REVIEW OF LITERATURE

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 into 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. Inventorizing, 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 CO₂ extraction (SC-CO₂). 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°-30° 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 F₁ 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 × long inflorescence, bold capsules × early bearing, long inflorescence × early bearing and early bearing × 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.