52	20.00 ±0.82	20.39 ±0.57	19.61 ±0.53	19.59 ±0.55	19.99 ±1.45	6.00*	1.35
% of 7 mm and above capsules	66.89 ±1.01	55.46 ±5.5	69.87 ±5.5	61.74 ±3.03	58.12 ±1.50	67.33 ±3.21	59.75 ±1.32	67.89 ±3.02	61.99 ±6.01	64.00 ±3.61	67.41 ±2.51	4.72**	6.29
100 capsule wt.—dry (g)	20.21 ±1.73	20.24 ±1.75	20.25 ±2.59	21.06 ±2.77	21.30 ±1.63	23.23 ±1.36	18.58 ±0.52	26.84 ±1.11	23.47 ±0.19	23.17 ±0.36	24.19 ±1.09	6.64**	2.70
Volatile oil content (%)	8.07 ±0.14	7.85 ±0.24	8.84 ±0.24	6.20 ±0.35	7.85 ±0.74	8.65 ±0.56	7.04 ±0.73	6.56 ±0.44	7.93 ±2.02	8.95 ±0.04	6.25 ±0.46	5.38**	1.27
Oleoresin content (%)	6.98 ±0	5.93 ±0.04	7.99 ±0.1	7.14 ±0.50	6.33 ±0.42	6.67 ±0.45	7.07 ±0.57	6.69 ±0	6.81 ±0.63	7.63 ±0.09	5.75 ±0.12	17.59**	0.45
Moisture content (%)	10.53 ±0.58	10.00 ±0.44	10.50 ±0.92	12.43 ±0.11	11.03 ±0.75	10.63 ±0.23	12.37 ±0.41	11.53 ±0.05	10.60 ±0.42	10.83 ±0.11	9.50 ±0.4	11.43**	0.78

**: significant at 1% level; *: significant at 5% level.

Table 4.24. Characters of the genotypes studied for adaptability analysis in Wayanad– value points attributed to the genotypes in relation to characters.

1. Growth characters											
Character	Genotypes										
	MHC-10	MHC-13	MHC-18	MCC-21	MCC-40	MCC-73	MCC-200	MCC-260	MCC-345	ICRI-2	Local
Tillers/ clump	10	1	11	3	7	4	8	2	7	6	9
Tiller height	9	7	10	11	1	5	2	6	8	3	4
Leaves per tiller	7	5	1	2	3	8	9	6	11	10	4
Leaf length	9	5	4	2	8	11	3	7	6	1	10
Leaf breadth	6	4	11	7	3	5	10	6	2	8	9
Number of veg. buds	10	9	9	7	6	11	5	9	8	9	6
Number of bearing tillers	9	2	11	6	10	8	5	1	3	7	9

2. Yield characters											
Panicles / clump	5	5	11	9	8	7	3	2	4	6	10
Panicle length	9	5	11	8	3	10	4	6	9	7	6
Racemes/ panicle	2	4	10	6	1	11	7	9	5	3	8
Capsules / raceme	3	8	10	11	2	4	6	5	9	7	1
Seeds per capsule	7	6	7	3	5	8	9	6	11	10	4
Internodal length	8	7	9	1	8	8	8	10	9	8	11
Yield / Plot	10	5	11	8	1	9	6	4	7	2	3
3. Quality characters											
Recovery %	5	8	11	4	1	10	7	9	3	2	6
% of 7 mm and above capsules	6	1	11	9	2	7	3	10	4	5	8
100 capsule wt -dry	2	4	3	5	6	8	1	11	9	7	10
Volatile oil content	8	6	10	4	6	9	5	3	7	11	2
Oleoresin content	7	2	1	9	3	4	8	6	5	10	1
Moisture content	4	2	3	11	8	6	10	9	5	7	1

Table 4.25. Characters of the genotypes studied for adaptability analyisis in Wayanad– performance indices attributed to the genotypes in relation to characters.

1. Growth characters											
Character	Genotypes										
	MHC-10	MHC-13	MHC-18	MCC-21	MCC-40	MCC-73	MCC-200	MCC-260	MCC-345	ICRI-2	Local
Tillers/ clump	0.82	0.09	1.00	0.27	0.64	0.36	0.73	0.18	0.45	0.55	0.82
Tiller height	0.82	0.64	0.91	1.00	0.09	0.45	0.18	0.55	0.73	0.27	0.36
Leaves per tiller	0.69	0.45	0.09	0.18	0.27	0.73	0.82	0.55	1.00	0.91	0.36
Leaf length	0.82	0.45	0.36	0.18	0.73	1.00	0.27	0.64	0.55	0.09	0.91
Leaf breadth	0.55	0.36	1.00	0.69	0.27	0.45	0.91	0.55	0.18	0.73	0.82
Number of veg. buds	0.91	0.82	0.82	0.69	0.55	1.00	0.45	0.82	0.73	0.82	0.55
Number of bearing tillers	0.82	0.18	1.00	0.55	0.91	0.73	0.45	0.09	0.27	0.64	0.82

2. Yield characters											
Character	Landraces / Control										
	MHC-10	MHC-13	MHC-18	MCC-21	MCC-40	MCC-73	MCC-200	MCC-260	MCC-345	ICRI-2	Local
Panicles / clump	0.45	0.45	1.00	0.82	0.73	0.64	0.27	0.18	0.36	0.55	0.91
Panicle length (cm)	0.82	0.45	1.00	0.73	0.27	0.91	0.36	0.55	0.82	0.69	0.55
Racemes/ panicle	0.18	0.36	0.91	0.55	0.09	1.00	0.64	0.82	0.45	0.27	0.73
Capsules/ raceme	0.27	0.73	0.91	1.00	0.18	0.36	0.55	0.45	0.82	0.69	0.09
Seeds per capsule	0.64	0.55	0.18	0.27	0.45	0.73	0.82	0.55	1.00	0.91	0.36
Inter nodal length	0.73	0.69	0.82	0.9	0.73	0.73	0.73	0.91	0.82	0.73	1.00
Yield / plot-dry	0.91	0.45	1.00	0.73	0.09	082	0.55	0.36	0.64	0.18	0.27

3. Quality characters											
Character	Landraces / Control										
	MHC-10	MHC-13	MHC-18	MCC-21	MCC-40	MCC-73	MCC-200	MCC-260	MCC-345	ICRI-2	Local
Recovery %	0.45	0.73	1.00	0.36	0.09	0.91	0.64	0.82	0.27	0.18	0.55
% of 7 mm and above capsules	0.55	0.09	1.00	0.82	0.18	0.64	0.27	0.91	0.36	0.45	0.73
100 capsule wt.- dry	0.28	0.36	0.27	0.45	0.55	0.73	0.09	1.00	0.82	0.61	0.91
Volatile oil content (%)	0.73	0.55	0.91	0.36	0.55	0.82	0.45	0.27	0.64	1.00	0.18
Oleoresin content (%)	0.64	0.18	1.00	0.82	0.27	0.36	0.73	0.55	0.45	0.91	0.09
Moisture content (%)	0.36	0.18	0.27	1.00	0.73	0.55	0.91	0.82	0.45	0.64	0.09
Total	12.44	8.76	15.45	12.37	8.37	13.92	10.82	11.57	11.81	11.82	11.10
Rank	3	10	1	4	11	2	9	7	6	5	8

Fig. 4.5. Genotypes of cardamom found suitable for Wayanad region

Chapter V

SUMMARY AND CONCLUSION

The present study on variability, performance and adaptability of some elite landraces and hybrids of small cardamom has been carried out to analyze the extent of genetic variability in the case of the landraces under study, to assess their comparative performance, to analyze certain hybrid populations based on their performance and also to study the adaptability of some pipe line hybrids and clones to the agro climatic conditions of Wayanad. The experiments were conducted in the experimental farm of Indian Cardamom Research Institute, Myladumpara, Kerala, India and in farmer's field at Kalpetta, Wayanad, Kerala, India from 2002 to 2006.

Even though about 12 improved varieties have been released in India, many of the farmers of the traditional cardamom tracts use farmer selected landraces as planting material and hence the importance of such landraces is not questionable. A study has been carried out presently to assess the extent of variability in the case of ten elite landraces of cardamom collected from Idukki district of Kerala namely Panikulangara-1, Panikulangara-2, Njallani, Vali green gold, Palakkudi, PNS Vaigai, Wonder cardamom, Ela Rani-1, Ela Rani-2 and Ela Rani-3 using ICRI-2, an improved variety released by Indian Cardamom Research Institute, Myladumpara, Idukki, Kerala, India as control. Observations on seven growth characters, nine yield characters, sixteen quality characters and thirty one biochemical characters were made for the purpose. Four growth characters, six yield characters, fourteen quality characters and twenty one biochemical characters showed statistically significant variation. This showed the occurrence of significant genotypic differences between the landraces.

Statistical analysis of the growth, yield and quality characters showed that the highest GCV and PCV were expressed by tillers per clump, highest heritability by leaf length and highest genetic advance by tillers per clump. This shows that tillers per clump is the most important growth character with highest GCV, PCV and

genetic advance and significantly high heritability (broad sense). Among the yield characters the highest GCV and genetic advance were shown by inter nodal length, highest PCV by panicles per clump and highest heritability by racemes per panicle. Among the quality characters GCV and PCV were the highest in the case of dry seed weight, highest heritability in the case of percentage of 7 mm and above sized capsules and highest genetic advance in the case of percentage of 7 mm and above capsules, seed weight and fresh husk weight. Among the biochemical characters acid insoluble ash content showed the highest GCV and heritability and the highest PCV was shown by chlorophyll b content in leaf. In the case of all the characters that were statistically significant, PCV was found to be higher than GCV indicating polygenic control of characters and additive gene action.

Most of the agronomic characters of the crop plants are polygenic and cardamom is no exemption. Polygenic characters show different levels of heritability based on their response to environmental factors. Among the growth characters heritability (broad sense) was found to be the highest in the case of leaf length followed by tillers per clump. Among the yield characters, racemes per panicle showed the highest heritability. In the case of quality characters the highest heritability was shown by percentage of 7 mm and above sized capsules which is a very desirable phenomenon.

Genetic advance of characters in percentage of mean is a very effective indicator of the characters that could be utilized in selection programmes. Statistically significant characters analyzed presently showed genetic advance ranging from 0.006 to 0.58. Total chlorophyll content- fresh capsule showed the maximum genetic advance and this is a very desirable condition since green colour of capsules is determined by its chlorophyll content and dry green capsules are preferred highly both in internal and international markets. Total chlorophyll content also showed high genetic advance. Among the growth characters, total tillers per clump showed the highest genetic advance and among the yield characters internodal length and racemes per panicle showed the highest genetic advance. Among the quality characters percentage of 7 mm and above sized capsules, dry

seed weight and fresh husk weight showed the highest genetic advance. Characters with high genetic advance can be utilized in selection programmes.

Characters of crop plants, especially quantitative characters show different levels of interrelationship. Correlation analysis is a tool to study interrelationship of characters so as to identify variables that show maximum relationship with others.

Sixty two characters of the eleven genotypes of cardamom studied presently were subjected to correlation analysis. The study revealed that tillers per clump showed significant positive correlation with number of bearing tillers and fruit set percentage. Tiller height was positively correlated with leaves per tiller. Panicle length showed significant positive correlation with racemes per panicle. Fresh and dry yield per plant showed significant positive correlation with each other. Recovery percentage and percentage of 7 mm and above sized capsules showed significant positive correlation. The biochemical characters of the genotypes studied showed significant positive correlations at different levels. Characters that show significant positive correlation can be considered in selection programmes.

Agronomic characters of crop plants that are polygenic show different levels of association. Grouping of characters in to clusters is an effective measure to reduce the number of variables under consideration. Factor analysis has been carried out presently in the case of growth, yield and quality characters of cardamom based on the study of ten elite landraces and a control conducted presently. The seven growth characters of cardamom studied presently could be grouped in to two based on factor loading with number of bearing tillers showing maximum factor loading in the first group and leaves per tiller showing maximum factor loading in the second group. Out of the two factors identified among the growth characters the first factor with four characters contributed 33.79% of variance exhibited by the growth characters studied and the second factor consisting of three characters contributed 31.08% of variance. Characters with the highest factor loadings can be considered as lead characters and the present analysis showed that number of bearing tillers and leaves per tiller are the most important characters of cardamom

based on which selection could be carried out. The yield characters also could be grouped into two factors and the two factors together contributed 58.57% of cumulative variance contributed by the yield characters. Yield per plant and inter nodal length of panicles were found to be the lead characters among the yield characters. Coming to quality characters nine out of eleven characters studied could be grouped into three factor groups with moisture content, volatile oil and 100 capsule weight- dry as the lead characters.

Genetic divergence analysis in the case of genotypically different accessions of crop plants provides an idea of the genetic divergence between them. Study of genetic divergence of the present experimental population consisting of ten elite landraces and one control carried out using principal component analysis showed that the genotypes could be grouped into two clusters at a genetic distance of 0.99, the first cluster consisting of 8 genotypes and the second cluster consisting of three genotypes. The elite landraces Panikulangara-1, Panikulangara-2, Njallani, Ela Rani-2, Vali green gold, Ela Rani-3, Ela Rani-1 and ICRI-2 formed one cluster and Palakkudi, PNS Vaigai and Wonder cardamom formed the second cluster. However, ICRI-2 formed a different cluster at a linkage distance of 0.985. Vali green gold and Ela Rani -3 revealed to be the closest genotypes.

A comparative analysis of the overall performance of ten landraces studied above has shown that Ela Rani-2, Ela Rani-3, Palakkudi and Vali green gold performed significantly superior to ICRI-2, the control. Ela Rani-2, Ela Rani-3 and Palakkudi produced higher number of tillers per clump when compared to ICRI-2. Tiller height, leaves per tiller and number of vegetative buds were higher in all the above four landraces when compared to the control. Number of bearing tillers was higher than the control in Ela Rani-2, Ela Rani-3 and Palakkudi. Panicles per clump, panicle length and fruit set percentage were the highest in Ela Rani-2. Dry yield per plant amounted to 840 g in Ela Rani-2 which is considerably high when compared to ICRI-2. Recovery percentage and percentage of 7 mm and above sized capsules were higher in all the four selected landraces mentioned above. Capsule size also was higher in all the above four landraces when compared to ICRI-2. Out

of the 32 characters compared 23 characters showed statistically significant variation among the genotypes and even in the case of other characters there was considerable variation among them. The study has indicated the potential of selecting Ela Rani-2, Ela Rani-3, Palakkudi and Vali green gold for further trials and evaluation protocols.

Performance evaluation of certain hybrids of cardamom in relation to their parents has shown the production of F1 and subsequent progenies with positive heterosis and heterobeltiosis enabling the selection of such superior genotypes and their further evaluation so as to develop improved hybrid strains of cardamom. Two double cross lines and two F2 lines were subjected to evaluation and selection of best performing plants suitable for further clonal evaluation and selection. The best performing progenies identified based on total performance index calculated for the purpose showed that they excelled the parents and F1 in most of the characters. Selection of the best performing plants and their clonal multiplication, evaluation and further statutory proceedings may result in the development of promising cardamom hybrids.

An experiment has been carried out to screen the adaptability of some elite land races and hybrids of cardamom to Wayanad agoclimatic region of Kerala. Three pipeline hybrids and six landraces have been used for the purpose along with two controls. The study showed that the hybrid MHC-18 and selection MCC-73 performed best in Wayanad when analyzed in relation to 20 growth, yield and quality characters. It is hoped that the new materials selected may prove to be superior in performance in further trials so that they can be recommended to farmers.

The present experiments have generated considerable quantum of information on the variability among 10 elite landraces of cardamom and the heritability, genetic advance, genetic divergence and association of characters in them. It has helped to identify the lead characters to be considered while practicing selection in cardamom. Four elite landraces found to be superior to ICRI-2 under

preliminary evaluation have been reported. Four hybrid plants showing heterobeltiosis in the case of many of the agronomic characters have been identified. One pipeline hybrid and one selection showing maximum adaptability to Wayanad region have been selected.

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