Chapter V
SUMMARY AND CONCLUSION

*Coffea* is economically the most important genus of the family Rubiaceae, producing the coffee of commerce. Coffee of commerce is obtained mainly from *Coffea arabica* and *Coffea canephora* var. robusta. Coffee can be cultivated only in the climatic conditions found in the tropical, subtropical and equatorial regions. *Coffea arabica*, popularly known as arabica coffee is a high land species and is an allotetraploid inbreeder. *Coffea canephora* var. robusta, popularly known as robusta coffee is a diploid outbreeder. Arabica coffee is preferred over robusta for its superior quality. However, robusta coffee possesses several useful characters like high tolerance to pathogens like leaf rust pathogen, white stem borer and nematodes and it gives consistent yield. But, inability to endure long drought, late cropping and later stabilization of yield are some of the negative aspects of robusta coffee.

Arabica and robusta coffee breeding programmes have the main objectives of developing new cultivars with the potential of yielding optimum economic returns to coffee growers. In India, selections were evolved through pure line selection, mass selection, pedigree selection and back cross breeding. The selections have helped to preserve and perpetuate genetic variability in coffee. The major selection criteria have been yield, resistance to leaf rust, low level of fruit and bean abnormalities, dwarf habit and good cup quality.

Genetic variability in the form of germplasm reservoir is the basic necessity of any plant breeding programme and study of genetic diversity in a species is important for preserving and utilizing the same in breeding. The wide natural
variability of robusta coffee, apparent in many characteristics, constitutes a sound base for breeding.

The present study on variability, divergence, hybridization and adaptability of robusta coffee has been carried out to analyze the extent of genetic variability in one of the major gene pools of robusta coffee of India, to study the correlation between different characters, character association and genetic divergence and genetic control of characters in robusta coffee, to select superior genotypes from the germplasm, to study the interspecific hybrids produced from crosses between Coffea racemosa and Coffea canephora var. robusta and to study the adaptability of robusta coffee to two conventional coffee growing regions of South India.

The field experiments were conducted during 2002-2005 in the germplasm collection of Regional Coffee Research Station, Chundale, Wayanad, Kerala, India, which is a regional station of Central Coffee Research Institute, Chickmagalur, Karnataka, India. The experiments carried out in farmers’ fields were conducted in Wayanad District of Kerala State and Coorg District of Karnataka State of India.

Seventy three accessions of robusta coffee have been used presently for the study of variability, correlation of characters, character association, genetic divergence, genetic control of characters and overall performance keeping S.274, a released variety of robusta coffee as control. S.274 has also been used to study the adaptability of robusta coffee to Wayanad and Coorg conditions.

A study of the performance of hybrid coffee plants derived from a cross between Coffea racemosa (female parent) and Coffea canephora var. robusta (male parent) has been carried out presently to analyze the behaviour of the hybrid plants in terms of growth, yield and quality.
Among the growth characters of robusta coffee leaf parameters were found to be the most stable and girth of primary branch, the most variable. This situation indicates the need for selecting superior genotypes of robusta coffee, based on girth of primary branches, giving due importance to other parameters. All the seventeen yield characters of robusta coffee studied presently showed statistically significant variation between the accessions. Study of coefficient of variation of yield characters revealed that the highest coefficient of variation was shown by number of fruits per node followed by fruit volume. Fruit length, fruit breadth and fruit thickness showed minimum variation. Among the bean characters the highest variability was shown by bean volume followed by bean density and the lowest variability by bean length. Among the different parameters of out turn, out turn -ripe to clean coffee showed the highest variability. Study of quantitative physical quality parameters showed that characters like percentage of A grade beans and percentage of pea berries showed statistically significant variation among the accessions. The above analysis of the variability of growth, yield and quality characters in 74 accessions of robusta coffee has revealed the occurrence of differential levels of variability among them, indicating the necessity of breeding programmes utilizing the germplasm resources analyzed presently.

Statistical parameters of growth, yield and quality characters of the accessions of robusta coffee studied presently were analyzed so as to partition the total quantum of variation available. In the case of growth characters the highest phenotypic coefficient of variation was shown by number of primary branches, number of secondaries per primary and girth of
primary branches and lowest phenotypic coefficient of variation by leaf breadth, leaf length, stem girth and leaf area. The highest genotypic coefficient of variation was shown by girth of primary branches followed by number of secondaries per primary. Lowest genotypic coefficient of variation was shown by leaf breadth, leaf length and leaf area. In all the cases phenotypic coefficient of variation was higher than genotypic coefficient of variation indicating polygenic control of the characters, additive gene action and different levels of influence of environment on the characters. Among the yield characters the highest phenotypic coefficient of variation and genotypic coefficient of variation were shown by yield per plant. Fruits per node showed moderately high phenotypic coefficient of variation and genotypic coefficient of variation. Among the yield characters the lowest phenotypic coefficient of variation and genotypic coefficient of variation were shown by bean breadth. Here also the characters showed higher phenotypic coefficient of variation when compared to genotypic coefficient of variation indicating polygenic control, additive gene action and differential levels of influence of environment on the characters. All the quantitative physical quality characters showed considerably high phenotypic coefficient of variation and genotypic coefficient of variation indicating the presence of high levels of environmental and genotypic variation in the case of the characters.

Heritability is the ability of a character to get inherited to the progeny. Oligogenic characters show very high heritability whereas polygenic characters exhibit different levels of heritability based on the number of genes involved and the influence of environment on their expression. The
study has shown that among the growth characters internodal length is the most heritable character and bean density and yield per plant are the most heritable characters among yield characters in robusta coffee. Percentage of A grade beans showed the highest heritability among bean grades and it is a very desirable phenomenon. High heritability of characters indicates the limited influence of environment on these characters. Characters like internodal length, fruit length, fruit breadth, fruit thickness, fruit volume, fruit weight, bean weight, bean density, yield per plant and percentage of A grade beans have been found to be highly heritable. This is a desirable phenomenon and breeding programs to improve genotypes based on these characters will prove to be highly promising.

Percentage of genetic advance is a measure indicating the quantum of improvement that is possible under selection. The growth, yield and quality characters of robusta coffee analyzed presently showed different levels of genetic advance varying from 4.03 to 101.83. Leaf characters showed the minimum genetic advance in the case of growth characters and number of secondaries per primary, followed by internodal length and girth of primary branches showed the highest genetic advance among them. Among the yield characters the highest genetic advance was shown by yield per plant whereas bean and fruit characters showed comparatively low genetic advance. Percentage of A grade beans showed a genetic advance of 32.55. The above observations show that there is ample scope for improvement of characters like girth of primary branches, number of secondaries per primary, yield per plant and percentage of superior grade beans in robusta coffee.
Most of the agronomic characters of crop plants are polygenic in nature and coffee is not an exception. As a result, agronomic characters of crop plants show different levels of interrelationship. This relationship is partly due to the involvement of same sets of alleles in the control of different characters and partly due to the mutually complementing nature of the characters. Correlation analysis is an important tool to identify the relationship between characters. Correlation of characters has been analyzed presently with reference to 28 characters of the 74 genotypes of robusta coffee studied. Out of the 28 characters, girth of primary branches, weight of 100 dry fruits and percentage of A grade beans showed significant positive correlation with the maximum number of characters and bean density, outturn, number of primary branches and fruits per node showed interrelationship with the minimum number of characters. Characters that show significant positive correlation are interrelated and they can be jointly considered for selection programmes. The present study shows that girth of primary branches, fruit weight, bean weight, bean volume and percentage of A grade beans are the most important characters that are to be considered in selection programmes, because they are interrelated with majority of the agronomic characters of coffee.

Polygenic characters of crop plants show different levels of association with each other. The reason is mainly the influence of same sets of alleles on different characters. Grouping characters based on their association with each other is a very effective tool to group the variables, to find out the lead variables thus reducing the bulk of characters under study. Presently character association has been analyzed by factor analysis using 28
growth, yield and quality characters of robusta coffee by principal component analysis. Six factors were obtained in the analysis but the 28 characters under study presently could be grouped into five groups. The characters under study contributed a cumulative percentage of variance of 76.91. Bush spread, length of primary branches and girth of primary branches were found to be the lead characters in the first group, out turn (ripe to clean) the lead character in the second group, internodal length the lead character in the third group, out turn (fresh to dry) the lead character in the fourth group and number of primary branches the lead character in the fifth group.

Bush spread, length of primary branches, girth of primary branches, number of primary branches, internodal length, out turn (ripe to clean) and out turn (fresh to dry) have been found to be the lead characters to be considered while planning breeding programmes in robusta coffee so that the bulk of variables for analysis could be reduced.

Different genotypes of crop plants collected from different plant populations show different levels of genetic divergence between them. Study of genetic divergence in the case of the 74 accessions of robusta coffee analyzed presently has been carried out using 28 phenotypic characters. The study showed that the 74 accessions including the released variety S.274 could be grouped into seven clusters at a linkage distance of one. The first cluster consisted of 11 genotypes, second cluster consisted of 13 genotypes, the third cluster consisted of 15 genotypes, fourth cluster consisted of 18 genotypes, fifth cluster consisted of 3 genotypes, sixth cluster consisted of 13
genotypes and the seventh cluster consisted of 1 genotype. Genotypes belonging to different clusters are genetically distinct and such genotypes could be used for selection and hybridization programmes based on their phenotypic superiority.

A preliminary study of the genetic control of ten growth characters, 17 yield characters and one quality character of robusta coffee has been carried out presently based on frequency distribution analysis. All the ten growth characters studied presently have been found to be of polygenic control as revealed by the continuous frequency distribution of the characters. Characters like stem girth, girth of primary branches, length of primary branches, internodal length, bush spread, leaf length, leaf breadth and leaf area showed normal distribution with different levels of skewness. All the 17 yield characters of coffee studied presently showed continuous distribution thus revealing the polygenic control of the characters. All the characters showed different levels of deviations from normal distribution and it may be due to nonsymmetrical distribution of the genotypes in the study population.

Robusta coffee is a tall shrub with higher stem girth, number of secondaries per primary, length and girth of primary branches, bush spread, leaf area and yield per plant. When arabica is taken as the model smaller plants with lesser bush spread and smaller leaves are considered to be superior but since Coffea canephora is a robust species, a different plant type with optimum size, bush spread and leaf area seems to be suitable in its case. Since girth of primary branches, fruit volume, weight of fresh and dry fruits,
bean volume, bean weight and percentage of A grade beans are very important characters contributing towards yield and percentage of A grade bean directly contributes to the physical quality of coffee, an ideal plant type of robusta coffee should be built upon such parameters.

Among the vegetative characters optimum stem girth, number of primary branches, number of secondaries per primary, length of primary branches, bush spread and leaf area seems to be ideal for superior robusta plant type. Among the yield characters higher fruit volume, higher fruit weight, higher bean volume, higher bean weight and higher yield are desirable for an ideal plant type in robusta and among the physical quality parameters higher percentage of A grade beans is desirable. Since most of the vegetative parameters like bush spread, length of primary branches, girth of primary branches, number of secondaries per primary, stem girth and leaf area have been grouped along with yield in the same factor group as per the present study, selection for ideal bush spread, length of primary branches, girth of primary branches and number of secondaries per primary may result in the selection of a good yielding robusta genotype. Number of primary branches also is a lead character in a factor group obtained in the present study and hence it can also be considered while selecting for a good plant type in robusta coffee.

When analyzed for overall performance based on performance index derived from 25 characters including 10 growth characters, 14 yield characters and one quality character, all of which were quantitative in nature, the genotypes under study showed ranking that ranged from 1 to 64. The ten
superior accessions selected based on overall performance consisted of S.3657, S.3399, Wt.1, Wt.2, Wt.4, DR.14, DR.13, WC.13, WC.27 and Wt.6 in that order. The released variety S.274 used as control in the present experiment ranked only 22nd in the present study.

Since robusta coffee is a cross pollinated species with very high level of self incompatibility, it is not advisable to select a single superior genotype, however superior it be. Hence the present recommendation is to practice further improvement measures as applicable to cross pollinated crops and to develop a composite variety, which is a mixture of superior genotypes which can perform well under field conditions by sharing their genetic potential by cross pollination and expressing agronomically superior aspects to the maximum. The number of genotypes selected finally for the purpose could be reduced based on further screening processes.

Nine interspecific hybrid plants of coffee raised by crossing the wild coffee species Coffea racemosa with S.274 variety of Coffea canephora var. robusta have been studied for their growth characters, yield characters, caffeine content and leaf rust resistance in comparison with their parents presently. 9 growth characters, 19 yield characters, caffeine content and leaf rust resistance were analysed. All the hybrid plants were generally inferior to the S.274 parent in most of the growth and yield characters. However the crop duration of the hybrid progeny has got reduced tremendously when compared to S.274 parents. This reduction in crop duration in the case of the hybrid if exploited scientifically could be utilized for the effective reduction of crop duration so that, coffee is harvested earlier and the plants get a gap
period before the onset of the next flowering period and hence it can replenish its potential for the next crop in a better way.

Further, low caffeine content is being considered an advantageous character of coffee. Robusta coffee has got a caffeine content of about 2%. Development of robusta varieties with lower caffeine content has been a thrust area in robusta coffee research right from the beginning of organized research in robusta coffee. *Coffea racemosa* is a species with mean caffeine content of 0.38%. The present study has resulted in producing hybrid plants with comparatively low caffeine content (1.47%). This is a very desirable condition and further breeding programmes using this material may result in the development of robusta hybrids with lower caffeine content.

Robusta coffee is widely cultivated in Wayanad and to some extent in Coorg, which are two different traditional coffee growing areas of South India. S.274 variety of *Coffea canephora* var. robusta, the robusta coffee genotype recommended to the robusta coffee growing areas of South India was used to study the adaptability of the same to Wayanad and Coorg regions. Ten growth characters and 14 yield characters were studied comparatively. ANOVA revealed no statistically significant variation in the case of the characters when compared area wise.

The present study has helped to assess the extent of genetic variability in one of the major robusta coffee gene pools conserved in India and to select superior genotypes from them. An ideal plant type has been suggested for robusta coffee. The hybrids generated from some racemosa x robusta coffee crosses have been
analyzed for their growth, yield and quality characters. A popular variety of robusta coffee has been analyzed for its comparative performance in the Wayanad and Coorg coffee growing areas of Kerala.