STUDIES ON VARIABILITY, DIVERGENCE, HYBRIDIZATION AND ADAPTABILITY OF ROBUSTA COFFEE

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

by

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CERTIFICATE

Certified that this thesis entitled **'STUDIES ON VARIABILITY, DIVERGENCE, HYBRIDIZATION AND ADAPTABILITY OF ROBUSTA COFFEE'** 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 Ms. K.R.Nikhila 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.

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10 October 2007 (Dr.K.V.MOHANAN)

DECLARATION

I, K.R.Nikhila, hereby declare that this thesis entitled 'STUDIES ON VARIABILITY, DIVERGENCE, HYBRIDIZATION AND ADAPTABILITY OF ROBUSTA COFFEE' being submitted in partial fulfilment of the requirements of Ph.D. Degree in Botany of University of Calicut embodies the results of a bona fide 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

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ACKNOWLEDGEMENT

I wish to express my deep sense of gratitude to my research guide Dr. K.V. Mohanan, Reader, Division of Genetics and Plant Breeding, Department of Botany, University of Calicut, Kerala, India for his inspiring guidance, affection and encouragement through out the course of this investigation.

My sincere thanks are due to Prof. (Dr.) N.Neelakandan, Prof. (Dr.) S.Nandakumar and Prof. (Dr.) P.V.Madhusoodanan, former heads of the Department of Botany, University of Calicut and Prof. (Dr.) M. Sivadasan, Head of the Department, Department of Botany, University of Calicut for permitting me to work in the department as a part time research scholar and also for constant encouragement. I thank all the faculty members and the librarian of the department for their support during the research programme.

I am deeply indebted to Dr.V.B.Suresh kumar, Assistant Specialist, Division of Botany, Regional Coffee Research Station, Chundale, Wayanad, Kerala for his helps, advices and encouragement and also for providing facilities to carry out the field experiments in the germplasm repository of the Research Station.

I am thankful to Dr.R.Naidu, former Director of Research and Dr. Jayarama, Director of Research, Central Coffee Research Institute, Chikmagalur, Karnataka, India for their kind permission to take up this study. I wish to thank Dr. A. Santaram, Head of the Department of Botany, Central Coffee Research Institute, Chikmagalur for all his encouragements during the study.

I record my deep sense of gratitude to Dr. A.G.S.Reddy, former Deputy Director of Research, Regional Coffee Research Station, Chundale, Wayanad for providing necessary facilities and also for his valuable support through out the study. Thanks are also due to Sri. M.Selvakumar, Deputy Director of Research, Regional Coffee Research Station, Chundale for providing facilities and also for valuable advices.

I record my deep sense of gratitude to Dr. C.K.Vijayalakshmi, Division of Entomology, Regional Coffee Research Station, Chundale, Wayanad for her helps, valuable advices and encouragement during the study. My sincere thanks are due to Dr .George Daniel, Sri. G.T. Shivarama, Smt. P.P.Deuthi, Sri. P.Abdul Rahiman and Smt. V.M. Saraswathi, scientists of Regional Coffee Research Station, Chundale for their valuable support during the course of the study. I express my sincere gratitude to the coffee tasters of the Quality Control Division, Coffee Board, Hassan, Karnataka for helping me in quality evaluation of coffee samples.

I extent my thanks to Mr. P.S. Krishnakumar, former technician, Mr. P.K.Mahesh and Mr. Teddy Jude former skilled assistants and Mr. Shyju, skilled assistant Regional Coffee Research Station, Chundale for their helps. The help extended by Sri. Sathyanarayana, Group D staff of Regional Coffee Research Station, Chundale is acknowledged gratefully.

The help rendered by the farm workers of Regional Coffee Research Station, Chundale, especially by Sri. Krishnaswami, Sri. Sanjeevan, Sri. Man Bahadur, Smt. Ratnamma and Late Smt. Ammini is gratefully acknowledged.

I am also thankful to the coffee planters of Wayanad district of Kerala and Coorg district of Karnataka who permitted me to record data from their plantations as a part of my study. The help extended by Sri. P.Sahadevan and family of Naina Estate, Coorg, who made arrangements for my data collection in Coorg district is specially acknowledged.

I extent my thanks to Ms. R.Uma Maheswari., Dr. T.K.Hrideek, Ms. M.Jayasree and Dr. C.B.Mini, my colleagues in the Plant Breeding Laboratory of the Division of Genetics and Plant Breeding, Department of Botany, University of Calicut for their help and support.

I am thankful to my father, mother, sister, brother, uncle, father in law and mother in law for their constant encouragement and support. Finally it is the support and patience of my loving husband while I was preoccupied with the work of my thesis and his help in typing the manuscript that helped me in the successful completion of this work.

Above all I am thankful to Almighty God for offering his blessings.

K.R.Nikhila

Dedicated to my husband and parents

PREFACE

Coffee is a very important non alcoholic beverage used world wide. The processed beans of two species of the genus *Coffea* namely *Coffea arabica* and *Coffea canephora* yield the coffee of commerce. *Coffea arabica* yields arabica coffee and *Coffea canephora* yields robusta coffee. Coffee beans are processed conventionally by wet and dry methods. Value added products are also produced using modern technology. Coffee is cultivated through out the world in the tropics. But, Brazil, Vietnam and Colombia are the top producers now. India is ranked sixth in production and it contributes about 4.5% of the commodity. India is famous for both its arabica and robusta products and Indian coffee enjoys a very significant niche in the world market. Coffee improvement research in India resulted in the development of twelve arabica and three robusta varieties so far. Since the coffee tracts of Kerala state of India are most suited for the cultivation of robusta coffee, intensive screening of the germplasm and development of new cultivars is the need of the hour. Moreover, the caffeine content of robusta coffee is comparatively high and reduction of its caffeine content has got high commercial importance. Many of the robusta planters used conventional strains for planting even now. Hence, investigations on the performance of the improved varieties in different coffee tracts are also important. The present study is a humble attempt in these directions.

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Chapter I
INTRODUCTION

Coffee, one of the most important non-alcoholic beverages of the world is obtained from the processed beans of two species of the genus *Coffea* namely *Coffea arabica* and *Coffea canephora.* Among the different varieties of *Coffea canephora*, var. robusta is the most popularly cultivated. *Coffea arabica* is a high land species grown at altitudes ranging from 500 m in subtropics to 2500 m near equator. *Coffea canephora* is a low land coffee suited for cultivation at an elevation ranging from 500-1000 meters above sea level (Willson, 1999). As majority of coffee areas in Kerala come under the elevation between 500-1000 meters above sea level, in more than 85% of the coffee areas robusta is cultivated (Anonymous, 1996).

The three top producers of coffee in the world presently are Brazil, Vietnam and Colombia and these countries contribute around 55% of global production (Lakshmi Venkatachalam, 2005). India is sixth in position in production (Anonymous, 2007a) and coffee is produced in an area around 3,50,000 ha., predominantly in Karnataka (70.7%), Kerala (21.3%) and Tamil Nadu (6.9%) (Anonymous, 2007b). India's share to coffee production of the world is about 4.5% and in 2005-06 it was 2,74,000 MT (Anonymous, 2007b). The estimated production in 2006-07 is 2,88,000 MT and the post blossom estimation in 2007-08 is 2,91,000 In 2007-08, 1,90, 250 MT is expected to be contributed by robusta coffee (Anonymous, 2007c).

Coffee is cultivated in an area of 84,644 ha. in Kerala out of which 80,549 ha. is robusta coffee. Robusta coffee plantations of Kerala constitute 22.7% of the area under coffee in India. Arabica coffee area of Kerala comes only to 1.2%. Kerala produced a total of 62,225 MT of coffee in 2005-06 out of which 60,875 MT was robusta coffee (Anonymous, 2006).

Coffee originated in the Abyssinian centre of origin in tropical Africa (Wintgens, 2004). The history of coffee as a beverage is closely linked to the growth of great empires and trade, under the influence of the Arabs in the first millennium, the Turks in the 15^{th} century and the Europeans in the 18^{th} century (Charrier and Eskes, 2004). Coffee was introduced to India around 1600 AD by a Muslim saint, Baba Budan, who brought seven seeds of coffee from Yemen and reportedly planted them near Chikmagalur (Jayarama, 2006).

Twelve arabica and three robusta varieties have been released in India for commercial cultivation till 2006. Coffee gene pools have been established at Central Coffee Research Institute, Chikmagalur and in its different regional stations.

Some of the finest arabicas and robustas of the world are grown in India. Indian coffees are shade grown, hand picked and sun dried. India cultivates coffee under a well defined two tier mixed shade canopy. Indian coffee has a significant position in the international market. Both the arabicas and robustas of India are highly valued. India has over 1,78,000 coffee growers of which 1,75,475 are small growers. Small holdings come to about 2,54,932 ha. which comes to 71.8% of the total coffee area (Anonymous, 2007b).

Coffee in India is labour intensive and it is an important source of rural employment. The most important limitation of the coffee sector of South India is high cost of production and low productivity. The only breakthrough from this situation is to increase productivity.

Even though considerable quantum of work has been carried out both towards the improvement of coffee planting material and better management strategies, most of them are arabica oriented. Since robusta coffee is the mainly cultivated type in Kerala state of India, efforts to develop new varieties and new management strategies in robusta coffee are critically important to the coffee sector of Kerala.

The objectives of the present study include assessing the genetic variability of robusta coffee, the study of correlation of characters, character association, genetic divergence and genetic control of characters in robusta coffee, selection of superior genotypes of robusta coffee, study of the behaviour of the hybrids of an interspecific cross of coffee and assessing the performance of an improved variety of robusta coffee in two coffee growing areas of South India.

Chapter II
REVIEW OF LITERATURE

2.1. The genus *Coffea*

Coffea is economically the most important genus of the family Rubiaceae, producing the coffee of commerce (Purseglove, 1968). Linnaeus described the genus *Coffea* in his Genera Plantarum in 1737. This genus consists of tropical members, ranging from slender sprawling plants that closely resemble jasmine, through all sizes of shrubs, to robust trees with clean trunks and spreading heads growing 30 to 60 feet tall. The plant characters vary widely. The leaves range in colour from yellowish to dark green, and they vary from 1 to 40 cm in length. The bark colour ranges from buff through light to dark brown or reddish brown. Fine hairs are seen on the young stem of some species. While the cultivated coffees have dense clusters of white fragrant flowers, some species have insignificant flowers without fragrance and in others they are cream, even tinged with pink or purplish red. The cherries show a variety of colours, varying from green through red and purple to black, while some others are yellow to white in colour. Fruits are as small as peas in some while in others they are as large as plums. The basic chromosome number of the genus *Coffea* is x=11 (Wrigley, 1988).

The striking features of the genus are the wide morphological variations between the species and their adaptation to a wide range of environments. Most of the species occur in the under storey of forests from sea level to 2000 m altitude. Habitats range from deep shade to bright sunshine, sandy to humic soils; from very wet to arid ones (Wrigley, 1988).

Caffeine content also varies widely among the species of *Coffea* (Charrier and Berthaud, 1975). Most of the described species of *Coffea* are native to tropical and subtropical regions of Africa. A few wild representatives of the genus occur in Myanmar, Thailand, Malaysia, Sri Lanka and Indonesia (Carvalho, 1959). According to Leroy (1983), the genus *Coffea* originated in Kenya and adjacent areas at a time before the dispersal of Gondwanaland.

2.2. Species of coffee

Many workers have attempted to classify the genus *Coffea* L., considering the various characteristics of the plants. Bush size, leaf size, flower number, fruit size and seed shape and size have been the major characters conventionally considered for classification. Carvalho and Monaco (1967) used crossability, seed set and seedling emergence from crossed seeds for evaluating species relationships within the genus, while Lopes and Monaco (1979), used flavanoid analysis for the same purpose. Chinnappa (1981) studied pollen morphology of various species and Santaram and Srinivasan (1981) used a number of chemical tests to determine the affinities between five coffee species and an interspecific hybrid (*Coffea liberica* x *Coffea eugenioides*).

The exact number of species within the genus is still controversial due to the many species described in the 20th century from West Africa, Central Africa, Madagascar and East Africa (Charrier and Eskes, 2004). According to Wrigley (1988) the number of species identified by various authors range from 25 to 100. Chevalier (1947) divided the genus *Coffea* into four sections, *Eucoffea* (24 species), *Mascarocoffea* (19 species), *Paracoffea* (13 species) and *Argocoffea* (11 species). *Paracoffea* and *Argocoffea* are now considered to be distinct genera. The *Eucoffea* section comprises the subsections *Erythrocoffea* (3 species), *Pachycoffea* (5 species), *Nanocoffea* (5 species), *Melanocoffea* (4 species) and *Mozambicoffea* (8 species)

(Wrigley, 1988). Chevalier (1947) reported 67 species of *Coffea* and included 25 species under *Eucoffea* (Table 2.1) (Wrigley, 1988).

Table 2.1. Species included by Chevalier in his subsections of section *Eucoffea* (Wrigley, 1988)

Subsections	Species
Erythrocoffea	*Coffea arabica, Coffea canephora, Coffea congensis*
Pachycoffea	*Coffea liberica, Coffea klainii, Coffea oyemensis, Coffea abeokutae, Coffea dewevrei*
Nanocoffea	*Coffea brevipes, Coffea humilis, Coffea mayombensis, Coffea montana, Coffea togoensis*
Melanocoffea	*Coffea affinis, Coffea carissoi, Coffea stenophylla, Coffea mayombensis*
Mozambicoffea	*Coffea eugenioides, Coffea ligustroides, Coffea mufindiensis, Coffea racemosa, Coffea salvatrix, Coffea schumanniana, Coffea vanroechoudtii, Coffea zangueburiae*

Cramer (1957), who studied the genus for many years is of opinion that about 100 true species of *Coffea* are still to be found. However, Purseglove (1968) suggested the probable number of species as 60 and Charrier (1978a) listed 56 species. According to Bridson and Verdcourt (1988), the genus consists of about 80 species of which 25 are endemic to Africa. According to Wintgens (2004), the genus *Coffea* consisted of approximately 70 species.

2.3. Cultivated species of *Coffea*

The most important species of cultivated coffee are, first, *Coffea arabica*, followed by *Coffea canephora*, with *Coffea liberica* and *Coffea excelsa* combined as poor third in popularity. Most of the other species of *Coffea* at present have got no economic value. However, geneticists can explore their value and utilize them for possible techniques of transfer of genes giving immunity to disease, resistance to drought or some other desired quality that may be hidden among them (Haarer, 1962). *Coffea arabica* or arabica coffee accounts for 70% of the world coffee trade and *Coffea canephora* or robusta coffee supplies most of the remaining 30%. *Coffea liberica* grown mainly in the west coast of Africa has poor liquoring qualities (Wrigley, 1988; Vossen, 2000). Coffee can be cultivated only in the climatic conditions found in the tropical, subtropical and equatorial regions (Willson, 1999).

2.3.1. *Coffea arabica* L.

Coffea arabica popularly known as arabica coffee is a high land species, which can be grown at altitudes ranging from 500 m at subtropics up to 2500 m near equator (Willson, 1999). The home of arabica coffee is the Kaffa province of Ethiopia where it occurs naturally in forests between 150 m to 1800 m elevations. Linnaeus first described this species in 1753 (Wrigley, 1988). Arabica coffee is an allotetraploid inbreeder (2n = 44) and is a small tree with grey to light brown bark. It is a shrub or even bush under training. It branches profusely and the leaves are dark green. The flowers are white and generally pentamerous. The flowers blossom in 9-10 days after the receipt of summer showers known as blossom showers. The fertilized ovary grows into a fruit in about 8-9 months. The berries are 10-12 per node and are oblong to round in shape. Removal of silver skin imparts bluish green tint to the seed (Shanmugavelu *et al*., 2002).

Arabica trees come into bearing 3-4 years after planting and are in full bearing by 6-8 years. Good yields are expected for 15-18 years, after which it declines, becoming unprofitable by 20-30 years (Wrigley, 1988). Caffeine content in arabica coffee is 0.5% to 1.8%, which is less when compared to robusta coffee (Charrier, 1983).

Coffea arabica has two varieties namely variety arabica (variety typica) and variety bourbon. Variety arabica is said to have the young leaves bronze-tipped and the fruit bearing branches pendulous, while variety bourbon has the young leaves green and the fruit bearing branches bent down only at the tips. Mutants of arabica are very numerous and include variations in leaf shape and colour, growth habit and flower, fruit and seed characters (Wrigley, 1988).

2.3.2. *Coffea canephora* Pierre ex Froehner

Coffea canephora is a low land species, cultivated up to 1000 m above MSL in a belt of 10º N and 10º S of equator (Willson, 1999). Though it tolerates warmer temperature and high humidity it is more sensitive to cold (Illy and Viani, 1995). *Coffea canephora* is a native of Belgian Congo. In 1895 Emile Laurent collected the material from Congo basin and later identified. However, *Coffea canephora* was named by Pierre in 1897 (Wrigley, 1988).

It is a diploid (2n = 22) species, bigger tree when compared to arabica with broader and larger pale green leaves. Flowers are white, fragrant and generally pentamerous. They are borne in clusters larger than that of arabica. Berries are small but higher in number per node varying from 40-60 or more. The flowers open on 7^{th} or 8^{th} day after the receipt of blossom showers. It is self-sterile and hence cross pollination is the rule. The fruits mature in 10-11 months. They are generally ready for harvest two months later than arabica (Shanmugavelu *et al*., 2002). The species contain more caffeine, ranging from 1.5% to 3.8%, but more neutral in cup quality although known for body (Wellman, 1961). *Coffea canephora* var. robusta is the cultivated variety of the species. Besides this there are two other varieties of some importance, var. kouillon and var. niaouli. *Coffea canephora* var. robusta is generally called robusta coffee (Wrigley, 1988). Robusta coffee possesses several useful characters like, high tolerance to leaf rust pathogen, white stem borer, nematode invasion and potentiality to give consistent yield. Because of these reasons, cost of robusta cultivation is relatively less compared to that of arabica. On the other hand, inability to endure long drought, late cropping, as well as later stabilization of yields and inferior quality compared to arabica, are some of the negative aspects of robusta coffee (Anonymous, 1996).

The variety kouillon has much longer leaves (up to 35 cm) and slightly higher yield. It is also known as quillon, and is indigenous to the Congo basin and cultivated in the Ivory Coast, Madagascar, Guinea and to a certain extent in North Brazil. Due to its rather small fruits this variety is generally less cultivated. It produces different kinds of coffee cherries, which are enervate, longish, narrowing and rather flat. Niaouli variety is a shrub,

cultivated in Benin, bears fruits through out the year. It is easily attacked by certain pests and it does not give good crops (Rothfos, 1980). Wellman (1961) has reported some other varieties of *Coffea canephora* like var. typica, var. ugandae (nganda), var. maclaudii, var. stuhlmannii, var. buobensis, var. laurentii etc.

2.4. Cytology of coffee

The basic chromosome number of the genus *Coffea* is x = 11. All the species of *Coffea* are diploid (2n = 22) except *Coffea arabica*, which is a tetraploid (2n = 44). All diploid species of coffee are self incompatible. *Coffea arabica* is the only self compatible species. In *Coffea arabica* the chromosomes present themselves as small rods, smaller than those of any of the diploid species (Mendes, 1959). Interspecific hybrids of *Coffea arabica* x *Coffea canephora* have been reported to be diploids (Sybenga, 1960) or triploids (Mendes, 1959).

2.5. Morphology and growth behavior of coffee

2.5.1. Vegetative growth

Coffee is a perennial plant and is ever green in nature. The coffee plant exhibits a unique dimorphism in its vegetative growth. The apical bud develops into an upright growing orthotropic stem with opposite decussate leaves and the horizontally growing plagiotropic branches with opposite leaves. Flowers and fruits are formed from the axillary buds of these branches (Alvim, 1959). The vegetative growth of a particular year determines the cropping wood of the succeeding year.

A salient feature of coffee leaves is the occurrence of domatia, which are small openings on the lower surface of leaves in the angles at the veins intersecting the midrib. Coffee has a shallow root system and particularly in robusta, roots are concentrated very close to the surface of the ground. However, arabica coffee produces most of the feeder roots relatively in deeper soil (Anonymous, 2000).

Coffee plants take approximately three years to develop from seed to first flowering and fruit production. A well managed coffee can be productive for up to 80 years or more, but the economic lifespan of a coffee plantation is rarely more than 30 years (Wintgens, 2004).

2.5.2. Flowers and flowering

Coffee is a short day plant. Flower buds are produced at the axils of mature green wood on short stalks, which are known as peduncles. In arabica, 4-5 inflorescence of 1-4 flowers each are produced per axil, while in robusta more number of flowers per inflorescence are commonly produced (Anonymous, 2000). Inflorescence is a condensed dichasial cymose fascicle subtended by bracts (Gamble, 1921).

The flower bud grows into a length of 7-8 mm after initiation and then remains quiescent until stimulated into flowering. Rain or irrigation after a dry period induces further growth in flower buds, which open into flowers within 8-10 days (Anonymous, 2000).

Flowers of cultivated species of coffee are epigynous with four floral whorls, calyx with five sepals attached to the ovary and small in size. Corolla

made of five petals, first growing into a tube, which towards the end gets divided into five lobes. Towards the upper end of the flower tube there are anthers attached by short filaments to the base of each lobe, this also five in number. Ovary is bicarpellary. On the ovary, underneath the tube, there is a long style, which towards the end grows into two separate thin and slightly bent stigmas (Gamble, 1921; Rothfos, 1980; Wintgens, 2004).

2.5.3. Pollination

Pollination takes place within 6 hours after flower opening under bright light and warm windy conditions. Rain during morning hours before or after flower opening affects pollination and there by lowers fruit set. Wind, gravity and bees are the agents of pollination. Arabica coffee is autogamous in contrast to robusta coffee, which is strictly allogamous with an inbuilt gametophytic system of self incompatibility. Robusta is having adaptive advantage in having longer styles compared to arabica, which may also facilitate cross pollination (Wintgens, 2004).

Rudolph (1914) studied the pollination of coffee by bees and reported that the presence of bees is not essential for successful pollination in coffee, but natural and most desirable form of pollination is achieved by the aid of flower visiting insects, of which bees are the most important.

Reddy *et al*. (1981) carried out studies on fruit set pattern following three different modes of pollination such as selfing, natural cross pollination and open pollination in 10 selections of *Coffea arabica*, in Andhra Pradesh and found that final fruit set under open pollination was relatively high and might be due to both selfing and cross pollination. It is also suggested that

ultimate fruit retention is not only dependent on pollination, but also influenced by the physical, physiological and environmental factors.

2.5.4. Fertilization and fruit

The process of fertilization is completed within 24-48 hours after pollination. The normal duration of a flower to develop into a fruit is about 6-8 months in arabica and 9-11 months in robusta. Ripe fruits have a thick fleshy pericarp with a mucilaginous layer surrounding the parchment, which is made up of stone cells or sclereids (Anonymous, 2000).

The fruit is a drupe and normally contains two seeds lying with their flat sides together, the other sides being rounded. Abortion of one ovule due to non fertilization leads to the formation of a single seeded fruit, called pea berry. Seeds are commonly known as beans (Rothfos, 1980).

2.5.5. Beans/ seeds

Seeds are elliptical or egg shaped, planoconvex, possessing a longitudinal furrow on the plane surface (Anonymous, 1996). The small embryo, localized at the bottom of the seed, on its convex surface is represented by a hypocotyl and two adherent cordiform cotyledons (Dedecca, 1959). Each of the two coffee beans is covered by a loose, thin skin (parchment), which also has the furrow (Rothfos, 1980).

2.6. Crop improvement studies in 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. Yield, plant vigour and quality have been the main selection criteria in both coffee types, but in

arabica coffee resistance to diseases and pests is the breeding objective of the highest priority. Variation in the circumstances of climate, soil, biotic and abiotic stresses, cropping systems, socioeconomic factors, market dynamics and consumer preferences further defines priorities of selection criteria applied in specific programmes (Vossen, 2000).

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 (Srinivasan and Vishveshwara, 1980a). According to Srinivasan (1980), greater emphasis must be given to longer primaries with shorter internodes in the identification of elite types of plants in a variety.

Breeding in *Coffea canephora* var. robusta was started in a systematic manner in Java in 1907 (Wellman, 1961). Robusta beans are generally small and improving the bean size is an important criterion in robusta breeding. But Cramer (1957) has reported that selected clones of robusta have the bean weight of more than 20g.

The quality of robusta coffee is inferior to that of arabica in bean size as well as organoleptic attributes (aroma, flavour, taste, etc.). Hence most of the present day robusta breeding efforts aim at improving the bean size and organoleptic quality and reducing caffeine content (Vossen, 2000). According to Santaram *et al.* (1994), in India, exploitation of *Coffea* *canephora* includes mass selection, clonal selection, diallele crossing and interspecific hybridization.

Narayan (1954) developed two selections of arabica coffee. For the purpose, a survey was conducted in all the coffee growing areas in South India and 267 plants from different zones were collected and nearly 25,000 seedlings were raised. From these 80 mother plants were selected in the first instance. At the same time self bred progeny of these mother plants as well as cross breeds between these and with the Kents and Coorgs were also raised. By the year 1988, three mother plants had been finally fixed for further propagation, whose progeny are known as S.288 family including S.795 and S.333 family including S.645. These selections are disease resistant, good yielding and of vigorous growth. Thomas (1960) conducted further studies in these selections and found that all were good yielders and good in other characters like bean size, lower percentage of triage and quality in the cup.

2.6.1. Variability studies in coffee

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 (Mishra, 1998; Srinivasan and Santaram, 1999).

2.6.1.1. Variability in arabica coffee

A major proportion of research that lead to the improvement of coffee plants has been carried out on *Coffea arabica*, whose product is higher in quality than that of *Coffea canephora* (Willson, 1999). Studies indicated that relatively large genetic diversity was found in *Coffea arabica* as with the studies carried out for botanical and morphological characteristics.

Narasimhaswamy (1940) conducted genetic studies in *Coffea arabica* L. The study showed that the colour of pericarp of ripe fruits appeared to be linked with young leaf colour. Plants with copper and brown leaves had red pericarp and plants with light green leaves had golden yellow pericarp. Plants for copper and light green leaves were found to be homozygous; where as plants with brown leaves were heterozygous. Copper leaves dominated over light green and brown leaves and light green leaves dominated over brown leaves.

According to Srinivasan (1969), stem girth has a positive and significant correlation with mean cherry yield in both arabica and robusta selections, thus indicating that stem girth might be a useful character for the purpose of selecting high yielding lines. Results of a study conducted by Srinivasan (1972) in 134_4 S.12 Kaffa and its two selfed progenies compared with 12 *Coffea arabica* cultivars indicated the presence of higher flower number per cyme and better fruit set in 134_4 S.12 Kaffa and its two selfed progenies than the other arabica cultivars studied.

Zapata (1975) studied yield and bean characteristics of coffee germplasm introduced to Colombia. Yield and bean quality of 37 introductions and five local Bourbon selections were studied. Materials from East Africa and the former Belgian Congo were similar in yield and bean characteristics to the Bourbon type. A third of 25 selections from Ethiopia had high yields and some had resistance to *Hemileia vastatrix*. None combined these characteristics with good commercial bean quality.

Charrier *et al.* (1978) conducted a study of variability of progenies from open and controlled pollination in Madagascar. A total of 200 progenies from 29 *Coffea arabica* populations were studied at low altitude. Intra family variation in open pollinated progeny was significant in two out of three populations for branch length and in seven out of twelve populations for internode length. Intra family variability was marked for berry yield. Two populations stood out for hundred bean weight. Three of the controlled crosses were very high yielding in comparison with open pollination.

Comparative diversity of *Coffea arabica* progenies obtained by selfing or by open pollination was studied by Louarn (1978). Nine populations were studied for nine characters in Ivory Coast. There were significant differences between populations and between families within the population for all characters. Families from open pollination were more heterogeneous than those from selfing.

Reynier *et al.* (1978) also studied the diversity in open pollinated progenies of coffee in Ivory Coast. The progenies from open pollination of five trees from each of 20 populations were studied for 14 characters. There was marked variation between populations and between families for all characters, variance between families ranged from one tenth to one third of the variance between populations owing to the effects of allogamy and heterozygosity.

Costa (1978) studied the relationship between degree of resistance to *Hemileia vastatrix* and yield in coffee. Five progenies were compared over a five year period. Though differences in resistance between progenies were not significant, each progeny included susceptible and strongly resistant plants and intermediate grades. No correlation between yield and resistance to *Hemileia vastatrix* was observed.

Berthoud *et al*. (1978) observed the variability of quantitative variables in 34 *Coffea arabica* populations in the Ivory Coast. The number of nodes of the side branches and of the main stems, and their basal diameters were all positively inter correlated. Berthaud (1978) tabulated the caffeine content of 70 populations at five planting sites, significant differences were observed between populations and their mean caffeine content was higher than that of cultivated varieties.

Charrier (1978b) analyzed the phenotypic variability of a *Coffea arabica* collection in Madagascar comprising of 67 progenies growing at low altitude. Growth rhythms varied within and between them. Height was correlated with collar diameter.

Observations on flower number in relation to final fruit set were made for two years between exotic varieties of *Coffea arabica* L. by Thimma Reddy and Srinivasan (1979). In general all the varieties were capable of producing average to high flower number. The final fruit set was, however determined by variable weather conditions and physiological factors.

Srinivasan (1980) studied association of some vegetative characters with initial fruit yield in *Coffea arabica*. Genotypic, phenotypic and environmental correlations were studied among five vegetative characters and first fruit in four cultivars. Stem girth, length of longest primary and its internodal length showed high positive genotypic correlation with fruit yield, while the number of primaries had negligible correlation and number of nodes on longest primary had negative correlation with fruit yield. Path analysis revealed that greater weightage should be given for longer primaries and shorter internodes in selection for yield.

Mean yield, coefficient of variation for yield over years as well as between plants, percentage of plants giving an average fruit yield of 3 kg and above and their percentage contribution to total yield of the progeny were used to differentiate 25 high yielding *Coffea arabica* and 34 high yielding *Coffea canephora* progenies at single location by Srinivasan and Subbalakshmi (1981). Arabica progenies had lower variation for yield and lower mean yield than robusta.

Srinivasan and Vishveshwara (1981) studied the variability and breeding value of some characters related to yield in a world collection of arabica coffee. The characters like bush spread, branch angle, leaf size, internodal length, floral differentiation and flowering period, flower number per axillary cyme, fruit size, days to fruit ripening, reaction to leaf rust and apomictic development of fruits and seeds were studied in 246 arabica varieties/cultivars maintained at Central Coffee Research Institute, Chikmagalur, India. Wide range of variability was observed for most of the characters, which confirmed the polymorphic nature of the species.

Moderate expression for most of the characters was capable of giving high yield.

Biometric genetic studies in arabica coffee have shown that the selection efficiency for higher yield is increased considerably by taking into account various growth parameters such as stem girth, canopy radius and nodes, number of berries per node and internode length (Walyaro and Vossen, 1979; Walyaro, 1983).

Carvalho *et al*. (1984a) studied the yield variability in Mundo novo coffee progenies. The yield of 15 populations was recorded for 37 consecutive years and the most productive single plant identified.

Srinivasan and Subbalakshmi (1984) studied the genetic convergence and divergence among selected cultivars of arabica coffee. Seventeen arabica selections of Indian and exotic origin were used for 11 morphological characters. The selections were grouped into 5 clusters. Divergence between clusters I, II, IV and V was the maximum and hence the varieties on these were suggested for hybridization. The characters internodal length, number of nodes and total length of primary, leaf area, fruit volume and weight were found to be more important for distinguishing.

Carvalho *et al*. (1984b) observed the genetic variability obtained through mutations. Coffee seeds were subjected to irradiation in 4 dozes from 5 to 23 kR and maximum genetic variability was obtained by the treatment of 12.5 kR.

In 1986, five *Coffea arabica* accessions each with 20 trees growing in Ethiopia were studied for variation between accessions, between trees within accessions and between fruits within trees for fruit length, width and thickness and ratios between these characters by Tadesse and Engels (1986). Results revealed that over 60% of variation in fruit characteristics were due to environmental characters.

Dharmaraj and Gopal (1986) studied the genetic variability of growth and yield characters in some selections of coffee and found that highly significant differences existed between the selections in respect of all growth and yield characters. The higher yield in Sln. 4A, Sln. 11 and Sln. 7 was due to higher length of primaries and more number of fruiting nodes and berries per primary in the initial years. Maximum phenotypic and genotypic coefficients of variation were observed in number of fruiting nodes per primary and secondary, number of berries per primary and in yield per plant. Relatively higher genetic advance was found in yield per plant, number of berries per primary, primary length and number of fruiting nodes on secondaries, as compared to other characters.

Ordonez (1991) reported a dwarf material of coffee from the Mataquescuintla region of Guatemala known as Pache Enano (M 87) in 1987. A study was conducted to assess identification, and level of variability in M 87. Over three years the trees were evaluated for 11 characters. Majority of characters measured were stable. It is suggested that the variants of M 87 are spontaneous mutants and dominant genes control leaf colour, angle of insertion, leaf length and width, leaf lamina form and abundance of secondary and tertiary stems.

Ten rust resistant Catimor cultivars from Australia and Portugal and five from Kenya developed from cv. colombia were evaluated, together with some commercial cultivars for yield, growth and quality characters in Papua New Guinea by Kiara (1993). Six Catimor lines were recommended for commercial planting, having yields of 2050-3200 kg green beans/ha over three years. Five Colombia lines were recommended for further selection as they were less advanced, but had greater variability for tree growth, coupled with resistance to coffee berry disease and outstanding yield, bean size and cup quality.

Conversion ratios for cherry to parchment, parchment to clean and cherry to clean were determined for two coffee cultivars, grown at Gera and processed by the wet and dry methods and significant differences were found between cultivars (Temesgen and Michael, 1995).

Resende *et al*. (2001) studied the estimation of genetic parameters and prediction of genotype values in coffee breeding. The accuracy of the genotype evaluation of the cultivars for stem diameter was 76%. The use of experimental design with two plants/plot and 20 replications can lead to 90% for stem diameter. The mixed model methodology was adequate for genetic parameter estimation and genotypic values prediction in coffee breeding.

Anil kumar *et al*. (2002) conducted a trial on the comparative performance of five arabica varieties, for growth, yield and bean parameters. S.4371 recorded significantly the best plant growth in terms of stem girth, number of primary branches per plant, bush spread and length of the longest primary branch followed by Tafarikela. The highest number of primary branches was observed in S.4695. Tafarikela showed the highest number of secondary branches per plant. Three year mean yield and percentage of ‘A’ grade beans were the highest in S.4422. S.4695 and S. 4371 recorded almost similar weight of 100 ‘A’ grade beans. The lowest out turn was recorded in Sln. 6 (Swarnagiri). This is because of the interspecific hybrid origin of this variety which results in high percentage of fruit floats.

The intrinsic coffee bean out turns, percent weight ratio of two normal flat beans and the respective whole fruit, were studied in coffee germplasm in Brazil by Pezzopane *et al.* (2004). Considerable genetic variability was detected within *Coffea arabica* and *Coffea canephora* and among other species of the genus *Coffea*. The magnitude of variations and the economic implication of bean intrinsic out turn indicate that this characteristic could be used as an additional selection criterion in improvement programmes aiming at the development of high yielding cultivars of *Coffea arabica* and *Coffea canephora*.

According to Aguiar *et al*. (2004), plant height, fruit colour, leaf rust resistance and earliness are sufficient for the identification of group of cultivars in *Coffea arabica*.

A study was conducted to estimate the variability and genetic parameters for the development of cultivars with higher frost resistance in *Coffea arabica* progenies, carrying *Coffea liberica* var. dewevrei genes. Genetic variability for frost resistance was observed among the progenies; rust resistance, vegetative vigour and yield potential should be considered when developing cultivars adapted to frost prone areas (Petek *et al*., 2005).

Randomly amplified polymorpic DNA (RAPD) markers generated by arbitrary decamers have been successfully employed to detect genetic polymorphism in coffee. In a study by Castillo *et al*. (1994), material originating from Ethiopia and the arabica subgroups var. typica and var. bourbon were clearly distinguished, showing that RAPD can be used to confirm morphological and geographical distance in coffee.

Sera *et al*. (2003) studied the genetic variability of *Coffea arabica* using RAPD markers and proved it to be a useful tool for genetic characterization of *Coffea arabica* genotypes.

Silveira *et al*. (2003) assessed the genetic variability within and among coffee progenies and cultivars using RAPD marker in Parama, Brazil. A total of 99 RAPD markers were evaluated of which 67 were polymorphic. Analysis of molecular variance (AMOVA) showed that 38.5% and 61.5% of the genetic variation was distributed among and within populations respectively. A distinct level of genetic variability was revealed for each of the coffee progenies and cultivars studied. The methodology used in this investigation was useful to determine the genetic variability within and among *Coffea arabica* populations providing significant information for coffee breeding.

Chaparro *et al*. (2004) evaluated the genetic diversity of 50 wild and semi-wild accessions of *Coffea arabica* from Ethiopia with RAPD markers. The analysis of molecular data revealed that a closely related group consisting of 86% of the Ethiopian *Coffea arabica* accessions evaluated was significantly different from the Caturra variety and could be used in a genetic breeding initiative to increase the variability of cultivated varieties. The results also indicated that a larger polymorphism is present in the Ethiopian coffee germplasm.

Maluf *et al*. (2005) studied the genetic diversity of cultivated *Coffea arabica* inbred lines, assessed by RAPD, AFLP and SSR marker systems. All methods identified polymorphism among the cultivars. The genetic diversity recognized by the methods is very similar, although is very narrow. RAPD and SSR marker systems grouped more efficiently the evaluated cultivars according to parental origin.

Diniz *et al*. (2005) studied the genetic variability of 40 accessions of *Coffea arabica* evaluated using a combination of RAPD technique and restriction digestion of genomic DNA. The accessions were properly clustered according to pedigree and agronomic features. The ability to distinguish among coffee accessions was greater for RAPD plus restriction digestion than for RAPD alone, providing evidence that the combination of the techniques was very efficient for the estimation of genetic relationship among *Coffea arabica* genotypes.

Aga *et al*. (2005) studied the genetic variation of forest coffee trees (*Coffea arabica*) from four regions of Ethiopia using inter sample sequence repeat (ISSR) markers. A total of 160 individuals representing 16 populations were sampled. Eleven ISSR primers amplified a total of 123 fragments of which 31 fragments (25%) were polymorphic. Estimates of total gene diversity and the coefficient of genetic differentiation were 0.37 and 0.81 respectively. This indicates that higher variability is between populations than within populations.

2.6.1.2. Variability in robusta coffee

The wide natural variability of *Coffea canephora* (robusta) coffee, apparent in many characteristics, constitutes a sound base for breeding. Variability of individual yields, for instance, is demonstrated by the fact that 50% of the total crop of a tree population may be contributed by 25% of the trees, the best 10% having a performance 20 times as high as the worst 10% (Ferwerda, 1959). Due to the strict allogamous nature of robusta, each plant can be considered a unique genotype (Charrier and Eskes, 2004).

According to Mawardi and Hartobudoyo (1981), the most important yield component in robusta coffee was the number of productive nodes per branch, followed by number of berries per branch, branch length, hundred berry weight and internode length.

Vasudeva and Ratageri (1981) studied leaf to crop ratio in arabica and robusta coffee. The leaf to fruit ratio averaged 1:3 in arabica and 1:6 in robusta. In arabica 17.7 cm^2 of leaf area was needed to support one fruit and in robusta the figure was 27 cm^2. Up to 20 fruits per node were observed in arabica and up to 50 in robusta. The percentage of non bearing nodes on the cropping branches was 52 in arabica and 61 in robusta.

Sundar (1983) studied fruit volume in relation to bean size and weight in robusta coffee. Fruit volume, weight, size and bean size and weight were more variable among clones. Fruit volume was positively and significantly correlated with all the other fruit and bean characters. Bean weight and size were linearly related to fruit volume.

Inheritance of flower number per node, inflorescence per node and flowers per inflorescence were studied in C x R coffee by Srinivasan (1985a) based on generation means and robusta showed higher values for all these characters. Inflorescence per node and flowers per inflorescence were found to be mainly governed by both additive and non additive gene effects. Reciprocal recurrent selection was suggested for upgrading this important character in coffee.

Srinivasan (1988) conducted a comparative study of juvenile growth characters of coffee varieties in north east India. Values of genetic parameters such as genotypic coefficient of variation, heritability and expected genetic advance were higher in robusta indicating greater scope for genetic improvement prevailing in this cross pollinated species.

Evaluation of sib mated progenies of C x R with open pollinated progenies and other robustas for growth characters and yield was carried out by Ahmed *et al*. (1996). Three common correlations between a) crop bearing nodes in primary branches and fruits per primary b) fruits per primary and fruits per node c) fruits per primary and yield per plant were recorded. Path analysis showed greater importance of stem circumference, number of primary branches, crop bearing nodes, nodes per primary and fruits per primary in determining yield. Six characters showed joint effect to the extent of 84% in sib mated progeny indicating greater coordination between characters contributing to yield increase in percentage of intermediate type plants in sib mated progeny, than open pollinated family.

The relationship of some vegetative characters *viz*., stem girth, tree radius, primary girth and internodal length with crop yield, percent seed grade, out turn and beverage quality was studied in different hybrid progenies of C x R by Ahmed and Sreenivasan (1988). A significant positive correlation between tree girth and radius, primary girth and stem girth were found. Crop yield of the C x R accession S. 2569 was higher than that of robusta parent. Seed grade ratio, out turn and cup quality features were normal.

Suresh kumar *et al.* (1999a) identified a dwarf CxR plant with desirable characters like short internode, compact bush size and bold beans. Weight of fruits and germination percentage of the dwarf are similar to that of normal robusta. A robusta plant belonging to S.274 having a mutant branch with lesser internodal length and smaller leaves was spotted at Regional Coffee Research Station, Chundale, Kerala, India. The compact bush shape is ideal for increasing the number of plants per unit area (Suresh kumar *et al*., 1999b).

Variability in the sibmated progenies of C x R were studied by Raghu *et al*. (2003). The five growth characters and three yield characters studied showed continuous frequency distribution, indicating their polygenic control. Transgressive segregation of characters was observed for the number of primary branches per plant, berries per node and fruiting nodes per plant. Crop yield was significantly related to total number of fruiting nodes per plant followed by the mean number of berries per plant.

The recurrent selection programme practiced in the Ivory Coast in 1984 has been outlined by Leroy and Charrier (1990). It was based on the presence of two genetically and geographically distinct groups within *Coffea canephora*, namely the Guinian and Congolese groups. Hybrids between these groups displayed enhanced vigour, precocity and yield. Selection criteria included resistance to *Hemileia vastatrix* and drought, plant habit and caffeine content.

The response of young *Coffea canephora* trees to drought was assessed through different observations: visual classification of drought incidence, mortality rate, leaf shape and appearance by Montagnon and Leroy (1993). The performance of genotypes of the Guinean group, the Congolese sub group I and II and Guinean – Congolese sub group II hybrids proved to be different. Drought had a significant impact on genotypes of Congolese sub group II. A detailed study, showed the importance of GCA for drought tolerance transmission, estimated by overall visual classification. However, the vigour of the between group hybrids seemed to mask drought tolerance transmission. The results indicated that it was possible to breed genotypes adapted to drought within each group.

Thirteen accessions of exotic robustas were assessed for ripe cherry to clean coffee ratio, grade percentage, yield and quality parameters by Suresh kumar *et al*. (2000). Analysis of data revealed that some accessions were promising in terms of grade percentage, yield and quality. S.1932 recorded the highest percentage of ‘A’ grade beans (63.20) followed by S. 1979(62.25). Highest yield was recorded in S.880 (999 kg/ha) followed by S.3399 (960 kg/ha). There was no significant difference observed in out turn ratio among these accessions.

Berthaud (1986) conducted isozyme electrophoresis to identify two genetic groups within the wild *Coffea canephora* populations Guineans and Congolese. Another study using the same technique showed that the Congolese genotypes could be grouped in to two subgroups- sub group I containing cultivated varieties originated from Gabon and Benin and sub group II containing wild genotypes and cultivated origins from continental Central Africa (Montagnon *et al*., 1992).

Budiani and Tahardi (1992) studied electrophoretic analysis of genetic variability in robusta coffee regenerated from leaf tissue culture and found lack of somaclonal variation. Mathius *et al*. (1998) studied the genetic polymorphism of robusta coffee germplasm in Indonesia determined by RAPD. Genetic variation in 93 genotypes of broad leaf robusta was evaluated. Coefficients of genetic similarities and genetic distances were determined by cluster analysis, and a dendrogram was obtained. The dendrogram showed that the germplasm was distributed in two major groups. However, the results indicated that genetic variation in the germplasm was quite low.

In 1999 Dussert *et al*. grouped the wild and cultivated forms of robusta coffee into five diversity groups based on analysis of RFLP polymorphism. Genetic diversity among 40 accessions of robusta coffee gene pool available in India was determined in comparison with 14 representative samples from a robusta core collection and three accessions of *Coffea congensis* using AFLP and SSR markers by Prakash *et al*. (2005). This study clearly established the high amount of diversity present in core samples, which is not represented in Indian gene pool. Further more, the three accessions of *Coffea congensis* did not exhibit any significant diversity from other robusta accessions supporting a school of thought that *Coffea congensis* forms a biotype of *Coffea canephora*.

2.6.2. Quality breeding in coffee

In coffee, the quality of bean and liquor is of paramount importance because the market and prize depend on quality standards. Between the two cultivated species, arabica gives a mild quality beverage, whereas robusta produces variable quality liquor; often its taste is 'harsh' and contains other undesirable flavours, which impair liquor quality (Graff, 1986).

For valuation of quality in coffee, physical characteristics of the bean (size, shape, uniformity, proportion of defective to wholesome beans), colour of the bean, characteristics of roasting (rate of roasting, appearance of the bean surface and the central groove and also silver skin adhering to it during and after roasting) quality of the beverage (aroma, body, acidity which compliment each other and give for each cup a known flavour) are usually considered (Vishveshwara, 1987).

Quality of coffee is assessed by the following two methods: 1.Physical/ visual evaluation of raw appearance of bean, 2. Organoleptic evaluation of the intrinsic taste of the coffee by cupping. Grading is the process of classifying coffee beans into specified grades based on their physical characteristics. The cup quality is organoleptically categorized into five classes *viz*., fine, good, fair average quality, falling off and poor, taking the three main characteristics of body, acidity and flavour into consideration (Nataraj *et al.,* 1998)

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According to Gialluly (1959), the quality of green coffee is affected by two types of factors, 1) environmental and physiological 2) genetic.

2.6.2.1. Environmental and physiological factors affecting coffee quality

The quality of coffee is not only due to the type of coffee grown but also due to the climatic factors prevailing during the developmental stages of the fruit, cultural operations inclusive of shade maintenance, nutrition and effective disease and pest control measures as well as processing at the estate and curing factory levels (Narasimhaswamy, 1987).

Attempts have been made by different scientists to determine the factors affecting quality of coffee. A trial conducted by Pulgarin (1975) confirmed the undesirable effect of Ethephon at 500 or 100 ppm in liquor quality of coffee. According to Njoroge and Mwakhe (1985), percentage of ‘A’ grade beans were higher in uncapped stems, and irrigation enhanced the quality of beans. However artificial fertilizers lowered the percentage of ‘A’ grade beans. In another study by Guyot *et al*. (1995), it was found that wet method gave improvement in quality when compared to dry method, characterized by increase in acidity and aroma, and decrease in body and bitterness. Shading and higher altitude increased the acidity and sucrose content of green coffee; high altitude delayed ripening and improved quality (Guyot *et al*. 1996).

According to Mendez *et al*. (1996) fruit quality, size and weight were the best in plants grown under shade but fruit yield was the highest in plants grown under full sunlight. Absence of stress during bean expansion and bean filling stages was necessary for maximum differentiation between genotypes for liquor traits (Agwanda *et al*., 1997). Venkatesh and Basavaraj (1998) reported that quality deterioration is taking place on estates, which lack adequate storage facilities. Mauri *et al*. (2005) suggest that high fertilizer level improved the vigour and quality of coffee seeds in *Coffea arabica.*

2.6.2.2. Genetic factors affecting coffee quality

Awatramani *et al*. (1974) evaluated the quality characters of Kents, S.785 and S.288 coffee. The highest total score was obtained by Kents, but raw bean colour and cup quality were the best in S.795. Raw bean colour was correlated with cup quality but there was no correlation between bean size and cup quality.

The beverage quality of hybrids involving *Coffea racemosa* as one of the parents was found to be good by Texeira and Fazuoli (1975). Amorim *et al*. (1976) studied physical aspects of Brazilian green coffee beans and quality of beverage. Green coffee samples were classified as soft (milk taste) and rio (phenolic or medicinal taste) with respect to beverage quality. Rio coffee had lower densities, thinner cell walls and lower cell wall/ cytosol volume ratio.

Texeira and Netto (1976) conducted a study on evaluation of the coffee quality of Catimor, HDT, Blumor and Catindu type. In many progenies the bean shape was more rounded than in arabica. The percentage of pea berries was more than 20% in some samples. The majority of progenies produced a normal beverage.

Seed thickness and the body and acidity of the liquor were found to be positively correlated with cup quality in *Coffea canephora* x *Coffea arabica* hybrids, studied by Raju *et al*. (1978). Over 50% of the quality was attributable to the above three characters of which body of liquor was found to be the most critical. According to Srinivasan and Vishveshwara (1980b) bean thickness, body of liquor and acidity showed significant positive correlation with cup quality. Liquor, body and acidity were positively correlated. Regression analysis revealed that the three characters jointly accounted for 52% of the variation in cup quality.

Selvakumar and Sreenivasan (1986) studied the morphology and quality of Ethiopian arabica coffee. It possessed good quality, acidity, body and flavour and could be considered to be the superior type. In order to find out the best cultivar, 54 accessions from Kaffa province were evaluated for cup quality characteristics. Cup grade of 10 accessions were ranked from fine to good. These accessions have fruits with long pedicel, early ripening and tolerance to wet conditions of soil. However, out turn, grade percentage, yield and tolerance to leaf rust disease varied among the accessions.

In a study by Ahmed and Sreenivasan (1988) in CxR hybrid, beverage quality was found to be fair to good. In certain individual samples 'good' acidity was noted in liquor, which is a trait of a quality beverage.

The commercial berries are graded into pea berry, A, B, C and T grades based on the physical standards of measurement and appearance. According to Sreenivasan (1988), in the breeding programme, importance is given for maximizing production of A grade beans by eliminating the triage components. Sreenivasan, in 1989 assessed the physical quality of Sln.12 (Cauvery) of arabica coffee and revealed that 70.5% of beans produced were of grade A, 3.5% grade B and 9.8% grade C.

Santaram *et al*. (1990) studied pea berry development in the parents and progenies of Devamachy hybrids. Development of pea berry was found to be associated with the availability of space in the ovary due to the pre fertilization abortion of one of the two ovules. A breeding scheme to evolve lines with reduced pea berry and empty locule production was suggested by the workers. This involves the selection of individual plants with low pea berry production and high self compatibility from the F2 progeny and further testing for fertility and adaptability.

Liquor quality of cherry and parchment samples, raw bean colour and liquor standard of four exotic robusta coffee accessions were evaluated by Ahmed and Sreenivasan (1992). Results revealed that in robusta 'brown' was the common colour, whose intensity varied in different samples. Light brown, golden brown and greyish brown gave average quality liquor, while brown with black gave poor quality liquor in cherry samples. Greyish, golden brown and greyish brown were the major colours that gave above average quality liquor in parchment coffee. Wet processing produced good quality coffee with more samples of 'average' or 'above average' liquor quality.

Roche (1995) reported that there was no correlation between bean size and quality, *i.e*., bean size was not a good indicator of cup quality while comparing cultivars from a single production area.

In a study of Moschetto *et al*. (1995), the relative importance of the clonal factor versus processing, location and harvesting date were tested. Cup quality varied among the genotypes tested and there were no interactions making it possible to breed *Coffea canephora* for cup quality efficiently.

Conversion ratios for cherry to parchment, parchment to clean coffee and cherry to clean coffee were determined for 13 coffee cultivars grown at Gera, Ethiopia by Temesgen and Michael (1995). Significant differences were found between cultivars.

Moschetto *et al*. (1996) studied the effect of genotype on cup quality of *Coffea canephora.* Significant genetic effects were observed for organoleptic characteristics within *Coffea canephora.* Typical undesirable aromas were identified with several clones. The better clones had relatively weak body, low bitterness, natural aroma and some showed slight acidity. The effects of location and harvesting date were generally non significant and no interactions with genotypes were identified.

A comparative evaluation of physical characteristics of green and roasted coffee and of the organoleptic quality of the beverage of the genotypes Catimor T 5175, Costa Rica 95, Caturra and Catuai was carried out in eight regions of Costa Rica by Roman and Vega (1998). Significant difference occurred in aroma, acidity and body. Correlation was observed between organoleptic inferiority and poor physical quality of beans.

A study was carried out for five years, in Tamil Nadu, to assess the performance of twelve arabica selections with reference to quality parameters by Manoharan *et al*. (2002). The data on raw, roast, liquor and cup qualities were recorded. Visual assessment showed variation in colour of the coffee bean of different cultivars, including bluish grey, brownish grey and greenish grey. The cup quality of Sln. 12 was FAQ$^+$ to good in 1998, Sln. 8 (HDT) was FAQ to good in 1999 and Sln. 11 was awarded FAQ to good. In all the years Sln. 5B was awarded FAQ.

Origa (2004) compared the quality of wild robusta coffee to cultivated ones. The wild variety showed a mean of 100 seed weight of 16.01 g, 11.1% moisture content, dull roast appearance, dull green raw appearance, poor centre cut, earthy and usual taste of liquor and 1.14% caffeine content. The cultivated variety showed a mean 100 seed weight of 22.1 g, 10.3% moisture content, coated roast appearance, greenish blue raw appearance, normal centre cut, neutral liquor and 0.44% caffeine content.

Giomo *et al*. (2004) reported that small and light seeds showed inferior physiological quality compared to the other types. Pea berry seeds showed physiological quality similar to flat seeds.

2.7. Hybridization and combining ability in coffee

Four basic methods of breeding and selection can be distinguished in *Coffea arabica* and *Coffea canephora*. These are tested in order of increasing complexity from line or mass selection to intra and interspecific hybridization and their application depending on breeding objectives and intended output (Vossen, 2000).

2.7.1. Intervarietal hybridization

The results of intervarietal hybridization guided by increasing knowledge of the genetical make up of the parents used may benefit the commercial production of arabica coffee (Haarer, 1962). Clonal selection had much greater promise, but even seedling families from selected crosses gave 25-50% greater yields than their mother trees (Wellman, 1961). In Java, clones from selected crosses out yielded the best seedling (Ferwerda, 1936).

Ruiz (1977) studied the variability of abnormal coffee seeds in an F_2 population of Caturra x Timor hybrid. While average values for triangular seeds and giant seeds were generally low in ten F_2 progenies, with the exception of three, in which certain trees produced large number of these defects, a high proportion of trees produced large number of empty fruits and pea berry seeds.

Tostain and Pierres (1978) studied controlled crosses between *Coffea arabica* of different origin. The study composed two diallele crosses of four components each and one of seven components. The highest heritability estimates were obtained for number of nodes per unit branch length. Two hybrid combinations were promising for both height and collar diameter. One parent of these combinations showed over dominance for collar diameter and had good general combining ability for collar diameter and number of nodes per unit branch length. It was also promising for low caffeine content. The hybrids in general were earlier and higher yielding than their parents.

Sreenivasan and Vishveshwara (1981) conducted studies on compatibility of *Coffea canephora*. To find out the best compatibility clones among the high yielding BR series, controlled diallel crosses were made using three clones of S.274 and two clones of S.270. BR_{10} clone exhibited the highest compatibility with other clones used as either of the parent, but was good as pollen parent. The highest percentage of fruit set (80.88) was observed in the cross BR_{10} x BR_{11}. Based on the above studies, biclonal and polyclonal gardens for establishing a balanced allelic pool has been suggested.

Breeding in Colombia for resistance to *Hemileia vastatrix*, based on HDT has produced resistant F_3 and F_4 progenies of the cross Caturra x HDT which equaled Caturra in yield, berry characteristics and cup quality (Zapata and Ruiz, 1982).

Coffea arabica varieties like Typia, Bourbon, Mundo nova, Caturra, Catuai etc., possess particular advantages, such as large seeds, tolerance of poor soils, high yields, disease resistance, dwarf stature, etc. and selection in the progenies of inter varietal crosses has given rise to forms which combine some of these advantages (Zapata *et al*., 1985).

Two model systems for the production of hybrid seeds of *Coffea arabica* were presented by Santaram and Ramaiah (1988). The first system is developed from the selective male sterilization of plants by chemicals. The second system exploits the competitive differences among the pollen from different inbred genotypes leading to unilateral fertilizations. Consequent hybrid production within appropriate combinations indicated that the combinations HDT x Agaro, HDT x Geisha and HDT x Cioccie were good for hybrid production.

Six *Coffea canephora* parental clones and their 30 F1 hybrids from an incomplete diallel cross were evaluated for plant height, main stem diameter, number of primary branches, susceptibility to leaf anthracnose and yield. General combining ability effects were significant or highly significant for all the traits studied, while specific combining ability was significant only of susceptibility to anthracnose. Maternal effects were significant only for vigour traits (Bouharmont and Awemo, 1990).

Charmetant *et al*. (1990) evaluated the hybrids produced in *Coffea canephora* seed gardens in the Cote d Ivoire. Analysis of data from four trials of 19 half sib progenies of hybrids between the Guinean and Congolese groups produced in triclonal seed gardens showed that eight are as productive as the control clones, the others being less productive. Further studies revealed that low value of those progenies was due to the high proportion of less productive hybrids in their ancestry.

Dharmaraj and Sreenivasan (1992) studied heterosis and combining ability in diallelic crosses involving five high yielding superior clones of *Coffea canephora*. Higher magnitude of both positive and negative heterosis was observed for growth characters. While magnitude of positive heterosis was higher than negative heterosis in yield contributing characters, BR_{10}, BR_9 and BR_5 were good general combiners and BR_9 and BR_{11} showed high SCA effects for yield.

Lashermes *et al*. (1994) studied the combining ability of doubled haploids in *Coffea canephora*. Doubled haploids were crossed with either heterozygous genotypes or doubled haploids to study their combining ability. Marked hybrid vigour was observed for all characters analyzed including yield. Large differences were evident among top crosses involving different doubled haploids produced from the same parental clone reflecting the high level of heterozygosity of clones. Factorial mating design analysis indicated that all genetic variance was attributable to additive effects in estimates of yield as well as plant height and leaf characteristics. The GCA variance component was also predominant for stem girth and susceptibility to leaf rust. Some hybrid combinations had yields comparable to standard clonal varieties.

Genetic analysis of yield and morphological traits has been carried out in *Coffea arabica* from a half diallel including the parental lines in Cameroon by Cilas *et al*. (1998). The hybrids were, on average, better performing than lines. There was no clear relationship between performance of lines and their GCA.

A factorial crossing scheme of *Coffea canephora* parents from Congolese group crossed to 14 parents of the Guinean group was used to evaluate genetic parameter of several biochemical compounds, bean weight and out turn. For most characters studied, additive genetic effects were predominant. Narrow sense heritability was high for caffeine content, fat matter content, bean weight and crop out turn (Montagnon *et al*., 1998).

Genetic analysis of different agronomic and vegetative traits was carried out of a half diallel crossing scheme in *Coffea arabica* in Cameroon by Cilas *et al*. (1999). The 7x7 half diallel comprised 21 hybrid progenies and seven parental selfed lines. Hybrids were superior to lines for all traits. There was no relationship between parental line values and their GCA. Caturra was high yielding and a good parent. On the other hand, Java, a variety selected in Cameroon, showed to be a good variety but a bad parent. Ecovalences were also estimated in order to evaluate the relative participation of each parent to SCA. Java was the most interactive parent, which might indicate a higher level of heterozygosity of this variety.

Coffee hybrids were evaluated for productivity, agronomic performance and resistance to rust and nematodes in Honduras by Pineda and Santacreo (2000). The genotypes evaluated included seven advanced progenies from four backcrosses between Catuai and Icatu, the hybrid Catuai x SH_2, SH_3 and two Sarchimor progenies. Best average production was obtained from the Catuai x Icatu progenies.

A field study was conducted in Brazil to evaluate the behavior of 28 *Coffea arabica* F_3 progenies obtained from crosses between Catuai cultivar and HDT descents. Genetic parameters and correlation coefficients among agronomic traits were estimated to determine the genetic structure and the potential of the population for future breeding programme. Yield and vegetative traits were analyzed. The progenies presented average coffee bean yields higher than the control and a high genetic variability suggesting the possibility of obtaining superior inbred lines. Some of the progenies were productive and vigorous while some were productive, vigorous and dwarf (Bonomo *et al*., 2004).

The performance of F_1 hybrid plants derived from crosses between traditional varieties of *Coffea arabica* of Latin America with a wild collection of Sudan Ethiopian origin were studied for yield, fertility and bean weight. Wild material possessed resistance to certain diseases and better beverage quality. Performance of selected hybrids was compared to those of the best parental control lines in each trial. Post zygotic ovule fertility was measured by the fraction of mature number of floating berries in water. The hybrid populations yielded 22-47% more than the maternal line, but hybrids showed significantly higher sterility and the hybrids produced 11-47% higher yields than the best line, along with significantly higher or identical

100 bean weight and performed identically for fertility (Bertrand *et al*., 2005).

2.7.2. Interspecific hybridization

Most of the species of the genus *Coffea* manifest a high degree of resistance to the leaf rust fungus *Hemileia vastatrix* and some of them possess quality traits such as low caffeine and fine aroma. Thus with the objective of obtaining material resistant to rust and having good cup quality, interspecific hybridization was performed by Narasimhaswamy and Vishveshwara (1961; 1967). There would be very little hope of any economic gain from interspecific hybridization if it is not for new knowledge of how to vary the chromosome count by chemical means (Haarer, 1962).

Jayanthi Ramamurthy *et al*. (1992) studied the relationship between pollen volume and style length and their possible influence on interspecific hybridization in the genus *Coffea*. Study of 13 coffee species indicated that in general, pollen volume was highly correlated with style length. In those instances where seed set occurred from interspecific crosses the male parent of the cross had a lower pollen volume: style length ratio.

Various factors acting as barriers of reproduction among sister plants of F_1 progenies of six interspecific hybrids involving six diploid species of the genus *Coffea* were studied by Santaram *et al*. (1992a). The osmotic concentration of the protoplasm of the pollen and stigmatic tissue and the reduced genetic variability of the hybrid population with regard to self sterility alleles were proposed to be the possible barriers of reproduction and thus the cause of sterility in these hybrids.

Several scientists have made attempts to cross the cultivated species of coffee *viz*., *Coffea arabica* (2n = 44) and *Coffea canephora* (2n = 22), with the objective of introgressing disease resistance into arabica or improved liquor quality into robusta (Vossen, 2000).

Williams (1972) suggest a method for differentiating between *Coffea arabica* and *Coffea canephora* plants and their hybrids using leaf surface characters. The frequency of stomata was the highest in *Coffea canephora* and smallest in *Coffea arabica*. Stomatal size increased with chromosome number. *Coffea canephora* leaves showed a high density of venation and the proportion of the palisade tissue to mesophyll tissue was also high. All these characters were intermediate in hybrids.

Capot (1972) reported an arabusta (*Coffea canephora* x *Coffea arabica*) material, which is both self fertile and intercompatible. Two families contained promising individuals, the best of which produced 12 kg of berries in the 3rd year. Bean size and liquor quality showed substantial improvement over robusta. Caffeine content ranged from 1.5 to 2%.

Orozco and Cassalett (1974) studied the relation between stomatal characters and chromosome number in an interspecific coffee hybrid *Coffea arabica* (2n = 44) x *Coffea canephora* (2n=22) and their triploid and hexaploid hybrids and back crosses to *Coffea arabica* showed that number of stomata per mm^2 tended to be positively correlated to number of chloroplasts in guard cells and adjoining cells and ploidy level. Stoma size was greater in the hexaploid and the back crosses than in the triploid hybrid on the parental species.

Capot and Assi (1975) reported a new hybrid from Ivory Coast, derived from *Coffea arabica* x (*Coffea arabica x Coffea canephora*). It differed from *Coffea canephora* in being shorter and having thicker fruits and flowers, the former being numerous and spherical.

Vishveshwara and Srinivasan (1977) studied qualitative inheritance in *Coffea canephora* and *Coffea arabica*. The mean flower number per inflorescence was 2.7 in *Coffea arabica* Kents and 4.2 in *Coffea canephora* S. 274, while in the F_1 hybrid between them it was 3.2, with the frequency distribution skewed towards the *Coffea arabica* parent. Back crosses to *Coffea arabica* showed greater variation than in the parents and F_1 and mean flower number in the first and second back cross generations was 3.1 and 2.8 respectively. The mean number of flowers per inflorescence of the spontaneous robusta x arabica hybrid Devamachy was 2.8 and that of *Coffea arabica* S.881 was 3.1. The F_1 hybrids also had a mean of 3.4 and two F_3 progenies had a mean of 2.8 and 3.4 respectively. Heritability of the character was estimated as 42%. Expected genetic advance for the F_2 mean in the second cross given a 5% selection pressure, was 12.65%.

According to Chaves (1978), hybrids of *Coffea arabica* x *Coffea canephora* such as HDT and Icatu, included high percentage of resistant plants belonging to group A in their progenies. Progenies of Catimor included plants of good agronomic quality and various levels of vertical resistance.

Srinivasan *et al*. (1978) studied the pattern of fruit growth and development in interspecific hybrids of *Coffea canephora* x *Coffea arabica* and found that near maximum fruit size was attained much earlier than fruit weight, which showed that further increase in fruit weight was mainly due to changes in the internal components of the fruit, such as endocarp and endosperm.

The F_1 hybrids crossed between four tetraploid *Coffea canephora* clones and *Coffea arabica* varieties were taller with thick stems, longer primaries, longer internodes, higher extension growth, a higher percentage of flowering nodes and more flowers per node than *Coffea arabica*. No increase in yield occurred since the interspecific hybrids were less pollen and female fertile than the parents (Owuor and Vossen, 1981).

Hexaploid hybrids were produced by doubling the chromosome number of the sterile progenies resulting from a *Coffea arabica* x *Coffea canephora* cross by Pierres and Anthony (1981). The quality and the ecological preferences of the hybrids were found to resemble those of *Coffea arabica.*

Hybridization between *Coffea arabica* cultivars and induced tetraploid *Coffea canephora* was started in 1973 in Kenya. The F_1 hybrids were vigorous but highly variable and generally had low fertility. Normal fertility was restored in the BC_1 and BC_2 to *Coffea arabica*. Although bean size and liquor quality of the hybrids were inferior to those of arabica material, they were better than those of robusta. It is considered that selections from BC_1 and BC_2 can be grown at lower altitudes (Vossen and Owuor, 1981).

Carvalho (1983) studied the crosses between *Coffea arabica* and *Coffea canephora* in Brazil. After repeated back crossing of F_1 to *Coffea* *arabica* culltivars Mundo novo, Catuai or Caturra, the plants were assigned the group name Icatu. They were self fertile and vigorous, producing high yields of high quality beans, with only a few pea berry types and some individuals with resistance to *Hemileia vastatrix*. Some showed resistance to *Meloidogyne exigua* and *Meloidogyne incognita*.

Yapo (1988) studied the influence of the direction of crossing on fertility and vegetative behaviour of arabusta hybrids and found that male and female fertility was the highest in *Coffea canephora* as the female parent. Vigour was unrelated to the direction of crossing and depended on the specific combination.

Cup quality of interspecific hybrids of coffee has been investigated by Carvalho *et al*. (1990) and found that *Coffea arabica* x *Coffea dewevrei, Coffea canephora* x *Coffea arabica* and *Coffea racemosa* x *Coffea arabica* were superior.

Premkumar and Ramanarayan (1992) reported a plant with vigorous growth in a private estate. Phenotypically the plant was intermediate to robusta and arabica genotypes, but yield was poor with high percentage of pea berry. Hence the plant may be a triploid originated from natural cross between *Coffea canephora* x *Coffea arabica*.

Interspecific hybrids between arabica and induced tetraploid of robusta plants were backcrossed to arabica and the resulting genotypes were evaluated in Kenya by Omondi and Owuor (1992). Stem girth, plant height, internode length, and length of longest primary, all significantly differed between genotypes. Yield also differed. Yield stability analysis revealed that the backcrosses had specific adaptation to marginal environments.

Rabemiafara *et al*. (1997) develped a new family of tetraploid three way hybrid of coffee, Ratelo, created through a prior chromosome doubling of F_1 of *Coffea eugenioides* and *Coffea canephora*. The resulting tetraploid was then crossed with *Coffea arabica*. It was then selfed and intercrossed. This new type of coffee is expected to combine the adaptability of *Coffea canephora*, the low caffeine content of *Coffea eugenioides* and flavour characteristics of *Coffea arabica.* Hybrids are small trees of reduced height, compact habit resulting from the branching pattern of numerous secondary and tertiary branches with short internodes. They are partially autogamous and tolerant to stem miners. Although heavy flowering suggested a high production potential, abnormal fruit development was observed. Clonal selection within the population yielded 2% of genotypes producing 10 kg of berries per stem per year. Flavour was much appreciated by panelists.

Observations on biological and agronomic traits were made on wild coffee hybrids between *Coffea arabica* and *Coffea canephora* by Jagoret *et al*. (1999). The hybrid nature of this planting material was confirmed and it was classified into two distinct groups, one of type 3C plants containing triploid hybrids, the other of 4C plants containing tetraploid hybrids. The results obtained showed that the level of ploidy had significant effect on most of the characters observed.

The effect of the percentage of floaters and pea berry seeds in the yield of 31 F_1 arabusta hybrids and *Coffea canephora* and *Coffea arabica* progenies were studied by Vacarelli *et al*. (2003). The arabusta hybrids recorded high percentage of floaters and pea berry seeds. The fruit and seed attributes reduced the average yield of hybrids (28%) relative to the average yield of the parental species (50%).

Santaram (2004) has described Sarchimor, a new coffee cultivar released from Central Coffee Research Institute of India for its good yield potential, high resistance to leaf rust, good vegetative vigour and well balanced reproductive features, derived from Villasarchi (mutant of *Coffea arabica* cv. bourbon) x HDT (*Coffea arabica* x *Coffea canephora*). It has high yield potential and high frequency of 'A' grade beans.

With the objective of obtaining material resistant to rust and having other good qualities, experimental hybridization of cultivated species of coffee to wild species was practiced by different scientists. Filho *et al.* (1976) described the characteristics of germplasm derived from *Coffea arabica* x *Coffea racemosa* and its potential in coffee breeding. Resistance to *Leucoptera* species was found in two hybrids of *Coffea racemosa* x *Coffea arabica* back crossed to *Coffea arabica*. One of these was self incompatible, had dark green fruits like those of *Coffea racemosa* and 45 chromosomes. A large number of aneuploids were found amongst its open pollinated progeny. The other was very similar to *Coffea arabica* in leaf and fruit coloring, stomatal density, habit, maturity date and quality of beverage. It was self fertile and had 44 chromosomes. Amongst its progeny resulting from selfing were six plants with 44 chromosomes, two with 45 and one with 43 and one with 46. Six triploid artificial hybrids from *Coffea arabica* x *Coffea racemosa*, 3 triploid natural hybrids and two back crosses of *Coffea racemosa* x *Coffea arabica* to *Coffea arabica* showed resistance to *Perileucoptera coffeella* and drought, while two varieties of *Coffea arabica* were susceptible to both (Filho *et al*., 1977).

Interspecific hybrids between *Coffea racemosa* and Sln. 3R (a hybrid between *Coffea congensis* and *Coffea canephora*) were evolved with an objective of developing varieties with low caffeine content and early ripening behaviour. Hybrid plants exhibited intermediate growth habit with regard to characters like leaf size and internode length. The hybrids recorded lesser fruit size and fruit weight when compared to both the parents. The percentage of floats also was found to be higher in the hybrids. With regard to maturity of fruits the hybrids resembled the female parent (Suresh kumar *et al*., 2004).

Seeds from open pollinated flowers collected from hybrids of several coffee species were analyzed for caffeine content by Mazzafera and Carvalho (1991). The caffeine content was not always intermediate to that of the parents and both higher and lower values were found. Diploid F_1 hybrid between accessions of *Coffea eugenioides* x *Coffea salvatrix* showed the lowest caffeine content. Seeds of tetraploid hybrids of *Coffea arabica* x *Coffea salvatrix* and *Coffea arabica* x *Coffea eugenioides* hybrids presented low caffeine content.

An early maturing (180 days from flowers to fruit) somaclonal population selected based on arabica and racemosa hybrids; highly resistant to drought has been developed by Sondahl *et al.* (1997).

Raina *et al*. (1998) reported that, *Coffea congensis* and *Coffea eugenioides* are the diploid progenitors of *Coffea arabica.* Genomic *in situ* hybridization and fluorescence *in situ* hybridization was used to study the genomic organization and evolution of this species.

Santaram *et al*. (2002) conducted genetic finger printing of coffee hybrids produced from Ligenioides x HDT. The results showed large genetic similarity between HDT and Ligeniodes and their F_1 hybrids. Cluster analysis classified both parents and some of their hybrids into one group. The results indicated that Ligenioides can be a potential source of new genes for breeding arabica coffee.

Reddy *et al*. (1985) studied the breeding behaviour of Ligenioides (spontaneous amphidiploid between *Coffea liberica* x *Coffea eugenioides*). The hybrid was often self fertile and easily crossable. The hybrid had an average fruit fertility of 67.3% and high yield potential but needs to be improved further for fruit, bean size and early ripening.

Reddy (1986) studied phenotypic variability, association of several morphological characters and relative genetic potency ratios in three diploid species and their F_1 hybrids with a view to explore the vigour of the latter. Relatively high variation of different morphological characters was obvious in the F_1 hybrids of *Coffea excelsa* x *Coffea eugenioides* than those of *Coffea liberica* x *Coffea eugenioides* and the variation in the parents is attributed to their cross fertile nature. Relative genetic potency of the parents showed that in both the crosses *Coffea eugenioides* had a greater role in imparting its character to the F_1 hybrids. Therefore, identification of compatible hybrid plants and subsequent sib mating is suggested for full expression in such progeny.

Ky *et al*. (2001) studied the inheritance of the alkaloid trigonelline in the interspecific hybrid of *Coffea pseudozanguebariae* x *Coffea liberica* var.

dewevrei. Trigonelline is present in coffee beans and during roasting it gives rise to the major coffee aroma compounds. Trigonelline content was measured by HPLC in both parental species; F_1 hybrids and the reciprocal back cross hybrids. The results showed that, on the average *Coffea pseudozanguebariae* accumulated twice as much trigonelline as dewevrei. Trigonelline showed high heritability (71%). Similar level of trigonelline content was seen in *Coffea pseudozanguebariae*, F_1 and both back crosses, *i.e.*, the male and female parent, all having the same maternal cytoplasm.

As robusta coffee is crossable with many of the diploid species, attempts were made to evolve interspecific hybrids of this species with other wild species by different workers. Eight *Coffea canephora* robusta trees and eight Guarini, six *Coffea congensis* 'Uganda' and eight Banglean plants were used in a hybridization study, together with certain pollen mixtures by Monaco and Carvalho (1972). Low fruit set occurred in intravarietal crosses within the variety Guarini, but higher figures were obtained when pollen mixtures of robusta were used.

Texeira and Fazuoli (1975) studied the quality of interspecific hybrid progenies, and found that the beverages of *Coffea canephora* and *Coffea congensis* were characterized as robusta and that of *Coffea racemosa* x *Coffea arabica* was good. The F_1 hybrids from crosses involving five *Coffea canephora* clones and *Coffea eugenioides* had leaf length, width and number of stomata/mm^2 were intermediate between the parental values and fruit size and weight close to that of *Coffea canephora*. The F_1 hybrids, like the parents had 2n = 22 and were self sterile. The caffeine content of the F_1 was intermediate between the parental values. The F_1 has resistance to *Hemileia vastatrix* like *Coffea canephora* (Louarn, 1976).

Ahmed *et al*. (1977) studied the flower number per inflorescence, inflorescence per node and flowers per node in *Coffea congensis, Coffea canephora,* their F_1, F_2, backcrosses and progenies from back crosses to robusta. The parents differed for all the three characters with higher number in robusta. F_1, F_2 and BC_1 showed intermediate values, while BC_2 showed values nearer to robusta. Parent- offspring correlations and heritability for all the three characters were low.

Lanaud (1979) conducted a study in F_1 hybrids from *Coffea kianjavatensis* x *Coffea canephora* and their BC_1 to *Coffea canephora*, cytologically and for 13 vegetative and flowering characters. Both species were diploid with 2n = 22. The F_1 had 7% pollen fertility and its habit, the colour of its young leaves and also its flowering date resembled those of *Coffea kianjavatensis*. The leaves were intermediate in length between the parental species and the multifloral inflorescences were like those of *Coffea canephora*. In BC_1, the unifloral inflorescences and the flowering on old wood found in *Coffea kianjavatensis* were not observed, internode length was in some cases shorter than that in either parent and flowering date tended to be that of *Coffea kianjavatensis*. Other characters of the BC_1 were intermediate between the values of the parental species.

Santaram *et al*. (1982) studied the pollen fertility of interspecific hybrids of coffee. The pollen stainability and germinability (brackets) obtained were as follows: *Coffea congensis* x *Coffea eugenioides* 89.6% (76.2%), *Coffea congensis* x *Coffea canephora* 81.1% (27.6%), *Coffea canephora* x *Coffea eugenioides* 96.2% (85.3%), *Coffea canephora* x *Coffea liberica* 82% (53.6%), *Coffea excelsa* x *Coffea eugenioides* 59.6% (18.6%), *Coffea racemosa* x *Coffea canephora* 13.5 (1.7%) and *Coffea liberica* x *Coffea eugenioides* 15.5% (14%).

A total of 39 F_1 hybrids were obtained from 50 controlled crosses among 13 *Coffea* species by Louarn (1983). *Coffea canephora* was crossed successfully with all twelve of the other species and *Coffea eugenioides* with ten others. *Coffea brevipes* was crossed successfully only with two species. In the five species considered the most important for coffee breeding (*Coffea canephora, Coffea congensis, Coffea eugenioides, Coffea liberica* and *Coffea dewevrei*), all reciprocal crosses were successful. Some hybrids such as those between *Coffea racemosa* and *Coffea canephora* were virtually sterile despite having up to 45% of PMCs with 11 bivalents.

Hybrids between the two cross fertile and distant diploid species (2n = 22), *Coffea racemosa* and *Coffea canephora* var. robusta were studied and found that high sterility barriers were in operation as reflected in the diploid F_1 hybrids. Under open pollination there was some fruit set, which gave rise to F_2 population with varied chromosome number. Fertility was not determined by the chromosome affinity shown in certain percent of cells in F_1 and F_2 hybrids (Reddy *et al*., 1988).

In a study of diploid F_1 hybrids between *Coffea canephora* and seven other species, only *Coffea canephora* x *Coffea congensis* showed adequate fertility for use in a breeding programme. With a fertility restoration phase, the most promising of the remaining combinations was *Coffea liberica* x *Coffea canephora* (Lauarn, 1988).

Yapo *et al*. (1990) evaluated 3840 coffee trees representing F_1, F_2 and BC_1 of *Coffea canephora* x *Coffea congensis* families as well as three *Coffea canephora* clones. Although some of the F_1 hybrids showed promise in terms of habit and cup quality, they were generally poorly adapted to field conditions in the Ivory Coast. Some BC_1 families showed good drought resistance but vigour and yield were generally poor. However, some trees were selected in BC_1 for further breeding.

Sib mating in C x R coffee was studied for further improvement by Nikhila *et al*. (2002). Transgressive variation was found in Sib_1 and Sib_2. The potentiality of selection at the levels of Sib_1 and Sib_2 for the exploitation of transgressive variation has been reported. Selection at Sib_1 level is more advantageous since it showed better transgressive segregation.

Male sterility of interspecific hybrids was analyzed in one F_1 and two backcrossed progenies originating from a cross between *Coffea canephora* and *Coffea heterocalyx* by Coulibaly *et al*. (2003). Male fertility was tested using pollen stainability with acetic carmine. The results showed a marked decline in fertility at the F_1 level and fertility was almost fully restored after two back crosses. The computed broad sense heritability represented 47% of the variance.

2.7.3. Intergeneric hybridization

Production of intergeneric hybrids also has been attempted in coffee. Immature embryos resulting from three intergeneric crosses involving *Coffea canephora* var. robusta (S.274) as the common female parent and three indigenous wild species, *Coffea travancorensis*, *Coffea bengalensis* and *Coffea wightiana* (later renamed as *Psilanthus travancorensis*, *Psilanthus* *bengalensis* and *Psilanthus wightianus* by Sivarajan *et al*., 1992) as different male parents were cultured in modified MS medium. Many hybrid plantlets were rescued by the above method and established in soil. The studies were taken up in the view to combining the agronomic properties of *Coffea canephora* with some useful characters of the wild species, especially the low caffeine content (Sreenath *et al*., 1992).

Hybrids between *Psilanthus ebractolatus* (2n = 22) and *Coffea arabica* (2n = 44) were successfully produced by crossing at the tetraploid level. Only nine plants survived after five months of growth. Hybrid status was confirmed by means of cytological and molecular methods. For most of the morphological characteristics analyzed, hybrids appeared intermediate between the two parental species (Couturon *et al*., 1998).

2.8. Adaptability of coffee to different agro climatic conditions

Yield, plant vigour, disease resistance and quality were considered to be the main criteria in both arabica and robusta breeding (Vossen, 2001). Besides these, the interaction between genotype and environment also influences plant growth and yield in coffee. The performance of coffee varieties varies significantly from one location to another (Srinivasan *et al*., 1979). This is due to the interaction between genetic components and the environment (Ahmed *et al*., 1995). Outstanding performance of a new variety on the trial fields of an experimental station does not offer a guarantee as to its behaviour under other climatic and edaphic conditions. The necessity of trials to assess local adaptability has been emphasized in various countries.

Besides breeding for resistance to pests and diseases, recognition of plant types for different eco climatic conditions is also necessary (Vishveshwara, 1975). Srinivasan and Vishveshwara (1978) studied the stability for yield in some coffee selections under multilocation trials. Varieties in the multilocation test showed greater sum of squares due to deviation from linear regression, which needs for conducting such trials with other varieties and solution for a more reliable assessment of stability in coffee.

Capot (1978) studied the performance of *Coffea arabica* collections in the Ivory Coast planted at two localities. The collection was less susceptible to *Hemileia vastatrix* than Ivory Coast varieties. At one locality, at high altitude the highest yielding populations gave yield similar to those they gave at low altitude. The mean yield at high altitude was higher than at low altitude. Yield showed a genotype x locality interaction.

Bouharmont (1978) studied the performance of 70 *Coffea arabica* collections planted in Cameroon. Data were tabulated for two localities. Over four years, three populations gave over 10 kg fruits/tree. 21 populations remained free from the attack by *Hemileia vastatrix*.

In a study, the *Coffea arabica* cv. Catuai Rojo was compared at three localities with five other cultivars. The cultivar Catuai Rojo outyielded all the other cultivars (Benavides and Gutierrez, 1978).

Evaluation of five cultivars for environmental adaptability demonstrated significant variation attributable to cultivars, year and cultivar x year interaction in an experiment by Srinivasan *et al*. (1979).

Dwarf plants of San Ramon hybrid were studied for variation in four localities by Srinivasan (1981). A wide range of variation was observed at each location, which indicated the prominent interplay of genetic and environmental factors. Analysis of variance within location and between locations revealed the greater and significant magnitude of latter in relation to the former indicating the differential growth of the same variety in different locations, which suggested the better adaptability of this hybrid to some locations.

Srinivasan (1984) studied the performance of arabica varieties at different locations in Coorg. Mean yield and stability of yield of some *Coffea arabica* selections, trained on topped single stem under shade were studied at three locations in Coorg based on six annual yields. Significant differences were found between varieties at all the locations.

Nine selections of arabica at eleven locations in Coorg were studied with respect to mean yield, coefficient of variation and stability for yield based on yield records by Srinivasan (1985b). Five selections of robusta planted in five estates were studied with respect to the same character. A comparison of stability parameters revealed S.795 and Sln.8 to possess general adaptability, while Sln.7, Cioccie and Agaro showed location specific adaptability.

A study of the growth parameters and yield of different coffee selections by Dharmaraj (1985) revealed that Sln.7, Sln.7.2, Sln.4A, Sln.11 and Sln.5 were promising for large scale cultivation under the eco climatic and edaphic conditions of Andhra Pradesh. Reddy (1985) reported that selections such as S.795, S.1934, Sln.4A, Sln.4C and Sln.7.2 in arabica and S.274 in robusta had adapted well to the northern and north eastern climatic regions (Andhra Pradesh, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Orissa and Tripura) as reflected in their yields.

According to Gopal (1985) the results of growth and yield obtained indicated that Sln.7, Sln.7.2, Sln.4, Sln.11 and Sln.5 were promising and suitable for large scale cultivation under the eco climatic and edaphic conditions of Andhra Pradesh.

Cornide *et al.* (1988) suggested a method for classifying assessment of environment for lines of *Coffea arabica* undergoing selection. This method involves the comparison of 24 environments defined by 11 variables (6 morphological and agronomic and 5 climatic). The environments were represented by the combination of the plots of three trails with eleven *Coffea arabica* lines at three sites. Main component analysis allowed differentiation of all sites and years in all environments, except those above 750 m. Most of the total variability was due to climatic variables. The genotype index method showed that the highest yield did not occur in these areas. High temperature (22-35.4ºC), high relative humidity (74%) and low rainfall (1219 mm) were not satisfactory for genotype differentiation.

Ameha and Belachew (1988) studied the genotype x environment interactions in coffee. In six years of trial at four sites in Ethiopia in which 17 high yielding selections were evaluated for yield and five other characters, they found that there were highly significant genotype-environment interactions for yield and its components. All the highest yielders originated from the intermediate altitude. No selection performed well at all sites. 12 hybrids showed good specific and general adaptability.

Santaram *et al*. (1992b) studied the growth and yield performance of selections of coffee in R.V. Nagar, Andhra Pradesh. Number of primary branches, number of nodes per primary, length of primary, bush spread and plant height showed significant variation among the selections. Sln.7 produced maximum number of primaries and number of nodes per primary. Because of the dwarf and compact nature, the plant showed the lowest height, length of primary and bush spread. Stem girth, bush spread, number of nodes per primary and yield per plant showed significant variations among the years.

Kiara (1993) studied the adaptability of rust resistant varieties of coffee in Papua New Guinea. Ten Catimor plants from Australia and Portugal and five developed from the cultivar colombia from Kenya were evaluated for adaptability trials in different ecological zones. Catimor cultivars grew well in traditional arabica coffee growing areas and six of them were recommended for commercial planting. Lines evolved from cv. colombia were recommended for further selection as they were less advanced.

Ahmed *et al*. (1995) studied the performance of five arabica coffee selections *viz.*, S.795, Sln.5, Sln.6, Sln.8 and Sln.9 in different agro climatic zones of Karnataka and Tamil Nadu. The survey showed varied performance of different cultivars in various zones. In Chikmagalur zone, S.795, Sln.5 and Sln.9 were the top performers. In Aldur/Mudigere, Sakleshpur/Somwarpet and Coorg zones, Sln. 5, Sln.6 and Sln.8 showed better performance. In Pulneys Sln.5, Sln.6 and Sln.9 averaged higher than others. Considering the performance over all the zones, Sln. 8 and S.795 indicated better yield responses to favorable environment, while Sln.5 showed marginal response. The differential performance of cultivars is attributed to interaction between their genetic complements and the environment.

Raju *et al*. (1996) studied the performance of Central Coffee Research Institute released arabica selections in Pulney in Tamil Nadu, to evaluate the performance under north east monsoon conditions. Growth parameters, yield and bean quality were compared. Stem girth, number of pairs of primaries and bush spread did not influence yield or bean quality. Yield data recorded at Tamil Nadu indicated that Sln.5 followed by Sln.10 were the best performers.

Agwanda *et al.* (1997) studied genotype by environment interaction and its implication on selection for improved quality in arabica coffee. Twenty two complex hybrid varieties and two controls were planted in five locations in Kenya and found that bean and liquor traits were antagonistic in terms of environments necessary for their expression.

Ratageri (2000) studied the performance of C x R coffee in Koppa liaison division, Karnataka. Observations showed that the C x R hybrid could establish well with good performance and higher yield. It was very responsive to irrigation for higher yields.

An adaptability trial with six Catimor (*Coffea arabica*) lines was conducted at Omuru at Pupua New Guinea at an altitude of 400 m a.s.l. It was found that Catimor can be grown in the coastal areas at 400 m a.s.l. but the yield was not economical. Empty cherry locules and bean defaults (59%) were dominant for the lines observed (Tevo *et al*., 2001).

Wamatu and Thomas (2001) studied the ecological variability in yield of selected clones of arabica coffee. Cherry yield of 11 elite clones was evaluated over a five year period in Kenya to determine the extent and influence of clone x environment interactions. In an analysis of variance, significant main effects and non significant clone x environment interactions were found. Interactions were however, further investigated using ecovalence values, the Eberhart and Russell regression model as well as the additive main effects and multiplicative interaction effects model. The clones were then clustered according to their response patterns using principal component and cluster analysis to obtain a delineation of ecological districts and more accurate predictions of clone performance. The adaptability and stability of different lines of the coffee varieties Lempira, Sarchimor and IAC were evaluated in five zones of Honduras by Santacreo *et al*. (2002). All lines of Lempira except one line had high capacity for adaptation and potential productivity. Two lines of Sarchimor had high capacity for adaptation and stability.

The above study of literature reveals the potential of robusta coffee as one of the rich genetic resources of coffee. Eventhough some efforts have been made in different parts of the world to assess the variability and to exploit the same for the development of improved planting material, only limited efforts have been made in India. Wayanad region of Kerala state of India is a traditional coffee growing area where robusta coffee is cultivated traditionally. Much effort has not been made so far to screen the genetic resources of robusta coffee in the area and to select superior ones from them so as to develop new and improved planting materials suitable for the area. The present effort is such a step which is envisaged to screen the diversity of the robusta germplasm maintained at Regional Coffee Research Station, Chundale, Wayanad, Kerala and to identify superior genotypes from it. An effort has also been made to study a hybrid population of coffee produced by *Coffea racemosa* x *Coffea canephora* var. robusta crosses and maintained in the experimental garden of Regional Coffee Research Station, Chundale, Wayanad, Kerala. Comparative analysis of the performance of robusta coffee in two traditional coffee growing areas of South India has also been attempted.

Chapter III

MATERIALS AND METHODS

Coffee, one of the most important non-alcoholic beverages of the world, is yielded by two species of the genus *Coffea* namely *Coffea arabica* and *Coffea canephora*. Among the different varieties of *Coffea canephora*, var. robusta is the most popularly cultivated. *Coffea arabica* is tetraploid and autogamous whereas *Coffea canephora* is diploid and allogamous. *Coffea canephora* is a low land coffee suited for cultivation at an elevation ranging from 500-1000 meters above sea level. As majority of coffee areas in Kerala come under the elevation between 500-1000 meters above sea level, in more than 85% of the coffee areas robusta is cultivated.

The present experiments have been designed to study the genetic variability, correlation of characters, character association, genetic divergence and genetic control of characters, to select superior genotypes from the germplasm, to study the progenies of interspecific hybrids of crosses between *Coffea racemosa* and *Coffea canephora* var. robusta cv. S.274 and to study the adaptability of robusta coffee to two conventional coffee growing regions of South India.

3.1. The experimental field

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

The experimental field at Regional Coffee Research Station, Chundale, Wayand is located at an altitude of 840m above mean sea level. The annual rainfall of this area ranges between 2000-3000mm of which 80% is the contribution of southwest monsoon and the rest that of northeast monsoon. Blossom showers are received during February/March and supporting backing showers are received during March/April. This area experiences a dry spell for a period of three months from December to February with occasional rains in between. It has an average humidity of 88.9% and an average minimum and maximum temperature of 17.6 ^{0}C and 27.3 ^{0}C. The soil of this station is generally lateritic to laterites. The soil structure varies from sandy to clayey loams with the soil pH varying from 5.2-6.3. Organic carbon content is medium and phosphorous and potassium status is low to medium. For adaptability studies a survey was conducted in the estates of Wayanad district of Kerala and Coorg district of Karnataka.

Wayanad is a conventional coffee growing area and a revenue district of Kerala state of India situated at an elevation ranging from 700m to 2100m above MSL. Wayanad lies between north latitude 11^0 27' and 15^0 58'and east longitude 75^0 47' and 70^0 27' (Anonymous, 2005). It is blessed with warm humid climate with an average rain fall of about 2500mm to 3000mm. The mean minimum temperature ranges from 14.5^{0}C to 20.2^{0}C and mean maximum temperature from 25.1^{0}C to 30.6^{0}C respectively. Relative humidity is very high, up to 90% during the southwest monsoon period. The soil belongs to red and lateritic group and differs in texture from sandy loam to clayey loam with colour varying from light grey to deep grey. The soils are acidic in nature and rich in organic matter (Tables 3.1 and 3.3).

Coorg or Kodagu is the smallest district of Karnataka, but is the leading district of India in coffee production. The river Cauvery divides the district into two parts called north Coorg and south Coorg. South Coorg has a warmer climate where robusta performs well (Srinivasan and Ahmed, 1998). Coorg lies between latitude 11º55’ and 12°50’ N and longitude75º25’ and 76°40’E, elevation ranging from 750-1100 meters above MSL (Anonymous, 2007c). Coorg enjoys moderate to cool climate of a hill station, with an average rainfall of about 1000 mm to 2500 mm. Winters are pleasant at 15-20^{0}C but in December - February temperature often drops to 9^{0}C. Summers are pleasantly sunny at 25-28^{0}C while the monsoon months of June - August are besieged with heavy rainfall and are cool, humid and wet. The soils are acidic and rich in organic matter (Tables 3.2 and 3.3).

Organic carbon content ranged from low to medium both in Wayanad and Coorg. Available Phosphorus content ranged from low to high in Wayanad and low to high in Coorg. Available Pottassium ranged from low to high both in Coorg and Wayanad (Table 3.3).

Table 3.1. Weather data of Regional Coffee Research Station, Chundale, Wayanad, Kerala during the experimental period

Year	Month	Rainfall (mm)	Temperature (^{0}C)	

			Minimum (Mean)	Maximum (Mean)	Relative humidity (%)
2002	January	22.8	16.2	26.0	88.0
	February	40.2	17.8	28.9	82.9
	March	26.6	19.8	32.2	71.0
	April	182.8	19.9	31.6	80.7
	May	137.4	20.3	32.5	80.9
	June	447.2	19.6	27.0	87.5
	July	351.8	19.9	24.9	90.5
	August	519.4	19.7	25.4	91.8
	September	44.2	18.2	27.6	81.1
	October	440.6	19.5	27.0	87.4
	November	87.2	18.8	27.2	89.5
	December	2.8	14.7	27.1	87.5
2003	January	30.2	16.2	28.1	84.7
	February	37.4	19.6	29.6	83.2
	March	49.2	19.9	32.1	80.6
	April	77.5	20.5	32.4	82.9
	May	72.8	20.4	30.5	77.9
	June	15.8	20.0	30.6	90.2
	July	545.8	21.5	23.5	93.9
	August	356.2	19.8	25.7	92.3
	September	80.0	19.9	27.4	85.6
	October	272.0	19.8	28.3	90.0
	November	46.8	18.2	28.6	79.3
	December	0.0	14.5	28.7	80.8
2004	January	0.0	18.8	30.6	74.6
	February	13.4	20.4	33.0	75.0
	March	5.4	20.7	32.9	72.6
	April	154.0	20.1	32.5	76.0
	May	382.6	20.0	28.0	88.3
	June	915.4	19.4	24.4	92.4
	July	532.0	19.7	24.9	92.3
	August	569.4	19.6	24.5	91.3
	September	170.7	19.5	27.6	83.8
	October	196.2	18.8	27.0	85.9
	November	110.4	18.1	26.9	87.7
	December	0.0	16.0	26.9	78.3
2005	January	91.2	16.9	27.0	78.6

	February	4.6	19.3	27.6	78.5
	March	14.8	20.3	29.8	77.4
	April	188.6	20.1	28.6	84.3
	May	73.8	20.6	30.4	80.1
	June	557.0	19.4	26.1	89.5
	July	1277.4	19.7	23.5	93.4
	August	532.0	20.1	25.0	91.5
	September	370.2	20.3	25.3	90.1
	October	327.0	20.0	27.4	87.6
	November	94.6	17.9	26.8	88.1
	December	1.8	17.7	27.6	82.4

Table 3.2. Weather data of Coorg during the experimental period

Year	Month	Rainfall (mm)	Temperature (^{0}C)		Relative humidity (%)
			Minimum (Mean)	Maximum (Mean)	
2004	January	0.8	15.6	28.0	81.5
	February	1.2	16.7	30.7	73.5
	March	38.2	18.8	32.7	76.0
	April	95.6	19.4	31.5	89.9
	May	179.5	19.6	27.0	97.0
	June	352.6	19.2	25.2	98.4
	July	112.6	18.9	24.6	99.0
	August	111.2	18.6	24.3	98.8
	September	69.0	18.4	26.8	96.0
	October	166.0	18.5	26.7	95.7
	November	0.0	16.9	26.1	91.2
	December	0.0	15.0	27.1	83.3

Table 3.3. Soil data of Wayanad and Coorg during the study period

Particulars	Wayanad (Range of the estates studied)	Coorg (Range of the estates studied)	Optimum requirement of coffee soil (Anonymous, 2005)
1. Soil pH*	4.10 - 6.80	5.50 – 6.00	6.20
2. Organic Carbon (%)**	0.76 – 2.45	0.25 – 2.50	0.50 – 2.50
3. Available	4.00 - 47.00	9.00 – 60.00	10.00 – 22.00

Phosphorus (kg/ha)***			
4. Available Potassium (kg/ha)****	75.00 – 425.00	115.00 – 260.00	126.00 – 250.00

*: Below 6- Acidic; 6-7: Normal/ Neutral; Above 7: Alkaline

**: Below 1: Low; 1-2.5: Medium; Above 2.5: High

***: Below 9: Low; 9-22: Medium; Above 22: High

****: Below 125: Low; 125-250: Medium; Above 250: High

3.2. The experimental materials

3.2.1. Robusta coffee accessions

Coffea canephora Pierre ex Froehner var. robusta is popularly known as robusta coffee. It is a diploid species with 2n = 22. It is a bigger bush when compared to arabica coffee plants. The leaves are broader, larger and pale green. Flowers are white, fragrant and are borne in larger clusters than in arabica. Under the conditions of South India, the buds initiate and reach maturity during November – February and precipitation (blossom showers) in February – March is ideal for blossoming. Robusta coffee is self sterile and cross pollination is necessary. The fruits mature in 10-11 months (Anonymous, 2000). 73 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.

3.2.2. Hybrid and parent plants of the hybridization experiment

A study of the performance of hybrid coffee plants derived from a cross between *Coffea racemosa* Lour. (female parent) and *Coffea canephora*

Pierre ex Froehner var. robusta (male parent) has been carried out presently to analyze the behaviour of the hybrid plants in terms of growth, yield and quality. Mean caffeine content is 2% in *Coffea canephora* Pierre ex Froehner var. robusta (Anonymous, 1987). *Coffea racemosa* grows in to a small profusely branching shrub about 4 feet tall. Leaves are small, leathery, undulating and flowers subterminal in erect bracteate racemes. Fruits are subglobose, small, red and watery when ripe having two hemispherical seeds (Haarer, 1962). Mean caffeine content is 0.83% which is lower when compared to both arabica and robusta coffee (Lopes and Herminda, 1972).

The F1 progeny of the cross between *Coffea racemosa* (female parent) and *Coffea canephora* var. robusta (male parent) made in 1989 and maintained in the experimental farm of Regional Coffee Research Station, Chundale, Wayanad along with their parents have been used for the present study.

3.3. Experimental methods

Experiments were designed so as to analyze the variability of the robusta coffee accessions studied, the correlation of characters in robusta coffee, character association in robusta coffee, genetic divergence in the coffee accessions studied, genetic control of the agronomic characters of coffee, overall performance of the different accessions under study, behaviour of the hybrid genotypes under study and the adaptability of robusta coffee to two different coffee growing areas of South India.

3.3.1. Genetic variability of robusta coffee

73 robusta coffee accessions/genotypes, which include 60 robusta accessions identified from India and 13 exotic robusta accessions introduced

by Central Coffee Research Institute from different coffee growing countries, planted during 1979-1983 period in the germplasm of the Regional Coffee Research Station, Chundale, Wayanad, Kerala, India have been utilized for the present study (Table 3.4). All the plants studied were stabilized and mature during the period of data collection. Variability and performance of these 73 robusta accessions have been compared presently with the most popular robusta variety S.274 released by Central Coffee Research Institute, India. The experiment was laid out in randomized block design, with three replications and fifteen plants per plot. The trees were planted at a spacing of 3m x 3m and maintained uniformly as per the package of practices recommended by Coffee Board, India under rain fed conditions.

The plants were subjected to observations on 10 growth characters, 17 yield characters, 8 physical quality parameters and 8 cup quality parameters (Table 3.5). Four plants per plot were randomly selected for the observation of growth and yield characters. Physical quality and cup quality observations were made considering each accession a unit. The observations were made during 2002-03, 2003-04 and 2004-05.

Variability has been assessed with the help of analysis of variance, study of phenotypic variance, genotypic variance, phenotypic coefficient of variation and genotypic coefficient of variation, study of heritability (broad sense) and study of genetic advance.

Table 3.4. Genotypes/accessions used for the study of genetic variability of robusta coffee

Sl. No.	Accession Number	Source

1	DR.1	P.V.Syriac Estate, Palvelicham, Mananthavadi, Kerala
2	DR.2	P.V.Syriac Estate, Palvelicham, Mananthavadi, Kerala
3	DR.3	P.V.Syriac Estate, Palvelicham, Mananthavadi, Kerala
4	DR.4	Beenachy Estate, Sulthan Bathery, Kerala
5	DR.5	Kottakkunnu Estate, Meenangadi, Kerala
6	DR.6	Kottakkunnu Estate, Meenangadi, Kerala
7	DR.7	Kottakkunnu Estate, Meenangadi, Kerala
8	DR.8	Nanu.V.K. Estate, Poomala, Sulthan Bathery, Kerala
9	DR.9	Nanu.V.K. Estate, Poomala, Sulthan Bathery, Kerala
10	DR.10	Wariat Estate, Muttil, Kerala
11	DR.11	P.V.Syriac Estate, Palvelicham, Mananthavadi, Kerala
12	DR.12	Wariat Estate, Muttil, Kerala
13	DR.13	Wariat Estate, Muttil, Kerala
14	DR.14	Wariat Estate, Muttil, Kerala
15	DR.15	Mangalam Carp Estate, Cheeral, Sulthan Bathery, Kerala
16	DR.16	Mangalam Carp Estate, Cheeral, Sulthan Bathery, Kerala
17	DR.17	Mangalam Carp Estate, Cheeral, Sulthan Bathery, Kerala
18	DR.18	Mangalam Carp Estate, Cheeral, Sulthan Bathery, Kerala
19	DR.19	Ellumannam Estate, Mananthavadi, Kerala
20	DR.20	Ellumannam Estate, Mananthavadi, Kerala
21	Wt.1	Wariat Estate, Muttil, Kerala
22	Wt.2	Wariat Estate, Muttil, Kerala
23	Wt.3	Wariat Estate, Muttil, Kerala
24	Wt.4	Wariat Estate, Muttil, Kerala
25	Wt.5	Wariat Estate, Muttil, Kerala
26	Wt.6	Wariat Estate, Muttil, Kerala
27	WC.1	Sabitha Estate, Sulthan Bathery, Kerala
28	WC.2	Sabitha Estate, Sulthan Bathery, Kerala
29	WC.3	Arivayal Estate, Sulthan Bathery, Kerala
30	WC.4	Pariyaram Estate, Muttil, Kerala
31	WC.5	Pariyaram Estate, Muttil, Kerala
32	WC.6	Wariat Estate, Muttil, Kerala
33	WC.7	Kamala Estate, Mylambadi, Meenangadi, Kerala
34	WC.8	Pariyaram Estate, Muttil, Kerala
35	WC.9	Ratnagiri Estate, Vythiri, Kerala
36	WC.10	Wariat Estate, Muttil, Kerala

37	WC.11	Kamala Estate, Mylambadi, Meenangadi, Kerala
38	WC.12	H.M. Estate, Meppady, Kerala
39	WC.13	Pariyaram Estate, Muttil, Kerala
40	WC.14	Edaguni Estate, Maniyankode, Kalpetta, Kerala
41	WC.15	Poomala Estate, Sulthan Bathery, Kerala
42	WC.16	Opal Estate, Sulthan Bathery, Kerala
43	WC.17	Krishna Vilas, Meenangadi, Kerala
44	WC.18	Madakkimala Estate, Kalpetta
45	WC.19	Chithrakoota Estate, Sulthan Bathery, Kerala
46	WC.20	Ratnagiri Estate, Vythiri, Kerala
47	WC.21	Ratnagiri Estate, Vythiri, Kerala
48	WC.22	Ratnagiri Estate, Vythiri, Kerala
49	WC.23	Arivayal Estate, Sulthan Bathery, Kerala
50	WC.24	Sabitha Estate, Sulthan Bathery, Kerala
51	WC.25	Pambra Estate, Sulthan Bathery, Kerala
52	WC.26	Sabitha Estate, Sulthan Bathery, Kerala
53	WC.27	Georgia Estate, Sulthan Bathery, Kerala
54	WC.28	Vijaya Estate, Padirippara, Kerala
55	WC.29	Georgia Estate, Sulthan Bathery, Kerala
56	WC.30	Sabitha Estate, Sulthan Bathery, Kerala
57	WC.31	Poomala Estate, Sulthan Bathery, Kerala
58	WC.32	Poomala Estate, Sulthan Bathery, Kerala
59	WC.33	Vijaya Estate, Padirippara, Kerala
60	WC.34	Wariat Estate, Muttil, Kerala
61	S.879	Java (Exotic)
62	S.1932	Madagascar (Exotic)
63	S.1902	Saigon (Exotic)
64	S.880	Uganda (Exotic)
65	S.1979	Uganda (Exotic)
66	S.3399	Costa Rica (Exotic)
67	S.1509	Ivory Coast (Exotic)
68	S.1977	Uganda (Exotic)
69	S.1481	Guatemala (Exotic)
70	S.3400	Costa Rica (Exotic)
71	S.3655	Ivory Coast (Exotic)
72	S.3656	Ivory Coast (Exotic)
73	S.3657	Ivory Coast (Exotic)
74	S.274 (Sln.1R)	Selection from CCRI, India

Table 3.5. Characters of robusta coffee accessions studied for variability analysis

Sl. No.	Character	Method of observation
I. Growth characters		
1	Stem girth (mm)	Diameter of the stem was taken about 5 cm above the ground level.
2	No. of primary branches	The number of primary branches produced from the main stem was counted.
3	No. of secondaries per primary	Total number of secondaries in two primary branches was recorded and average was taken.
4	Girth of primary branches (mm)	Girth of two primaries was recorded and average was taken.
5	Length of primary branches (cm)	Length of two primary branches was measured using a measuring tape and average of the two values taken.
6	Internodal length (cm)	Calculated by dividing the length of branches by number of nodes.
7	Bush spread (cm)	Observed from two opposite directions and mean spread was recorded.
8	Leaf length (cm)	Length of three pairs of mature leaves was recorded and mean computed.
9	Leaf breadth (cm)	Breadth of three pairs of mature leaves at the middle portion was recorded and average was taken.
10	Leaf area (cm^2)	Area was calculated by length x breadth x 0.65 (conversion factor) as suggested by Awatramani and Gopalakrishna (1965).
II. Yield characters		
1	Fruits per node	Total number of fruits and number of fruiting nodes in two tertiary branches were recorded and fruits/node calculated by dividing total number of fruits/branch by number of fruiting nodes.
2	Fruit length (mm)	Length of 10 two seeded fruits was recorded using vernier calipers and average was taken.
3	Fruit breadth (mm)	Breadth of 10 two seeded fruits was

		recorded using vernier calipers and average was taken.
4	Fruit thickness (mm)	Thickness of 10 two seeded fruits was recorded using vernier calipers and average was taken.
5	Fruit volume (mm^3)	Volume of 10 two seeded fruits was estimated as length x breadth x thickness x 0.52 (conversion factor) as suggested by Reddy (1976).
6	100 fruit weight (fresh) (g)	Fresh weight of 100 two seeded fruits was recorded.
7	100 fruit weight (dried) (g)	Dry weight of 100 two seeded fruits was recorded.
8	Bean length (mm)	Length of 10 ‘A’ grade beans was recorded using vernier calipers and average was taken.
9	Bean breadth (mm)	Breadth of 10 ‘A’ grade beans was recorded using vernier calipers and average was taken.
10	Bean thickness (mm)	Thickness of 10 ‘A’ grade beans was recorded using vernier calipers and average was taken.
11	Bean volume (mm^3)	Volume of bean was estimated as length x breadth x thickness x 0.61 (conversion factor calculated by the author)
12	Bean density	Weight of hundred beans was divided with volume of 100 beans to get bean density.
13	Hundred bean weight (g)	Dry weight of 100 ‘A’ grade bean was recorded.
14	Yield per plant (kg)	Yield/plant in fresh weight was recorded at the time of harvest.
15	Out turn (fresh to dry)	The ratio of ripe cherry to dry cherry was observed and recorded in percentage.
16	Out turn (dry to clean)	The ratio of dry cherry to clean coffee was calculated and expressed in percentage.
17	Out turn (ripe to clean)	The ratio of ripe cherry to clean coffee was calculated and expressed

		in percentage.
III.a. Physical quality parameters (quantitative)		
1	Percentage of ‘A’ grade beans	The percentage of beans that retained on a sieve with round holes of 6.65 mm.
2	Percentage of ‘B’ grade beans	The percentage of beans that retained on a sieve with round holes of 6.00 mm.
3	Percentage of ‘C/bits’ grade beans	The percentage of beans that retained on a sieve with round holes of 5.50 mm. Bits are the broken coffee beans of less than 1/3rd of a bean size.
4	Percentage of beans below C grade	The percentage of beans with less than 5.5 mm size.
5	Percentage of pea berries	Percentage of coffee beans of nearly ovoid form, resulting from the development of a single seed in the fruit.
III.b. Physical quality parameters (qualitative)		
1	Colour	The dried coffee beans were visually observed and colour was recorded.
2	Smell	The smell of the dried beans was observed.
3	Physical quality rating	All coffee samples were valued against the FAQ sample, which was specially prepared for the quality evaluation of coffee by visual assessment.
IV. Cup quality parameters		
1	Fragrance	Sweetness of the smell of the brew was assessed.
2	Aroma	Odour perceived by the nose was observed. Volatile aroma substances are liberated when boiling water comes into contact with freshly ground coffee.
3	Body	Feeling of heaviness or richness on the tongue while tasting was observed.
4	Cleanliness	Cleanliness of the brew was observed.

5	Off taste	Any undesirable taste, other than coffee taste was observed.
6	Taste	Was perceived by the tongue.
7	After taste	The taste that remains in the mouth longer than usual after drinking was observed.
8	Cup quality rating	The cups were organoleptically categorized into seven classes *viz*., fine, good, above average, average, below average, falling off and poor, taking into consideration three main characteristics of body, acidity and flavour. Made coffee was tested for cup quality rating.

3.3.1.1. Analysis of variance

Analysis of variance (ANOVA) was carried out to test the significance of variations between the accessions. Significance of F value was tested with reference to standard F table (Fischer and Yates, 1963). CD was calculated using the formula

$$CD = t_{0.05} \times \sqrt{\frac{2VE}{r}}$$

Where $t_{0.05}$ is $t_{0.05}$ for error degree of freedom, VE is the error mean square and r is the number of replications.

3.3.1.2. Phenotypic and genotypic variances and phenotypic and genotypic coefficients of variation

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

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

$$\text{Phenotypic variance } (\sigma^2 p) = \sigma^2 g + \sigma^2 e$$

where $\sigma^2 e$ is error variance.

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

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

where σp = the phenotypic standard deviation and $\bar{X}$ = grand mean of the character.

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

where σg = the genotypic standard deviation.

3.3.1.3. Heritability

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).

Heritability (broad sense) (H^2) = $\frac{\sigma^2 g}{\sigma^2 p} \times 100$

3.3.1.4. Genetic advance

Genetic advance under selection was calculated using the following formula

GA= $\frac{KH^2 \sigma p}{\bar{X}}$ (Singh and Choudhary, 1985)

where H^2 = heritability (broad sense); σp = phenotypic standard deviation; K= selection differential which is 2.06 at 5% intensity of selection in large samples (Allard, 1960).

3.3.2. Correlation of characters

Quantitative characters of crop plants show different levels of interrelationship due to the common sharing of alleles between them. Correlation of the quantitative characters studied presently has been analyzed as suggested by Rangaswamy (1995).

3.3.3. Character association

Study of association of characters is being carried out for data reduction so as to find out the characters useful in selection. Factor analysis by means of principal component analysis has been done for the purpose presently using the statistical software STATISTICA.

3.3.4. Genetic divergence

Different genotypes of plant species can be grouped into different clusters based on genetic divergence studies. The 74 robusta accessions were subjected to cluster analysis based on 28 phenotypic characters using the software STATISTICA following UPGMA procedure (unweighted pair group mathematical average procedure) (Sneath and Sokal, 1973).

3.3.5. Genetic control of characters

The 10 morphometric plant characters and 17 yield characters studied presently have been subjected to analysis of their genetic control based on the nature of their frequency distribution. Data on 12 plants each of 73 accessions were grouped together for frequency distribution analysis.

3.3.6. Physical quality parameters (qualitative) of the coffee accessions studied

The 73 accessions of robusta coffee studied presently were classified based on three physical quality parameters namely bean colour, bean smell and physical quality rating observed for three consecutive years and analyzed comparatively (Table 3.5).

3.3.7. Cup quality parameters of the coffee accessions studied

Eight cup quality parameters of coffee (Table 3.5) were observed as described elsewhere for three consecutive years and analyzed comparatively.

3.3.8. Overall performance of the robusta coffee accessions

The overall performance of the 74 accessions of robusta coffee studied was comparatively analyzed based on performance index calculated from characters that show positive relationship with yield giving comparative weightage to each character as suggested by Amaravenmathy and Srinivasan (2003). To calculate the performance index, the accession means of characters were divided by the grand mean of the corresponding character in the experimental population.

3.3.9. Study of *Coffea racemosa* x *Coffea canephora* var. robusta hybrids

Interspecific hybrids evolved by crossing the wild *Coffea* species *Coffea racemosa* (female parent) with *Coffea canephora* var. robusta (S.274) and their parents were used for the present experiment (Tables 3.6 and 3.7). Parents and progenies of the crosses made in 1989 and maintained in the germplasm of the Regional Coffee Research Station, Chundale, Wayanad, Kerala, were used as the study material. Package of practices recommended by Coffee Board, India were followed for cultivation. *Coffea racemosa*, even though poor yielding, shows desirable characters such as low caffeine content and high resistance to leaf rust and hence the transfer of these characters to robusta coffee was the major objective of the hybridization programme.

Table 3.6. Details of the parental species used in hybridization studies

Sl. No.	Species	Description
1	*Coffea racemosa*	*Coffea racemosa* grows in to a small profusely branching shrub about 4 feet tall. Leaves are small, leathery, undulating and flowers subterminal in erect bracteate racemes. Fruits are subglobose, small, red and watery when ripe having two hemispherical seeds (Haarer, 1962). Mean caffeine content is 0.83% which is lower when compared to both arabica and robusta coffee (Lopes and Herminda, 1972).
2	*Coffea canephora* var. robusta	*Coffea canephora* var. robusta is a large shrub with broad large and pale green leaves. Flowers are borne in axillary fascicles. Flowers are white, fragrant and are borne in large clusters. Under the conditions of South India, the buds initiate and reach to maturity during November – February and precipitation in February – March is ideal for blossoming. It is self sterile and cross pollination is necessary for fertilization. The fruits mature in 10-11 months (Anonymous, 2000). Mean caffeine content is 2% (Anonymous, 1987).

Table.3.7. Genotypes used in the study of interspecific hybridization of coffee

Genotype	Year of planting
Coffea racemosa (Female parent)	1983
Coffea canephora var. robusta cv. S.274 (Male parent)	1978
Coffea racemosa x S.274 (F1)	1990

Nine F1 plants and their respective parents were observed for 10 growth characters and 18 yield characters (Table 3.8) in each of the parent plants and hybrids in 2003-04. The hybrids and parents were also analysed for caffeine content (ISO 4052 – 1983 method) and leaf rust resistance (visual scoring).

Table 3. 8. Characters studied in the case of the interspecific hybrids and their parents

Sl. No.	Character
I. Growth characters	
1	Stem girth (mm)
2	Number of secondaries per primary
3	Girth of primary branches (mm)
4	Length of primary branches (cm)
5	Internodal length (cm)
6	Bush spread (cm)
7	Leaf length (cm)
8	Leaf breadth (cm)
9	Leaf area (cm^2): leaf area was calculated using 0.65 as conversion factor for robusta (Awatramani and Gopalakrishna, 1965) and 0.68 as conversion factor for racemosa and the hybrids (worked out by the present worker)
10	Crop duration
II. Yield characters	
1	Fruits per node
2	Fruit length (mm)
3	Fruit breadth (mm)
4	Fruit thickness (mm)
5	Fruit volume (mm^3)
6	100 fruit weight (fresh) (g)
7	100 pea berry weight (fresh) (g)
8	100 fruit weight (dried) (g)
9	100 pea berry weight (dried) (g)
10	Bean length (mm)
11	Bean breadth (mm)
12	Bean thickness (mm)
13	Bean volume (mm^3)

14	100 bean weight (g)
15	100 bean weight (pea berry) (g)
16	Yield per plant (kg)
17	Out turn % (fresh to dry)
18	Percentage of floats
III. Quality characters	
1	Caffeine content
IV. Disease resistance characters	
1	Leaf rust resistance

Heterosis and heterobeltiosis shown by the F1 plants have been worked out as follows as suggested by Gupta (2000).

$$\text{Average heterosis} = \frac{\text{F1 value} - \text{Midparent value}}{\text{Midparent value}} \times 100$$

$$\text{Heterobeltiosis} = \frac{\text{F1 value} - \text{Better parent value}}{\text{Better parent value}} \times 100$$

3.3.10. Adaptability of robusta coffee to different growing regions of South India

S.274 variety of *Coffea canephora* var. robusta was used for adaptability study of robusta coffee at two agro climatic regions of conventional coffee growing areas of Western Ghats namely Wayanad and Coorg. S.274 plants growing in six estates each of Wayanad and Coorg regions of Western Ghat area adapting uniform package of practices recommended by Coffee Board, India were used for the present analysis (Table 3.9).

Table 3.9. Coffee estates selected for adaptability study of robusta coffee

Sl. No.	Name of the plantation	Year of planting	Area (ha)
I. Wayanad			
1	Relon Estate, Madiyur, Kalpetta	1983	8.1
2	Chaithanya Estate, Kalpetta	1958	4.05
3	TEC Block, Coffee Demonstration Farm, Kalpetta	1959	0.4
4	Santhosh Coffee Plantation, Appad, Meenangadi	1960	4.05
5	Regional Coffee Research Station Farm, Chundale	1980	1.01
6	Kodali House, Vellaramkunnu, Chundale	1964	0.61
II. Coorg			
1	Naina Estate, Engilekere, Sidhapur, Coorg	1965	10.12
2	Balaram Estate, Gattathala, Coorg	1989	7.69
3	Raj Estate, Guhiaa, Coorg	1970	24.29
4	Nalinda Estate, Guhiaa, Coorg	1980	5.67
5	Poovannikkunnel House, Engilekere, Sidhapur, Coorg	1966	0.81
6	Gowri Estate, Engilekere, Sidhapur, Coorg	1989	0.81

Observations were made on 10 growth characters and 14 yield characters (Table 3.10) as mentioned earlier in the case of six plants selected at random in the case of each estate in 2004-05 and the data were comparatively analyzed for differential performance in the two coffee growing areas using analysis of variance.

Table.3.10. Characters of the S.274 coffee plants selected for adaptability studies

Sl. No.	Character
I. Growth Characters	
1	Stem girth (mm)
2	Number of primary branches
3	Number of secondaries per primary
4	Girth of primary branches (mm)
5	Length of primary branches (cm)
6	Internodal length (cm)
7	Bush spread (cm)
8	Leaf length (cm)
9	Leaf breadth (cm)
10	Leaf area (cm^2)
II. Yield characters	
1	Fruits per node
2	Fruit length (mm)
3	Fruit breadth (mm)
4	Fruit thickness (mm)
5	Fruit volume (mm^3)
6	100 fruit weight (fresh) (g)
7	100 fruit weight (dried) (g)
8	Bean length (mm)
9	Bean breadth (mm)
10	Bean thickness (mm)
11	Bean volume (mm^3)
12	100 bean weight (g)
13	Yield per plant (kg)
14	Out turn (fresh to dry) (%)

Chapter IV

RESULTS AND DISCUSSION

Coffee is one of the most popular non alcoholic beverages preferred world wide for its stimulating properties and unique aroma and taste. Coffee of commerce is mainly obtained from two species of the genus *Coffea*, namely *Coffea arabica* and *Coffea canephora* var. robusta. Arabica coffee flourishes at comparatively high altitudes and robusta coffee performs well at low altitudes also. *Coffea canephora* var. robusta (robusta coffee) is the coffee species usually cultivated in Kerala State of India. Wayanad district of Kerala is a traditional coffee growing district with 67000 hectares of land under coffee cultivation and an average production of 54000 MT (Anonymous, 2007c). Robusta coffee genotypes with high diversity have been cultivated in the district. Even though inferior to arabica coffee in quality, robusta coffee is widely cultivated in Wayanad because of the lower altitude of the area and the climatic conditions that make arabica coffee unsuitable to the area (Anonymous, 1996). Improvement of robusta coffee has been attempted so far only to a limited extent due to various reasons.

The present study has been designed to assess the genetic variability among indigenous and exotic accessions of robusta coffee, to study an interspecific hybrid population of coffee for its general performance and also to study the adaptability of S.274, an impoved variety of robusta coffee to Wayanad region of Kerala State and Coorg region of Karnataka State of India, two traditional coffee areas of South India. The observations made are presented, analyzed and discussed below based on available literature.

4.1. Study of genetic variability of robusta coffee

4.1.1. Study of significance of variability

Robusta breeding programmes in India have the main objective of developing new varieties with optimum yield potential and quality. Robusta breeding in India started in the 1950s (Narayan, 1954). In 1960s further studies were conducted to develop varieties with improved yield and quality (Thomas, 1960). The gene pool of robusta coffee in India is rich and diverse and earlier workers have stressed the importance of the study of genetic variability among them, preserving it and utilizing the same in breeding programmes (Mishra, 1998; Srinivasan and Santaram, 1999).

Wayanad district of Kerala is a rich genetic reservoir of robusta coffee, both indigenous and exotic. The present study was designed to evaluate the extent of variability available among the different genotypes of robusta coffee conserved in the germplasm of the Regional Coffee Research Station, Coffee Board, Chundale, Wayanad, Kerala, India. The study was conducted utilizing 73 accessions of the germplasm which include 60 robusta accessions identified from India and 13 accessions introduced from other coffee growing countries as shown elsewhere. S.274, a standard variety of robusta coffee released by Central Coffee Research Institute, India has been used as the control. The experimental observations were made on coffee plants planted from 1979 to 1983 and presently stabilized and mature. All the plants were of more than 20 years of age and managed as per the package of practices recommended by Coffee Board, India. The experimental observations were made during 2002–03, 2003–04 and 2004–05.

Observations on 10 growth characters, 17 yield characters, 5 quantitative physical quality characters, 3 qualitative physical quality charaters and 8 qualitative cup quality characters were made for the purpose (Table 3.4). The 10 growth characters studied include stem girth, number of primary branches, number of secondaries per primary, girth of primary branches, length of primary branches, internodal length, bush spread, leaf length, leaf breadth and leaf area (Table 4.1).

All the 10 growth characters showed significant statistical variations between the accessions. Mean stem girth of the accessions was observed as 97.07mm, mean number of primary branches varied from 1.58 to 3.42 and number of secondaries per primary varied from 2.50 to 6.33. Mean length of primary branches was 185.14cm and mean girth 51.12mm. Mean internodal length was observed as 7.18cm and mean bush spread 324.81cm. Mean leaf area was found to be 149.35cm^2. Among the growth characters the highest quantum of variability in terms of coefficient of variation was observed for girth of primary branches, followed by number of secondaries per primary. Minimum variability was shown by leaf breadth, followed by leaf length.

The above observations show that among the growth characters of robusta coffee leaf parameters are the most stable and girth of primary branch is 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. Stem and branch diameter were found to be important yield contributors by Berthoud *et al.* (1978). Stem girth and length of primary were found to show high positive correlation with fruit yield by Srinivasan (1980). Walyaro and Vossen (1979) and Walyaro (1983) have indicated the importance of stem girth in yield.

Table 4.1. Growth characters of the seventy three accessions of robusta coffee and S.274 (control) studied

Accessions	Stem girth (mm)	Number of primary branches	Number of secondaries per primary	Girth of primary branches (mm)	Length of primary branches (cm)	Internodal length (cm)	Bush spread (cm)	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm^2)
DR.1	82.81 ± 8.59	3.33 ± 0.52	4.38 ± 0.78	42.44 ± 6.85	175.96 ± 23.56	6.39 ± 0.49	318.92 ± 69.48	21.41 ± 0.37	9.37 ± 0.84	133.50 ± 14
DR.2	108.07 ± 3.57	2.67 ± 0.28	4.88 ± 0.78	54.58 ± 12.42	199.36 ± 41.84	7.57 ± 0.75	350.67 ± 69.88	22.11 ± 1.44	11.03 ± 0.32	162.13 ± 15.33
DR.3	97.66 ± 5.51	2.42 ± 0.14	4.38 ± 0.57	51.56 ± 3.37	192.79 ± 13.83	7.80 ± 0.75	336.25 ± 40.05	21.54 ± 0.83	10.55 ± 0.77	149.44 ± 17.55
DR.4	95.01 ± 9.89	2.50 ± 0.44	3.92 ± 0.14	54.67 ± 6.55	170.83 ± 7.16	6.97 ± 0.45	306.33 ± 51.65	23.08 ± 1.31	11.13 ± 1.02	170.12 ± 25.01
DR.5	93.99 ± 9.75	3.08 ± 0.14	4.33 ± 0.57	48.2 ± 4.56	161.00 ± 9.29	7.09 ± 0.85	278.92 ± 26.95	22.94 ± 0.85	10.80 ± 0.14	163.84 ± 2.77
DR.6	87.56 ±14.66	3.33 ± 0.57	3.88 ± 0.24	46.18 ± 6.78	155.38 ± 12.09	6.80 ± 0.99	267.42 ± 9.55	21.22 ± 0.61	9.75 ± 0.33	136.95 ± 19.16
DR.7	100.57 ± 7.63	3.25 ± 0.75	3.92 ± 0.44	41.63 ± 7.84	178.04 ± 22.11	7.30 ± 0.51	299.25 ± 36.44	21.21 ± 0.14	9.74 ± 0.2	137.50 ± 2.18
DR.8	91.32 ± 9.4	3.33 ± 1.26	4.00 ± 0.65	48.56 ± 4.32	178.88 ± 0.22	7.14 ± 0.26	303.25 ± 32.14	22.16 ± 1.07	9.95 ± 0.22	146.35 ± 15.43
DR.9	99.36 ±12.81	2.08 ± 0.39	4.21 ± 0.85	52.3 ± 7.91	183.21 ± 9.21	8.00 ± 0.2	320.08 ± 47.04	21.67 ± 2.08	9.65 ± 0.55	140.37 ± 21.56
DR.10	88.62 ± 6.45	3.00 ± 0.44	3.63 ± 0.65	42.08 ± 2.25	168.96 ± 13.54	7.26 ± 0.68	301.33 ± 32.68	21.69 ± 1.14	9.45 ± 0.62	136.55 ± 18.04

DR.11	98.33 ± 10.3	2.92 ± 0.76	4.88 ± 0.22	59.76 ± 7.47	215 ± 27.39	8.39 ± 0.2	368.33 ± 31.76	23.23 ± 2.35	10.48 ± 0.78	161.62 ± 27.83
DR.12	93.77 ± 7.3	2.67 ± 0.39	3.96 ± 0.57	43.51 ± 8.92	173.21 ± 12.42	7.69 ± 0.46	306.25 ± 13.43	22.55 ± 2.35	9.67 ± 0.76	146.92 ± 26.67
DR.13	95.04 ± 3.22	2.58 ± 0.39	4.25 ± 0.37	56.6 ± 9.69	180.5 ± 15.19	7.70 ± 0.88	323.08 ± 15.69	22.62 ± 0.41	9.90 ± 0.44	145.13 ± 3.22
DR.14	96.63 ± 6.03	3.33 ± 0.57	4.08 ± 0.62	45.53 ± 2.99	178 ± 11.14	6.8 ± 0.33	323.5 ± 14.77	20.85 ± 0	9.09 ± 0.14	125.32 ± 2.99
DR.15	87.99 ± 3.65	2.92 ± 0.88	4.54 ± 0.26	48.61 ± 8.66	162.92 ± 15.41	6.41 ± 0.46	286.58 ± 25.51	22.08 ± 0.79	9.75 ± 0.32	142.47 ± 9.2
DR.16	90.22 ± 4.26	2.58 ± 0.14	3.38 ± 0.33	46.55 ± 6.66	174.83 ± 21.76	7.37 ± 0.4	277.42 ± 69.47	21.41 ± 1.82	10.07 ± 0.72	143.33 ± 22.05
DR.17	90.35 ± 4.7	2.67 ± 0.52	3.33 ± 0.2	47.26 ± 3.07	161.17 ± 26.29	8.02 ± 0.71	295.75 ± 37.46	21.83 ± 2.1	10.08 ± 0.56	144.84 ± 21.52
DR.18	94.34 ± 8.26	2.58 ± 1.26	3.50 ± 0.88	46.44 ± 6.46	193.54 ± 25.24	8.66 ± 0.48	314.17 ± 26.14	20.34 ± 1.68	9.85 ± 0.64	132.18 ± 18.62
DR.19	89.69 ± 7.58	2.50 ± 0.24	4.71 ± 0.51	49.75 ± 7.19	173.58 ± 19.1	6.76 ± 0.46	299.75 ± 39.39	21.32 ± 0.75	9.56 ± 0.7	134.33 ± 12.5
DR.20	89.39 ± 9.68	2.58 ± 0.14	4.88 ± 0.14	41.29 ± 2.82	161.96 ± 4.08	6.30 ± 0.14	292.33 ± 7.92	22.42 ± 1.86	9.33 ± 0.45	141.83 ± 22.76
Wt.1	99.08 ± 7.82	2.50 ± 1	4.08 ± 0.92	59.92 ± 6.34	175.25 ± 14.85	5.56 ± 0.14	304.42 ± 29.25	24.28 ± 0.56	9.49 ± 0.17	150.63 ± 0.77
Wt.2	93.33 ± 9.17	2.75 ± 0.44	4.17 ± 0.51	52.12 ± 7.89	192.79 ± 11.23	6.05 ± 0.79	344.17 ± 10.92	24.89 ± 0.26	9.39 ± 0.54	153.06 ± 9.82
Wt.3	97.29 ± 4.72	1.75 ± 0.24	5.13 ± 0.24	54.65 ± 4.59	188.79 ± 6.07	5.75 ± 0.14	315.58 ± 38.11	24.9 ± 0.99	9.47 ± 0.22	154.3 ± 7.4
Wt.4	97.77 ± 9.87	2.08 ± 0.39	5.13 ± 1.27	58.34 ± 7.15	184.5 ± 15.09	5.66 ± 0.57	306.08 ± 26.51	23.73 ± 0.51	10.02 ± 0.57	155.52 ± 12.95

Wt.5	99.08 ± 8.67	2.00 ± 0.66	4.50 ± 0.33	55.38 ± 10.62	165.54 ± 26.56	6.30 ± 0.57	278.58 ± 62.41	25.31 ± 1.51	10.53 ± 0.36	173.5 ± 13.28
Wt.6	108.51 ± 5.45	2.00 ± 0.5	4.46 ± 0.26	66.83 ± 5.53	194.29 ± 30.47	6.42 ± 0.63	334.83 ± 45.5	24.08 ± 1	10.65 ± 0.22	168.96 ± 10.42
WC.1	89.54 ± 9.13	2.75 ± 0.44	4.13 ± 0.57	42.61 ± 6.5	177.33 ± 32.05	8.07 ± 0.36	318.42 ± 36.13	21.86 ± 0.46	10.22 ± 0.4	146.55 ± 8.97
WC.2	92.19 ± 8.99	3.42 ± 0.57	4.88 ± 0.75	47.86 ± 6.92	242.42 ± 22.59	7.25 ± 0.39	395.00 ± 47.15	21.36 ± 0.84	9.95 ± 0.22	140.09 ± 8.16
WC.3	98.60 ± 5.19	2.92 ± 0.39	4.04 ± 0.4	46.38 ± 3.52	194.13 ± 15.37	6.61 ± 0.51	398.67 ± 60.32	22.73 ± 0.35	9.55 ± 0.36	142.31 ± 6
WC.4	104.58 ± 6.93	2.50 ± 0.24	5.08 ± 0.32	58.27 ± 5.91	236.21 ± 9.65	9.41 ± 0.53	436.58 ± 32.24	23.42 ± 1.19	10.51 ± 0.49	161.86 ± 15.43
WC.5	91.54 ± 4.64	2.08 ± 0.52	4.83 ± 1.19	57.28 ± 11.44	209.21 ± 25.26	8.62 ± 0.71	342.67 ± 2.5	23.33 ± 0.51	9.98 ± 1	151.10 ± 15.54
WC.6	74.32 ± 4.84	2.58 ± 0.14	4.00 ± 0.45	41.63 ± 5.03	174.04 ± 23.06	8.24 ± 0.28	308.08 ± 43.4	22.02 ± 0.71	10.03 ± 0.46	144.53 ± 4.22
WC.7	91.49 ± 8.3	2.17 ± 0.52	4.58 ± 0.32	54.23 ± 20.53	213.33 ± 28.02	9.96 ± 1.18	381.92 ± 54.92	24.22 ± 0.44	11.06 ± 0.44	169.24 ± 1.52
WC.8	93.83 ± 4.66	2.08 ± 0.63	5.17 ± 1.05	57.35 ± 9.24	226.71 ± 14.67	8.39 ± 0.24	369.08 ± 12.73	24.95 ± 0.72	10.52 ± 0.5	172.13 ± 11.73
WC.9	99.72 ± 21.5	2.92 ± 0.76	5.96 ± 1.04	58.55 ± 12.56	205.83 ± 3.5	7.94 ± 0.41	370.08 ± 44.92	21.63 ± 4.49	10.62 ± 0.33	163.42 ± 20.45
WC.10	96.31 ±11.78	2.00 ± 0.5	5.46 ± 1.12	60.42 ± 9.39	201.92 ± 8.13	9.16 ± 0.17	366.83 ± 25.77	24.17 ± 1	9.75 ± 0.14	154.85 ± 3.58
WC.11	84.4 ± 6.38	2.42 ± 0.63	3.38 ± 0.33	34.14 ± 3.51	153.13 ± 20.27	8.56 ± 0.46	250.58 ± 33.61	22.65 ± 0.55	9.27 ± 0.32	137.15 ± 7.51
WC.12	100.84 ±18.51	2.25 ± 0.5	4.79 ± 0.4	52.13 ± 21.17	206.92 ± 36.84	8.34 ± 1.2	362.33 ± 107.9	23.73 ± 1.26	11.17 ± 1.11	175.97 ± 24.4

WC.13	98.75 ± 2.61	2.00 ± 0.44	5.17 ± 1.59	68.19 ± 5.58	216.54 ± 9.83	6.25 ± 0.6	381.83 ± 16.98	23.11 ± 1.66	10.17 ± 0.88	153.94 ± 23.74
WC.14	100.24 ± 2.3	2.33 ± 0.28	5.00 ± 0.37	55.10 ± 7.1	214.71 ± 21.88	6.06 ± 0.1	386.58 ± 40.15	22.09 ± 1.27	9.18 ± 0.1	132.94 ± 10.18
WC.15	98.34 ± 6.08	2.42 ± 0.63	5.33 ± 0.52	52.53 ± 5.13	208.04 ± 19.7	6.14 ± 0.49	354.5 ± 32.69	23.56 ± 1.4	10.28 ± 0.26	157.94 ± 13.4
WC.16	116.07 ± 8.8	2.42 ± 0.52	5.75 ± 1.07	62.48 ± 3.29	200.13 ± 21.22	6.23 ± 0.14	378.5 ± 37.2	24.65 ± 1.29	10.19 ± 0.83	163.92 ± 22.03
WC.17	106.43 ± 5.29	2.67 ± 0.39	4.99 ± 0.62	42.11 ± 5.76	161.89 ± 25.01	5.65 ± 0.14	306.67 ± 56.29	20.18 ± 1.38	8.89 ± 0.89	118.39 ± 20.13
WC.18	100.40 ± 4.54	2.33 ± 1.23	4.42 ± 0.44	49.16 ± 8.01	164.67 ± 10.16	5.76 ± 0.24	304.50 ± 34.59	21.62 ± 1.08	9.69 ± 0.26	137.57 ± 10.82
WC.19	110.96 ± 9.87	2.50 ± 0.24	5.08 ± 1.12	45.16 ± 6.91	162.25 ± 17.09	5.74 ± 0	294.92 ± 40.06	21.28 ± 2.22	9.50 ± 1.51	134.32 ± 39.95
WC.20	103.46 ± 4.37	2.17 ± 0.14	5.17 ± 0.32	59.82 ± 10.38	194.33 ± 12.86	6.40 ± 0.61	338.17 ± 33.98	20.80 ± 2.54	10.23 ± 0.95	147.92 ± 25.88
WC.21	96.09 ± 2.35	3.33 ± 0.95	5.08 ± 0.81	41.95 ± 11.48	171.83 ± 19.96	7.41 ± 0.95	326.25 ± 10.56	20.63 ± 1.26	9.09 ± 0.22	128.34 ± 8.07
WC.22	101.21 ±11.72	2.25 ± 0.44	4.88 ± 0.76	55.47 ± 8.71	180.5 ± 33.51	6.63 ± 0.57	343.25 ± 73.69	23.31 ± 1.82	10.42 ± 1.13	160.13 ± 29.35
WC.23	91.04 ± 9.91	2.75 ± 0.24	4.71 ± 1.05	43.41 ± 15.19	169.46 ± 48.17	6.46 ± 0.52	313.83 ± 52.53	24.03 ± 0.47	9.81 ± 0.46	154.02 ± 9.6
WC.24	96.02 ± 3.96	2.33 ± 0.72	5.75 ± 0.5	53.90 ± 7.32	178.33 ± 8.9	6.84 ± 0.36	306.17 ± 37.17	23.95 ± 1.1	9.71 ± 0.62	152.04 ± 17.29
WC.25	107.08 ± 9.52	3.17 ± 0.76	4.96 ± 0.59	52.60 ± 2.52	182.79 ± 2.22	5.36 ± 0.72	351.75 ± 28.56	22.04 ± 1.71	9.53 ± 0.96	139.84 ± 23.44
WC.26	102.22 ± 3.19	2.25 ± 0.5	5.46 ± 0.51	52.29 ± 7.74	175.54 ± 24.58	6.23 ± 0.2	282.67 ± 51.17	21.02 ± 1.62	9.59 ± 0.5	133.71 ± 16.23

WC.27	109.63 ± 8.19	2.67 ± 0.95	5.58 ± 0.36	58.83 ± 0.98	205.88 ± 33.61	5.95 ± 0.39	341.42 ± 49.06	22.07 ± 1.18	8.88 ± 0.42	135.14 ± 15.33
WC.28	88.17 ± 15.3	1.58 ± 0.39	3.54 ± 1.63	32.49 ± 16.59	115.08 ± 30.66	6.45 ± 1	234.00 ± 39.92	22.6 ± 1.57	10.27 ± 1.15	152.71 ± 26.64
WC.29	112.44 ±10.59	2.42 ± 0.63	5.04 ± 0.26	59.10 ± 8.28	204.38 ± 30.85	6.13 ± 0.62	346.17 ± 31.63	20.79 ± 0.97	9.29 ± 0.1	129.49 ± 4.53
WC.30	78.17 ±13.61	1.67 ± 0.39	3.17 ± 0.28	31.12 ± 8.67	124.83 ± 29.13	7.77 ± 0.56	224.33 ± 44.16	23.74 ± 1.23	10.41 ± 1.02	162.76 ± 21.75
WC.31	95.99 ± 8.57	2.42 ± 0.14	2.88 ± 1.02	44.09 ± 8.77	171.17 ± 18.8	8.03 ± 0.97	325.67 ± 67.27	21.23 ± 0.55	9.31 ± 0.57	130.11 ± 4.87
WC.32	88.31 ± 5.89	1.75 ± 0.5	3.04 ± 1.23	27.84 ± 4.96	154.38 ± 30.62	8.60 ± 0.81	244.92 ± 20.13	21.85 ± 0.74	9.67 ± 0.37	137.62 ± 10.53
WC.33	88.44 ± 5.55	2.42 ± 0.52	3.63 ± 0.33	33.51 ± 3.05	166.58 ± 12.59	8.68 ± 0.6	266.42 ± 32.42	22.18 ± 1.62	10.13 ± 0.82	149.37 ± 22.26
WC.34	91.69 ± 17.3	2.08 ± 0.14	2.50 ± 0.57	39.69 ± 11.15	159.71 ± 14.08	8.12 ± 1.57	283.58 ± 26.79	21.45 ± 0.7	9.43 ± 0.74	133.89 ± 15.15
S.879	101.95 ± 9.09	2.83 ± 0.39	5.50 ± 0.65	67.24 ± 3.49	213.29 ± 7.75	7.41 ± 1.93	378.58 ± 12.13	24.72 ± 1.31	10.32 ± 1.05	167.02 ± 25.21
S.1932	87.80 ± 7.05	2.5 ± 0.66	4.88 ± 0.44	52.75 ± 9.36	187.25 ± 18.14	8.21 ± 0.71	350.25 ± 5.45	24.68 ± 0.63	10.70 ± 0.73	173.82 ± 17.77
S.1902	107.92 ± 3.41	2.67 ± 0.52	4.46 ± 0.59	51.93 ± 8	169.29 ± 27.42	7.62 ± 0.61	332.08 ± 37.4	22.78 ± 1.8	10.03 ± 0.85	151.90 ± 24.12
S.880	98.74 ± 9.3	2.50 ± 0.44	4.83 ± 0.81	44.89 ± 3.01	170.38 ± 24.79	7.94 ± 1	292.58 ± 67.54	24.68 ± 1.55	10.35 ± 0.86	169.52 ± 19.94
S.1979	95.04 ± 7.15	2.33 ± 0.76	5.67 ± 0.26	51.47 ± 6.79	187.13 ± 19.02	7.26 ± 0.59	319.17 ± 30.71	24.12 ± 1	9.56 ± 0.85	152.15 ± 19.8
S.3399	128.49 ± 1.53	2.17 ± 0.14	6.33 ± 0.52	85.64 ± 4.57	256.42 ± 8.11	8.93 ± 0.46	423.42 ± 25.27	26.21 ± 1.47	11.19 ± 0.49	191.80 ± 17.44

S.1509	98.04 ± 1.47	2.58 ± 0.39	5.67 ± 0.32	57.75 ± 6.01	212.08 ± 3.94	6.41 ± 1.55	349.58 ± 16.02	22.34 ± 2.19	9.66 ± 0.77	142.52 ± 21.93
S.1977	97.31 ± 5.88	2.50 ± 0.66	4.92 ± 0.59	41.16 ± 8.12	178.00 ± 24.15	6.76 ± 0.42	297.58 ± 26.93	24.19 ± 1.3	9.59 ± 0.87	153.20 ± 21.65
S.1481	97.86 ± 8.96	2.17 ± 0.57	4.67 ± 0.59	54.25 ± 1.92	194.83 ± 16.64	7.13 ± 0.3	328.5 ± 25.49	21.19 ± 0.57	9.53 ± 0.69	132.63 ± 12.5
S.3400	99.14 ± 3.98	2.50 ± 0.44	4.75 ±0.65	59.50 ± 14.11	180.79 ± 22.66	7.25 ± 0.1	293.00 ± 20.5	22.75 ± 1.57	9.82 ± 0.79	145.83 ± 21.71
S.3655	95.24 ± 9.5	2.33 ± 0.52	5.92 ± 0.26	60.48 ± 6.26	191.58 ± 21.23	6.96 ± 0.22	351.58 ± 22.17	23.55 ± 1.44	10.08 ± 0.75	147.28 ± 31.45
S.3656	94.15 ±11.91	2.08 ± 0.28	4.83 ± 1.06	47.68 ± 19.91	164.58 ± 33.21	6.56 ± 1.45	270.5 ± 67.59	22.68 ± 1.99	10.41 ± 0.49	154.59 ± 19.61
S.3657	110.57 ± 7.49	2.33 ± 0.28	6.25 ± 0.9	61.24 ± 4.65	222.08 ± 14.21	5.99 ± 0.14	378.33 ± 59.44	22.1 ± 0.88	9.49 ± 0.2	140.49 ± 12.49
S.274 (Sln.1R)	106.52 ± 6.48	2.25 ± 0.44	5.29 ± 0.92	60.74 ± 10.79	207.88 ± 19.4	7.00 ± 0.58	381.50 ± 53.31	24.40 ± 1.2	10.90 ± 0.91	173.31 ± 22.83
Mean	97.07	2.50	4.62	51.12	185.14	7.18	324.81	22.70	9.95	149.35
Range	74.32-128.49	1.58-3.42	2.50-6.33	27.84-85.64	115.08-256.42	5.36-9.96	224.33 - 436.58	20.18 - 26.21	8.88-11.19	118.39-191.80
Standard deviation	8.55	0.42	0.80	9.62	24.36	1.03	42.66	1.37	0.56	14.30
Coefficient of variation	8.81	16.80	17.32	18.82	13.16	14.35	13.13	6.04	5.63	9.57
CD @ 5%	14.16	0.89	1.12	13.79	34.09	1.04	66.11	2.23	1.06	28.38
CD @ 1%	18.60	1.18	1.47	18.13	44.80	1.25	86.89	3.34	1.40	37.29

All the seventeen yield characters of robusta coffee studied presently showed statistically significant variation between the accessions in the case of all the characters (Tables 4.2 & 4.3). Fruits per node ranged from 7.29 to 19.80 among the different accessions. Mean fruit length was found to be 13.88 mm, fruit breadth 12.97 mm and fruit thickness 10.99 mm. Fruit volume ranged from 723.70 mm^3 to 1300.80 mm^3 with a mean fruit volume of 1044.05 mm^3. Weight of 100 fresh fruits varied from 95.44 g to 168.98 g and the mean value was 136.07 g. Dry weight of 100 fruits ranged from 37.71g to 63.88 g, and the mean dry weight of 100 fruits was 52.96 g.

Table 4.2. Yield characters of the seventy three accessions of robusta coffee and S.274 (control) studied- 1.Fruit characters

Accessions	Fruits/ node	Fruit length (mm)	Fruit breadth (mm)	Fruit thickness (mm)	Fruit volume (mm^3)	Weight of 100 fresh fruits (g)	Weight of 100 dry fruits (g)
DR.1	14.56 ± 2.01	13.23 ± 0.17	12.88 ± 0.4	10.49 ± 0.17	940.71 ± 40.19	134.12 ± 5.03	52.68 ± 3.69
DR.2	15.40 ± 2.82	13.66 ± 0.71	13.1 ± 0.37	10.59 ± 0.45	992.49 ± 112.96	132.76 ± 8.46	50.42 ± 2.3
DR.3	12.96 ± 1.02	14.13 ± 0	13.86 ± 0.24	11.44 ± 0	1169.94 ± 18.1	152.96 ± 5.58	59.46 ± 2.56
DR.4	13.08 ± 2.46	14.65 ± 0.66	13.74 ± 0.36	11.43 ± 0.66	1188.04 ± 170.99	162.18 ± 12.87	63.14 ± 3.92
DR.5	17.41 ± 1.92	14.35 ± 0.32	13.60 ± 0.33	11.67 ± 0	1194.64 ± 51.82	155.21 ± 10.92	58.82 ± 2.7
DR.6	14.59 ± 3.06	15.05 ± 0.42	13.59 ± 0.24	11.52 ± 0	1242.84 ± 66.1	160.12 ± 6.19	59.78 ± 2.52
DR.7	12.62 ± 2.13	14.56 ± 0.69	13.86 ± 0.22	11.73 ± 0.26	1239.91 ± 108.17	154.98 ± 4.92	61.15 ± 1.77
DR.8	13.66 ± 1.78	13.97 ± 0	13.78 ± 0.33	11.59 ± 0.42	1170.2 ± 78.33	149.00 ± 0.1	58.98 ± 0.48
DR.9	10.99 ± 0.33	14.26 ± 0.47	13.37 ± 0.26	11.40 ± 0.45	1131.23 ± 38.82	153.67 ± 11.16	57.47 ± 4.78
DR.10	11.82 ± 1.14	15.15 ± 0.33	13.53 ± 0.33	11.60 ± 0.2	1244.66 ± 26.51	176.31 ± 8.97	63.88 ± 3.49
DR.11	10.77	15.18	13.49	11.57	1234.84	167.69	60.24

	± 1.28	± 0.32	± 0.57	± 0.28	± 102.81	± 12.83	± 4.95
DR.12	15.27 ± 2.36	14.31 ± 0.14	13.36 ± 0.14	11.29 ± 0	1114.05 ± 39.67	150.31 ± 5.97	55.02 ± 2.41
DR.13	13.92 ± 2.12	14.92 ± 0.52	14.08 ± 0.77	11.87 ± 0.52	1300.80 ± 161.46	161.57 ± 20.46	58.65 ± 7.36
DR.14	14.34 ± 2.57	14.04 ± 0.35	13.75 ± 0.57	11.59 ± 0.42	1168.68 ± 118.36	152.82 ± 5.48	58.06 ± 3.37
DR.15	13.31 ± 2.03	14.23 ± 0.36	13.51 ± 0.37	11.29 ± 0.32	1149.86 ± 77.08	154.82 ± 14.64	57.31 ± 4.56
DR.16	14.42 ± 0.56	13.93 ± 0.36	12.97 ± 0.36	10.95 ± 0.26	1034.64 ± 61.75	131.22 ± 8.3	48.39 ± 2.04
DR.17	13.08 ± 0.1	14.33 ± 0.36	13.02 ± 0.4	11.02 ± 0.35	1078.88 ± 65.08	138.80 ± 5.72	52.41 ± 2.8
DR.18	12.32 ± 1.7	14.41 ± 0.73	13.81 ± 0.5	11.52 ± 0.58	1201.22 ± 170.19	154.59 ± 16.79	56.02 ± 4.43
DR.19	13.51 ± 3.18	14.38 ± 0.32	13.25 ± 0.2	11.05 ± 0.1	1099.88 ± 41.69	150.16 ± 13.34	54.41 ± 3.6
DR.20	14.22 ± 1.76	14.70 ± 0.62	13.39 ± 0.77	11.47 ± 0.45	1161.76 ± 117.61	147.22 ± 6.69	56.81 ± 2.56
Wt.1	13.7 ± 3.1	14.56 ± 0.22	13.99 ± 0.1	11.55 ± 0.22	1230.87 ± 40.16	168.98 ± 5.75	59.54 ± 4.36
Wt.2	18.57 ± 2.32	13.65 ± 0.54	13.11 ± 0.36	11.04 ± 0.2	1028.8 ± 53.09	145.19 ± 3.68	51.02 ± 1.68
Wt.3	16.76 ± 2.5	14.04 ± 0.44	13.17 ± 0.14	11.33 ± 0.17	1095.58 ± 43.42	136.42 ± 10.62	50.45 ± 4.54
Wt.4	16.88 ± 3.35	13.90 ± 0.65	12.97 ± 0.33	10.99 ± 0.36	1039.38 ± 87.45	149.23 ± 13.2	52.72 ± 5.08
Wt.5	17.12 ± 2.96	13.46 ± 0.17	13.14 ± 0.32	10.88 ± 0.14	1003.89 ± 18.19	141.08 ± 5.83	49.64 ± 3
Wt.6	15.22 ± 2.13	14.51 ± 0.64	13.47 ± 0.49	11.29 ± 0.2	1155.38 ± 109.06	155.83 ± 12.18	55.31 ± 5.51
WC.1	19.80 ± 0.42	13.06 ± 0.2	11.76 ± 0.3	10.11 ± 0.24	809.44 ± 43.12	121.12 ± 4.6	49.90 ± 2.99
WC.2	12.91 ± 1.61	12.31 ± 0.86	11.56 ± 0.35	9.68 ± 0.42	723.7 ± 96.92	118.27 ± 4.49	45.71 ± 1.04
WC.3	11.46 ± 1.61	12.4 ± 0.82	11.72 ± 0.59	9.99 ± 0.72	762.02 ± 146.04	114.42 ± 6.33	48.55 ± 2.56
WC.4	15.29 ± 3.02	13.59 ± 0.26	12.26 ± 0.14	10.41 ± 0.22	907.06 ± 6.71	139.15 ± 8.67	56.91 ± 3.69
WC.5	15.09 ± 2.93	12.65 ± 0.4	12.13 ± 0.14	10.06 ± 0.26	804.12 ± 50.95	134.17 ± 9.03	52.81 ± 3.6
WC.6	11.92 ± 0.53	13.02 ± 0.62	12.35 ± 0.52	10.43 ± 0.44	887.54 ± 112.05	144.31 ± 11.26	55.75 ± 4.09
WC.7	13.47	12.57	12.09	10.17	806.51	125.87	50.66

	± 1.16	± 0.22	± 0.3	± 0.41	± 59.38	± 10.9	± 1.7
WC.8	13.92 ± 2.23	13.73 ± 0.71	12.85 ± 0.41	10.67 ± 0.2	984.34 ± 85.59	152.55 ± 7.88	62.09 ± 3.3
WC.9	12.01 ± 0.78	12.51 ± 0.89	12.34 ± 0.47	10.21 ± 0.42	835.49 ± 108.67	128.63 ± 11.95	49.85 ± 1.51
WC.10	15.92 ± 2.25	13.60 ± 0.44	12.59 ± 0.22	10.54 ± 0.28	943.63 ± 76.54	137.45 ± 13.52	57.31 ± 5.71
WC.11	13.38 ± 4.29	12.15 ± 0.24	12.09 ± 0.3	10.35 ± 0.28	800.18 ± 45.08	127.58 ± 4.74	46.14 ± 4.56
WC.12	16.66 ± 4.03	12.97 ± 0.22	12.75 ± 0.17	10.61 ± 0.33	918.98 ± 53.08	136.29 ± 2.44	51.51 ± 1.2
WC.13	15.76 ± 2.04	13.67 ± 0.17	13.35 ± 0.28	11.04 ± 0.2	1055.22 ± 44.66	158.33 ± 8.82	61.21 ± 3.19
WC.14	10.63 ± 2.23	13.27 ± 0.28	12.85 ± 0.53	10.56 ± 0.3	936.02 ± 92.77	143.36 ± 8.05	55.89 ± 3.47
WC.15	15.81 ± 0.24	13.80 ± 0.62	12.60 ± 0.42	10.41 ± 0.2	943.87 ± 6.24	139.49 ± 7.26	55.88 ± 4.73
WC.16	12.89 ± 1.77	13.30 ± 0.32	12.92 ± 0.2	10.68 ± 0.36	958.55 ± 68.01	145.21 ± 6.62	58.86 ± 3.01
WC.17	18.77 ± 4.12	12.34 ± 0.35	11.99 ± 0.1	9.87 ± 0.1	768.66 ± 24.58	111.87 ± 11.3	44.53 ± 5.09
WC.18	14.60 ± 1.47	13.32 ± 0.62	12.44 ± 0.44	10.56 ± 0.45	917.04 ± 115.09	139.93 ± 8.97	52.27 ± 4.46
WC.19	13.24 ± 3.46	13.24 ± 0.69	12.64 ± 0.3	10.58 ± 0.5	928.70 ± 105.19	138.56 ± 10.98	53.90 ± 4.71
WC.20	18.83 ± 1.11	12.19 ± 0.44	12.53 ± 0.22	10.73 ± 0.2	857.51 ± 63.43	100.04 ± 12.66	39.88 ± 5.31
WC.21	14.70 ± 2.09	13.89 ± 0.58	13.21 ± 0.28	11.55 ± 0.4	1106.18 ± 110.89	128.15 ± 6.78	50.13 ± 3.1
WC.22	16.10 ± 2.55	13.54 ± 0.45	13.07 ± 0.1	11.34 ± 0.32	1050.26 ± 70.82	134.97 ± 7.18	53.31 ± 2.7
WC.23	13.43 ± 0.4	13.07 ± 0	13.32 ± 0.14	11.00 ± 0.51	998.33 ± 48.46	124.29 ± 16.61	46.87 ± 4.2
WC.24	11.39 ± 0.69	13.79 ± 0.6	13.32 ± 0.41	11.24 ± 0.42	1115.55 ± 115.64	130.64 ± 9.48	53.71 ± 4.16
WC.25	13.02 ± 1.96	13.56 ± 0.35	12.93 ± 0.49	11.57 ± 0.35	1063.55 ± 86.25	126.86 ± 7.53	52.89 ± 2.73
WC.26	13.71 ± 0.4	13.67 ± 0.22	12.74 ± 0.1	11.12 ± 0.17	958.28 ± 78.31	116.34 ± 11.68	46.68 ± 6.64
WC.27	10.77 ± 1.4	13.81 ± 0.22	13.93 ± 0.39	11.86 ± 0.2	1185.77 ± 46.49	144.24 ± 9.92	58.73 ± 1.63
WC.28	7.29 ± 1.7	14.39 ± 0.57	12.58 ± 0.1	10.38 ± 0.28	981.25 ± 72.73	113.58 ± 17.88	44.99 ± 5.69
WC.29	13.05	13.46	12.94	11.03	1004.49	119.74	50.53

	± 0.62	± 0.3	± 0.32	± 0.17	± 52.44	± 5.87	± 1.93
WC.30	9.21 ± 0.96	14.31 ± 0.45	12.77 ± 0.39	10.75 ± 0.17	1044.81 ± 39.09	113.61 ± 9.91	42.29 ± 0.96
WC.31	12.61 ± 3.25	14.33 ± 0.65	12.17 ± 0.36	10.62 ± 0.14	973.20 ± 77.55	109.63 ± 8.53	41.14 ± 4.99
WC.32	12.45 ± 1.96	13.41 ± 0.94	12.07 ± 0.82	10.15 ± 0.46	873.66 ± 156.16	99.14 ± 7.52	37.71 ± 3.9
WC.33	9.88 ± 1.08	14.05 ± 0.52	12.84 ± 0.2	11.13 ± 0.14	1046.12 ± 42.4	116.57 ± 3.36	45.48 ± 2.92
WC.34	11.32 ± 2.79	14.07 ± 0.4	12.31 ± 0.28	10.70 ± 0.39	970.57 ± 80.92	107.94 ± 10.39	43.69 ± 3.94
S.879	9.94 ± 1.26	15.21 ± 0.14	12.85 ± 0.37	11.21 ± 0.33	1170.6 ± 34.21	126.61 ± 3.49	54.13 ± 4.82
S.1932	13.72 ± 1.04	14.75 ± 0.48	12.72 ± 0	11.08 ± 0.36	1103.93 ± 59.63	123.06 ± 10.58	46.09 ± 1.54
S.1902	13.31 ± 2.88	13.62 ± 0.4	13.01 ± 0.1	10.98 ± 0.1	1039.48 ± 44.99	128.1 ± 12.96	48.83 ± 3.05
S.880	13.36 ± 5.55	15.50 ± 0.72	12.73 ± 0.1	11.20 ± 0.14	1172.87 ± 64.53	129.89 ± 11.4	49.56 ± 3
S.1979	13.77 ± 2.52	14.58 ± 1.13	13.55 ± 0.36	11.51 ± 0.59	1216.5 ±180.29	140.00 ± 11.83	58.23 ±12.35
S.3399	16.06 ± 2.77	14.32 ± 0.58	13.08 ± 0.4	10.96 ± 0.53	1093.1 ± 100.3	121.82 ± 7.1	46.41 ± 2.18
S.1509	11.11 ± 3.78	14.23 ± 0.53	13.02 ± 0.82	11.27 ± 0.65	1113.57 ±159.15	120.23 ± 20.43	49.26 ± 8.32
S.1977	13.12 ± 1.93	14.66 ± 0.75	13.2 ± 0.39	11.85 ± 0.22	1219.99 ±120.43	131.87 ± 18.11	54.41 ± 4.83
S.1481	9.76 ± 2.78	12.97 ± 0.47	12.08 ± 0.33	10.09 ± 0.3	848.24 ± 74.37	95.44 ± 8.5	42.21 ± 3.83
S.3400	10.93 ± 3.1	13.99 ± 0.44	12.8 ± 0.57	11.19 ± 0.5	1075.22 ±110.93	118.65 ± 21.22	51.60 ± 3.98
S.3655	14.06 ± 2.14	15.15 ± 0.42	13.71 ± 0.49	11.68 ± 0.3	1265.12 ±141.14	141.13 ± 21.68	57.10 ± 13.01
S.3656	12.33 ± 1.25	15.19 ± 0.64	13.21 ± 0.3	11.55 ± 0.3	1241.43 ± 64.96	142.49 ± 6.26	63.46 ± 6.26
S.3657	15.11 ± 2.11	14.53 ± 0.42	13.45 ± 0.1	11.31 ± 0.39	1181.02 ± 71.25	141.62 ± 3.08	62.18 ± 3.08
S.274 (Sln.1R)	16.12 ± 0.78	14.08 ± 0.79	12.44 ± 0.5	10.79 ± 0.28	984.98 ± 114.96	129.11 ± 4.22	55.88 ± 4.22
Mean	13.71	13.88	12.97	10.99	1044.05	136.07	52.96
Range	7.29- 19.80	12.15- 15.50	11.56- 14.08	9.68- 11.87	723.70- 1300.80	95.44- 168.98	37.71- 63.88
Standard deviation	2.36	0.79	0.59	0.54	142.20	17.24	6.06

Coefficient of variation	17.21	5.69	4.55	4.91	13.62	12.67	11.44
CD @ 5%	3.67	0.82	0.61	0.55	142.61	17.25	7.00
CD @ 1%	4.82	1.08	0.80	0.73	187.43	22.67	9.20

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. Bean length of the robusta coffee accessions studied presently varied from 7.60mm to 9.39mm, bean breadth varied from 6.77mm to 7.81mm, bean thickness varied from 4.22mm to 4.93mm, bean volume varied from 137.93mm^3 to 210.88mm^3, bean density varied from 0.89 to 1.50 and 100 bean weight varied from 13.01gm to 20.74gm. Yield per plant on the average was found to be 4.07kg; however it ranged from 0.18 kg to 10.15kg among the different accessions. Out turn (fresh to dry) ranged from 35.16% to 44.90%, out turn (dry to clean) from 46.19% to 61.78%, and out turn (ripe to clean coffee) from 18.84% to 26.06%. Among the bean characters the highest variability was shown by bean volume followed by bean density and the minimum variability by bean length. Weight of 100 beans showed a coefficient of variation of 11.30 and yield showed a coefficient of variation of 61.67%. Among the different parameters of out turn, out turn (ripe to clean coffee) showed the highest variability. The above discussion shows that yield per plant is the most variable yield character of the robusta coffee accessions under study. This wide variation in yield can be severally utilized for selection and hybridization so that better genotypes with high stable yield are evolved. High variability of yield among accessions of coffee has been reported by earlier workers like Ferwerda (1959) and Dharmaraj and Gopal (1986).

Table 4.3. Yield characters of the seventy three accessions of robusta coffee and S.274 (control) studied- 2. Bean characters, yield and out turn

Accessions	Bean length (mm)	Bean breadth (mm)	Bean thickness (mm)	Bean volume (mm^3)	Bean density	Wt. of 100 beans (g)	Yield per plant(kg)	Out turn (fresh to dry) (%)	Out turn (dry to clean) (%)	Out turn (ripe to clean) (%)
DR.1	8.37 ± 0.14	6.97 ± 0.14	4.54 ± 0.14	162.27 ± 9.92	1.23 ±0.04	16.94 ± 1.32	2.84 ± 1.08	39.25 ± 1.25	54.67 ± 3.11	22.52 ± 1.47
DR.2	8.21 ± 0.35	6.79 ± 0.1	4.40 ± 0.14	150.26 ± 12.96	1.13 ±0	15.59 ± 1.37	2.67 ± 0.32	37.39 ± 1.72	49.67 ± 4.33	19.24 ± 1.18
DR.3	8.84 ± 0.33	7.43 ± 0.24	4.93 ± 0.1	196.15 ± 16.33	1.08 ±0.01	19.89 ± 0.75	2.63 ± 1.13	38.97 ± 1.38	50.11 ± 3.22	21.59 ± 0.37
DR.4	8.97 ± 0.37	7.33 ± 0.14	4.79 ± 0	193.35 ± 12.3	1.08 ±0.04	20.42 ± 1.13	3.71 ± 0.51	39.03 ± 0.69	55.97 ± 2.47	22.29 ± 1.52
DR.5	8.74 ± 0.35	7.40 ± 0	4.64 ± 0.1	184.25 ± 12.42	1.20 ±0.05	18.74 ± 0.97	4.75 ± 1.32	38.00 ± 1.01	53.60 ± 3.38	21.18 ± 1.75
DR.6	9.12 ± 0.22	7.18 ± 0.1	4.72 ± 0.14	188.30 ± 6.68	1.22 ±0.03	19.10 ± 0.65	2.63 ± 0.37	37.41 ± 0.17	54.56 ± 6.56	21.52 ± 2.32
DR.7	8.91 ± 0.17	7.40 ± 0.2	4.68 ± 0.1	186.31 ± 6.86	1.00 ±0.03	19.15 ± 0.37	3.71 ± 0.81	39.70 ± 1.32	50.89 ± 3.78	20.58 ± 1.42
DR.8	8.63 ± 0.33	7.25 ± 0.22	4.71 ± 0	181.15 ± 5.89	1.16 ±0.03	19.10 ± 0.45	3.09 ± 0.81	39.35 ± 0.22	54.78 ± 3.66	21.77 ± 1.75
DR.9	8.76 ± 0.26	7.18 ± 0.37	4.48 ± 0.14	172.81 ± 20	1.20 ±0.05	18.43 ± 1.04	2.42 ± 0.95	37.30 ± 0.88	55.09 ± 5.8	22.72 ± 2.17
DR.10	9.37 ± 0.37	7.40 ± 0.4	4.68 ± 0.2	199.52 ± 25.67	1.08 ±0	20.47 ± 1.58	2.56 ± 0.1	36.33 ± 2.32	55.94 ± 7.04	23.33 ± 2.96
DR.11	9.25 ± 0.26	7.33 ± 0.17	4.63 ± 0.44	192.92 ± 14.58	0.99 ±0.01	19.6 ± 1.39	4.58 ± 0.75	35.92 ± 0.2	51.78 ± 4.66	20.96 ± 1.69

DR.12	8.90 ± 0.1	7.18 ± 0.17	4.72 ± 0.1	184.99 ± 9.2	1.15 ±0.06	18.85 ± 1.45	3.75 ± 0.45	36.96 ± 0	57.17 ± 0.17	22.72 ± 1.03
DR.13	9.10 ± 0.2	7.48 ± 0.1	4.90 ± 0.22	204.13 ± 15.57	1.03 ±0.01	20.44 ± 2.01	5.83 ± 0.76	36.26 ± 0.79	54.56 ± 3.88	21.70 ± 0.17
DR.14	8.67 ± 0.24	7.42 ± 0.4	4.83 ± 0.1	190.02 ± 19.48	1.02 ±0	19.36 ± 1.46	6.58 ± 0.81	38.05 ± 2.08	48.27 ± 0.62	20.24 ± 0.24
DR.15	8.95 ± 0.28	7.38 ± 0.26	4.76 ± 0.24	192.79 ± 17.33	1.22 ±0.09	19.30 ± 1.57	5.63 ± 2.25	37.23 ± 0.47	53.34 ± 1.77	23.06 ± 0.57
DR.16	8.65 ± 0.33	6.88 ± 0.1	4.55 ± 0.1	168.43 ± 5.02	1.28 ±0	16.27 ± 0.96	5.63 ± 0.69	36.89 ± 0.85	50.34 ± 0.33	22.21 ± 0.54
DR.17	8.95 ± 0.14	7.03 ± 0	4.62 ± 0.1	178.11 ± 4.03	1.04 ±0	17.22 ± 0.74	6.00 ± 2.88	37.77 ± 0.84	51.23 ± 2.33	21.99 ± 0.8
DR.18	8.82 ± 0.14	7.13 ± 0.17	4.67 ± 0.14	179.09 ± 12.13	1.03 ±0	18.18 ± 0.74	6.04 ± 1.06	36.16 ± 0.79	54.41 ± 1.47	22.25 ± 0.24
DR.19	9.08 ± 0.28	7.07 ± 0	4.68 ± 0.1	183.84 ± 11.7	1.16 ±0	18.35 ± 1.22	8.25 ± 0.24	36.32 ± 0.91	51.56 ± 3.56	22.14 ± 2.14
DR.20	9.36 ± 0.17	7.23 ± 0.1	4.60 ± 0.1	191.84 ± 12.7	1.13 ±0	18.66 ± 0.42	4.42 ± 1.38	38.93 ± 2.05	54.23 ± 1.33	23.73 ± 1.06
Wt.1	8.87 ± 0.24	7.18 ± 0.17	4.88 ± 0.14	190.29 ± 10.97	1.19 ±0.11	18.88 ± 0.95	8.25 ± 4.57	35.85 ± 1.05	51.34 ± 1.56	19.97 ± 0.39
Wt.2	8.71 ± 0.3	7.19 ± 0.14	4.71 ± 0.1	180.6 ± 9.8	1.21 ±0.02	18.08 ± 1.05	10.15 ± 1.46	35.16 ± 1.14	52.34 ± 0.33	20.92 ± 0.32
Wt.3	8.48 ± 0.1	7.15 ± 0	4.56 ± 0.1	169.05 ± 3.43	1.21 ±0.03	17.65 ± 0.52	8.94 ± 3.25	36.37 ± 0.36	53.64 ± 1.2	21.22 ± 0.1
Wt.4	8.77 ± 0.58	7.26 ± 0.17	4.56 ± 0.17	179.33 ± 18.55	1.13 ±0.04	18.29 ± 2.71	9.73 ± 1.81	36.36 ± 1.09	61.78 ± 0	24.25 ± 0
Wt.5	8.38 ± 0.37	7.12 ± 0.2	4.53 ± 0.1	165.14 ± 13.43	1.24 ±0.02	17.23 ± 0.53	8.38 ± 2.39	35.28 ± 0.68	51.67 ± 3.22	21.17 ± 0.99

Wt.6	8.80 ± 0.2	7.21 ± 0.2	4.61 ± 0	178.36 ± 6.89	1.33 ±0.14	18.34 ± 0.4	8.92 ± 2.59	35.60 ± 1.17	49.78 ± 0.89	19.79 ± 0.48
WC.1	8.46 ± 0.36	7.07 ± 0.14	4.45 ± 0.17	162.66 ± 4.31	1.06 ±0.03	15.85 ± 0.57	1.65 ± 0.97	41.33 ± 2.75	54.53 ± 6.36	20.05 ± 0.96
WC.2	8.19 ± 0.3	7.02 ± 0.14	4.48 ± 0.22	157.64 ± 11.79	1.10 ±0	15.82 ± 0.92	1.40 ± 0.45	38.87 ± 0.57	55.56 ± 1.33	24.89 ± 1.34
WC.3	8.52 ± 0	7.14 ± 0.17	4.50 ± 0.1	158.06 ± 12.7	1.18 ±0	16.16 ± 0.41	1.94 ± 0.71	41.65 ± 0.58	50.11 ± 1	22.11 ± 0.88
WC.4	9.39 ± 0.1	7.28 ± 0.35	4.52 ± 0.1	189.58 ± 16.48	1.07 ±0	17.61 ± 1.37	3.09 ± 1.72	41.17 ± 0.14	51.86 ± 1.64	21.63 ± 0.35
WC.5	8.59 ± 0.24	7.38 ± 0.26	4.61 ± 0.2	178.44 ± 15.99	0.89 ±0.11	17.66 ± 1.32	1.88 ± 0.62	39.39 ± 0.98	50.1 ± 8.66	21.71 ± 3.2
WC.6	8.86 ± 0.17	7.29 ± 0.1	4.63 ± 0.1	184.84 ± 11.3	1.02 ±0.02	17.48 ± 0.81	1.02 ± 0.33	37.93 ± 2.29	53.71 ± 1.71	22.41 ± 1.14
WC.7	8.56 ± 0.22	7.20 ± 0.2	4.56 ± 0	162.3 ± 24.61	1.08 ±0.02	16.3 ± 1.59	1.29 ± 0.1	40.39 ± 2.35	55.11 ± 0.89	23.54 ± 0.35
WC.8	9.32 ± 0.48	7.55 ± 0.24	4.87 ± 0.22	210.88 ± 25.81	1.14 ±0.03	20.74 ± 1.41	2.95 ± 0.99	40.72 ± 1.46	51.04 ± 6.6	22.5 ± 3.09
WC.9	8.61 ± 0.58	7.15 ± 0.46	4.66 ± 0.28	177.13 ± 35.1	0.94 ±0.02	17.02 ± 2.7	1.32 ± 1	38.90 ± 2.53	52.00 ± 0.89	21.70 ± 0.4
WC.10	9.05 ± 0.48	7.75 ± 0.2	4.81 ± 0.24	203.12 ± 33.14	1.08 ±0.07	19.33 ± 2.61	2.31 ± 0.33	41.70 ± 0.2	52.89 ± 3.55	23.05 ± 1.33
WC.11	7.91 ± 0.28	6.87 ± 0.17	4.39 ± 0.14	144.56 ± 2.6	1.15 ±0.09	13.98 ± 0.66	0.30 ± 0.36	36.49 ± 2.86	53.17 ± 0.62	23.88 ± 1.87
WC.12	8.07 ± 0.54	7.29 ± 0	4.57 ± 0	172.55 ± 3.7	1.22 ±0.06	16.96 ± 0.49	1.14 ± 1.01	37.87 ± 1.59	58.78 ± 5.45	23.32 ± 1.98
WC.13	9.08 ± 0.28	7.81 ± 0.53	4.82 ± 0.14	209.04 ± 22.4	1.10 ±0.02	19.85 ± 1.4	4.38 ± 0.77	38.68 ± 0.8	51.40 ± 2.51	22.24 ± 0.48

WC.14	8.66 ± 0.1	7.21 ± 0	4.57 ± 0.17	174.24 ± 4.46	1.08 ±0.01	17.37 ± 1.24	3.24 ± 0.66	39.26 ± 0.3	58.85 ± 0.58	26.26 ± 0.26
WC.15	9.09 ± 0.14	7.35 ± 0.37	4.70 ± 0	191.89 ± 9.84	1.17 ±0.01	17.88 ± 1.05	2.17 ± 0.62	41.16 ± 0.79	55.11 ± 4	23.38 ± 3.1
WC.16	8.78 ± 0.1	7.15 ± 0.14	4.63 ± 0.17	179.72 ± 6.75	1.20 ±0.05	18.28 ± 0.14	4.79 ± 0.28	40.52 ± 2.28	50.34 ± 1.45	23.42 ± 3.18
WC.17	8.21 ± 0.28	6.94 ± 0	4.42 ± 0.1	156.32 ± 4.25	1.11 ±0.02	15.60 ± 0.83	3.27 ± 1.98	39.97 ± 1.39	51.56 ± 0.45	22.89 ± 1.26
WC.18	8.81 ± 0.57	7.29 ± 0.1	4.67 ± 0.17	183.93 ± 21.13	0.97 ±0.06	17.18 ± 2.03	4.33 ± 2.63	37.33 ± 0.79	53.56 ± 2	21.65 ± 1.65
WC.19	8.72 ± 0.2	6.88 ± 0.14	4.51 ± 0	165.04 ± 7.88	1.12 ±0.03	15.89 ± 1.02	2.47 ± 0.24	39.10 ± 0.63	52.34 ± 3.22	23.96 ± 2.62
WC.20	7.90 ± 0.5	6.83 ± 0.1	4.30 ± 0.14	142.08 ± 13.87	0.90 ±0.02	13.67 ± 1.06	3.79 ± 0.94	40.16 ± 0.99	56.00 ± 5.78	22.11 ± 1.17
WC.21	9.01 ± 0.1	7.12 ± 0	4.52 ± 0.1	177.64 ± 7.21	1.23 ±0.03	16.35 ± 0.93	2.33 ± 0.57	39.1 ± 0.3	54.00 ± 2.44	23.77 ± 2.28
WC.22	8.99 ± 0.17	7.42 ± 0.39	4.65 ± 0.14	191.06 ± 16.16	1.21 ±0.09	18.41 ± 0.6	3.81 ± 2.04	38.73 ± 1.02	49.89 ± 0.1	21.54 ± 1.71
WC.23	8.34 ± 0.14	6.90 ± 0.14	4.37 ± 0.2	144.92 ± 26.09	1.17 ±0	15.12 ± 1.24	0.18 ± 0.17	39.82 ± 1.53	53.00 ± 3.67	21.00 ± 1.51
WC.24	9.20 ± 0.26	7.12 ± 0.17	4.57 ± 0.17	183.07 ± 16.37	1.02 ±0	18.08 ± 1.73	1.98 ± 1.48	41.16 ± 0.4	54.84 ± 0.17	23.63 ± 2.53
WC.25	8.79 ± 0.4	7.23 ± 0	4.42 ± 0.1	172.81 ± 5.83	1.06 ±0.05	16.38 ± 0.72	2.74 ± 0.78	41.87 ± 1.7	49.78 ± 1.33	21.47 ± 0.32
WC.26	8.29 ± 0.1	6.90 ± 0.14	4.28 ± 0.1	140.21 ± 19.21	1.50 ±0.16	15.19 ± 1.2	3.29 ± 0.83	40.02 ± 3.72	51.72 ± 0.72	23.46 ± 1.01
WC.27	8.70 ± 0.2	7.32 ± 0	4.73 ± 0	184.67 ± 1.72	1.08 ±0.07	18.52 ± 0.32	4.13 ± 1.64	40.84 ± 1.99	51.89 ± 1.67	23.48 ± 1.3

WC.28	7.89 ± 0.2	6.77 ± 0	4.36 ± 0.1	143.12 ± 7.94	1.00 ±0.13	14.36 ± 1.27	1.11 ± 0.47	39.85 ± 2.15	50.94 ± 0.26	21.92 ± 0.39
WC.29	8.63 ± 0.17	6.88 ± 0	4.38 ± 0	158.98 ± 4.52	0.96 ±0.02	16.28 ± 0.53	2.98 ± 1.17	41.15 ± 1.95	54.27 ± 2.71	23.55 ± 0.35
WC.30	8.37 ± 0.17	6.82 ± 0.1	4.33 ± 0.2	151.46 ± 10.29	1.25 ±0.09	13.89 ± 0.6	1.35 ± 1.4	37.41 ± 3.36	53.38 ± 3.38	23.74 ± 1.65
WC.31	8.19 ± 0.46	6.88 ± 0	4.29 ± 0.17	148.05 ± 14.86	0.92 ±0.01	13.85 ± 1.49	3.17 ± 0.61	37.70 ± 1.59	55.56 ± 4.45	23.46 ± 2.34
WC.32	7.60 ± 0.46	6.84 ± 0.2	4.27 ± 0.22	136.26 ± 19.07	1.18 ±0.01	13.01 ± 2.31	0.80 ± 0.14	37.92 ± 2.22	53.47 ± 5.03	22.54 ± 3.57
WC.33	8.05 ± 0.1	7.16 ± 0.1	4.57 ± 0.1	161.47 ± 3.96	1.02 ±0	15.06 ± 1.11	4.67 ± 1.29	39.01 ± 2.17	54.36 ± 4.14	22.66 ± 2.57
WC.34	8.05 ± 0.17	6.94 ± 0.1	4.30 ± 0.1	147.51 ± 5.66	1.09 ±0.02	14.11 ± 0.87	1.97 ± 0.57	40.30 ± 0.96	54.78 ± 1	23.11 ± 1.15
S.879	9.15 ± 0.4	7.24 ± 0.17	4.54 ± 0	180.12 ± 14.61	1.18 ±0.02	18.17 ± 1.08	5.94 ± 2.37	42.69 ± 2.75	50.41 ± 1.08	21.35 ± 0.03
S.1932	8.36 ± 0.4	7.02 ± 0.14	4.53 ± 0.1	162.60 ± 6.1	1.08 ±0.01	15.41 ± 0.76	9.78 ± 2.49	37.75 ± 2.09	52.57 ± 0.45	20.7 ± 0.06
S.1902	8.30 ± 0.17	6.94 ± 0.1	4.44 ± 0	156.45 ± 4.24	1.03 ±0.02	15.63 ± 1.87	5.25 ± 1.85	39.08 ± 1.58	50.29 ± 1.71	21.95 ± 1.02
S.880	9.30 ± 0.52	6.97 ± 0	4.37 ± 0.1	170.51 ± 10.27	1.23 ±0.06	16.39 ± 1.22	7.63 ± 1.37	38.32 ± 1.49	48.09 ± 2.76	19.00 ± 1.17
S.1979	8.83 ± 0.5	7.14 ± 0.62	4.61 ± 0.3	179.76 ± 37.24	1.12 ±0.04	17.97 ± 4.04	3.07 ± 0.98	41.62 ± 1.51	51.61 ± 1.39	19.54 ± 0.73
S.3399	8.27 ± 0.24	6.83 ± 0	4.53 ± 0.1	157.25 ± 6.49	1.13 ±0	15.62 ± 1.05	9.47 ± 2.01	37.90 ± 0.68	50.35 ± 2.15	19.12 ± 0.52
S.1509	8.18 ± 0.41	6.77 ± 0.1	4.22 ± 0.24	143.1 ± 17.06	1.16 ±0.05	13.92 ± 2.02	1.96 ± 2.22	41.22 ± 3.05	47.45 ± 4.34	19.64 ± 1.39

S.1977	8.42 ± 0.46	7.57 ± 0.33	4.60 ± 0.2	181.23 ± 25.42	1.03 ±0.19	17.75 ± 2.55	1.94 ± 1.07	40.56 ± 1.75	49.40 ± 0.51	19.47 ± 0.3
S.1481	7.80 ± 0.14	6.80 ± 0.1	4.23 ± 0	137.93 ± 4.27	1.10 ±0	13.46 ± 0.4	2.96 ± 0.57	44.20 ± 1.5	48.77 ±1.21	20.56 ± 0.06
S.3400	8.33 ± 0.6	6.98 ± 0.1	4.38 ± 0.17	158.43 ± 16.23	1.13 ±0.03	15.75 ± 1.92	3.81 ± 2.24	43.1 ± 3.13	51.51 ± 0.4	20.44 ± 0.39
S.3655	8.97 ± 0.41	7.15 ± 0.1	4.66 ± 0.14	183.67 ± 14.99	1.17 ±0.05	19.61 ± 1.84	4.08 ± 0.61	40.29 ± 3.62	48.55 ± 0.35	19.95 ± 0.06
S.3656	9.36 ± 0.22	7.31 ± 0.24	4.68 ± 0	197.22 ± 10.9	0.98 ±0	19.19 ± 0.93	6.35 ± 1.9	44.90 ± 5.7	53.87 ± 2.13	22.95 ± 1.53
S.3657	8.79 ± 0.3	7.20 ± 0.1	4.70 ± 0	182.67 ± 6.3	1.00 ±0.02	19.09 ± 0.66	6.35 ± 1.67	44.11 ± 0.89	46.19 ± 3.52	18.84 ± 1.34
S.274 (Sln.1R)	8.98 ± 0.37	6.80 ± 0.14	4.25 ± 0.17	164.26 ± 12.62	0.99 ±0.02	16.75 ± 1.72	7.23 ± 1.85	40.28 ± 0.51	49.85 ± 1.5	20.37 ±1.2
Mean	8.67	7.15	4.57	173.56	1.11	17.25	4.07	39.07	52.59	21.96
Range	7.60-9.39	6.77-7.81	4.22-4.93	137.93-210.88	0.89-1.50	13.01-20.74	0.18-10.15	35.16-44.90	46.19-61.78	18.84-26.06
Standard deviation	0.10	0.23	0.17	18.24	0.10	1.95	2.51	2.18	2.76	1.52
Coefficient of variation	1.15	3.22	3.71	10.51	9.01	11.30	61.67	5.58	5.25	6.92
CD @5%	0.52	0.33	0.23	23.94	0.08	2.20	2.33	2.83	5.05	2.44
CD @1%	0.69	0.44	0.30	31.40	0.11	2.89	3.07	3.72	6.64	3.21

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 (Table 4.4). Percentage of A grade beans varied from 20.84% to 65.35% and percentage of pea berries varied from 9.03% to 35.42%. Percentage of A grade beans showed 20.84% of variability and percentage of pea berries showed 22.67% of variability. Occurrence of high percentage of A grade beans is a very important quality character of coffee since it is directly related to the yield and quality of coffee. Moreover, bold beans fetch a premium price in the market. Higher incidence of pea berries is undesirable because it reduces coffee yield and percentage of A grade beans. The importance of maximizing the production of A grade beans has been emphasized by earlier workers like Srinivasan (1988). Sreenivasan (1989) assessed the physical quality of Sln.12 of arabica coffee and found that 70.5% of beans produced were of A grade. In the present experiment the highest percentage of A grade beans produced was 65.35 in the accession S.1932. This observation emphasizes the importance of improving robusta coffee by practicing selection for percentage of A grade beans.

Table 4.4. Physical quality characters (quantitative) of the seventy three accessions of robusta coffee and S.274 (control) studied

Accessions	% of A grade beans	% of B grade beans	% of C grade beans	% of beans below C grade	% of pea berries
DR.1	47.00 ± 0.84	20.11 ± 3.18	5.26 ± 3.33	2.82 ± 2.07	24.81 ± 5.2
DR.2	33.77 ± 1.69	22.23 ± 1.87	6.11 ± 2.52	2.46 ± 1.2	35.42 ± 1.02
DR.3	52.89 ± 1.1	10.32 ± 3.86	4.94 ± 1.75	2.79 ± 0.33	29.07 ± 5.96
DR.4	55.04 ± 1.94	10.53 ± 7.52	6.05 ± 4.01	1.93 ± 1.24	26.45 ± 2.53
DR.5	54.30 ± 2.56	4.59 ± 0.46	9.37 ± 7.68	3.53 ± 2.52	28.21 ± 8.08
DR.6	41.69 ± 3.18	12.80 ± 2	10.17 ± 0.42	3.52 ± 0.64	31.83 ± 0.55

DR.7	59.67 ± 4.37	10.82 ± 1.98	3.21 ± 1.91	1.50 ± 0.77	24.80 ± 3.73
DR.8	48.69 ± 3.81	10.65 ± 3.58	10.22 ± 7.85	5.06 ± 1.91	25.38 ± 2.76
DR.9	48.12 ± 6.17	10.73 ± 3.1	6.54 ± 1.65	3.12 ± 1.48	31.49 ± 7.12
DR.10	53.49 ± 3.88	6.10 ± 2.01	7.86 ± 5.28	3.84 ± 1.1	28.71 ± 1.62
DR.11	50.11 ± 3.27	10.09 ± 5.47	11.03 ± 6.66	3.14 ± 1.8	25.63 ± 0.81
DR.12	55.77 ± 4.73	10.51 ± 3.48	4.09 ± 2.59	2.26 ± 0.24	27.37 ± 3.36
DR.13	54.70 ± 6.65	7.95 ± 5.71	7.13 ± 5.36	2.34 ± 0.7	27.89 ± 6.52
DR.14	52.01 ± 1.08	21.60 ± 3.36	10.86 ± 13.29	2.08 ± 0.33	20.06 ± 1.77
DR.15	48.31 ± 2.21	26.66 ± 1.92	12.64 ± 4.82	3.36 ± 2.49	9.03 ± 2.9
DR.16	43.72 ± 4.42	26.52 ± 7.94	4.83 ± 2.85	2.96 ± 0.41	21.97 ± 6.74
DR.17	45.65 ± 12.43	17.30 ± 1.36	8.37 ± 5.98	3.66 ± 2.68	25.02 ± 2.87
DR.18	50.58 ± 5.23	12.37 ± 6.94	5.58 ± 3.54	2.98 ± 0.82	28.49 ± 7.85
DR.19	25.65 ± 11.95	29.61 ± 1.96	16.01 ± 3.51	4.70 ± 1.08	24.03 ± 8.81
DR.20	46.89 ± 1.27	30.9 ± 2.82	5.18 ± 1.32	2.76 ± 1.59	14.26 ± 1.36
Wt.1	50.04 ± 1.92	21.49 ± 3.46	4.32 ± 3.46	2.27 ± 0.36	21.89 ± 1.2
Wt.2	47.64 ± 8.12	22.79 ± 7.2	6.52 ± 1.59	2.19 ± 0.42	20.86 ± 0.71
Wt.3	56.8 ± 3.91	11.99 ± 0.46	5.75 ± 3.79	2.79 ± 0.33	22.68 ± 0.62
Wt.4	45.84 ± 2.53	23.69 ± 3.25	7.75 ± 3.76	3.47 ± 0.48	19.25 ± 1.1
Wt.5	46.75 ± 3.1	16.44 ± 1.41	11.96 ± 4.9	4.44 ± 4.56	20.42 ± 5.01
Wt.6	37.7 ± 10.9	18.38 ± 16.21	11.15 ± 2.14	2.32 ± 0.57	30.45 ± 5.33
WC.1	30.59 ± 5.51	28.06 ± 7.62	12.67 ± 2.36	3.44 ± 0.89	25.24 ± 3.93
WC.2	38.06 ± 1.82	27.94 ± 6.45	8.42 ± 1.7	3.46 ± 2.47	22.13 ± 5.5

WC.3	27.28 ± 1.91	35.44 ± 4.32	14.09 ± 2.11	4.51 ± 0.46	18.69 ± 3.39
WC.4	47.35 ± 2.23	16.03 ± 1.81	12.01 ± 1.45	3.95 ± 1.33	20.66 ± 1.26
WC.5	54.09 ± 4.14	17.02 ± 3.5	10.39 ± 5.93	4.59 ± 3.58	13.91 ± 3.45
WC.6	52.33 ± 8.24	18.26 ± 8.6	9.37 ± 0.76	2.46 ± 0.55	17.59 ± 1.39
WC.7	57.52 ± 4.2	12.66 ± 6.07	6.25 ± 4.42	1.65 ± 1.14	21.92 ± 6.39
WC.8	43.04 ± 3.35	14.49 ± 4.27	10.99 ± 2.63	4.45 ± 1.25	27.02 ± 1.58
WC.9	47.31 ± 2.86	20.66 ± 6.07	9.03 ± 3.76	3.66 ± 1.28	19.34 ± 4.13
WC.10	58.05 ± 11.61	11.46 ± 3.27	6.69 ± 5.06	2.99 ± 0.49	20.81 ± 6.78
WC.11	40.43 ± 9.52	25.01 ± 12.43	10.82 ± 2.52	3.02 ± 1.02	20.72 ± 2.21
WC.12	58.34 ± 9.61	10.61 ± 2.44	7.19 ± 4.66	2.82 ± 1.48	21.04 ± 4.35
WC.13	49.01 ± 3.86	17.74 ± 5.48	11.96 ± 1.67	2.16 ± 0.97	19.95 ± 7.04
WC.14	40.41 ± 8.88	24.88 ± 7.64	10.25 ± 1.34	4.39 ± 0.84	20.07 ± 1.66
WC.15	53.27 ± 5.36	15.43 ± 5.24	9.15 ± 4.54	1.58 ± 0.57	20.57 ± 5.18
WC.16	46.67 ± 9.76	21.31 ± 1.86	10.33 ± 5.88	3.94 ± 0.87	17.75 ± 4.47
WC.17	27.19 ± 3.1	35.95 ± 4.3	13.31 ± 1.22	3.12 ± 1.89	20.43 ± 2.08
WC.18	45.25 ± 4.28	26.6 ± 6.04	10.02 ± 3.08	3.00 ± 1.29	15.14 ± 2.64
WC.19	32.65 ± 4	35.17 ± 0.84	9.41 ± 1.06	3.58 ± 2.05	19.19 ± 3.64
WC.20	20.84 ± 7.15	37.92 ± 0.1	15.06 ± 2.1	4.55 ± 2.09	21.63 ± 3.85
WC.21	39.99 ± 12	25.39 ± 4.72	12.91 ± 6.31	4.44 ± 1.81	17.26 ± 0.85
WC.22	37.5 ± 3.62	16.17 ± 2.74	20.73 ± 0.7	6.94 ± 1.56	18.67 ± 0.81
WC.23	41.38 ± 4.11	22.01 ± 7.54	11.16 ± 5.94	4.37 ± 1.78	21.07 ± 3.53
WC.24	25.79 ± 4.26	38.59 ± 4.42	18.35 ± 2.64	3.76 ± 1.11	13.52 ± 0.94

WC.25	44.24 ± 5.71	21.27 ± 4.87	12.38 ± 3.1	3.85 ± 1.01	18.26 ± 3.59
WC.26	35.99 ± 3.98	26.18 ± 1.84	10.25 ± 0.88	3.48 ± 1.33	24.09 ± 2.48
WC.27	50.68 ± 3.84	15.52 ± 5.19	13.2 ± 0.96	2.92 ± 0.85	17.68 ± 0.46
WC.28	31.97 ± 2.42	31.73 ± 5.89	15.58 ± 5.01	4.53 ± 2.56	16.19 ± 6.4
WC.29	26.62 ± 12.91	28.46 ± 6.68	17.28 ± 6.56	3.42 ± 1.36	24.22 ± 1.23
WC.30	45.86 ± 6.04	15.84 ± 2.84	9.31 ± 1.86	2.12 ± 0.24	26.87 ± 3.2
WC.31	56.20 ± 6.65	11.93 ± 8.44	8.05 ± 4.78	1.43 ± 0.4	22.39 ± 3.02
WC.32	46.80 ± 3.21	18.29 ± 4.82	12.03 ± 0.63	3.21 ± 2.08	19.67 ± 1.01
WC.33	63.28 ± 13.02	10.20 ± 5.27	7.10 ± 5.59	2.20 ± 0.68	17.21 ± 2.47
WC.34	54.61 ± 2.8	5.18 ± 2.04	12.5 ± 4.97	3.03 ± 1.22	24.69 ± 2.87
S.879	54.21 ± 5.94	16.02 ± 3.75	7.96 ± 1.2	3.72 ± 2.35	18.10 ± 8.67
S.1932	65.35 ± 3.16	9.94 ± 4.17	5.11 ± 2.22	4.20 ± 1.59	15.40 ± 1.05
S.1902	49.91 ± 6.52	21.74 ± 3.19	7.89 ± 3.38	3.56 ± 1.71	16.90 ± 8.85
S.880	51.50 ± 5.51	16.40 ± 5.72	12.93 ± 6.85	3.45 ± 3.11	15.72 ± 5.26
S.1979	61.17 ± 5.57	12.29 ± 3.63	4.94 ± 5.88	2.96 ± 0.65	18.64 ± 3.79
S.3399	60.96 ± 8.03	11.35 ± 1.45	6.36 ± 1.46	2.26 ± 0.94	19.08 ± 10.72
S.1509	45.59 ± 18.75	26.09 ± 17.24	7.26 ± 4.85	4.46 ± 1.89	16.60 ± 4.78
S.1977	45.09 ± 6.95	20.18 ± 14.61	6.52 ± 1.83	5.27 ± 0.52	22.94 ± 10.02
S.1481	34.72 ± 2.1	27.39 ± 4.89	14.28 ± 2.45	5.33 ± 0.24	18.28 ± 3.98
S.3400	52.61 ± 3.76	15.13 ± 2.83	11.86 ± 4.73	2.98 ± 3.22	17.42 ± 10.14
S.3655	51.20 ± 5.13	11.00 ± 2.63	6.52 ± 5.05	3.71 ± 0.77	27.58 ± 3.03
S.3656	48.75 ± 3.34	12.54 ± 6.31	11.98 ± 3.62	2.89 ± 0.85	23.84 ± 12.99

S.3657	48.86 ± 3.38	18.60 ± 4.87	12.43 ± 4.9	2.77 ± 1.07	17.33 ± 7.27
S.274 (Sln.1R)	44.43 ± 1.89	23.97 ± 1.22	13.12 ± 4.3	1.45 ± 0.85	17.03 ± 4.78
Mean	46.46	19.04	9.73	3.30	21.57
Range	20.84-65.35	4.59-38.59	3.21-20.73	1.43-6.94	9.03-35.42
Standard deviation	9.68	8.13	3.60	1.03	4.89
Coefficient of variation	20.84	42.7	36.99	31.21	22.67
CD @5%	10.08	9.09	6.75	NS	7.87
CD @1%	13.25	11.95	8.87	NS	10.35

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 analysed presently. Among the growth characters girth of primary branches was found to show the highest variation. Among yield characters yield per plant varied tremendously between the accessions with a coefficient of variation as high as 61.67%. Percentage of pea berries also showed 22.67% of variation. Breeding programmes based on such parameters that show significantly high variability will result in the production of improved varieties that are good in growth, yield and quality.

Some efforts to analyze the variability of arabica coffee genotypes have already been carried out in India. A study to differentiate 25 *Coffea arabica* genotypes and 34 *Coffea canephora* genotypes has been carried out by Srinivasan and Subbalakshmi (1981). They found that arabica genotypes showed lower variation for yield. Srinivasan and Vishveshwara (1981) also studied the variability and breeding value of characters related to yield in arabica coffee. Dharmaraj and Gopal (1986) studied the genetic variability of growth and yield characters in coffee and observed highly significant variation in respect of growth and yield characters. Anil kumar *et al.* (2002) conducted similar studies and assessed the comparative performance of five arabica coffee varieties.

Outside India also several workers have attempted to analyze arabica coffee germplasm. Zapata (1975) analysed the yield and bean characteristics of coffee germplasm introduced to Colombia. Charrier *et al.* (1978b) conducted a study of variability of progeny of *Coffea arabica* in Madagascar. Louarn (1978) attempted a study of the comparative diversity of *Coffea arabica* progenies in Ivory Coast and observed significant differences between populations and families. The diversity of open pollinated progenies of coffee in Ivory Coast was studied by Reynier *et al.* in 1978. There was marked variation between populations and between families for all the characters studied. Berthoud *et al.* (1978) observed the variability of quantitative characters in 34 *Coffea arabica* populations in the Ivory Coast. Charrier (1978) analysed the phenotypic variability of a *Coffea arabica* collection in Madagascar. Walyaro and Vossen (1979) and Walyaro (1983) found that in arabica coffee the selection efficiency for higher yield is increased considerably taking into account growth parameters like stem girth, canopy radius, number of berries per node and internodal length. Carvalho *et al.* (1984b) studied the possibility of inducing genetic variability through mutations. Tadesse and Engels (1986) studied variability of arabica coffee accessions in Ethiopia based on fruit characters and stressed the importance of the influence of environment on these characters. Aguiar *et al.* (2004) reported that plant height, fruit colour, leaf rust resistance and earliness are sufficient for the identification of good cultivars in *Coffea arabica*.

Molecular techniques like RAPD, AFLP, SSR and ISSR marker systems are being used recently for the assessment of variability in coffee (Castillo *et al.*, 1994; Sera *et al.*, 2003; Silveira *et al.*, 2003; Chaparro *et al.*, 2004; Maluf *et al.*, 2005 and Diniz *et al.*, 2005).

Study of variability in robusta coffee has also been attempted by coffee breeders to some extent. Charrier and Eskes (2004) have suggested that due to its allogamous nature each robusta plant can be considered a unique genotype. According to Mawardi and Hartobudoyo (1981) the most important yield component in robusta coffee is the number of productive nodes per branch. Leroy and Charrier (1990) have reported the recurrent selection programme practiced in Ivory Coast based on the presence of two genetically and geographically distinct groups of *Coffea canephora* present in the area. Differential resistance of *Coffea canephora* genotypes to drought stress has been reported by Montagnon and Leroy in 1993. Vasudeva and Ratageri (1981) studied the difference in leaf to crop ratio in arabica and robusta coffee. Srinivasan (1988) conducted a comparative study of juvenile growth characters of coffee varieties in northeast India. Ahmed *et al.* (1996) evaluated the sib-mated progenies of C x R comparatively with open pollinated progenies and other robusta for growth and yield characters. A dwarf C x R hybrid plant with desirable characters like short internode, compact bush size and bold beans was identified by Suresh kumar *et al.* (1999a). Variability in the sib mated progenies of C x R coffee has been assessed by Raghu *et al.* (2003). They observed that crop yield was significantly related to total number of fruiting nodes per plant followed by mean number of berries per plant. Suresh kumar *et al.* (2000) assessed 13 accessions of exotic robustas for yield and quality parameters and found that the accessions could be classified based on yield and quality.

Certain efforts to study the genetic variability of robusta coffee based on electrophoretic and molecular approaches have also been made (Budiani and Tahardi, 1992; Mathius *et al.*, 1998; Dussert *et al.*, 1999 and Prakash *et al.*, 2005).

The present assessment of variability of robusta coffee has confirmed earlier observations on the existence of significant quantum of variability among robusta coffee accessions and the potential of this variability as rich source of genes and genotypes in breeding programmes. Further it has highlighted the importance of girth of primary branches, yield per plant and percentage of A grade beans as highly variable characters that need special attention in breeding programmes.

4.1.2. Study of phenotypic variance, genotypic variance, phenotypic coefficient of variation and genotypic coefficient of variation

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 (Table 4.5). 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, sem 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.

Table 4.5. Statistical parameters of the growth, yield and quality (quantitative) characters of robusta coffee studied

Character	Phenotypic variance	Genotypic variance	PCV	GCV	Heritability (broad sense)	Genetic advance
1. Growth characters						
Stem girth	125.30	47.10	11.53	7.08	37.59	8.93
Number of primary branches	0.38	0.07	24.66	10.58	18.42	9.67
Number of secondaries per primary	0.97	0.48	21.36	15.03	49.48	24.76

Girth of primary branches	139.41	65.14	23.17	15.79	46.73	22.24
Length of primary branches	895.97	442.32	16.17	11.36	49.37	16.44
Internodal length	1.35	0.93	16.16	13.37	68.89	22.93
Bush spread	2957.27	1250.68	16.74	10.89	42.29	14.56
Leaf length	3.17	1.22	7.98	4.93	38.49	6.33
Leaf breadth	0.61	0.17	7.84	4.12	27.87	4.50
Leaf area	414.23	99.82	13.63	6.69	24.10	6.96
2. Yield characters						
Character	Phenotypic variance	Genotypic variance	PCV	GCV	Heritability (broad sense)	Genetic advance
Fruits per node	9.09	3.84	21.95	14.44	42.24	19.17
Fruit length	0.80	0.54	6.41	5.26	67.50	8.92
Fruit breadth	0.45	0.30	5.17	4.24	66.67	7.09
Fruit thickness	0.37	0.25	5.55	4.55	67.57	7.73
Fruit volume	25518.18	17576.82	15.30	12.70	68.88	21.71
Weight of 100 fresh fruits	374.65	258.44	14.23	11.82	68.98	20.22
Weight of 100 dry fruits	49.47	30.33	13.27	10.40	61.31	16.77
Bean length	0.26	0.14	5.88	4.27	53.85	6.53
Bean breadth	0.08	0.04	3.92	2.80	50.00	4.03
Bean thickness	0.04	0.02	4.38	3.06	50.00	4.51
Bean volume	482.03	258.19	12.65	9.26	53.56	13.96
Bean density	0.013	0.010	10.27	9.01	76.92	16.27
Weight of	4.98	3.10	12.93	10.20	62.25	16.58

100 beans						
Yield per plant	7.71	5.58	68.30	57.99	72.37	101.83
Out turn (fresh to dry)	6.83	3.71	6.65	4.91	54.32	7.44
Out turn (dry to clean)	14.29	4.32	7.19	3.96	30.23	4.48
Out turn (ripe to clean)	3.85	1.53	8.92	5.64	39.74	7.30
3. Physical quality characters (quantitative)						
Character	Phenotypic variance	Genotypic variance	PCV	GCV	Heritability (broad sense)	Genetic advance
Percentage of A grade beans	120.20	80.52	23.59	19.31	66.99	32.55
Percentage of B grade beans	87.67	55.41	49.16	39.08	63.20	64.00
Percentage of C grade beans	24.86	7.06	51.28	27.34	28.40	30.00
Percentage of beans below C grade	2.66	0.26	49.39	15.45	9.77	9.94
Percentage of pea berries	39.99	15.80	29.30	18.41	39.51	23.85

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. Among the five characters studied viz., percentage of A grade beans, percentage of B grade beans, percentage of C grade beans, percentage of beans below C grade and percentage of pea berries, percentage of C grade beans showed the highest variability followed by percentage of beans below C grade and percentage of B grade beans. Genotypic variability was the highest in the case of percentage of B grade beans followed by percentage of C grade beans. Percentage of A grade beans and percentage of pea berries showed lower levels of variability. Extent of variability in the case of yield has been studied in arabica and robusta coffee by Srinivasan and Subbalakshmi in 1981. They found that arabicas have got lower variation when compared to robusta cultivars. Maximum phenotypic and genotypic coefficients of variation were obtained in the case of number of fruiting nodes per primary and secondary, number of berries per primary and yield per plant by Dharmaraj and Gopal (1986). Srinivasan (1985a) observed that characters like inflorescence per node and flowers per inflorescence were found to be governed by both additive and non additive genes. Srinivasan (1988) observed higher genotypic coefficient of variation in robusta coffee when compared to arabica indicating greater scope for improvement in robusta.

4.1.3. Heritability (broad sense)

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 ten growth characters of robusta coffee studied presently showed broad sense heritability varying from 18.42% in the case of number of primary branches to 68.89% in the case of internodal length (Table 4.5). Stem girth showed 37.59% of heritability, number of secondaries per primary showed 49.48% of heritability, length of primary branches showed 49.37% of heritability, girth of primary branches showed 46.73% of heritability and bush spread showed 42.29% of heritability.

The yield characters showed a heritability ranging from 76.92% in bean density to 30.23% in the case of out turn (dry to clean). Characters like fruit length, fruit breadth, fruit thickness, fruit volume, fruit weight and bean weight showed considerably high heritability and fruits per node, bean length, bean breadth, bean thickness, bean volume and out turn (fresh to dry) showed medium heritability. However out turn (dry to clean) and out turn (ripe to clean) showed comparatively low heritability. Yield per plant showed a high heritability of 72.37 %. Among the quality characters % of A grade beans showed 66.99% heritability and percentage of pea berries showed 39.51% of heritability. 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. 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. Studies on heritability of characters in robusta coffee have been carried out by earlier workers (Srinivasan, 1988; Montagnon *et al.*, 1998). Studies on heritability have been carried out in other crops also by earlier workers (Tripathi *et al.*, 2000; Radhakrishnan, 2003). They have also observed that the reason for low heritability in the case of some characters is the influence of environment on them.

4.1.4. Genetic advance

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 (Table 4.5). 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 where as bean and fruit characters showed comparatively low genetic advance. Percentage of A grade beans showed a genetic advance of 32.55 where as percentage of B grade beans showed a genetic advance of 64.00. 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. Earlier workers like Dharmaraj and Gopal (1986) and Srinivasan (1988) have conducted studies on the genetic parameters of coffee. Dharmaraj and Gopal (1986) have reported high genetic advance in the case of yield per plant, number of berries per primary, primary length and number of fruiting nodes. Srinivasan (1988) observed higher genetic advance in the case of different characters in robusta coffee when compared to arabica and reported the higher scope for improvement in robusta coffee.

The present study of genetic variability, heritability, and genetic advance of characters of robusta coffee has revealed the presence of high genetic diversity in the crop and has suggested the possibility and need of improvement using the diverse genetic resources as the source of superior genes and genotypes.

4.2. Correlation of characters

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 character. 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 (Tables 4.6 and 4.7). 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, out turn, number of primary branches and fruits per node showed inter relationship with the minimum number of characters. Bean density, out turn (dry to clean coffee, fresh to clean coffee), number of primary branches and fruits per node showed interrelationship with the minimum number of characters. Girth of primary branch was found to be significantly correlated with stem girth, number of secondaries per primary, length of primary branches, bush spread, leaf length, leaf breadth, leaf area, fruits per node, weight of 100 dry fruits, bean length, bean thickness, bean volume, weight of 100 beans and yield per plant. Weight of 100 dry fruits showed significant positive correlation with 14 characters namely number of primary branches, number of secondaries per primary, girth of primary branches, fruit length, fruit breadth, fruit thickness, fruit volume, weight of 100 fresh fruits, bean length, bean breadth, bean thickness, bean volume, weight of 100 beans and percentage of A grade beans. Percentage of A grade beans showed significant positive correlation with 14 characters, namely internodal length, leaf length, leaf breadth, leaf area, fruit length , fruit breadth, fruit thickness, fruit volume, weight of 100 fresh fruits, weight of 100 dry fruits, bean breadth, bean thickness, bean volume and weight of 100 beans. Weight of 100 fresh fruits, bean volume, weight of 100 beans and yield per plant showed significant positive correlation with 13 characters each. Yield per plant was significantly and positively correlated with stem girth, girth of primary branches, leaf length, leaf area, fruits per node, fruit length, fruit breadth, fruit thickness, fruit volume, weight of 100 fresh fruits, bean length, bean thickness, and bean volume. 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.

Study conducted by Srinivasan (1969) has shown that stem girth has significant positive correlation with cherry yield, both in arabica and robusta selections thus indicating that stem girth might be a useful character for the purpose of selecting high yielding lines. A study by Berthoud *et al*. (1978) showed that stem and primary branch diameter and number of nodes were positively intercorrelated. A study by Srinivasan (1980) revealed high positive correlation of stem girth and length of primary branches with fruit yield. Sundar (1983) found that in robusta coffee fruit volume was positively and significantly correlated with all other fruit and bean characters. Crop bearing nodes and fruits per primary, fruits per primary and fruits per node and fruits per primary and yield were found to be positively correlated by Ahmed *et al*. (1996). The significant positive relationship in CxR coffee between stem girth and tree radius and girth of primary branches and stem girth have been reported by Ahmed and Sreenivasan (1988). Raghu *et al*. (2003) have reported significant relationship of crop yield in C x R coffee with total number of fruiting nodes per plant and mean number of berries per plant.

The positive correlation of raw bean colour with cup quality has been reported by Awatramani *et al*. (1974). According to Srinivasan and

Vishveshwara (1980b) bean thickness, body of liquor and acidity showed significant positive correlation with cup quality. Raju *et al*. (1978) found that bean thickness, body of the liquor and acidity showed significant positive correlation with cup quality in C x R coffee. Correlation between organoleptic inferiority and poor physical quality of beans has been reported by Roman and Vega (1998) in Costa Rica. Similar approaches to study the interrelationship of characters in other crops like cardamom (Radhakrishnan, 2003; Hrideek, 2007) tea (Ramasubramanian, 2005), medicinal plants (Raghu, 2005) etc. have been made by earlier workers.

4.3. Character association

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 (Sneath and Sokal, 1973). The statistical software STATISTICA has been used for the purpose. The results are presented in Tables 4.8, 4.9 and 4.10.

Six factors were obtained in the analysis but the 28 characters under study presently could be grouped into five groups as shown in Table 4.10. The characters under study contributed a cumulative percentage of variance of 76.91 (Table 4.9). The five groups of characters when analyzed based on relative factor loading of the characters showed that the first group consisted of 8 characters namely bush spread, length of primary branches, girth of primary branches, number of secondaries per primary, stem girth, leaf area, leaf length and yield per plant; the second group consisted of out turn (ripe to clean), bean breadth, bean volume, bean thickness, weight of 100 dry fruits, weight of 100 beans, bean length and weight of 100 fresh fruits; the third group consisted of internodal length , leaf breadth, out turn (dry to clean) and percentage of A grade beans; the fourth group consisted of out turn (fresh to dry), fruit length, fruit volume and fruit thickness and the fifth group consisted of number of primary branches, fruits per node and fruit breadth (Table 4.10). 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. Thus the study reveals the association of bush spread, length of primary branches and girth of primary branches with number of secondaries per primary, stem girth, leaf area, leaf length and yield per plant, the association of out turn (ripe to clean) with bean breadth, bean volume, bean thickness, weight of 100 dry fruits, weight of 100 beans, bean length and weight of 100 fresh fruits; the association of internodal length with leaf breadth, out turn (dry to clean) and percentage of A grade beans; the association of out turn (fresh to dry) with fruit length, fruit volume and fruit thickness and the association of number of primary branches with fruits per node and fruit breadth. This analysis shows that 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) are the lead characters to be considered while planning breeding programmes in robusta coffee so that the bulk of variables for analysis could be reduced.

Factor analysis can be used as an efficient tool to find out character association and to group the variables so as to effect data reduction by identifying the lead variables of each group. This method has been utilized in crops like rubber (Abraham *et al*., 2002), cardamom (Radhakrishnan *et al,* 2004; Hrideek, 2007), tea (Ramasubramanian, 2005), rice (Mini, 2006) chillies (Hrideek *et al.*, 2006) and coconut (Abdul Kadher *et al*., 2007).

Table 4.6. Correlation of characters in the case of the robusta coffee accessions studied

	Stem girth	No. of primary branches	No. of secondaries/ primary	Girth of primary branches	Length of primary branches	Inter nodal length	Bush spread	Leaf length	Leaf breadth	Leaf area	Fruits/ node	Fruit length	Fruit breadth	Fruit thick ness
Stem girth	1.00													
No. of primary branches	-0.08	1.00												
No. of secondaries per primary	0.59 **	-0.04	1.00											
Girth of primary branches	0.68 **	-0.13	0.70 **	1.00										
Length of primary branches	0.52 **	0.05	0.63 **	0.75 **	1.00									
Internodal length	-0.25	-0.10	-0.25	-0.09	0.18	1.00								
Bush spread	0.54 **	0.12	0.60 **	0.71 **	0.91 **	0.13	1.00							
Leaf length	0.15	-0.38	0.34 **	0.44 **	0.28 *	0.12	0.27 *	1.00						
Leaf breadth	0.11	-0.24	0.13	0.34 **	0.26 *	0.41 **	0.24 *	0.49 **	1.00					

Leaf area	0.20	-0.32	0.30**	0.47**	0.32**	0.30**	0.31**	0.83**	0.86**	1.00				
Fruits per node	0.21	0.04	0.22	0.25*	0.19	-0.13	0.20	0.16	0.14	0.18	1.00			
Fruit length	-0.04	0.02	-0.06	0.07	-0.17	-0.02	-0.22	0.20	0.09	0.16	-0.23	1.00		
Fruit breadth	0.09	0.20	0.08	0.20	-0.09	-0.25	-0.15	0.07	-0.04	0.03	-0.04	0.66**	1.00	
Fruit thickness	0.08	0.22	0.07	0.14	-0.14	-0.22	-0.20	0.07	-0.10	0.00	-0.08	0.75**	0.90**	1.00
Fruit volume	0.03	0.17	0.03	0.14	-0.14	-0.16	-0.20	0.13	-0.01	0.08	-0.15	0.89**	0.90**	0.95**
Wt. of 100 fresh fruits	-0.04	0.26*	0.02	0.21	0.07	-0.12	0.04	0.12	0.07	0.10	0.12	0.47**	0.72**	0.57**
Wt. of 100 dry fruits	0.08	0.25*	0.24*	0.30**	0.21	-0.14	0.19	0.12	0.06	0.10	0.04	0.46**	0.65**	0.56**
Bean length	0.02	0.22	0.25*	0.27*	0.16	-0.07	0.21	0.18	0.07	0.14	0.07	0.51**	0.47**	0.47**
Bean breadth	-0.08	0.11	0.14	0.20	0.22	0.03	0.22	0.18	0.05	0.13	0.16	0.20	0.39**	0.35**
Bean thickness	-0.07	0.21	0.09	0.23*	0.15	-0.03	0.14	0.14	0.06	0.11	0.16	0.28*	0.59**	0.41**
Bean volume	-0.03	0.19	0.19	0.27*	0.19	-0.04	0.20	0.18	0.08	0.15	0.15	0.41**	0.55**	0.48**
Bean density	-0.06	0.00	0.00	-0.02	-0.14	-0.19	-0.18	0.20	0.00	0.10	0.13	0.09	0.13	0.10

Weight of 100 beans	0.02	0.22	0.21	0.32 **	0.20	-0.12	0.19	0.18	0.08	0.14	0.16	0.45 **	0.66 **	0.55 **
Yield per plant	0.28 *	-0.09	0.15	0.43 **	0.13	-0.24	0.08	0.37 **	0.12	0.29 *	0.31 **	0.44 **	0.37 **	0.37 **
Out turn (fresh to dry)	0.23 *	-0.04	0.42 **	0.13	0.24 *	-0.06	0.26 *	-0.05	-0.07	-0.08	-0.21	-0.12	-0.26	-0.14
Out turn (dry to clean)	-0.31	-0.01	-0.27	-0.22	-0.13	0.07	-0.16	-0.14	-0.03	-0.09	0.10	-0.15	-0.07	-0.11
Out turn (fresh to clean)	-0.22	-0.04	-0.19	-0.29	-0.13	-0.02	-0.11	-0.30	-0.26	-0.32	-0.19	-0.35	-0.25	-0.29
A grade beans %	-0.12	0.00	-0.08	0.10	0.13	0.40 **	0.07	0.36 **	0.23 *	0.33 **	-0.08	0.42 **	0.29 *	0.33 **
	Fruit volu me	Wt. of 100 fresh fruits	Wt. of 100 dry fruits	Bean length	Bean breadth	Bean thickn ess	Bean volume	Bean density	Weight of 100 beans	Yield/ plant	Out turn (fresh to dry)	Out turn (dry to clean)	Out turn (fresh to clean)	A grade beans %
Fruit volume	1.00													
Wt. of 100 fresh fruits	0.62 **	1.00												
Wt. of 100 dry fruits	0.60 **	0.88 **	1.00											
Bean length	0.52 **	0.73 **	0.80 **	1.00										
Bean breadth	0.33 **	0.67 **	0.72 **	0.61 **	1.00									
Bean thickness	0.46 **	0.81 **	0.77 **	0.63 **	0.81 **	1.00								
Bean volume	0.52 **	0.83 **	0.87 **	0.86 **	0.87 **	0.90 **	1.00							

Bean volume	0.52 **	0.83 **	0.87 **	0.86 **	0.87 **	0.90 **	1.00							
Bean density	0.08	0.07	-0.06	-0.01	-0.11	-0.06	-0.09	1.00						
Weight of 100 beans	0.59 **	0.89 **	0.93 **	0.81 **	0.81 **	0.88 **	0.94 **	-0.01	1.00					
Yield/ plant	0.42 **	0.31 **	0.17	0.25 *	0.05	0.25 *	0.23 *	0.14	0.28 *	1.00				
Out turn (fresh to dry)	-0.16	-0.42	0.03	-0.02	-0.02	-0.22	-0.10	-0.25	-0.13	-0.35	1.00			
Out turn (dry to clean)	-0.14	0.10	-0.04	-0.02	0.08	0.05	0.05	-0.04	0.03	-0.15	-0.27	1.00		
Out turn (fresh to clean)	-0.35	-0.05	-0.10	0.00	0.05	-0.01	0.00	0.02	-0.06	-0.34	-0.06	0.69	1.00	
A grade beans %	0.38 **	0.31 **	0.28 *	0.15	0.37 **	0.35 **	0.32 **	-0.05	0.29 *	0.21	-0.13	0.06	-0.16	1.00

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

Sl. No.	Character	Characters showing significant positive correlation
1	Stem girth	Number of secondaries per primary, girth of primary branches, length of primary branches, bush spread, yield, out turn (fresh to dry)
2	Number of primary branches	Weight of 100 fresh fruits, weight of 100 dry fruits
3	Number of secondaries per primary	Stem girth, girth of primary branches, length of primary branches, bush spread, leaf length, leaf area, weight of 100 dry fruits, bean length, out turn (fresh to dry)
4	Girth of primary branches	Stem girth, number of secondaries per primary, length of primary branches, bush spread, leaf length, leaf breadth, leaf area, fruits per node, weight of 100 dry fruits, bean length, bean thickness, bean volume, weight of 100 beans, yield per plant
5	Length of primary branches	Stem girth, number of secondaries per primary, girth of primary branches, bush spread, leaf length, leaf breadth, leaf area, out turn (fresh to dry)
6	Internodal length	Leaf breadth, leaf area, percentage of A grade beans
7	Bush spread	Stem girth, number of secondaries per primary, girth of primary branches, length of primary branches, leaf length, leaf breadth, leaf area, out turn (fresh to dry)
8	Leaf length	Number of secondaries per primary, girth of primary branches, length of primary branches, bush spread, leaf breadth, leaf area, yield, percentage of A grade beans
9	Leaf breadth	Girth of primary branches, length of primary branches, internodal length, bush spread, leaf length, leaf area, percentage of A grade beans
10	Leaf area	Number of secondaries per primary, girth of primary branches, length of primary branches, internodal length, bush spread, leaf length, leaf breadth, yield, percentage of A grade beans
11	Fruits per node	Girth of primary branches, yield per plant
12	Fruit length	Fruit breadth, fruit thickness, fruit volume, weight of 100 fresh fruits, weight of 100 dry fruits, bean length, bean thickness, bean volume, weight of 100 beans, yield, percentage of A grade beans
13	Fruit breadth	Fruit length, fruit thickness, fruit volume, weight of 100 fresh fruits, weight of 100 dry fruits, bean length, bean breadth, bean thickness, bean volume, weight of 100 beans, yield, percentage of A grade beans
14	Fruit thickness	Fruit length, fruit breadth, fruit volume, weight of 100 fresh fruits, weight of 100 dry fruits, bean length, bean breadth, bean thickness, bean volume, weight of 100 beans, yield, percentage of A grade beans
15	Fruit volume	Fruit length, fruit breadth, fruit thickness, weight of 100 fresh fruits, weight of 100 dry fruits, bean length, bean breadth, bean thickness, bean volume, weight of 100 beans, yield, percentage of A grade beans
16	Weight of 100 fresh fruits	Number of primary branches, fruit length, fruit breadth, fruit thickness, fruit volume, weight of 100 dry fruits, bean length, bean breadth, bean thickness, bean volume, weight of 100 beans, yield, percentage of A grade beans
17	Weight of 100 dry fruits	Number of primary branches, number of secondaries per primary, girth of primary branches, fruit length, fruit breadth, fruit thickness, fruit volume, weight of 100 fresh fruits, bean length, bean breadth, bean thickness, bean

Table 4.7. Correlation of characters in the case of the robusta coffee accessions studied- Characters showing significant positive correlation

Table 4.8. Factor analysis in the case of robusta coffee- Factor loadings

Character	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Stem girth	-.141044	**.639807**	.010860	-.489978	-.102137	-.017221
No.of primary branches	-.189399	-.258061	.339424	-.249582	.071041	**.584578**
No. of secondaries per primary	-.276996	**.693735**	.179370	-.370573	-.020532	-.242038
Girth of primary branches	-.438842	**.768921**	.017594	-.184672	-.104438	-.038807
Length of primary branches	-.239201	**.787217**	.322455	-.017096	.095973	.163332
Internodal length	.105474	.135302	-.092991	**.666879**	.455414	.298342
Bush spread	-.207111	**.789702**	.387527	-.033421	.094140	.175637
Leaf length	-.324993	**.535227**	-.436830	.331351	-.104391	-.266479
Leaf breadth	-.165937	.504894	-.346099	**.525249**	.053210	.018369
Leaf area	-.285437	**.617314**	-.445298	.471808	-.036310	-.127094
Fruits per node	-.135767	.300932	.102978	.050531	-.641511	**.336301**
Fruit length	-.632961	-.272419	-.525034	-.119287	**.247852**	-.095637
Fruit breadth	-.787193	-.310406	-.234442	-.255921	-.028621	**.000968**
Fruit thickness	-.722942	-.329220	-.320904	-.324690	**.095800**	-.019566
Fruit	-.768723	-.320853	-.403248	-.252134	**.165224**	-.033170

volume						
Weight of 100 fresh fruits	-.878072	-.240434	**.136114**	.120254	-.171444	.071142
Weight of 100 dry fruits	-.889713	-.081938	**.272386**	-.025109	.107783	-.086876
Bean length	-.797987	-.050973	**.230790**	.024259	.040114	-.152445
Bean breadth	-.730016	-.041285	**.398686**	.276403	.062357	-.058822
Bean thickness	-.818700	-.128993	**.293330**	.204594	-.068796	.076314
Bean volume	-.891010	-.085331	**.325072**	.175105	.011692	-.060867
Bean density	-.027831	-.080459	-.303469	-.051589	-.490819	-.161270
Weight of 100 beans	-.928518	-.088490	**.265992**	.077842	-.046643	-.039405
Yield per plant	-.454389	**.181576**	-.439722	-.156994	-.421445	.137304
Out turn (fresh to dry)	.164533	.322010	.261043	-.335086	**.574606**	-.345442
Out turn (dry to clean)	.090217	-.302854	.298986	**.477259**	-.332473	-.199624
Out turn (fresh to clean)	.254105	-.308482	**.539188**	.292250	-.204953	-.428329
Percentage of A grade beans	-.431256	.008672	-.272944	**.429739**	.310582	.165955
Expl.Var	8.354891	4.635690	2.901932	2.587603	1.828842	1.225318
Prp.Totl	.298389	.165560	.103640	.092414	.065316	.043761

Table 4.9. Factor analysis in the case of robusta coffee- Eigen values

Factor	Eigen value	% of total variance	Cumulative Eigen value	Cumulative percentage of variance
1	8.354891	29.83890	8.35489	29.83890
2	4.635690	16.55604	12.99058	46.39493

3	2.901932	10.36404	15.89251	56.75897
4	2.587603	9.24144	18.48012	66.00041
5	1.828842	6.53158	20.30896	72.53199
6	1.225318	4.37613	21.53428	76.90813

Table 4.10. Factor analysis in the case of robusta coffee- factors identified

Factor	Characters
1	Nil
2	**Bush spread, length of primary branches, girth of primary branches,** number of secondaries per primary, stem girth, leaf area, leaf length, yield per plant
3	**Out turn (ripe to clean),** bean breadth, bean volume, bean thickness, weight of 100 dry fruits, weight of 100 beans, bean length, weight of 100 fresh fruits
4	**Internodal length,** leaf breadth, out turn (dry to clean), percentage of A grade beans
5	**Out turn (fresh to dry)**, fruit length, fruit volume, fruit thickness
6	**Number of primary branches**, fruits per node, fruit breadth

4.4. Genetic divergence

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 with the help of the software STATISTICA using UPGMA procedure (Table 4.11 and Figure 4.1). 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. The WC (Wayanad) collections were found to be distributed among five clusters, the Wariat (Wt) collections in three clusters, DR (Drought resistant) collections in five clusters and the exotic (S) collections in five clusters. DR.1 was found to form a separate cluster with a single genotype. S.274 segregated to the third cluster along with other 14 genotypes.

The genotypes WC.1 and Wt. 2 were found to be the closest. WC.30, WC.32, S.1481; S.3399 and WC.20; WC.7 and Wt. 4; WC.25 and WC.16; WC.9 and WC.24; WC.14 and WC.12; WC.10 and DR.15; S.1902 and WC.17; DR.12 and DR.9; DR.2 and WC.21; WC.4 and S.3400; DR.10 and DR.7; WC.33 and WC.15; WC.31 and WC.2 were found to be very close in genetic configuration based on the characters studied.

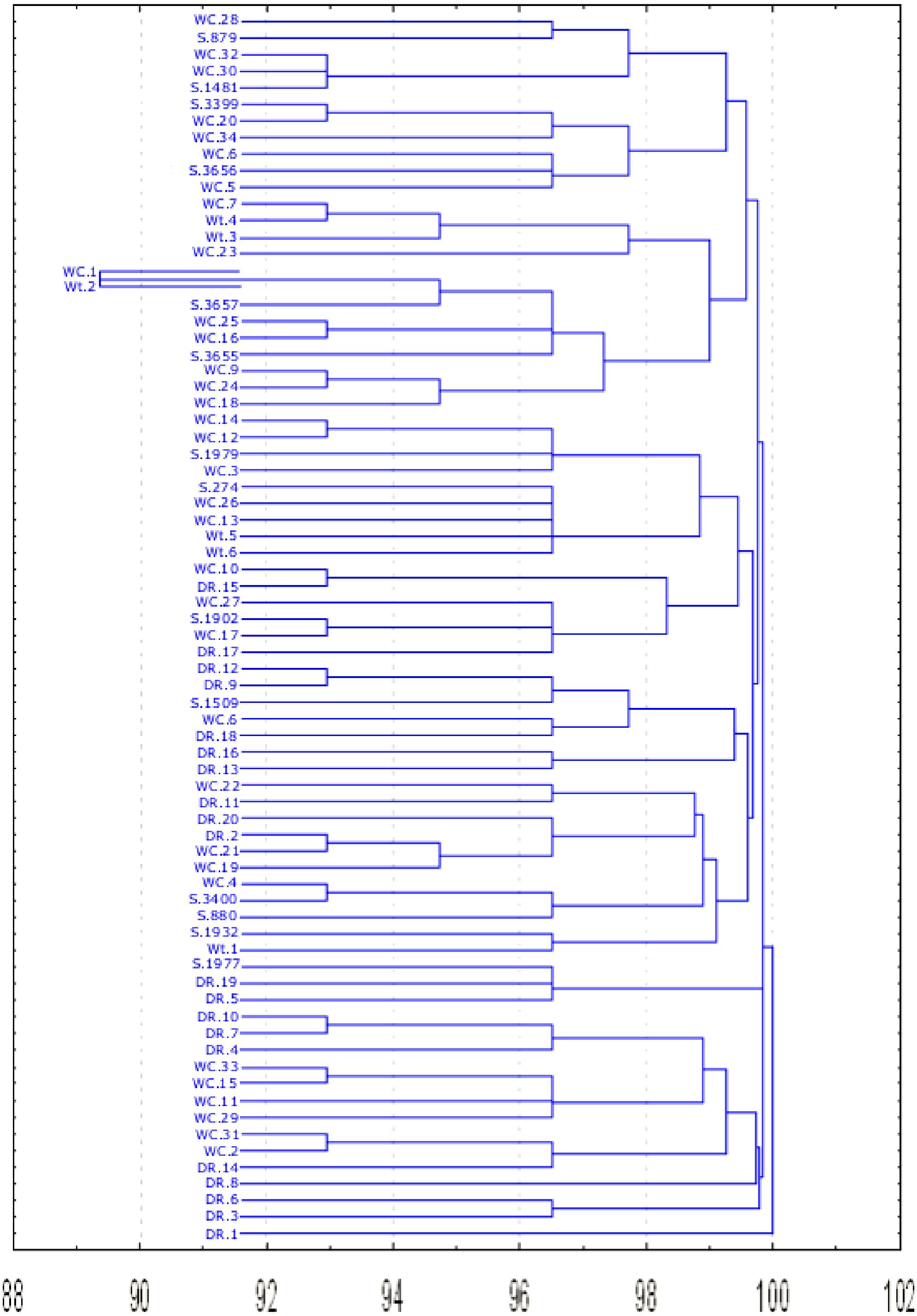
Genotypes belonging to different clusters are genetically distinct and such genotypes could be used for selection and hybridization programmes based on their phenotypic superiority.

Srinivasan and Subbalakshmi (1984) studied 17 arabica selections for genetic divergence based on 11 morphological characters and they obtained five clusters with different levels of linkage distance. In 1999 Dussert *et al*. grouped wild and classified forms of robusta coffee in to five diversity groups based on RFLP analysis. Prakash *et al.* (2005) conducted genetic diversity studies in robusta coffee gene pool available in India and determined the variability. They found that the gene pool of robusta coffee in India is highly variable. Studies have been carried out by several authors in other crops so as to group the genotypes into different clusters based on genetic divergence. Misra *et al.*, 1990 (dahlia); Indira, 1994 (capsicum); Srivastava *et al*., 2000 (coriander); Ramasubramanian, 2005 (tea); Prasanth and Venugopal, 2004; Radhakrishnan and Mohanan, 2005; Radhakrishnan *et al*., 2006 and Hrideek, 2007 (cardamom); Mini, 2006 (rice); Prasanth, 2006 (coconut) are some of such works.

Table 4.11. Clustering of genotypes in the case of the accessions of robusta coffee studied

Cluster No.	Genotypes
I	WC.28, S.879, WC.32, WC.30, S.1481, S.3399, WC.20, WC.34, WC.6, S.3656, WC.5.
II	WC.7, Wt. 4, Wt. 3, WC.23, WC.1, Wt.2, S.3657, WC.25, WC.16, S.3655, WC.9, WC.24, WC.18.
III	WC.14, WC.12, S.1979, WC.3, S.274, WC.26, WC.13, Wt. 5, Wt. 6, WC.10, DR.15, WC.27, S.1902, WC.17, DR.17.
IV	DR.12, DR.9, S.1509, WC.6, DR.18, DR.16, DR.13, WC.22, DR.11, DR.20, DR.2, WC.21, WC.19, WC.4, S.3400, S.880, S.1932, Wt.1.
V	S.1977, DR.19, DR.5.
VI	DR.10, DR.7, DR.4, WC.33, WC.15, WC.11, WC.29, WC.31, WC.2, DR.14, DR.8, DR.6, DR.3.
VII	DR.1.

Fig. 4.1. Clustering of genotypes in the case of the accessions of robusta coffee studied



4.5. Genetic control of characters

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.

4.5.1. Growth characters

All the ten growth characters studied presently and presented in Table 4.12 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. Plants with medium to higher stem girth were found to be comparatively higher in number in the population of 888 robusta plants analyzed for the purpose. Stem girth is considered as a character positively correlated with yield (Srinivasan, 1980) and hence the behaviour of the population is desirable. However, elimination of inferior plants and selection in favour of the superior ones is essential to develop a composite variety of robusta coffee with good yield.

Number of primary branches was found to be comparatively low in the present accessions of robusta coffee studied. Selection for optimum number of primary branches is essential for the development of varieties with desirable plant architecture. Plants with higher number of secondaries per primary were lower in number whereas plants with low to medium number of secondaries per primary were higher in number in the present population. Optimum number of secondaries per primary is desirable in an ideal plant type of robusta coffee and hence selection should be practiced so as to develop such a plant type.

Girth of primary branches has been found to show almost a balanced distribution in the population studied. Maximum number of plants showed medium girth of primary branches. This type of distribution, even though is desirable in a germplasm collection, when the objective is to select superior plants, selection should be concentrated towards higher girth of primary branches because girth of primary branches shows significant positive correlation with 14 important agronomic characters including yield.

Length of primary branches also showed an almost balanced distribution in the study population indicating the normal probability distribution of the alleles involved. Length of primary branches has been found to be positively correlated with 8 agronomically important characters of coffee in the present study (Table 4.7). Moreover it has been identified as one of the lead characters of robusta coffee by factor analysis presently and hence selection for higher length of primary branches is desirable for the development of an ideal plant type of robusta coffee.

Internodal length has been found to be almost distributed normally in the study population. Lower internodal length is the desirable phenomenon since it means more number of productive nodes per unit length of branch and selection should be in favour of plants with lower internodal length.

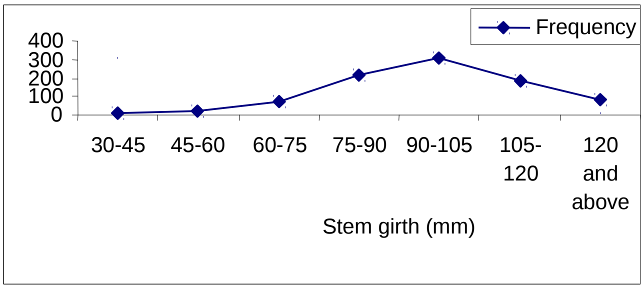
Bush spread showed an almost balanced and continuous distribution in the population studied. 'Small plants with fine architecture and maximum exposure of the leaves to sun and the presence of higher number of smaller leaves per unit area' is the desirable plant type proposed in arabica coffee. However since robusta plants are larger, robust and with larger leaves, plants with optimum bush spread, good tree architecture and medium sized leaves seem to be the desirable phenotype. Hence breeding programmes should be focused on the development of plants with optimum bush spread.

Leaf length, leaf breadth and leaf area show continuous distribution with different levels of deviation from the normal curve. Plants with higher leaf length are more in number, while majority of the plants are with low to medium leaf breadth. However, leaf area shows a desirable distribution in which majority of the plants show medium leaf area.

Table 4.12. Frequency distribution of quantitative growth characters of robusta coffee

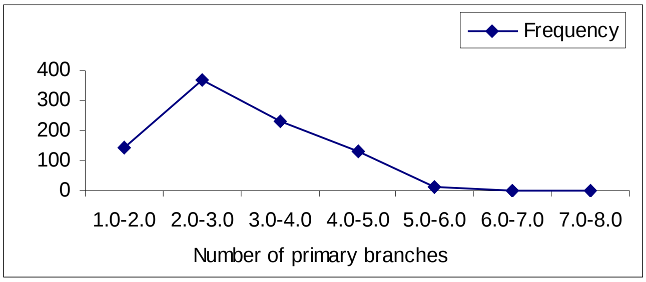
1. Stem girth (mm)

30-45	7
45-60	16
60-75	72
75-90	213
90-105	307
105-120	186
120 and above	87
Total	888



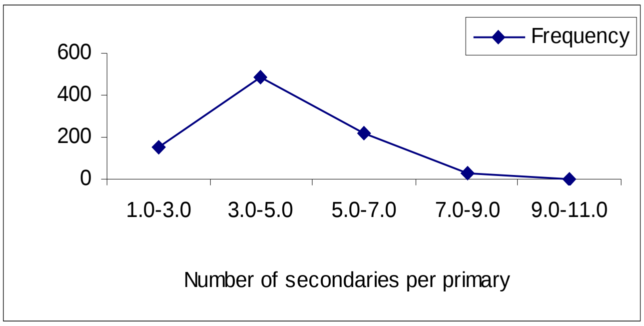
2. Number of primary branches

1-2	143
2-3	368
3-4	230
4-5	131
5-6	12
6-7	1
7-8	3
Total	888



3. Number of secondaries per primary

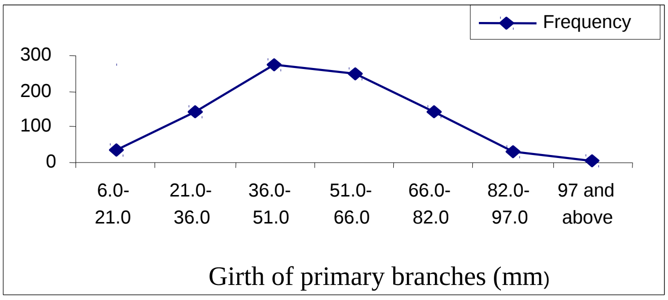
1-3	149
3-5	485
5-7	220
7-9	33
9-11	2
Total	888



4. Girth of primary branches (mm)

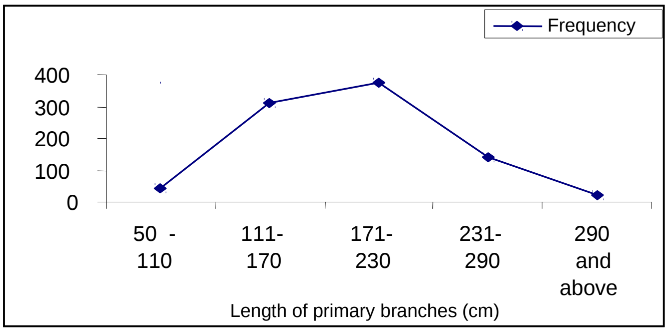
6-21	37
21-36	143

36-51	277
51-66	250
66-82	141
82-97	33
97 and above	7
Total	888



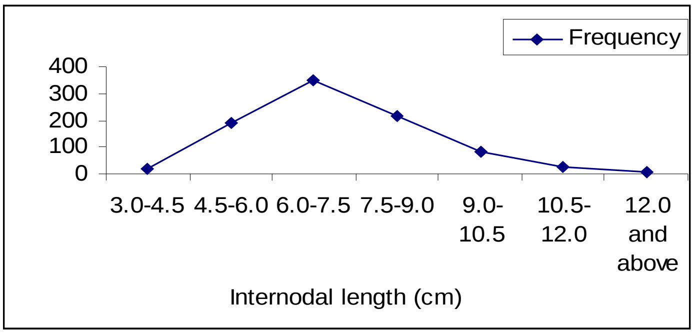
5. Length of primary branches (cm)

50 -110	44
111-170	311
171-230	373
231-290	140
290 and above	20
Total	888



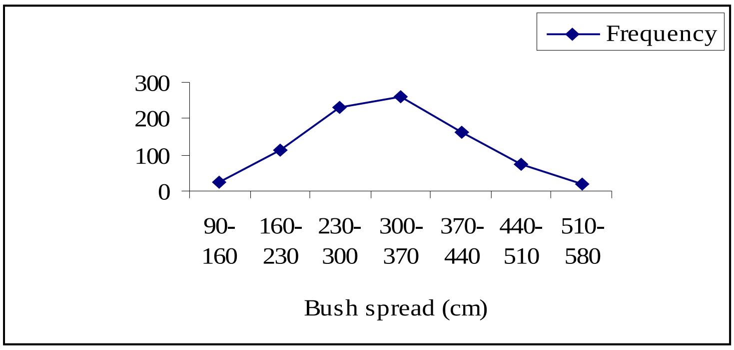
6. Internodal length (cm)

3.0-4.5	17
4.5-6.0	193
6.0-7.5	352
7.5-9.0	213
9.0-10.5	84
10.5-12.0	24
12.0 and above	5
Total	888



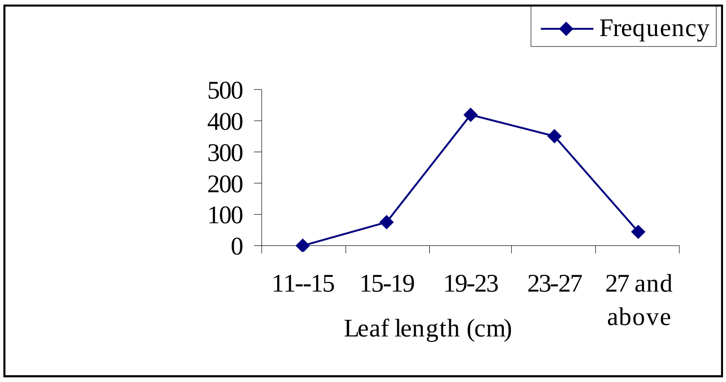
7. Bush spread (cm)

90-160	25
160-230	113
230-300	232
300-370	260
370-440	164
440-510	74
510-580	20
Total	888



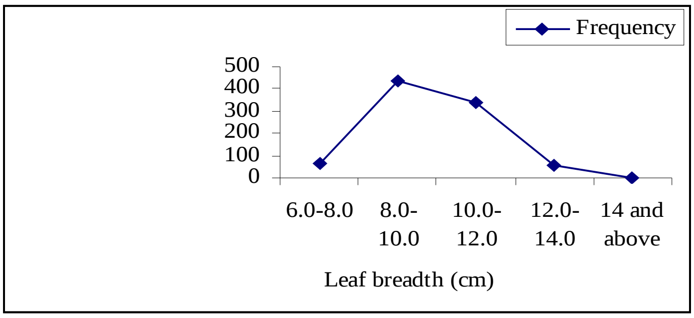
8. Leaf length (cm)

11-15	1
15-19	77
19-23	418
23-27	347
27 and above	45
Total	888



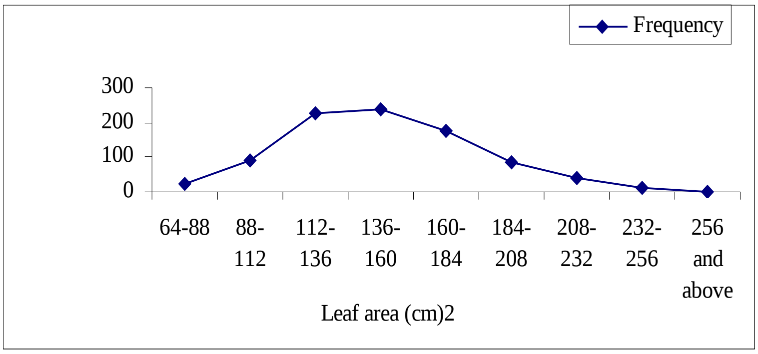
9. Leaf breadth (cm)

6.0-8.0	62
8.0-10.0	432
10.0-12.0	337
12.0-14.0	55
14 and above	2
Total	888



10. Leaf area (cm^2)

64-88	21
88-112	89
112-136	225
136-160	239
160-184	177
184-208	87
208-232	37
232-256	11
256 and above	2
Total	888



4.5.2. Yield characters

All the 17 yield characters of coffee studied presently showed continuous distribution (Table 4.13) 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.

The distribution of fruits per node in the case of different genotypes show higher frequency of plants towards mean number of fruits and lower frequency towards the extreme values. Number of fruits per node is an important yield character and it is directly and significantly correlated with girth of primary branches and yield per plant. Plants with higher number of fruits per node are always preferred by coffee breeders as it highly influences crop yield.

Plants with medium fruit length, fruit breadth, fruit thickness and fruit volume were found to be the maximum in the population, whereas the extreme types were represented in lower number. Fruit breadth, fruit thickness and fruit volume showed significant positive correlation with 12 other yield characters each and fruit length showed significant positive correlation with 11 yield characters. Hence selection for desirable fruit characters should be practiced in the population so that varieties with bold fruits are developed.

Weight of both fresh and dried fruits showed normal distribution with fruits with medium weight showing higher frequency. Fruit weight (fresh) and fruit weight (dry) are very important yield characters. They showed significant positive correlation with 13 and 14 other quantitative characters respectively and hence selection for higher fruit weight is desirable in robusta coffee.

Bean length, bean breadth, bean thickness, bean volume and bean density showed normal frequency distribution with some deviations. Bean length, bean breadth, bean thickness and bean volume are important quality characters and they are correlated significantly and positively with 12, 10, 12 and 13 agronomic characters of coffee respectively. Increasing the bean size is also important in coffee breeding since it brings about production of higher percentage of A grade beans.

Bean weight showed a gradual increase from lower bean weight to higher bean weight with some variations. Weight of 100 beans shows significant positive correlation with 13 agronomic characters of coffee and it is a very important character directly related to yield. Selection for the improvement of bean weight is a desirable step that is to be practiced in robusta coffee improvement.

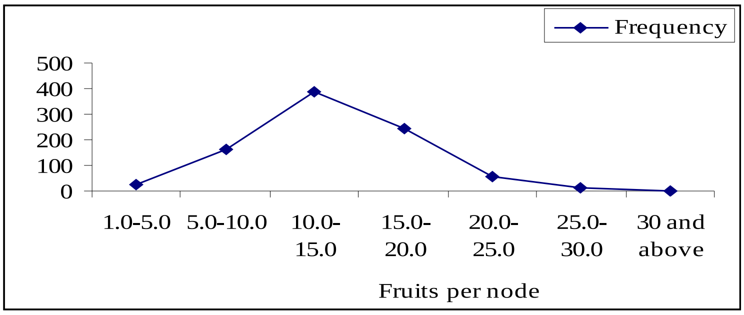
Yield per plant in the robusta coffee accessions studied ranged from less than 2 kg to more than 8 kg. But the mode value was between 2 kg – 4 kg per plant, which is not very desirable and hence improvement programmes focusing on higher coffee yield should be carried out primarily in any robusta improvement programme.

Out turn (fresh cherry to dry cherry), out turn (dry to clean), out turn (ripe to clean) showed normal frequency distribution with some deviations. However majority of the plants studied showed only medium out turn and hence improvement of out turn percentage should be targeted in robusta coffee breeding programmes.

Table 4.13. Frequency distribution of quantitative yield characters of robusta coffee

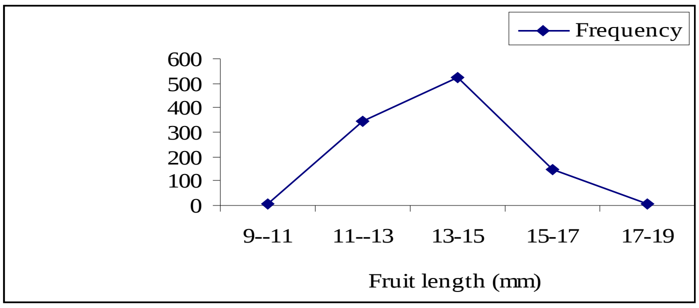
1. Fruits per node

1-5	23
5-10	164
10-15	389
15-20	241
20-25	55
25-30	14
30 and above	2
Total	888



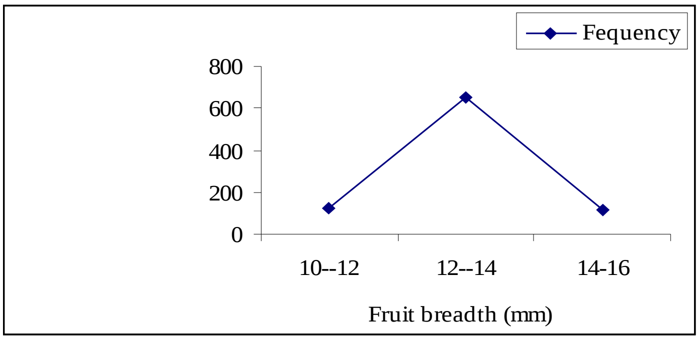
2. Fruit length (mm)

9-11	5
11-13	347
13-15	522
15-17	147
17-19	5
Total	888



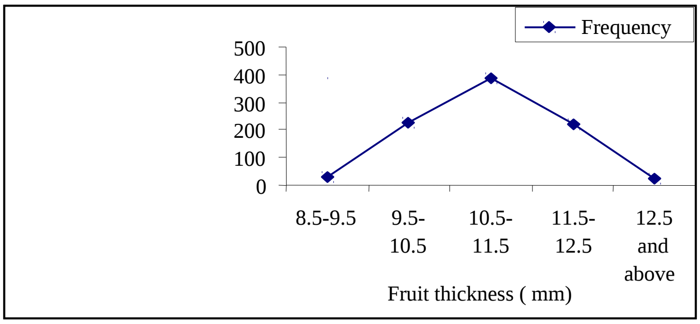
3. Fruit breadth (mm)

10-12	122
12-14	654
14-16	112
Total	888



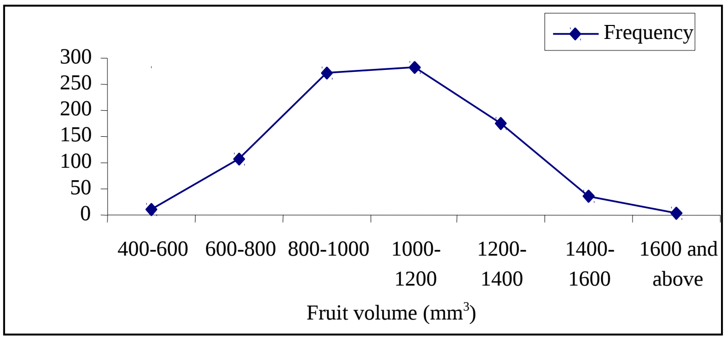
4. Fruit thickness (mm)

8.5-9.5	32
9.5-10.5	225
10.5-11.5	388
11.5-12.5	222
12.5 and above	21
Total	888



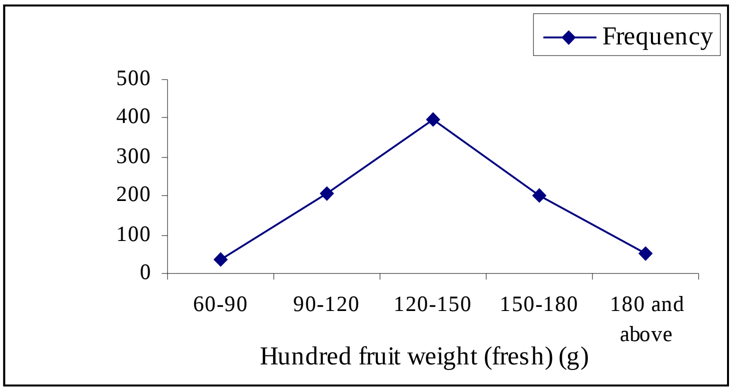
5. Fruit volume (mm)^3

400-600	12
600-800	106
800-1000	270
1000-1200	283
1200-1400	175
1400-1600	37
1600 and above	5
Total	888



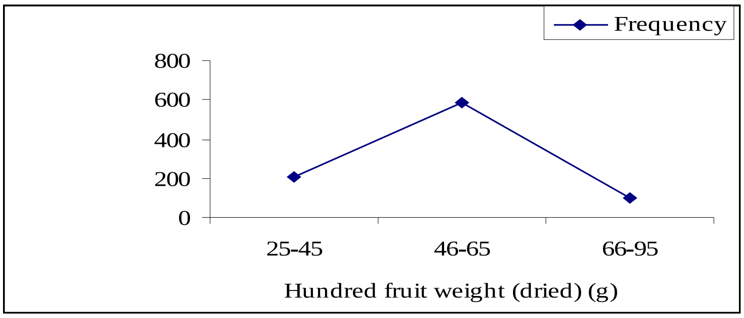
6. Hundred fruit weight (fresh) (g)

60-90	38
90-120	204
120-150	397
150-180	200
180 and above	49
Total	888



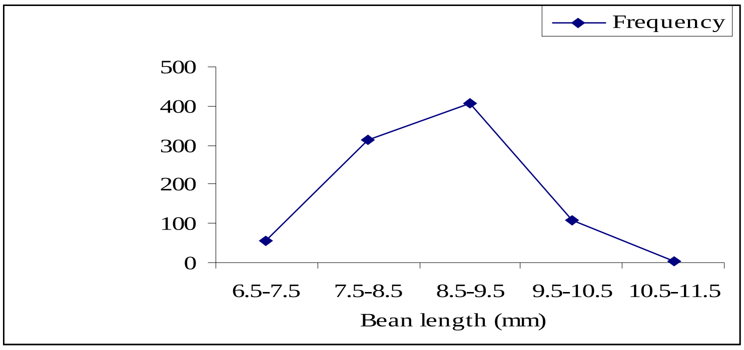
7. Hundred fruit weight (dried) (g)

25-45	207
46-65	586
66-95	95
Total	888



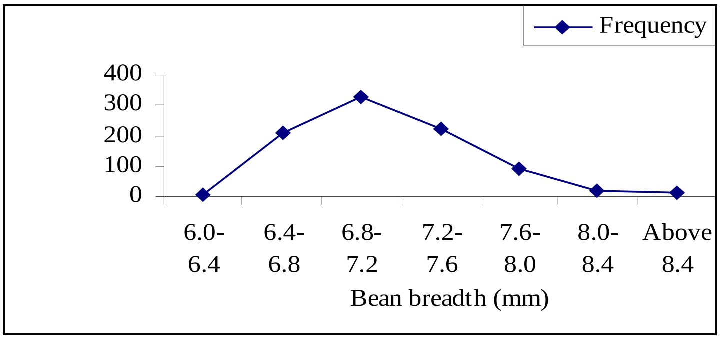
8. Bean length (mm)

6.5-7.5	56
7.5-8.5	312
8.5-9.5	408
9.5-10.5	108
10.5-11.5	4
Total	888



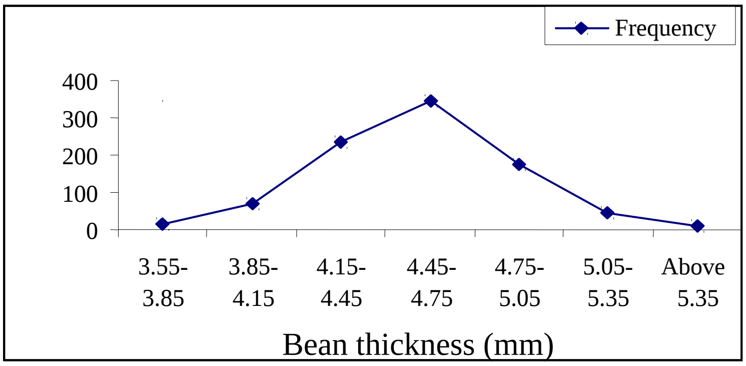
9. Bean breadth (mm)

6.0-6.4	5
6.4-6.8	210
6.8-7.2	330
7.2-7.6	222
7.6-8.0	89
8.0-8.4	20
8.4 and above	12
Total	888



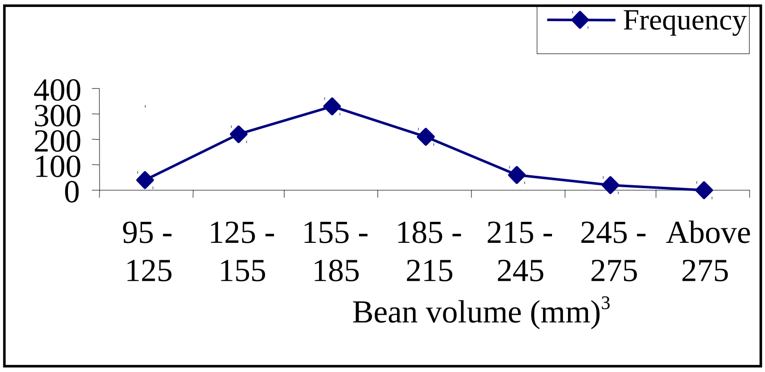
10. Bean thickness (mm)

3.55-3.85	15
3.85-4.15	68
4.15-4.45	236
4.45-4.75	343
4.75-5.05	174
5.05-5.35	43
5.35 and above	9
Total	888



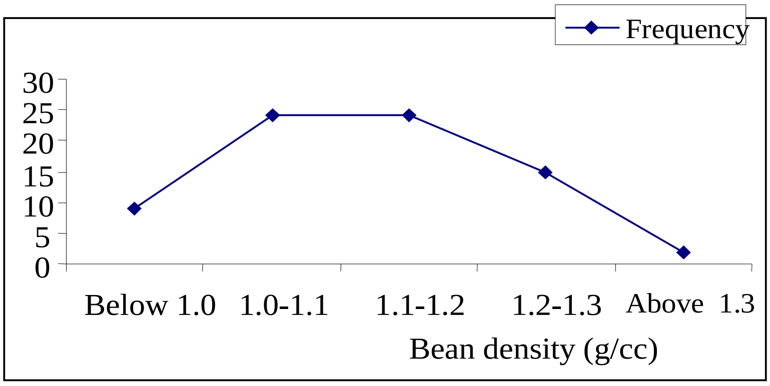
11. Bean volume $(mm)^3$

95 -125	37
125 -155	224
155 -185	330
185 -215	213
215 -245	62
245 -275	18
275 and above	4
Total	888



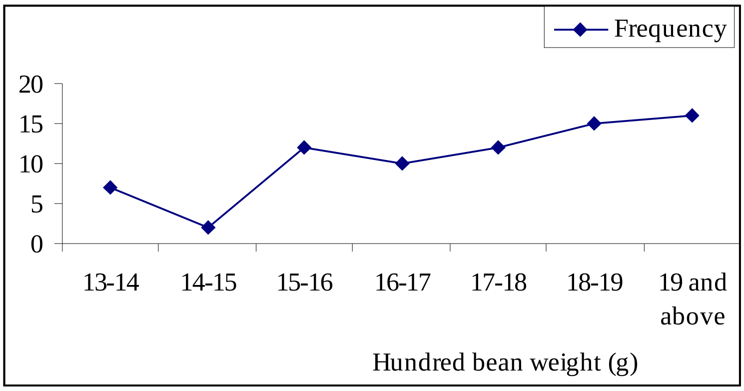
12. Bean density (g/cc)

Below 1.0	9
1.0-1.1	24
1.1-1.2	24
1.2-1.3	15
1.3 and above	2
Total	74



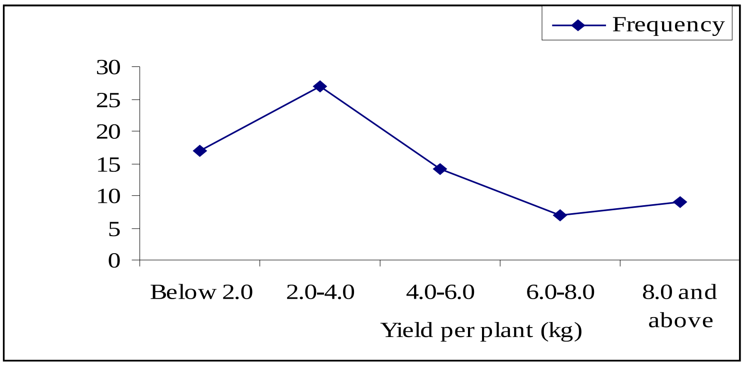
13. Hundred bean weight (g)

13-14	7
14-15	2
15-16	12
16-17	10
17-18	12
18-19	15
19 and above	16
Total	74



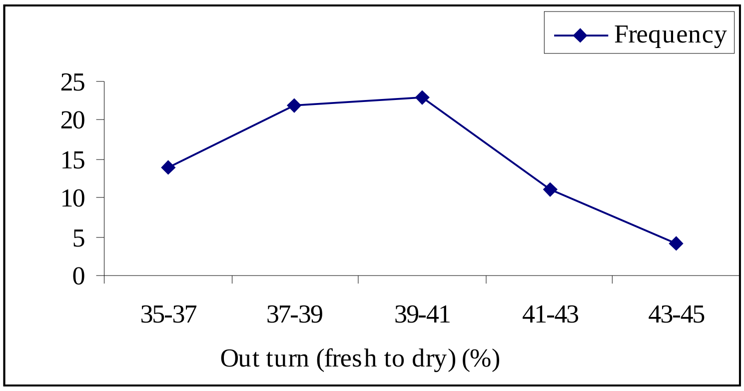
14. Yield per plant (kg)

Below 2	17
2-4	27
4-6	14
6-8	7
8 and above	9
Total	74



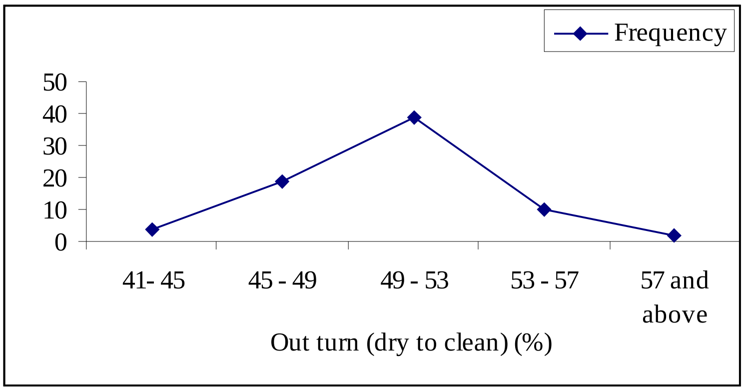
15. Out turn (fresh to dry) (%)

35-37	14
37-39	22
39-41	23
41-43	11
43-45	4
Total	74



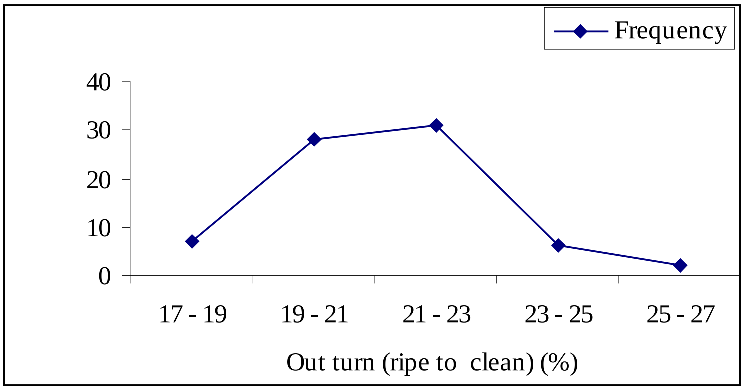
16. Out turn (dry to clean) (%)

41- 45	4
45 - 49	19
49 - 53	39
53 - 57	10
57 and above	2
Total	74



17. Out turn (ripe to clean) (%)

17 - 19	7
19 - 21	28
21 - 23	31
23 - 25	6
25 - 27	2
Total	74



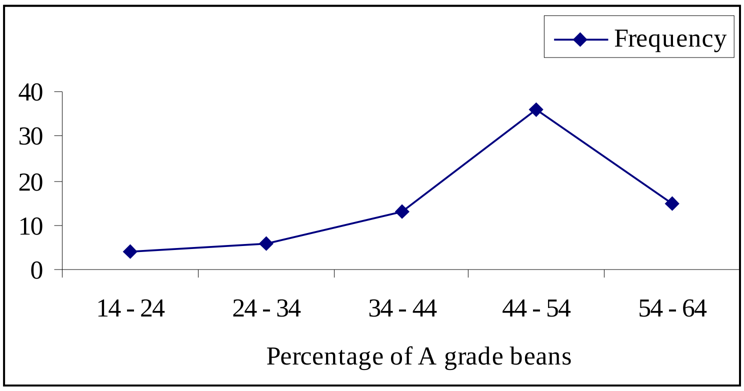
4.5.3. Physical quality characters (quantitative)

Percentage of A grade beans is the most important quantitative quality character of coffee, since it directly tells upon the physical quality of the coffee beans produced. The present study has shown a very desirable phenomenon in which more than 50% of the plants showed a percentage of A grade beans above 44 (Table 4.14). However the desirable percentage level varied between 44 and 64 only and hence there is ample scope for further improvement of this quality character in the coffee population studied.

Table 4.14. Frequency distribution of quantitative quality characters of robusta coffee

1. Percentage of A grade beans

14 - 24	4
24 - 34	6
34 - 44	13
44 - 54	36
54 - 64	15
Total	74



4.6. Study of qualitative quality characters in coffee

4.6.1. Physical quality characters

Three qualitative physical quality parameters were studied in the case of the 74 accessions of robusta coffee presently namely colour, smell and physical quality rating (Tables 4.15 & 4.16). Colour of the bean varied from brownish to greenish brown. 7 genotypes gave brownish bean colour which is the most superior bean colour. Majority of the accessions showed greenish brown to brownish colour which indicates the moderately good nature of majority of the robusta coffee accessions studied. The study indicates that 61 out of the 74 accessions studied showed brownish bean colour though bean to bean variation was noticed. This shows that the physical quality of the beans produced by the robusta coffee accessions studied is average or above average in terms of colour.

The smell of the beans in the case of all the 74 accessions was normal. Physical quality rating of the beans varied from above FAQ (Fair Average Quality) to below FAQ. Majority of the accessions proved to produce good quality beans of FAQ or above FAQ grades (Tables 4.15 & 4.16).

Bean quality of coffee was studied in relation to cup quality by Awatramani *et al*. (1974) and they found that raw bean colour was correlated with cup quality. Study by Ahmed and Sreenivasan (1992) revealed that in robusta brown was the common colour whose intensity varied in different standards. Light brown, golden brown and greyish brown gave average quality liquor in cherry samples. Greyish, golden brown and greyish brown were the major colours that gave above average quality liquor in parchment coffee. A study by Manoharan *et al*. (2002) revealed variation in physical quality parameters of arabica coffee beans of different cultivars.

Table 4.15. Physical quality parameters (qualitative) of the beans of the accessions of robusta coffee studied

Accessions	Colour	Smell	Physical quality rating
DR.1	Greenish brown - brownish	Normal	Slightly above FAQ – above FAQ
DR.2	Greenish brown - brownish	Normal	FAQ – above FAQ
DR.3	Greenish brown - brownish	Normal	Below FAQ – above FAQ
DR.4	Greenish brown - brownish	Normal	Above FAQ
DR.5	Greenish brown - brownish	Normal	FAQ – above FAQ
DR.6	Brownish green - brownish	Normal	FAQ – above FAQ
DR.7	Brownish green - brownish	Normal	Slightly above FAQ – above FAQ
DR.8	Blackish brown - brownish	Normal	Below FAQ – above FAQ
DR.9	Greenish brown – brownish green	Normal	FAQ – above FAQ
DR.10	Greenish brown - brownish	Normal	Above FAQ
DR.11	Brownish green - brownish	Normal	FAQ – above FAQ
DR.12	Greenish brown - brownish	Normal	Above FAQ
DR.13	Greenish brown – brownish green	Normal	FAQ – above FAQ
DR.14	Brownish	Normal	Above FAQ

DR.15	Greenish brown	Normal	FAQ – above FAQ
DR.16	Greenish brown – brownish green	Normal	Below FAQ – FAQ
DR.17	Greenish brown - brownish	Normal	Above FAQ
DR.18	Greenish brown - brownish	Normal	FAQ – above FAQ
DR.19	Greenish brown - brownish	Normal	Below FAQ – above FAQ
DR.20	Greenish brown - brownish	Normal	Slightly below FAQ – above FAQ
Wt.1	Greenish brown - brownish	Normal	FAQ – above FAQ
Wt.2	Greenish brown - brownish	Normal	Slightly above FAQ – above FAQ
Wt.3	Greenish brown – brownish green	Normal	Above FAQ
Wt.4	Greenish brown - brownish	Normal	Above FAQ
Wt.5	Greenish brown - brownish	Normal	Above FAQ
Wt.6	Greenish brown - brownish	Normal	FAQ – above FAQ
WC.1	Greenish brown - brownish	Normal	FAQ – above FAQ
WC.2	Greenish brown - brownish	Normal	Slightly above FAQ – above FAQ
WC.3	Greenish brown - brownish	Normal	FAQ – above FAQ
WC.4	Greenish brown - brownish	Normal	Below FAQ – slightly above FAQ
WC.5	Greenish brown - brownish	Normal	Slightly above FAQ – above FAQ
WC.6	Brownish green - brown	Normal	Slightly below FAQ – above FAQ
WC.7	Greenish brown - brownish	Normal	Above FAQ
WC.8	Brownish	Normal	FAQ – above FAQ
WC.9	Greenish brown - brownish	Normal	Slightly below FAQ – above FAQ
WC.10	Greenish brown - brownish	Normal	Below FAQ – above FAQ
WC.11	Greenish brown - brownish	Normal	FAQ – above FAQ
WC.12	Greenish brown - brownish	Normal	Above FAQ
WC.13	Brown -	Normal	Slightly below FAQ – above FAQ

	brownish		
WC.14	Greenish brown - brownish	Normal	FAQ – above FAQ
WC.15	Brownish green - brownish	Normal	Slightly below FAQ – above FAQ
WC.16	Greenish brown - brownish	Normal	FAQ – above FAQ
WC.17	Brown - brownish	Normal	Above FAQ
WC.18	Greenish brown - brown	Normal	FAQ – above FAQ
WC.19	Greenish brown - brown	Normal	Slightly above FAQ – above FAQ
WC.20	Greenish brown - brown	Normal	Slightly below FAQ – above FAQ
WC.21	Greenish brown - brownish	Normal	FAQ – above FAQ
WC.22	Greenish brown - brown	Normal	Slightly below FAQ – above FAQ
WC.23	Greenish brown - brown	Normal	Slightly below FAQ – above FAQ
WC.24	Brownish	Normal	FAQ – slightly above FAQ
WC.25	Greenish brown - brownish	Normal	Below FAQ – above FAQ
WC.26	Greenish brown - brownish	Normal	FAQ – above FAQ
WC.27	Greenish brown - brownish	Normal	Slightly below FAQ – above FAQ
WC.28	Greenish brown - brownish	Normal	Slightly below FAQ – above FAQ
WC.29	Greenish brown - brownish	Normal	FAQ – above FAQ
WC.30	Greenish brown - brownish	Normal	FAQ – above FAQ
WC.31	Greenish brown - brownish	Normal	FAQ – above FAQ
WC.32	Brownish green - brownish	Normal	FAQ – above FAQ
WC.33	Brownish	Normal	FAQ – above FAQ
WC.34	Greenish brown - brownish	Normal	FAQ – above FAQ
S.879	Greenish brown - brownish	Normal	FAQ – above FAQ
S.1932	Brown - brownish	Normal	FAQ – above FAQ
S.1902	Greenish brown -	Normal	Above FAQ – slightly above FAQ

	brownish		
S.880	Greenish brown	Normal	FAQ – above FAQ
S.1979	Greenish brown - brownish	Normal	FAQ – above FAQ
S.3399	Brown - brownish	Normal	FAQ – above FAQ
S.1509	Greenish brown - brownish	Normal	Above FAQ
S.1977	Brownish	Normal	FAQ – above FAQ
S.1481	Greenish brown - brownish	Normal	FAQ – above FAQ
S.3400	Brownish	Normal	FAQ – above FAQ
S.3655	Greenish brown - brownish	Normal	FAQ – above FAQ
S.3656	Brownish	Normal	Slightly above FAQ – above FAQ
S.3657	Brown - Brownish	Normal	FAQ – above FAQ
S.274 (Sln.1R)	Greenish brown - brown	Normal	Slightly above FAQ – above FAQ

Table 4.16. Distribution of physical quality rating in the case of the robusta coffee accessions studied

Rating	Number of accessions
Above FAQ	12
Slightly above FAQ – above FAQ	9
FAQ – above FAQ	35
Slightly below FAQ – above FAQ	10
Below FAQ – above FAQ	5
FAQ – slightly above FAQ	1
Below FAQ – slightly above FAQ	1
Below FAQ - FAQ	1

4.6.2. Cup quality characters

The cup quality of the liquor made from the 74 accessions of robusta coffee studied presently has been analyzed based on 8 qualitative cup quality parameters (Tables 4.17 and 4.18).

4.6.2.1. Fragrance

Fragrance of the liquor varied from fair+ to good in most of the accessions showing that the liquor of the accessions of robusta coffee studied presently showed satisfactory fragrance.

4.6.2.2. Aroma

Aroma ranged between fair and fair+ in most of the cases studied. Here also the quality is satisfactory.

4.6.2.3. Body

The body of the liquor of the coffee accessions studied presently varied from Fair + to good - good. Most of the plants produced Fair+ to good - good body of the liquor showing that the body of the liquor produced is of good quality.

4.6.2.4. Cleanliness

Cleanliness of liquor is also an important cup quality parameter. Most of the accessions gave a clean cup of liquor while only very few ones gave slightly unclean or unclean cups thus revealing the good quality of the brew produced in terms of cleanliness.

4.6.2.5. Off taste

Presence of off tastes like chemical taste is an undesirable quality of coffee. 71 out of the 74 accessions studied presently produced liquor with out any off taste and this also shows the good quality of the liquor in the case of those accessions.

4.6.2.6. Taste

Taste of the liquor was slightly harsh, neutral or fairly neutral in most of the cases.

4.6.2.7. Aftertaste

Aftertaste was fair, slightly neutral or slightly harsh in most of the cases studied. Harsh liquor was also produced in some cases.

4.6.2.8. Cup quality rating

Cup quality rating based on organoleptic categorization revealed that the liquor in the case of different accessions varied from above average to average. Cup quality thus shows fairly good quality rating in majority of the robusta accessions studied presently.

Gialluly (1959) have opined that the quality of green coffee is affected by environmental, physiological and genetic factors. Narasimhaswamy (1987) has also opined that the quality of coffee is not only determined by the type of coffee grown but also the climatic factors prevailing during the development of fruit, cultural operations and the method of processing. Guyot *et al*. (1995) observed that wet method of processing produced improvement in the quality of coffee when compared to dry method. However attempts have been made by different workers to determine the factors affecting quality of coffee. High altitude delayed ripening and improved coffee quality. According to Mendez *et al*. (1996) fruit quality, size and weight was best when grown under shade, but fruit yield was the maximum in plants grown under full sunlight. Absence of stress during bean expansion and bean filling was necessary for maximum differentiation between genotype for liquor traits (Agwanda *et al*., 1997). According to Venkatesh and Basavaraj (1998) lack of adequate storage facilities may also result in quality deterioration.

However other workers have correlated quality of coffee with genetic factors. When Kents, S.875 and S.288 were compared, higher total score was obtained by Kents (Awatramani *et al*., 1974). They also found that raw bean colour was correlated with cup quality but there was no correlation between bean size and cup quality. Amorim *et al*. (1976) classified green coffee samples as soft and rio (phenolic or medicinal taste) with respect to beverage quality. Seed thickness and body and acidity of the liquor were found to be positively correlated with cup quality in CxR coffee by Raju *et al*. (1978). According to Srinivasan and Vishveshwara (1980b) bean thickness, body of liquor and acidity showed significant positive correlation with cup quality. Fair to good and good taste of the liquor was observed in CxR coffee by Ahmed and Sreenivasan (1988). Results of a study by Ahmed and Sreenivasan (1992) revealed that in robusta brown was the common colour and golden brown, greyish, greyish brown and light brown colours gave good quality liquor. Roche (1995) reported that bean size was not a good indicator of cup quality in coffee. Moschetto *et al*. (1996) observed significant genetic effects for organoleptic characteristics in *Coffea canephora*. Roman and Vega (1998) observed correlation between organoleptic inferiority and poor physical quality of beans. Giomo *et al*. (2004) observed that small and light seeds showed inferior physiological quality compared to the other types. Pea berries showed physiological quality similar to flat seeds.

Table 4.17. Cup quality parameters (qualitative) of the accessions of robusta coffee studied

Accessions	Fragrance	Aroma	Body	Cleanliness	Off taste	Taste	After taste	Cup quality rating
DR.1	Fair + - good (slight fruity)	Fair -fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Slightly harsh- fairly neutral (slight fruity)	Fair - slightly harsh	Average – slightly above average
DR.2	Fair + - good (slight fruity)	Fair -fair + (cereal like, slight fruity)	Fair + to good - good	Clean cup	Nil	Slightly harsh- slight neutral	Slightly harsh, bitter- average	Average
DR.3	Fair + - good (slight fruity)	Fair (slightly harsh)- fair +	Fair + to good - good	Clean cup	Nil	Harsh- fairly neutral (slight	Harsh- slight neutral	Below average – slightly above

		(cereal like)				fruity)		average
DR.4	Fair + - good (slight fruity)	Fair -fair + (slight chocolaty)	Fair + to good - good	Clean cup	Nil	Slightly neutral (slight fruity)- slight neutral	Average - slight neutral	Average – slightly above average
DR.5	Fair + (slight fruity) - good (slight fruity)	Fair -fair + (slight over ripe)	Fair + to good - good	Clean cup	Nil	Slightly harsh- fairly neutral	Slightly harsh- fairly neutral (slight fruity)	Average – above average
DR.6	Fair + (slight fruity) - good (slight fruity)	Fair (slight pungent) -fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Slightly neutral (slight fruity)- fairly neutral	Slightly harsh- slight neutral	Average – above average
DR.7	Fair + - good (slight fruity)	Fair -fair + (cereal like, slight fruity)	Fair + to good - good	Clean cup	Nil	Slightly neutral (slight fruity)- fairly neutral	Average - fair	Average – above average
DR.8	Fair + - good (slight fruity)	Fair (slightly harsh)- fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Harsh- fairly neutral	Harsh- fair	Below aveage - above average
DR.9	Fair + - good (slight fruity)	Fair -fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Slightly neutral -fairly neutral	Average - fair	Average – above average
DR.10	Fair + - good (slight fruity)	Fair -fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Slightly neutral- fairly neutral (slight fruity)	Average - fair +	Below average – above average
DR.11	Fair + - good (slight fruity)	Fair (slight pungent) -fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Slightly harsh- fairly neutral (slight over ripe)	Harsh- fair	Average – above average
DR.12	Fair + - fair + to good (slight	Fair -fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Slightly harsh	Slightly harsh, bitter - average	Average – slightly above average

	fruity)							
DR.13	Fair + - Fair + to good (slight harsh)	Fair (slightly pungent) -fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Slightly harsh- slightly neutral	Average - slightly neutral (slight fruity)	Average – slightly above average
DR.14	Fair + - good (slight fruity)	Fair (slightly harsh) -fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Slightly harsh- fairly neutral (uneven cup)	Slightly harsh -average	Average – above average
DR.15	Fair + - fair + to good	Fair + (harsh) -fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Harsh- slightly harsh	Slightly bitter- average	Average
DR.16	Fair + (cereal like) - fair +	Fair (slightly harsh) -fair +	Fair + to good	Clean cup	Nil	Harsh- slightly harsh	Harsh- fair	Below average – average
DR.17	Fair + - fair + to good (slight fruity)	Fair- fair + (slight over ripe)	Fair + to good - good	Clean cup	Nil	Slightly harsh- fairly neutral (slight fruity)	Slightly harsh -fair	Average – above average
DR.18	Fair + - fair + to good (slight fruity)	Fair -fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Slightly harsh- fairly neutral	Slightly harsh -average	Average – slightly above average
DR.19	Fair +	Fair -fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Harsh- fairly neutral	Harsh -average	Below average - average
DR.20	Fair + - fair + to good	Fair -fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Harsh- fairly neutral	Harsh- fair	Below average – slightly above average
Wt.1	Fair + (cereal like) - fair + to good	Fair -fair +	Fair + to good	Clean cup	Nil	Fairly neutral (slight fruity)- fairly neutral	Average - fair	Slightly above average - above average
Wt.2	Fair + - fair + to good	Fair -fair + (cereal like)	Fair + to good – good	Clean cup	Nil	Slightly neutral- fairly neutral	Fair- Fair+ (slight fruity)	Above average
Wt.3	Fair +	Fair	Fair +	Clean	Nil	Slightly	Average	Slightly

		-fair + (cereal like)	to good - good	cup		neutral- fairly neutral	- fair+	above average - above average
Wt.4	Fair + (slightly harsh)- fair + to good	Fair -fair +	Fair + to good - good	Clean cup	Nil	Slightly harsh- slightly neutral	Slightly harsh -fair	Average - above average
Wt.5	Slightly harsh- fair +	Fair -fair +	Fair + to good	Unclean cup - clean cup	Chemical - nil	Unpleasant harsh, chemical taste- fairly neutral	Unpleasant, harsh, chemical taste -fair	Falling off to poor- above average
Wt.6	Fair +	Fair -fair +	Fair + to good - good	Clean cup	Nil	Harsh- slightly neutral	Harsh- fair	Slightly below average - slightly above average
WC.1	Fair + (slight fruity)- fair + to good	Fair- fair + (slight over ripe)	Fair + to good - good	Slightly unclean cup - clean cup	Nil	Slightly harsh- fairly neutral (slight fruity)	Slightly harsh- Fair+ (slight fruity)	Slightly below average - above average
WC.2	Fair + (slight fruity)- fair +	Fair -fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Slightly harsh- slightly neutral	Slightly harsh -average	Slightly below average - average
WC.3	Fair + (slight pungent)- fair +	Fair -fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Harsh- slightly neutral (slight fruity)	Harsh, bitter- fair	Average - slightly above average
WC.4	Fair + (slight pungent)- fair +	Fair -fair + (cereal like)	Fair + to good - good	Clean cup	Chemical - nil	Fairly harsh- slightly neutral (slight fruity)	Slightly harsh- Fair+ (slight fruity)	Average
WC.5	Fair + (slight pungent)- fair + to good	Fair -fair +	Fair + to good - good	Clean cup	Nil	Harsh- fairly neutral	Harsh, bitter- average	Slightly below average - slightly above average

WC.6	Fair + (slight fruity)- fair +	Fair -fair + (cereal like, slight fruity)	Fair + to good - good	Slightly unclean cup - clean cup	Nil	Slightly harsh- fairly neutral	Slightly harsh- average	Below average - average
WC.7	Fair + (slight fruity)- fair +	Fair -fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Slightly harsh- fairly neutral	Slightly harsh, bitter- average	Average - above average
WC.8	Fair (slight fruity)- fair +	Fair -fair +	Fair + to good - good	Clean cup	Nil	Harsh- slightly neutral	Harsh- average	Slightly below average - slightly above average
WC.9	Fair (harsh)- fair +	Fair -fair + (malt like)	Fair + to good - good	Clean cup	Nil	Harsh- fairly neutral	Slightly harsh- average	Below average - average
WC.10	Fair (slightly harsh)- fair +	Fair + (malt like) -fair +	Fair + to good - good	Slightly unclean cup - clean cup	Nil	Slightly harsh- fairly neutral	Slightly harsh- fair	Slightly below average - average
WC.11	Fair + (slightly harsh)- fair + to good	Fair -fair +	Fair + to good - good	Clean cup	Nil	Harsh- slightly neutral	Slightly harsh- average	Average
WC.12	Fair + (slightly harsh)- fair + to good	Fair -fair + (malt like)	Fair + to good - good	Clean cup	Nil	Slightly harsh- slightly neutral	Slightly harsh, bitter- average	Average
WC.13	Fair + (slightly harsh)- fair +	Fair -fair + (malt like)	Fair + to good - good	Clean cup	Nil	Slightly neutral	Average	Average - slightly above average
WC.14	Fair (slightly harsh)- fair +	Fair -fair +	Fair + to good - good	Clean cup	Nil	Slightly harsh- slightly neutral	Slightly harsh – slightly neutral	Average - slightly above average
WC.15	Fair + (slightly harsh)- fair +	Fair -fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Fairly harsh- slightly neutral	Harsh- fair	Average
WC.16	Fair +	Fair -fair +	Fair + to good	Clean cup	Nil	Fairly harsh-	Average -fair	Average -

		(cereal like)	- good			fairly neutral		slightly above average
WC.17	Fair + (cereal like)- fair +	Fair -fair + (slightly harsh)	Fair + to good - good	Clean cup	Nil	Slightly harsh- fairly harsh	Slightly harsh – fair	Average - above average
WC.18	Fair (slightly harsh)- fair +	Fair (slightly harsh)- fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Harsh- fairly neutral	Harsh – slightly neutral	Average
WC.19	Fair - fair +	Fair -fair +	Fair + to good - good	Clean cup	Nil	Harsh, bitter- slightly neutral (slight fruity)	Harsh, bitter – slightly neutral	Below average - slightly above average
WC.20	Fair (slightly harsh)- fair +	Fair -fair + (malt like)	Fair + to good - good	Clean cup	Nil	Slightly harsh- fairly neutral	Slightly harsh – average	Below average - slightly above average
WC.21	Fair - fair +	Fair -fair +	Fair + to good - good	Clean cup	Chem ical - nil	Harsh- fairly neutral	Slightly harsh – slightly neutral	Slightly below average - above average
WC.22	Fair (slightly harsh)- fair +	Fair (cereal like)- fair +	Fair + to good - good	Clean cup	Nil	Slightly neutral (slight fruity)- fairly neutral	Slightly harsh – slightly neutral	average - slightly above average
WC.23	Fair (slightly harsh)- fair +	Fair (slightly harsh)- fair	Fair + to good - good	Clean cup	Nil	Harsh- slightly neutral	Slightly harsh – average	Average - slightly above average
WC.24	Fair + (slight fruity)- fair +	Fair (slightly harsh)- fair +	Good	Clean cup	Nil	Slightly harsh- fairly neutral	Average – slightly neutral	Slightly below average - slightly above average
WC.25	Fair (slightly harsh)- fair +	Fair - fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Harsh- fairly neutral	Harsh – slightly neutral	Slightly below average -

								average
WC.26	Fair (slightly harsh)- fair +	Fair - fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Harsh- fairly neutral	Slightly harsh – fair	Average
WC.27	Fair - fair +	Fair - fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Slightly harsh- slightly neutral	Slightly harsh	Average – above average
WC.28	Fair +	Fair - fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Slightly harsh- slightly soft	Slightly harsh – fair	Slightly below average - average
WC.29	Fair - fair +	Fair - fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Slightly harsh- fairly neutral	Slightly harsh – fair	Average
WC.30	Fair +	Fair - fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Slightly harsh- slightly soft	Slightly harsh – average	Slightly below average - slightly above average
WC.31	Fair +	Fair - fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Slightly harsh- slightly soft	Slightly harsh – slightly neutral	Average - slightly above average
WC.32	Fair +	Fair - fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Harsh- slightly neutral	Slightly harsh – fair	Average
WC.33	Fair +	Fair - fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Slightly harsh- slightly neutral	Average – slightly neutral	Average - slightly above average
WC.34	Fair +	Fair - fair + (cereal like)	Fair + to good - good	Clean cup	Nil	Slightly harsh- fairly neutral	Slightly harsh – average	Average - slightly above average
S.879	Fair + (slight fruity)- fair +	Fair + (slight fruity)- fair +	Fair + to good - good	Clean cup	Nil	Slightly harsh- fairly neutral	Slightly harsh – fair	Average - above average
S.1932	Fair + (slight fruity)- fair + to good	Fair + (cereal like)- fair + to good	Fair + to good - good	Clean cup	Nil	Slightly harsh- slightly neutral	Slightly harsh – fair	Average - above average

	(slight fruity)	(slight fruity)						
S.1902	Fair + (slight fruity)- fair +	Fair + (slightly harsh)- fair + (slight fruity)	Fair + to good - good	Clean cup	Nil	Harsh- fairly neutral	Harsh – fair	Average - above average
S.880	Fair + (slight fruity)- fair +	Fair + (slight over ripe)- fair +	Good	Clean cup	Nil	Fairly neutral	Fair (slight fruity)- fair	Slightly below average - above average
S.1979	Fair + (slight fruity)- fair +	Fair + (cereal like)- fair +	Fair + to good - good	Clean cup	Nil	Slightly neutral- fairly neutral	Average –fair	Above average
S.3399	Fair + - fair + to good (slight fruity)	Fair + (cereal like)- fair +	Fair + to good - good	Clean cup	Nil	Harsh, slightly bitter- slightly neutral	Harsh, slightly bitter – fair	Average - slightly above average
S.1509	Fair + (slight fruity)- fair + to good (slight fruity)	Fair + (slight over ripe)- fair +	Fair + to good - good	Clean cup	Nil	Harsh, slightly bitter- slightly neutral	Fair (slight fruity)- fair	Below average - above average
S.1977	Fair + - fair + to good (slight fruity)	Fair + (cereal like)- fair +	Fair + to good - good	Clean cup	Nil	Harsh- fairly neutral	Slightly harsh – fair	Average - above average
S.1481	Fair +	Fair + (cereal like)- fair +	Fair + to good - good	Clean cup	Nil	Harsh, bitter- slightly neutral	Harsh, bitter – fair	Average - above average
S.3400	Fair + (slight fruity)- fair + to good (slight fruity)	Fair + (cereal like)- fair +	Fair + to good - good	Clean cup	Nil	Harsh- fairly neutral	Slightly harsh – fair	Below average - above average
S.3655	Fair (harsh)- fair +	Fair + (malty)- fair +	Fair + to good - good	Clean cup	Nil	Slightly neutral (slight fruity)- fairly neutral	Slightly harsh- Fair (slight fruity)	Average - above average
S.3656	Fair + (slight	Fair + (cereal	Fair + to good	Clean cup	Nil	Slightly harsh-	Slightly harsh –	Average -

	fruity)- fair + to good (slight fruity)	like)- fair +	- good			fairly neutral	fair	slightly above average
S.3657	Fair +	Fair + (malty)- fair +	Fair + to good - good	Clean cup	Nil	Harsh- slightly neutral	Harsh – fair	Average - above average
S.274 (Sln. 1R)	Fair +	Fair + (slight over ripe)- fair +	Fair + to good - good	Clean cup	Nil	Slightly neutral (slight fruity)- fairly neutral	Fair (slight fruity)- fair	Average

Table 4.18. Cup quality rating of the robusta coffee genotypes studied

Rating	Number of accessions
Above average	2
Slightly above average – above average	2
Average – above average	18
Slightly below average – above average	3
Below average – above average	4
Falling off to poor – above average	1
Average – slightly above average	16
Slightly below average – slightly above average	5
Below average – slightly above average	4
Average	11
Slightly below average – average	4
Below average - average	4

4.7. Analysis of an ideal plant type for robusta coffee

Coffea canephora var. robusta popularly known as robusta coffee is a diploid species with 2n=22, and is a bigger bush with robust growth when compared to arabica coffee. Three robusta strains known as Sln.1R, Sln.2R and Sln. 3R have been developed by Central Coffee Research Institute of India (Anonymous, 2000). Being a cross pollinated species superior strains suitable for commercial cultivation should be mixtures of genotypes from different sources. Sln.1R is a mixture of two genotypes, Sln.2R is a mixture of three genotypes and Sln.3R is a selection made from the backcross progeny of *Coffea congensis* and

Coffea canephora. Even though single superior strains are being cultivated by planters, well adapted strain of a perennial cross pollinating and self incompatible tree crop should be a mixture of genotypes with the status of a composite variety.

Robusta collections maintained at Regional Coffee Research Station, Chundale provides a valuable gene pool for selection of superior genotypes and development of superior commercial varieties. 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 more suitable. 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 beans 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 (Table 4.7). 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 (Table 4.10), 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 (Table 4.10).

Yield, plant vigour and quality have been the main selection criteria in arabica and robusta coffee (Vossen, 2000). Robusta coffee breeding was started in a systematic manner in Java in 1907 (Wellman, 1961). Since the quality of robusta coffee is inferior to that of arabica in bean size and organoleptic attributes, Vossen (2000) has reported that most of the present day robusta breeding efforts aim at improving the bean size and organoleptic quality and reducing the caffeine content. According to Santharam *et al*. (1994) *Coffea canephora* improvement in India included mass selection, clonal selection, diallele crossing and interspecific hybridization.

4.8. Overall performance of the robusta coffee accessions

Study of overall performance of genetically diverse accessions of a crop plant is the first step in selection of superior genotypes that can be used for further crop improvement programmes. The 74 robusta coffee accessions analyzed presently have been subjected to overall performance analysis based on performance index calculated from growth and yield contributing characters as suggested by Amaravenmathy and Srinivasan (2003) and as described else where.

When analysed 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 (Table 4.19). 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 accession S.3657 proved to be the best performer with a mean stem girth of 110.57mm, 2.33 primary branches on the average and 6.25 secondaries per primary (Table 4.20). The genotype showed a primary branch girth of 61.25mm, primary branch length of 222.08cm, internodal length of 5.99cm, bush spread of 378.33cm, leaf area of 140.49cm^2, 15.11 fruits per node, fruit volume of 1181.02mm^3, hundred fruit weight of 141.62g, bean volume of 182.67mm^3, mean hundred bean weight of 19.09g, mean yield per plant of 6.35kg and out turn percentage of 18.84% and 48.86% A grade beans. However some other accessions coming under the first ten excelled this accession in the case of some parameters. 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. The ten superior genotypes selected presently are shown in Figures 4.2-4.11 and the control variety S.274 shown in Figure 4.12. The growth, yield and quality characters of the ten accessions selected as superior have been presented in Table 4.20.

Robusta coffee breeding in India has so far resulted in the release of three series of selections namely Sln. 1R, Sln.2R and Sln. 3R. The three selections have been released by Central Coffee Research Institute of India. Sln. 1R is a mixture of two genotypes (S.270 and S. 274), Sln. 2R consists of three genotypes (BR. 9, BR.10 and BR.11) and Sln. 3R is a hybrid variety developed through interspecific hybridization involving *Coffea congensis* and *Coffea canephora* var. robusta (Anonymous, 2000).

Table 4.19. Performance analysis of the robusta coffee accessions studied

Acce ssions	Characters/ performance indices							
	1	2	3	4	5	6	7	8
DR.1	0.85	1.33	0.95	0.83	0.95	0.98	1.06	0.95
DR.2	1.11	1.07	1.06	1.07	1.08	1.08	1.12	0.98
DR.3	1.01	0.97	0.95	1.01	1.04	1.04	0.95	1.02
DR.4	0.98	1.00	0.85	1.07	0.92	0.94	0.95	1.06
DR.5	0.97	1.23	0.94	0.94	0.87	0.86	1.27	1.03
DR.6	0.90	1.33	0.84	0.90	0.84	0.82	1.06	1.08
DR.7	1.04	1.30	0.85	0.81	0.96	0.92	0.92	1.05
DR.8	0.94	1.33	0.87	0.95	0.97	0.93	1.00	1.01
DR.9	1.02	0.83	0.91	1.02	0.99	0.99	0.80	1.03
DR.10	0.91	1.20	0.78	0.82	0.91	0.93	0.86	1.09
DR.11	1.01	1.17	1.06	1.17	1.16	1.13	0.79	1.09
DR.12	0.97	1.07	0.86	0.85	0.94	0.94	1.11	1.03
DR.13	**0.98**	**1.03**	**0.92**	**1.11**	**0.97**	**0.99**	**1.02**	**1.07**
DR.14	**1.00**	**1.33**	**0.88**	**0.89**	**0.96**	**1.00**	**1.05**	**1.01**
DR.15	0.91	1.17	0.98	0.95	0.88	0.88	0.97	1.03
DR.16	0.93	1.03	0.73	0.91	0.94	0.85	1.05	1.00
DR.17	0.93	1.07	0.72	0.92	0.87	0.91	0.95	1.03
DR.18	0.97	1.03	0.76	0.91	1.05	0.97	0.90	1.04
DR.19	0.92	1.00	1.02	0.97	0.94	0.92	0.99	1.04
DR.20	0.92	1.03	1.06	0.81	0.87	0.90	1.04	1.06
Wt.1	**1.02**	**1.00**	**0.88**	**1.17**	**0.95**	**0.94**	**1.00**	**1.05**
Wt.2	**0.96**	**1.10**	**0.90**	**1.02**	**1.04**	**1.06**	**1.35**	**0.98**
Wt.3	1.00	0.70	1.11	1.07	1.02	0.97	1.22	1.01
Wt.4	**1.01**	**0.83**	**1.11**	**1.14**	**1.00**	**0.94**	**1.23**	**1.00**
Wt.5	1.02	0.80	0.97	1.08	0.89	0.86	1.25	0.97
Wt.6	**1.12**	**0.80**	**0.97**	**1.31**	**1.05**	**1.03**	**1.11**	**1.05**
WC.1	0.92	1.10	0.89	0.83	0.96	0.98	1.44	0.94
WC.2	0.95	1.37	1.06	0.94	1.31	1.22	0.94	0.89
WC.3	1.02	1.17	0.87	0.91	1.05	1.23	0.84	0.89
WC.4	1.08	1.00	1.10	1.14	1.28	1.34	1.12	0.98
WC.5	0.94	0.83	1.05	1.12	1.13	1.05	1.10	0.91
WC.6	0.77	1.03	0.87	0.81	0.94	0.95	0.87	0.94
WC.7	0.94	0.87	0.99	1.06	1.15	1.18	0.98	0.91
WC.8	0.97	0.83	1.12	1.12	1.22	1.14	1.02	0.99
WC.9	1.03	1.17	1.29	1.15	1.11	1.14	0.88	0.90

WC.10	0.99	0.80	1.18	1.18	1.09	1.13	1.16	0.98
WC.11	0.87	0.97	0.73	0.67	0.83	0.77	0.98	0.88
WC.12	1.04	0.90	1.04	1.02	1.12	1.12	1.21	0.93
WC.13	**1.02**	**0.80**	**1.12**	**1.33**	**1.17**	**1.18**	**1.15**	**0.98**
WC.14	1.03	0.93	1.08	1.08	1.16	1.19	0.78	0.96
WC.15	1.01	0.97	1.15	1.03	1.12	1.09	1.15	0.99
WC.16	1.20	0.97	1.24	1.22	1.08	1.17	0.94	0.96
WC.17	1.10	1.07	1.08	0.82	0.87	0.94	1.37	0.89
WC.18	1.03	0.93	0.96	0.96	0.89	0.94	1.06	0.96
WC.19	1.14	1.00	1.10	0.88	0.88	0.91	0.97	0.95
WC.20	1.07	0.87	1.12	1.17	1.05	1.04	1.37	0.88
WC.21	0.99	1.33	1.10	0.82	0.93	1.00	1.07	1.00
WC.22	1.04	0.90	1.06	1.09	0.97	1.06	1.17	0.98
WC.23	0.94	1.10	1.02	0.85	0.92	0.97	0.98	0.94
WC.24	0.99	0.93	1.24	1.05	0.96	0.94	0.83	0.99
WC.25	1.10	1.27	1.07	1.03	0.99	1.08	0.95	0.98
WC.26	1.05	0.90	1.18	1.02	0.95	0.87	1.00	0.98
WC.27	**1.13**	**1.07**	**1.21**	**1.15**	**1.11**	**1.05**	**0.79**	**0.99**
WC.28	0.91	0.63	0.77	0.64	0.62	0.72	0.53	1.04
WC.29	1.16	0.97	1.09	1.16	1.10	1.07	0.95	0.97
WC.30	0.81	0.67	0.69	0.61	0.67	0.69	0.67	1.03
WC.31	0.99	0.97	0.62	0.86	0.92	1.00	0.92	1.03
WC.32	0.91	0.70	0.66	0.54	0.83	0.75	0.91	0.97
WC.33	0.91	0.97	0.78	0.66	0.90	0.82	0.72	1.01
WC.34	0.94	0.83	0.54	0.78	0.86	0.87	0.83	1.01
S.879	1.05	1.13	1.19	1.32	1.15	1.17	0.73	1.10
S.1932	0.90	1.00	1.06	1.03	1.01	1.08	1.00	1.06
S.1902	1.11	1.07	0.97	1.02	0.91	1.02	0.97	0.98
S.880	1.02	1.00	1.05	0.88	0.92	0.90	0.97	1.12
S.1979	0.98	0.93	1.23	1.01	1.01	0.98	1.00	1.05
S.3399	**1.32**	**0.87**	**1.37**	**1.68**	**1.39**	**1.30**	**1.17**	**1.03**
S.1509	1.01	1.03	1.23	1.13	1.15	1.08	0.81	1.03
S.1977	1.00	1.00	1.06	0.81	0.96	0.92	0.96	1.06
S.1481	1.01	0.87	1.01	1.06	1.05	1.01	0.71	0.93
S.3400	1.02	1.00	1.03	1.16	0.98	0.90	0.80	1.01
S.3655	0.98	0.93	1.28	1.18	1.03	1.08	1.03	1.09
S.3656	0.97	0.83	1.05	0.93	0.89	0.83	0.90	1.09
S.3657	**1.14**	**0.93**	**1.35**	**1.20**	**1.20**	**1.16**	**1.10**	**1.05**
S.274 (Sln.1R)	1.10	0.90	1.15	1.19	1.12	1.17	1.18	1.01

Acce ssions	9	10	11	12	13	14	15
DR.1	0.99	0.95	0.90	0.99	0.99	0.97	0.97
DR.2	1.01	0.96	0.95	0.98	0.95	0.95	0.95

DR.3	1.07	1.04	1.12	1.12	1.12	1.02	1.04
DR.4	1.06	1.04	1.14	1.19	1.19	1.03	1.03
DR.5	1.05	1.06	1.14	1.14	1.11	1.01	1.04
DR.6	1.05	1.05	1.19	1.18	1.13	1.05	1.00
DR.7	1.07	1.07	1.19	1.14	1.15	1.03	1.03
DR.8	1.06	1.06	1.12	1.09	1.11	1.00	1.01
DR.9	1.03	1.04	1.08	1.13	1.09	1.01	1.00
DR.10	1.04	1.06	1.19	1.30	1.21	1.08	1.04
DR.11	1.04	1.05	1.18	1.23	1.14	1.07	1.03
DR.12	1.03	1.03	1.07	1.10	1.04	1.03	1.00
DR.13	**1.09**	**1.08**	**1.25**	**1.19**	**1.11**	**1.05**	**1.05**
DR.14	**1.06**	**1.05**	**1.12**	**1.12**	**1.10**	**1.00**	**1.04**
DR.15	1.04	1.03	1.10	1.14	1.08	1.03	1.03
DR.16	1.00	1.00	0.99	0.96	0.91	1.00	0.96
DR.17	1.00	1.00	1.03	1.02	0.99	1.03	0.98
DR.18	1.07	1.05	1.15	1.14	1.06	1.02	1.00
DR.19	1.02	1.01	1.05	1.10	1.03	1.05	0.99
DR.20	1.03	1.04	1.11	1.08	1.07	1.08	1.01
Wt.1	**1.08**	**1.05**	**1.18**	**1.24**	**1.12**	**1.02**	**1.00**
Wt.2	**1.01**	**1.00**	**0.99**	**1.07**	**0.96**	**1.00**	**1.01**
Wt.3	1.02	1.03	1.05	1.00	0.95	0.98	1.00
Wt.4	**1.00**	**1.00**	**1.00**	**1.10**	**1.00**	**1.01**	**1.02**
Wt.5	1.01	0.99	0.96	1.04	0.94	0.97	1.00
Wt.6	**1.04**	**1.03**	**1.11**	**1.15**	**1.04**	**1.02**	**1.01**
WC.1	0.91	0.92	0.78	0.89	0.94	0.98	0.99
WC.2	0.89	0.88	0.69	0.87	0.86	0.95	0.98
WC.3	0.90	0.91	0.73	0.84	0.92	0.98	1.00
WC.4	0.95	0.95	0.87	1.02	1.07	1.08	1.02
WC.5	0.94	0.92	0.77	0.99	1.00	0.99	1.03
WC.6	0.95	0.95	0.85	1.06	1.05	1.02	1.02
WC.7	0.93	0.93	0.77	0.92	0.96	0.99	1.01
WC.8	0.99	0.97	0.94	1.12	1.17	1.07	1.06
WC.9	0.95	0.93	0.80	0.95	0.94	0.99	1.00
WC.10	0.97	0.96	0.90	1.01	1.08	1.04	1.08
WC.11	0.93	0.94	0.77	0.94	0.87	0.91	0.96
WC.12	0.98	0.97	0.88	1.00	0.97	0.93	1.02
WC.13	**1.03**	**1.01**	**1.01**	**1.16**	**1.16**	**1.05**	**1.09**
WC.14	0.99	0.96	0.90	1.05	1.06	1.00	1.01
WC.15	0.97	0.95	0.90	1.03	1.06	1.05	1.03
WC.16	1.00	0.97	0.92	1.07	1.11	1.01	1.00
WC.17	0.92	0.90	0.74	0.82	0.84	0.95	0.97
WC.18	0.96	0.96	0.88	1.03	0.99	1.02	1.02
WC.19	0.97	0.96	0.89	1.02	1.02	1.01	0.96

WC.20	0.97	0.98	0.82	0.74	0.75	0.91	0.96
WC.21	1.02	1.05	1.06	0.94	0.95	1.04	1.00
WC.22	1.01	1.03	1.01	0.99	1.01	1.04	1.04
WC.23	1.03	1.00	0.96	0.91	0.89	0.96	0.96
WC.24	1.03	1.02	1.07	0.96	1.01	1.06	1.00
WC.25	1.00	1.05	1.02	0.93	1.00	1.01	1.01
WC.26	0.98	1.01	0.92	0.85	0.88	0.96	0.96
WC.27	**1.07**	**1.08**	**1.14**	**1.06**	**1.11**	**1.00**	**1.02**
WC.28	0.97	0.94	0.94	0.83	0.85	0.91	0.95
WC.29	1.00	1.00	0.96	0.88	0.95	1.00	0.96
WC.30	0.98	0.98	1.00	0.83	0.80	0.97	0.95
WC.31	0.94	0.97	0.93	0.81	0.78	0.95	0.96
WC.32	0.93	0.92	0.84	0.73	0.71	0.88	0.96
WC.33	0.99	1.01	1.00	0.86	0.86	0.93	1.00
WC.34	0.95	0.97	0.93	0.79	0.83	0.93	0.97
S.879	0.99	1.02	1.12	0.93	1.02	1.06	1.01
S.1932	0.98	1.01	1.06	0.90	0.87	0.96	0.98
S.1902	1.00	1.00	1.00	0.94	0.92	0.96	0.97
S.880	0.98	1.02	1.12	0.95	0.94	1.07	0.98
S.1979	1.04	1.05	1.17	1.03	1.10	1.02	1.00
S.3399	**1.01**	**1.00**	**1.05**	**0.90**	**0.88**	**0.95**	**0.96**
S.1509	1.00	1.03	1.07	0.88	0.93	0.94	0.95
S.1977	1.02	1.08	1.17	0.97	1.03	0.97	1.06
S.1481	0.93	0.92	0.81	0.70	0.80	0.90	0.95
S.3400	0.99	1.02	1.03	0.87	0.97	0.96	0.98
S.3655	1.06	1.06	1.21	1.04	1.08	1.03	1.00
S.3656	1.02	1.05	1.19	1.05	1.20	1.08	1.02
S.3657	**1.04**	**1.03**	**1.13**	**1.04**	**1.17**	**1.01**	**1.01**
S.274 (Sln.1R)	0.96	0.98	0.94	0.95	1.06	1.04	0.95

Accessions	16	17	18	19	20	21	22
DR.1	1.00	0.93	0.98	0.70	1.03	1.01	1.12
DR.2	0.96	0.87	0.90	0.66	0.88	0.73	0.95
DR.3	1.08	1.13	1.15	0.65	0.98	1.14	0.92
DR.4	1.05	1.11	1.18	0.91	1.02	1.18	1.03
DR.5	1.02	1.06	1.09	1.17	0.96	1.17	1.01
DR.6	1.03	1.08	1.11	0.65	0.98	0.90	1.06
DR.7	1.02	1.07	1.11	0.91	0.94	1.28	0.98
DR.8	1.03	1.04	1.11	0.76	0.99	1.05	1.00
DR.9	0.98	1.00	1.07	0.59	1.03	1.04	0.90
DR.10	1.03	1.15	1.19	0.63	1.06	1.15	0.99

DR.11	1.01	1.11	1.14	1.13	0.95	1.08	0.85
DR.12	1.03	1.07	1.09	0.92	1.03	1.20	0.93
DR.13	**1.07**	**1.18**	**1.19**	**1.43**	**0.99**	**1.18**	**0.93**
DR.14	**1.06**	**1.09**	**1.12**	**1.62**	**0.92**	**1.12**	**1.06**
DR.15	1.04	1.11	1.12	1.38	1.05	1.04	1.12
DR.16	1.00	0.97	0.94	1.38	1.01	0.94	0.97
DR.17	1.01	1.03	1.00	1.47	1.00	0.98	0.89
DR.18	1.02	1.03	1.05	1.48	1.01	1.09	0.83
DR.19	1.02	1.06	1.06	2.03	1.01	0.55	1.06
DR.20	1.01	1.11	1.08	1.09	1.08	1.01	1.14
Wt.1	**1.07**	**1.10**	**1.09**	**2.03**	**0.91**	**1.08**	**1.29**
Wt.2	**1.03**	**1.04**	**1.05**	**2.49**	**0.95**	**1.03**	**1.19**
Wt.3	1.00	0.97	1.02	2.20	0.97	1.22	1.25
Wt.4	**1.00**	**1.03**	**1.06**	**2.39**	**1.10**	**0.99**	**1.27**
Wt.5	0.99	0.95	1.00	2.06	0.96	1.01	1.14
Wt.6	**1.01**	**1.03**	**1.06**	**2.19**	**0.90**	**0.81**	**1.12**
WC.1	0.98	0.94	0.92	0.41	0.91	0.66	0.89
WC.2	0.98	0.91	0.92	0.35	1.13	0.82	0.99
WC.3	0.99	0.91	0.94	0.48	1.01	0.59	1.09
WC.4	0.99	1.09	1.02	0.76	0.98	1.02	0.76
WC.5	1.01	1.03	1.02	0.46	0.99	1.16	0.83
WC.6	1.01	1.06	1.01	0.25	1.02	1.13	0.87
WC.7	1.00	0.94	0.94	0.32	1.07	1.24	0.72
WC.8	1.07	1.21	1.20	0.72	1.02	0.93	0.85
WC.9	1.02	1.02	0.99	0.32	0.99	1.02	0.90
WC.10	1.05	1.17	1.12	0.57	1.05	1.25	0.78
WC.11	0.96	0.83	0.81	0.07	1.09	0.87	0.84
WC.12	1.00	0.99	0.98	0.28	1.06	1.26	0.86
WC.13	**1.06**	**1.20**	**1.15**	**1.08**	**1.01**	**1.06**	**1.15**
WC.14	1.00	1.00	1.01	0.80	1.20	0.87	1.18
WC.15	1.03	1.11	1.04	0.53	1.06	1.15	1.17
WC.16	1.01	1.04	1.06	1.18	1.07	1.00	1.15
WC.17	0.97	0.90	0.90	0.80	1.04	0.59	1.27
WC.18	1.02	1.06	1.00	1.06	0.99	0.97	1.25
WC.19	0.99	0.95	0.92	0.61	1.09	0.70	1.25
WC.20	0.94	0.82	0.79	0.93	1.01	0.45	1.12
WC.21	0.99	1.02	0.95	0.57	1.08	0.86	0.97
WC.22	1.02	1.10	1.07	0.94	0.98	0.81	1.08
WC.23	0.96	0.83	0.88	0.05	0.96	0.89	1.11
WC.24	1.00	1.05	1.05	0.49	1.08	0.56	1.05
WC.25	0.97	1.00	0.95	0.67	0.98	0.95	1.34
WC.26	0.94	0.81	0.88	0.81	1.07	0.77	1.15
WC.27	**1.04**	**1.06**	**1.07**	**1.01**	**1.07**	**1.09**	**1.21**

WC.28	0.96	0.82	0.83	0.27	1.00	0.69	1.11
WC.29	0.96	0.92	0.94	0.73	1.07	0.57	1.17
WC.30	0.95	0.87	0.81	0.33	1.08	0.99	0.92
WC.31	0.94	0.85	0.80	0.78	1.07	1.21	0.89
WC.32	0.93	0.79	0.75	0.20	1.03	1.01	0.83
WC.33	1.00	0.93	0.87	1.15	1.03	1.36	0.83
WC.34	0.94	0.85	0.82	0.48	1.05	1.18	0.88
S.879	0.99	1.04	1.05	1.46	0.97	1.17	0.97
S.1932	0.99	0.94	0.89	2.40	0.94	1.41	0.87
S.1902	0.97	0.90	0.91	1.29	1.00	1.07	0.94
S.880	0.96	0.98	0.95	1.87	0.87	1.11	0.90
S.1979	1.01	1.04	1.04	0.75	0.89	1.32	0.99
S.3399	**0.99**	**0.91**	**0.91**	**2.33**	**0.87**	**1.31**	**0.80**
S.1509	0.92	0.82	0.81	0.48	0.89	0.98	1.12
S.1977	1.01	1.04	1.03	0.48	0.89	0.97	1.06
S.1481	0.93	0.79	0.78	0.73	0.94	0.75	1.01
S.3400	0.96	0.91	0.91	0.94	0.93	1.13	0.99
S.3655	1.02	1.06	1.14	1.00	0.91	1.10	1.03
S.3656	1.03	1.14	1.11	1.56	1.05	1.05	1.09
S.3657	**1.03**	**1.05**	**1.11**	**1.56**	**0.86**	**1.05**	**1.20**
S.274 (Sln.1R)	0.93	0.95	0.97	1.78	0.93	0.96	1.03

Acce ssions	23	24	25	Total performance index	Rank
DR.1	1.06	1.06	1.12	24.67	39
DR.2	1.03	0.90	0.92	24.12	50
DR.3	1.05	0.94	1.00	25.56	27
DR.4	0.98	0.89	0.88	25.68	24
DR.5	0.99	0.92	0.91	25.96	19
DR.6	1.07	1.02	1.09	25.41	31
DR.7	1.07	1.02	1.09	26.02	18
DR.8	1.02	1.00	1.02	25.47	29
DR.9	1.05	1.03	1.06	24.72	38
DR.10	1.05	1.05	1.09	25.81	22
DR.11	0.98	0.95	0.92	26.44	12
DR.12	1.01	1.03	1.02	25.4	32
DR.13	**1.00**	**1.01**	**1.03**	**26.92**	**7**
DR.14	**1.09**	**1.09**	**1.19**	**26.97**	**6**
DR.15	1.03	1.02	1.05	26.18	15
DR.16	1.06	0.99	1.04	24.56	40

DR.17	1.04	0.99	1.03	24.89	37
DR.18	1.12	1.01	1.13	25.89	21
DR.19	1.06	1.04	1.11	26.05	17
DR.20	1.01	1.07	1.05	25.76	23
Wt.1	**0.93**	**1.05**	**0.99**	**27.24**	**3**
Wt.2	**0.91**	**1.06**	**0.98**	**27.18**	**4**
Wt.3	0.91	1.05	0.97	26.69	11
Wt.4	**0.96**	**0.99**	**0.96**	**27.14**	**5**
Wt.5	0.90	0.95	0.86	25.57	26
Wt.6	**0.94**	**0.93**	**0.88**	**26.71**	**10**
WC.1	1.04	0.97	1.02	23.21	57
WC.2	1.06	1.00	1.07	24.03	51
WC.3	1.00	1.04	1.05	23.36	56
WC.4	0.97	0.95	0.92	25.46	30
WC.5	0.97	1.00	0.99	24.23	48
WC.6	1.03	0.99	1.03	23.48	55
WC.7	0.94	0.90	0.88	23.54	54
WC.8	0.91	0.95	0.87	25.46	30
WC.9	1.05	0.94	0.91	24.39	44
WC.10	0.94	1.02	0.96	25.46	30
WC.11	1.00	1.07	1.09	21.65	61
WC.12	0.96	0.89	0.85	24.26	46
WC.13	**0.98**	**0.98**	**0.97**	**26.9**	**8**
WC.14	1.03	1.08	1.12	25.47	29
WC.15	0.96	0.97	0.95	25.47	29
WC.16	0.92	0.98	0.91	26.18	15
WC.17	1.12	1.12	1.26	24.25	47
WC.18	1.05	1.03	1.09	25.11	35
WC.19	1.07	1.05	1.11	24.4	43
WC.20	1.09	0.97	1.01	23.83	52
WC.21	1.10	1.09	1.16	25.09	36
WC.22	0.97	0.96	0.93	25.26	34
WC.23	0.94	1.01	0.97	23.03	58
WC.24	0.95	1.02	0.98	24.31	45
WC.25	1.03	1.04	1.07	25.49	28
WC.26	1.08	1.04	1.12	24.18	49
WC.27	**1.03**	**1.12**	**1.11**	**26.79**	**9**
WC.28	1.00	0.97	0.98	20.88	64
WC.29	1.09	1.07	1.15	24.89	37
WC.30	0.96	0.96	0.92	21.14	62
WC.31	1.07	1.07	1.15	23.48	55
WC.32	1.04	1.03	1.09	20.94	63
WC.33	1.02	0.98	1.00	23.59	53

WC.34	1.06	1.06	1.12	22.47	60
S.879	0.92	0.96	0.89	26.41	13
S.1932	0.92	0.93	0.86	26.05	17
S.1902	1.00	0.99	0.98	24.89	37
S.880	0.92	0.96	0.88	25.32	33
S.1979	0.94	1.04	0.98	25.6	25
S.3399	**0.87**	**0.89**	**0.78**	**27.54**	**2**
S.1509	1.02	1.03	1.05	24.39	44
S.1977	0.94	1.04	0.97	24.5	42
S.1481	1.07	1.04	1.13	22.83	59
S.3400	1.00	1.01	1.02	24.52	41
S.3655	0.96	0.99	1.01	26.3	14
S.3656	1.00	0.96	0.97	26.06	16
S.3657	**1.03**	**1.05**	**1.06**	**27.56**	**1**
S.274 (Sln.1R)	0.93	0.91	0.86	25.95	20

Characters:

1. Stem girth
2. Number of primary branches
3. Number of secondaries per primary
4. Girth of primary branches
5. Length of primary branches
6. Bush spread
7. Fruits per node
8. Fruit length
9. Fruit breadth
10. Fruit thickness
11. Fruit volume
12. Fruit weight
13. Fruit weight (dried)
14. Bean length
15. Bean breadth
16. Bean thickness
17. Bean volume
18. Bean weight
19. Yield per plant
20. Out turn (ripe to clean)
21. Percentage of A grade beans
22. Internodal length
23. Leaf length
24. Leaf breadth
25. Leaf area

Table 4.20. Major growth, yield and quality characters of the ten superior accessions of robusta coffee selected presently

Characters	Accession Numbers as per rank									
	1	2	3	4	5	6	7	8	9	10
	S. 3657	**S. 3399**	**Wt. 1**	**Wt. 2**	**Wt. 4**	**DR. 14**	**DR. 13**	**WC. 13**	**WC. 27**	**Wt. 6**
Stem girth (mm)	110.57	128.49	99.08	93.33	97.77	96.63	95.04	98.75	109.63	108.51
Number of primary branches	2.33	2.17	2.50	2.75	2.08	3.33	2.58	2.00	2.67	2.00

Number of secondaries per primary	6.25	6.33	4.08	4.17	5.13	4.08	4.25	5.17	5.58	4.46
Girth of primary branches (mm)	61.25	85.64	59.92	52.12	58.34	45.53	56.60	68.19	58.83	66.83
Length of primary branches (cm)	222.08	256.42	175.25	192.79	184.50	178.00	180.50	216.55	205.88	194.59
Internodal length (cm)	5.99	8.93	5.56	6.05	5.66	6.80	7.70	6.25	5.95	6.42
Bush spread (cm)	378.33	823.42	304.42	344.17	306.08	323.50	323.08	381.83	341.42	334.83
Leaf area (cm^2)	140.49	191.80	150.63	153.06	155.52	125.32	145.13	153.94	135.14	168.96
Fruits per node	15.11	16.06	13.70	18.57	16.88	14.34	13.92	15.76	10.77	15.22
Fruit length (mm)	14.53	14.32	14.56	13.65	13.90	14.04	14.92	13.67	13.81	14.51
Fruit breadth (mm)	13.45	13.08	13.99	13.11	12.97	13.75	14.08	13.35	13.93	13.47
Fruit thickness (mm)	11.31	10.96	11.55	11.04	10.99	11.59	11.87	11.04	11.86	11.29
Fruit volume (mm^3)	1181.0	1093.1	1230.9	1028.8	1039.4	1168.7	1300.8	1055.2	1185.8	1155.3
Weight of 100 fresh fruits (g)	141.62	121.82	168.98	145.11	149.23	152.82	161.57	158.33	144.24	155.83
100 fruit weight (dried) (g)	62.18	46.41	59.54	51.02	52.72	58.06	58.65	61.21	58.73	55.31
Bean length (mm)	8.79	8.27	8.87	8.71	8.77	8.67	9.10	9.08	8.40	8.80
Bean breadth (mm)	7.2	6.83	7.18	7.19	7.26	7.42	7.48	7.81	7.32	7.21
Bean thick ness (mm)	4.7	4.53	4.88	4.71	4.56	4.83	4.90	4.82	4.73	4.61
Bean volume (mm^3)	182.67	157.25	190.29	180.60	179.33	190.02	204.13	209.04	184.67	178.36
100 bean	19.09	15.62	18.88	18.08	18.29	19.36	20.44	19.85	18.52	18.34

weight (g)										
Yield per plant (kg)	6.35	9.47	8.25	10.15	9.73	6.58	5.83	4.38	4.13	8.92
Out turn (ripe to clean) (%)	18.84	19.12	19.97	20.92	24.25	20.24	21.70	22.24	23.48	19.79
Percentage of A grade beans	48.86	60.96	50.04	47.64	45.84	52.01	49.01	49.01	50.68	37.70

Fig. 4.2. Accession No. S.3657

Fig. 4.3. Accession No. S.3399

Fig. 4.4. Accession No. Wt. 1

Fig. 4.5. Accession No. Wt.2

Fig. 4.6. Accession No. Wt.4

Fig. 4.7. Accession No. DR.14

Fig. 4.8. Accession No. DR. 13

Fig. 4.9. Accession No. WC.13

Fig. 4.10. Accession No. WC.27

Fig. 4. 11. Accession No. Wt.6

Fig. 4.12. Control plant: S.274

4.9. Performance of interspecific hybrids

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 (Figs. 4.13 – 4.21). 9 growth characters, 19 yield characters, caffeine content and leaf rust resistance were analysed. Hybrid plant number Ra.12-1 showed superiority above the better parent (*Coffea canephora* var. robusta) only in the case of fruit length (Table 4.21). Hybrid plant number Ra.12-2 showed superiority above the better parent value in the case of bean thickness (Table 4.22). Hybrid plant number Ra.12-3 showed superiority over the better parent in the case of number of secondaries per primary among the growth and yield characters (Table 4.23). Hybrid plant number Ra. 12-4 showed improvement over the better parent value in the case of number of secondaries per primary, length of primary branches, bush spread, fruit length, fruit thickness, fruit volume, 100 fresh fruit weight and 100 fresh pea berry weight (Table 4.24). Hybrid plant number Ra. 12-5 showed improvement over the better parent in the case of internodal length and fruit thickness (Table 4.25). Ra. 13-1 showed improvement over the better parent value in the case of internodal length and fruit thickness (Table 4.26). Hybrid plant number Ra. 14-1 showed improvement over the better parent value in the case of fruit length, fruit thickness and fruit volume (Table 4.27). Hybrid plant number Ra.15-1 showed improvement over the better parent value in the case of length of primary branches, bush spread, fruit length, fruit volume, weight of 100 fresh fruits, 100 pea berry weight (fresh), bean length,100 bean weight and 100 bean weight (pea berry) (Table 4.28). The hybrid plant number Ra. 15-2 showed improvement over the better parent value in the case of number of secondaries per primary, 100 pea berry weight (fresh), bean thickness, 100 bean weight and 100 bean weight (pea berry) (Table 4.29). Most of the hybrid plants produced floats of fruits in different percentages indicating absence of complete fruit/ seed filling (Tables 4.21 to 4.29).

Fig. 4.13. Parents and Hybrid- Ra.12-1

C. racemosa 1/3 (Female parent)

S.274 1/1 (Male parent)

Ra.12-1 (Hybrid)

Fig. 4.14. Parents and Hybrid- Ra.12-2

C. racemosa 1/3 (Female parent)

S.274 1/1 (Male parent)

Ra.12-2 (Hybrid)

Fig. 4.15. Parents and Hybrid- Ra.12-3

C. racemosa 1/3 (Female parent)

S.274 1/1 (Male parent)

Ra.12-3 (Hybrid)

Fig. 4.16. Parents and Hybrid- Ra.12-4

C. racemosa 1/3 (Female parent)

S.274 1/1 (Male parent)

Ra.12-4 (Hybrid)

Fig. 4.17. Parents and Hybrid- Ra.12-5

C. racemosa 1/3 (Female parent)

S.274 1/1 (Male parent)

Ra.12-5 (Hybrid)

Fig. 4.18. Parents and Hybrid- Ra.13-1

C. racemosa 3/1 (Female parent)

S.274 10/10 (Male parent)

Ra.13-1 (Hybrid)

Fig. 4.19. Parents and Hybrid- Ra.14-1

C. racemosa 4/3 (Female parent)

S.274 1/4 (Male parent)

Ra.14-1 (Hybrid)

Fig. 4.20. Parents and Hybrid- Ra. 15-1

C. racemosa 1/3 (Female parent)

S.274 1/4 (Male parent)

Ra.15-1 (Hybrid)

Fig. 4.21. Parents and Hybrid- Ra.15-2

C. racemosa 1/3 (Female parent)

S.274 1/4 (Male parent)

Ra.15-2 (Hybrid)

Table 4.21. Studies on interspecific hybridization- data on Hybrid Plant No. Ra.12-1

Growth characters									
	Stem girth (mm)	No. of sec. per primary	Girth of primary branches (mm)	Length of primary branches (cm)	Inter nodal length (cm)	Bush spread (cm)	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm^2)
Hybrid	42	6	6.41	79.5	2.37	97	6.9	2.6	12.19
Female parent *C. racemosa* 1/3	85.92	9.5	28.28	174.28	2.02	352	4.65	1.95	6.17
Male parent S.274 1/1	96.62	6	61.83	170.5	5.81	344	27.3	10.85	192.53
Mid parent value	91.27	7.75	45.06	172.39	3.92	348	15.98	6.4	99.35
Better parent value	96.62	9.5	61.83	174.28	2.02	352	4.65	1.95	6.17
% of +ve heterosis	-53.98	-22.58	-85.77	-53.88	+39.54	-72.13	+56.82	+59.38	+87.73
% of heterobeltiosis	-56.53	-36.84	-89.63	-54.38	-17.33	-72.44	-48.39	-33.33	-97.57

Yield characters										
	Crop duration (days)	Fruits per node	Fruit length (mm)	Fruit breadth (mm)	Fruit thick ness (mm)	Fruit volume (mm^3)	100 fruit wt. (fresh) (g)	100 pea berry wt. (fresh) (g)	100 fruit wt. (dried) (g)	100 pea berry wt. (dried) (g)
Hybrid	160	1	15.3	11	9.2	805.15	73.1	46.1	16.58	13.5
Female parent *C. racemosa* 1/3	80	1.46	13.05	13.63	11.89	1099.74	127.9	66.9	22.5	15.1
Male parent S.274 1/1	310	23.69	14.57	13.89	11.54	1214.43	142.13	89.9	62	34.4
Mid parent value	220	12.58	13.81	13.76	11.72	1157.09	135.02	78.4	42.25	24.75
Better parent value	80	23.69	14.57	13.89	11.89	1214.43	142.13	89.9	62	34.4
% of +ve heterosis	+27.27	-92.05	+10.79	-20.06	-21.5	-30.42	-45.86	-41.2	-60.76	-45.45
% of heterobeltiosis	-100	-95.78	5.01	-20.81	-22.62	-33.7	-48.57	-48.72	-73.26	-60.76

Yield characters contd..

	Bean length (mm)	Bean breadth (mm)	Bean thick ness (mm)	Bean volume (mm^3)	100 bean wt. (g)	100 bean wt. (pea berry) (g)	Yield per plant (kg)	Outturn (%)	% of floats
Hybrid	5.83	4.92	4.08	71.39	9.21	7.5	0.05	22.68	0
Female parent *C.racemosa* 4/3	5.77	3.24	3.24	36.95	6.35	5.6	0.25	17.59	0
Male parent S.274 ¼	8.68	6.72	4.44	157.98	15.2	13.5	15.31	43.62	0
Mid parent value	7.23	4.98	3.84	97.22	10.78	9.55	7.78	30.61	0
Better parent value	8.68	6.72	4.44	157.98	15.2	13.5	15.31	43.62	0
% of +ve heterosis	-19.36	-1.2	+6.25	-26.57	-14.56	-21.47	-99.36	-25.91	-
% of heterobeltiosis	-32.83	-26.79	-8.11	-54.81	-39.41	-44.44	-99.67	-48.01	-

Table 4.22. Studies on interspecific hybridization- data on Hybrid Plant No. Ra-12-2

Growth characters									
	Stem girth (mm)	No. of sec. per primary	Girth of primary branches (mm)	Length of primary branches (cm)	Inter nodal length (cm)	Bush spread (cm)	Leaf length (cm)	Leaf breadth (cm)	Leaf area $(cm)^2$
Hybrid	25.3	1.5	10.7	107.5	2.22	185	9.45	3.9	25.06
Female parent *C.racemosa* 1/3	85.92	9.5	28.28	174.28	2.02	352	4.65	1.95	6.17
Male parent S.274 1/1	96.62	6	61.83	170.5	5.81	344	27.3	10.85	192.53
Mid parent value	91.27	7.75	45.06	172.39	3.92	348	15.98	6.4	99.35
Better parent value	96.62	9.5	61.83	174.28	2.02	352	4.65	1.95	6.17
% of +ve heterosis	-72.28	-80.65	-76.25	-37.64	+43.37	-46.84	+40.86	_+39.06	+74.78
% of heterobeltiosis	-84.21	-73.81	-82.69	-38.32	-9.9	-47.44	-103.23	-100	-306.16

Yield characters										
	Crop duration (days)	Fruits per node	Fruit length (cm)	Fruit breadth (cm)	Fruit thick ness (mm)	Fruit volume (mm^3)	100 fruit wt. (fresh) (g)	100 pea berry wt. (fresh) (g)	100 fruit wt. (dried) (g)	100 pea berry wt. (dried) (g)
Hybrid	165	2	11.37	9.05	9.69	552.86	61.25	43.67	13.24	11.33
Female parent *C.racemosa* 4/3	180	1.46	13.05	13.63	11.89	1099.74	127.9	66.9	22.5	15.1
Male parent S.274 1/4	315	23.69	14.57	13.89	11.54	1214.43	142.13	89.9	62	34.4
Mid parent value	197.5	12.58	13.81	13.76	11.72	1157.09	135.02	78.4	42.25	24.75
Better parent value	80	23.69	14.57	13.89	11.89	1214.43	142.13	89.9	62	34.4
% of +ve heterosis	+16.46	-84.1	-17.67	-34.23	-17.32	-52.22	-54.64	-44.3	-68.66	-54.22
% of hetero-beltiosis	-106.25	-91.56	-21.96	-34.85	-18.5	-54.48	-56.91	-51.42	-78.65	-67.06

Yield characters contd..									
	Bean length (mm)	Bean breadth (mm)	Bean thicknes s (mm)	Bean volume (mm^3)	100 bean wt. (g)	100 bean wt. (pea berry) (g)	Yield per plant (kg)	Outturn (%)	% of floats
Hybrid	5.78	4.56	4.63	58.36	12.08	10.33	0.25	25.24	25
Female parent *C. racemosa* 1/3	5.77	3.24	3.24	36.95	6.35	5.6	0.25	17.59	0
Male parent S.274 1/1	8.68	6.72	4.44	157.98	15.2	13.5	15.31	43.62	0
Mid parent value	7.23	4.98	3.84	97.22	10.78	9.55	7.78	30.61	0
Better parent value	8.68	6.72	4.44	157.98	15.2	13.5	15.31	43.62	0
% of +ve heterosis	-20.06	-8.43	+20.57	-39.97	12.06	8.17	-96.79	-17.54	-
% of heterobeltiosis	-33.41	-32.14	+4.28	-63.06	-20.53	-23.48	-98.37	-42.14	-

Table 4.23. Studies on interspecific hybridization- data on Hybrid Plant No. Ra-12-3

Growth characters									
	Stem girth (mm)	No. of sec. per primary	Girth of primary branches (mm)	Length of primary branches (cm)	Inter nodal length (cm)	Bush spread (cm)	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm^2)
Hybrid	48	12.5	15.1	100	2.6	122	7	2.9	13.8
Female parent *C. racemosa* 1/3	85.92	9.5	28.28	174.28	2.02	352	4.65	1.95	6.17
Male parent S.274 1/1	96.62	6	61.83	170.5	5.81	344	27.3	10.85	192.53
Mid parent value	91.27	7.75	45.06	172.39	3.92	348	15.98	6.4	99.35
Better parent value	96.62	9.5	61.83	174.28	2.02	352	4.65	1.95	6.17
% of +ve heterosis	-47.41	61.29	-66.49	-41.99	+33.67	-64.94	+56.2	+54.69	+86.11
% of heterobeltiosis	-50.32	31.58	-75.58	-42.62	-28.71	-65.34	-50.54	-48.72	-123.66

Yield characters										
	Crop duration (days)	Fruits per node	Fruit length (mm)	Fruit breadth (mm)	Fruit thickness (mm)	Fruit volume (mm3)	100 fruit wt. (fresh) (g)	100 pea berry wt. (fresh) (g)	100 fruit wt. (dried) (g)	100 pea berry wt. (dried) (g)
Hybrid	170	1	11.27	11.11	10.68	695.36	85.87	86.8	19.38	19.5
Female parent *C. racemosa* 1/3	80	1.46	13.05	13.63	11.89	1099.74	127.9	66.9	22.5	15.1
Male parent S.274 1/1	315	23.69	14.57	13.89	11.54	1214.43	142.13	89.9	62	34.4
Mid parent value	202.5	12.58	13.81	13.76	11.72	1157.09	135.02	78.4	42.25	24.75
Better parent value	90	23.69	14.57	13.89	11.89	1214.43	142.13	89.9	62	34.4
% of +ve heterosis	+16	-92.05	-18.39	-19.26	-8.87	-39.9	-36.4	+10.71	-54.13	-21.21
% of heterobeltiosis	-88.99	-95.78	-22.65	-20.01	-10.18	-42.74	-39.58	-3.45	-68.74	-43.31

Yield characters contd….

	Bean length (mm)	Bean breadth (mm)	Bean thick ness (mm)	Bean volume (mm^3)	100 bean wt. (g)	100 bean wt. (pea berry) (g)	Yield per Plant (kg)	Out turn (%)	% of floats
Hybrid	5.87	5.21	4.26	79.47	9.45	9.5	0.1	22.62	
Female parent *C.racemosa* 1/3	5.77	3.24	3.24	36.95	6.35	5.6	0.25	17.59	0
Male parent S.274 1/1	8.68	6.72	4.44	157.98	15.2	13.5	15.31	43.62	0
Mid parent value	7.23	4.98	3.84	97.22	10.78	9.55	7.78	30.61	0
Better parent value	8.68	6.72	4.44	157.98	15.2	13.5	15.31	43.62	0
% of +ve heterosis	-18.81	4.62	10.94	-18.26	-12.34	-0.52	-98.71	-26.1	-
% of heterobeltiosis	-32.37	-22.47	-4.05	-49.7	-37.83	-29.63	-99.35	-48.14	-

Table 4.24. Studies on interspecific hybridization- data on Hybrid Plant No. Ra-12-4

Growth characters									
	Stem girth (mm)	No. of sec. per primary	Girth of primary branches (mm)	Length of primary branches (cm)	Inter nodal length (cm)	Bush spread (cm)	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm^2)
Hybrid	50	12	16.06	203	3.39	357	10.45	4.25	30.2
Female parent *C. racemosa* 1/3	85.92	9.5	28.28	174.28	2.02	352	4.65	1.95	6.17
Male parent S.274 1/1	96.62	6	61.83	170.5	5.81	344	27.3	10.85	192.53
Mid parent value	91.27	7.75	45.06	172.39	3.92	348	15.98	6.4	99.35
Better parent value	96.62	9.5	61.83	174.28	2.02	352	4.65	1.95	6.17
% of +ve heterosis	-45.22	+54.84	-64.36	+17.76	+13.52	2.59	+34.61	+33.59	+69.6
% of heterobeltiosis	-48.25	26.32	-74.03	16.48	-67.82	1.42	-124.73	-117.95	-389.47

Yiled characters										
	Crop duration (days)	Fruits per node	Fruit length (mm)	Fruit breadth (mm)	Fruit thickness (mm)	Fruit volume (mm^3)	100 fruit wt. (fresh) (g)	100 pea berry wt. (fresh) (g)	100 fruit wt. (dried) (g)	100 pea berry wt. (dried) (g)
Hybrid	165	1	15.89	13.28	12.15	1333.22	150.97	104.13	29.49	24.9
Female parent *C .racemosa* 1/3	85	1.46	13.05	13.63	11.89	1099.74	127.9	66.9	22.5	15.1
Male parent S.274 1/1	315	23.69	14.57	13.89	11.54	1214.43	142.13	89.9	62	34.4
Mid parent value	200	12.58	13.81	13.76	11.72	1157.09	135.02	78.4	42.25	24.75
Better parent value	85	23.69	14.57	13.89	11.89	1214.43	142.13	89.9	62	34.4
% of +ve heterosis	+17.5	-92.05	+15.06	-3.49	+3.67	+15.22	+11.81	+32.82	-30.2	+0.61
% of heterobeltiosis	-94.12	-95.78	-9.06	-4.39	-2.19	-9.78	-6.22	-15.83	-52.44	-27.62

Yield characters contd..									
	Bean length (mm)	Bean breadth (mm)	Bean thickness (mm)	Bean volume (mm^3)	100 bean wt. (g)	100 bean wt. (pea berry) (g)	Yield per plant (kg)	Outturn (%)	% of floats
Hybrid	8.61	5.79	4.32	131.37	12.97	13	0.05	19.53	70
Female parent *C. racemosa* 1/3	5.77	3.24	3.24	36.95	6.35	5.6	0.25	17.59	0
Male parent S.274 1/1	8.68	6.72	4.44	157.98	15.2	13.5	15.31	43.62	0
Mid parent value	7.23	4.98	3.84	97.22	10.78	9.55	7.78	30.61	0
Better parent value	8.68	6.72	4.44	157.98	15.2	13.5	15.31	43.62	0
% of +ve heterosis	+19.09	+16.27	+12.5	+35.13	+20.32	+36.13	-99.36	-36.2	-
% of heterobeltiosis	-0.81	-13.84	-2.7	-16.84	-14.67	-3.7	-99.67	-55.23	-

Table 4.25. Studies on interspecific hybridization- data on Hybrid Plant No. Ra-12-5

Growth characters									
	Stem girth (mm)	No. of sec. per primary	Girth of primary branches (mm)	Length of primary branches (cm)	Inter nodal length (cm)	Bush spread (cm)	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm^2)
Hybrid	53.3	3.5	10.9	10.2	1.95	217	9.75	3.7	24.53
Female parent *C. racemosa* 1/3	85.92	9.5	28.28	174.28	2.02	352	4.65	1.95	6.17
Male parent S.274 1/1	96.62	6	61.83	170.5	5.81	344	27.3	10.85	192.53
Mid parent value	91.27	7.75	45.06	172.39	3.92	348	15.98	6.4	99.35
Better parent value	96.62	9.5	61.83	174.28	2.02	352	4.65	1.95	6.17
% of +ve heterosis	-41.6	-54.84	-75.81	-94.08	-50.26	-37.64	+38.99	+42.19	+75.31
%of heterobeltiosis	-44.84	-63.16	-82.37	-94.15	+3.47	-38.35	-109.68	-89.74	-297.57

Yield characters										
	Crop duration (days)	Fruits per node	Fruit length (mm)	Fruit breadth (mm)	Fruit thickness (mm)	Fruit volume (mm)	100 fruit wt. (fresh) (g)	100 pea berry wt. (fresh) (g)	100 fruit wt. (dried) (g)	100 pea berry wt. (dried) (g)
Hybrid	165	2	14.07	13.2	12.08	1166.64	130.67	87.5	24.84	20.75
Female parent *C. racemosa* 1/3	85	1.46	13.05	13.63	11.89	1099.74	127.9	66.9	22.5	15.1
Male parent S.274 1/1	315	23.69	14.57	13.89	11.54	1214.43	142.13	89.9	62	34.4
Mid parent value	200	12.58	13.81	13.76	11.72	1157.09	135.02	78.4	42.25	24.75
Better parent value	85	23.69	14.57	13.89	11.89	1214.43	142.13	89.9	62	34.4
% of +ve heterosis	+17.5	-84.1	+1.88	-4.07	+3.07	+0.83	-3.22	+11.61	-41.21	-16.16
% of heterobeltiosis	-94.12	-91.56	-3.43	-4.97	+1.6	-3.94	-8.06	-2.67	-59.94	-39.68

Yield characters contd..									
	Bean length (mm)	Bean breadth (mm)	Bean thick ness (mm)	Bean volume (mm^3)	100 bean wt. (g)	100 bean wt. (pea berry) (g)	Yield per plant (kg)	Out turn (%)	% of floats
Hybrid	6.29	5.38	3.99	82.36	11.18	9.33	0.05	19.01	33.33
Female parent *C. racemosa* 1/3	5.77	3.24	3.24	36.95	6.35	5.6	0.25	17.59	0
Male parent S.274 1/1	8.68	6.72	4.44	157.98	15.2	13.5	15.31	43.62	0
Mid parent value	7.23	4.98	3.84	97.22	10.78	9.55	7.78	30.61	0
Better parent value	8.68	6.72	4.44	157.98	15.2	13.5	15.31	43.62	0
% of +ve heterosis	-13	+8.03	+3.91	-15.28	+3.71	-2.3	-99.36	-37.9	-
% of heterobeltiosis	-27.53	-19.94	-10.14	-47.87	-26.45	-30.89	-99.67	-56.42	-

Table 4. 26. Studies on interspecific hybridization- data on Hybrid Plant No.Ra-13-1

Growth characters									
	Stem girth (mm)	No. of sec. per primary	Girth of primary branches (mm)	Length of primary branches (cm)	Internodal length (cm)	Bush spread (cm)	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm^2)
Hybrid	56.3	8.5	16.16	114.5	2.1	214	7.9	2.85	15.31
Female parent *C. racemosa* 3/1	75	8.5	12.52	264	2.45	307	5.05	2.6	8.93
Male parent S.274 10/10	112	7	58.5	177.5	6.03	391	24.85	8.85	142.95
Mid parent value	93.5	7.75	35.51	220.75	4.24	349	14.95	5.73	73.94
Better parent value	112	8.5	58.5	264	2.45	391	5.05	2.6	8.93
% of +ve heterosis	-39.79	9.68	-54.49	-48.13	+50.47	-38.68	+47.16	+50.26	+79.29
% of heterobeltiosis	-49.73	0	-72.38	-56.63	+14.29	-45.27	-56.44	-9.62	-71.44

Yield characters

	Crop duration (days)	Fruits per node	Fruit length (mm)	Fruit breadth (mm)	Fruit thickness (mm)	Fruit volume (mm^3)	100 fruit wt. (fresh) (g)	100 pea berry wt. (fresh) (g)	100 fruit wt. (dried) (g)	100 pea berry wt. (dried) (g)
Hybrid	170	2.57	13.77	12.92	11.68	1080.54	135.8	85.8	21.32	17.4
Female parent *C. racemosa* 3/1	90	1.16	13.63	12.76	11.29	1021.04	135.53	80.5	27.86	20
Male parent S.274 10/10	310	10.25	15.43	13.28	11.13	1208.75	137	87	51.2	27
Mid parent value	200	5.71	14.53	13.02	11.21	1114.89	136.27	83.75	39.53	23.64
Better parent value	90	10.25	15.43	13.28	11.29	1208.75	137	87	51.2	27
% of +ve heterosis	+15	-54.99	-5.23	-0.77	+4.19	-3.08	-0.34	+2.45	-46.07	-26.4
% of heterobeltiosis	-88.89	-74.93	-10.76	-2.71	+3.45	-10.61	-0.88	-1.38	-58.36	-35.56

Yield charcters contd..									
	Bean length (mm)	Bean breadth (mm)	Bean thickness (mm)	Bean volume (mm^3)	100 bean wt. (g)	100 seed wt. (pea berry) (g)	Yield per plant (g)	Out turn (%)	% of floats
Hybrid	6.42	5.55	3.31	71.94	9.56	7.8	0.15	15.67	20
Female parent *C. racemosa* 3/1	6.99	3.07	3.07	40.19	7.5	7	0.5	20.56	0
Male parent S.274 10/10	9.88	7.07	4.46	161.99	18.1	17	4	37.37	0
Mid parent value	8.44	5.07	3.77	101.09	12.8	12	2.25	28.97	0
Better parent value	9.88	7.07	4.46	161.99	18.1	17	4	37.37	0
% of +ve heterosis	-23.93	+9.47	-12.2	-28.84	-25.31	-35	-93.33	-45.91	-
% of heterobeltiosis	-35.02	-21.5	-25.78	-55.59	-47.18	-54.12	-96.25	-58.07	-

Table 4. 27. Studies on interspecific hybridization- data on Hybrid Plant No.Ra-14-1

Growth characters									
	Stem girth (mm)	No. of sec. per primary	Girth of primary branches (mm)	Length of primary branches (cm)	Internodal length (cm)	Bush spread (cm)	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm^2)
Hybrid	70.7	9	21.15	162	2.24	279	8.75	3.15	18.74
Female parent *C. racemosa* 4/3	62.1	10.5	19.55	134.5	2.07	270	5.05	1.6	5.49
Male parent S.274 1/4	115.4	4.5	82.4	178	6.42	364	26.5	11	189.48
Mid parent value	88.75	7.5	50.98	156.25	4.25	317	15.78	6.3	97.49
Better parent value	115.4	10.5	82.4	178	2.07	364	5.05	1.6	5.49
% of +ve heterosis	-20.34	20	-58.51	3.68	+47.29	-11.99	+44.55	+50	+80.78
% of heterobeltiosis	-38.73	-14.29	-74.33	-8.99	-8.21	-23.35	-73.27	-96.88	-241.35

Yield characters										
	Crop duration (days)	Fruits per node	Fruit length (mm)	Fruit breadth (mm)	Fruit thick ness (mm)	Fruit volume (mm)	100 fruit wt. (fresh) (g)	100 pea berry wt. (fresh) (g)	100 fruit wt. (dried) (g)	100 pea berry wt. (dried) (g)
Hybrid	165	1.6	13.16	11.84	10.82	876.67	94.1	57.9	23.88	19.3
Female parent *C. racemosa* 4/3	85	3.5	12.54	11.57	9.57	722.01	84.5	58	22	13
Male parent S.274 1/4	315	16.83	12.82	12.05	10.8	867.57	94.72	57.6	35.7	23.4
Mid parent value	200	10.17	12.68	11.81	10.19	794.79	89.61	57.8	28.85	18.2
Better parent value	85	16.83	12.82	12.05	10.8	867.57	94.82	58	35.7	23.4
% of +ve heterosis	-17.5	-84.27	+3.79	+0.25	+6.18	+10.3	+5.01	+0.17	-17.23	+6.04
% of heterobeltiosis	-94.12	-90.49	+2.65	-1.74	+0.19	+1.05	-0.76	-0.17	-33.11	-17.52

Yield characters contd..									
	Bean length (mm^3)	Bean breadth (mm)	Bean thickness (mm)	Bean volume (mm^3)	100 bean wt. (g)	100 bean wt.(pea berry) (g)	Yield per plant	Out turn %	% of floats
Hybrid	5.6	4.76	3.78	61.46	8.65	7	0.5	25.38	30
Female parent *C. racemosa* 1/3	6.24	3.48	3.48	46.1	6	5	0.05	26.04	0
Male parent S.274 1/4	7.11	6.65	4.21	121.42	9.8	9	7.43	37.69	0
Mid parent value	6.68	5.07	3.85	83.76	7.9	7	3.74	31.87	0
Better parent value	7.11	6.65	4.21	121.42	9.8	9	7.43	37.69	0
% of +ve heterosis	-16.17	-6.11	-1.82	-26.62	+9.49	0	-86.63	-20.36	-
% of heterobeltiosis	-21.24	-28.42	-10.21	-49.38	-11.73	-22.22	-93.27	-32.66	-

Table 4. 28. Studies on interspecific hybridization- data on Hybrid Plant No.Ra.15-1

Growth characters									
	Stem girth (mm)	No. of sec. per primary	Girth of primary branches (mm)	Length of primary branches (cm)	Internodal length (cm)	Bush spread (cm)	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm^2)
Hybrid	106.7	6.5	24.25	197.5	3.72	371	9.65	3.6	23.62
Female parent *C. racemosa* 1/3	85.92	9.5	28.28	174.28	2.02	352	4.65	1.95	6.17
Male parent S.274 1/4	115.4	4.5	82.4	178	6.42	364	26.5	11	189.48
Mid parent value	100.66	7	55.34	176.14	4.22	199.6	15.58	6.48	97.83
Better parent value	115.4	9.5	82.4	178	2.02	364	4.65	1.95	6.17
% of +ve heterosis	+6.00	-7.14	-56.18	+12.13	+11.85	+85.87	+38.06	+44.44	+75.86
% of heterobeltiosis	-7.54	-31.58	-70.57	+10.96	-84.16	+1.92	-107.53	-84.62	-282.82

Yield characters										
	Cop duration (days)	Fruits per node	Fruit length (g)	Fruit breadth (g)	Fruit thickness (mm)	Fruit volume (mm^3)	100 fruit wt. (fresh) (g)	100 pea berry wt. (fresh) (g)	100 fruit wt. (dried) (g)	100 pea berry wt. (dried) (g)
Hybrid	160	1.4	16.43	12.32	11.29	1188.35	144.85	100.55	25.64	21.7
Female parent *C. racemosa* 1/3	80	1.46	13.05	13.63	11.89	10.99.74	127.9	66.9	22.5	15.1
Male parent S.274 1/4	310	16.83	12.82	12.05	10.8	867.57	94.72	57.6	35.7	23.4
Mid parent value	195	9.15	12.94	12.84	11.35	983.66	111.31	62.25	29.1	19.25
Better parent value	80	16.83	13.05	13.63	11.89	1099.74	127.9	66.9	35.7	23.4
% of +ve heterosis	+17.95	-84.7	26.97	-4.05	-0.53	+20.81	+30.13	+61.53	-11.89	+12.73
% of heterobeltiosis	-100	-91.68	+25.9	-9.61	-5.05	+8.06	+13.25	+50.3	-28.18	-7.26

Yield characters contd..									
	Bean length (mm)	Bean breadth (mm)	Bean thickness (mm)	Bean volume (mm^3)	100 bean wt. (g)	100 bean wt. (pea berry) (g)	Yield per plant (kg)	Out turn (%)	% of floats
Hybrid	8.28	4.99	4.05	102.07	12.27	10.4	1.00	20.89	20
Female parent *C. racemosa* 1/3	5.77	3.24	3.24	36.95	6.35	5.6	0.25	17.59	0
Male parent S.274 1/4	7.11	6.65	4.21	121.42	9.8	9	7.43	37.69	0
Mid parent value	6.44	4.95	3.73	79.19	8.08	7.3	3.84	27.64	0
Better parent value	7.11	6.65	4.21	121.42	9.8	9	7.43	37.69	0
% of +ve heterosis	28.57	0.81	8.58	28.89	51.86	42.47	-73.96	-24.42	-
% of heterobeltiosis	16.46	-24.96	-3.8	-15.94	25.2	15.56	-86.54	-44.57	-

Table 4. 29. Studies on interspecific hybridization- data on Hybrid Plant No.Ra-15-2

Growth characters									
	Stem girth (mm)	No. of sec. per primary	Girth of primary branches (mm)	Length of primary branches (cm)	Internodal length (cm)	Bush spread (cm)	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm^2)
Hybrid	53.3	16	14.22	71.5	6.3	112	10.65	4.15	30.05
Female parent *C. racemosa* 1/3	85.92	9.5	28.28	174.28	2.02	352	4.65	1.95	6.17
Male parent S.274 1/4	115.4	4.5	82.4	178	6.42	364	26.5	11	189.48
Mid parent value	100.66	7	55.34	176.14	4.22	199.6	15.58	6.48	97.83
Better parent value	115.4	9.5	82.4	178	2.02	364	4.65	1.95	6.17
% of +ve heterosis	-47.05	128.57	-74.3	-59.41	-49.29	-43.89	+31.64	+35.96	+69.28
%of heterobeltiosis	-53.81	+68.42	-82.74	-59.83	-211.88	-69.23	-129.03	-112.82	-387.03

Yield characters										
	Crop duration (days)	Fruits per node	Fruit length (mm)	Fruit breadth (mm)	Fruit thick ness (mm)	Fruit volume (mm^3)	100 fruit wt. (fresh) (g)	100 pea berry wt. (fresh) (g)	100 fruit wt. (dried) (g)	100 pea berry wt. (dried) (g)
Hybrid	165	1	11.11	11	10.41	156.19	84.62	83.18	19.59	19.4
Female parent *C . racemosa* 1/3	85	1.46	13.05	13.63	11.89	1099.74	127.9	66.9	22.5	15.1
Male parent S.274 1/4	315	16.83	12.82	12.05	10.8	867.57	94.72	57.6	35.7	23.4
Mid parent value	200	9.15	12.94	12.84	11.35	983.66	111.31	62.25	29.1	19.25
Better parent value	85	16.83	13.05	13.63	11.89	1099.74	127.9	66.9	35.7	23.4
% of +ve heterosis	+17.5	-89.07	-14.14	-14.33	-8.28	-84.12	-23.98	+33.62	-32.68	+0.78
% of heterobeltiosis	-94.06	-94.06	-14.87	-19.3	-12.45	-85.8	-33.84	24.33	-45.13	-17.09

Yield characters contd..									
	Bean length	Bean breadth	Bean thickness	Bean volume	100 bean wt. (g)	100 bean wt. (pea berry) (g)	Yield per plant (kg)	Out turn (%)	% of floats
Hybrid	5.81	5.42	4.34	83.37	10	9.7	0.1	23.15	5
Female parent *C. racemosa* 1/3	5.77	3.24	3.24	36.95	6.35	5.6	0.25	17.59	0
Male parent S.274 1/4	7.11	6.65	4.21	121.42	9.8	9	7.43	37.69	0
Mid parent value	6.44	4.95	3.73	79.19	8.08	7.3	3.84	27.64	0
Better parent value	7.11	6.65	4.21	121.42	9.8	9	7.43	37.69	0
% of +ve heterosis	-9.78	+9.49	+16.35	+5.28	+23.76	+32.88	-97.4	-16.24	-
% of heterobeltiosis	-18.28	-18.5	3.09	-31.34	2.04	7.78	-98.65	-38.58	-

The above study shows that all of the hybrid plants are 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 (Tables 4.21- 4.31). Crop duration of *Coffea racemosa* was found to be 80-90 days from the day of flower opening, that of S.274 plants 310-320 days and that of the F1 plants160-170 days (Table 4.30). This tremendous 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.

Certain efforts have been made to develop early maturing coffee plants by earlier workers. An early maturing (180 days from flower to fruit) somaclonal population selected from arabica - racemosa hybrids have been developed by Sondahl *et al*. (1997). Interspecific hybrids between *Coffea racemosa* x (CxR) coffee with early maturing habit have been reported by Suresh kumar *et al*. (2004).

Further, low caffeine content is being considered an advantageous character of coffee. Arabica coffee has got caffeine content of about 1% and robusta has got caffeine content of about 2% (Anonymous, 1987). 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%) (Table 4.30). 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.

Interspecific hybridization has been proposed as a method to develop varieties with low caffeine content in robusta coffee. Narasimhaswamy and Vishveshwara (1961; 1967) have conducted hybridization experiments in coffee with the objective of obtaining materials with good quality.

Capot (1972) reported an arabusta material (*Coffea canephora* x *Coffea arabica*), which is both self-fertile and intercompatible with a caffeine content ranging from 1.5 to 2%. Rabemiafara *et al*. (1997) developed a family of three way hybrids of coffee, named Ratelo, through a *Coffea eugenioides* x *Coffea canephora* cross and chromosome doubling and subsequent crosses with *Coffea arabica* followed by selfing and intercrossing. The hybrids were smaller trees of reduced height, compact habit, partial autogamy and heavy flowering. The hybrid was expected to combine the adaptability of *Coffea canephora*, low caffeine content of *Coffea eugenioides* and flavour characteristics of *Coffea arabica*. Mazzafera and Carvalho (1991) have reported hybrids between *Coffea eugenioides* and *Coffea salvatrix* with very low caffeine content. Seeds of tetraploid hybrids of *Coffea arabica* x *Coffea salvatrix* and *Coffea arabica* x *Coffea eugenioides* also showed lower caffeine content. Texeira and Fazuoli (1975) developed *Coffea canephora* x *Coffea eugenioides* hybrids with intermediate caffeine content. Sreenath *et al.* (1992) have also attempted crosses between *Coffea canephora* and wild coffee species to combine the agronomic properties of *Coffea canephora* with some useful characters of the wild species especially the low caffeine content.

Both female and male parents (*Coffea racemosa* and S.274 respectively) and F1 progeny were visually screened for leaf rust resistance in the present experiment. S.274 showed 30% of plants with leaf rust incidence. *Coffea racemosa* showed no incidence of coffee rust and F1 plants showed 9% of leaf rust incidence. These results positively indicate the advantage of F1 plants over the robusta parents in the case of leaf rust resistance. It shows that the hybrids produced presently can be used for subsequent crosses and selection so that genotypes with robusta characters incorporating the features of *Coffea racemosa* like shorter maturing period, low caffeine content and high resistance to leaf rust are developed.

Interspecific hybridization of coffee has resulted in plants with general inferiority but with certain superior traits in certain earlier works also (Capot, 1972; Texeira and Fazuoli, 1975; Rabemiafara *et al*., 1977; Mazzafera and Carvalho, 1991; Sreenath *et al*., 1992; Sondahl *et al*., 1997; Suresh kumar *et al*., 2004). Some of them have developed superior hybrids from them through different techniques like back crosses, sib mating and selection (Capot, 1972; Texeira and Fazuoli, 1975; Rabemiafara *et al*., 1977; Mazzafera and Carvalho, 1991).

Table 4.30. Studies on interspecific hybridization- Data on crop duration, caffeine content and incidence of leaf rust

Genotypes	Crop duration (days)	Caffeine content (%)	Leaf rust (% of incidence)
S.274	310-320	1.76	30
Coffea racemosa	80-90	0.38	0
F1	160-170	1.47	9

Table 4.31. Studies on interspecific hybridization- hybrid behaviour in relation to characters studied

Sl. No.	Character	Hybrid behaviour
1	Stem girth	Shows reduction from S.274 in all the hybrids studied.
2	Girth of primary branches	Shows reduction from S.274 in all the hybrids studied.
3	Number of secondaries per primary	Shows positive heterosis in the hybrids Ra.12-3; Ra.12-4; Ra. 13-1; Ra.14-1; Ra.15-2.
4	Internodal length	Shows positive heterobeltiosis Ra.12-1; Ra.12-2; Ra.12-3; Ra.12-4; Ra.14-1; Ra.15-1; Ra.15-2.
5	Bush spread	Shows positive heterosis and heterobeltiosis in Ra-12.4 and Ra.15-1.
6	Length of primary branches	Shows positive heterosis in Ra.12-4; Ra.14-1; Ra.15-1.
7	Leaf area	Shows positive heterobeltiosis in Ra.12-1; Ra.12-2; Ra.12-3; Ra.12-4; Ra.12-5; Ra13-1; Ra.14-1; Ra.15-1; Ra.15-2.
8	Fruits per node	Shows reduction from S.274 in all the hybrids studied.
9	Yield per plant	Shows reduction from S.274 in all the hybrids studied.
10	Fruit volume	Shows positive heterosis and heterobeltiosis in Ra.12-4, Ra.14-1 and Ra.15-1; positive heterosis in Ra.12-5.
11	Bean volume	Shows positive heterosis in Ra.12-4; Ra.15-1and Ra 15.2.
12	100 fruit weight (fresh)	Shows positive heterosis and heterobeltiosis in Ra.12-4 and Ra.15-1 and positive heterosis in Ra.14-1
13	100 pea berry weight (fresh)	Shows positive heterosis and heterobeltiosis in Ra. 12-4; Ra.15-1 and Ra.15-2 and positive heterosis in Ra.12-3; Ra.12-5; Ra.13-12; Ra.14-1
14	100 fruit weight (dried)	Shows reduction from S.274 in all the hybrids studied.

15	100 pea berry weight (dried)	Shows positive heterosis in Ra.12-4; Ra.14-1; Ra.15-1 and Ra.15-2.
16	100 bean weight	Shows positive heterosis and heterobeltiosis in Ra.15-1 and Ra.15-2 and positive heterosis in Ra.12-2; Ra. 12-4; Ra.12-5 and Ra.14-1
17	100 seed weight (pea berry)	Positive heterosis and heterobeltiosis in Ra.15-1 and Ra.15-2 and posiive heterosis in Ra.12-2 and Ra.12-4.
18	Out turn (fresh to dry)	Shows reduction from S.274 in all the hybrids studied.
19	Percentage of floats	Hybrid plants show presence of floats whereas it is absent in the case of *Coffea racemosa* and S.274.
20	Caffeine content	Intermediate in the hybrid plants.
21	Seed density	Intermediate in the hybrid plants.
22	Incidence of leaf rust	Incidence of leaf rust is nil in *Coffea racemosa* and intermediate in the hybrids.
23	Crop duration	Crop duration is intermediate in the hybids.

4.10. Adaptability of robusta coffee to different coffee growing regions of South India

Robusta coffee is widely cultivated in Wayanad and to some extent in Coorg, which are two different traditional coffee growing areas of South India. Wayanad is situated between 700 m to 2100 m above msl between north latitude 11^0 27’ and 15^0 58’ and east longitude 75^0 47’ to 70^0 27’ with an average rainfall of 2500-3000 mm, mean minimum temperature range of 14.5^0C - 20.2^0C and mean maximum temperature range of 25.1^0C – 30.6^0C.

Coorg lies between 750-1100 m above msl at 12^0 25' north latitude and 75^0 45' east longitude with an annual rainfall of 1000-2500 mm and a mean minimum temperature of 15^0C and mean maximum temperature of 28^0C.

The soil pH of Wayanad ranges between 4.1 and 6.8 and that of Coorg ranges from 5.5 to 6; Organic Carbon content was found to vary from 0.76% to 2.45% in Wayanad and 0.25 to 2.5% in Coorg. Available Phosphorous was found to vary between 4 kg and 47 kg/ha in Wayanad and 9 kg to 60 kg/ha in Coorg. Available Potassium varied between 75 to 425 kg/ha in Wayanad and 115-260 kg/ ha in Coorg. The soils were generally acidic to normal in both the areas. Organic Carbon percentage was low to medium in both the places, available Phosphorous was low to high in Wayanad and medium to high in Coorg and available Potassium was low to high in both the areas (Table 3.3). The conditions are generally ideal for robusta coffee growing and the major factor that varied was quantity and distribution of rain.

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. Six estates each adapting uniform package of practices recommended by Coffee Board, India and with uniformly mature plants were selected for the study in both the areas.

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 (Table 4.32).

Stem girth, number of primary branches, girth of primary branches, internodal length, leaf breadth, leaf area, fruits per node, fruit length, fruit breadth, fruit volume, weight of 100 fresh fruits, weight of 100 dry fruits, bean length, bean breadth, bean thickness, bean volume and weight of 100 beans showed higher variation in the estates of Coorg and number of secondaries per primary, length of primary branches, bush spread, leaf length, fruit thickness and out turn showed higher variability in the estates of Wayanad. Mean stem girth, mean number of secondaries per primary, mean girth of primary branches, mean length of primary branches, mean internodal length, mean leaf breadth, mean number of fruits per node and mean bean breadth were higher in Wayanad whereas mean number of primary branches, mean leaf length, mean leaf area, mean fruit length, mean fruit breadth, mean fruit thickness, mean fruit volume, mean weight of 100 fresh fruits, mean weight of 100 dry fruits, mean bean length, mean bean thickness, mean bean volume, mean weight of 100 beans and mean yield per plant were higher in Coorg. However, variations in the case of the agronomical characters due to difference in the growing area were not statistically significant. Mean yield per plant was 5.75kg in Wayanad and 6.70kg in Coorg. This variation was also not statistically significant. The variability of yield was almost same in both the areas. The above observations show that robusta coffee is well adapted to both the growing regions under study namely Wayanad and Coorg.

Certain efforts have been made by earlier workers to study the performance of different coffee cultivars at different coffee growing areas. Srinivasan (1984) studied performance of arabica varieties at different locations in Coorg. Varieties showed significant differences between them but not the locations. Srinivasan (1985b) has also reported differential adaptability at varietal level in the case of arabica coffee varieties from Coorg. Ahmed *et al*. (1995) studied the performance of five arabica coffee selections in different agro climatic zones of Karnataka and Tamil Nadu. Varied performance of different cultivars in various zones was observed. Ratageri (2000) studied the performance of C x R coffee at Koppa liaison division of Karnataka and found that C x R established well with good performance and higher yield in the area.

Table 4.32. Study of adaptability of S.274 coffee under Wayanad and Coorg conditions- data on morphological characters

Wayanad | **Coorg**

1. Stem girth (cm)

Wayanad:

Estates	Mean	Range
1	103.00	93.10 -- 114.10
2	122.80	113.30 -- 133.60
3	104.57	73.30 -- 120.10
4	103.38	90.80 -- 119.90
5	109.74	96.62 -- 124.64
6	89.62	73.00 – 101.00
Mean	105.52	
Range	73.00-133.60	
SD	10.78	
CV	10.22	

Coorg:

Estates	Mean	Range
1	116.77	102.10 -- 130.60
2	96.87	78.00 -- 109.50
3	113.97	93.00 – 134.00
4	99.47	83.70 – 115.00
5	111.17	89.60 -- 126.94
6	82.54	68.23 -- 98.10
Mean	103.47	
Range	68.23-134.00	
SD	12.99	
CV	12.55	

2.Number of primary branches

Wayanad:

Estates	Mean	Range
1	2.00	1 -- 4
2	1.67	1 -- 3
3	2.00	1 -- 3
4	2.33	2 -- 3
5	2.33	1 -- 3
6	2.17	1 -- 4
Mean	2.08	
Range	1.00-4.00	
SD	0.25	
CV	12.02	

Coorg:

Estates	Mean	Range
1	2.17	1 -- 3
2	2.50	2 -- 3
3	2.67	2 -- 4
4	2.00	1 -- 3
5	3.17	2 -- 5
6	2.17	2 -- 3
Mean	2.45	
Range	1.00-5.00	
SD	0.43	
CV	17.55	

3. Number of secondaries per primary

Estates	Mean	Range
1	6.50	5 -- 7
2	5.00	4 -- 6
3	5.33	4 -- 7
4	5.83	4 -- 7
5	5.75	4.5 -- 7
6	6.83	5 -- 9
Mean	5.87	
Range	4.00-9.00	
SD	0.69	
CV	11.75	

Estates	Mean	Range
1	6.25	3.5 -- 8.5
2	5.58	4.5 -- 7
3	5.67	4 -- 7
4	5.50	5 -- 7
5	5.67	5 -- 6
6	5.17	4 -- 7
Mean	5.64	
Range	3.50-8.50	
SD	0.35	
CV	6.21	

4. Girth of primary branches (mm)

Estates	Mean	Range
1	67.86	55.70 -- 90
2	68.50	53.70 -- 101.8
3	81.11	50.56 -- 111.9
4	79.19	68.80 -- 90.9
5	68.75	42.00 -- 93.20
6	64.07	24.30 -- 80.22
Mean	71.58	
Range	24.30-111.90	
SD	6.88	
CV	9.61	

Estates	Mean	Range
1	78.16	62.86 -- 123.32
2	59.98	36.7 -- 103.45
3	69.73	37.4 -- 106.75
4	64.29	43.60 – 87.00
5	61.43	43.20 -- 80.70
6	52.75	31.50 -- 87.60
Mean	64.39	
Range	31.50-123.32	
SD	8.74	
CV	13.57	

5. Length of primary branches (cm)

Estates	Mean	Range
1	218.17	175 -- 276
2	146.83	132 -- 160
3	204.00	130 -- 270
4	218.17	183 -- 290
5	201.08	126.5 -- 281.5
6	211.17	128 -- 285
Mean	199.90	
Range	126.50-290.00	
SD	26.94	
CV	13.48	

Estates	Mean	Range
1	241.33	162 -- 312
2	185.67	124 -- 275
3	185.5	122 -- 294
4	185.67	129 -- 227
5	172.17	136 -- 220
6	177.67	147 -- 234
Mean	191.34	
Range	122.00-312.00	
SD	25.11	
CV	13.12	

6. Internodal length (cm)

Estates	Mean	Range
1	6.01	5.00 -- 6.75
2	6.59	5.25 – 8.00
3	8.24	6.71 – 11.00
4	7.47	6.4 0– 9.00
5	6.59	5.49 -- 8.14
6	6.91	5.33 -- 8.33
Mean	6.97	
Range	5.00-11.00	
SD	0.78	
CV	11.19	

Estates	Mean	Range
1	6.49	4.54 -- 7.69
2	5.59	4.30 -- 6.88
3	5.65	5.17 --6.00
4	8.47	7.00 -- 9.20
5	5.78	3.75 -- 8.75
6	6.47	5.33 -- 7.86
Mean	6.41	
Range	3.75-9.20	
SD	1.09	
CV	17.00	

7. Bush spread (cm)

Estates	Mean	Range
1	359	308 -- 415
2	225.17	183 -- 265
3	293.83	230 -- 370
4	323.33	236 -- 423
5	388	249 -- 500
6	316.67	223 -- 399
Mean	317.67	
Range	183.00-500.00	
SD	56.24	
CV	17.70	

Estates	Mean	Range
1	392.17	281 -- 464
2	301.83	217 -- 388
3	370.17	237 -- 475
4	278.83	204 -- 352
5	288.5	228 -- 328
6	276.33	208 -- 407
Mean	317.97	
Range	204.00-475.00	
SD	50.25	
CV	15.80	

8. Leaf length (cm)

Estates	Mean	Range
1	18.67	17.00—21.00
2	20.5	18.00 – 24.00
3	21.83	21.00 – 24.00
4	21.17	18.00 – 23.00
5	24.38	21.25 -- 27.30
6	22.50	20.00 – 26.00
Mean	21.51	
Range	17.00-27.30	
SD	1.92	
CV	8.93	

Estates	Mean	Range
1	23.29	20.00 -- 27.25
2	22.38	17.75 – 25.00
3	19.63	17.75 – 21.00
4	24.67	23.00 – 28.00
5	21.92	19.00 – 23.00
6	23.17	21.00 – 29.00
Mean	22.51	
Range	17.75-29.00	
SD	1.70	
CV	7.55	

9. Leaf breadth (cm)

Estates	Mean	Range
1	8.17	6.00 – 10.00
2	10.00	8.00 – 13.00
3	9.92	8.00 – 12.00
4	9.08	8.00 -- 10.50
5	9.91	8.85 – 11.00
6	11.33	9.00 -- 13.50
Mean	9.74	
Range	6.00-13.50	
SD	1.05	
CV	10.78	

Estates	Mean	Range
1	8.75	4.25 – 11.00
2	10.52	7.75 -- 13.25
3	8.96	5.00 -- 12.50
4	10.83	9.50 -- 12.50
5	7.63	5.00 -- 9.50
6	10.00	6.50 -- 14.50
Mean	9.45	
Range	4.25-14.50	
SD	1.22	
CV	12.91	

10. Leaf area $(cm)^2$

Estates	Mean	Range
1	96.23	64.26 -- 113.40
2	130.94	90.72 -- 196.56
3	136.87	105.84 -- 173.88
4	121.8	96.39 -- 152.15
5	152.87	125.17 -- 186.61
6	162.12	113.4 -- 221.13
Mean	133.47	
Range	64.26-221.13	
SD	23.40	
CV	17.53	

Estates	Mean	Range
1	130.16	58.24 -- 188.84
2	150.93	86.66 -- 204.51
3	112.51	55.91 -- 165.38
4	168.53	137.66 -- 196.88
5	105.09	72.45 -- 131.67
6	147.79	85.99 -- 219.24
Mean	135.84	
Range	58.24-219.25	
SD	24.34	
CV	17.92	

11. Fruits per node

Estates	Mean	Range
1	21.45	17.00 -- 36.67
2	13.20	8.00 – 25.00
3	14.71	10.00 – 20.00
4	17.72	11.00 – 24.00
5	18.45	10.53 -- 23.69
6	18.56	16.00 -- 23.33
Mean	17.35	
Range	8.00-36.67	
SD	2.96	
CV	17.06	

Estates	Mean	Range
1	21.05	14.62 -- 32.33
2	12.28	8.40 -- 16.22
3	23.35	13.75 – 30.00
4	21.18	12.83 -- 32.5
5	12.46	5.80 – 17.00
6	10.63	3.80 – 17.00
Mean	16.83	
Range	3.80-32.50	
SD	5.61	
CV	33.33	

12. Fruit length (mm)

Estates	Mean	Range
1	15.12	13.08 -- 16.64
2	13.77	12.85 -- 14.62
3	15.61	14.45 -- 16.72
4	14.34	13.2 -- 15.69
5	14.20	12.64 -- 15.43
6	14.47	11.85 -- 15.88
Mean	14.59	
Range	11.85-16.72	
SD	0.67	
CV	4.59	

Estates	Mean	Range
1	14.12	13.31 -- 15.06
2	15.28	13.80 -- 18.22
3	15.45	13.84 -- 17.92
4	15.95	14.21 -- 17.66
5	14.49	13.03 -- 15.98
6	14.21	13.29 -- 15.4
Mean	14.92	
Range	13.03-18.22	
SD	0.75	
CV	5.03	

13. Fruit breadth (mm)

Estates	Mean	Range
1	13.28	11.98 -- 14.01
2	13.23	12.93 -- 13.52
3	14.06	13.57 -- 14.70
4	13.99	13.19 -- 14.68
5	12.72	11.60 -- 13.89
6	13.46	12.27 -- 14.46
Mean	13.46	
Range	11.60-14.70	
SD	0.50	
CV	3.71	

Estates	Mean	Range
1	12.89	12.51 -- 13.83
2	13.42	12.39 -- 14.21
3	13.48	12.62 -- 14.71
4	14.11	12.30 -- 15.19
5	13.06	11.97 -- 13.76
6	14.44	12.33 -- 15.92
Mean	13.57	
Range	11.97-15.92	
SD	0.60	
CV	4.42	

14. Fruit thickness (mm)

Estates	Mean	Range
1	11.50	10.72 -- 12.04
2	11.34	10.69 -- 11.92
3	11.99	10.93 -- 12.42
4	12.02	11.11 -- 12.90
5	10.90	10.00 -- 11.54
6	11.34	10.44 -- 12.10
Mean	11.52	
Range	10.00-12.90	
SD	0.43	
CV	3.73	

Estates	Mean	Range
1	11.37	10.95 -- 12.37
2	11.76	11.16 -- 12.97
3	11.55	10.67 -- 13.16
4	12.12	10.51 -- 13.38
5	10.87	9.92 -- 11.52
6	11.72	10.45 -- 12.78
Mean	1.57	
Range	9.92-13.38	
SD	0.43	
CV	3.72	

15. Fruit volume (mm^3)

Estates	Mean	Range
1	1209.78	888.17 -- 418.37
2	1070.72	929.65-- 1164.08
3	1371.8	1114.48 -- 1518.89
4	1261.09	1005.86 -- 1543.99
5	1031.71	762.44 -- 1214.43
6	1176.82	789.34 -- 1472.58
Mean	1186.99	
Range	762.44-1543.99	
SD	124.82	
CV	10.52	

Estates	Mean	Range
1	1076.42	960.22-- 1216.08
2	1256.85	992.24 --1560.68
3	1271.03	972.93--1803.89
4	1434.31	955.22-- 1761.78
5	1076.43	804.55 --1230.21
6	1194.08	822.97-- 1506.56
Mean	1218.19	
Range	804.55-1803.89	
SD	135.88	
CV	11.15	

16. Weight of hundred fresh fruits (g)

Estates	Mean	Range
1	144.14	107.6 -- 167.6
2	132.05	114.4 -- 144.8
3	157.10	128.6 -- 169.2
4	156.17	131.6 -- 191.9
5	122.70	89.3 -- 148.9
6	135.97	92.6 -- 172.5
Mean	141.36	
Range	89.30-191.90	
SD	13.70	
CV	9.69	

Estates	Mean	Range
1	122.39	103.1 -- 143.8
2	145.68	108.7 -- 183.2
3	149.61	106.6 -- 208.0
4	159.23	107.9 -- 209.3
5	126.83	97.6 -- 146.2
6	146.95	116.7 -- 165.8
Mean	141.78	
Range	97.60-209.30	
SD	14.19	
CV	10.01	

17. Weight of hundred dry fruits (g)

Estates	Mean	Range
1	60.55	46.5 -- 68.6
2	61.15	49.9 -- 72.5
3	65.95	50.8 -- 70.8
4	64.47	49.7 -- 78.6
5	51.23	35.7 – 62.0
6	57.32	39.1 -- 69.3
Mean	60.11	
Range	35.70-78.60	
SD	5.31	
CV	8.83	

Estates	Mean	Range
1	42.84	36.4 -- 50.9
2	60.93	40.2 -- 74.8
3	66.40	49.1 -- 91.3
4	64.83	36.3 -- 90.4
5	64.91	38.4 – 130.0
6	64.71	55.3 – 72.0
Mean	60.77	
Range	36.30-130.00	
SD	8.97	
CV	14.76	

18. Bean length (mm)

Estates	Mean	Range
1	8.86	8.03 -- 9.76
2	8.2	7.6 -- 9.27
3	8.81	8.32 -- 9.17
4	8.3	7.48 -- 9.06
5	8.63	7.11 -- 9.88
6	8.53	6.78 -- 9.71
Mean	8.56	
Range	6.78-9.88	
SD	0.27	
CV	3.15	

Estates	Mean	Range
1	8.3	7.15 -- 9.21
2	9.62	8.27 -- 12.19
3	9.19	8.41 -- 10.54
4	9.19	7.94 -- 10.18
5	8.92	8.05 -- 9.63
6	8.49	7.94 -- 9.62
Mean	8.95	
Range	7.15-12.19	
SD	0.49	
CV	5.47	

19. Bean breadth (mm)

Estates	Mean	Range
1	6.91	6.68 -- 7.09
2	7.08	6.34 -- 7.77
3	7.05	6.50 -- 7.51
4	6.80	6.55 -- 7.34
5	6.59	6.00 -- 7.07
6	6.92	5.95 -- 7.54
Mean	6.89	
Range	5.95-7.77	
SD	0.18	
CV	2.61	

Estates	Mean	Range
1	6.68	6.27 -- 6.96
2	7.07	6.54 -- 8.20
3	6.85	6.14 -- 8.30
4	7.2	6.18 -- 7.85
5	6.62	6.30 -- 6.76
6	6.79	6.04 -- 7.12
Mean	6.87	
Range	6.04-8.30	
SD	0.23	
CV	3.35	

20. Bean thickness (mm)

Estates	Mean	Range
1	4.48	4.27 -- 4.74
2	4.54	4.38 -- 4.69
3	4.70	4.44 -- 4.90
4	4.42	4.15 -- 4.94
5	4.26	3.94 -- 4.46
6	4.56	3.80 -- 5.19
Mean	4.49	
Range	3.80-5.19	
SD	0.15	
CV	3.34	

Estates	Mean	Range
1	4.32	4.24 -- 4.42
2	4.56	4.12 -- 5.01
3	4.34	3.74 -- 5.30
4	4.82	4.36 -- 5.06
5	4.49	4.25 -- 4.69
6	4.79	4.22 -- 5.03
Mean	4.55	
Range	3.74-5.30	
SD	0.22	
CV	4.84	

21. Bean volume (mm^3)

Estates	Mean	Range
1	167.46	140.76 - 186.96
2	161.48	133.44 - 201.23
3	178.73	150.43 - 205.39
4	152.97	127.25 - 190.44
5	149.54	108.40 - 190.04
6	168.42	93.51 - 231.79
Mean	163.1	
Range	93.51-231.79	
SD	10.78	
CV	6.61	

Estates	Mean	Range
1	145.84	122.53 - 157.21
2	190.35	144.15 - 240.23
3	171.77	117.81 - 282.83
4	196.74	130.50 - 242.89
5	162.21	131.48 - 179.47
6	169.79	124.07 - 208.91
Mean	172.78	
Range	117.81-282.83	
SD	18.60	
CV	10.80	

22. Weight of hundred beans (g)

Estates	Mean	Range
1	16.80	13.9 -- 19.7
2	17.97	14.8 -- 21.4
3	18.58	16.3 -- 20.6
4	16.97	14.5 -- 21.9
5	14.97	9.8 -- 18.9
6	17.67	10.4 -- 22.5
Mean	17.16	
Range	9.80-22.50	
SD	1.26	
CV	7.34	

Estates	Mean	Range
1	13.91	11.8 -- 14.8
2	18.99	13.4 -- 23.1
3	18.30	11.0 -- 28.5
4	20.17	15.4 -- 25.5
5	15.17	12.1 – 18.0
6	17.32	13.3 -- 19.1
Mean	17.31	
Range	11.00-28.50	
SD	2.37	
CV	13.69	

23. Yield per plant (kg)

Estates	Mean	Range
1	17.17	12.00 – 25.00
2	8.58	3.00 – 15.00
3	9.08	2.00 – 25.00
4	10.33	5.00 – 20.00
5	8.16	3.50 -- 15.33
6	9.00	3.00 – 20.00
Mean	5.75	
Range	2.00-25.00	
SD	0.54	
CV	9.39	

Estates	Mean	Range
1	20.17	10.00 – 28.00
2	7.33	2.00 – 18.00
3	17.17	10.00 –25.00
4	7.92	0.50 – 15.00
5	6.67	5.00 – 8.00
6	4.75	2.50 – 7.00
Mean	6.70	
Range	0.50-28.00	
SD	0.63	
CV	9.40	

24. Out turn (fresh to dry) (%)

Estates	Mean	Range
1	23.45	21.76 -- 25.84
2	27.21	24.89 -- 29.56
3	23.77	20.49 -- 26.91
4	21.73	19.52 -- 24.86
5	24.33	19.31 -- 28.82
6	25.7	22.46 -- 27.89
Mean	24.37	
Range	19.31-29.56	
SD	1.90	
CV	7.80	

Estates	Mean	Range
1	22.92	20.42 -- 28.13
2	26.01	24.7 -- 28.72
3	24.1	20.65 -- 27.42
4	25.5	21.43 -- 28.54
5	24.08	20.94 -- 27.96
6	23.57	21.47 -- 25.85
Mean	24.36	
Range	20.42-28.72	
SD	1.17	
CV	4.80	

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, out turn, number of primary branches and fruits per node showed inter relationship 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.

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