CHAPTER I

INTRODUCTION

The combination of plant with attractive Jasmine like fragrant flowers and seeds so called beans produced out of crimson red ripe cherry is generally known as “Coffee”. The beverage prepared out of the roasted beans possessing desirable aroma, acidity, flavor and caffeine satisfies the taste of the consumers so as to work tirelessly and maintain good health for prolonged life. Coffee being a vital non-alcoholic beverage, it is commercially cultivated in different parts of the world situated along the tropical regions (Clifford and Willson, 1987). It supports the growers financially as well as improves the economic condition of several coffee growing countries by earning foreign exchange. The caffeine, one of the well known constituents of coffee beans has been found to possess medicinal values in preventing several diseases and disorders like; skin cancer caused due to UV radiation (Zaidela and Latarjet 1973) besides the reduction in gama radiation effect on human blood lymphocytes by pre-treatment of caffeine (Shukla, et al., 2010). The effect of caffeine has also been studied on X-ray induced chromosomal aberrations and DNA synthesis of radiated and unradiated human blood cells (Natarajan et al., 1980 and Painter, 1980). Devasagayam et al., (1996) used caffeine as an antioxidant to inhibit the lipid preoxidation caused by reactive oxygen species.

It contains the unique features and properties that attracted the peer group of people who understood the value of coffee in reality and its future prospects by its compact and fruit-bearing pendulous branches covered with lush green-glossy foliage, sweet scented pentamerous flowers and shining crimson red ripe cherries. However, this is the “Nature” which provides several botanical benefits out of little coffee seeds to the mankind (Butenko, 2007) and decides the commercial cultivation of coffee based on its preferential order of geographical and climatic requirements. Perhaps, for this reason,
coffee cultivation was restricted to the fewer countries adequately, suitable for its plant vigor and yield.

Coffee belongs to the family – Rubiaceae, genus- *Coffea* that possesses more than 70 species out of which commercially cultivated species are *Coffea arabica* var. arabica and *Coffea canephora* var. robusta. *Coffea liberica* is grown on a small scale (Haarer, 1956). Beside this, there are some *Coffea* species of Indian origin namely; *C. travancorensis, C. bengalensis, C. khasiana, C. wightiana* occurring in the forests of Kerala, Tamil Nadu, Meghalaya and Assam. *C. arabica* is a tetraploid and *C. canephora* diploid species. Arabica carries 2n=44 and Robusta 2n=22 chromosomes (Wintgens, 2004).

Both the species of *Coffea* namely; *Coffea arabica* var. arabica and *Coffea canephora* var. robusta widely grown in Southern states of India as well as other coffee growing countries. Among the countries growing coffee, Brazil is on the top of the list with annual production of 48.0 million bags (60 kg bag$^{-1}$) of cured coffee (Anonymous, 2011). Vietnam with 18.5 million bags and Columbia with 9.2 million bags are at second and third position respectively. India is sixth largest coffee producing country with an annual production of 4.7 million bags (Anonymous, 2011). This comprises 1.325 million bags of Arabica and 3.408 million bags of Robusta coffee. India shares 3.9 percent of 133.065 million bags of coffee globally produced by several countries.

In India coffee occupies the total area of 399,801 ha out of which arabica shares 193,155 ha and robusta 206,646 ha of the total area (Anonymous, 2011). There are three major coffee growing states of South India namely; Karnataka, Kerala and Tamil Nadu and contribute around 56.9 percent, 21.2 percent and 7.8 percent of coffee growing areas respectively. The remaining 14.1 percent of the total area comes under Andhra Pradesh (Non-traditional zone) and North Eastern Region (Anonymous, 2011). As per the statistics
2010-11, the total coffee production in India is 299,000 M.T. comprising 95,000 M.T. (32 percent) of arabica and 204,000 (68 percent) robusta coffee. In India, coffee is produced by 257,672 numbers of holdings grouped as small and large holdings (Anonymous, 2011). Small holdings possess 74.6 percent and large holdings 25.4 percent of total area and contribute 70 percent and 30 percent of total production respectively (Anonymous, 2008). The total coffee productivity in India is 815 kg ha$^{-1}$ where 592 kg ha$^{-1}$ for arabica and 997 kg ha$^{-1}$ robusta. Of the total production, 70 percent is exported to European countries and rest of the quantity is consumed internally. Coffee export fetches around $560 million annually. Coffee plantations in India provide employment opportunities to the different cadre of people interested to work in coffee growing areas. The average number of 5.9 lakhs persons required per day in coffee plantations in the country (Anonymous, 2011). Hence, coffee plantations in India have great contribution in solving the unemployment problems in the country.

It is believed that most of the wild forms of arabica coffee are native of Ethiopia in Africa. Arabica was discovered during A.D. 850 and came under cultivation by the Arabians. It reached Mecca and there from it was brought to the other Muslim countries by the Islamic pilgrims. In India, coffee was introduced during 1600 A.D. by a Muslim pilgrim, Baba Budan who brought 7 seeds of arabica coffee from Yemen and planted at Dattatreya Peeta in the hills of Chikmagalur, Karnataka state. Gradually it reached to the backyards and gardens in Attigundi area. Latter, it spread in Coorg and developed into coffee plantations. Commercial plantations commenced after the year 1820s in South India by the British Enterprise (Anonymous, 2003).

During 1856, there were 7 nos. of British planters besides the Indian plantations and in 1869 the numbers increased to 662 covering an area of 8094 ha of the total coffee area of 58670 ha during that period. Considerably, higher yield (1525kg ha$^{-1}$) and good
quality encouraged the Indian coffee plantations to follow systematic and large scale
cultivation. After 1869, outbreak of Stem borer, Leaf rust and Green bug led to
introduction of robusta from Indo-China at the end of 19th Century. Due to the ravage
caused by the leaf rust (*Hemileia vastatrix* B. a substantial crop loss was realized by the
planters. That was a beginning of arabica improvement when, some of the enterprising
planters made frantic efforts to develop the new cultivars by thorough selection and
breeding. As a result some of the hybrids such as, ‘Hamilton’s’, ‘Jacksions’, ‘Netrakonda’,
and selections like ‘Coorg’, ‘Chicks’ and ‘Kents’ came into existence to rescue the interest
of the growers. Evenly, at later stage, ‘Kents’ was found to be of promising characteristics
like high yielding and superior beverage quality and exploited in breeding after the Central
Coffee Research Institute commenced its organized research on coffee improvement
(Srinivasan *et al*, 2000; Srinivasan, 2001).

In 1925, Mysore Coffee Experiment Station was established at Balehonur,
Chikmagalur District of Karnataka. After formation of the Coffee Board in 1946, Central
Coffee Research Institute (CCRI) was established in place of Mysore Coffee Experiment
Station. To tackle the regional problems related to coffee, five Regional Coffee Research
Stations located in Karnataka, Kerala, Tamil Nadu, Andhra Pradesh and Assam were set
up. After setup of Central Coffee Research Institute, the Institute has rendered yeoman
services to the planting community by releasing several station-bred selections of the
planter’s choices. CCRI has developed 13 arabica and 3 robusta varieties through rigorous
selection and hybridization techniques with an objective to supply the improved planting
material having resistance to pest and diseases, high productivity, better quality and wide
adaptability to the planting community.

Out of the two commercially cultivated species, *C. arabica* has been found more
attracted to the major insect-pests and diseases as compared to *C. canephora* and hence,
most of the genetic enhancement protocols have been evolved for arabica improvement. Since, robusta possesses resistant/tolerant genes to most of the coffee leaf rust races and white stem borer (*Xylotrechus quadripes*, Cher.) more emphasis has been given to enlarge the genetic base of arabica by incorporating robusta genes through inter-specific hybridization and molecular techniques. Due to its perennial nature, evolving a new variety of coffee is a herculean task to the researchers which consumes at least a duration of 20 years through conventional breeding. In recent days, several biotechnological tools have been developed and being applied in commercial crops for genetic transformation (Lashiremes *et al*, 2000).

The breeding programmes pertaining to arabica and robusta have the similar objectives of evolving new varieties with high yielding potential, plant vigour and superior quality. More emphasis have been given to arabica to breed the cultivars with durable resistance to coffee leaf rust (CLR) and coffee berry disease (CBD) coupled with higher productivity. Breeding in coffee primarily depends on the fertilizing behavior of the varieties where tetraploid and diploid species differ in their genetic constitution. Arabica produces the crop after the completion of self-fertility process while robusta yields as a result of cross-fertility in the plants.

Several studies have been conducted to ascertain the latent essentials of coffee diversity and phylogenetic relationship among different groups of genus *Coffea* applying various methods related to molecular marker techniques. The studies on evaluation of genetic diversity between cultivated and wild accessions of *C. arabica* through RAPD analysis indicated a large genetic miscellany among arabica germplasm collections. Important differences were observed between *C. arabica* var. ‘bourbon’ and *C.arabica* var. ‘typica’ due to their diverse source of collection. The Kenyan cultivar ‘K7’ was closely related to the other Kenyan accession introduced from northern part of Kenya
A clear cut difference was noticed between Ethiopian germplasm and cultivated varieties spread worldwide from Yemen and the accession from North Kenya. Findings revealed that the arabica plants that were taken to Yemen by the Arabs (Smith, 1985) were originated in Ethiopia coffee growing regions (Lashermes et al, 1995).

The arabica selections with self-pollinating behavior are the true breeding lines when multiplied as single plant progeny in the normal course but in case of inter-specific hybrids follow some degrees of deviation due to introgression of diploid genetic traits in the arabica cultivars. Evenly, 7-9 percent cross-pollination have been reported in arabica varieties and robusta being a cross-pollinated variety, self fertility to an extent of 28 percent have been recorded (Haarer, 1956). Improvement in self- fertile species like arabica is generally undertaken by way of pure line selection using seedling progeny, pedigree selection of the hybridized progenies through seeds, intra-specific F₁ hybrids as well as by inter-specific hybridization followed by back crossings. In diploid species like C. canephora var. robusta, mass selection, family and clonal selection, reciprocal recurrent selection and inter-specific hybridization between arabica and robusta (for robusta quality improvement) are generally advocated for robusta coffee genetic enhancement (Van der Vossen, 2000). Varietal upgradation in coffee through clonal propagation have tremendous scope but its application on commercial scale seemed to be inadequate and confined to robusta only in arabica, it is used only for maintenance of germplasm materials. To some extent heterosis has also been utilized in coffee breeding curriculum by crossing two parents of genetically diverse origin in Cote de Ivoire for production of genotypes with higher yield, superior quality and some related traits (Leroy et al, 1997).

Breeding for resistance towards CLR and CBD is into practice for long time in the countries growing arabica coffee. Several genotypes of variety Catimor were developed by crossing Caturra (a mutant form of Bourbon coffee) with Hibrido-de Timor (HDT) a
natural hybrid of arabica and robusta coffee which had exhibited complete resistance for CLR and CBD in many countries. The Catimor lines were evolved following the breeding methodology generally applied to the self-pollinated crops (Carvalho, 1988; Bettencourt and Rodrigues, 1988). Similarly, in Kenya also, a new resistant cultivar to CBD namely, Ruiru II was developed and was found to be regulated by a few major genes. Obtaining resistance in arabica by incorporating robusta genes have been successfully made in different countries like, Brazil which led to the release of a cultivar ‘Icatu’ through hybridizing arabica with robusta coffee. Cultivar ‘Icatu’ possessed resistance to CLR and variety ‘Arabusta’ was developed by crossing an arabica and robusta coffee with improved liquor quality in Ivory Coast. Apart from these, India has developed Sln.6 (S.2828) arabica variety by crossing robusta with arabica (cv. Kents’) and achieved higher resistance to CLR and higher average yield combined with FAQ liquor quality. Improvement in robusta selection in relation to high productivity and stability have also been made by breeding a new variety called C x R (Coffea congensis x C. canephora var. robusta) through introduction of high quality characters from C. congensis into robusta coffee (Srinivasan, 2000).

There are several arabica genotypes with high yield potential, resistant to the major diseases like CLR and CBD superseding the old cultivars on a commercial scale in many of the coffee growing countries. Cultivars like Catimor, Sarchimor in Colombia, Brazil, Central American countries and India, Icatu in Brazil, Java in Cameroon, Ruiru II in Kenya and Ababuna in Ethiopia were found to possess resistance against CLR and CBD. Among the robusta cultivars such as BP and SA clones in Indonesia, the BR clonal series in India, the IF clones in the Ivory Coast and variety Apoata in Brazil are some of the commercially cultivated ones.
Further, the breeding quality has been advanced by the recent powerful and efficient plant biotechnology tools and is capable to meet the unattainable objectives of the breeders. The germplasm characterization and management, detection of genetically divergent plant materials for prediction of hybrid vigour and gene introgression from allied species are some of the molecular breeding protocols being utilized in coffee improvement programs. Beside this, molecular marker assisted selection has been found to be very useful in coffee breeding (Lashermes et al., 1997 and 2000). Gene isolation and transfer are comparatively easier by molecular techniques but it has certain limitations in genetic transformation of those characters that are controlled by major genes. Plant regeneration through *in vitro* micro propagation techniques and somatic embryogenesis are well established in several *Coffeea* species (Etienne *et al*., 1997a, b; Berthouly and Michaux-Ferriere, 1996) besides, the transgenic plants with insect resistance and beans without caffeine have already set an example in the arena of coffee research (Leroy *et al*., 1999; Moysiadi *et al*., 1999).

It is well understood that application of classical and molecular methods could meet the present challenges arose in coffee breeding by reducing the production cost, evolving the cultivars of superior bean and cup quality and encouraging biologically produced coffee. For further advancement in coffee varietal improvement, the available genetic resources, breeding and selection based on plant vigour and yield, quality, resistance to disease and insect-pests, drought tolerance and propagation techniques have to be strictly adopted (Van der Vossen, 1985)

The present study is an effort to undertake work focused on the areas of research highly demanded and identified by the coffee breeding community. The study was initiated at Coffee Research Sub Station, Chettalli, Kodagu District, Karnataka in a view to carryout genetic analysis of 15 lines of F₁ hybrids developed through hybridization
between promising genotypes of arabica of different genetic back ground. Among the 15 F₁ progenies, one inter-specific hybrid line was also included. The genetic analysis was done using various statistical tools designed for analysis of quantitative characters and molecular markers in order to meet the following objectives.

**OBJECTIVES:**

1. To evaluate the F₁ hybrids for growth, yield and quality components
2. To study the variability and estimate the genetic parameters in F₁ hybrids
3. To identify the parental traits and quantify their degree of transmission to the F₁ hybrids
4. To carry out molecular characterization of F₁ and F₂ population of tetraploid arabica cv. ‘Cauvery’ and diploid cv. ‘CxR’ cross.
5. To assess the resistance against coffee leaf rust disease in F₁ progeny