STUDIES ON GENOTYPE X ENVIRONMENT INTERACTION AND INTERRELATIONSHIPS AMONG GROWTH, YIELD AND QUALITY COMPONENTS OF ROBUSTA COFFEE (*Coffea canephora* Pierre ex Froehner) CLONES IN KAGERA REGION

BY

ELIAWONI FESTO THOMAS MARANDU

DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURE OF SOKOINE UNIVERSITY OF AGRICULTURE, MOROGORO, TANZANIA

2002

ABSTRACT

In March 1998, on-farm robusta coffee trials were established in farmers' fields and three farmers in each villages of Chanika, Bisheshe, Kabirizi A and Kabirizi B were selected in Kagera region, Tanzania. The aim of the study was to evaluate the response, stability and to determine the association between variables of selected robusta clones in order to give recommendations specific for the different agro-ecological zones in Kagera region. Each farmer planted 8 genotypes and for each genotype, five trees were planted making a total of 40 trees per farmer/replicate. Planting was done at a spacing of 3m x 2m in a randomised complete block design with three replicates in each location. Data collection was carried out on already established robusta coffee plants. Collected data were subjected to ANOVA, covariance, correlations, stability and path coefficient analyses. From the ANOVA across four locations; plant height, plant girth, canopy radius, number of primary branches, percentage bearing primary branches, yield of clean coffee and coffee leaf rust indicated significant location variations. Percentage bearing primary branches and coffee leaf rust indicated significant genotype x location interactions. Two years yield depicted significant variations for location x year interactions and location differences. Kabirizi A and Kabirizi B showed better performance on yield and its components as compared to Bisheshe and Chanika. Two locations ANOVA viz: Kabirizi A and Kabirizi B indicated significant location variations for CBB while percentage screen 16, 14 and 13 indicated genotypic variations.

MS1/95, MS2/95 and MS3/95 had higher percentage screen 16 an indication of large bean size. Results from correlation and path coefficient analyses revealed that plant height and number of berries per node are important variables which directly influence yield with high positive correlations with yield. For quality variables, percentage screen 16 and percentage screen 14 are important variables which directly influence yield. Plant girth, canopy radius and number of primary branches interacted positively with plant height in their contribution to yield. Clean coffee in 1kg cherries and 100 seed weight also interacted positively with percentage screen 16 in their contribution to yield. Results from expected genetic advance and heritability across the four locations revealed that plant girth, number of berries per node and fruit set percentage had high heritability estimates and good expected genetic advance hence selection for these variables may start from the early generations of robusta coffee improvement programme. Stability analyses used revealed that, MS5/95 was stable for plant height, number of flowers per node and fruit set percentage while FS was stable for plant height with desired stature. MS6/95 was stable for percentage bearing primary branches. For yield, MS1/95, MS2/95, MS3/95 and MS5/95 if intercrossed have potential to give segregants with stable and high yield. Therefore, the stable genotypes for particular traits should be used as source of stability genes for breeding work in robusta coffee.

DECLARATION

I, ELIAWONI FESTO THOMAS MARANDU, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and has not been submitted for a higher degree award in any other University.

Signature .....

Date 11/7/2002

COPYRIGHT

ACKNOWLEDGEMENT

I am greatly indebted to the Client Oriented Research Lake Zone (COR), a project financed by the Netherlands Government and the Government of Tanzania for financing my study. Special thanks go to Dr. Joel Kabissa who deeply accepted my request to go for further studies and other members of Lake Zone Agricultural Research Institutes (Maruku and Ukiriguru) who in one way or another convinced the COR-Lake Zone Project to finance my M.Sc. study.

I am sincerely indebted to my supervisor Prof. Reuben, S.O.W.M. for his tireless assistance, guidance, encouragement and constructive criticism extended to me up to the end of this research work.

My deep and heartiest thanks and appreciation are due to my wife Elina Machange, for her patience, encouragement and to the great task of taking care of our family during my study, without forgetting my lovely sons Isaack, Goodluck and Godbless for their patience and encouragement they extended to me during my study.

Also, I would like to extend my sincere thanks to extension workers Mr. A. Kagissa, Mr. C. Byesisira and Mr Mujwauzi of Kabirizi, Bisheshe and Chanika villages respectively for their commitment in trial supervision and sometimes data collection. My sincere

thanks go to all farmers who are conducting the trial plots. Also without forgetting BEKA Transworld PVT Ltd a coffee liquoring company based in Moshi, Kilimanjaro, for conducting liquoring test to the coffee samples.

I am grateful to my fellow workers at ARDI-Maruku, who in one way or another had made my family stay comfortably during my absence.

Lastly, I am grateful to my colleagues and all members of staff of the department of Crop Science and Production of Sokoine University of Agriculture who in one way or another contributed towards the completion of my study.

DEDICATION

This dissertation is dedicated to my parents, Festo Thomas Marandu and Elifuraha Ainea Mosha, who endeavoured to send me to school.

LIST OF TABLES

Table

LIST OF FIGURES

Figure

LIST OF APPENDICES

Appendix

LIST OF ACRONYMS

ANOVA	Analysis of variance
COR	Client Oriented Research
C/N	Carbon Nitrogen ratio
CBB	Coffee Berry Borer
CBM	Coffee Berry Moth
CEC	Cation Exchange Capacity
CLR	Coffee Leaf Rust
EGA	Expected Genetic Advance
g	gram
GDP	Gross Domestic Product
GxE	Genotype by Environment interaction
h^2	heritability
kg.	Kilogram
Kg/ha.	Kilogram per hectare
m.a.s.l.	metres above sea level
MARI	Maruku Agricultural Research Institute
MSTAT-C	Michigan State University Computer Software
°C	Degrees Centigrade
P	Phosphorus
P≤	Statistical significance
pH	Hydrogen ion concentration
pp	page
ppm	parts per million
Pr. Br.	Primary Branches
RCBD	Randomised Complete Block Design
T.N.	Total Nitrogen
TCB	Tanzania Coffee Board

CHAPTER ONE

1.0. INTRODUCTION

1.1 Background information

Robusta coffee (*Coffea canephora* Pierre ex Froehner) originates from the equatorial forest of West Africa including the Democratic Republic of Congo, Sudan, Uganda, Angola and north-western Tanzania (Wrigley,1988). In farmers' fields, the robusta trees are found in a diversity of forms, that is, every tree has its own genotypic and phenotypic characters. The latter is due to the fact that robusta coffee is an out-crossing plant. Traditionally, the best robusta coffee for chewing used by the residents of Kagera Region was selected from the wild. It was not grown from seed, but rather farmers used vegetative materials. To propagate the plants for production, large woodcuttings, a metre or more long, were used and planted in an inter-cropping system with bananas near the homestead (Speke,1863). Farmers used to train the plants to obtain large and spreading trees. Sometimes the cuttings were bent and both ends inserted into the ground whereby both ends would root and give shoots (Thomas, 1940). By using vegetative propagation methods, the robusta coffee growers maintained the clonal materials they had selected from the wild, thus maintaining the good quality flavour for chewing, but also maintaining a certain level of genetic diversity. However, when robusta coffee was promoted to be planted in large scale in Kagera region, the only means farmers used in

the initial development of the crop to rapidly multiply coffee was through use of seed. The coffee growers, having adopted the seed multiplication method, continued to select seeds from good trees, which they thought would raise good seedlings resembling their mother trees, the practice which did not meet their expectations due to genetic segregation. Therefore, robusta coffee farmers in Kagera region are currently facing the problem of obtaining good robusta coffee planting materials. This among other factors, contributes to declining quality and production of robusta coffee in the region despite increased acreage (Nyange and Marandu ,1997).

After the inception of the Maruku Research Institute in Kagera region in 1948, a selection programme of robusta coffee was initiated in 1957 by collecting robusta accessions from the region. More robusta materials were introduced from Kawanda Research Station in Uganda and the rest of the world. The programme initially aimed at producing good robusta coffee planting materials through use of vegetative materials (clones), in the beginning continued well but later stagnated. Coffee farmers in Kagera region continued to grow robusta coffee seedlings which had low yield genetic potential due to segregation. Also, some of the trees are very old more than a hundred years warranting them to have low yield and therefore a need to replace them with a high yielding and disease and insect pest resistant varieties (Annon.,1994). It is until recently that five clones namely MS1/95, MS2/95, MS3/95, MS5/95 and MS6/95 have been selected by the Maruku Agricultural Research Institute (MARI).

Kagera region is very variable in terms of rainfall, temperature, soil type, altitude and duration of dry spell. Such variability affects both the performance of robusta coffee clones in the different variables at different localities and also the stability of the variables across environments. Thus, the study sets out to investigate consistency in performance of clones across environments for the variables of interest namely stem girth, plant height, canopy diameter, internode length, bearing primary branches, number of flowers, fruit set, yield, and quality. The information derived will aid breeders to plan their improvement programmes based on GxE interaction effects and in making appropriate recommendations on the utilisation of the clones for variables of interest in different environments in the study area.

1.2 Importance of coffee in Tanzania.

There are two types of coffee grown in Tanzania. These are arabica (*Coffea arabica*) and robusta (*Coffea canephora*) coffees. Arabica coffee is grown in Northern highlands of Kilimanjaro, Arusha and Pare/Usambara mountains, Southern highlands in Mbeya and Ruvuma regions but little is grown in the Lake zone especially Ngara, Muleba, Karagwe, Ukerewe and Tarime districts and very little amount is grown in Kigoma region. Robusta coffee is mainly grown in Kagera region and recently it has been introduced to Musoma district in Mara region.

Coffee is important in the world trade terms and although it is overtaken by cereals in tonnage, in value terms and in commercial dealings, it follows closely after oil (Cambrony, 1992). In Tanzania, coffee is one of the top three crops in terms of monetary value, cotton and sisal being the other two, which form the backbone of the country's domestic exports (Mbilinyi, 1976). It also contributes about 5 per cent of the monetary Gross Domestic Product (GDP).

Coffee production in Kagera region contributes about one-quarter of the total coffee export earning of Tanzania and this been mainly from robusta coffee (Anon. 1994; Marshall, 1983).

1.3 Coffee production constraints in Tanzania

1.3.1. General Constraints

Production of coffee in Tanzania for the last ten years has been on average declining or stagnating as shown by the statistics below.

Table 1a. Tanzania coffee production statistics in tonnes of clean coffee

No.	Season	Total tonnes	No.	Season	Total tonnes
1.	1990/91	45,333	6.	1995/96	53,276
2.	1991/92	48,008	7.	1996/97	41,000
3.	1992/93	59,373	8.	1997/98	38,000
4.	1993/94	34,151	9.	1998/99	41,068
5.	1994/95	42,215	10.	1999/2000	59,500

Source: Tanzania Coffee Board (TCB)

This gives an annual average production of approximately 45,000 tonnes for the last ten years. It is a small production for a country like Tanzania with good arable land for coffee cultivation. Reason for declining productivity and quality of coffee for both arabica and robusta despite increased acreage as reported by (Eskes, 1997; Annon ,1994; Kabwoto,1976; Mbilinyi,1976) are; lack of improved superior genotypes/varieties, with resistance to diseases and insect pests, inadequate extension services, high costs of inputs, poor pricing and marketing policies which lead farmers to neglect their fields, and poor field management practices.

1.3.2 Specific constraints of robusta coffee

There are specific constraints that have direct effect on coffee yields. These are insect pests and diseases and poor coffee field management practices.

1.3.2.1 Robusta coffee insect pests and diseases

The major economical robusta coffee insect pests in Kagera region are coffee berry borer (*Stephanoderes hampei*), coffee berry moth (*Prophantis smaragdina*), scales and mealybugs. Other insect pests of robusta coffee which are less economical are leaf miner, leaf skeletonizer and tailed caterpillar. Kaiza and Piters (1997) reported that berry moth ranks first followed by coffee berry borer in reducing coffee yield. The major disease in robusta coffee is leaf rust (*Hemileia vastatrix*) although some robusta types are said to be resistant to this disease (Wrigley,1988). Other diseases are fusarium wilt (*Tracheomycosis*), Fusarium bark (*Fusarium stilboides*) and redblister(*Cercospora coffeicola*).

1.3.2.2 Poor coffee field management practices

Coffee fields must be managed as recommended otherwise lack of application of one practice for example weeding despite application of all other practices, coffee yields will be reduced tremendously. If coffee plants are not pruned, yields are reduced due to increased insect pests and diseases. Also, mulching and manure/fertiliser application is important in increasing soil nutrients as the harvested coffee reduces a large amount of nutrients from the soil.

1.4. Justification of the study.

The effect of Genotype x Environment interaction on growth, yield and quality components in coffee have been reported by many researchers elsewhere (Muwardi and Hulupi, 1995; Moschetto *et al.* 1996; Agwanda *et al.*, 1997). Test of effects of environments on performance of coffee though done in other countries, for both arabica and robusta coffee no such studies have been done in Tanzania for robusta coffee. Based on differences in altitude, amount and distribution of rainfall and soil types, three villages in Kagera region were selected to test the selected robusta clones. Therefore the need to study the growth, yield and quality variables of the plants in the field in order to recommend specific clones or attributes to specific localities or across environments in Kagera region is of special interest.

1.5 Objectives

1.5.1 General objective.

To investigate the performance of selected clones of robusta coffee in different agro-ecological zones in Kagera region.

1.5.2 Specific objectives:

(i) To evaluate the response and stability of selected robusta coffee clones for the different variables under differing environments and give recommendations specific for the agro-ecological zones in Kagera region.

(ii) To determine the association between growth, yield and quality variables of robusta coffee.

CHAPTER TWO

2.0. LITERATURE REVIEW.

2.1 Robusta coffee production and environmental requirements.

Cote d'ivoire is the largest producer of coffee in Africa, the second largest producer of robusta after Indonesia and the fourth largest producer of coffee in the world (Wrigley, 1988). Robusta coffee occupies 33% of the total world coffee growing area and gives coffee of lower quality than arabica coffee due to its high caffeine content (Walyaro, 1983). It is indigenous in all lowland tropical forests of Western and Central Africa. The centre of greatest diversity is in the Congo basin. It is mainly grown in Ivory Coast, Angola, Democratic Republic of Congo, Uganda, Tanzania, Cameroon, Sudan, Central African Republic, Congo, Gabon, Benin, Togo, Ghana, Guinea, Sierra Leone, India, Indonesia, New Caledonia, Philippines, Viet Nam, Cambodia, Brazil (Conilon), Bolivia and Trinidad.

In Tanzania, robusta coffee is mainly produced in Kagera region and is the major cash crop, produced solely by smallholders. In farmers' fields, the production per ha. ranges from 250-350 kg/ha. clean coffee (Marandu *et al.* 1997). According to Cambrony

(1992), this production is considered to be poor. Poor production is considered to be below 300kg/ha, average to be 400 to 800kg/ha, good to be 900 to 1400, very good to be 1500 to 2000kg/ha and excellent to be above 2000kg/ha of clean coffee. In Uganda, it has been reported that under good management and high plant densities (1667 plants/ha), robusta coffee production stands at 3000 to 5000 kg/ha. (Cambrony, 1992). Yield is usually expressed in kgs or tonnes per ha on a per year basis of clean coffee beans after accumulation of several harvests of dried cherries at 10-12 per cent moisture content. In experimental plots of normal plant densities of 1,350 trees/ha, robusta coffee can produce up to 3.5 tonnes/ha (Van der Vossen, 1985).

Rainfall is of fundamental importance to the cultivation of all species of coffee and a minimum of 1200 to 1500 mm per year without too long a hot, sunny dry season, is considered necessary for good regular crops. There are good areas of coffee where although rainfall is frequently less than optimum range, it is well distributed. In Kagera, different areas of the region have different rainfall distributions and amount. The amount ranges from 800-2000 mm depending on the locality. The amount and distribution is unpredictable, creating different agro-ecological zones within the region.

Coffee requires a deep well drained loamy soil, slightly acid, rich in humus and exchangeable bases particularly potassium. Phosphorus seems to be of less importance, but it is essential, particularly at flowering (Wrigley, 1988). Cambrony (1992) reported

that the structure of the soil, its depth ideally greater than 1.2m and its water-holding capacity are more important than chemical fertility. Acid soils of pH between 4.5 and 6.5 are considered to be favourable for growing coffee. Soils of below pH 4 are not favourable unless magnesium limestone is applied. Above pH 7, the humus will have to be renewed frequently by mulching, burying cover crops or manuring.

The optimum temperature ranges for the various species will be similar to those of their natural environment and for arabica coffee, the range is 15 to 24^{0}C. Willson (1985) reported that at temperatures above 25^{0}C, the photosynthetic rate is reduced and leaves are damaged by continuous exposure to high temperatures of over 30^{0}C. Robusta coffee requires higher temperatures, the optimum range being 24 to 30°C. The tree will withstand an occasional temperature of as low as 7^{0}C but long periods of as low as 15°C are harmful. Fruits and leaves are destroyed at 5°C. Cambrony (1992) reported that various species of coffee are normally found growing in temperatures between 18^{0}C and 25^{0}C, with fixed lower and upper limits of 15^{0}C and 30^{0}C respectively, which corresponds to most locations between the tropics of Capricon and Cancer where coffee is grown.

Altitude influences temperature such that in equatorial areas, arabica is a highland crop grown at 1,000 to 2,000 m.a.s.l., while robusta grows from sea level to 700 metres above sea level. Altitude affects the average temperatures by a drop of 1^{0}C for every 180m of

elevation. As the distance from the equator increases, robusta becomes uneconomic, whereas arabica will continue to be a valuable crop at increasing altitudes until restricted by frequent or lengthy frosts (Willson, 1985).

2.2 The meaning of Genotype x Environment interactions.

Hildebrand and Russell (1996) defined environment as the product of the entire set of factors, both biophysical and socio-economic, that can materially affect crop or livestock productivity. These factors include: farm type, nature of the farm household, climate, soil types and farmer management practices. Other environmental factors are geographical locations or agro-ecological zones and commonly occurring disease and insect pest pressures.

The environmental factors mentioned affect genotypes/cultivars performance in different ways. A genotype in this case is the entire genetic makeup of an individual (Fehr, 1987). When cultivars are compared in different environments, their performance relative to each other may not be the same and changes in relative performance of genotypes across environments are referred to as Genotype x Environment interaction (Fehr, 1987). For plant breeders, Genotype x Environment interactions are very important in developing and recommending cultivars to suitable environments for specific variables. Ceccarelli (1989) reported that by exposing a number of genotypes to a set of contrasting

environments it is possible to identify genotypes with (a) a high average yield and low GxE interaction; (b) a high average yield and high GxE interaction; (c) a low average yield and low GxE interaction and (d) a low average yield and high GxE interaction. Genotypes in category (a) are obviously preferred because they are able to express their high yield potential in a range of environmental conditions. These are often referred to as widely adapted genotypes in contrast to (b) or (d) which are referred to as more specifically adapted genotypes. Genotypes in category (c) are obviously undesirable because they are consistently low performers due to their relatively low GxE interaction and low average yield. The rank changes among genotypes across environments may consequently limit the effectiveness of selection of superior genotypes for a wider range of environments. In coffee improvement, phenotypic yield stability and the contribution of the environmental effects to genotype versus environment interaction were evaluated for 8 successive harvests of coffee cultivar Catuai in 5 countries of Southern Minas Gerais, Brazil. Coffee has a biennial bearing habit, that is, if in one year it has high yield, then the following year it will have low yield. Therefore the precision of the evaluation was improved by analyses of groups of low and high yield harvest years. The most important environmental effect observed was year of harvests. Stability parameters varied with the materials tested. Progenies with low average yields responded best to improved environments. In this study, it was concluded that for optimum selection of superior progenies, data from 3 or 4 harvests should be analysed (Mendes *et al.*, 1996).

2.3 Methods of analysis of Genotype x Environment interaction.

For more than half a century, agricultural scientists, have been using some form of stability analysis to evaluate genotypes over a range of locations, an estimate known as Genotype x Environment interaction. Hildebrand and Russell (1996) reported that, early statistical analysis of G x E interaction among genotypes involved the analysis of variance (ANOVA) procedure to partition the variability in a multilocational varietal trial into those variance components attributable to differences among varieties, those due to differences among locations and those due to the interaction of the genotype and environment. ANOVA method was characterised by a statistical sophistication that was difficult to apply without a strong background in mathematical statistics. However, the method is still in use in the evaluation of genetic components of variation from comparable experiments in two or more experiments. In ANOVA, GxE interaction will be evident if the Genotype x Environment source of variation will be significant for any specific variable. Johnson *et al.* (1955) reported that the relative magnitude of variance of components indicate stability of variables in a group of genotypes.

Apart from ANOVA method, regression analysis has been used to measure the relationship between genotype-environment interactions. The method measures that portion of the interaction between genotype and environment which is a linear function of the effect of the environment (Baker, 1969). Another method used according to

Hildebrand and Russell (1996) is adaptability analysis which regresses treatment on an environmental index not to identify those treatments that are stable or that have broad adaptability, but to identify those treatments that are best adapted to particular environments. Another method used in stability analysis for a genotype is the ecovalence which uses the GXE interaction effects for the genotype squared and summed across all environments (Lin *et al*, 1986). The method estimates the relative contribution of each genotype/clone to the sum of the squares of the interaction effect.

Of all the methods used above, none of them provided information on the environment stability of individual genotypes (Fehr, 1987). Alternatively, a regression analysis method was adapted to measure stability of genotypes over a range of environments. Finlay and Wilkinson (1963) were the first researchers to develop the concept of using linear regression of varietal yields on site means as a technique for assessing adaptation in a plant breeding program. Eberhart and Russell (1966) modified an earlier regression analysis put forward by Yates and Cochran (1938) to a statistical linear regression model for the analysis of stable genotypes for adaptation. The linear regression model, classified varietal stability by regression coefficient (phenotypic response) 'b' and deviation from regression ``Sd^2'' (Eberhart and Russell ,1966). The latter defined a good and adapted genotype/variety as one with high yield, a regression coefficient of unity (b_i = 1), and small (close to zero) deviations from regression when genotypic means are plotted against overall means of all genotypes for each environment.

2.4. Genotype x Environment interactions for different variables.

Morphological characters such as stem girth, width of canopy, number of primary branches and number of secondary branches are known to influence fruit yield in coffee (Dancer, 1964; Srinivasan, 1980). Studies in both *Coffea arabica* and *Coffea canephora* showed that there were pronounced Genotype x Environment interaction effects on yield and therefore more than one environment must be sampled to carry out tests of genotypes over several seasons before recommending coffee clones or a variety (Van der Vossen, 1985). Agwanda and Owuor (1989) noted that several environmental conditions contribute to both between location and the between year fluctuations in cherry yield of arabica coffee in Kenya. Montagnon *et al,* (1999) studied genotype-location interactions for *Coffea canephora* yield in the Ivory Coast in a mult-site clonal trial comprising 16 clones and 9 locations and found that certain interactions were detected, even though several clones proved to be stable.

2.4.1 Robusta coffee yields

2.4.2 Robusta coffee yield components.

Some of yield components in coffee include growth characters for instance stem girth, plant height, canopy diameter, internode length, length of longest primary branch;

percentage bearing primaries, percentage bearing nodes, number of flowers per node, and number of berries per node. Omondi and Owuor (1992) evaluated twenty six genotypes of arabica coffee at two sites in Western Kenya during the first five-year crop cycle. Records were taken from plot means on one year measurements after planting for important yield components including stem girth, plant height, internode length on stem and length of longest primary branch. Yield in kg/tree was also recorded for the subsequent four years. Results indicated that the expression of yield and stem girth were highly influenced by the environment and their Genotype x Environment effects were significant.

2.4.3 Yield components and their interrelationships.

Simple correlation coefficient analysis proves to be ineffective because it does not give detailed information on the paths of influence contributing to the total correlation. Path-coefficient was used in addition to the correlation analysis because this type of analysis enables partitioning of correlation coefficients to their components of direct effect of one variable upon the other and indirect effects of the variables giving a clear picture of the individual contribution of each variable to a dependent variable. The method is important in determining compensation mechanisms operating among variables in plants thus, making improvement of one variable less rewarding because increment in yield will reach a certain level after which it declines because of sacrificial effect of another

component. Strategies can be designed to circumvent the problem of yield sacrifice through component compensation effects due to adverse relationships. The method was first devised by Wright (1921), revised by Dewey and Lu (1959) and subsequently used by other investigators for instance Shoran (1982), and Singh *et al.* (1985).

A knowledge of the interrelationships between yield and its major components is important for selecting two or more concurrent complex traits contributing to yield. Walyaro (1983) studied 11 varieties representing a number of introductions and cultivars of *Coffea arabica* in Kenya. It was found that yield of cherry is positively correlated with a number of growth characters, and highly correlated with some yield characters, especially percentage bearing nodes, flowers per node and number of berries per node. Srinivasan, (1980) studied genotypic, phenotypic and environmental correlations among five vegetative characters and first fruit yield in four cultivars of arabica coffee. It was concluded that stem girth, length of longest primary and its internodal length showed high positive genotypic correlation with fruit yield. Cannell, (1971) by using path-coefficient analysis of three characters- number of fruiting nodes, number of fruits per node and weight per fruit; concluded that the three components jointly accounted for 75% of the variation in fruit yield of coffee. Dancer, (1964) reported that plant characters such as stem girth, width of canopy and mean diameter of primaries influenced yield of coffee.

2.4.4 Robusta coffee quality.

Another study on the effect of genotype on cup quality of *Coffea canephora* samples taken from three different areas in Cote d'ivoire confirmed the predominant effect of genotypes in relation to location (Moschetto *et al.* 1996). Agwanda *et al.*(1997) studied some 22 complex hybrid varieties of arabica coffee with two arabica varieties as control in 5 locations in Kenya. Ripe cherries were collected and parchments were hulled and graded according to size and shape. Quality of roast beans, acidity, body, flavour and overall standard were also evaluated. Absence of stress during berry expansion and bean filling stages were necessary for maximum differentiation between genotypes for liquor traits. Bean and liquor traits were antagonistic in terms of environments necessary for their expression, therefore combined selection for both traits was recommended.

Muward and Hulupi (1995) also studied the effect of Genotype x Environment interaction on coffee bean shape in 12 coffee arabica genotypes at 3 locations in East Java. Genotype x Environment interactions were significant for bean shape. Bean abnormalities were predominantly affected by the different locations rather than different crop years. The higher the altitude, the higher the percentage of abnormal beans were found. According to Walyaro (1983) on the study of 11 varieties of *Coffea arabica* in Kenya, quality characters were less influenced by effects of Genotype x Environment interaction.

CHAPTER THREE

3.0 MATERIALS AND METHODS.

3.1 Background information

Preparation of planting materials started in April 1997. Bisheshe and Chanika villages in Karagwe district and Kabirizi village in Bukoba district were selected to carry out the experiments. Two robusta coffee trees in each village were selected on the basis of phenotypic expression in farmers' fields at Bisheshe and Chanika villages in Karagwe District and at Kabirizi A and Kabirizi B villages in Bukoba District for the purpose of producing cuttings to be used in the trials. One different tree from the above in each of the above mentioned villages were also selected on the basis of phenotypic expression in farmers' fields for the purpose of producing robusta coffee seedlings. Cuttings and seeds from farmers' fields and cuttings from the five MARI selected clones were rooted and potted and sent to farmers to be tested under their environments. Chanika and Bisheshe represent zone 9A and 9B respectively while Kabirizi village represents zone 8. The attached map (Appendix 10) shows seven existing agro-ecological zones of Kagera region namely the Bukoban high rainfall, Bukoban medium rainfall, Bukoban low rainfall, Karagwe-Ankolean medium rainfall, Karagwe-Ankolean low rainfall, alluvial

system and the basement complex according to Baijukya and Folmer (1999). Locations of trial sites are also indicated in the map.

In March 1998, the trials were established in farmers' fields and three farmers were selected in each of the villages of Chanika and Bisheshe while in Kabirizi, six farmers were selected to conduct the trials. Each farmer planted five trees of each of the five Maruku selected clones, five trees of each of the two farmers' selected clones and five trees of each of the farmers' selected seedlings making a total of 40 trees per farmer/site/replicate. The arrangement makes a total of 8 treatments that is 7 robusta clones and 1 robusta seedling per farmer and each chosen farmer's site is a replicate. The five plants for every selected clones/seedlings were planted in one line in each site and this constituted a plot. The randomisation of treatments was done within sites (see the layout in Appendix 9). Planting of the clones was done at a spacing of 3m. between rows and 2m. between plants within a row. The planting hole was made at 60cm x 60cm x 60cm. and farmyard manure 20kg (approximately two 'debes') for each hole was incorporated with the topsoil to fill a hole while other management practices continued to be done as recommended for robusta coffee (Marandu *et al.* 1997). Therefore, data collection was carried out on already established robusta coffee plants.

3.2 Description of Clones/seedlings used.

The clones/farmers'seedlings used in this trial were as follows:

MS1/95 formerly known as BK21 a robusta tree selected in 1957 in Bukoba district.

MS2/95 formerly known as BK22 a robusta tree selected in 1957 in Bukoba district.

MS3/95 formerly known as BK47 a robusta tree selected in 1957 in Bukoba district.

MS5/95 formerly known as U.218/32 a Uganda selected robusta tree introduced to Tanzania in early 1960's.

MS6/95 formerly known as U.224/37 a Uganda selected robusta tree introduced to Tanzania in early 1960's.

FS Robusta coffee plants raised by using seeds selected from farmers' fields.

KR1 and KR2 Robusta coffee clones raised from two selected robusta trees in farmers'fields in Chanika village in Karagwe district in 1997.

KR3 and KR4 Robusta coffee clones raised from two selected robusta trees in farmers' fields in Bisheshe village in Karagwe district in 1997.

BK1 and BK2 Robusta coffee clones raised from two selected robusta trees in farmers' fields in Kabirizi A village in Bukoba district in 1997.

BK3 and BK4 Robusta coffee clones raised from two selected robusta trees in farmers' fields in Kabirizi B village in Bukoba district in 1997.

3.3 Description of the trial locations.

Locations used in this study were selected according to the Lake Zone zonation map and the locations fall under zones 8, 9A and 9B. Kabirizi, Chanika and Bisheshe villages represent zone 8, 9A and 9B respectively and these villages are among the villages selected by Lake Zone Farming Systems Research to conduct research activities since 1988. According to Heemskerk and Mafuru (1998), zone 8 is a medium rainfall Bukoban system and zone 9A and 9B are medium rainfall Ankolean system although zone 9A and 9B differ in altitude and type of soils. The soils of zone 8 (Kabirizi village) are made up of sandstones and shales throughout and are highly weathered, well drained, deep, and of very low fertility (Annon, 1995). Chanika and Bisheshe village soils are made up of meta-sediments of quartzites, quartzitic sandstones, shales and phyllites. The soils are highly weathered, well drained, deep soils of low to medium fertility on ridges; poorly drained soils with high organic matter content in valleys (Annon., 1995). Bisheshe village is situated on a ridge and slopes of the ridge while Chanika village is mostly situated on a plane of the plateau. Soils of Bisheshe do retain moisture and have higher nutrients in comparison with Chanika soils. The soils in Chanika village get dried quickly, have low nutrients and do not retain moisture as compared to Bisheshe soils.

3.4. Variables recorded:

3.4.1 Growth variables.

The growth variables viz. girth, plant height, canopy diameter, and internode length, were measured. The growth measurements were taken once and three plants were selected out of the five plants of an accession in each replicate for the measurement. Girth of the main stem was measured at 5 cm. from the ground level by measuring the diameter of the plant using vernier callipers (slide callipers). Since the coffee trees have been trained into multiple stem system, the main stem is below the area of establishing the multiple stems and this is the area of the 5 cm. selected for girth measurement.

Plant height was measured (in cm) from the ground level to the tallest stem terminal apical orthotropic bud on the plant. For each of the three selected coffee trees in a plot, the canopy cover was assessed by measuring the length (in cm) of 5 primaries situated at the middle of the crown. The same 5 primaries were used to estimate the internode length by dividing the total length of the 5 primary branches with the total number of nodes in the 5 primary branches.

3.4.2 Yield components.

The yield component variables viz. bearing primary branches, number of flowers, and fruit set were measured as follows: Bearing and un-bearing primary branches were counted and these were later used to calculate the percentage bearing branches as the number of bearing branches divided by the total number of branches and were multiplied by 100.

Number of flowers were counted from a segment of five nodes of earlier selected five primary branches in the selected tree per plot. Total number of flowers were divided by the number of nodes to get the average number of flowers per node. The counted nodes were again labelled for further fruit set counting.

From the labelled nodes when coffee fruits were four months old, the number of fruits were again counted. The total number of fruits were divided by the number of nodes to get average fruits per node.

3.4.3 Yield (kg/ha.).

Yield data for 2000/2001 was recorded as follows:

The fresh cherries were harvested per tree and harvested trees per plot were recorded for each harvest. Then, average yield per tree for each harvest in a plot was calculated and expressed as Kg/tree. Yield per hectare was then calculated by multiplying yield/tree by recommended total number of trees per hectare (1667tree) to get yield of fresh cherries/ hectare per harvest. The total yield of fresh cherries harvests per season were added up to get overall yield per hectare per season. To convert the yield of fresh cherries/hectare to clean coffee/ha., the fresh cherries/ha. were multiplied by a conventional figure of 0.22 for robusta coffee, while that used for arabica coffee is 0.18 (Wellman, 1961).

Yield data for 1999/2000 recorded as fresh cherries per hectare was converted to clean coffee per hectare by using the same procedure as above.

3.4.4 Bean size.

Harvested dried coffee cherries were hulled to obtain clean coffee beans. 100-clean coffee beans from each plot were counted and weighed. These records gave 100-seed/bean weight for each accession.

A sample of 1 kg. of dry coffee cherries was taken from each plot and then hulled to obtain clean coffee beans. The clean coffee obtained was again weighed. This measure gave the amount of clean coffee obtained from one kilogramme of dry cherries.

Piano wire screens with different hole sizes were used to measure different sizes of beans found in a sample of 1/2 kg of clean coffee from each plot. Screens for separation of coffee bean sizes were used. The bean fractions retained by the following screen numbers 16, 14 and 13 were expressed in terms of percentage by weight.

3.4.5 Cup quality.

A sample of clean coffee from each plot was sent to a liquoring company known as BEKA Trasworld PVT Ltd in Moshi, Kilimanjaro Region, for liquoring test. The liquor quality was assessed according to body, both with scores of (1-3) and flavour (1-6) of the brewed coffee.

3.4.6 Non-treatment factors.

Soil samples were taken from each trial site and were analysed at Ukiriguru (Mwanza) National Soil Laboratory. The analysis carried out was for pH, organic carbon, total nitrogen, available phosphorous, cation exchange capacity, exchangeable potassium, and

particle size. The soil analysis was carried out according to National Soil Science (NSS) classification for general soil fertility evaluation. Soil analysis results are shown in Appendix 5.

Simple rain gauges were used to measure rainfall data in each location. The recorded rainfall data for each location is shown in Appendix 6. Altitudes of each experimental site were recorded as indicated in Appendix 7.

Leaf rust, a major disease of robusta coffee, was scored in each plot in a site for all the locations. Total scores for each tree in a plot were added up and divided by the number of trees scored in a plot to get the average disease severity scores for a plot. Standard scales (see Appendix 8) for scoring the whole tree for coffee leaf rust (CLR) caused by *Hemileia vastatrix* Berk. and Br. disease was used.

The major insect pests of robusta coffee are coffee berry moth (CBM) and coffee berry borer (CBB) and these insect pests were scored from a half kilogramme of dry cherries from each plot by counting the number of infested cherries. The number of infested cherries by CBM were divided by the number of cherries in a half kilogramme and multiplied by 100 to get percentage infested cherries. The same was done for CBB.

3.5 Data analysis.

Recorded data were analysed using MSTAT-C software (Michigan State University, 1990). Data were at first subjected to the conventional analysis of variance (ANOVA) for each location using the procedure after Gomez and Gomez (1983) for a randomised completely block design (RCBD). Combined analysis of variance to obtain estimates of variance components was used in the analysis of variance.

The villages/locations had different sets of treatments; therefore the analysis was done within villages/locations and across villages/locations for the Maruku selected clones and farmer's seeds (FS). Analysis of variance, covariance, correlation and path-coefficient analyses were used in analysing data.

3.5.1 Statistical models for ANOVA.

Two statistical models were used in the combined analysis. The first one involves analysis of genotypes over locations in a single year and the other one involves analysis of genotypes over locations and years.

The statistical models are:

$$X_{ijlk} = u + g_i + z_j + gz_{ij} + y_l + gy_{il} + gzy_{ijl} + e_{ijlk} \quad \text{.....(i)}$$

Where: X_{ijlk} = the observed value

μ = overall mean

g_i = the effect of the $i^{th.}$ genotype.

z_j = the effect of the $j^{th.}$ zone

gz_{ij} = interaction effect of the $i^{th.}$ genotype at the $j^{th.}$ zone.

y_l = is the $l^{th.}$ year effect

gy_{il} = interaction effect of the $i^{th.}$ genotype at the $l^{th.}$ year

gzy_{ijl} = interaction between ith. genotype $j^{th.}$ zone and $l^{th.}$ year

e_{ijlk} = random experimental error.

$$X_{ijk} = \mu + g_i + \varepsilon_j + g_{ij} + e_{ijk} \quad \text{.....(ii)}$$

Where: X_{ijk} = the observed value

μ = Overall mean

g_i = The mean of ith genotype

ε_j = The mean of the jth location

g_{ij} = interaction effect of the ith genotype of jth. location

e_{ijk} = random experimental error

Table 1b. Combined analysis of variance for evaluating genotypes under different zones and within zones for model (i) above is given bellow:

Source of variation	Df	Mean square	Expected mean square
Zones	z-1	M1	$\delta^2e + \delta^2r + n\delta^2gzy + ny\delta^2gz + ngy\delta^2z$
Years	y-1	M2	$\delta^2e + \delta^2r + n\delta^2gzy + nz\delta^2gy + nzg\delta^2y$
Replication within Zone and Years(R/Z/Y)	(z-1)(y-1)	M3	$\delta^2e + \delta^2r$
Genotypes	g-1	M4	$\delta^2e + n\delta^2gzy + nz\delta^2gy + ny\delta^2gz + nzy\delta^2g$
Gen. x Zone (G x Z)	(g-1)(z-1)	M5	$\delta^2e + n\delta^2gzy + ny\delta^2gz$
Gen. x Year (G x Y)	(g-1)(y-1)	M6	$\delta^2e + n\delta^2gzy + nz\delta^2gy$
Gen.x Zone x Year (GxZx Y)	(g-1)(z-1)(y-1)	M7	$\delta^2e + n\delta^2gzy$
Error		M8	δ^2e

Assumption: All the variables are random.

Table 1c. Combined analysis of variance for evaluating genotypes under different zones and within zones for model (ii) above is given bellow:

Source of variance	Df	Mean square	Expected mean square
Environments (E)	n-1	M_1	$\delta^2 e + r\delta^2_{GxE} + \delta^2 g_{R/E} + rg\delta^2_E$
Replications R/E	n (r-1)	M_2	$\delta^2 e + \delta^2 g_{R/E}$
Genotypes (G)	g-1	M_3	$\delta^2 e + \delta^2 g_{GxE} + re\delta^2_G$
G x E	(g-1) (n-1)	M_4	$\delta^2 e + r\delta^2_{GxE}$
Error [(R/E) xG]	n(r-1) (g-1)	M_5	$\delta^2 e$

Assumption: All the variables are random

Where: $\delta^2 e$ = Plot error variance

$\delta^2 g$ = Genotypic variance among clones/varieties

δ^2_E = Environment (location) variance

δ^2 Gx E = Genotype x Environment (location) variance

r = number of replications

n = number of environments (locations)

g = number of genotypes

From combined ANOVA tables above, conventional analysis of variance pooled over locations and different estimates of components of variance were calculated. The estimates of components of variance were calculated according to a method given by Al-Jibouri *et al* (1958). Observed mean squares obtained in the conventional analysis of variance were used to separate out the effects of genotypes, environments and their interactions.

3.5.2 Correlation coefficient analysis

Correlation coefficient analysis was carried out by using MSTAT-C software. Correlations between yield and yield attributes as well as yield and quality attributes were done for each location and across locations as a combined analysis.

3.5.3 To compute phenotypic variance, heritability (broad sense), and Expected Genetic Advance (EGA).

The phenotypic variance (δ^2ph) among genotype means tested in r-replications and l-locations was computed by using the following formula (Robinson *et al*,1949):

$$\delta^2 ph = \delta^2 g + (\delta^2 lg / l) + (\delta^2 e / lr) \quad \text{.....(iii)}$$

Where: δ^2ph = phenotypic variance

δ^2 g = genetic variance

δ^2lg = variance due to genotypes and locations

δ^2e = error variance

l = number of locations

r = number of replications

The numerators in formula (iii) above are the estimates of the respective variance components.

Heritability (broad sense) was computed by using the estimates of phenotypic and genotypic variances, a formula proposed by Hanson *et al* (1956) as shown below:

$$h^2 = (\delta^2 g / \delta^2 ph) \times 100 \quad \text{.....(iv)}$$

Where: h^2 = heritability in the broad sense

$\delta^2 g$ = genetic variance

$\delta^2 ph$ = phenotypic variance

Expected genetic advance was estimated by a formula proposed by Johnson *et al* (1955) as shown below:

$$EGA = k\,(100\delta g / \chi\,) \times (\delta g / \delta ph) \quad \text{.....(v)}$$

Where: δg = genetic standard deviation

χ = population mean

δph = phenotypic standard deviation.

k = is a constant which varies with selection intensity.

3.5.4 Analysis of genotypic and phenotypic correlation coefficents.

Covariance analysis was done to estimate genotypic ($\delta g_{1.2}$) and phenotypic ($\delta ph_{1.2}$) covariance components between two selected variables for comparison. MSTAT-C software was used to obtain the covariance components as it was used to obtain the variance components. The covariance components were used to compute genotypic and

phenotypic correlation coefficients between chosen characters by using the formula given by Robinson *et al.* (1951) as shown below:

Genotypic correlation $r = (\delta g_{1.2}) / \sqrt{(\delta^2 g_1)(\delta^2 g_2)}$ .....(vi)

Where: $\delta g_{1.2}$ = the genetic covariance between the two variables

$\delta^2 g_1$ = the genotypic variance of the first variable, and

$\delta^2 g_2$ = the genotypic variance of the second variable.

Phenotypic correlation $r = (\delta ph_{1.2}) / \sqrt{(\delta^2 ph_1)(\delta^2 ph_2)}$ .....(vii)

Where: $\delta ph_{1.2}$ = the phenotypic covariance of the two variables

$\delta^2 ph_1$ = the phenotypic variance of the first variable, and

$\delta^2 ph_2$ = the phenotypic variance of the second variable.

3.5.5 Regression analysis.

After the ANOVA, linear regression analysis method by Eberhart and Russell (1966) for varietal stability over a range of environments was done.

The Regression Model: $Y_{ij} = \mu_i + \beta_i I_j + \delta_{ij}(S^2 d)$ was used..

Where: Y_{ij} = genotype mean of the i^{th} genotype at the j^{th} environment (i=1,2,....v, j= 1,2,...n).

μ_i = the i^{th} genotype mean over all environments.

βj = the regression coefficient that measures the response of the i^{th} genotype to varying environments.

I_j = the environmental index obtained as the means of all genotypes at the j^{th}.environment, minus grand mean.

δ_{ij} (S^2d) = the deviation from regression of the i^{th} variety at the j^{th} environment.

3.5.6. Path-coefficient analysis.

Path-coefficient analysis as designed by Wright (1921) and revised by Dewey and Lu (1959) to describe the relationship between correlation coefficient and path coefficients was done to discern the paths of influence among the components. The formula arranged in matrix notation was solved simultaneously using the model arranged in matrix notation as shown bellow:

$$r_{16} = P_{16} + r_{12}P_{26} + r_{13}P_{36} + r_{14}P_{46} + r_{15}P_{56}$$

$$r_{26} = r_{12}P_{16} + P_{26} + r_{23}P_{36} + r_{24}P_{46} + r_{25}P_{56}$$

$$r_{36} = r_{13}P_{16} + r_{23}P_{26} + P_{36} + r_{34}P_{46} + r_{35}P_{56}$$

$$r_{46} = r_{14}P_{16} + r_{24}P_{26} + r_{34}P_{36} + P_{46} + r_{45}P_{56}$$

$$r_{56} = r_{15}P_{16} + r_{25}P_{26} + r_{35}P_{36} + r_{45}P_{46} + P_{56}$$

$$1 = P^2x_6 + P^2_{16} + P^2_{26} + P^2_{36} + P^2_{46} + P^2_{56} + 2P_{16}r_{12}P_{26} + 2P_{16}r_{13}P_{36} + 2P_{16}r_{14}P_{46} + 2P_{16}r_{15}P_{56} + 2P_{26}r_{23}P_{36} + 2P_{26}r_{24}P_{46} + 2P_{26}r_{25}P_{56} + 2P_{36}r_{34}P_{46} + 2P_{36}r_{35}P_{56} + 2P_{46}r_{45}P_{56}$$

Where r's are the correlation coefficients and P's are the direct effects. Px is the residual effect.

The paths of influence are shown in the path diagram indicated in Fig.1.

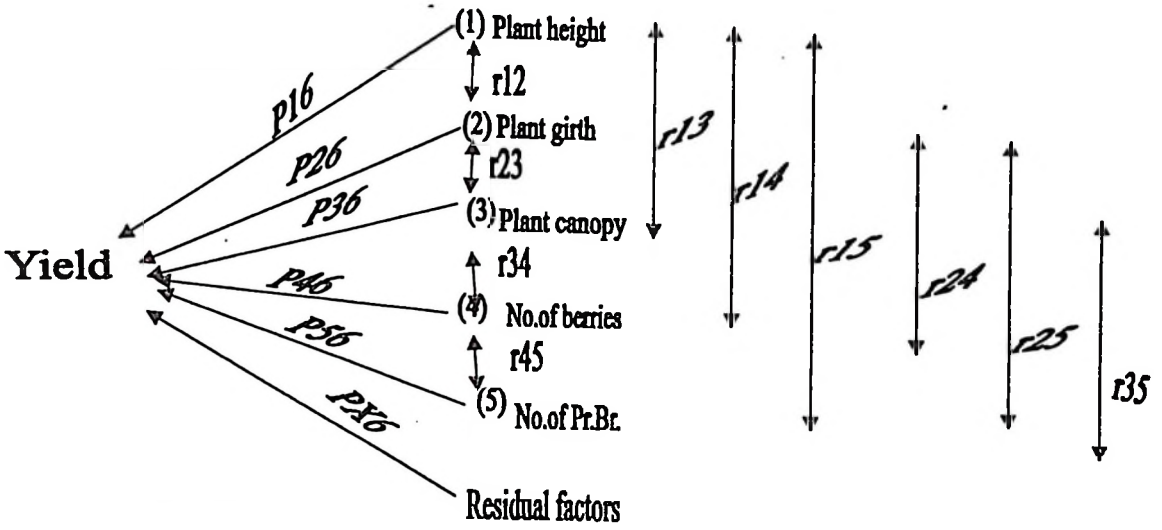


Fig. 1 Path diagram indicating the paths of influence where P_{ij} single arrows indicate the direct effects and the double arrows r_{ij} represent the simple correlation coefficients. Px6 the residual effects. The indirect effect of one variable upon another through another variable was determined by the product of correlation coefficient with the direct effect.

CHAPTER FOUR

4.0 RESULTS.

4.1 Non-treatment factors during data collection

4.1.1 Soils of the trial sites

Soil characteristics of the trial sites varied from zone to zone and within zones (see Appendix 5). Bisheshe and Chanika soils are clayish in texture except for replication 1 of Chanika which is clay loam. Soils of Kabirizi A (replication 1) are sandy loam while replications 2 and 3 are silt clay and clay respectively. Kabirizi B, (soils of replication 1, 2 and 3) are sandy clay loam, clay and silt clay respectively.

The soil reaction (pH) for all of the zones ranged from pH 5.0-6.5 except for Chanika replication 1 which has soils with pH 6.8. The soil reaction differed from zone to zone and within zones (Appendix 5).

Bisheshe replication 1 soils are medium in organic matter and low in total nitrogen content while replication 2 has high organic matter and medium in total nitrogen content. Replication 2 of Chanika has medium content of organic matter and low total nitrogen

content while replications 3 and 1 had very high organic matter and medium total nitrogen content. Kabirizi A (replications 2 and 3) have soils with medium content of organic matter and low total nitrogen while replication 1 has very low organic matter and very low total nitrogen. Kabirizi B (replications 1 and 2) have medium organic matter and low in total nitrogen while replication 2 has high organic matter and medium in total nitrogen. Replication 1 of Bisheshe has medium available phosphorus while replication 2 has low amount of available phosphorus. Chanika (replications 2 and 3) have medium and high amount of available phosphorus respectively. However, replication 1 of Chanika has exceptionally high amount of available phosphorus (560mg/kg). Replications 2 and 3 of Kabirizi B and replications 3 and 1 Kabirizi A have medium amounts of available phosphorus while replication 2 Kabirizi A and replication 1 Kabirizi B have low amounts of available phosphorus. Soils of Bisheshe and Chanika have high exchangeable calcium except for replication 2 of Chanika which has medium exchangeable calcium. Replications 1 and 2 of Bisheshe have low and very low exchangeable potassium respectively while replications 2 and 3 of Chanika have medium contents of exchangeable potassium. However, levels of exchangeable potassium for replication 1 of Chanika are high. Kabirizi A replication 1 has low levels of all exchangeable bases including CEC. Replications 2 and 3 of Kabirizi A and all replications of Kabirizi B have medium and high levels of exchangeable calcium respectively. Kabirizi A replication 3 and replications 1 and 2 of Kabirizi B have low exchangeable potassium and Kabirizi B replication 3 has medium exchangeable

potassium while replication 2 of Kabirizi A has high levels of exchangeable potassium. Replications 2 and 3 of Kabirizi A and all replications of Kabirizi B have low and medium levels of exchangeable magnesium respectively. Kabirizi B (replications 1 and 3) and replication 2 of Kabirizi A have low CEC while replication 3 of Kabirizi A and replication 2 of Kabirizi B have medium CEC levels.

4.1.2. Rainfall during 2000/2001

Rainfall data was recorded from September 2000 to July 2001 (see Appendix 6). However, before the start of short rains (September- December 2000), the coffee trees in all zones were severely affected by drought as long rains (March-May 2000) stopped earlier (in late April) compared to previous years (data not shown). However, some zones and even replications within the zones were more affected compared to others. Normally, coffee require some showers in order to stimulate flower flash and this occurs within August each year but during 2000/2001 due to drought, coffee trees in Kabirizi A and Kabirizi B set flowers in September 2000 and in both Bisheshe and Chanika, the coffee trees set flowers in October 2000. After the onset of flowers, rains did not continue and moisture in the soil was not enough at some zones especially Chanika where flowers had to dry up. In replication 3 of Chanika, all the flowers dried up and no yield was obtained during 2000/2001. High rainfall during short rains were recorded in December 2000 and January 2001 in all zones and during long rains, the highest rainfall

was recorded for Kabirizi A and Kabirizi B in April and May 2001 while Bisheshe and Chanika received high rainfall in March. All the zones received high rainfall in July 2001, rains which were considered abnormal in comparison to previous seasons. Bisheshe received highest total rainfall followed by Kabirizi A while Kabirizi B received the lowest. Total rain days for Kabirizi A were higher followed by Kabirizi B while Bisheshe recorded the least number of rain days.

4.1.3. Altitude

The altitude recorded differs from one zone to another and even within zones. Bisheshe recorded the highest altitude followed by Chanika, Kabirizi A and Kabirizi B respectively (Appendix 7). The recorded altitude had an influence on temperature for growing robusta coffee as well as disease pressure especially coffee leaf rust (CLR).

4.1.4 Disease and insect pests.

Leaf rust disease caused by *Hemileia vastatrix* Berk and Br. which is the major disease in coffee was scored during the study. The disease infection was observed to be higher at low altitudes and very low in higher altitudes. Therefore coffee in Kabirizi A and Kabirizi B was more infected than at Bisheshe and Chanika. Coffee leaf rust infection in robusta coffee was observed to appear during the dry period when coffee berries were mature almost at ripening stage.

Coffee berry moth *Prophantis smaragdina* and Coffee berry borer *Stephanoderes hampei* infestation were both observed in the field as well as in the harvested coffee cherries. Infestation by these insect pests may have tremendous effect in the final yield of coffee as observed in the field and in the harvested cherries.

4.2. Means and Analysis of Variance (ANOVA).

4.2.1. ANOVA extract of yield and its components for eight robusta coffee genotypes in each location

Results of ANOVA extracts for yield and its components in each of the study locations are given in appendices 1a-1d. At Chanika and Bisheshe locations, there were no significant genotypic effects in any of the yield variables however, farmers (replications) showed consistent significant differences for number of berries per node and percentage fruit set. For Kabirizi A and Kabirizi B, genotypic differences were only observed at Kabirizi A for number of flowers produced per node, however, farmers consistently differed for plant height, plant girth, canopy radius, internode length and number of primary branches produced.

4.2.2. ANOVA extract of quality variables for eight robusta genotypes at each location.

Results of ANOVA for quality variables at each location are presented in Appendices 2a-2d. At all locations, there were significant differences between genotypes on Coffee Leaf Rust (CLR) severity, however, screen 14 percentage clean coffee showed significant genotypic effect at Chanika and Kabirizi B; while screen 13 percentage clean coffee differed between genotypes at Bisheshe. Farmers differed significantly and consistently at Chanika and Bisheshe for screen 14 percentage clean coffee and screen 13 percentage clean coffee.

4.2.3. ANOVA extract of yield and components of yield for six robusta coffee genotypes at each location.

The results of ANOVA for yield and its components in each location for the six robusta genotypes are shown in Appendices 3a-3d. Significant genotypic differences were observed only for plant girth at Kabirizi A. There were no consistent significant differences between farmers across locations for yield and its components. For yield of clean coffee, Bisheshe showed significant variability between farmers ($P<0.01$).

4.2.4. ANOVA extract of quality variables for six robusta coffee genotypes at each location.

The results of ANOVA for quality variables in each location for the six robusta coffee genotypes are shown in Appendices 4a-4d. Coffee leaf rust severity showed significant differences between genotypes at all locations except at Chanika where there was no significant genotypic effect. However, only Chanika exhibited significant differences between genotypes for percentage clean coffee, 100 seed weight, number of dry cherries in 1/2kg , percentage screen 16 and percentage screen 14 while only at Bisheshe did percentage screen 13 show significant differences between genotypes.

4.2.5. ANOVA extract of yield of clean coffee (kg/ha.) combined for two years (1999/2000 and 2000/2001) for six robusta coffee genotypes.

Result of ANOVA for the six robusta coffee genotypes yields of clean coffee combined over two years is shown in Table 2a. The analysis indicated significant differences in the locations and years x location interactions.

Table 2a. ANOVA extract and probability levels for two years (1999/2000 and 2000/2001) yield data for six robusta coffee genotypes grown at four locations in Kagera region.

Source of variation	Degrees of freedom	Mean squares and P
Year	1	176128.96 ns
Location	3	3085330.64**
Year x Location	3	651957.98*
Replication (location x year)	8	2983419.02**
Genotypes	5	316624.90 ns
Genotype x Year	5	295604.72 ns
Genotype x Location	15	356785.10 ns
Genotype x Year x location	15	157918.34 ns
Error	40	211833.72

4.2.6. Year x location interactions mean performance for yield of clean coffee for two years.

Mean values of year x location interactions on yield clean coffee for two years are shown in Table 2b. The results indicated that Kabirizi B recorded the highest yield in years one and two followed by Kabirizi A while Bisheshe and Chanika recorded the lowest yields.

Table 2b. Mean yield clean coffee (kg/ha.) for year x location interactions for two years.

	Years		
Location	1999/2000	2000/2001	Mean ± 93.95
Chanika	5.27	358.80	182.04
Bisheshe	108.44	619.39	363.91
Kabirizi A	137.45	891.89	514.67
Kabirizi B	180.34	1853.75	1017.04
Mean ± 132.86	107.87	930.96	

$LSD_{0.05}$ within table = ± 379.73

4.2.7. Mean performance of eight robusta genotypes on growth and yield characters at each location

Mean values for yield and components of yield of robusta genotypes at all locations are shown in Tables 3, 4, 5 and 6.

4.2.7.1 Clean coffee yield

For the genotypes commonly studied across locations, 3 genotypes viz. MS2/95, MS3/95 and MS6/95 consistently gave higher yields at Kabirizi B and Bisheshe. Of these, the highest was 1470kg/ha. for MS3/95, followed by 1451.2kg/ha.for MS6/95 both at Kabirizi B.Yields were generally lower at Bisheshe, ranging from 198-1058kg/ha.as compared to Kabirizi B, which ranged from 449-2546kg/ha. The other locations did not show significant differences between genotypes on yield. The lowest trial mean was obtained at Chanika (228.7kg/ha) while the highest was at Kabirizi B (1324.1kg/ha).

Table 3. Mean performance of robusta genotypes on growth and yield characters at Chanika for the 2000/2001

Genotypes	Plant height (cm)	Plant girth (cm)	Inter-node length (cm)	Primary Branches (No.)	Flowers/node (No.)	Bearing Pr.Br. (%)	Berries/ node (No.)	Fruit set (%)	Clean coffee Yield (kg/ha)	Canopy radius (cm)
MS1/95	84.44ab	2.49f	4.81	27.33bc	12.33	60.51ab	0.00	0.00b	0.00	49.15b
MS2/95	79.42b	2.52e	4.27	28.67bc	14.00	59.20ab	0.00	0.00b	0.00	47.55b
MS3/95	84.11ab	2.01h	4.27	24.67c	25.33	53.48b	5.67	19.40a	580.67	52.79ab
MS5/95	95.03ab	2.91c	4.39	30.00abc	31.33	62.82ab	5.67	14.76ab	504.27	55.40ab
MS6/95	89.56ab	2.38g	4.39	32.67abc	20.33	62.84ab	0.33	1.15ab	264.67	61.96a
KR 1	110.75a	3.41a	4.52	42.67a	30.67	73.17a	2.00	5.72ab	360.63	61.99a
KR 2	84.05ab	3.13b	4.80	40.67ab	21.33	73.88a	0.33	0.98ab	33.82	57.87ab
FS	88.83ab	2.77d	4.52	29.33abc	23.33	65.81ab	3.67	15.14ab	85.57	54.44ab
Mean	89.52	2.70	4.50	32.00	22.33	63.89	2.21	7.14	228.70	55.14
S.E±	7.44	0.02	0.24	3.73	6.17	5.13	1.76	5.15	200.4	3.49
C.V. %	14.4	18.7	9.1	20.2	47.9	13.9	137.9	124.8	151.8	11.0

Means within columns followed by the same letter(s) or without letters are not significantly different from each other according to DMRT at 5% level

Table 4. Mean performance of robusta genotypes on growth and yield characters at Bisheshe for the 2000/2001.

Genotypes	Plant height (cm)	Plant girth (cm)	Inter-node length (cm)	Primary Branches (No.)	Flowers/ node (No.)	Bearing Pr.Br. (%)	Berries/ node (No.)	Fruit set (%)	Yield clean coffee (kg/ha)	Canopy radius (cm)
MS1/95	93.17ab	3.68a	4.68ab	35.00abc	29.00	65.84ab	9.00	27.28	527.20ab	59.10
MS2/95	114.00a	3.96a	4.39ab	44.00ab	27.50	74.85a	8.50	28.34	607.42ab	68.04
MS3/95	93.50ab	3.53a	4.56ab	44.00ab	28.50	75.00a	10.50	35.42	728.90ab	64.63
MS5/95	102.50ab	3.61a	4.10b	42.00abc	31.00	73.81ab	10.00	31.00	259.78b	62.57
MS6/95	92.84ab	2.56b	4.37ab	34.00bc	26.50	70.49ab	6.00	16.22	534.83ab	64.54
KR 3	97.00ab	3.74a	4.38ab	45.00a	25.50	68.75ab	7.00	21.88	630.34ab	68.77
KR 4	89.00b	3.60a	4.08b	40.00abc	24.00	70.18ab	5.00	22.78	198.65b	70.74
FS	113.38a	3.54a	4.95a	32.00c	29.00	62.50b	11.00	35.86	1058.21a	64.37
Mean	99.30	3.53	4.44	39.50	27.63	70.18	8.38	27.35	568.17	65.35
S.E±	5.97	0.22	0.22	2.93	2.65	3.15	2.43	9.80	213.50	5.90
C.V. %	8.5	8.8	7.2	10.5	13.5	6.3	40.8	50.7	53.1	12.8

Means within columns followed by the same letter(s) or without letters are not significantly different from each other according to DMRT at 5% level

Table 5. Mean performance of robusta genotypes on growth and yield characters at Kabirizi A for the 2000/2001

Genotypes	Plant height (cm)	Plant girth (cm)	Internode length (cm)	Primary Branches (No.)	Flowers/ node (No.)	Bearing Pr.Br. (%)	Berries/ node (No.)	Fruit set (%)	Yield clean coffee (kg/ha)	Canopy radius (cm)
MS1/95	107.20	3.74	4.54ab	44.67	30.67a	68.09	7.67ab	24.62	508.85	59.62b
MS2/95	112.60	4.09	4.94a	47.33	33.67a	73.17	11.67a	34.42	860.82	62.04b
MS3/95	109.90	3.89	4.85ab	48.00	25.00ab	68.80	7.33ab	29.83	738.37	79.04a
MS5/95	117.40	4.08	5.07a	52.00	30.67a	72.70	9.67ab	31.32	1136.90	75.31ab
MS6/95	97.80	3.41	4.33ab	44.00	27.33ab	66.62	6.67ab	21.11	626.72	62.31ab
BK 1	114.87	4.09	4.13b	50.67	19.67b	70.68	5.00ab	25.16	955.56	62.94ab
BK 2	116.87	3.88	4.74ab	44.67	25.00ab	65.74	6.67ab	26.66	729.81	62.29ab
FS	114.33	3.88	4.74ab	48.00	20.00b	67.28	4.33b	21.92	559.28	65.07ab
Mean	111.37	3.88	4.67	47.42	26.50	69.14	7.38	26.88	764.54	66.08
S.E±	5.49	0.19	0.21	2.62	2.73	3.58	1.95	6.07	306.40	4.69
C.V. %	8.5	8.5	7.6	9.6	17.8	9.0	45.8	39.1	69.4	12.3

Means within columns followed by the same letter(s) or without letters are not significantly different from each other according to DMRT at 5% level

Table 6. Mean performance of robusta genotypes on growth and yield characters at Kabirizi B for the 2000/2001

Genotypes	Plant height (cm)	Plant girth (cm)	Inter-node length (cm)	Primary Branches. (No.)	Flowers/ node (No.)	Bearing Pr. Br. (%)	Berries/node (No.)	Fruit set (%)	Yield clean coffee (kg/ha)	Canopy radius (cm)
MS1/95	102.60	3.93	4.48ab	40.00	22.67bc	55.86	4.67	18.59	844.73b	63.63ab
MS2/95	121.53	4.71	4.46ab	52.00	30.67ab	74.14	11.33	37.74	2546.81a	72.69ab
MS3/95	108.13	3.99	4.37b	44.67	25.00bc	69.67	8.00	26.78	1470.02ab	64.24ab
MS5/95	117.87	4.28	5.04a	50.00	24.67bc	74.56	9.33	37.93	1295.81ab	77.45a
MS6/95	112.56	3.85	4.46ab	48.67	27.33bc	73.08	6.00	17.94	1451.17ab	74.25ab
BK 3	115.55	3.57	4.68ab	46.00	25.00bc	69.25	4.67	17.41	1015.16ab	78.22a
BK 4	111.23	4.14	5.01ab	45.33	39.33a	74.32	15.33	36.54	1519.93ab	77.96a
FS	112.67	4.17	4.59ab	44.00	19.67c	71.08	4.00	16.84	449.26b	58.84b
Mean	112.77	4.08	4.64	46.33	26.79	70.25	7.92	26.22	1324.11	70.91
S.E±	9.08	0.36	0.18	3.81	2.73	5.76	3.75	9.04	440.80	4.36
C.V. %	13.9	15.3	6.8	14.2	26.6	14.2	82.0	59.7	57.7	10.6

Means within columns followed by the same letter(s) or without letters are not significantly different from each other according to DMRT at 5% level

4.2.7.2. Percentage fruit set.

Percentage fruit set showed significant differences between genotypes only at Chanika, where MS3/95 had the highest percentage fruit set value of 19.4 and the lowest was for MS1/95 and MS2/95 which had no fruit set. However, Bisheshe recorded the highest trial mean of fruit set (27.35%) while Chanika recorded the lowest (7.14%).

4.2.7.3. Number of berries per node.

Number of berries per node showed significant differences between genotypes only at Kabirizi A, where MS2/95 recorded the highest number of berries per node of 11.67 and the lowest was for FS with a value of 4.33. The other locations did not show significant differences between genotypes on number of berries per node. However, Bisheshe recorded the highest trial mean of number of berries per node (8.38) while Chanika recorded the lowest (2.21).

4.2.7.4. Number of flowers per node

For the genotypes commonly studied across locations, only MS2/95 consistently gave higher number of flowers per node at Kabirizi A and Kabirizi B. However, BK4 which was only grown at Kabirizi B, gave the highest number of flowers per node of all, being

39.33. The other locations did not show statistical differences between genotypes on number of flowers per node. However, Bisheshe recorded the highest trial mean of number of flowers per node (27.63) while Chanika recorded the lowest (22.33).

4.2.7.5. Number of bearing primary branches

MS1/95, MS2/95, MS5/95 and MS6/95 which were commonly studied across locations, consistently gave higher number of bearing primary branches at Chanika and Bisheshe. Of these, the highest was MS2/95 which gave 74.85 bearing primary branches at Bisheshe. However, KR1 and KR2 which were only grown at Chanika, did not differ statistically from the clones which consistently gave more branches at the two locations. The other locations did not show statistical differences between genotypes on number of bearing primary branches. The highest trial mean for number of bearing primary branches was recorded at Kabirizi B (70.25) and the lowest was at Chanika (63.89).

4.2.7.6. Plant height

For the genotypes commonly studied across locations, 4 genotypes viz. MS1/95, MS3/95 MS5/95, MS6/95 and FS consistently gave taller plants at Chanika and Bisheshe. Of these, the highest was 113.38cm for FS followed by 102.50cm for MS5/95 at Bisheshe. However, at Kabirizi B though genotypes did not differ, recorded the highest trial mean of plant height (112.77cm) while Chanika recorded the lowest (89.52cm).

4.2.7.7. Internode length

The commonly studied genotypes across locations, MS1/95, MS2/95, MS6/95 and FS consistently gave longer internodes at Bisheshe, Kabirizi A and Kabirizi B. However, MS5/95 recorded the longest internodes at both Kabirizi A and Kabirizi B of 5.07 and 5.04cm respectively. There was no statistical difference between genotypes on internode length at Chanika. Kabirizi A recorded the highest trial mean of internode length (4.67cm) while Bisheshe recorded the lowest (4.44cm).

4.2.7.8. Number of primary branches

For the genotypes commonly studied across locations, only MS5/95 consistently gave higher number of primary branches at Chanika and Bisheshe. The other locations did not show significant differences between genotypes on number of primary branches. The lowest trial mean was obtained at Chanika (32.00) while the highest was at Kabirizi A (47.42). Generally, number of primary branches were higher at both Kabirizi A and Kabirizi B as compared to Bisheshe and Chanika.

4.2.7.9. Canopy radius

For canopy radius it is only at Bisheshe where there was no statistical difference between the genotypes. The commonly studied genotypes across locations, MS3/95, MS5/95, and MS6/95 consistently gave larger canopy radius at Chanika, Kabirizi A and Kabirizi B. Of these, the largest was 79.04 for MS3/95 at Kabirizi A, followed by 77.45 for MS5/95 at Kabirizi B. Conapy radius was generally smaller at Chanika, ranging from 47.55-61.99cm as compared to both Kabirizi A and Kabirizi B, ranging from 58.84-79.04cm.

The largest trial mean was obtained at Kabirizi B (70.91cm) and the smallest trial mean was at Chanika (55.14cm).

4.2.7.10. Plant girth

For plant girth, there was no consistent performance of the genotypes tested across the four locations although at Chanika and Bisheshe there were statistical differences between the genotypes. Plant girth was generally lower at Chanika, ranging from 2.01-3.41cm as compared to Bisheshe which ranged from 2.56-3.96cm. However, Kabirizi A and Kabirizi B had higher trial means as compared to Chanika and Bisheshe. The highest trial mean was recorded at Kabirizi B (4.08cm) while the smallest was at Chanika (2.70cm).

4.2.8. Mean performance of eight robusta genotypes for quality characters, disease severity and insect pests infestations at each location.

Mean values for quality attributes are shown in Tables 7, 8, 9 and 10. CLR, CBB and CBM are included in these tables as among factors that contributes to low quality of coffee.

4.2.8.1. Percentage clean coffee

Percentage clean coffee showed significant differences among genotypes only at Kabirizi A. MS5/95 had the highest percentage of clean coffee of 64% while MS6/95 recorded

the lowest value (53.9%). The highest trial mean was obtained at Kabirizi A (58.6%) while the lowest value was at Chanika (25.5%).

4.2.8.2. Hundred seed weight

Statistical differences among the genotypes for 100 seed weight was only found at Kabirizi A where the highest was 18.80g for BK1 and the lowest was 13.87g for FS. However, the lowest trial mean was recorded at Chanika (6.11g) while the highest was recorded at Kabirizi A (15.75g) followed by Kabirizi B (14.41).

Table 7. Mean performance of robusta genotypes on quality characters at Chanika for the 2000/2001

Genotypes	Clean coffee (%)	100 seed weight (g)	Dry cherries in1/2kg (No.)	Screen 16 clean coffee (%)	Screen 14 clean coffee (%)	Screen 13 clean coffee (%)	CBB count (%)	CBM count (%)	CLR severity (0–8)
MS1/95	0.00	0.00	0.00b	0.00b	0.00b	0.00b	0.00	0.00	0.00
MS2/95	0.00	0.00	0.00b	0.00b	0.00b	0.00b	0.00	0.00	0.00
MS3/95	40.09	9.33	1077.00a	41.10ab	21.00a	4.23ab	0.85	1.11	0.00
MS5/95	21.20	4.60	877.00ab	39.53ab	20.40a	4.90ab	0.77	0.83	0.00
MS6/95	39.64	9.83	950.00a	44.63ab	13.53ab	6.87a	1.00	0.82	0.00
KR 1	36.87	10.07	772.00ab	50.03a	12.27ab	3.63ab	1.07	1.33	0.00
KR 2	19.85	6.23	362.33ab	29.13ab	3.10ab	0.90ab	0.78	0.97	0.00
FS	46.71	8.83	873.33ab	41.83ab	20.53a	4.60ab	0.97	1.21	0.00
Mean	25.54	6.11	613.96	30.78	11.35	3.14	0.86	0.96	0.00
S.E±	13.25	3.29	250.30	13.24	5.20	1.87	0.37	0.23	0.00
C.V. %	9.0	93.3	70.6	74.5	79.4	103.3	23.2	41.2	0.0

Means within columns followed by the same letter(s) or without letters are not significantly different from each other according to DMRT at 5% level

Table 8. Mean performance of robusta genotypes on quality characters at Bisheshe for the 2000/2001.

Genotypes	Clean coffee (%)	100 seed weight (g)	Dry cherries in1/2kg (No.)	Screen 16 clean coffee (%)	Screen 14 clean coffee (%)	Screen 13 clean coffee (%)	CBB count (%)	CBM count (%)	CLR severity (0–8)
MS1/95	26.15	7.35	611.50	28.20	18.50bc	3.30d	0.89	0.87	0.00
MS2/95	28.46	7.15	664.00	32.50	13.90c	3.60d	1.10	0.88	0.00b
MS3/95	53.94	12.70	1503.50	49.10	41.90ab	9.00ab	1.13	1.22	0.00b
MS5/95	63.48	12.75	1568.50	62.55	26.45abc	10.15ab	1.01	1.37	0.00b
MS6/95	29.06	7.40	612.00	34.50	13.00c	2.45d	1.04	0.95	0.00b
KR 3	67.85	13.30	1473.00	50.65	39.75ab	3.95cd	1.09	1.24	0.00b
KR 4	60.63	13.40	1530.50	60.50	29.15abc	6.95bc	0.93	1.16	0.00b
FS	61.48	12.65	1421.00	43.95	44.15a	11.90a	0.86	0.99	0.87a
Mean	48.88	10.84	1173.00	45.24	28.35	6.41	1.01	1.09	0.73
S.E±	15.43	3.71	319.00	18.22	6.67	0.92	0.25	0.20	0.002
C.V. %	44.6	48.4	38.5	56.9	33.2	20.3	35.7	26.0	1.7

Means within columns followed by the same letter(s) or without letters are not significantly different from each other according to DMRT at 5% level

Table 9. Mean performance of robusta genotypes on quality characters at Kabirizi A for the 2000/2001

Genotypes	Clean coffee (%)	100 seed weight. (g)	Dry cherries in 1/2kg (%)	Screen 16 clean coffee (%)	Screen 14 clean coffee (%)	Screen 13 clean coffee (%)	CBB count (%)	CBM count (%)	CLR severity (0–8)	Flavour (1–6)	Body (1–3)
MS1/95	55.23ab	15.37b	1345.33a	85.47a	12.80b	0.93b	1.31	1.12	0.81c	3.67	1.58ab
MS2/95	58.03ab	15.87ab	1243.67ab	74.13ab	23.20ab	1.93ab	1.97	1.18	0.77c	2.33	1.46ab
MS3/95	59.09ab	17.17ab	1049.67ab	85.80a	11.73b	1.47b	1.44	1.17	1.50a	3.33	1.58ab
MS5/95	64.05a	14.87b	1289.00ab	63.73ab	33.67ab	2.20ab	1.02	1.07	1.40ab	2.33	1.46ab
MS6/95	53.85b	15.37b	1284.33ab	69.33ab	22.13ab	2.87ab	2.17	1.29	0.81c	2.67	1.46ab
BK 1	62.05ab	18.80a	975.00b	66.20ab	25.87ab	3.13ab	1.97	1.32	1.05bc	2.67	1.34b
BK 2	59.78ab	14.70b	1180.67ab	77.47ab	19.33ab	2.33ab	2.23	1.09	0.73c	3.67	1.68a
FS	56.90ab	13.87b	1262.67ab	47.53b	44.27a	6.53a	1.23	1.09	1.51a	2.67	1.58ab
Mean	58.62	15.75	1203.79	71.21	24.13	2.67	1.67	1.17	1.07	2.92	1.52
S.E±	26.45	0.93	99.20	9.29	8.20	1.37	0.53	0.12	0.12	0.74	0.10
C.V. %	7.8	10.2	14.3	22.6	58.9	88.5	55.0	17.6	19.5	44.0	11.0

Means within columns followed by the same letter(s) or without letters are not significantly different from each other according to DMRT at 5% level

Table 10. Mean performance of robusta genotypes on quality characters at Kabirizi B for the 2000/2001

Genotypes	Clean coffee (%)	100 seed wt. (g)	Dry cherries in 1/2kg (No.)	Screen 16 clean coffee (%)	Screen 14 clean coffee (%)	Screen 13 clean coffee (%)	CBB count (%)	CBM count (%)	CLR severity (0–8)	Flavour (1–6)	Body (1–3)
MS1/95	40.01	11.27	846.67	53.53	11.33c	1.23b	0.94	0.82	0.72b	3.00	1.58a
MS2/95	60.34	15.40	1174.33	78.07	19.73bc	1.67b	1.36	1.19	0.94b	2.67	1.46a
MS3/95	40.96	10.87	735.00	60.47	5.40c	0.53b	1.01	0.85	1.01b	3.33	1.34ab
MS5/95	61.73	15.03	1189.33	82.53	15.80bc	1.20b	1.01	1.00	1.64a	3.00	1.58a
MS6/95	56.17	15.70	1172.33	79.60	16.93bc	2.33b	1.17	1.05	0.71b	2.00	1.22b
BK 3	54.97	16.13	1182.33	65.73	29.33ab	3.40ab	1.19	1.12	0.79b	3.33	1.46a
BK 4	54.55	16.63	1019.33	80.40	16.13bc	2.33b	1.15	1.10	0.72b	3.00	1.46a
FS	57.85	14.27	1369.33	53.53	38.73a	5.87a	1.09	0.97	1.54a	3.00	1.58a
Mean	53.32	14.41	1086.08	69.23	19.17	2.32	1.12	1.01	1.01	2.92	1.46
S.E±	9.45	2.68	208.40	13.10	4.18	0.99	0.21	0.11	0.09	0.65	0.07
C.V. %	30.7	32.3	33.2	32.8	37.7	74.0	32.4	18.7	14.6	38.5	8.3

Means within columns followed by the same letter(s) or without letters are not significantly different from each other according to DMRT at 5% level

4.2.8.3. Number of dry cherries in 1/2kg

For the genotypes commonly studied across locations, 4 genotypes viz. MS3/95, MS5/95, MS6/95 and FS consistently gave higher number of dry cherries at Kabirizi A and Chanika. Of these, the highest was 1345.33 for MS1/95, followed by 1289.00 for MS5/95 both from Kabirizi A. Number of dry cherries was generally lower at Chanika, ranging from 0-1077 as compared to Kabirizi A which ranged from 975-1345.33. The other locations did not show significant differences between genotypes on number of dry cherries. The lowest trial mean was obtained at Chanika (613.96) while the highest was at Kabirizi A (1203.79).

4.2.8.4. Percentage screen 16 clean coffee

Of the commonly studied genotypes across locations, MS3/95, MS5/95, and MS6/95 consistently gave larger percentage of screen 16 clean coffee at Chanika and Kabirizi A. However,the largest value recorded was 85.80% for MS3/95 followed by 85.47% for MS1/95 both at Kabirizi A. Percentage screen 16 at Chanika was generally lower ranging from 0-50.03% while the highest percentage was at Kabirizi A ranging from 47.53-85.80%. The lowest trial mean for percentage screen 16 was obtained at Chanika (30.78%) while the highest was at Kabirizi A (71.21%). The other locations did not show significant differences between genotypes on percentage screen 16 clean coffee.

4.2.8.5. Percentage screen 14 clean coffee

For the genotypes commonly studied across locations, FS consistently gave higher percentage of screen 14 clean coffee across all locations with the highest percentage (44.27%) at Kabirizi A and the lowest (20.53%) at Chanika. However, the highest (28.35%) trial mean for percentage screen 14 was recorded at Bisheshe and the lowest (11.35%) was recorded at Chanika.

4.2.8.6. Percentage screen 13 clean coffee

FS, among the commonly studied genotypes across locations, consistently gave higher percentage of screen 13 clean coffee across all locations with the highest percentage (11.90%) at Bisheshe and the lowest (4.60%) at Chanika. The highest trial mean of 6.41% was recorded at Bisheshe and the lowest was recorded at Kabirizi B (2.32%).

4.2.8.7. Percentage Coffee Berry Borer (CBB) count in 1/2kg of cherries

For CBB count across locations, there was no significant difference between the genotypes studied. However, the lowest trial mean of (0.86%) was recorded at Chanika and the highest (1.67%) was recorded at Kabirizi A.

4.2.8.8. Percentage Coffee Berry Moth (CBM) count in 1/2kg of cherries

For CBM count across locations, there was no significant difference between the genotypes recorded. However, the lowest trial mean of 0.96% was recorded at Chanika while the highest (1.17%) was recorded at Kabirizi A.

4.2.8.9. Coffee Leaf Rust (CLR) severity

At Chanika, there was no CLR while at Bisheshe, Kabirizi A and Kabirizi B, the genotypes showed statistical differences for CLR severity. For the genotypes commonly studied across locations, only MS6/95 consistently showed lower CLR severity at Kabirizi A, Kabirizi B and Bisheshe. The lowest trial mean of 0.00 was recorded at Chanika and the highest (1.07) was recorded at Kabirizi A.

4.2.8.10. Flavour and Body

Flavour and body was analysed for Kabirizi A and Kabirizi B locations only where enough samples warranting liquor test was obtained. For the two sites, flavour did not show statistical differences among the genotypes while body showed statistical differences among the genotypes. Among genotypes tested across locations, MS1/95,

MS2/95, MS3/95, MS5/95 and FS consistently gave higher values of body at Kabirizi A and Kabirizi B.

4.2.9. ANOVA for combined data over locations for yield and components of yield for six genotypes.

The analysis of variance of yield and its components for six robusta genotypes combined over four locations is given in Table 11. There were no significant genotypic effects observed for all the variables studied. Locations differed significantly on plant height, plant girth, canopy radius, number of primary branches, percentage bearing primary branches and yield of clean coffee. Significant Genotype x Location interaction was observed only for percentage bearing primary branches.

4.2.9.1. Location means for components of yield which showed significant location effect in the ANOVA.

Location means for the variables which indicated significant differences in the ANOVA are shown in Table 12a. Kabirizi A and Kabirizi B showed better performance on yield and its components as compared to Bisheshe and Chanika.

Table 11. ANOVA extract and probability levels for growth and yield characters of six robusta coffee genotypes grown in four locations in Kagera region for the 2000/2001 (Mean squares given)

Source of Variation.	Df	Mean squares and P									
		Plant height	Plant girth	Canopy radius	Inter-node length	Primary Branches (No.)	Flowers/ node (No.)	Bearing Pr. Br. (%)	No.of berries/ node	Fruit set (%)	Yield of clean coffee
Replication	1	337.66	1.08	471.63	0.10	44.08	3.52	15.50	44.64	467.06	346543.4
Location	3	3494.71**	10.38**	1098.89**	0.38	29.68**	167.13	654.93**	69.45	346.29	5110046.6**
Genotype	5	101.98	0.57	126.19	0.08	1250.08	40.87	13.75	25.89	692.84	571465.8
Gen. x Loc.	15	111.96	0.20	101.79	0.14	40.62	75.58	54.18*	15.24	124.73	573072.8
Error	23	164.10	0.28	119.68	0.22	34.69	65.13	21.69	28.07	220.17	446300.3
Total	47	16903.55	44.35	8678.76	8.75	5349.92	3340.98	3360.54	1256.71	11211.90	37395010.79

Table 12a. Location means for components of yield which showed significant location effects.

Location	Variables					
	Plant height	Plant girth	Canopy radius	Pr. Br. (No.)	Bearing Pr.Br. (%)	Yield of clean coffee (Kg/ha.)
1. Chanika	87.03	2.49	52.83	30.00	58.10	358.80
2. Bisheshe	101.40	3.48	63.87	38.50	70.41	619.39
3. Kabirizi A	115.12	4.10	69.85	50.00	72.87	891.89
4. Kabirizi B	126.46	4.66	75.12	51.67	74.29	1853.75
Mean	107.50	3.68	65.42	42.54	68.92	930.96
SE±	3.70	0.15	3.16	2.08	1.34	192.85
$LSD_{0.05}$	10.82	0.44	9.24	6.09	0.39	564.28

4.2.9.2. Genotype x Location means for percentage bearing primary branches.

Table 12b shows the genotype x location means for percentage bearing primary branches. The highest number of percentage bearing primary branches was obtained with MS3/95 at Kabirizi B (76.38%) while the lowest (48.07%) for the same genotype MS3/95 was obtained at Chanika.

Table 12b. Combination means of Genotype x Location for percentage bearing primary branches.

Genotypes	Bisheshe	Chanika	Kabirizi A	Kabirizi B	Mean ± 1.65
MS1/95	65.83	65.77	74.63	72.25	69.62
MS2/95	74.84	52.13	73.39	75.49	68.96
MS3/95	75.00	48.07	71.62	76.38	67.77
MS5/95	73.81	56.66	74.96	74.88	70.08
MS6/95	70.48	65.69	68.97	75.41	70.14
FS	62.50	60.26	73.64	71.32	66.93
Mean ± 1.73	70.41	58.10	72.87	74.29	

$LSD_{0.05}$ within table is ± 3.92

4.2.10. Combined means over locations for yield and components of yield of six robusta genotypes.

Genotypic means over locations for yield and growth variables which did not show significant G x E are shown in Table 13. Plant girth and percentage fruit set are shown to have significant genotypic effect, whereby MS6/95 had the thinnest (3.19cm) stems, the other 5 genotypes for plant girth were statistically the same on girth ranging from 3.58cm for MS3/95 to 3.92cm for MS2/95. Similarly, MS3/95 had the highest percentage of fruit set (31.42%) while MS6/95 had the least fruit set percentage (13.49%)

Table 13. Mean performance of robusta genotypes on growth and yield characters of six robusta genotypes combined over four locations during the 2000/2001

Genotypes	Plant height (cm)	Plant girth (cm)	Canopy radius (cm)	Internode length (cm)	Primary Branches (No.)	Bearing Pr. Br. (%)	Flowers/ node (No.)	Berries /node (No.)	Fruit set (%)	Yield clean coffee (kg/ha).
MS1/95	106.14	3.81a	60.20	4.56	40.50	69.62	27.50	6.25	19.61ab	617.04
MS2/95	109.34	3.92a	61.92	4.43	44.50	68.97	25.00	7.50	23.50ab	1216.55
MS3/95	105.86	3.58ab	69.03	4.54	42.75	67.77	29.63	9.50	31.42a	1216.66
MS5/95	110.37	3.84a	68.57	4.53	45.00	70.08	29.63	9.00	29.63ab	993.64
MS6/95	101.84	3.19b	69.10	4.33	42.00	70.14	25.00	4.62	13.49b	912.84
FS	111.44	3.76a	63.69	4.61	40.50	66.93	25.13	6.50	24.46ab	629.00
Mean	107.50	3.68	65.42	4.50	42.54	68.92	26.98	7.23	23.69	931.00
S.E ±	4.53	0.18	3.87	0.15	2.08	1.73	2.85	1.87	5.25	236.19
C.V%	11.9	14.3	16.7	9.1	13.8	7.1	29.9	73.1	62.6	71.8

Means within columns followed by the same letter(s) or without letters are not significantly different from each other according to DMRT at 5% level

4.2.11. ANOVA of combined data over two locations for quality components.

The analysis of variance for quality components of six robusta genotypes across two locations is given in Table 14a. Significant genotypic effects were observed for percentage screen 16, percentage screen 14, and percentage screen 13. Locations differed significantly for percentage CBB count.

4.2.11.1 ANOVA of combined data over four locations for Coffee Leaf Rust severity.

Coffee Leaf Rust was scored over the four locations studied and the analysis of variance is given in Table 14b. Locations, genotype x location interactions and genotypes were observed to differ significantly for Coffee Leaf Rust severity.

Table 14a. ANOVA extract and probability levels for quality characters of six robusta coffee genotypes grown in two locations in Kagera region for the 2000/2001 (Meansquares given)

Source of Variation	df	Means and P							
		Clean coffee (%)	100 seed weight (g)	Dry cherries in 1/2kg (No.)	Screen 16 clean coffee (%)	Screen 14 clean coffee (%)	Screen 13 clean coffee (%)	CBB count (%)	CBM count (%)
Replication	1	2416.03	0.81	3151.04	59.53	55.21	0.33	0.39	0.37
Location	1	1991.08	0.54	29190.37	513.37	361.93	6.83	2.48**	0.32
Genotype	5	3519.20	4.06	15490.17	1104.83**	730.43**	28.59**	0.38	0.02
Gen. x Loc.	5	1399.94	0.91	8822.77	124.11	91.51	1.89	0.31	0.02
Error	11	1257.51	2.30	15814.22	140.77	92.32	4.59	0.34	0.08
Total	23	42835.36	51.46	327862.62	8266.10	5542.37	209.91	10.08	1.78

Table 14b. ANOVA extract and probability levels for CLR severity of six robusta coffee genotypes grown in four locations in Kagera region for the 2000/2001 (Meansquares given)

Source of Variation	df	Means and P
		CLR severity (0-8)
Replication	1	0.003
Location	3	0.343**
Genotype	5	0.620**
Gen. x Loc.	15	0.120**
Error	23	0.02
Total	47	33.27

4.2.11.2. Location means for the variables which indicated significant location effects over two locations (Kabirizi A and Kabirizi B)

Table 14c shows the location means for the variable which showed significant location effects. Results indicated that Kabirizi B had lower CBB scores than Kabirizi A.

Table 14c. Location means of the quality variables which showed significant location effects for the two studied locations.

Location	Variable
	Coffee Berry Borer count (%)
1. Kabirizi A	1.72
2. Kabirizi B	1.07
Mean	1.39
SE ±	0.17
$LSD_{0.05}$	0.53

4.2.11.3. Genotype x Location means for coffee leaf rust severity analysed over four locations.

Table 14d shows the genotype x location means for coffee leaf rust severity. Results show that the lowest incidence was obtained at Bisheshe and Chanika for all genotypes except FS and also at Kabirizi B for MS1/95 and MS6/95.

Table 14d. Combination means of Genotype x Location for Coffee Leaf Rust severity

Genotypes	Bisheshe	Chanika	Kabirizi A	Kabirizi B	Mean ± 0.14
MS1/95	0.00	0.00	0.74	0.00	0.18
MS2/95	0.00	0.00	0.80	0.88	0.42
MS3/95	0.00	0.00	1.55	0.93	0.62
MS5/95	0.00	0.00	1.49	1.64	0.78
MS6/95	0.00	0.00	0.77	0.00	0.19
FS	0.87	0.00	1.61	1.52	0.83
Mean ± 0.11	0.14	0.0	1.16	0.83	

$LSD_{0.05}$ within table is ± 0.32

4.2.11.4. Combined means over two locations (Kabirizi A and Kabirizi B) for quality components, of six robusta genotypes.

Genotypic means for six genotypes over the two locations for quality variables are shown in Table 15. Percentage screen 16, percentage screen 14, percentage screen 13 and coffee leaf rust showed statistical genotypic differences. For percentage screen 16, MS3/95 had the highest (86.10%) but did not differ statistically with MS1/95, MS2/95, MS5/95 and MS6/95 while FS had the lowest (41.15%). In case of percentage screen 14, MS3/95 recorded the lowest (11.85%) but did not differ statistically with the other genotypes except FS which recorded the highest (48.70%). MS1/95 and MS3/95 recorded the lowest (1.35%) but did not differ statistically with MS2/95, MS5/95 and MS6/95 while FS recorded the highest (8.10%). For CLR severity MS1/95, MS2/95 and

MS6/95 recorded the lowest while FS recorded the highest but did not differ statistically with MS3/95 and MS5/95.

4.2.12. Mean performance of six robusta genotypes on growth and yield characters at each location

Mean values for yield and components of yield of six robusta genotypes at all locations are shown in Tables 16, 17, 18 and 19.

4.2.12.1.Clean coffee yield

For the six genotypes, 4 genotypes viz. MS1/95, MS2/95, MS3/95 and MS6/95 consistently gave higher yields at Kabirizi B and Bisheshe. Of these, the highest was 3285.39kg/ha. for MS2/95 followed by 2205.03kg/ha.for MS3/95 at Kabirizi B.Yields were generally lower at Bisheshe, ranging from 259.78-1058kg/ha.as compared to Kabirizi B which ranged from 650.97-3285.39kg/ha. The other locations did not show significant differences between genotypes on yield. The lowest trial mean was obtained at Bisheshe (108.44kg/ha) while the highest was at Kabirizi B (1853.75kg/ha).

4.2.12.2.Percentage fruit set.

Percentage fruit set showed significant differences between genotypes only at Kabirizi A, where MS2/95 had the highest fruit set value of 34.97% while MS6/95 had the lowest value of 9.09%. However, Bisheshe recorded the highest trial mean of fruit set (29.02%) while Chanika recorded the lowest (12.62%).

Table 15. Mean performance of robusta genotypes on quality characters of six robusta genotypes combined over two locations (Kabirizi A and Kabirizi B) for the 2000/2001

Genotypes	Clean coffee (%)	100 seed weight (g)	Dry cherries in 1/2kg (No.)	Screen 16 clean coffee (%)	Screen 14 clean coffee (%)	Screen 13 clean coffee (%)	CBB count (%)	CBM count (%)	CLR severity (0-8)
MS1/95	59.32	16.17	1312.75	84.25a	13.75b	1.35b	1.21	1.02	0.02b
MS2/95	58.21	15.87	1161.75	80.10a	18.00b	1.40b	1.69	1.14	0.24b
MS3/95	60.84	16.20	1137.00	86.10a	11.85b	1.35b	1.46	1.07	1.20a
MS5/95	63.42	14.83	1219.25	73.70a	24.25b	1.70b	0.99	1.06	1.95a
MS6/95	55.99	15.75	1233.25	77.65a	18.85b	2.20b	1.78	1.21	0.05b
FS	55.63	13.62	1238.75	41.15b	48.70a	8.10a	1.23	1.05	1.97a
Mean	58.90	15.41	1217.13	73.83	22.57	2.68	1.39	1.09	0.90
S.E ±	17.73	0.76	62.88	5.93	4.80	1.07	0.29	0.14	0.29
C.V%	6.02	9.84	10.33	16.07	42.58	79.73	42.13	25.83	64.07

Means within columns followed by the same letter(s) or without letters are not significantly different from each other according to DMRT at 5% level

Table 16. Mean performance of robusta genotypes on growth and yield characters of six robusta genotypes at Bisheshe for the 2000/2001

Genotypes	Plant height (cm)	Plant girth (cm)	Canopy radius (cm)	Inter-node length (cm)	Primary Branches (No.)	Flowers/ node (No.)	Bearing Pr. Br. (%)	Berries/ node (No.)	Fruit set (%)	Yield clean coffee (kg/ha)
MS1/95	93.17	3.68a	59.10	4.68	35.00ab	29.00	65.84	9.00	27.28	527.20ab
MS2/95	114.00	3.96a	68.04	4.39	44.00a	27.50	74.85	8.50	28.34	607.42ab
MS3/95	92.50	3.53a	64.63	4.56	44.00a	28.50	75.00	10.50	35.42	728.90ab
MS5/95	102.50	3.61a	62.57	4.09	42.00ab	31.00	73.81	10.00	30.98	259.78b
MS6/95	92.84	2.56b	64.54	4.37	34.00ab	26.50	70.49	6.00	16.22	534.83ab
FS	113.38	3.54a	64.37	4.95	32.00b	29.00	62.50	11.00	35.86	1058.21a
Mean	101.40	3.48	63.88	4.51	38.50	28.58	70.42	9.17	29.02	108.44
S.E±	6.28	0.23	5.75	0.26	3.13	3.08	3.28	1.99	8.81	98.90
C.V%	8.7	9.2	12.7	8.0	11.5	15.2	6.6	30.7	42.9	129.0

Means within columns followed by the same letter(s) or without letters are not significantly different from each other according to DMRT at 5% level

Table 17. Mean performance of robusta genotypes on growth and yield characters of six robusta genotypes at Chanika for the 2000/2001

Genotypes	Plant height (cm)	Plant girth (cm)	Canopy radius (cm)	Internode length (cm)	Primary Branches (No.)	Flowers/ node (No.)	Bearing Pr. Br. (%)	Berries/ node (No.)	Fruit set (%)	Yield clean coffee (kg/ha)
MS1/95	93.00	2.85	51.13ab	4.67	33.00	18.50	65.77	0.00b	0.00	0.00
MS2/95	72.46	2.28	42.83b	4.04	28.00	7.50	52.14	0.00b	0.00	0.00
MS3/95	86.75	1.86	51.15ab	4.12	23.00	29.00	48.08	8.90a	29.10	871.01
MS5/95	92.38	2.84	53.27ab	4.18	30.00	33.50	56.67	7.60a	22.14	756.41
MS6/95	84.59	2.32	62.59a	4.13	35.00	14.50	65.69	0.95b	1.73	397.00
FS	93.00	2.79	56.00ab	4.36	31.00	26.00	60.26	5.50ab	22.72	128.36
Mean	87.03	2.49	52.83	4.25	30.00	21.50	58.10	3.82	12.62	358.80
S.E±	8.32	0.33	4.94	0.44	4.55	7.95	4.88	2.51	6.53	288.40
C.V%	13.5	18.7	13.2	14.6	21.4	52.3	11.9	92.6	73.2	113.7

Means within columns followed by the same letter(s) or without letters are not significantly different from each other according to DMRT at 5% level

Table 18. Mean performance of robusta genotypes on growth and yield characters of six robusta genotypes at Kabirizi A for the 2000/2001

Genotypes	Plant height (cm)	Plant girth (cm)	Canopy radius (cm)	Inter-node length (cm)	Primary Branches (No.)	Flowers/ node (No.)	Bearing Pr. Br. (%)	Berries/ node (No.)	Fruit set (%)	Yield clean coffee (kg/ha)
MS1/95	114.20ab	3.96bc	60.27b	4.28	47.00ab	32.50	74.64	9.50ab	29.52ab	673.89
MS2/95	119.30ab	4.31ab	61.40b	4.83	49.00ab	32.50	73.40	11.50a	34.97a	973.39
MS3/95	120.10ab	4.49a	87.47a	4.88	53.00ab	27.50	71.62	7.50ab	27.25ab	1061.72
MS5/95	121.10a	4.27ab	79.60ab	4.80	56.00a	29.00	75.00	8.50ab	29.33ab	1402.79
MS6/95	103.90b	3.52c	63.64ab	4.40	45.00b	25.50	69.00	3.00b	9.09b	561.12
FS	112.10ab	4.04ab	66.74ab	4.45	50.00ab	21.00	73.65	4.00ab	18.99ab	678.48
Mean	115.12	4.10	69.85	4.60	50.00	28.00	72.89	7.33	24.86	891.90
S.E±	4.38	0.14	6.78	0.19	2.50	3.84	2.15	2.11	5.98	414.90
C.V%	5.4	4.7	13.9	5.9	7.1	19.4	4.2	40.8	34.0	65.8

Means within columns followed by the same letter(s) or without letters are not significantly different from each other according to DMRT at 5% level

Table 19. Mean performance of robusta genotypes on growth and yield characters of six robusta genotypes at Kabirizi B for the 2000/2001

Genotypes	Plant height (cm)	Plant girth (cm)	Canopy radius (cm)	Inter-node length (cm)	Primary. Branches . (No.)	Flowers/ node (No.)	Bearing Pr. Br. (%)	Berries/ node (No.)	Fruit set (%)	Yield clean coffee (kg/ha.)
MS1/95	124.20	4.74ab	70.30ab	4.62	47.00	30.00	72.26	6.50	21.64	1267.09ab
MS2/95	131.60	5.11a	75.44ab	4.49	57.00	32.50	75.49	10.00	30.69	3285.39a
MS3/95	124.10	4.44b	72.87ab	4.60	51.00	33.50	76.39	11.50	33.92	2205.03ab
MS5/95	125.50	4.65ab	78.83ab	5.06	52.00	25.00	74.89	9.00	36.06	1555.59ab
MS6/95	126.04	4.36b	85.64a	4.43	54.00	33.50	75.42	9.00	26.92	2158.43ab
FS	127.30	4.67ab	67.67b	4.70	49.00	24.50	71.33	5.50	20.27	650.97b
Mean	126.46	4.66	75.13	4.65	51.67	29.83	74.30	8.58	28.25	1853.75
S.E±	7.36	0.15	4.15	0.21	4.41	2.93	2.91	1.93	4.68	651.40
C.V%	8.2	4.6	7.8	6.4	12.1	13.9	5.5	31.9	23.4	49.7

Means within columns followed by the same letter(s) or without letters are not significantly different from each other according to DMRT at 5% level

4.2.12.3. Number of berries per node.

Number of berries per node showed statistical differences between genotypes at Kabirizi A and Chanika, where MS2/95 recorded the highest number of berries per node of 11.50 and the lowest was for MS1/95 and MS2/95 at Chanika. The other locations did not show significant differences between genotypes on number of berries per node. However, Kabirizi B recorded the highest trial mean of number of berries per node (8.58) while Chanika recorded the lowest (3.82).

4.2.12.4. Number of flowers per node

All locations did not show statistical differences between genotypes on number of flowers per node. However, Kabirizi B recorded the highest trial mean of number of flowers per node (29.83) while Chanika recorded the lowest (21.50).

4.2.12.5. Percentage bearing primary branches

The locations did not show statistical differences between genotypes on number of bearing primary branches. However, the highest trial mean for number of bearing primary branches was recorded at Kabirizi B (74.30%) and the lowest was at Chanika (58.10%).

4.2.12.6. Plant height

It's only at Kabirizi A where the genotypes showed statistical difference on plant height. MS5/95 being the tallest genotype with 121.10cm and MS6/95 the shortest (103.90cm). However, Kabirizi B recorded the highest trial mean of plant height (126.46cm) while Chanika recorded the lowest (87.03cm).

4.2.12.7. Internode length

All locations did not show genotypic differences on internode length. However, the highest trial mean for internode length was recorded at Kabirizi B (4.65cm) and the lowest at Chanika which is (4.25cm).

4.2.12.8. Number of primary branches

For the six genotypes, 4 genotypes viz. MS1/95, MS2/95, MS3/95 and MS5/95 consistently gave higher number of primary branches at Kabirizi A and Bisheshe. Of these, the highest was 56.00 for MS5/95 at Kabirizi A. Number of primary branches were generally higher at Kabirizi A, ranging from 45-56 as compared to Bisheshe which ranged from 32-44. The other locations did not show significant differences between genotypes on number of primary branches. The lowest trial mean was obtained at Chanika (30.00) while the highest was at Kabirizi B (51.67).

4.2.12.9. Canopy radius

Across locations, the genotypes MS3/95, MS5/95, and MS6/95 consistently gave larger canopy radius at Chanika, Kabirizi A and Kabirizi B. Of these, the largest was 87.47cm for MS3/95 at Kabirizi A, followed by 85.64cm for MS6/95 at Kabirizi B. Bisheshe had no statistical differences between the genotypes for canopy radius. Conapy radius was generally smaller at Chanika, ranging from 42.83-62.59cm as compared to both Kabirizi A and Kabirizi B, which ranged from 60.27-87.47cm. The largest canopy radius trial mean was obtained at Kabirizi B (75.13cm) and the smallest trial mean was at Chanika (52.83cm).

4.2.12.10. Plant girth

Among the six genotypes, 3 genotypes viz. MS2/95, MS5/95 and FS consistently gave larger plant girth at Kabirizi A, Kabirizi B and Bisheshe. Plant girth was generally lower at Bisheshe, ranging from 2.56-3.96cm as compared to Kabirizi A and Kabirizi B which ranged from 3.52-5.11cm. However, Kabirizi A and Kabirizi B had higher trial means as compared to Chanika and Bisheshe. The highest trial mean was recorded at Kabirizi B (4.66cm) while the smallest was at Chanika (2.49cm).

4.2.13. Mean performance of six robusta genotypes for quality variables at each location.

Mean performance values for quality attributes of six genotypes are shown in Tables 20, 21, 22 and 23.

4.2.13.1. Percentage clean coffee

Percentage clean coffee showed statistical differences among genotypes at Kabirizi B and Chanika. Among the six genotypes studied across locations, 3 genotypes viz. MS3/95, MS5/95 and MS6/95 consistently gave higher percentage of clean coffee at Kabirizi B and Chanika. MS3/95 had the highest percentage of clean coffee of 61.44% at Kabirizi B while MS1/95 and MS2/95 at Chanika had the lowest values. However, the highest trial mean was obtained at Kabirizi B (59.81%) while the lowest value was at Chanika (36.84%).

Table 20. Mean performance of robusta genotypes on quality characters of six robusta genotypes at Bisheshe for 2000/2001

Genotypes	Clean coffee (%)	100seed weight (g)	Dry cherries in 1/2kg (No.)	Screen 16 clean coffee (%)	Screen 14 clean coffee (%)	Screen 13 clean coffee (%)	CBB count (%)	CBM count (%)	CLR severity (0–8)
MS1/95	26.15	7.35	611.50	28.20	18.50ab	3.30c	0.89	0.87	0.00b
MS2/95	28.46	7.15	664.00	32.50	13.90b	3.60c	1.10	0.88	0.00b
MS3/95	53.94	12.70	1503.50	49.10	41.90a	9.00b	1.13	1.22	0.00b
MS5/95	63.48	12.75	1568.50	62.55	26.45ab	10.15ab	1.01	1.41	0.00b
MS6/95	29.06	7.40	612.00	34.50	13.00b	2.45c	0.96	0.95	0.00b
FS	61.48	12.65	1421.00	43.95	44.15a	11.90a	0.86	0.99	0.87a
Mean	43.76	10.00	1063.42	41.80	26.32	6.73	0.99	1.05	0.15
S.E±	16.24	4.03	335.40	20.50	6.78	0.74	0.26	0.21	0.00
C.V%	52.5	57.0	44.6	69.4	36.4	15.6	36.4	28.4	2.0

Means within columns followed by the same letter(s) or without letters are not significantly different from each other according to DMRT at 5% level

Table 21. Mean performance of robusta genotypes on quality characters of six robusta genotypes at Chanika for the 2000/2001

Genotypes	Clean coffee (%)	100seed weight (g)	Dry cherries in 1/2kg (No.)	Screen 16 clean coffee (%)	Screen 14 clean coffee (%)	Screen 13 clean coffee (%)	CBB count (%)	CBM count (%)	CLR severity (0–8)
MS1/95	0.00b	0.00b	0.00c	0.00b	0.00b	0.00b	0.00b	0.00b	0.00
MS2/95	0.00b	0.00b	0.00c	0.00b	0.00b	0.00b	0.00b	0.00b	0.00
MS3/95	59.73a	14.00a	1615.50a	61.65a	31.50a	6.35ab	0.84ab	1.50a	0.00
MS5/95	31.80ab	6.90ab	1315.50b	59.30a	30.60a	7.35ab	0.80ab	0.89ab	0.00
MS6/95	59.46a	14.75a	1425.00b	66.95a	20.30a	10.30a	1.78a	0.86ab	0.00
FS	70.06a	13.25a	1310.00b	62.75a	30.80a	6.90ab	1.10ab	1.47a	0.00
Mean	36.84	8.15	944.33	41.78	18.87	5.15	0.99	1.02	0.00
S.E±	12.44	3.02	43.80	5.44	3.52	2.64	0.27	0.18	0.00
C.V%	47.8	52.4	6.6	18.4	26.4	72.4	38.8	24.8	0.0

Means within columns followed by the same letter(s) or without letters are not significantly different from each other according to DMRT at 5% level

Table 22. Mean performance of robusta genotypes on quality characters of six robusta genotypes at Kabirizi A for the 2000/2001

Genotypes	Clean coffee (%)	100 seed weight (g)	Dry cherries in 1/2kg (No.)	Screen 16 clean coffee (%)	Screen 14 clean coffee (%)	Screen 13 clean coffee (%)	CBB count (%)	CBM count (%)	CLR severity (0–8)	Flavour (1–6)	Body (1–3)
MS1/95	58.62	15.45ab	1355.50	88.20a	10.50b	0.80b	1.36	1.17	0.74b	3.67	1.58
MS2/95	56.14	16.50a	1120.50	79.90a	18.00b	1.60b	2.26	1.20	0.80b	2.33	1.46
MS3/95	60.24	16.10a	1171.50	81.50a	15.60b	1.90b	1.76	1.23	1.55a	3.33	1.58
MS5/95	65.73	14.50ab	1315.50	64.60ab	32.80ab	2.30b	1.02	1.09	1.49a	2.33	1.46
MS6/95	52.73	15.85ab	3798.00	70.40a	24.30b	3.10b	2.53	1.44	0.77b	2.67	1.46
FS	54.48	13.15b	1251.00	30.60b	57.50a	9.60a	1.38	1.12	1.61a	2.67	1.58
Mean	57.99	15.26	1668.67	69.20	26.45	3.21	1.72	1.21	1.16	2.83	1.52
S.E±	36.15	0.74	1011.00	10.06	8.53	1.37	0.56	0.16	0.13	0.11	0.97
C.V%	8.8	6.9	85.7	20.6	45.6	60.3	46.3	18.8	15.7	10.6	47.1

Means within columns followed by the same letter(s) or without letters are not significantly different from each other according to DMRT at 5% level

Table 23. Mean performance of robusta genotypes on quality characters of six robusta genotypes at Kabirizi B for the 2000/2001

Genotypes	Clean coffee (%)	100 seed weight (g)	Dry cherries in 1/2kg (No.)	Screen 16 clean coffee (%)	Screen 14 clean coffee (%)	Screen 13 clean coffee (%)	CBB count (%)	CBM count (%)	CLR severity (0–8)	Flavour (1–6)	Body (1–3)
MS1/95	60.02a	16.90	1270.00	80.30a	17.00b	1.90	1.06	0.87	0.00b	3.00	1.58a
MS2/95	60.29a	15.25	1203.00	80.30a	18.00b	1.20	1.12	1.08	0.88b	2.67	1.40ab
MS3/95	61.44a	16.30	1102.50	90.70a	8.10b	0.80	1.17	0.92	0.93b	3.33	1.40ab
MS5/95	61.10a	15.15	1123.00	82.80a	15.70b	1.10	0.96	1.04	1.64a	3.00	1.58a
MS6/95	59.26ab	15.65	1168.50	84.90a	13.40b	1.30	1.05	0.98	0.00b	2.00	1.22b
FS	56.77b	14.10	1226.50	51.70b	39.90a	6.60	1.10	0.98	1.52a	3.00	1.58a
Mean	59.81	15.56	1182.25	78.45	18.68	2.15	1.07	0.98	1.07	2.83	1.46
S.E±	8.36	1.39	58.37	7.00	5.24	1.62	0.18	0.09	0.15	0.68	0.09
C.V%	2.0	12.6	7.0	12.6	39.6	106.7	23.3	12.8	20.4	32.2	0.1

Means within columns followed by the same letter(s) or without letters are not significantly different from each other according to DMRT at 5% level

4.2.13.2. 100 seed weight

Among the six genotypes, 3 genotypes viz. MS3/95, MS5/95 and MS6/95 consistently gave higher values of 100 seed weight at Kabirizi A and Chanika. The lowest trial mean was recorded at Chanika (8.15g) while the highest was recorded at Kabirizi A (15.56g).

4.2.13.3. Number of dry cherries in 1/2kg

It is only at Chanika where number of dry cherries in 1/2kg showed statistical differences between the six genotypes with MS3/95 having the highest number, 1615.5, while MS1/95 and MS2/95 had the lowest. However, the lowest trial mean was obtained at Chanika (944.33) while the highest was at Kabirizi A (1668.67).

4.2.13.4. Percentage screen 16 clean coffee

For the six genotypes studied across the four locations, only MS3/95 consistently gave higher percentage of screen 16 clean coffee at Chanika, Kabirizi A and Kabirizi B. The largest was 90.70% for MS3/95 at Kabirizi B. However, percentage screen 16 at Chanika was generally lower ranging from 0-66.95% while the highest percentage was at Kabirizi B ranging from 51.70-90.70%. FS consistently gave lower percentage screen 16 clean coffee at Kabirizi A and Kabirizi B while at Chanika MS1/95 and MS2/95 gave the

lowest. The lowest trial mean for percentage screen 16 was obtained at Chanika (41.78%) while the highest was at Kabirizi B (78.45%).

4.2.13.5. Percentage screen 14 clean coffee

For the six genotypes, FS consistently gave higher percentage of screen 14 clean coffee across all locations with the highest percentage (57.50%) at Kabirizi A and the lowest (30.80%) at Chanika. However, the highest (26.45%) trial mean for percentage screen 14 was recorded at Kabirizi A and the lowest (18.68%) was recorded at Kabirizi B.

4.2.13.6. Percentage screen 13 clean coffee

FS, consistently gave higher percentage of screen 13 clean coffee across all locations with the highest percentage (11.90%) at Bisheshe and the lowest (6.60%) at Kabirizi B. The highest trial mean of 6.73% was recorded at Bisheshe and the lowest was recorded at Kabirizi B (2.15%).

4.2.13.7. Percentage Coffee Berry Borer (CBB) count in 1/2kg of cherries

For the six gnotypes, it is only at Chanika where CBB count had statistical differences between the genotypes recorded. MS6/95 had the highest percentage (1.78%) of CBB

while MS1/95 and MS2/95 had the lowest scores (0.00%). However, the highest trial mean of 1.72% was recorded at Kabirizi A and the lowest (0.99%) was recorded both at Chanika and Bisheshe.

4.2.13.8. Percentage Coffee Berry Moth (CBM) count in 1/2kg of cherries

It is only at Chanika for the six gnotypes studied where CBM count had statistical differences between the genotypes. MS3/95 had the highest percentage (1.50%) of CBM while MS1/95 and MS2/95 had the lowest (0.00%). However, the highest trial mean of (1.21%) was recorded at Kabirizi A and the lowest (0.98%) was recorded at Kabirizi B.

4.2.13.9. Coffee Leaf Rust (CLR) severity

It is only at Chanika, where there was no CLR while at Bisheshe, Kabirizi A and Kabirizi B, the genotypes showed statistical differences for CLR severity. For the six genotypes, MS1/95and MS2/95 consistently showed lower CLR severity at Kabirizi A, Kabirizi B and Bisheshe. The highest trial mean of 1.16 was recorded at Kabirizi A and the lowest (zero) was recorded at Chanika.

4.2.13.10. Flavour and Body

Flavour and body was analysed for only Kabirizi A and Kabirizi B locations where enough samples for liquor test was obtained. For the two sites, flavaour did not show statistical differences among the genotypes while body showed statistical differences among the genotypes at Kabirizi B only. MS1/95, MS5/95 and FS had higher and same values of body at Kabirizi B.

4.3. Correlation analysis

4.3.1. Simple correlations for growth and yield attributes combined over four locations.

Interrelationships among yield and yield attributes combined over four locations are presented in Table 24. Plant height, plant girth, canopy radius, number of primary branches, number of flowers per node, percentage bearing primary branches, number of berries per node and fruit set percentage showed significant ($P \leq 0.01$) positive correlation with yield of clean coffee. Fruit set was also significantly and positively ($P \leq 0.01$) correlated with plant height, plant girth, canopy radius, number of flowers per node and number of berries per node. Number of berries per node were positively correlated with all the variables except internode length while number of primary branches were positively correlated with all the variables except internode length and fruit set percentage. It is important to note that there was no negative correlation observed among the variables under study in the combined analysis.

Table 24. Simple correlation coefficients among yield and yield components of six robusta coffee genotypes (n=48) averaged over four locations during the 2000/2001

Variables	1	2	3	4	5	6	7	8	9	10
1. Plant height	1.000									
2. Plant girth	0.911**	1.000								
3. Canopy radius	0.769**	0.741**	1.000							
4. Internode length	0.412**	0.400**	0.342*	1.000						
5. Number of primary branches	0.817**	0.868**	0.733**	0.282	1.000					
6. Number of flowers per node	0.530**	0.467**	0.520**	0.290*	0.358*	1.000				
7. Percentage bearing primary branches	0.658**	0.734**	0.580**	0.354*	0.817**	0.408**	1.000			
8. Number of berries per node	0.472**	0.458**	0.494**	0.248	0.294*	0.790**	0.288*	1.000		
9. Fruit set percentage	0.443**	0.411**	0.445**	0.252	0.273	0.659**	0.251	0.946**	1.000	
10.Yield of clean coffee	0.642**	0.590**	0.575**	0.211	0.510**	0.480**	0.402**	0.549**	0.507**	1.000

* Significant at 5% level ** Significant at 1% level

4.3.2. Simple correlations for yield and quality attributes combined over two locations (Kabirizi A and Kabirizi B).

Correlation coefficients of yield and quality attributes are presented in Table 25. Yield of clean coffee was positive and significantly ($P \leq 0.05$) correlated with percentage clean coffee in 1kg cherries. Significant positive correlation was observed between 100 seed weight with percentage screen 16 while percentage screen 14 was positive and significantly correlated with percentage screen 13 and CLR severity. Coffee Berry Borer was positive and significantly correlated with CBM. On the other hand, percentage screen 16 was negative and significantly correlated with percentage screen 14, percentage screen 13 and CLR severity. Hundred seed weight was negative and significantly correlated with percentage screen14 and percentage screen 13.

Table 25. Simple correlation coefficients among yield and quality attributes of six robusta coffee genotypes (n=48) averaged over two locations (Kabirizi A and Kabirizi B)during the 2000/2001

Variable	1	2	3	4	5	6	7	8	9	10
1. Clean coffee (%)	1.000									
2. Number of dry cherries in 1/2 kg dry cherries	–0.245	1.000								
3. Hundred seed weight (clean coffee)	0.087	–0.199	1.000							
4. Percentage screen 16 (FAQ)	0.277	–0.109	0.709**	1.000						
5. Percentage screen 14 (SUG)	–0.233	0.085	–0.703**	–0.996**	1.000					
6. Percentage screen 13 (UG)	–0.386	0.192	–0.706**	–0.947**	0.916**	1.000				
7. Percentage coffee berry borer	–0.282	–0.003	0.221	0.082	–0.098	–0.080	1.000			
8. Percentage coffee berry moth	–0.064	0.236	0.001	–0.120	0.098	0.138	0.694**	1.000		
9. Coffee Leaf rust severity (CLR)	0.089	–0.216	–0.380	–0.425*	0.443*	0.338	–0.168	–0.106	1.000	
10.Yield of clean coffee .	0.496*	–0.442	0.001	0.301	–0.269	–0.372	–0.204	–0.242	–0.224	1.000

* Significant at 5% level ** Significant at 1% level

4.3.3. Genotypic and phenotypic correlations for growth and yield attributes combined over four locations.

Genotypic and phenotypic correlations for some growth and yield attributes for data combined over four locations are presented in Table 26. Plant height and number of primary branches had high positive genotypic and phenotypic correlations with higher value for phenotypic correlation. Number of primary branches had highly significant negative genotypic correlation with percentage bearing primary branches while the phenotypic correlation was strong and positive. Number of flowers per node had significant negative genotypic correlation with percentage bearing primary branches while the phenotypic correlation was positively significant.

Table 26. Genotypic and phenotypic correlation coefficients of some growth and yield components from six robusta coffee genotypes (n=48) combined over four locations.

(Phenotypic correlations in parentheses)

Variables	Plant height	Percentage bearing primary branches
Number of primary branches	0.700** (0.764**)	– 0.718** (0.670**)
Number of flowers/node	– –	–0.348* (0.452**)

*Significant at 5% level **Significant at 1% level

4.3.4. Simple correlations for growth and yield attributes within locations.

Results of correlations among yield and its components are shown in Tables 27, 28, 29 and 30. The findings indicate that at all locations, significant and positive correlations were observed for flowers per node with berries per node and berries per node with fruit set percentage. Similarly there were significant positive correlations between berries per node with yield at all locations except at Kabirizi A where the relationship was not significant. Also, there were significant positive correlations between plant height with plant girth at all locations except at Bisheshe where the relationship was not significant. Fruit set percentage was positively and significantly correlated with yield at Chanika and Bisheshe but not at Kabirizi A and Kabirizi B. Canopy radius was positively and significantly correlated with number of primary branches at Kabirizi A and Kabirizi B but not at Bisheshe and Chanika.

Table 27. Simple correlation coefficients among yield and yield attributes of six robusta coffee genotypes (n=12) at Chanika during the 2000/2001

Variables	1	2	3	4	5	6	7	8	9	10
1. Plant height	1.000									
2. Plant girth	0.729**	1.000								
3. Canopy radius	0.761**	0.499	1.000							
4. Internode length	0.838**	0.746**	0.597*	1.000						
5. Number of primary branches	0.307	0.587*	0.279	0.478	1.000					
6. Number of flowers pernode	0.786**	0.489	0.535	0.546	0.110	1.000				
7. Percentage bearing primary branches	0.544	0.709**	0.559	0.611*	0.863**	0.139	1.000			
8. Number of berries per node	0.513	0.164	0.380	0.176	−0.331	0.769**	−0.281	1.000		
9. Fruit set percentage	0.434	0.062	0.302	0.076	−0.420	0.673*	−0.360	0.976**	1.000	
10. Yield of clean coffee	0.393	−0.042	0.417	0.077	−0.346	0.439	−0.190	0.720**	0.685*	1.000

* Significant at 5% level ** Significant at 1% level

Table 28. Simple correlation coefficients among yield and yield attributes of six robusta coffee genotypes (n=12) at Bisheshe during the 2000/2001

Variables	1	2	3	4	5	6	7	8	9	10
1. Plant height	1.000									
2. Plant girth	0.517	1.000								
3. Canopy radius	0.560	0.231	1.000							
4. Internode length	−0.010	−0.024	−0.080	1.000						
5. Number of primary branches	0.190	0.462	0.359	−0.386	1.000					
6. Number of flowers per node	0.395	0.364	0.769**	−0.189	0.158	1.000				
7. Percentage bearing primary branches	−0.099	0.236	0.265	−0.687	0.687*	0.285	1.000			
8. Number of berries per node	0.356	0.384	0.606*	0.168	−0.012	0.816**	−0.079	1.000		
9. Fruit set percentage	0.508	0.424	0.637*	0.237	0.151	0.704**	−0.047	0.918**	1.000	
10. Yield of clean coffee	0.550	0.334	0.698**	0.234	−0.089	0.710**	−0.080	0.806**	0.843**	1.000

* Significant at 5% level ** Significant at 1% level

Table 29. Simple correlation coefficients among yield and yield attributes of six robusta coffee genotypes (n=12) at Kabirizi A during the 2000/2001

Variables	1	2	3	4	5	6	7	8	9	10
1. Plant height	1.000									
2. Plant girth	0.937**	1.000								
3. Canopy radius	0.634*	0.767**	1.000							
4. Internode length	–0.253	–0.143	0.160	1.000						
5. Number of primary ranches	0.890**	0.842**	0.757**	–0.103	1.000					
6.Number of flowers/node	0.353	0.399	0.299	0.252	0.160	1.000				
7. Percentage bearing primary branches	0.304	0.190	–0.053	0.034	0.363	0.056	1.000			
8. Number of berries/node	0.367	0.438	0.278	0.379	0.239	0.819**	0.163	1.000		
9. Fruit set percentage	0.300	0.372	0.189	0.403	0.213	0.653*	0.185	0.965**	1.000	
10. Yield of clean coffee	0.543	0.590*	0.507	0.360	0.517	0.385	0.440	0.348	0.286	1.000

* Significant at 5% level ** Significant at 1% level

Table 30. Simple correlation coefficients among yield and yield attributes of six robusta coffee genotypes (n=12) at Kabirizi B during the 2000/2001

Variables	1	2	3	4	5	6	7	8	9	10
1. Plant height	1.000									
2. Plant girth	0.647*	1.000								
3. Canopy radius	0.291	−0.083	1.000							
4. Internode length	0.246	0.189	−0.214	1.000						
5. Number of primary branches	0.591*	0.443	0.669*	−0.311	1.000					
6. Number of flowers per node	−0.000	−0.095	0.301	−0.706**	0.449	1.000				
7. Percentage bearing primary branches	0.422	0.218	0.254	0.011	0.612*	0.536	1.000			
8. Number of berries per node	−0.206	−0.172	0.283	−0.507	0.418	0.780**	0.536	1.000		
9. Fruit set percentage	0.001	−0.183	0.215	−0.231	0.298	0.444	0.430	0.906**	1.000	
10. Yield of clean coffee	0.273	0.252	0.260	−0.212	0.367	0.621*	0.451	0.610*	0.453	1.000

* Significant at 5% level ** Significant at 1% level

4.3.5. Simple correlations for yield and quality attributes within the locations.

Interrelationships among the yield and quality attributes for the individual locations are shown in Tables 31, 32, 33 and 34. Results indicate that at all locations, significant and positive correlations were observed for 100 seed weight with percentage screen 16; percentage screen 14 with percentage screen 13. Similarly, there were significant positive correlations between clean coffee percentage with percentage screen 16 at all locations except at Kabirizi A where the relationship was not significant. At Kabirizi A and Kabirizi B, percentage screen 16 was negatively and significantly correlated with percentage screen 14 and percentage screen 13. Also, there were significant positive correlations between number of dry cherries in1/2kg with coffee berry moth at all locations except at Kabirizi B where the relationship was not significant. Hundred seed weight had negative and significant correlations with percentage screen 14 and percentage screen 13 at Kabirizi A and Kabirizi B while at Chanika and Bisheshe, the relationships were positive and strongly significant.

Table 31. Simple correlation coefficients among yield and quality attributes of six robusta coffee genotypes (n=12) at Bisheshe during the 2000/2001

Variable	1	2	3	4	5	6	7	8	9	10
1. Clean coffee (%)	1.000									
2. Number of dry cherries in 1/2 kg dry cherries	0.982**	1.000								
3. Hundred seed weight (clean coffee)	0.960**	0.949**	1.000							
4. Percentage screen 16	0.935**	0.908**	0.953**	1.000						
5. Percentage screen 14	0.871**	0.899**	0.870**	0.713**	1.000					
6. Percentage screen 13	0.864**	0.897**	0.787**	0.665*	0.898**	1.000				
7. Percentage coffee berry borer	0.541	0.535	0.653*	0.732**	0.365	0.182	1.000			
8. Percentage coffee berry moth	0.715**	0.725**	0.663*	0.674*	0.525	0.595*	0.377	1.000		
9. Coffee Leaf rust severity	0.318	0.252	0.187	0.051	0.454	0.472	–0.217	–0.093	1.000	
10. Yield of clean coffee	0.594*	0.583*	0.723**	0.529	0.737**	0.616*	0.359	0.303	0.279	1.000

* Significant at 5% level ** Significant at 1% level

Table 32. Simple correlation coefficients among yield and quality attributes of six robusta coffee genotypes (n=12) at Chanika during the 2000/2001

Variable	1	2	3	4	5	6	7	8	9
1. Clean coffee (%)	1.000								
2. Number of dry cherries in 1/2 kg dry cherries	0.838**	1.000							
3. Hundred seed weight (clean coffee)	0.968**	0.848**	1.000						
4. Percentage screen 16	0.784**	0.925**	0.825**	1.000					
5. Percentage screen 14	0.690*	0.894**	0.649*	0.744**	1.000				
6. Percentage screen 13	0.553	0.760**	0.530	0.655*	0.700**	1.000			
7. Percentage coffee berry borer	0.225	0.259	0.324	0.192	0.400	0.158	1.000		
8. Percentage coffee berry moth	0.651*	0.598*	0.606*	0.418	0.755**	0.237	0.492	1.000	
9. Yield of clean coffee	0.083	0.467	0.132	0.479	0.322	0.462	−0.259	−0.175	1.000

* Significant at 5% level ** Significant at 1% level

Table 33. Simple correlation coefficients among yield and quality attributes of six robusta coffee genotypes (n=12) at Kabirizi A during the 2000/2001

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. Clean coffee (%)	1.000											
2. Number of dry cherries in 1/2 kg dry cherries	−0.282	1.000										
3. Hundred seed weight (clean coffee)	−0.005	0.330	1.000									
4. Percentage screen 16	0.116	0.092	0.751**	1.000								
5. Percentage screen 14	−0.059	−0.114	−0.747**	−0.995**	1.000							
6. Percentage screen 13	−0.284	−0.080	−0.721**	−0.941**	0.906**	1.000						
7. Percentage coffee berry borer	−0.254	0.726**	0.518	0.292	−0.316	−0.246	1.000					
8. Percentage coffee berry moth	0.061	0.700**	0.356	0.063	−0.099	0.013	0.679*	1.000				
9. Coffee Leaf rust severity	0.236	−0.298	−0.595*	−0.528	0.545	0.449	−0.342	−0.277	1.000			
10. Flavour	0.177	0.235	0.433	0.155	−0.160	−0.136	0.174	0.472	−0.141	1.000		
11. Body	0.118	0.083	0.134	−0.055	0.060	0.058	0.274	0.240	0.052	0.683*	1.000	
12. Yield of clean coffee	0.715**	−0.249	−0.017	−0.047	0.125	−0.235	−0.076	−0.204	0.339	0.111	0.317	1.000

* Significant at 5% level ** Significant at 1% level

Table 34. Simple correlation coefficients among yield and quality attributes of six robusta coffee genotypes (n=12) at Kabirizi B during the 2000/2001

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. Clean coffee (%)	1.000											
2. Number of dry cherries in 1/2 kg dry cherries	−0.569*	1.000										
3. Hundred seed weight (clean coffee)	0.262	−0.360	1.000									
4. Percentage screen 16	0.731**	−0.592*	0.710**	1.000								
5. Percentage screen 14	−0.733**	0.593*	−0.709**	−0.998**	1.000							
6. Percentage screen 13	−0.693*	0.559	−0.707**	−0.965**	0.945**	1.000						
7. Percentage coffee berry borer	0.318	−0.164	−0.114	0.074	−0.078	−0.079	1.000					
8. Percentage coffee berry moth	−0.207	0.322	−0.736**	−0.375	0.398	0.306	−0.203	1.000				
9. Coffee Leaf rust severity	−0.130	−0.292	−0.202	−0.334	0.356	0.236	−0.316	0.158	1.000			
10. Flavour	0.266	0.104	−0.211	−0.121	0.128	0.095	0.047	0.234	0.109	1.000		
11. Body	−0.408	0.316	−0.030	−0.398	0.417	0.303	−0.372	0.113	0.472	0.433	1.000	
12. Yield of clean coffee	0.519	−0.237	−0.080	0.446	−0.436	−0.445	0.484	0.174	−0.517	−0.047	−0.517	1.000

* Significant at 5% level ** Significant at 1% level

4.4. Estimates of variance components, heritability and expected genetic advance

4.4.1. Growth and yield attributes.

Estimates of variance components, heritability and expected genetic advance for yield and yield attributes of six genotypes combined over four locations are presented in Table 35. The estimates of the genetic variance, $\delta^2 g$, were relatively small for each of the variables as compared to the corresponding phenotypic variances, $\delta^2 ph$, except for plant girth which had slightly higher genetic variance. The location variance, $\delta^2 l$, was important for yield of clean coffee, plant height, canopy radius, number of primary branches, and percentage bearing primary branches while for the other variables, it was not important. Genetic variance $\delta^2 g$, was important for plant girth, canopy radius, number of berries per node, and fruit set percentage while for the other variables it was less important.

The heritability estimates, h^2, and expected genetic advance for plant girth, canopy radius, number of berries per node and fruit set percentage were important and high except for canopy radius which was medium. However, heritability estimates for plant girth was extremely high (125%). Fruit set percentage recorded the highest (36.48%) expected genetic advance.

Table 35. Variance components, heritability (broad sense) and expected genetic advance (EGA) of some yield components of six robusta coffee genotypes grown at four locations in Kagera region during the 2000/2001.

Variables	$\delta^2 g$	$\delta^2 l$	$\delta^2 gl$	$\delta^2 e$	$\delta^2 ph$	h^2	EGA(% of mean)
Yield	–200.87	3868.52	·105756.37	361560.00	71433.23	–	–
Plant height	–1.25	241.69	–15.69	90.92	6.19	–	–
Plant girth	0.05	0.74	–0.07	0.10	0.04	125.00	13.53
Canopy radius	3.05	46.06	–12.16	60.32	7.55	40.40	2.42
Internode length	–0.01	–0.00	–0.01	0.17	0.01	–	–
Number of primary branches	–1.37	1167.47	6.27	28.08	3.71	–	–
Number of flowers per node	–4.34	0.37	5.22	48.04	2.97	–	–
Percentage bearing Pr. Br.	–5.05	51.29	15.15	23.84	1.72	–	–
Number of berries per node	0.06	–0.03	0.27	0.36	0.11	54.54	11.22
Fruit set percentage	27.69	–23.42	17.90	88.93	43.28	63.98	36.48

$\delta^2 g$ = genetic variance $\delta^2 l$ = Location (environment) variance $\delta^2 gl$ = genotype x location variance
$\delta^2 e$ = error variance $\delta^2 ph$ = phenotypic variance h^2 = heritability(broad sense) EGA = expected genetic advance

4.4.2. Yield and quality attributes.

Table 36 shows the variance components, heritability and expected genetic advance for yield and quality attributes of six genotypes combined over two locations viz: Kabirizi A and Kabirizi B. The phenotypic variance, δ^2ph, was relatively high for each of the variables as compared to the corresponding genotypic variances, δ^2g. The genotype x location variance was observed to be relatively very low as compared to genotypic, and phenotypic variances except for CLR severity. Leaf rust severity was observed to have high genotype x location interaction variance as compared to genotypic, phenotypic and location variances.

Heritability values for percentage screen 13 (98.27%), percentage screen 16 (90.13%) percentage screen 14 (87.47%) hundred seed weight (66.67%) and clean coffee in 1kg cherries (60.22%) were high. Expected genetic advances for percentage screen 13 (390.08%), and percentage screen 14 (100.92%) were also high. Heritability estimates and expected genetic advance for percentage CBM and CLR severity were too low to be of any predictive value.

Table 36. Variance components, heritability (broad sense) and expected genetic advance (EGA) of some yield and quality components of six robusta coffee genotypes grown at two locations in Kagera region during the 2000/2001

Variables	$\delta^2 g$	$\delta^2 l$	$\delta^2 gl$	$\delta^2 e$	$\delta^2 ph.$	h^2	EGA(% of mean)
Clean coffee (%)	529.81	23.54	71.21	1257.51	879.79	60.22	4.85
Number of dry cherries in 1/2kg cherries	1666.85	-1587.32	-3495.72	15814.22	3872.54	43.04	2.97
100-seed weight (clean coffee)	0.44	1.66	-0.70	2.30	0.66	66.67	5.88
Percentage screen 16	245.18	-36.43	-16.67	140.77	272.03	90.13	39.38
Percentage screen 14	159.73	-25.49	-0.41	92.32	182.61	87.47	100.92
Percentage screen 13	26.71	-0.32	-1.34	4.58	27.18	98.27	390.08
Percentage CBB	0.02	-2.05	-0.02	0.34	0.09	18.48	3.55
Percentage CBM	-0.00	0.01	-0.03	0.08	0.01	-	-
Coffee Leaf Rust (CLR) severity	-0.06	-0.30	0.09	0.34	0.07	-	-

$\delta^2 g$ = genetic variance $\delta^2 l$ = Location (environment) variance $\delta^2 gl$ = genotype x location variance
$\delta^2 e$ = error variance $\delta^2 ph$ = phenotypic variance h^2 = heritability(broad sense) EGA = expected genetic advance

4.5. Stability analysis

4.5.1. Stability analysis for growth and yield variables

Stability parameters of growth and yield variables of six genotypes combined across four locations are presented in Table 37.

4.5.1.1. Plant height

Results indicate that all the genotypes studied responded on the average with changing environment on plant height; that is the regression coefficients did not differ significantly from a value of 1 (b = 1). However, MS5/95, MS6/95 and FS had relatively low values of variance of deviation from regression while MS2/95 had the highest value of variance of deviation from regression .

4.5.1.2. Plant girth

All the genotypes studied except MS5/95 on plant girth responded on the average with changing environment; that is the regression coefficients did not differ significantly from a value of 1 (b = 1). However, all the genotypes recorded significant variance of deviation from regression (S^2d) on plant girth.

4.5.1.3. Plant canopy

The findings show that only one genotype, FS had its regression coefficient, b, significantly different from zero (b = 0) and lower than unity that is (b = 0.54) although as with other genotypes, responded on the average with changing environments on canopy radius; that is their regression coefficients did not differ significantly from a value of unity (b = 1). MS1/95, and FS had relatively low values of variance of deviation from regression, S^2d,. MS3/95 had the highest value of variance of deviation from regression. The variances of deviation from regression, S^2d, were not significant for all the genotypes on this variable.

4.5.1.4. Internode length

All the genotypes studied except MS6/95 on internode length responded on the average with changing environment; that is the regression coefficients did not differ significantly from a value of 1 (b = 1). MS6/95 responded significantly less than average. However, all the genotypes studied recorded significant variances of deviation from regression (S^2d) on internode length.

4.5.1.5. Number of primary branches

Results indicate that all the genotypes studied responded on the average with changing environment on number of primary branches; that is the regression coefficients did not differ significantly from a value of unity (b = 1). MS1/95, had relatively low value of variance of deviation from regression, S^2d,. The variances from regression, S^2d, were not significant for all the genotypes tested.

4.5.1.6. Number of flowers per node

For number of flowers per node, all the genotypes studied except MS2/95 and MS5/95 responded on the average with changing environments; that is the regression coefficients did not differ significantly from unity (b = 1). MS2/95 responded well above average while MS5/95 responded significantly below average with changing environments. The variances of deviation from regression, S^2d, were not significant for all the genotypes.

4.5.1.7. Percentage bearing primary branches

Results indicate that all the genotypes studied responded on the average with changing environments on percentage bearing primary branches; that is the regression coefficients did not differ significantly from unity (b = 1). However, MS2/95, MS5/95 and MS6/95

had relatively low values of variance of deviation from regression. The variances of deviation from regression, S^2d, were also not significant.

4.5.1.8. Number of berries per node

Results indicate that all the genotypes studied except MS5/95 responded on the average with changing environment on number of berries per node; that is the regression coefficients did not differ significantly from unity (b = 1). MS5/95 responded well below average on this variable (b = 0.31±0.06*) although it responded significantly from zero. However, MS3/95 and FS recorded non-significant variance of deviations from regression (S^2d).

4.5.1.9. Percentage fruit set

For percentage fruit set, all the genotypes studied responded on the average with changing environments; that is the regression coefficients did not differ significantly from a value of unity (b = 1). MS3/95 and MS5/95 had relatively low values of variance of deviation from regression, S^2d,. The deviations from regression, S^2d, were not statistically significant for all genotypes.

4.5.1.10. Yield of clean coffee

Results indicate that all the genotypes studied except MS2/95 responded on the average with changing environment on yield of clean coffee; that is the regression coefficients did not differ significantly from a value of unity (b = 1). MS2/95 responded well above average on yield of clean coffee with changing environments. MS1/95 and MS2/95 had relatively lower values of variance of deviation from regression. The variances of deviation from regression, S^2d, were not statistically significant for all the genotypes.

Table 37a . The means and stability parameters for growth and yield characters of six robusta genotypes combined over four locations during the 2000/2001.

Genotypes	Plant height (cm)	Stability parameters				Plant girth (cm)	Stability parameters				Plant canopy (cm)	Stability parameters			
		$b \pm SE_b$	b–1	S^2d	R^2		$b \pm SE_b$	b–1	S^2d	R^2		$b \pm SE_b$	b–1	S^2d	R^2
MS1/95	106.14	0.86± 0.22	–0.14	42.46	0.88	3.81	0.83 ± 0.10	–0.17	0.03**	0.97	60.20	0.78 ± 0.18	–0.22	9.23	0.90
MS2/95	109.34	1.40 ± 0.39	0.40	130.36	0.87	3.92	1.26 ± 0.15	0.26	0.06**	0.97	61.92	1.31 ± 0.45	0.31	56.85	0.81
MS3/95	105.86	1.06 ± 0.23	0.06	47.82	0.91	3.58	1.27 ± 0.27	0.27	0.19**	0.92	69.03	1.28 ± 0.67	0.28	122.76	0.65
MS5/95	110.37	0.90 ± 0.12	–0.10	12.29	0.97	3.84	0.85 ± 0.04	–0.15*	0.01**	0.99	68.57	1.28 ± 0.30	0.28	25.11	0.90
MS6/95	101.84	1.01 ± 0.21	0.01	38.50	0.92	3.19	0.94 ± 0.25	–0.06	0.16**	0.88	69.10	0.82 ± 0.57	–0.18	90.89	0.50
FS	111.44	0.77 ± 0.21	–0.23	39.94	0.87	3.76	0.85 ± 0.05	–0.15	0.01*	0.99	63.69	0.54 ± 0.10*	–0.46	2.55	0.94
Mean	107.50					3.68					65.42				
r Xb	–0.106					0.024					0.318				

* Significant at 5% level ** Significant at 1% level

Table 37a contd...

Genotypes	Internode length (cm)	Stability parameters				Pr. Br. (No.)	Stability parameters				Flowers /node (No.)	Stability parameters			
		$b \pm SE_b$	b–1	S^2d	R^2		$b \pm SE_b$	b–1	S^2d	R^2		$b \pm SE_b$	b–1	S^2d	R^2
MS1/95	4.56	–0.50 ± 0.67	–1.50	0.04**	0.21	40.50	0.72 ± 0.13	–0.28	5.16	0.94	27.50	1.54 ± 0.44	0.54	1.00	0.86
MS2/95	4.43	1.55 ± 0.68	0.55	0.04**	0.72	44.50	1.14 ± 0.26	0.14	21.07	0.91	25.00	3.11 ± 0.56	2.11*	1.28	0.94
MS3/95	4.54	1.56 ± 0.57	0.56	0.03**	0.79	42.75	1.26 ± 0.33	0.26	33.54	0.88	29.63	0.25 ± 0.47	–0.75	1.08	0.12
MS5/95	4.53	2.00 ± 1.21	1.00	0.14**	0.58	45.00	1.11 ± 0.18	0.11	10.28	0.95	29.63	–0.79 ± 0.40	–1.79*	0.91	0.66
MS6/95	4.33	0.75 ± 0.09	–0.25*	0.00**	0.97	42.00	0.81 ± 0.32	–0.19	31.40	0.76	25.00	2.03 ± 0.41	1.03	0.94	0.92
FS	4.61	0.63 ± 0.95	–0.37	0.09**	0.18	40.50	0.97 ± 0.23	–0.03	16.66	0.90	25.13	–0.14 ± 0.63	–1.14	1.44	0.03
Mean	4.50					42.54					26.98				
r Xb	–0.161					0.669					–0.633				

* Significant at 5% level ** Significant at 1% level

Table 37a contd...

Genotypes	% bearing Pr. Br.	Stability parameters				No.of Berries /node	Stability parameters				Fruit set (%)	Stability parameters			
		$b \pm SE_b$	b–1	S^2d	R^2		$b \pm SE_b$	b–1	S^2d	R^2		$b \pm SE_b$	b–1	S^2d	R^2
MS1/95	69.62	0.43 ± 0.31	–0.57	15.7	0.49	6.25	2.00 ± 0.58	1.00	0.32**	0.49	19.61	1.61 ± 0.53	0.61	48.3	0.82
MS2/95	68.97	1.49 ± 0.24	0.49	9.1	0.95	7.50	1.90 ± 0.76	0.90	0.56**	0.95	23.50	1.92 ± 0.59	0.92	60.7	0.84
MS3/95	67.77	1.74 ± 0.31	0.74	16.0	0.94	9.50	0.24 ± 0.29	–0.76	0.08	0.94	31.42	0.31 ± 0.29	–0.69	14.2	0.37
MS5/95	70.08	1.20 ± 0.14	0.20	3.3	0.97	9.00	0.31 ± 0.06**	–0.69**	0.01**	0.97	29.63	0.69 ± 0.22	–0.31	8.7	0.82
MS6/95	70.14	0.44 ± 0.23	–0.56	8.5	0.65	4.62	1.32 ± 0.06	0.32	0.35**	0.65	13.49	1.16 ± 0.57	0.16	56.2	0.67
FS	66.93	0.71 ± 0.38	–0.29	23.4	0.64	6.50	0.23 ± 0.63	–0.77	0.38	0.64	24.46	0.31 ± 0.69	–0.69	81.6	0.09
Mean	68.92					7.23					23.68				
r Xb	–0.301					–0.514					–0.539				

* Significant at 5% level ** Significant at 1% level

Table 37a contd...

Genotypes	Yield clean coffee (kg/ha.)	Stability parameters			
		$b \pm SE_b$	b–1	S^2d	R^2
MS1/95	617.04	0.77 ± 0.16	–0.23	32429.6	0.92
MS2/95	1216.55	2.20 ± 0.11**	1.20**	16897.0	0.99
MS3/95	1216.66	0.99 ± 0.20	–0.01	50003.6	0.93
MS5/95	993.64	0.68 ± 0.44	–0.32	244835.1	0.55
MS6/95	912.84	1.23 ± 0.23	0.23	69882.6	0.93
FS	629.00	0.13 ± 0.40	–0.87	207441.8	0.05
Mean	930.96				
r Xb	0.702				

* Significant at 5% level ** Significant at 1% level

Table 37b. Means and stability parameters for CLR severity of six robusta genotypes combined over four locations during the 2000/2001.

Genotypes	CLR severity	Stability parameters			
		$b \pm SE_b$	b-1	S^2d	R^2
MS1/95	0.72	0.00 ± 0.00	1.00	6.95	0.00
MS2/95	0.77	0.00 ± 0.00	1.00	7.79	1.00
MS3/95	0.97	0.09 ± 0.00	-0.91	3.77	1.00
MS5/95	1.13	0.29 ± 0.00	0.71	2.95	1.00
MS6/95	0.72	2.66 ± 0.00**	1.66	7.50	1.00
FS	1.18	2.47 ± 0.00**	1.47	4.08	1.00
Mean	0.91				
r_{xb}	0.152				

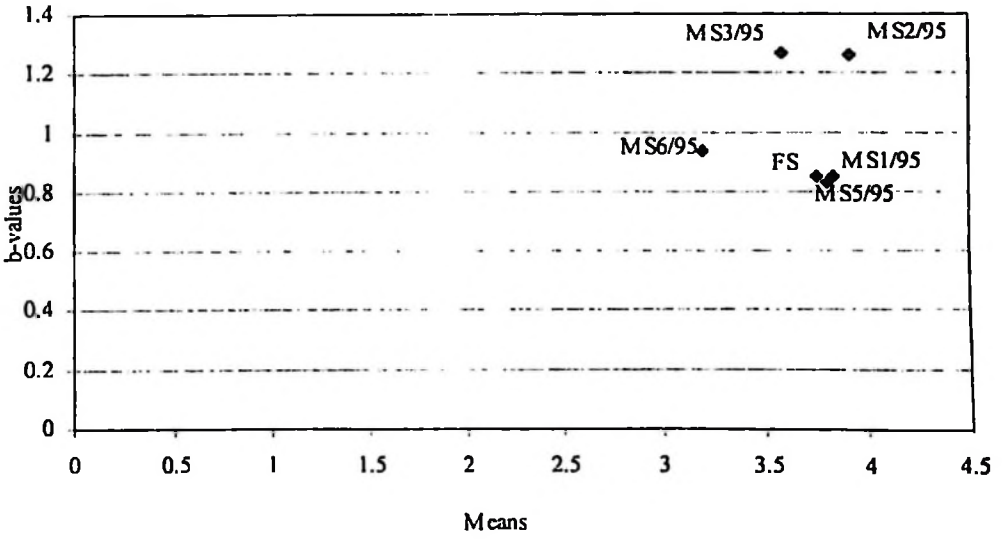
4.5.2. Relationships between regression coefficients and means of genotypes for yield and growth variables

The relationships between regression coefficients and means for the variables studied are depicted in scatter diagrams (Figures 2- 11).

4.5.2.1. Plant girth

The scatter diagram indicating the relationship between regression coefficients and means for plant girth shows that MS1/95, MS5/95 and FS had relatively low b-values and thicker stems. On the other hand, MS6/95 had low b-value, and its stem girth was thinner.

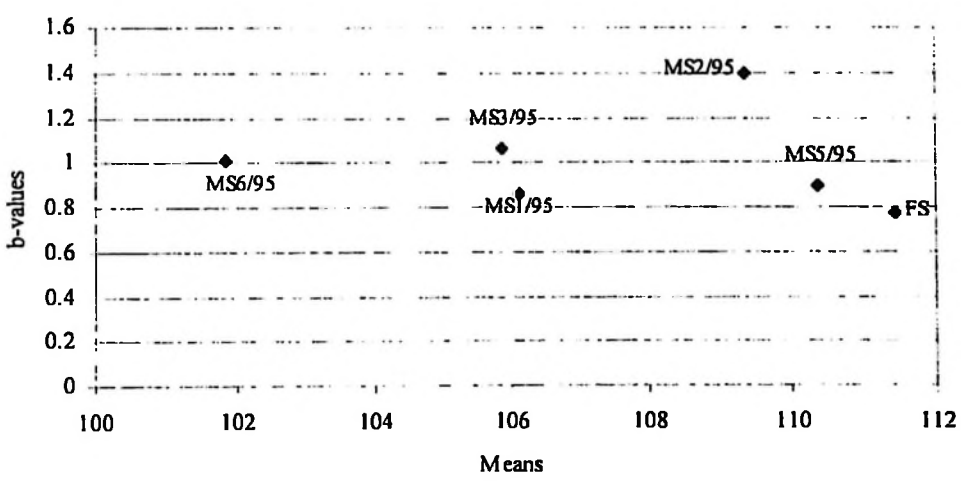
Fig.2. Scatter diagram of b-values against means for plant girth



4.5.2.2. Plant height

The scatter diagram indicating the relationship between regression coefficients and means for plant height shows that MS5/95 and FS had relatively low b-values with taller plants. On the other hand, MS1/95 though had low b-value, its plant height was medium. It is important to note that MS6/95 performed on average (b = 1) for plant height but with shorter plants than the other genotypes.

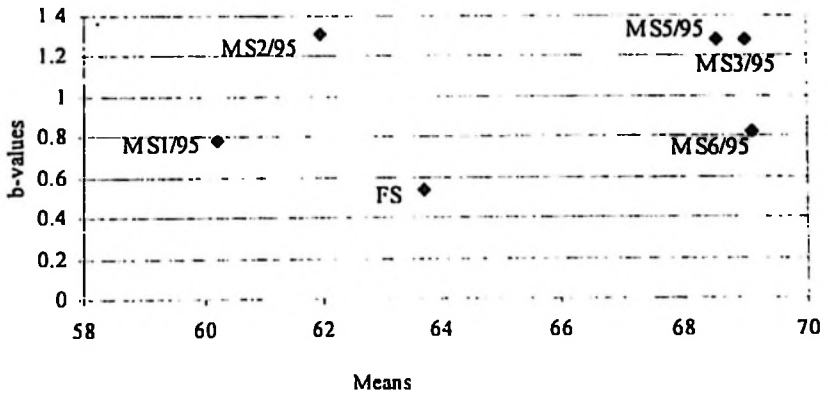
Fig.3. Scatter diagram of b-values against means for plant height



4.5.2.3. Canopy radius

The relationship between regression coefficients and means for canopy radius is depicted in scatter diagram and indicates that MS6/95 had relatively low b-values for canopy radius and occupies a larger area. On the other hand, FS though had low b-value, its canopy occupied a medium area while MS1/95 had low b-value and occupied the smallest area.

Fig.4. Scatter diagram of b-values against means for canopy radius

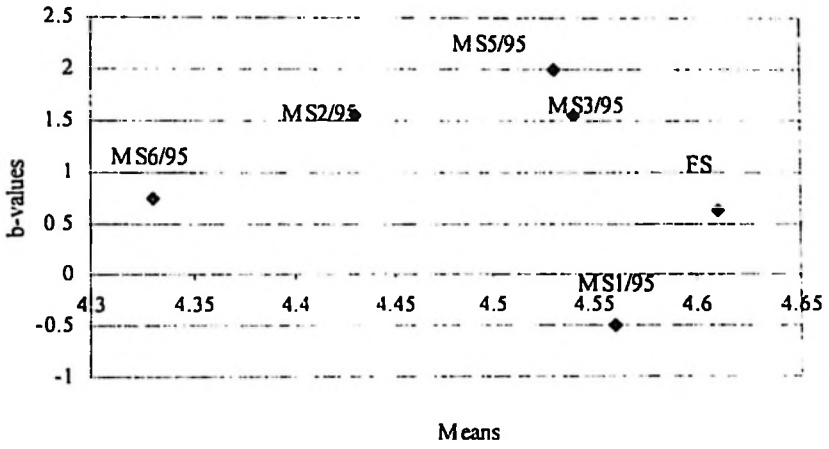


4.5.2.4. Internode length

The scatter diagram indicating the relationship between regression coefficients and means for internode length shows that FS and MS1/95 had relatively low b-values with

longer internodes. On the other hand, MS6/95 was relatively stable; that is had low b-value, and its internode length was shorter, a character that is preferred in coffee.

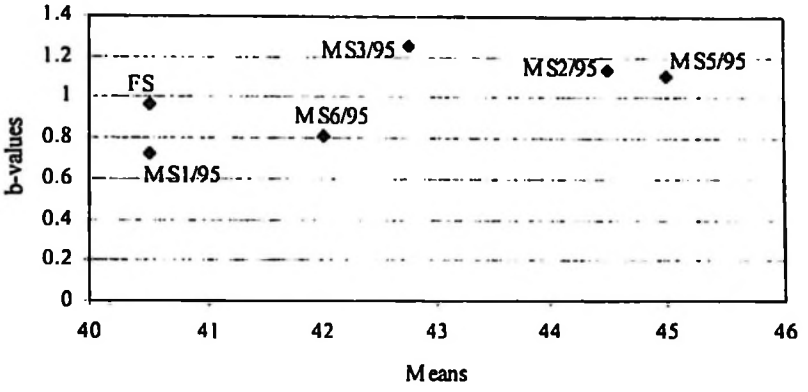
Fig.5. Scatter diagram of b-values against means for internode length



4.5.2.5. Number of primary branches

The scatter diagram indicating the relationship between regression coefficients and means for number of primary branches indicates that MS6/95 had relatively low b-value and medium primary branches. On the other hand, MS1/95 and FS though had low b-values, their number of primary branches were fewer.

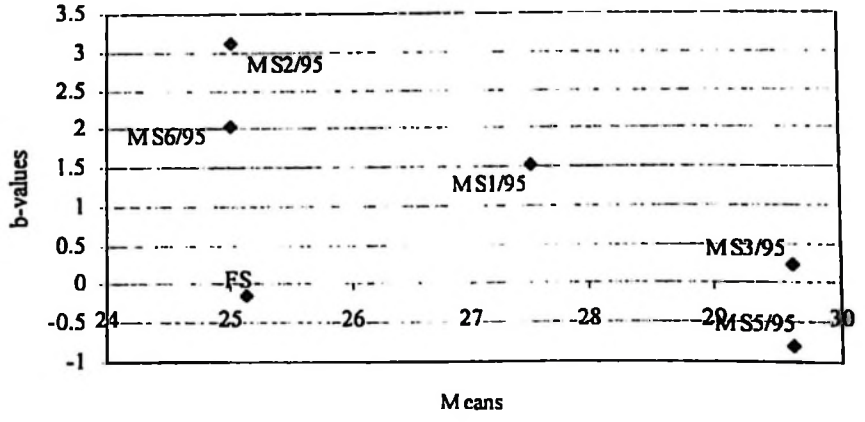
Fig. 6. Scatter diagram of b-values against means for number of primary branches.



4.5.2.6. Number of flowers per node

The relationship between regression coefficients and means for number of flowers per node is depicted in scatter diagram and indicates that MS3/95 and MS5/95 had relatively low b-values for number of flowers per node and had many flowers per node. On the other hand, FS though had low b-value, its number of flowers per node were fewer.

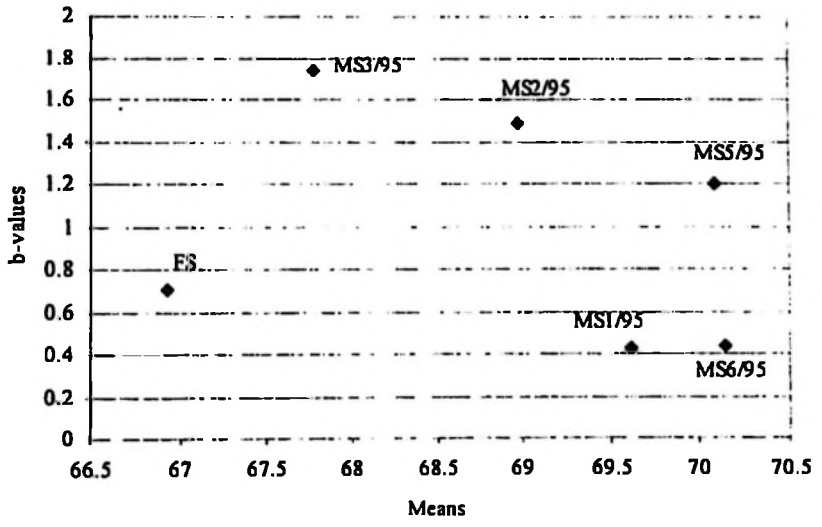
Fig.7. Scatter diagram of b-values against means for number of flowers per node



4.5.2.7. Percentage bearing primary branches

The scatter diagram indicating the relationship between regression coefficients and means for percentage bearing primary branches indicates that MS3/95 and MS5/95 had relatively low b-values and many bearing primary branches. On the other hand, FS though had low b-value, had fewer bearing primary branches.

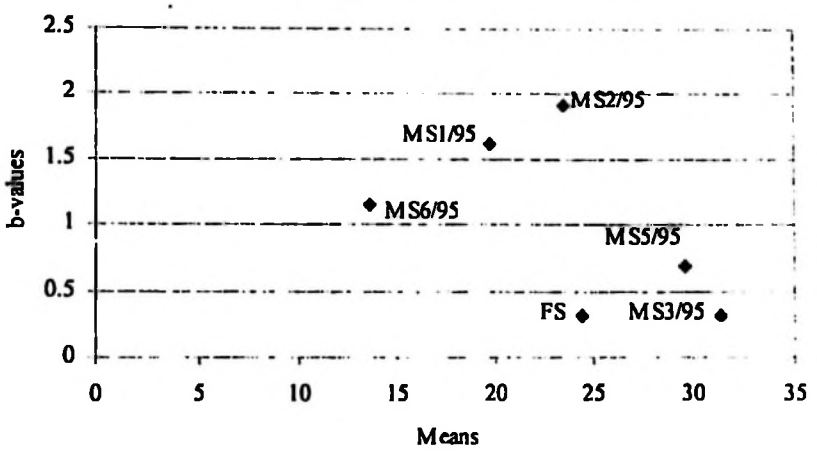
Fig.8 Scatter diagram of b-values against means for percentage bearing primary branches



4.5.2.8. Percentage fruit set

The scatter diagram indicating the relationship between regression coefficients and means for fruit set shows that MS3/95, MS5/95 and FS had relatively low b-values and many fruits set.

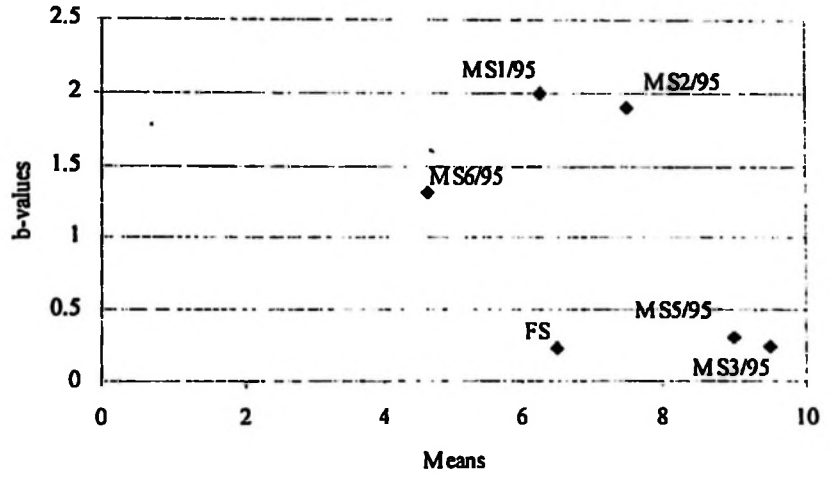
Fig. 9 Scatter diagram of b-values against means for fruit set percentage



4.5.2.9. Number of berries per node

The scatter diagram indicating the relationship between regression coefficients and means for number of berries per node indicates that MS3/95 and MS5/95 had relatively low b-values and many berries per node. On the other hand, FS though had low b-value, it produced fewer berries per node.

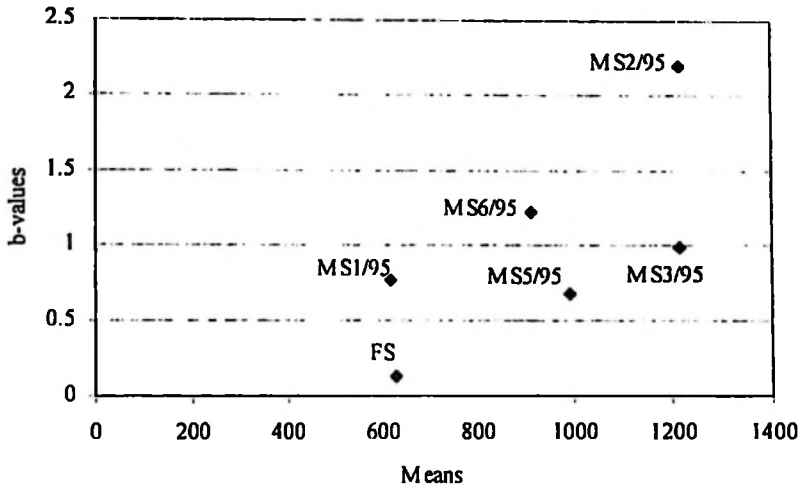
Fig.10 Scatter diagram of b-values against means for number of berries per node



4.5.2.10. Yield of clean coffee

The relationship between regression coefficients and means for yield of clean coffee is depicted in scatter diagram and shows that MS5/95 has relatively low b-values for yield of clean coffee with good yield. On the other hand, FS and MS1/95 though relatively stable; that is had low b-values, yields of clean coffee were lower. MS3/95 responded on average with changing environments with higher yield of clean coffee.

Fig.11. Scatter diagram of b-values against means for yield of clean coffee

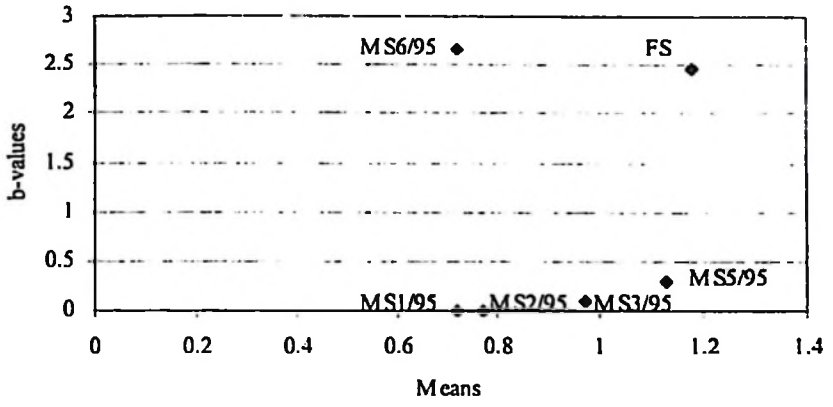


4.5.3. Relationships between regression coefficients and means of genotypes for CLR severity.

4.5.3.1. Coffee Leaf Rust (CLR) severity

The scatter diagram indicating the relationship between regression coefficients and means for CLR severity shows that MS1/95 and MS2/95 had relatively low b-values and lower levels of CLR severity. On the other hand, MS3/95 and MS5/95 though had low b-values, their CLR severity levels were higher.

Fig.12 Scatter diagram of b-values against means for CLR severity



4.5.4. Relationship between genotype means and variance of deviation from regression, S^2d, for yield and growth variables.

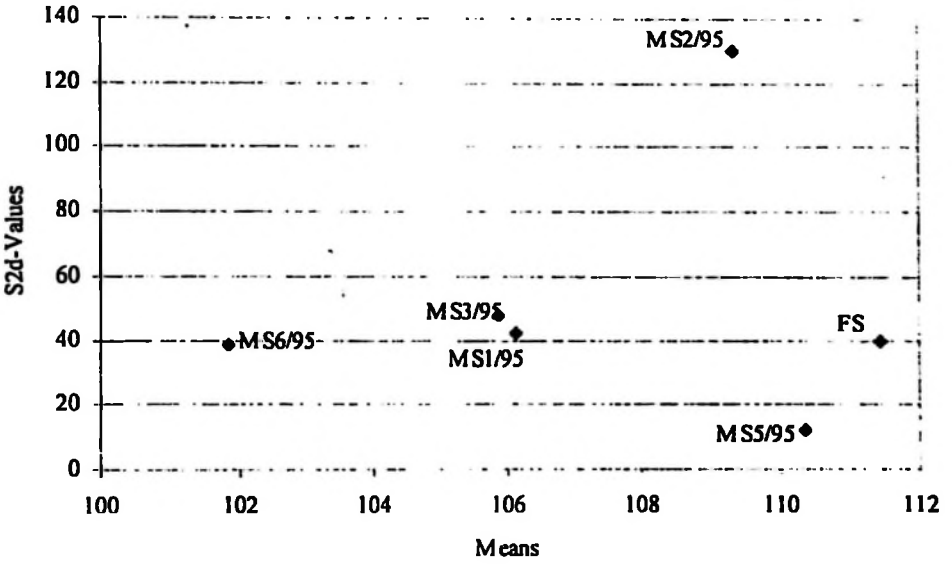
The relationships between means of genotypes and variance of deviation from regressions for the studied variables are shown in scatter diagrams (figures 13-23)

4.5.4.1. Plant height

The scatter diagram indicating the relationship between means and the variance of deviation from regression, S^2d, for plant height shows that FS and MS5/95 had low values of S^2d with high means. On the other hand, MS6/95 had low plant height mean

with low value of variance of deviation from regression. Although MS1/95 and MS3/95 had relatively low variances of deviation from regression, the plant heights were medium.

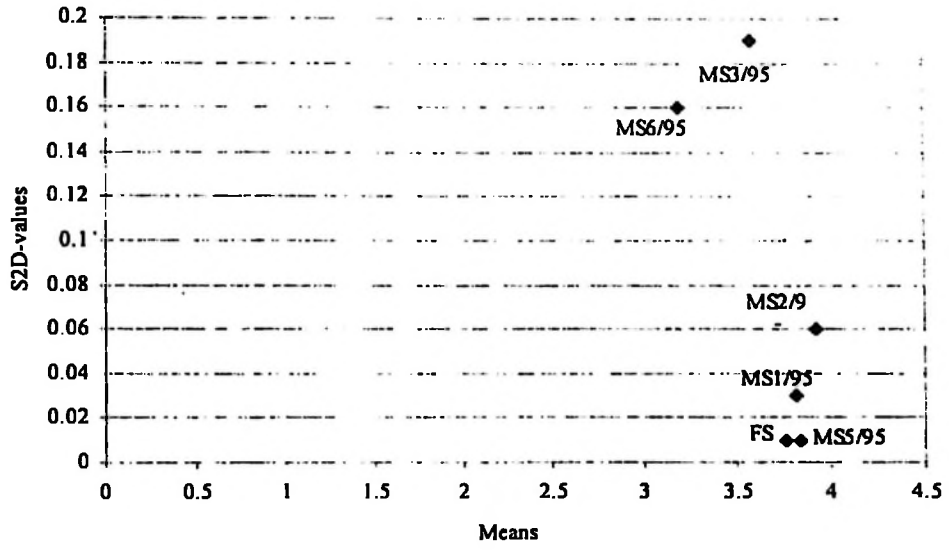
Fig.13. Scatter diagram of means against S2d for plant height



4.5.4.2. Plant girth

The relationship between means and variance of deviation from regression for plant girth shows that MS1/95, MS2/95, MS5/95 and FS had low values of variance of deviation from regression and high means.

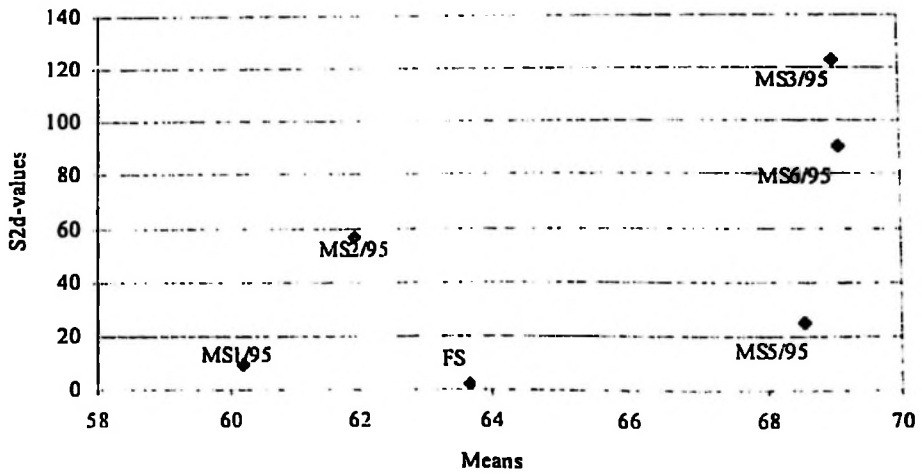
Fig. 14..Scatter diagram of means against S2d-values for plant girth



4.5.4.3. Plant canopy radius

The scatter diagram indicating the relationship between means and the variance of deviation from regression, S^2d, for plant canopy radius shows that MS5/95 had low values of variance of deviation from regression with high means. On the other hand, MS1/95 and FS had low means and low values of variance of deviation from regression.

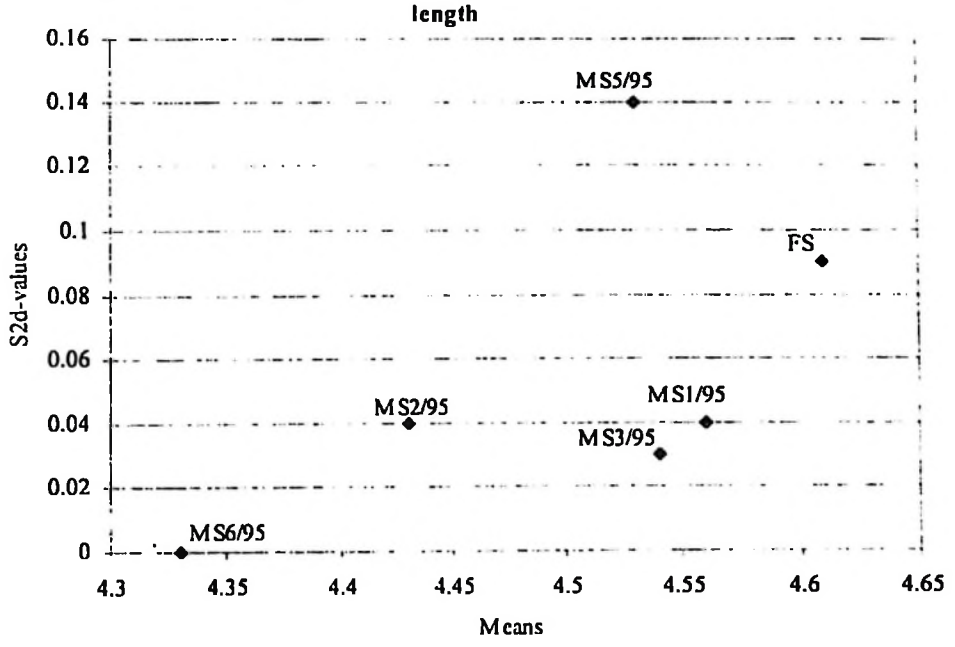
Fig.15.Scatter diagram of means aginst S2d-values for plant canopy



4.5.4.4. Internode length

The relationship between means and variance of deviation from regression for internode length shows that MS1/95 and MS3/95 had low values of variance of deviation from regression and relatively high means while MS2/95 and MS6/95 had low values of variance of deviation from regression and shorter internodes.

Fig.16. Scatter diagram of means against S2d-values for internode length

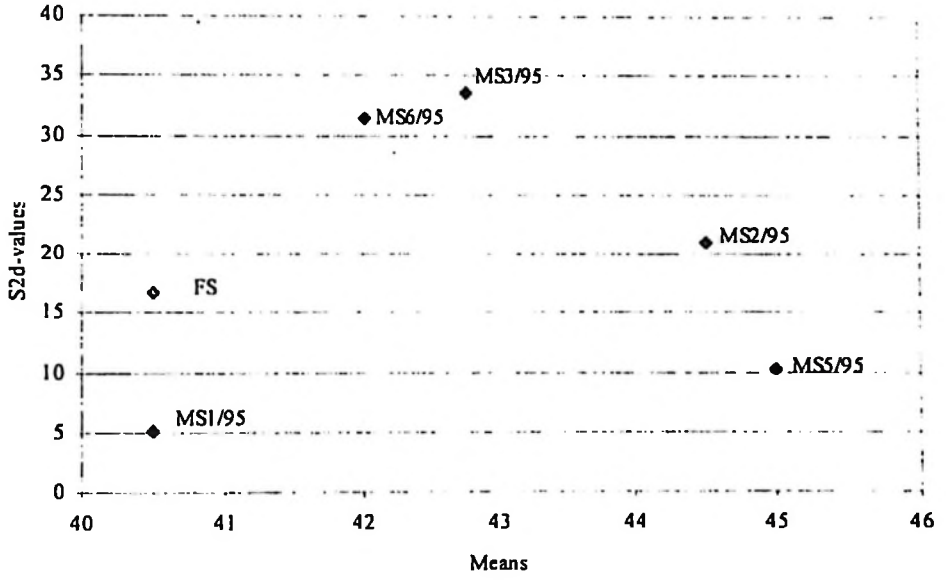


4.5.4.5. Number of primary branches

The relationship between means and variance of deviation from regression for number of primary branches is depicted in a scatter diagram and shows that MS5/95 had low value

of variance of deviation from regression and a high mean. On the other hand, MS1/95 and FS had low values of variance of deviation from regression with fewer primary branches.

Fig.17. Scatter diagram of means against S2d for number of primary branches

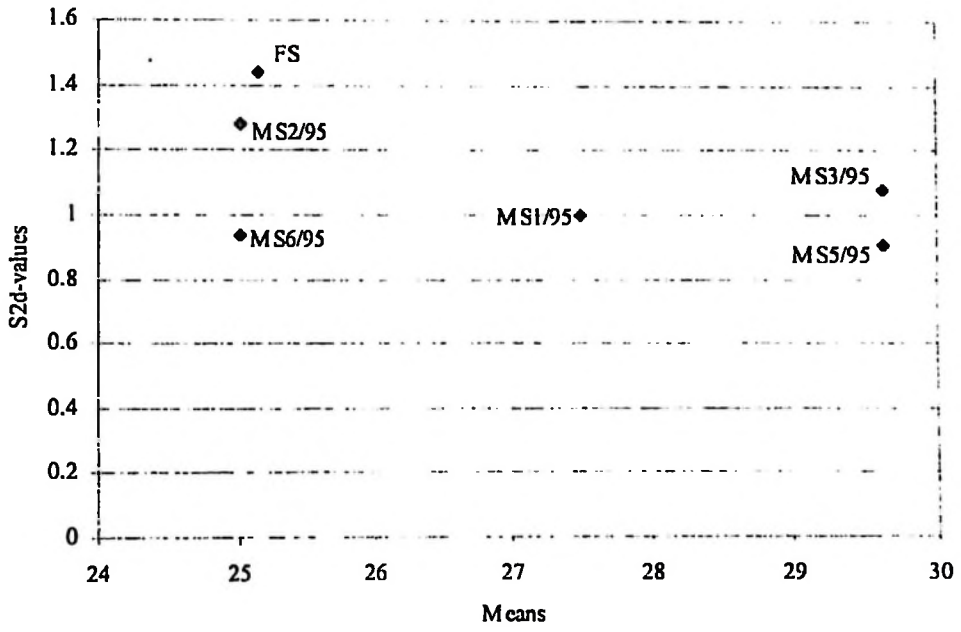


4.5.4.6. Number of flowers per node

The scatter diagram indicating the relationship between means and the variance of deviation from regression for number of flowers per node shows that MS3/95 and MS5/95 had relatively low values of variance of deviation from regression with more flowers produced. MS1/95 had medium mean and low value of variance of deviation

from regression while MS6/95 had fewer flowers and low variance of deviation from regression.

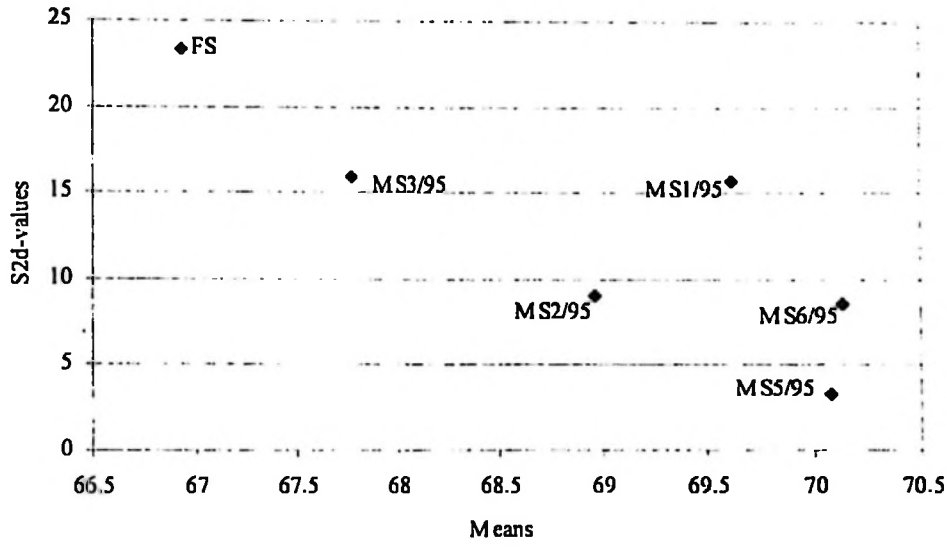
Fig.18.Scatter diagram of means against S2d-values for number of flowers per node



4.5.4.7. Percentage bearing primary branches

The scatter diagram indicating the relationship between means and the variance of deviation from regression for percentage bearing primary branches shows that MS5/95 and MS6/95 had low values of variance of deviation from regression with higher percentage of bearing primary branches. On the other hand, MS2/95 had medium mean and low value of variance of deviation from regression.

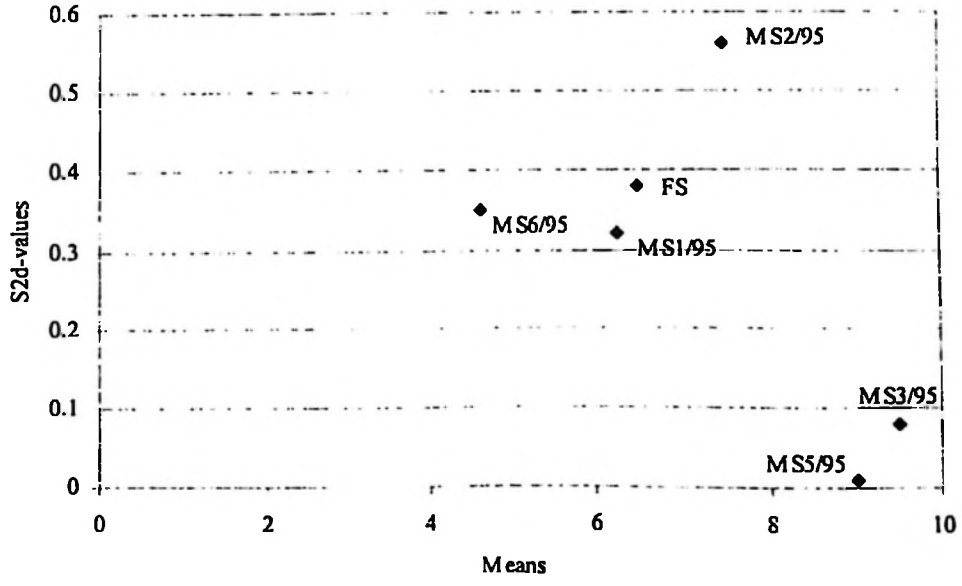
Fig.19.Scatter diagram of means against S2d-values for percentage bearing primary branches



4.5.4.8. Number of berries per node

The relationship between means and variance of deviation from regression for number of berries per node is depicted in a scatter diagram and shows that MS3/95 and MS5/95 were the only genotypes which had low values of variance of deviation from regression and high means.

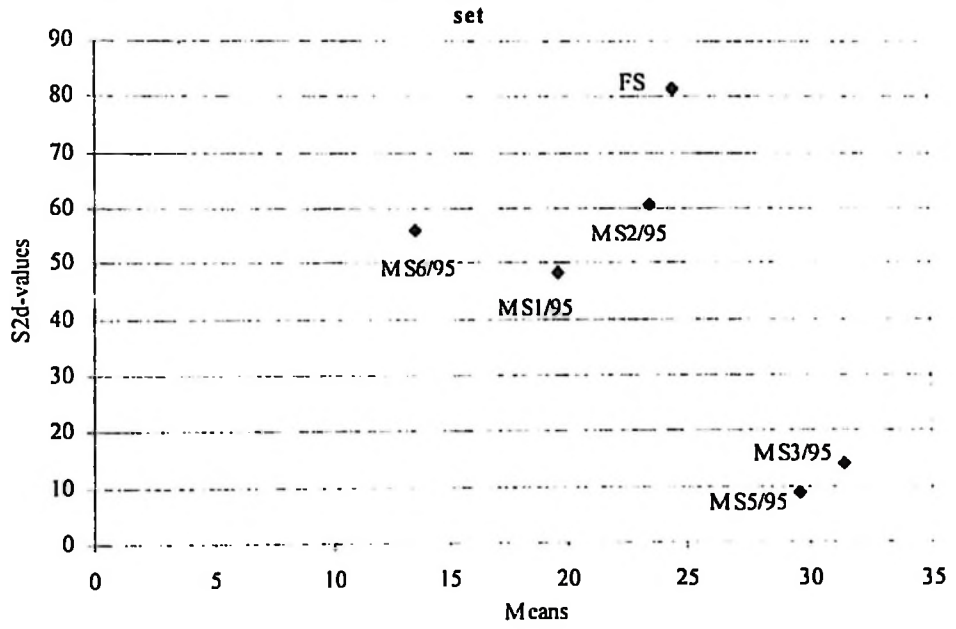
Fig.20. Scatter diagram of means against S2d-values for number of berries per node



4.5.4.9. Percentage fruit set

The scatter diagram indicating the relationship between means and the variance of deviation from regression for percentage fruit set shows that MS3/95 and MS5/95 had low values of variance of deviation from regression with higher percentages of fruit set.

Fig.21. Scatter diagram of means against S2d-values for percentage fruit set

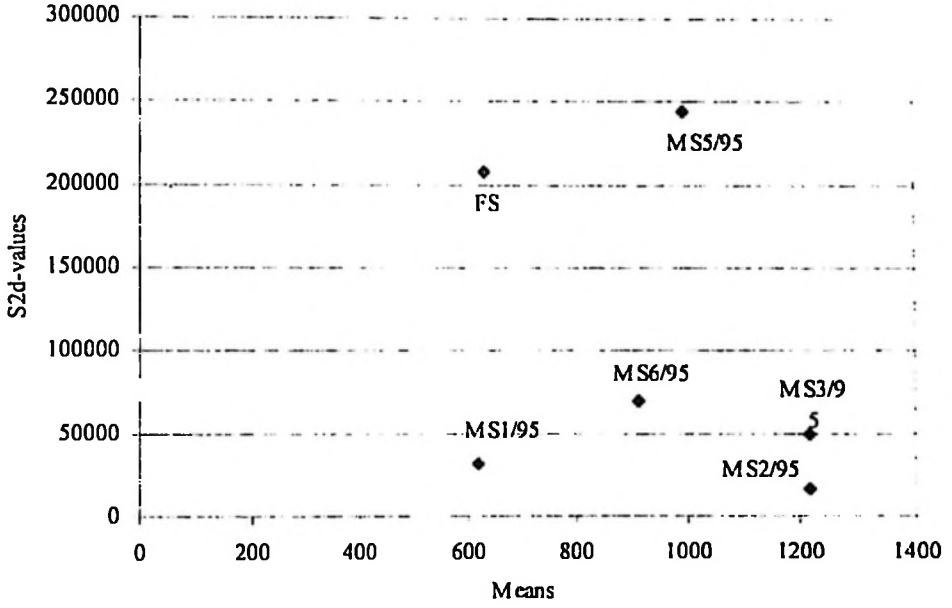


4.5.4.10. Yield of clean coffee

The relationship between means and variance of deviation from regression for yield of clean coffee is depicted in a scatter diagram and shows that MS3/95 and MS2/95 had low values of variance of deviation from regression and higher yields. MS6/95 had

medium mean but low variance of deviation from regression while MS1/95 had relatively low mean and low variance of deviation from regression.

Fig.22. Scatter diagram of means against S2d for yield of clean coffee



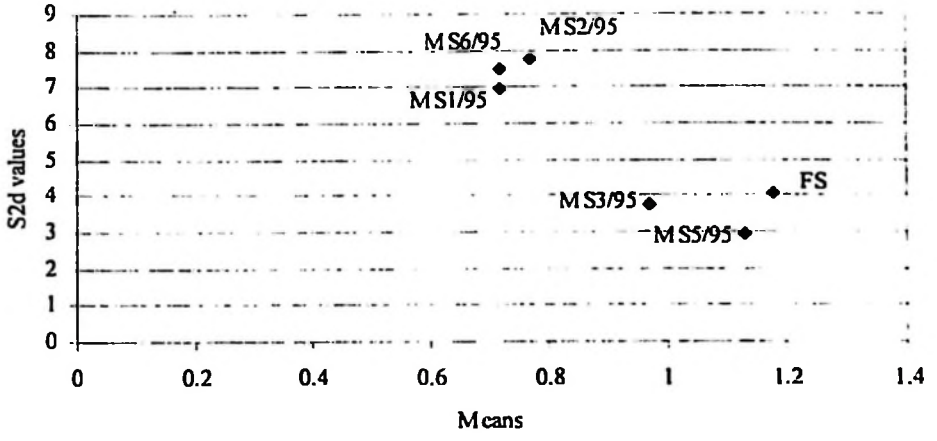
4.5.5. Relationship between genotype means and variance of deviation from regression, S^2d, for CLR severity

4.5.5.1. Coffee Leaf Rust (CLR) severity

The relationship between means and variance of deviation from regression for CLR is depicted in a scatter diagram and shows that there is no genotype which had both low mean and low value of deviation from regression on CLR severity. Although MS1/95,

MS6/95 and MS2/95 had relatively the lowest means, their variance of deviation from regression were high.

Fig.23 Scatter diagram of S2d values against means for CLR severity



4.6. Path coefficient analysis

4.6.1. Path coefficient analysis for some growth and yield characters.

Results indicating direct and indirect effects of some growth and yield characters using phenotypic correlations combined over four locations for six genotypes are shown in Figure 24 and Table 38 with a detailed illustration on how the indirect effects were obtained. The correlation between plant height and yield (r =0.642**) was

predominantly attributed by the direct influence (0.401) of plant height on the yield of coffee. With respect to the relationship between plant girth and yield (r = 0.590**) this was largely attributed to the indirect effect of plant girth through plant height (0.365). The latter was due to the relatively high direct effect of plant height on yield (0.401) and a significant and positive correlation between plant height and plant girth (r = 0.911**). For the relationship between plant canopy and yield, (r = 0.575**), it was largely due to indirect effect of canopy radius through plant height (0.308) as plant height had high direct effect on yield (0.401) and significant and positive correlation between canopy radius with plant height (r = 0.769**). The correlation between number of primary branches and yield (r = 0.510**) was mainly due to indirect effect of number of primary branches through plant height (0.328). The latter was in turn attributed to the positive relationship between number of primary branches with plant height (r = 0.817**) and a positive direct effect of plant height on yield (0.401). The correlation between number of berries per node and yield (r =0.549**) was predominantly attributed by the direct influence (0.315) of number of berries per node on the yield of coffee.

Fig. 24. Path diagram indicating paths of influence for yield and growth components of robusta coffee.

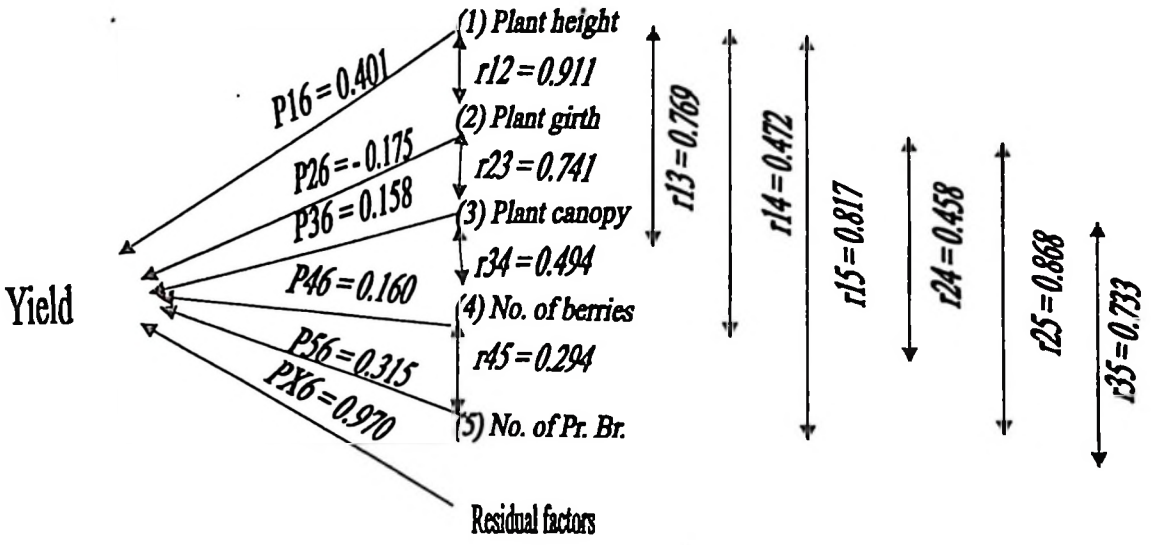


Table 38. Path coefficient analysis for some growth and yield characters on robusta coffee effects on yield.

1. Effect of plant height	r_{16}	**0.642****
Direct effect	P_{16}	0.401
Indirect effect via plant girth	$r_{12}P_{26}$	−0.159
Indirect effect via canopy radius	$r_{13}P_{36}$	0.121
Indirect effect via number of primary branches	$r_{14}P_{46}$	0.131
Indirect effect via number of berries per node	$r_{15}P_{56}$	0.148
Total r		**0.642**
2. Effect of plant girth	r_{26}	**0.590****
Direct effect	P_{26}	−0.175
Indirect effect via plant height	$r_{12}P_{16}$	0.365
Indirect effect via canopy radius	$r_{23}P_{36}$	0.116
Indirect effect via number of primary branches	$r_{24}P_{46}$	0.140
Indirect effect via number of berries per node	$r_{25}P_{56}$	0.144
Total r		**0.590**
3. Effect of plant canopy	r_{36}	**0.575****
Direct effect	P_{36}	0.158
Indirect effect via plant height	$r_{13}P_{16}$	0.308
Indirect effect via plant girth	$r_{23}P_{26}$	−0.130
Indirect effect via number of primary branches	$r_{34}P_{46}$	0.083
Indirect effect via number of berries per node	$r_{35}P_{56}$	0.156
Total r		**0.575**
4. Effect of number of primary branches	r_{46}	**0.510****
Direct effect	P_{46}	0.160
Indirect effect via plant height	$r_{14}P_{16}$	0.328
Indirect effect via plant girth	$r_{24}P_{26}$	−0.152
Indirect effect via plant canopy	$r_{34}P_{36}$	0.082
Indirect effect via number of berries per node	$r_{45}P_{56}$	0.092
Total r		**0.510**
5. Effect of number of berries per node	r_{56}	**0.549****
Direct effect	P_{56}	0.315
Indirect effect via plant height	$r_{15}P_{16}$	0.189
Indirect effect via plant girth	$r_{25}P_{26}$	−0.080
Indirect effect via plant canopy radius	$r_{35}P_{36}$	0.078
Indirect effect via number of primary branches	$r_{45}P_{46}$	0.047
Total r		**0.549**

Residual effect, $Px_6 = 0.970$

4.6.2. Path coefficient analysis over two locations (Kabirizi A and Kabirizi B) for some quality characters .

Path coefficient results on some quality characters indicating direct and indirect effects using phenotypic correlations combined over two locations for six genotypes are shown in Figure 25 and Table 39 with a detailed illustration on how the indirect effects were obtained. The correlation between percentage clean coffee with yield of coffee (r = 0.496*) was largely due to the indirect effect of percentage clean coffee through percent screen 16 (0.805). The latter was in turn attributed to the direct effect of percentage screen 16 on yield of coffee (2.908) and a positive correlation obtained between percentage clean coffee and percentage screen 16 (r = 0.277). Hundred seed weight had a high indirect effect on yield through percentage screen 16 (2.062). This indirect effect was largely attributed to the high direct effect of percentage screen 16 (2.908) and a significant and positive correlation between 100 seed weight and percentage screen 16 (r = 0.709**). The high positive indirect effect was reduced to a low and non significant correlation (r = 0.001) predominantly by the negative indirect effect of 100 seed weight through percentage screen 14 (–1.708). The latter was in turn caused by the significant negative correlation between 100 seed weight and percentage screen 14 (r = –0.703**) and a high positive direct effect of percentage screen 14 on yield (2.429). Thus 100 seed weight and percentage screen 14 interacted negatively in their relationships with yield of clean coffee. Percentage screen 16 had a high positive direct effect on yield of coffee

(2.908). This was however reduced to a low and non significant correlation (r = 0.301) predominantly by the negative indirect effect through percentage screen 14 (–2.419). The latter was due to the significant negative correlation (r = –0.996**) between percentage screen 16 and percentage screen 14 and a high direct effect (2.429) of percentage screen 14 on yield of clean coffee. Thus, percentage screen 16 and percentage screen 14 interacted negatively in their relationships with yield of clean coffee. Percentage screen 14 had high direct effect on yield of coffee (2.429). This was however reduced to a low and negative non significant correlation (r = –0.269) predominantly by the negative indirect effect through percentage screen 16 (–2.896). For CBB the relationships were too low to be of any predictive value and hence CBB was less important in its effect on yield of clean coffee.

Fig. 25. Path diagram indicating the paths of influence for quality components of robusta coffee

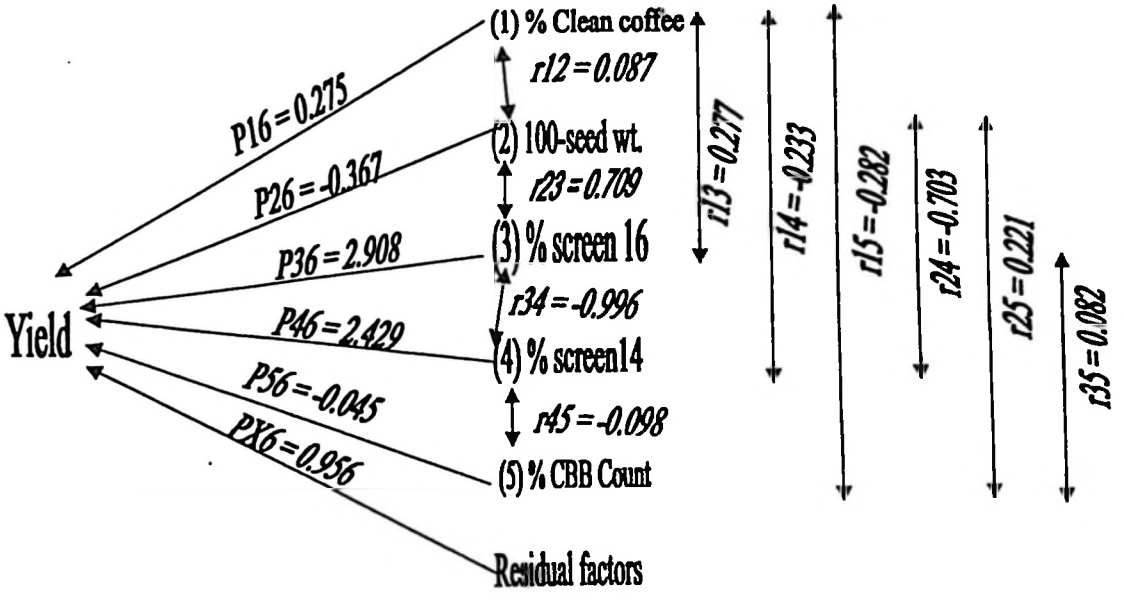


Table 39. Path coefficient analysis for some quality characters on robusta coffee clones tested under two locations (Kabirizi A and Kabirizi B)

Effects on yield of clean coffee		
1. Effect of percentage clean coffee	r_{16}	**0.496***
Direct effect	P_{16}	0.275
Indirect effect via 100-seed weight	$r_{12}P_{26}$	−0.032
Indirect effect via percentage screen 16	$r_{13}P_{36}$	0.805
Indirect effect via percentage screen 14	$r_{14}P_{46}$	−0.566
Indirect effect via percentage Coffee Berry borer	$r_{15}P_{56}$	0.014
Total r		**0.496***
2. Effect of percentage 100-seed weight	r_{26}	**0.001**
Direct effect	P_{26}	−0.367
Indirect effect via percentage clean coffee	$r_{12}P_{16}$	0.024
Indirect effect via percentage screen 16	$r_{23}P_{36}$	2.062
Indirect effect via percentage screen 14	$r_{24}P_{46}$	−1.708
Indirect effect via percentage Coffee Berry borer	$r_{25}P_{56}$	−0.010
Total r		**0.001**
3. Effect of percentage screen 16	r_{36}	**0.301**
Direct effect	P_{36}	2.908
Indirect effect via percentage clean coffee	$r_{13}P_{16}$	0.076
Indirect effect via 100-seed weight	$r_{23}P_{26}$	−0.260
Indirect effect via percentage screen 14	$r_{34}P_{46}$	−2.419
Indirect effect via percentage Coffee Berry borer	$r_{35}P_{56}$	−0.004
Total r		**0.301**
4. Effect of percentage screen 14	r_{46}	**−0.269**
Direct effect	P_{46}	2.429
Indirect effect via percentage clean coffee	$r_{14}P_{16}$	−0.064
Indirect effect via 100-seed weight	$r_{24}P_{26}$	0.258
Indirect effect via percentage screen 16	$r_{34}P_{36}$	−2.896
Indirect effect via percentage Coffee Berry borer	$r_{45}P_{56}$	0.004
Total r		**−0.269**
5. Effect of percentage Coffee Berry borer	r_{56}	**−0.204**
Direct effect	P_{56}	−0.045
Indirect effect via percentage clean coffee	$r_{15}P_{16}$	−0.078
Indirect effect via 100-seed weight	$r_{25}P_{26}$	−0.081
Indirect effect via percentage screen 16	$r_{35}P_{36}$	0.238
Indirect effect via percentage screen 14	$r_{45}P_{46}$	−0.238
Total r		**−0.204**

Residual effect, $Px_6 = 0.956$

CHAPTER FIVE

5.0. DISCUSSION

When cultivars are compared under different agro-ecological zones, their performance relative to each other may not be the same and changes in relative performance of genotypes across environments are referred to as Genotype x Environment interaction (Fehr, 1987). Fehr (1987), defined a genotype as an entire genetic makeup of an individual. Hildebrand and Russell (1996) defined an environment as the product of the entire set of factors, both biophysical and socio-economic, that can materially affect crop productivity.

In evaluating genotypes across environments, the presence of genotype x environment interaction implies the behaviour of the genotypes with respect to the environments under which they are tested. The differences in behaviour of the genotypes, may be due to the result of alterations of the order of the genotypes from one environment to another or absolute differences between the genotypes, which leave the rank order unchanged. When environments are similar or the genetic make-up of trait/variable is highly heritable, genotype x environment interaction will become less important (Ceccarelli, 1989). For plant breeders, G x E interactions are very important in developing and recommending cultivars to suitable environments for specific variables.

In the four locations under which the coffee genotypes were tested, there were differences among and within locations in rainfall amount and distribution, soil types, altitude, disease and pest pressure. Such variability may affect the performance of the genotypes in the different variables as well as the stability of the variables across different environments.

In the study sites, rainfall was not predictable and drought affected some zones like Chanika where one site completely failed to set fruits. The rainfall across the four zones varied between 800 to 1200 mm. and the total rain days varied from 60 to 85 rain days. According to Wrigley (1988), this amount of rainfall if well distributed, without too long a hot and sunny dry season is considered to be enough for coffee production. Rainfall in the study zone especially Chanika and Bisheshe were not well distributed and were accompanied by a long hot and sunny dry season which resulted into differences between locations on performance of the genotypes.

Apart from rainfall, soil variability between zones and within the zones were among factors that affected the performance of the genotypes. Soils of the study areas were so varied with pH ranging from 5.0 to 6.8 while according to Cambrony (1992), acid soils of pH 4.5 to 6.5 are considered to be ideal for growing coffee. At Chanika, especially with farmer number 1 (replication 1), the soil had pH of 6.8 and exceptionally high amount of available phosphorus (560mg/kg) which needs an improvement by adding

humus materials. Replication 2 of Chanika performed better in comparison with the other two replications due to low phosphorus and a desirable pH for coffee growing (Appendix 5). Cambrony (1992), reported that excessive phosphorus in the soil promotes rapid mobilization of nitrogen and potassium hence exhaustion of these two elements which are important elements for coffee production. Other soil variables also had differences in their range within and across locations (see Appendix 5). Due to soil variability within and across locations, it warrants one to do soil analysis before growing coffee.

Altitude across locations ranged from 1100 to 1650m above sea level. Willson (1985) reported that for every an increase of 180m of elevation there is 1^0C drop in temperature, and since robusta coffee requires higher temperatures (24 to 30^0C) than arabica coffee, the differences in altitude affected the performance of the genotypes across or within locations. For example Kabirizi B had the highest yields of clean coffee with lowest altitude. Kabirizi A, Chanika and Bisheshe had higher altitudes with lower yields which did not differ significantly from each other (see Table 12a and Appendix 7). Also, coffee leaf rust according to Mawardi *et al* (1995) who studied the disease on arabica coffee at different altitudes found that at high temperatures and low altitudes the disease is severe. Our study has revealed the same that at Kabirizi A and Kabirizi B leaf rust was higher in comparison with Chanika and Bisheshe which are at higher altitudes (Table 14d and Appendix 7). However, CLR severity differences between locations was not reflected in

yield differences between the locations or genotypes. This is also shown by non-significant correlation coefficient between CLR severity with yield. Similarly although genotypes differed on CLR severity this was not reflected in differences in yield since genotypes did not show significant differences in yield. This is because CLR severity was generally too low to significantly affect yield and bring differences in yield between locations or between genotypes (see Table 14d). In literature so far, the effect of CLR on yield of robusta coffee is very limited.

From the study, plant height, plant girth, canopy radius, number of primary branches and yield of clean coffee varied only between locations indicating that there is no genetic variation with the genotypes studied in this study for the mentioned variables. Future studies should include more genotypes in the analysis in order to widen the genetic variation. Plant height at Kabirizi A and Kabirizi B performed better than Bisheshe and Chanika due to differences in rainfall, soil types, and altitude (Table 12a, Appendix 5, 6 and 7). This finding confirms the results reported by Omondi and Owuor (1992), who worked with inter-specific crosses involving arabica and robusta coffee species in Kenya who found that plant height varied between locations. On the other hand, since these trials are in farmers fields, different management practices especially mulching might have also contributed to the within and across location variations. At Chanika (replication 2) and Bisheshe (replication 1) only one farmer/replicate in each of the two locations had their trial plots mulched while at Kabirizi A and Kabirizi B all farmers had

mulched their trial plots and their plant heights were correspondingly higher (Table 12a). In coffee, usually mulch of 6 inches depth should be applied as from the date of planting in the field and lasts for two seasons before next application but due to the cost and availability of mulch in some areas like Chanika, very few farmers can afford to apply mulch. However, proper mulching of a coffee field has been found to increase yield by 120% (Marandu *et al*, 1997).

The performance for canopy radius, plant girth and number of primary branches at Kabirizi A and Kabirizi B was superior to Chanika and Bisheshe (Table 12a). This is because stable and optimum temperature experienced at Kabirizi A and Kabirizi B throughout the growing period favoured vegetative growth while periodic fluctuation in temperature at Chanika and Bisheshe during the growing season retarded growth. Omondi and Owuor (1992) in Kenya working on interspecific crosses involving arabica and robusta coffee species found that girth was influenced by differences in genotypes and genotype x environment interactions but with non-significant location effects. Differences in results might be attributed to different planting materials used; the present study using robusta clones while the other worker using inter-specific crosses involving arabica and robusta coffee species.

Yield of clean coffee for the one year data showed location differences but when analysis of variance was done for the two year study on combined yield data, there were

significant effects on location and years x location interaction (Table 2a). On the other hand, effects of genotypes, genotype x year and genotype x year x location interaction were not important suggesting that there is no need of analysing genotypes for each year on yield.

From this study, internode length, number of flowers per node, number of berries per node and fruit set percentage across the environments were not affected by either genotypes, locations or genotype x environment interaction differences (Table 11). Lack of significant effects in any of the sources of variation for these variables might be due to lack of genetic variability and environmental influences on the variables. Future work should include more clones/genotypes and a wider range of environments for a more meaningful analysis of these variables. The significant effects of location and genotype x location interactions observed for the percentage bearing primary branches, indicated that the contribution to the variation in percentage bearing primary branches was due to differences in soil nutrients, rainfall and other environmental conditions and not due to the differences between genotypes. The highest number of percentage bearing primary branches was obtained with MS3/95 at Kabirizi B (76.38%) while the lowest was with the same genotype MS3/95 at Chanika (48.07%) (Table 12b). Eberhart and Russell (1966) suggested that a genotype which performs best in the most favourable location performs the least in the least favourable location. It also, supports the hypothesis that the best performers on the average are less stable with significant G x E interactions.

Walyaro (1983), working with arabica coffee plants in Kenya, obtained significant effects on bearing primaries for genotypes x environment interaction. Therefore, recommendations on the performance of percentage bearing primary branches should be looked at each location separately rather than on pooled data across locations since relative performance of the genotypes will depend on specific locations for this variable. The analysis of coffee quality attributes studied was carried out at two locations (Kabirizi A and Kabirizi B) where enough sample was obtained to warrant the analysis. On the other hand, CLR severity analysis was carried out in all the four locations (Table 14b). Coffee Berry Borer analysis in the two locations indicated location variations for the variable depicting that the environmental factors such as rainfall, soil types and altitude had effect on the variable. Kabirizi B had consistently lower scores for percentage CBB count compared to Kabirizi A though not significantly so (Table 14c). The amount of clean coffee obtained from a sample of dry cherries is important for study as some genotypes have big cherries but small beans. Number of cherries in 1/2kg is an indicator of genotype cherry size, since a genotype with high number usually has small cherries.

Hundred seed weight, percentage screen 16 clean coffee and percentage screen 14 clean coffee are among the measures of bean size. Muhamad-Ghawas and Wan-Rubiah (1991) working with 14 robusta coffee progenies in Kluang, Johore, Malaysia reported a 100 seed weight range of 14.14 to 15.95g among four genotypes studied while in this

combined analysis of two locations, a range of 13.62 to 16.20g (Table 15) was recorded among the genotypes. However, the analysis shows that genotypes did not differ significantly on this variable and hence, a need to diversify the gene pool for seed size. Yield variation among genotypes in the present study cannot be attributed to variation among genotypes on 100 seed weight. Coffee grading either at farm level or at factory level is done by use of screens. Screens separate clean coffee beans into different bean sizes. A mixture of screen 16-18 is regarded as robusta superior and a mixture of screen 14-16 is regarded as robusta fair average quality (FAQ) while screen 13-14 is robusta special under-grade (SUG). Below screen 13 is regarded as robusta under-grade (UG) according to Tanzania Coffee Board (TCB) (2000/2001). In this study, screen 16, 14 and 13 were used in separating 1/2kg of clean coffee beans. Combined analysis over two locations showed significant differences for genotypes on screen 16, screen14 and screen 13. The importance of genotype on the variations of screen 16, 14 and 13 suggested that the variability of the variables could be due to their genetic differences. A genotype with higher percentage of screen 13 should not be selected as the main aim of robusta coffee breeding is to breed a genotype with at least higher percent of screen 16 and above. In this study, all the genotypes except FS should be recommended for production and or as sources of genes for improving accessions for higher quality coffee. It is interesting to note that FS which had lower proportion of percentage screen 16 coffee, had higher levels of percentage screen 14 and 13. Thus, FS can generally be regarded as having lower quality coffee in terms of bean size.

Coffee leaf rust combined ANOVA for four locations showed significant differences on locations, genotype and genotype x location interactions (Table 14b). This indicates that the genotypes react differently to the disease and hence there is genetic variation which is potential for selection and genetic improvement. Also, the location differences in temperature and altitude contribute to the disease severity differences. Coffee leaf rust disease pathogens prefer areas with low altitudes which are characterised by high temperatures. At higher altitudes, rust becomes less severe and this is the case when comparing Chanika and Bisheshe which have high altitude and less disease severity compared with Kabirizi A and Kabirizi B which have low altitudes and high disease severity. This is in agreement with results reported by Muwardi *et al* (1995), who found that at higher altitudes, rust becomes less severe. Since there is genotype x location interaction for this variable (Table 14b) there is a need to have location specific genotypes recommendations rather than blanket recommendations. Considering the cost of fungicide and environmental pollution, there is a need to select resistant genotypes for use, for example MS1/95 and MS6/95 (Table 14d) and also use these genotypes for providing genes for resistance to coffee leaf rust in breeding programmes. It is however, important to note that CLR severity rate was generally very low, ranging from 0.18-0.78 on a scale of 0-8. This shows that under the conditions of the study , leaf rust development was not favoured and hence, may not be economically important. CLR for robusta coffee is generally low (Haarer, 1962) and that is why robusta coffee is used as source of genes for improving resistance to CLR in other coffee species.

A knowledge of interrelationships between yield and its major components is important for selecting two or more concurrent complex variables contributing to yield. In this study, simple correlations were studied to find the associations of growth and yield attributes to the final yield. From simple correlation coefficients combined over four locations, yield was highly significant and positively correlated with all the tested variables except internode length (Table 24). This indicated that selection for high yielding clones is possible by indirectly selecting variables which are positively correlated with yield of clean coffee. However, for any variables tested to be meaningfully important as selection criteria for yield the variables themselves should be positively and significantly correlated among themselves. In this study, selecting genotypes for plant height, plant girth, canopy radius, number of flowers per node, percentage bearing primary branches and number of berries per node will at the same time select for yield of clean coffee. Also, these variables can be selected simultaneously in a selection breeding programme since they are positively correlated among themselves hence selection for any of these components will select for yield without the risk of component compensatory effects (Adams, 1967). It can be concluded therefore, that a number of growth and important yield variables, in particular plant height, plant girth, canopy radius, number of flowers per node, percentage bearing primary branches and number of berries per node are worth improving in robusta coffee breeding programmes for improvement of yield. Fruit set percentage and number of berries per node had consistent positive and significant correlation in each location indicating that the

relationship is not easily influenced by changes of environments. Therefore, selection for number of berries after flowering will also select for higher fruit set percentage and finally improving yield of clean coffee since these variables were also positively correlated with yield.

Apart from yield, coffee quality is also an important aspect to be considered in an improvement programme. When simple correlation coefficients were performed for combined analysis over two locations (Table 25), yield of clean coffee was significant and positively correlated with clean coffee in 1kg of dry cherries. It is important to note that 100 seed weight and percentage screen 16 were significantly and negatively correlated with percentage screen 14 and percentage screen 13 indicating that selection of superior genotypes for 100 seed weight and percentage screen 16 will decrease percentage screen 14 and screen 13. Hundred seed weight and percentage screen 16 had consistent positive and significant correlations in all locations indicating that the relationship is not easily influenced by changes of environments. Therefore, selection for hundred seed weight will also select for higher percentage screen 16 and finally improving yield and quality of clean coffee. Quality coffee is characterised by having large bean size. Most research work on coffee is geared to breeding large bean size coffee varieties (Walyaro, 1983). Therefore, this study suggests that greater weightage should be given to coffee varieties which are stable with highest percentage screen 16 and higher weight of 100 seed. MS1/95, MS2/95 and MS6/95 look promising for 100

seed weight and percentage screen 16 for production and providing genes for improvement on performance.

Other quality characters observed were body and flavour. These quality characters were recorded only at Kabirizi A and Kabirizi B where enough sample for cup quality assessment was found. Correlation coefficient analysis at Kabirizi A revealed that body is significant and positively correlated with flavour. This confirms similar results on arabica coffee by Walyaro (1983) who found that most liquor quality characters like acidity, body, flavour and overall standard were positively correlated, implying that one can select both variables simultaneously in an improvement programme. Liquor quality can be poor due to poor liquor genotypes used, poor processing of coffee samples or the effect of the environment during the developmental stages of the coffee berries, for example drought. Kabirizi A had more rains and number of rain days per month than Kabirizi B but soil moisture retention for Kabirizi A is poor as compared to Kabirizi B hence vulnerable to drought (Appendix 5). However, Kabirizi A and Kabirizi B did not differ for the cup quality variables studied (Tables 22 and 23). For selection of robusta coffee, only the overall standard (which is a score given to a coffee sample after considering bean size and liquor quality analyses) need to be considered as pointed out by Walyaro (1983) in arabica coffee breeding in Kenya.

Covariance components were estimated from covariance analyses in an analogous manner to the variance components computed from the analyses of variance to calculate the phenotypic and genotypic correlation coefficients. The phenotypic correlation is the outcome of the genetic and environmental effects. Environmental correlation is of little importance to the breeder when simultaneous selection for more than one quantitative characters are attempted. The current study, indicates that primary branches with plant height were significantly and positively correlated with respect to phenotypic and genotypic correlations on a combined analysis (Tables 26). Also, both phenotypic and genotypic correlations were similar indicating that little environmental effects were involved in the association of the two variables and that genetic causes were more responsible for the correlation between primary branches with plant height. Both of these variables can simultaneously be selected for in improvement programmes. However, the phenotypic correlations were not consistent in each location, suggesting that the relationship between primary branches and plant height depend on the environment. For instance, the relationships were positive and significant at Kabirizi A and Kabirizi B but not at Chanika and Bisheshe. Kabirizi A and Kabirizi B have generally lower altitudes and higher temperatures while Chanika and Bisheshe have higher altitudes and lower temperatures. It seems therefore that relationships between branching and height ares pronounced under more favourable conditions of growth. On the other hand, number of primary branches and percentage bearing primary branches had highly positive phenotypic correlations as it was the case for the correlation obtained from combined

analysis across the four locations. However, we have highly negative genetic correlation between the two variables. The opposite signs for genotypic and phenotypic correlations exhibited by number of primary branches with percentage bearing primary branches as well as number of flowers per node with percentage bearing primary branches and according to Chandraratna (1964), this implies the complexity response to selection and that it might impair or enhance the achievement of breeding objectives.

Significant and negative genetic correlations but positive and significant phenotypic correlations were obtained between percentage bearing primary branches with number of flowers per node and number of primary branches based on a combined analysis. The findings suggest that there are negative genetic influences involved on the relationships of these variables which bring negative relationships. Reasons for negative relationships among components of yield among other factors, may be due to pleiotropy, or genetic linkage. Thus, selection for genes promoting percentage bearing primary branches will select against branching and flowering. The differential relationships between phenotypic and genetic correlations indicate that the environment has a differential effect from genetic causes on the relationships. These variables should have a positive relationship from genetic causes and ways should be sought to break these negative associations. Also, genetic studies should be conducted to discern the cause of such adverse associations. If it is from genetic linkage, then such associations could be broken

by inter-crossing and selection of recombinants. However, if it is pleiotropy, then little can be done to circumvent the problem.

Results of path analysis of components of yield indicate that only plant height and number of berries per node produced had significant and positive correlations with yield and also, their independent effects on yield were relatively high and positive as compared to the other indirect effects. Plant growth variables have been reported to influence yield of coffee (Dancer, 1964; Srinivasan, 1980; Walyaro, 1983). On the other hand, associated yield components such as number of flowers per node, percentage bearing primary branches, fruit set, and number of berries per node have been reported to influence yield according to studies by Cannell, (1971). The findings therefore suggest that for the variables used in the study, taller genotypes which produce more berries per node favour production of higher yields of robusta coffee. With the other variables, viz: plant girth, plant canopy, number of primaries, their positive and significant relationships with yield were predominantly due to their positive interactions with plant height (see Table 39). Thus, in robusta coffee, height interacts favourably with these variables in the production of higher yields. Breeders should therefore produce taller robusta genotypes which are also bending as farmers prefer bending type of robusta coffee for picking and spraying easiness. However, the high residual effect (0.970) obtained in this analysis might be caused by the problem of not getting uniform plants in perennial crops especially in the early years of production and also, the need to increase more number of

contributing variation factors in the analysis. Srinivasan (1980) working with arabica coffee in India by using path coefficient using genotypic correlations found that greater weightage should be given for longer primaries and shorter internodes in selection for yield, as they had high and direct effects. Differential findings could be attributed to differences in species, environments and variables included in the analysis.

Path analysis for some quality characters for two locations (Kabirizi A and Kabirizi B) revealed that percentage screen 16 and percentage screen 14 had high direct contributions to yield of clean coffee. Therefore, percentage screen 16 and percentage screen 14 should be taken as important variables to select for increased yield of clean coffee. However, results suggest that the negative correlation existing between percentage screen 16 and 14 adversely affect the overall relationships between these quality attributes and yield. Had it not been for the negative indirect effects through percentage screen 16 and 14, the overall relationship between the quality attributes with yield would have been positive and significant. The findings show the importance of compensatory mechanisms operating within a system of variable interrelations (Adams, 1967). To improve the correlation between the quality characters with yield, we need to break the negative relationships between percentage screen 16 and 14. We therefore need to investigate on the cause of these associations; if genetic, then, procedures should be used to break them for instance, irradiation, inter-crossing and selection after crossovers. If the cause is environmental, then appropriate husbandry practices could be used to

minimize inter and intra-plant competition for resources. Percentage clean coffee in 1kg of dry cherries and 100-seed weight via percentage screen 16 had high indirect contributions to yield of clean coffee indicating that these variables interact positively in determining yield. However, percentage clean coffee and 100 seed weight also interacted negatively with percentage screen 14 in their influence on yield of clean coffee. It seems therefore that percentage screen 14 has adverse relationships with most of the quality variables which render their relationships with yield low and non-significant. Causes of these negative relationships should be sought and appropriate measures taken to break them. Coffee Berry Borer had very little contribution in yield of clean coffee. This is because the percentage attack of CBB to the cherries/berries was too low ranging from 0.99-1.78% (Table 15) although genotypes differed. But, 100 seed weight was not important either from total correlation or from its direct effect (Table 40). However, for the relationship between 100 seed weight and yield of clean coffee to be meaningful, we need to improve the interaction between 100 seed weight and percentage screen 14 through either genetic or environmental manipulations. Similarly, for percentage screen 16 to be a meaningful criteria in selection for yield of clean coffee, we also need to improve the interaction of percentage screen 16 with percentage screen 14 and vice versa. However, percentage screen 14 is still preferred in the market and hence to be included in a breeding programme.

Accurate estimates of variance of components provide a basis for critically evaluating breeding and testing procedures. In this study, yield and yield attributes estimates of variance components showed that the genetic variances were relatively small for each of the variables (Table 35) as compared with the corresponding phenotypic variances, except for plant girth which had higher genetic variance. High phenotypic variances for the variables indicated that the variables are highly influenced by environmental factors than genetic differences among them. Also, the interaction variances between genotypes and locations, δ^2gl, were higher as compared to the genotypic variances except for plant height, plant girth, and canopy radius which were less important. The interaction variance indicates the variability in the relative performance of genotypes in different environments and their magnitude in comparison to genetic variances for various characters. In this study, the variables which did not exhibit high, δ^2gl, were not affected by the genotype x location interaction. The lack of importance of the genotype x location interaction on these variables suggests that breeders can recommend genotypes based on the improved traits over a wider range of environments without change of relative superiority. Plant girth was more influenced by its genetic make-up than by environmental factors, as reflected by very high heritability estimates. Walyaro and Van der Vossen (1979) reported high heritability value in arabica coffee for stem girth and low heritability for number of primaries in multiple stem, unshaded coffee, in Kenya. When estimates of genotypic variance are high for a variable, its heritability estimates is also simultaneously high with little environmental influence. Heritability in this case, is

the degree to which the variability of a character is transmitted to the progeny. Selections in breeding programmes are made to improve a population or to create a superior population. The advance made by selecting desired types is known as genetic advance under selection. Therefore heritability and genetic advance in selection are very important aspects to be looked at during a breeding programme. Heritability of yield *per se* is generally reported to be low in most crop plants (Srinivasan, 1982). In this study plant girth, number of berries per node and fruit set percentage had high heritability while plant canopy had medium heritability. The heritability for the rest of the variables were not important. Since heritability was high for plant girth, number of berries per node and fruit set percentage and their expected genetic advance were high; selection for these variables may start from the early generations of crop improvement. Canopy radius had low expected genetic advance of 2.42 % of population mean and medium heritability indicating that this variable in a coffee breeding programme can be selected during late stages of the breeding programme.

The analysis for quality attributes was based on two locations; that is Kabirizi A and Kabirizi B where enough sample to warrant analysis was obtained. Considering coffee quality characters, the higher phenotypic variances observed compared to genotypic variances indicated that the differences observed between genotypes were mainly influenced by environmental factors (Table 36). Also, the high G x E variance observed on coffee leaf rust indicated that recommendation of genotypes for coffee leaf rust

should not be done based on blanket recommendation, but each location should be considered separately. Percentage screen 13, and percentage screen 14, although had high heritability and genetic advance values they are not desired in coffee. Percentage clean coffee in 1kg of cherries, 100 seed weight and percentage screen 16 had high heritability and good genetic advances hence look promising for faster improvement and early selection in a coffee breeding programme. On the other hand, number of dry cherries in 1/2kg dry cherries had medium heritability and low genetic advance while percentage CBB had low heritability and low genetic advance, indicating that these variables should be selected in a late stage of a breeding programme.

Yield stability is of particular importance to smallholder farmers like those in Tanzania where control over weeds, diseases and insect pests is limited. Tanzania is also composed of coffee agro-ecological zones which differ in terms of altitude, temperature, humidity and soil characteristics. Coffee breeders, therefore have always aimed at identifying high yielding and stable coffee genotypes. Results from stability analysis on growth and yield attributes indicated that plant height, number of primary branches, percentage bearing primary branches and fruit set percentage were stable variables across all the four locations (Table 37). Stability varied among the tested genotypes as also reported by Mendes *et al* (1996) while working with arabica coffee in Southern Minas Gerais, Brazil.

Scores for genotypes satisfying all stability parameters studied and desired mean for growth variables are shown in (Table 40). For plant height, MS5/95, and FS were stable on plant height response with changing environmental conditions and were taller. This result indicated that the genotypes can perform relatively similar with good performance in all the tested locations on plant height. Thus MS5/95 and FS have potential genes for taller plants and stability of height for use in breeding programmes. All the genotypes were characterised by having high values of coefficient of determination, R^2, for plant height indicating that large amount of variability was attributed to variation among genotypes.

Stability results for plant girth indicated that, all the genotypes had significant variance of deviation from regression showing that the G x E interactions were not a linear function of environmental effects and the means and the b-values are not adequate measures of stability for the genotypes over the environments. Thus, stem girth seems to be less stable in robusta coffee. However, MS1/95, MS5/95 and FS had relatively thicker stems though not meeting all the stability criteria since they had high and significant variances of deviation from regression. Future studies should seek for more clones of coffee containing genes for stability on plant girth. Those could be inter-crossed with MS1/95, MS5/95 and FS with subsequent selections of segregants containing backgrounds for thicker stems and stability. Thicker genotypes are preferred in coffee as an indication of vigour.

For coffee, genotypes with wider canopies are considered optimum but these, should be stable when grown under different environmental conditions. In the present investigation, MS5/95 and MS6/95 had wider canopies but again they do not satisfy all the stability qualities since they had high variances of deviation from regression. However, genotypes MS1/95, MS5/95 and MS6/95 if inter-crossed in a breeding programme there is a possibility of getting segregants with a combination of wider canopies and all the stability attributes.

Shorter internodes are desirable in coffee because they provide for more sites where flowers and berries are formed on a plant. In the current study, there is no single genotype which had short internode with all the stability parameters required. Although MS2/95 had short internodes, it was not stable. All the genotypes tested had significant and high variances of deviation from regression. It seems that genetic variability for the studied clones is too low for a combination of stable and short internodes. Breeders should look for clones with stable genes and cross them with MS2/95 in order to combine shorter internodes with stable genes.

No genotype which produced many branches with all the stability parameters required. However, the current genotypes can be selected and included in a crossing programme to select for clones with many branches and high stability. These are MS5/95 and MS6/95

with possible segregants combining high number of primary branches and stability when grown over wide range of environmental conditions.

Table 40. Scores for genotypes satisfying all stability parameters studied and mean performance for growth characters

Variables	Genotypes	Stability parameters					Remarks
		b significant or non-significant	S^2d significant or non-sign.	S^2d low and non-significant	b vs mean- low b and desired mean	S^2d vs Mean S^2d low and desired mean	
Plant height	MS1/95	NS	NS				
	MS2/95	NS	NS				
	MS3/95	NS	NS				
	MS5/95	NS	NS	YES	YES	YES	Stable/tall
	MS6/95	NS	NS	YES			
	FS	NS	NS	YES	YES	YES	Stable/tall
Plant girth	MS1/95	NS	SIG.		YES		
	MS2/95	NS	SIG				
	MS3/95	NS	SIG.				
	MS5/95	NS	SIG		YES	YES	
	MS6/95	NS	SIG				
	FS	NS	SIG		YES	YES	
Plant canopy	MS1/95	NS	NS	YES			
	MS2/95	NS	NS				
	MS3/95	NS	NS				
	MS5/95	NS	NS			YES	
	MS6/95	NS	NS		YES		
	FS	SIG.	NS				
Internode length	MS1/95	NS	SIG				
	MS2/95	NS	SIG			YES	
	MS3/95	NS	SIG				
	MS5/95	NS	SIG				
	MS6/95	NS	SIG				
	FS	NS	SIG				
No. of Primary Branches.	MS1/95	NS	NS	YES			
	MS2/95	NS	NS				
	MS3/95	NS	NS				
	MS5/95	NS	NS	YES		YES	
	MS6/95	NS	NS		YES		
	FS	NS	NS				

Scores for genotypes satisfying all stability parameters studied and desired mean for yield and yield variables are shown in Table 41. A genotype with many flowers is a good indicator of good yield as more berries under favourable conditions will be produced. For number of flowers per node, MS3/95 and MS5/95 were stable and producing many flowers per node. Thus MS3/95 and MS5/95 have potential genes for numerous flower production and stability for use in breeding programmes.

For percentage bearing primary branches a genotype with high percentage bearing primary branches is more preferred as high percentage bearing primaries will subsequently increase yield. MS6/95 produced many and stable percentage bearing primary branches over a wider range of environmental conditions. This result indicated that the genotype can perform in a relatively similar manner with good performance in all the tested locations on percentage bearing primary branches. Thus MS6/95 has potential stable genes for many bearing primary branches for use in breeding programmes.

Selection for number of berries per node for the genotypes is important as an indicator of higher yield. MS3/95 was stable with many berries per node over a wider range of changing environmental conditions. This result indicated that the genotypes can perform relatively similar with good performance in all the tested locations on number of berries

per node. MS3/95 has potential stable genes for many berries per node for use in breeding programmes.

Fruit set percentage is a measure of the ability of a clone/genotype to form fruits after flowering. The current study indicated that MS3/95 and MS5/95 were stable and had high percentage fruit set with changing environments. The findings imply that the genotypes can perform in a relatively similar way with good performance in all the tested locations on percentage fruit set. MS3/95 and MS5/95 have potential genes for stability and many fruits for use in breeding programmes.

No genotype which produced high yield of clean coffee with all the stability parameters was found in this study. Montagnon et al (1999), working with different robusta clones in Ivory Coast found that their four most productive clones (119, 503, 526 and 588) at all sites tested were stable as regards to Nassar and Huhn test: irrespective of the location, they always ranked among the highest yielders. Our results differed due to the different clones used and probably, the different stability methods of analysis used. However, the current genotypes can be selected and included in a crossing programme to select for clones with high yield and high stability. These are MS1/95, MS2/95, MS3/95 and MS5/95 with possible segregants combining high yield of clean coffee and stablilty when grown over wide range of environmental conditions.

Table 41. Scores for genotypes satisfying all stability parameters studied and mean performance for yield and yield components

Variables	Genotypes	Stability parameters					Remarks
		b significant or non-significant	S^2d significant or non-sign.	S^2d low and non-significant	b vs mean low b and desired mean	S^2d vs Mean S^2d low and desired mean	
No. of flowers/node	MS1/95	NS	NS	YES			
	MS2/95	NS	NS				
	MS3/95	NS	NS	YES	YES	YES	Stable/many
	MS5/95	NS	NS	YES	YES	YES	Stable/many
	MS6/95	NS	NS	YES			
	FS	NS	NS				
Bearing Pr.Br.(%)	MS1/95	NS	NS		YES		
	MS2/95	NS	NS	YES			
	MS3/95	NS	NS				
	MS5/95	NS	NS	YES		YES	
	MS6/95	NS	NS	YES	YES	YES	Stable/high
	FS	NS	NS				
No. of berries/node	MS1/95	NS	SIG				
	MS2/95	NS	SIG				
	MS3/95	NS	NS	YES	YES	YES	Stable/many
	MS5/95	SIG	SIG		YES	YES	
	MS6/95	NS	SIG				
	FS	NS	NS	YES			
Fruit set (%)	MS1/95	NS	NS				
	MS2/95	NS	NS				
	MS3/95	NS	NS	YES	YES	YES	Stable/high
	MS5/95	NS	NS	YES	YES	YES	Stable/high
	MS6/95	NS	NS				
	FS	NS	NS		YES		
Yield clean coffee	MS1/95	NS	NS	YES			
	MS2/95	SIG	NS	YES		YES	
	MS3/95	NS	NS			YES	
	MS5/95	NS	NS		YES		
	MS6/95	NS	NS				
	FS	NS	NS				

Scores for genotypes satisfying all stability parameters studied and desired mean for CLR severity is shown in Table 42.

In case of insect pests, a genotype with low levels of insect infestation and disease infection is mostly preferred.

For CLR severity, there was no single genotype, which had low CLR severity, with all the stability traits. However, the current genotypes can be selected and included in a crossing programme to select for clones with low CLR severity and high stability. These are MS1/95, MS2/95, MS3/95 and MS5/95 with possible segregants combining low CLR severity and stablity across environments.

Table 42 Scores for genotypes satisfying all stability parameters studied and mean performance for CLR severity.

Variables	Genotypes	Stability parameters					Remarks
		b significant or non-significant	S^2d significant or non-sign.	S^2d low and non-significant	b vs mean-low b and desired mean	S^2d vs Mean low S^2d and desired mean	
Coffee Leaf Rust severity	MS1/95	NS	NS		YES	YES	
	MS2/95	NS	NS		YES	YES	
	MS3/95	NS	NS	YES			
	MS5/95	NS	NS	YES			
	MS6/95	SIG	NS			YES	
	FS	SIG	NS				

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

In the 2000/2001, a study was conducted to evaluate the effect of genotype x environment interaction and the interrelationships among growth, yield and quality components of robusta coffee clones in Kagera region, Tanzania. The study revealed that:

In the four locations, under which the coffee genotypes were tested, the locations differed in rainfall amount and distribution, soil types, altitude, disease, insect pest pressure and farmers' management practices.

From the study, the analysis of variance revealed that plant height, plant girth, canopy radius, number of primary branches, percentage bearing primary branches and yield of clean coffee were influenced by location variations due to differences in rainfall, soil types, management practices and altitude. The importance of location and genotype x location interactions were observed for the percentage bearing primary branches across the studied locations. Therefore there is a need to test genotypes in different locations and recommend genotypes to a specific location rather than having blanket recommendation.

Yield of clean coffee analysis of variance for two years in the combined analysis, indicated location and year x location interaction effects thus suggesting the need to have more number of testing years for more meaningful results. Yield is a quantitative trait, controlled by many genes and hence easily influenced by changes of environments. However, there is still a need to seek for stable quantitative genes with high yielding characteristics and include them in a breeding programme.

The analysis of variance carried out in two locations indicated location variations for percentage CBB count and CLR severity. Kabirizi B had the lowest scores for both percentage CBB count and CLR severity.

The significant differences between genotypes showed by percentage screen 16, percentage screen 14 and percentage screen 13 traits in combined analysis of variance over two locations suggested that the variability of the traits were influenced by their genetic make-up. Thus, selection for or against these traits can be based on their genotypic differences.

Based on the statistical analysis for two locations on quality traits, MS1/95, MS2/95 and MS3/95 had higher percentage screen 16 and 100 seed weight and therefore should be selected in the improvement of desired coffee bean size.

Combined ANOVA over four locations for CLR severity indicated G x E interaction showing that some genotypes were influenced by differences in environmental factors and therefore the need to develop clones to specific environments for CLR severity.

Plant height and number of berries per node had significant positive correlations and direct influence on yield of clean coffee while plant girth, canopy radius, and number of primary branches had significant positive correlations and indirect influence on yield of clean coffee which indicated that breeding for improvement of these variables will also increase yield of clean coffee. For quality characters, percentage screen 16 and percentage screen 14 had high direct effect on yield of clean coffee. Percentage clean coffee and 100 seed weight interacted favourably with percentage screen 16 in influencing yield of clean coffee indicating that breeding for improvement of these variables will also increase yield of clean coffee.

Phenotypic and genotypic correlation coefficients analysis indicated that number of primary branches with plant height had similar phenotypic and genotypic correlations indicating that both of these variables can simultaneously be selected for in robusta coffee improvement programmes. The opposite signs for genotypic and phenotypic correlations exhibited by number of primary branches and percentage bearing primary branches as well as number of flowers per node and percentage bearing primary branches

suggest that selection for genes promoting percentage bearing primary branches will select against branching and flowering.

Estimates of variance of components showed high phenotypic variances as compared with the corresponding genetic variances for the yield and growth variables except plant girth indicating that the variables are highly influenced by environmental factors than genetic differences among them.

In this study, heritability was high for plant girth, number of berries per node and fruit set percentage and their expected genetic advances were high; thus selection for these variables may start from the early generations of crop improvement. Plant canopy had medium heritability and low expected genetic advance of 2.42% of population mean indicating that this variable in a coffee breeding programme can be selected in a late stage of the breeding programme.

The higher phenotypic variances observed for the quality variables in the analysis of two locations as compared to genotypic variances and higher G x E interaction variance for CLR severity suggested that recommendation should not be done based on blanket recommendation, but each location should be considered separately. Percentage screen 14 and percentage screen 13 had high heritability and high genetic advance, but they are not desired in coffee and should be selected against in a coffee breeding programme.

Hundred seed weight, percentage screen 16 and clean coffee in 1kg cherries had relatively high heritability and good genetic advances hence look promising for faster improvement and early selection in a coffee breeding programme. Number of dry cherries in 1/2kg had medium heritability and low genetic advance while percentage CBB had low heritability and low genetic advance suggesting that these traits should be selected in a late stage of a breeding programme.

Based on all stability tools used in this study, MS5/95 was stable with desired mean for plant height, number of flowers per node and fruit set percentage while FS was stable for plant height implying that the relative performance of genotypes for the traits are not affected with environmental changes and should be used as source of stability genes for the traits. On the other hand, MS6/95 was stable with desired mean for percentage bearing primary branches, thus can be used as source of genes for improvement in a robusta coffee breeding programme.

Extension of this study for 1-2 consecutive year(s) is necessary for conclusive results.

7.0 REFERENCES.

Al-Jibouri, H.L. Miller, P.A. and Robinson, H.F. (1958). Genotypic and environment variances and covariances in upland cotton cross of interspecific origin. *Agronomy Journal.* 50: 633-636

Annon., (1994). Coffee sector study in Kagera Region. The Netherlands Economic Institute (NEI) The Hague. pp 26-30

Annon., (1995). Lake zone Zonation: In: Proceedings of the Lake zone zonation workshop. Field note No.54 Lake Zone Agricultural Research Institute. pp 13-15

Agwanda, C.O. and Owuor J.B.O. (1989). Clonal comparative trials in arabica coffee (*Coffea arabica* Linn) 1: The effect of broadening the genetic base on the stability of yield in Kenya. *Kenya coffee.* 54 : 633, 639-643.

Agwanda,C.O.; Baradat, P; Cilas, C; Charrier, A. (1997). Genotype x environment interaction and its implications on selection for improved quality in arabica coffee (*Coffea arabica* L.). *CAB Abstract* 1998/08- 2000/04

Baker, R.J. (1969).Genotype-Environment interactions in yield of wheat. *Canadian .Journal Plant Scence.* 49: 743-751

Baijukya, F.P. and Folmer E.C.R. (1999). Agro-ecological zonation of Kagera region.*In: Planning the future: Past, Present and Future Perspectives of Land Use in the Kagera Region.* 50th. anniversary of Maruku Agricultural Research Institute report. pp 9-15

Cambrony, H.R. (1992). *Coffee growing* The Macmillan Press Ltd London. pp 4-19

Chandraratna, M.F. (1964). *Genetics and Breeding of rice.* Longman, Green and Co., London. pp 389

Cannell, M.G.R. (1971). Components of fruit yield. *Coffee Research. Foundation. Kenya Annual Report.* 1970/71: 43-45

Ceccarelli, S. (1989). Wide adaptation: how wide?. *Euphytica.* 40:197-205

Dancer, J. (1964). The measurement of growth in coffee. 11. The relationship between components of shoot and stem diameter at the base of the shoot. *East African Agricultural Forest Journal.* 30: 21-25

Dewey, D.R. and Lu, K.H. (1959): A correlation and path analysis of components of crested wheat grass seed production. *Agronomy Journal.* 51: 515-518.

Eberhart, S.A. and Russell, W.A. (1966). Stability parameters for comparing varieties. *Crop Science Journal.* 6: 36-40.

Eskes, A.B. (1997). Report of Coffee Mission: Coffee breeding and related activities in the context of the EDF support to coffee research in Tanzania. CIRAD-CP, Montpellier. pp 18-24

Finlay, K.W., and Wilkinson G.N. (1963). The analysis of adaptation in a plant breeding programme. *Australia Journal of Agricultural Research.* 14: 742-754.

Fehr, R.F. (1987). Genotype x environment interaction. *Principles of cultivar development.* Vol.1. MacMillan Publishing Company, New York. pp 525.

Gomez, K.A. and Gomez, A.A. (1983). *Statistical procedures for agricultural Research. 2nd. Ed.* John Wiley and Sons, Singapore. pp 20-29

Haarer, A.E. (1962). *Modern coffee production 2nd. Ed.* Leonard Hill, London. pp. 296

Hanson, H.L., Robinson, H.F. and Comstock, R.E. (1956). Biometrical studies of yield in segregating population of Korean Lespedeza. *Agronomy Journal.* 48: 268-272.

Hildebrand P.E. and Russell J.T. (1996). *Adaptability Analysis a method for the Design, Analysis and Interpretation of On-Farm Research- Extension.* Iowa State University Press/Ames. pp 8-26

Heemskerk, W. and Mafuru, J. (1998) *Towards client-oriented research in agriculture. State of the art 1992-1996.* Lake Zone Agricultural Research Institute, Mwanza Tanzania and Royal Tropical Institute, The Netherlands. pp 13

Johnson, H.W; Robinson, H.F.; and Comston, R.E. (1955). Estimates of genetic and environmental variability in soybeans. *Agronomy Journal.* 47:314-318.

Kabwoto,E. (1976). Causes of decline in major crop production, banana, coffee and tea. M.A. thesis University of Dar-es-Salaam Tanzania. pp 15-23

Kaiza,D.A. and B.de Steenhuijsen Piters (1997). Coffee Management and Plant protection problems in Karagwe district. Field Note No. 72. Lake Zone Agric. Research and Training. pp 17-25

Lin, C.S., M.R.Binns, L.P. Lefkovitch (1986). Stability Analysis: Where Do We Stand? *Crop Science Journal.* 26: *894-900.*

Marandu, E.F., D.A. Kaiza, F.P.Baijukya, B.de Steenhuijsen Peters and S.B.Mgenzi (1997). Coffee Research Needs and Recommendations; *In: Proceedings of coffee workshop for Kagera region.* Field No. 76. Lake Zone Agric. Research and Training Institute. pp 32

Marshall, C.F. (1983). *The world coffee trade. A guide to the production, trading and consumption of coffee.* Woodhead-Faulkner Ltd Cambridge CB2 QY, England. pp 85.

Mbilinyi, S.M. (1976). *The economics of peasant coffee production: the case of Tanzania.* Kenya literature bureau, Box 300022 Nairobi. pp 6-7

Michigan State University (1990). MSTAT-C, *A microcomputer for design, management and analysis of agronomic research experiments.* Michigan State University, East Lancing MI.

Montagnon, C; Cilas,C; Leroy,T; Yapo,A; Charmetant, P. (1999). Genotype-location interactions for *Coffea canephora* yield in the Ivory Coast. *Agronomic.* 20:101-109

Moschetto, D., C. Montagnon, B. Guyot, J.J.Perriot, T.Leroy and A.B.Eskes. (1996) Studies on the effect of genotype on cup quality of Coffea canephora. *Tropical Science.* 36: 18-31.

Mendes, A.N.C.; Ramalho, M.A.P; Pereira, A.A.; Bartholo, G.F. (1996). Evaluation of methodologies currently deployed in the selection of Catuai (*Coffee arabica* L.) progenies. *CAB Abstract.* 1996- 1998/07.

Muwardi, S; and Hulupi, R. (1995). Genotype by environment interaction of bean characteristics in arabica coffee. *CAB Abstract.* 1996-1998/07.

Muwardi, S; Sastrowinoto, S.; Pusposendjojo, N.; Nasrullah, D. (1995). Stability of incomplete resistance on arabica coffee to leaf rust at different altitudes. *CAB Abstract.* 1996-1998/07.

Muhamad-Ghawas, M.; Wan-Rubiah, A.; (1991). Yield performance and selection of robusta coffee progenies at Kluang, Johare. *MARDI-Research Journal Malaysia.* 19(1): 43-47.

Nyange, N.E; and Marandu, E.F. (1997). Improvement of *Coffea canephora* gerplasm, in Tanzania: Exploration and collection of new robusta material from farmers' plots. A paper presented to 17th. International Conference on Coffee science ASIC'97 Nairobi Kenya From 20-25 July 1997. pp 71

Omondi, C.O., and Owuor J.B.O. (1992). The performance of interspecific crosses and backcrosses involving arabica and tetraploid robusta coffee species. *Kenya Coffee.* 57(666):1307-1312

Robinson, H.F., Comstock, R.E. and Harvey, P.H.(1949). Estimates of heritability and the degree of dominance in corn. *Agronomy Journal.* 41: 353- 359

Robinson, H.F., Comstock, R.E. and Harvey, P.H.(1951). Genotypic and phenotypic correlations in corn and their implications in selection. *Agronomy Journal.* 43:282-287.

Srinivasan, C.S. (1969). Correlation studies in coffee I Preliminary studies on correlation between stem girth and ripe cherry yield in some coffee selections. *Indian Coffee.* 33:318-320.

Srinivasan, C.S. (1980). Association of some vegetative characters with initial fruit yield in coffee (Coffea arabica L). *Indian Journal of Coffee Research.* 10 (2): 21-27.

Singh, J.V.; Yadava, T.P.; and Kharb, R.P.S.; (1985). Correlation and path-coefficient analysis in sunflower. *Indian Journal of Agricultural Science.* 55(4): 243-246.

Shoran, J.A.G. (1982). Path analysis in pigeonpea. *Indian Journal Genetics.* 42: 319-321

Speke, J.H. (1863); *Journal of the discovery of the source of the Nile.* (Cited by Wrigley, G. (1988); *Coffee;* Longman Scientific & Technical, John Wiley & Sons. New York)

Thomas, A.S. (1940); *Agriculture in Uganda (Edited by Tothill J.D.)* Oxford University Press. p 289-325.

Van der Vossen, H.A.M. (1985). Coffee Selection and Breeding. *In: Coffee: Botany, Biochemistry and production of beans and beverage (Edited by Clifford, M.N. and Willson, K.C.)* Croom Helm. New York. pp 48-96.

Waller, J.W. (1985) Coffee diseases. In: *Coffee: Botany, Biochemistry and production of beans and beverage* (Edited by Clifford, M.N. and Willson, K.C.) Croom Helm. New York. pp 225

Walyaro, D.J.A. (1983). Considerations in breeding for improved yield and quality in arabica coffee (*Coffea arabica* L.). PhD Thesis, Agricultural University, Wageningen, The Netherlands. pp 12-14, 42-43, 70-71, 74-98 and 108

Wellman, F.L. (1961). *Coffee, Botany, Cultivation and Utilization.* Lernard Hill (Books) Limited. London. pp 448

Wrigley, G. (1988); *Coffee;* Longman Scientific & Technical, John Wiley & Sons. New York. pp 639.

Wright, S. (1921); Correlation and causation. *Journal of Agricultural Research.* 20: 557-587

Willson, K.C. (1985). Climate and soil. In: *Coffee: Botany, Biochemistry and production of beans and beverage (Edited by Clifford, M.N. and Willson, K.C.)* Croom Helm. New York. pp 97-107.

Yates, F. and Cochran W.G.(1938): The analysis of group of experiments. *Journal Agricultural Science.* 28: 556-580.

8. APPENDICES

Appendix. (i). ANOVA extract and probability levels for growth and yield characters at Chanika, Bisheshe, Kabirizi A and Kabirizi B for eight robusta coffee genotypes for the 2000/2001

(1a). Chanika

Source of Variation	Df	Mean squares and P									
		Plant height	Plant girth	Canopy radius	Internode length	Primary Branches (No)	Flowers/ node (No.)	Bearing Pr. Br.(%)	Berries/ node (No.)	Fruit set (%)	Yield of clean coffee (kg/ha)
Replication	2	223.51	0.28	220.40*	1.18**	40.50	189.54	136.50	45.79*	357.78*	344852.76
Genotype	7	286.52	0.59	601.10	0.134	123.05	143.52	143.72	18.37	192.90	163540.30
Error.	14	166.12	0.25	511.44	0.17	41.83	114.26	79.03	9.27	79.47	120536.90

* Significant at 5% level ** Significant at 1% level

(1b). Bisheshe

Source of Variation	Df	Mean squares and P									
		Plant height	Plant girth	Canopy radius	Internode length	Primary Branches (No.)	Flowers/ node (No.)	Bearing Pr. Br.(%)	Berries/ node (No.)	Fruit set (%)	Yield of clean coffee (kg/ha)
Replication	1	98.70	0.26	248.69	0.004	4.00	484.00**	14.21	540.56**	4028.12**	2888708.07**
Genotype	7	188.98	0.34	27.67	0.167	52.57	9.96	39.48	8.63	93.30	144518.42
Error	7	71.27	0.10	69.63	0.101	17.14	14.00	19.89	11.85	192.23	91195.67

* Significant at 5% level ** Significant at 1% level

(1c). Kabirizi A

Source of Variation	Df	Mean squares and P									
		Plant height	Plant girth	Canopy radius	Internode length	Primary Branches (No.)	Flowers/ node (No.)	Bearing Pr. Br.(%)	Berries/ node (No.)	Fruit set (%)	Yield of clean coffee (kg/ha)
Replication	2	2139.69**	4.56**	688.34**	1.13**	373.17**	11.37	459.66**	3.50	60.19	282379.75
Genotype	7	125.48	0.16	150.29	0.30	25.31	77.24*	23.11	16.99	64.81	134058.38
Error	14	90.40	0.11	66.02	0.13	20.59	22.33	38.43	11.40	110.40	281640.90

* Significant at 5% level ** Significant at 1% level

(1d).Kabirizi B

Source of Variation	Df	Mean squares and P									
		Plant height	Plant girth	Canopy radius	Internode length	Primary Branches (No.)	Flowers /node (No.)	Bearing Pr. Br.(%)	Berries /node (No.)	Fruit set (%)	Yield of clean coffee (kg/ha)
Replication	2	3546.59**	4.89**	1062.47**	0.43*	523.17**	310.17*	350.88	4.54	16.37	5011016.79**
Genotype	7	101.93	0.34	172.82	0.20	43.05	107.71	114.54	46.64	286.73	1140947.78
Error	14	247.23	0.39	57.06	0.10	43.55	50.69	99.62	42.16	244.88	583026.31

* Significant at 5% level ** Significant at 1% level

Appendix. (ii). ANOVA extract and probability levels for quality characters, insect pest infestation and disease severity at Chanika, Bisheshe, Kabirizi A and B for eight robusta coffee genotypes for the 2000/2001

(2a). Chanika

Source of Variation	Df	Mean squares and P								
		Clean coffee (%)	100 seed weight (g)	Dry cherries in 1/2kg (No.)	Screen 16 clean coffee (%)	Screen 14 clean coffee (%)	Screen 13 clean coffee (%)	CBB count (%)	CBM count (%)	CLR severity (0–8)
Replication	2	392456.13**	226.54**	2282835.54**	6255.21**	779.37**	61.32*	0.15	0.38	0.00**
Genotype	7	100402.39	53.26	559705.66	1185.19	253.15*	19.41	0.06	0.16	0.00**
Error	14	52697.14	32.53	187959.30	526.12	81.18	10.52	0.04	0.16	0.00

* Significant at 5% level ** Significant at 1% level

(2b). Bisheshe

Source of Variation	Df	Mean squares and P								
		Clean coffee (%)	100 seed weight (g)	Dry cherries in 1/2kg (No.)	Screen 16 clean coffee (%)	Screen 14 clean coffee (%)	Screen 13 clean coffee (%)	CBB count (%)	CBM count (%)	CLR severity (0–8)
Replication	1	14648.06	132.25	960400.00	1630.14	882.09*	80.10**	0.01	0.14	0.00
Genotype	7	63476.00	17.32	409727.14	327.53	316.83	25.84**	0.02	0.07	0.01**
Error	7	47622.80	27.52	203572.29	663.80	88.87	1.70	0.13	0.08	0.00

* Significant at 5% level ** Significant at 1% level

(2c). Kabirizi A

Source of Variation	Df	Mean squares and P								
		Clean coffee (%)	100 seed weight (g)	Dry cherries in 1/2kg (No.)	Screen 16 clean coffee (%)	Screen 14 clean coffee (%)	Screen 13 clean coffee (%)	CBB count (%)	CBM count (%)	CLR severity (0–8)
Replication	2	1108.48	1.58	14425.29	173.70	201.50	4.34	1.53	0.38	0.01
Genotype	7	3441.11	7.31	49488.28	475.25	346.87	8.79	0.66	0.03	0.35**
Error	14	2098.65	2.57	29519.96	258.72	201.83	5.61	0.84	0.04	0.04

* Significant at 5% level ** Significant at 1% level

(2d). Kabirizi B

Source of Variation	Df	Mean squares and P								
		Clean coffee (%)	100 seed weight (g)	Dry cherries in 1/2kg (No.)	Screen 16 clean coffee (%)	Screen 14 clean coffee (%)	Screen 13 clean coffee (%)	CBB count (%)	CBM count (%)	CLR severity (0–8)
Replication	2	63582.04	43.74	134540.29	1844.15	85.15	3.09	0.09	0.02	0.02
Genotype	7	20686.95	14.31	128750.45	458.21	326.97**	8.45	0.05	0.05	0.43**
Error	14	26814.62	21.61	130237.15	514.96	52.29	2.96	0.13	0.04	0.02

* Significant at 5% level ** Significant at 1% level

Appendix (iii). ANOVA extract and probability levels for growth and yield characters at Chanika, Bisheshe, Kabirizi A and Kabirizi B for six robusta coffee genotypes for the 2000/2001

(3a). Chanika

Source of Variation	Df	Mean squares and P									
		Plant height	Plant girth	Canopy radius	Internode length	Primary Branches (No)	Flowers/ node (No.)	Bearing Pr. Br.(%)	Berries/ node (No.)	Fruit set (%)	Yield of clean coffee (kg/ha)
Replication	1	316.83	0.27	343.68*	0.67	33.33	161.33	1.00	1.06	67.88	178434.82
Genotype	5	127.28	0.33	84.49	0.11	35.20	189.80	103.70	2.33	360.44	292994.22
Error.	5	138.41	0.22	48.87	0.38	41.33	126.53	47.58	0.40	85.35	166402

* Significant at 5% level ** Significant at 1% level

(3b.) Bisheshe

Source of Variation	Df	Mean squares and P								
		Plant height	Canopy radius	Internode length	Primary Branches (No.)	Flowers/ node (No.)	Bearing Pr. Br.(%)	Berries/ node (No.)	Fruit set (%)	Yield of clean coffee (kg/ha)
Replication	1	184.71	381.71	0.01	0.33	330.75**	12.46	13.08**	3640.43**	2361966.84**
Genotype	5	209.47	17.23	0.17	59.00	4.68	54.32	0.56	103.61	139866.49
Error	5	78.79	66.00	0.13	19.53	18.95	21.55	0.37	155.13	

* Significant at 5% level ** Significant at 1% level

(3c). Kabirizi A

Source of Variation	Df	Mean squares and P									
		Plant height	Plant girth	Canopy radius	Internode length	Primary Branches (No.)	Flowers/ node (No.)	Bearing Pr. Br.(%)	Berries/ node (No.)	Fruit set (%)	Yield of clean coffee (kg/ha)
Replication	1	1713.63**	4.89**	1196.20*	0.32	225.33**	40.33	0.17	0.27	8.35	379208.27
Genotype	5	85.55	0.23*	246.74	0.13	32.00	38.80	10.05	0.94	173.07	199592.27
Error	5	38.29	0.04	91.99	0.07	12.53	29.53	9.26	0.42	71.47	344278.10

* Significant at 5% level ** Significant at 1% level

(3d). Kabirizi B

Source of Variation	Df	Mean squares and P									
		Plant height	Plant girth	Canopy radius	Internod e length	Primary Branches (No.)	Flowers / node (No.)	Bearing Pr. Br.(%)	Berries / node (No.)	Fruit set (%)	Yield of clean coffee (kg/ha)
Replication	1	78.39	0.03	97.13	0.66*	21.33	8.33	24.05	0.21	35.81	460639.31
Genotype	5	15.56	0.14	83.33	0.10	25.33	34.33	8.15	0.33	83.36	1658231.14
Error	5	108.18	0.05	34.43	0.09	38.93	17.13	16.97	0.26	43.76	848531.04

* Significant at 5% level ** Significant at 1% level

Appendix (iv). ANOVA extract and probability levels for quality characters at Chanika, Bisheshe, Kabirizi A and Kabirizi B for six robusta coffee genotypes for the 2000/2001

(4a). Chanika

Source of Variation	Df	Mean squares and P								
		Clean coffee (%)	100 seed weight (g)	Dry cherries in 1/2kg (No.)	Screen 16 clean coffee (%)	Screen 14 clean coffee (%)	Screen 13 clean coffee (%)	CBB count (%)	CBM count (%)	CLR severity (0–8)
Replication	1	54810.08	7.36	34133.33*	229.69	73.01	10.45	0.13	0.11	0.00
Genotype	5	195176.51*	95.28*	1094605.13**	2106.47**	461.45**	35.56	0.34	0.26	0.00
Error	5	30954.16	18.27	3837.53	59.10	24.83	13.89	0.15	0.06	0.00

* Significant at 5% level ** Significant at 1% level

(4b). Bisheshe

Source of Variation	Df	Mean squares and P								
		Clean coffee (%)	100 seed weight (g)	Dry cherries in 1/2kg (No.)	Screen 16 clean coffee (%)	Screen 14 clean coffee (%)	Screen 13 clean coffee (%)	CBB count (%)	CBM count (%)	CLR severity (0–8)
Replication	1	212108.42	161.33	1260360.08	2064.56	1015.68*	78.03**	0.02	0.14	0.00
Genotype	5	62670.29	17.51	457675.08	325.29	381.40	33.38**	0.02	0.09	0.01**
Error	5	52779.85	32.50	224955.08	840.48	92.00	1.11	0.13	0.09	0.00

* Significant at 5% level ** Significant at 1% level

(4c). Kabirizi A

Source of Variation	Df	Mean squares and P								
		Clean coffee (%)	100 seed weight (g)	Dry cherries in 1/2kg (No.)	Screen 16 clean coffee (%)	Screen 14 clean coffee (%)	Screen 13 clean coffee (%)	CBB count (%)	CBM count (%)	CLR severity (0–8)
Replication	1	845.04	1.27	2555787.00	0.48	7.36	1.47	0.71	0.90	0.07
Genotype	5	4353.03	3.06	2191586.93	855.74	581.03	20.71	0.67	0.03	0.37**
Error	5	2613.83	1.11	2044297.00	202.60	145.66	3.77	0.63	0.05	0.03

* Significant at 5% level ** Significant at 1% level

(4d). Kabirizi B

Source of Variation	Df	Mean squares and P								
		Clean coffee (%)	100 seed weight (g)	Dry cherries in 1/2kg (No.)	Screen 16 clean coffee (%)	Screen 14 clean coffee (%)	Screen 13 clean coffee (%)	CBB count (%)	CBM count (%)	CLR severity (0–8)
Replication	1	1635.67*	0.02	5764.08	104.43	60.75	4.08	0.00*	0.01	0.03
Genotype	5	566.10	1.90	8059.35	373.20	240.91	9.77	0.01	0.01	0.33*
Error	5	139.75	3.85	6814.28	98.03	54.87	5.26	0.06	0.02	0.05

* Significant at 5% level ** Significant at 1% level

Appendix (v). Soil analysis data for four locations(Kabirizi A, Kabirizi B, Chanika and Bisheshe) of the trial areas during the 2000/2001

Location	Replication (Farmer No.)	Analysis (percentage separation)			Texture class	pH	Organic matter %	T.N. %	C/N	Available P (ppm)	Cond. mS/cm	Exch.Cations of soil meq/100g			CEC Meq/ 100g
		Sand	Silt	Clay						Bray 1		K	Ca	Mg	
Kabirizi A	1	79	8	13	SL	5.35	0.96	0.05	11	14	0.021	0.17	4.76	0.52	2.61
Kabirizi A	2	11	44	45	SiC	5.52	3.44	0.2	10	4.2	0.026	1.45	18.40	2.9	9.83
Kabirizi A	3	33	18	49	C	6.07	2.49	0.15	10	11.9	0.029	0.11	7.08	0.42	13.21
Kabirizi B	1	51	14	35	SCL	5.85	3.49	0.18	11	4.2	0.028	0.33	10.60	1.00	7.83
Kabirizi B	2	19	28	53	C	5.61	4.70	0.21	13	9.1	0.036	0.22	9.24	0.44	14.44
Kabirizi B	3	7	44	49	SiC	5.45	3.42	0.17	12	12.6	0.022	0.66	10.84	0.66	9.98
Chanika	1	25	40	35	CL	6.80	9.70	0.47	12	560.0	0.070	1.62	26.36	4.04	28.26
Chanika	2	13	34	53	C	5.72	3.30	0.17	11	9.1	0.053	0.53	6.44	1.06	16.28
Chanika	3	11	38	51	C	6.10	6.55	0.32	12	24.5	0.048	0.56	12.00	0.56	23.35
Bisheshe	1	29	20	51	C	6.10	2.99	0.16	11	11.9	0.037	0.40	13.84	0.80	15.36
Bisheshe	2	31	20	49	C	5.85	5.09	0.30	10	2.8	0.035	0.11	13.26	0.34	15.21

Key: S= Sandy, L= Loam, Si = Silt, C= Clay

Appendix (vi). Eleven months of rainfall records in mm. and rain days per month of the study locations during the 2000/2001

Site	SEPT	OCT	NOV	DEC	JAN	FEB.	MAR	APR	MAY	JUN.	JUL	TOTAL	MEAN
Kabirizi A	36	71	79	125	224	32	86	146	102	34	145	1080	98.18
	(3)	(7)	(9)	(9)	(11)	(4)	(12)	(11)	(8)	(5)	(5)	(84)	(8)
Kabirizi B	33	46	72	102	193	26	47	132	83	21	125	880	80.00
	(3)	(6)	(9)	(8)	(13)	(5)	(7)	(10)	(7)	(3)	(2)	(73)	(7)
Bisheshe	27	57	64	109	115	96	253	112	176	67	109	1185	108.73
	(2)	(5)	(7)	(7)	(5)	(6)	(8)	(6)	(11)	(2)	(3)	(62)	(6)
Chanika	25	59	61	102	104	90	183	49	100	57	102	932	84.73
	(3)	(5)	(6)	(7)	(5)	(6)	(8)	(6)	(11)	(2)	(4)	(63)	(6)

Rain days per month in brackets

Appendix (vii). Altitudes of the trial sites

Location	Replication	Altitude m.a.s.l.
Kabirizi A	1	1330
Kabirizi A	2	1330
Kabirizi A	3	1230
Kabirizi B	1	1170
Kabirizi B	2	1190
Kabirizi B	3	1110
Chanika	1	1530
Chanika	2	1490
Chanika	3	1540
Bisheshe	1	1620
Bisheshe	2	1550

Appendix (viii). Standard scale for scoring the whole tree for coffee leaf rust disease.

The scale puts emphasis on proportion of branches with leaves containing sporulating lesions.

CLR 0 - Nil leaves with sporulating lessions

CLR 1 - Number of branches with infected leaves less than 5%

CLR 2 - Number of branches with infected leaves 5-10%

CLR 3 - Number of branches with infected leaves 10-25%

CLR 4 - Number of branches with infected leaves 25- 40%

CLR 5 - Number of branches with infected leaves 40-60%

CLR 6 - Number of branches with infected leaves 60-75%

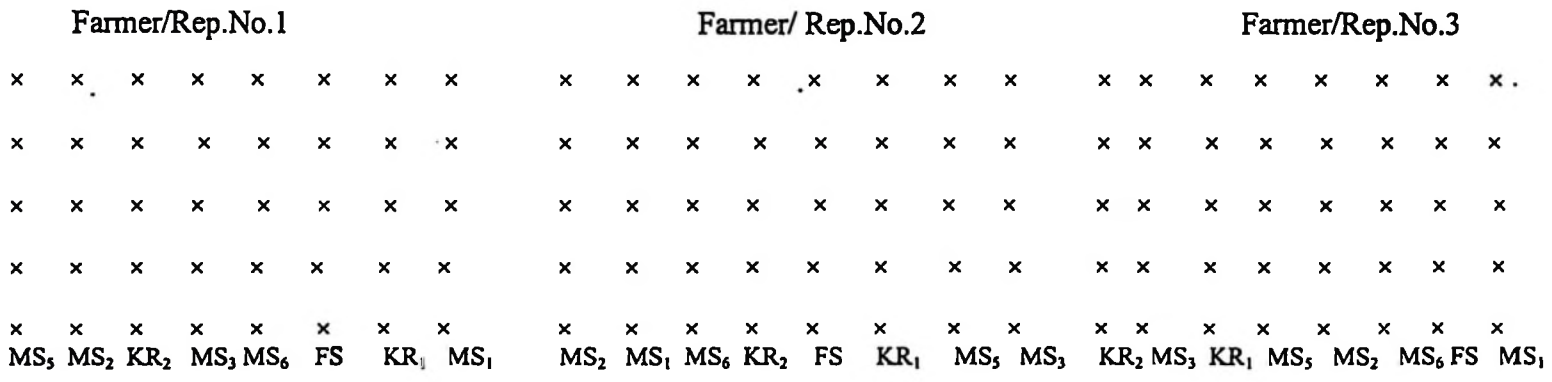
CLR 7 - Number of branches with infected leaves 75-90%

CLR 8 - Number of branches with infected leaves 90-100%

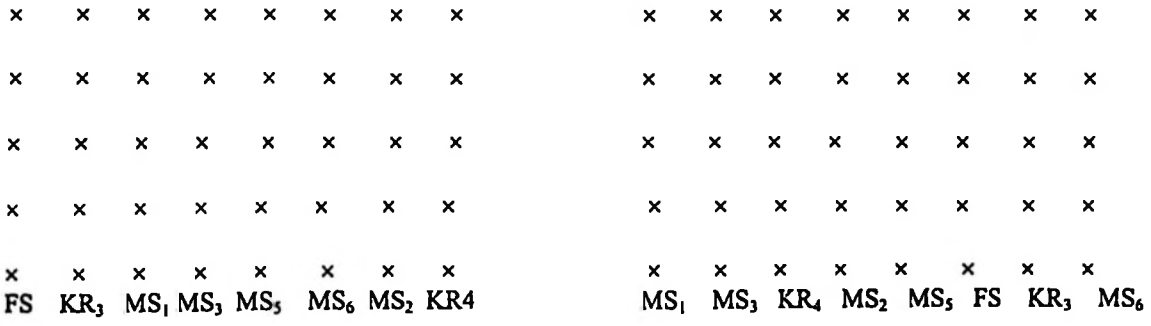
Source: Lyamungu Coffee Research Station

Apendix (ix): Randomization, field layout and replications for the four villages/zones

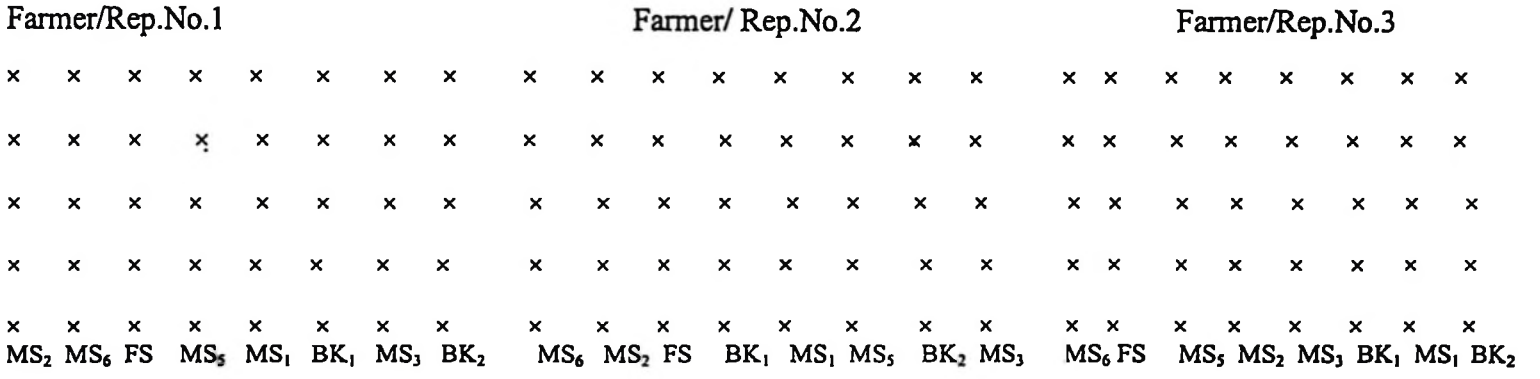
Chanika village robusta coffee on-farm trials



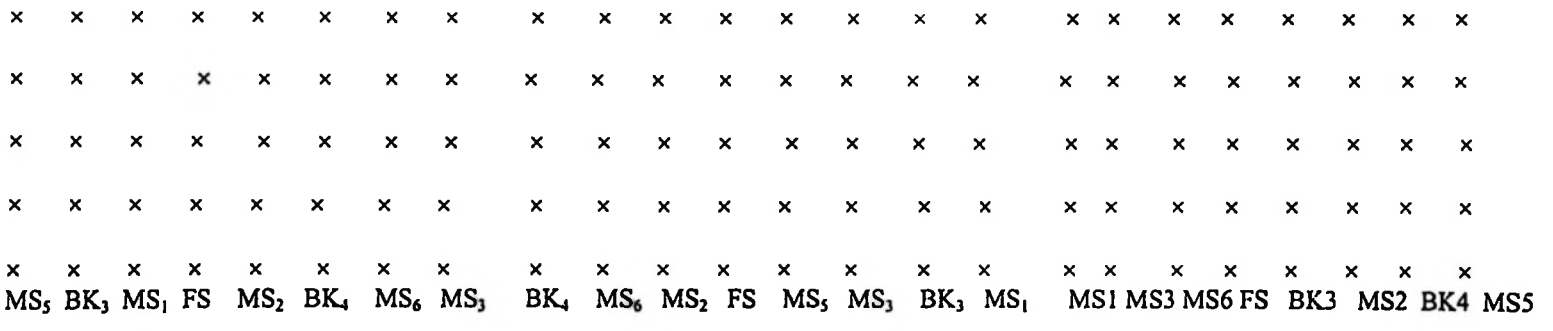
Bisheshe village robusta coffee on-farm trials



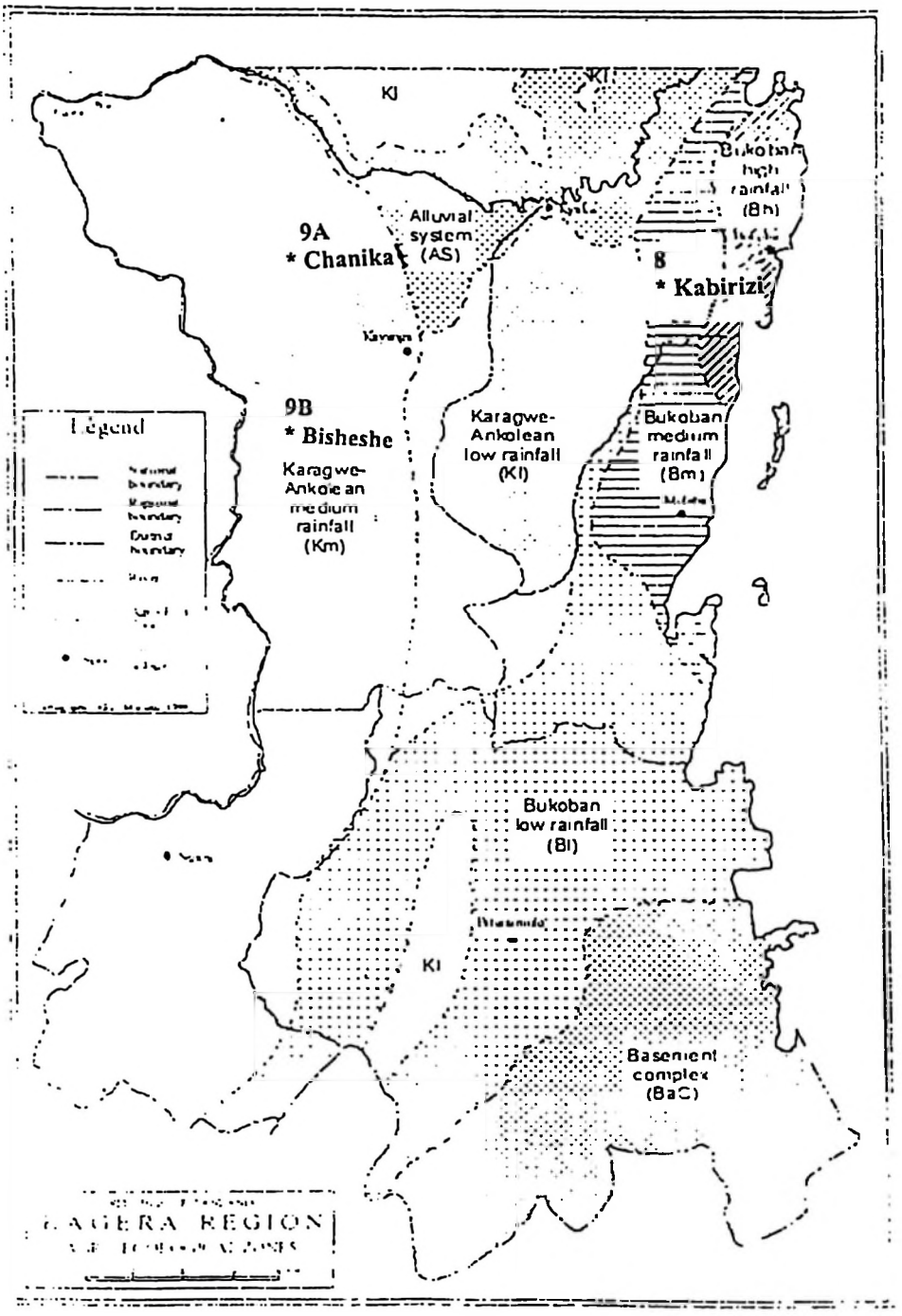
Kabirizi A village robusta coffee on-farm trials



Kabirizi B village robusta coffee on-farm trials



Appendix. (x). A map showing seven agro-ecological zones of Kagera region and locations/villages of trial sites



Appendix. (xi). Path coefficient analysis for some growth and yield characters on robusta coffee

The diagonals are the direct effects and the off diagonals are the indirect effects

Variables	Plant height	Plant girth	Canopy radius	Number of Pr. Br.	Number of berries/node	Total correlation
Plant height	**0.401**	–0.159	0.121	0.131	0.148	0.642
Plant girth	0.365	**–0.175**	0.116	0.140	0.144	0.590
Canopy radius	0.308	–0.130	**0.158**	0.083	0.156	0.575
Number of Pr. Br.	0.328	–0.152	0.082	**0.160**	0.092	0.510
Number of berries/node	0.189	–0.080	0.078	0.047	**0.315**	0.549

Residual efffects/factors $P_{X6} = 0.970$

Appendix (xii). Path coefficient analysis for some quality character on robusta coffee

The diagonals are the direct effects and the off diagonals are the indirect effects

Variables	Clean coffee in 1kg dry cherries(%)	100-seed weight	Percentage screen 16	Percentage screen 14	Percentage coffee berry moth	Total correlation
Clean coffee in 1kg dry cherries(%)	**0.275**	–0.032	0.805	–0.566	0.013	0.496
100-seed weight	0.024	**–0.367**	2.062	–1.708	–0.010	0.001
Per centage screen 16	0.076	–0.260	**2.908**	–2.419	–0.004	0.301
Per centage screen 14	–0.064	0.258	–2.896	**2.429**	0.004	0.269
Per centage coffee berry moth	–0.078	–0.081	0.238	–0.238	**–0.045**	–0.204

Residual efffects/factors $P_{X6} = 0.956$