GENETIC VARIABILITY AND ASSOCIATION OF YIELD AND ITS RELATED TRAITS IN KORARIMA (*Aframomum corrorima* (Braun) Jansen)) GERMPLASM UNDER JIMMA CONDITION, SOUTHWESTERN ETHIOPIA

M.Sc. THESIS

SIMEGN KINFU

NOVEMBER, 2012

JIMMA UNIVERSITY

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M.Sc Thesis

Submitted to the School of Graduate Studies Jimma University, College of Agriculture and Veterinary Medicine

In Partial Fulfillment of the Requirements for the Degree of Master of Science in Horticulture (Coffee, Tea and Spices)

by

Simegn Kinfu

November, 2012

Jimma University

SCHOOL OF GRADUATE STUDIES
JIMMA UNIVERSITY COLLEGE OF AGRICULTURE AND VETERINARY MEDICINE

APPROVAL SHEET

As thesis research advisors we hereby certify that we have read and evaluated the thesis prepared under our direction by Simegn Kinfu, entitled "**Genetic Variability and Association of Yield and Its Related Traits In Korarima *(Aframomum corrorima* (Braun) Jansen.) Germplasm Under Jimma Condition, Southwestern Ethiopa**". We recommend that it will be accepted as fulfilling the thesis requirements.

Sentayehu Alamerw (PhD)	_____	_____
Major Advisor	Signature	Date
Melaku Addisu (M.Sc)	_____	_____
Co-advisor	Signature	Date

As members of Board of Examiners of the M.Sc. thesis open defense examination, we certify that we have read and evaluated the thesis prepared by Simegn Kinfu, and examined the candidate. We recommended that the thesis be submitted as fulfilling the thesis requirements for the Degree of Master of Science in Horticulture (Coffee, Tea and Spices).

_____	_____	_____
Chairman	Signature	Date
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Internal Examiner	Signature	Date
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DEDICATION

To my **FAMILY** for their devotion to the success in my life.

STATEMENT OF THE AUTHOR

First, I declare that this thesis is my work and that all sources of materials used for this thesis have been acknowledged. This thesis has been submitted in partial fulfillment of the requirements for an M. Sc. degree at the **Jimma University College of Agriculture and Veterinary Medicine** and is deposited at the University Library to be made available to borrowers under the rules of the Library. I declare that this thesis is not submitted to any other institution anywhere for the award of academic degree, diploma, or certificate.

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Name: Simegn Kinfu Terefe Signature: _____

Place: Jimma University, Jimma, Ethiopia

Submission Date: _____

BIBLOGRAPHICAL SKETCH

The author was born on September 23, 1988 at Jimma Town. He attended his primery school from 1996 -2003 at chida and Hirmata primary school in konta special woreda and Jimma town respectively. He attended high school education from2004-2006 in Seto Semro Secondary School and preparatory program from 2006 to 2008 at Jimma comprhensive school at Jimma town.

In November 2008 he joined Jimma University College Of Agriculture and Veterinary Medicine and graduated with a B. Sc. Degree in Horticulture in June 2010. Finally he re joined Jimma University College of Agriculture and Veterinary Medicine School of Graduate Studies to peruse his study for masters of science in Horticulture in September 2010.

ACKNOWLEDGEMENTS

Praise and thanks for almighty God, the most merciful, who made every thing possible!!

I am greatly indebted to my major advisor, Dr. Sintayew Alamerew. His expertise guidance, constructive criticism, the incredible amount of patience he had with me and his much-needed insight on research have made a deep impression on me. The strict and extensive comments from him directly impacted on the final form and quality of this thesis. I am also especially grateful to my co-advisor, Ato Melaku Addisu who kept an eye on the progress of my work and always was available when I needed his advises.

I proudly would like to thank the Jimma Agricultural Research Center (JARC) for providing research materials and willingness of giving opportunity to do research on germplasm they collcted. I am also very grateful to Dr. Taye Kufa, Center director of JARC, for his encouragement. My special thanks goes to Ato Haile Abshiro and Masresh Sirag for their generous assistance on the field data collection activities

I am indebted to Ato Girma Haylemichael of Tepi National Agricultural Research Center for his friendly and genuine guidance, help, valuable comment and cooperation starting from the beginning of this work to the end. Above all, I take this as an opportunity to express my heart felt appreciation for unreserved sharing of his knowledge and experiences since proposal writing.

My family, especially Birtukan Kinfu and Ato Yerango Yebo have been a persistent source of encouragement not only during the thesis work but also throughout my academic career and life. I want them to know that I respect and memorize their boundless and invaluable support, beyond a simple thank you. I also extend my heartfelt appreciation to my sisters Emebet Yerango, Rahel Kinfu and Asmarech Kinfu and my lovely brothers AntenehYerango(*abe*), Eyob Yerango, Netsanet Shibeshi, Nigatu Hailemariyam and Taye Tamiru for their boundless love and support.

With this opportunity, I would like to express my affection with great thank to all my friends especially Nejmuddin Seid , Sintayehu Shiferaw , Fuad Oumer , Anteneh Mitiku , Dawit Woldesenbet , Hailiye Nigussie, Hassen Yassin, Feki Misbah and Getenesh Nega for their love, help and courage rendered to me. Sinte my stay in Jimma University College of Agriculture and Veterinary Medicine from BSc. – MS.c study would have been boring and intolerable without your flirting words and fruit full advice during my hardship.

I thank the whole staff of Jimma University Chemistry Laboratory particularly Mr Adam Tamiru whom I greatly appreciate for providing me with ovens and other laboratory materials and Department of Animal Science College of Agriculture and Veterinary Medicine Jimma University Animal Nutrition Laboratory staff Ato Abyot Hunde for willingness to assist me during fat, ash dry matter and crud fiber content analysis

Finally, I also take this opportunity to thank Jimma University College of Agriculture and Veterinary Medicine for providing me fund for my thesis research and allowing me to use all the available materials during the study

LIST OF ACRONYMES AND ABRIVATIONS

ANOVA	Analysis of Variance
CL	Cluster
GA	Genetic Advance
GAM%	Genetic Advance Under Percent Mean
GCV	Genotypic Coefficients of Variation
GV	Genetic Variance
H^2	Heritabilty in Broad Sense
IPGRI	International Plant Genetic Resource Institute
JARC	Jimma Agricultural Research Center
PCA	Principal Component Analysis
PCV	Phenotypic Coefficients of Variation
PV	Phenotypic Variance
SAS	Statistical Analysis System
V/W	Volume per weight
W/W	Weight per weight

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GENETIC VARIABILITY AND ASSOCIATION OF YIELD AND ITS RELATED TRAITS IN KORARIMA (*Aframomum corrorima* (Braun) Jansen*)* GERMPLASM UNDER JIMMA CONDITION, SOUTHWESTERN ETHIOPIA

ABSTRACT

Information on genetic variability for yield and related traits is prerequisite for further improvement of any crops. Currently, under Ethiopia korerima improvement project, large numbers of korarima accessions are collected from different major growing regions of Ethiopia by Jimma Agricultural Research Center (JARC). As far as the variability and association among characters in these accessions of korarima is concerned nothing has been done. Therefore twenty five korarima (Aframomum corrorima) germplasm accessions were tested using simple lattice design at Jimma Agricultural Research Center in 2011/12.Data were recorded on 21 characters with the objective of estimating the extent of variation and correlation between pairs of characters. Analysis of variance revealed that there was significance difference among the genotypes for the characters studied except internodal length, seed weight and dry matter content. High phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) recorded for bearing tiller, leaf area, and ash and crud fiber content. High heritability coupled with high genetic advance as percent mean were estimated for plant height, bearing tiller, number of capsule per plant, diameter of fresh and dry capsule, ash, crud fiber and oleoresin content; moderate heritability values coupled with higher genetic advance were observed for total tiller, length of fresh capsule, weight of dry capsule, length of dry capsule, volatile oil and crud fat content. This indicates that these characters could be improved through selection. Yield per plant had positive and significant association with total tiller, bearing tiller, number of leaves per stem, number of capsule per plant, weight of fresh capsule and length of dry capsule both at genotypic and phenotypic level of significance: indicating the possibility of correlated response to selection. Genotypic path analysis showed that, number of capsule per plant exerted maximum direct effect on yield .This justifies the correlation explains true relationship and direct selection through this traits will be effective. Diameter of dry capsule, total tiller, weight of dry capsule and length of fresh capsule also has positive direct effect on yield. Cluster analysis revealed that the 25 korarima germplasm were grouped in to four clusters. Distance among these clusters is significantly different for all the cluster combination. This indicates that there is an opportunity to bring about improvement through hybridization of germplasm from different clusters and subsequent selection from the segregating generations. Principal component analysis indicated that six principal components explained about 80.51% of the total variation. Differentiation of germplasm into different cluster was because of cumulative effect of number of characters. The present study generally implied the presence of significant genetic variability among the tested genotypes. Thus, there is an excellent opportunity to bring about improvement through direct selection and hybridization which involves crossing of genotypes from different clusters. This finding, being the result of one year and one location, it is recommended that the experiment should be repeated at more location and years with more germplasm to confirm the these results.

Key words: korarima (Aframomum corrorima), genetic variability, heritability, path coefficients, genetic divergence, yield per plant.

INTRODUCTION

Korarima *(Aframomum corrorima* (Braun) P.C.M. Jansen*)* belongs to the family Zingiberaceae and genus *Aframomum*, and originated in Ethiopia . It is a perennial tropical aromatic herb, often of large size, bearing flowers either terminally on aerial leaf shoots or from ground level. Korarima grows usually with strong fibrous subterranean scaly rhizomes and with leafy stems reaching 1–2 m high. It is usually self-pollinated. The position of stigma in the flower is below or against the base of the anther. Occasionally cross-pollination by insects is possible due to the presence of large nectaries at the top of the ovaries. In Ethiopia, korarima grows naturally at 1,700–2,000 m asl (Jansen, 2002).

Korarima, also called "false cardamom", has been part of daily Ethiopian dishes for preparation of curry powder used for culinary purposes. Earlier it was mainly harvested from wildly grown plants in the forests. The dried pods are sold in almost every Ethiopian market and are quite expensive compared to other spices. The seeds are used to flavour coffee, bread, butter and all kinds of sauces. They are ground and often mixed with other spices(Jansen, 2002).

The seeds of korarima contain different types of essential oils having typical odour (Jansen 1981; Abegaz *et al*.,1994; Eyob *et al*.,2007) and are traditionally used as tonic, carminative and purgative drug. From a formal survey, korarima seeds, pods, leaves, rhizomes and flowers are used in southern Ethiopia as traditional medicine for human and animal ailments caused by unknown agents; and particularly used to treat any part of the animal body upon swelling (Eyob *et al.,*2008).

Korarima has been used as an export crop from southern Ethiopia. Ethiopia exported dried pods of korarima to Sudan, Egypt, Arabia, Iran, India and the Scandinavian markets (Jansen, 1981; Lock, 1997). On average 11,000 and 118,000 kg of dried pods were exported annually to Finland and Sweden, respectively, in the early 70s. However, the total annual export decreased to less than 60,000 kg from 1994 to 1998 fetching only some 2.1 million USD (Chanyalew, 1999).

In the early 1978 korarima was sold for 9 USD kg^{-1} in the export market, mainly as a substitute to cardamom (Eyob *et al.,*2008). Due to shortage of supply in the year 2001, the export market price reached as high as 23.5 USD kg^{-1}.

The economic returns obtained from korarima (yields per ha) were much higher than food cereals grown in the major korarima growing administrative zones as reported by Ethiopian Agricultural Research Organization, EARO (2000). The great potential of this plant has, however, encountered different production problems.

In the last few decades', yields, areas of production and biodiversity have declined both from farmers' field and natural forests of southern Ethiopia. Destruction of the plant's natural habitat for expansion of arable and grazing land, new settlement, forest fire and lack of improved verities have resulted in low supply and high demand of korarima in local and export markets.

Hoogendijk and Williams (2002) cited in Eyob *et al*.(2008) conducted the house hold survey to understand the reasons for changes in the production status of korarima in southern Ethiopia and to see what concerns farmers have in producing korarima and if any indigenous practices were related to the yield reduction. According to the growers the actual average yield of dried pods recorded in farmers field in the 1980s ranged from 700 to 950 kg ha^{-1} when the korarima plants received filtered sunlight all day through permanent tree shades. A few hours of direct sun light, 3–5 hr seemed to damage the plants. Presently the yield reduced to 250–400 kg ha^{-1}

In Ethiopia korarima breeding was started in 1972. But variety development is still not in progress (Anon, 1998). The knowledge of the extent of genetic variability present in the population is essential for improvement of korarima. Similarly, information on the extent and nature of interrelationship among characters help in formulating efficient scheme of multiple trait selection, as it provides means of direct and indirect selection of component characters.
Currently, under Ethiopia korarima improvement project, large numbers of korarima accessions are collected from different major growing regions of Ethiopia by Jimma

Agricultural Research Center (JARC). As far as the variability and association among characters in these accessions of korarima is concerned nothing has been done. Hence, the present study was undertaken with the following objectives:

- To estimate the extent of variability for capsule yield and other related characters
- To estimate genetic differences among the genotypes
- To estimate the extent of correlation among characters at phenotypic and genotypic levels and thereby compare the direct and indirect effects of the characters on yield.

2. LITERATURE REVIEW

2.1. Taxonomy, Botanical Description and Distribution of Korarima

According to Jansen(1981) Korarima (Aframomum corrorima) or Ethiopian cardamom is herbaceous, perennial and aromatic spice and medicinal crop of the species in the monocotyledonous ginger family, Zingiberaceae native to Ethiopia. It is a shade loving plant that grows wild in moist and open woodlands, in the same climate areas as wild coffee, but may also be planted and cultivated. The plant consists of an underground rhizome, a pseudostem, and several broad leaves and resembles Elettaria species morphologivally.

Roots borne on the rhizomes, often perforating the scales, subterete, up to 4 mm diameter., whitish to light-brown, fibrous. Stems unbranched, subterete, up to 1 cm diameter., mainly formed by the leaf-sheaths; base usually thickened, up to 3 cm diameter, Leaves distichous,1-8 cm apart; sheaths covering each other, yellow-green, with prominent parallel darker-green veins and scarious, Inflorescence a 5-flowered, short-stalked head, arising from the rootstock near the base of the leafy stem, sometimes situated at the end of a rhizomatous runner; peduncle up to 7 cm long, usually slightly curved, completely covered by imbricate, brown to purplish-brown, glabrous to scarcely puberulous (Jansen, 1981).

Fruit indehiscent; fleshy, subconical, up to 6 cm long and 3.5 cm in diameter., shiny green when immature , turning bright red at maturity, usually showing 3 longitudinal furrows(3 carpels), sometimes more furrows are present; dried fruits (as often sold on markets) flask shaped, 3-6 cm long and 1.5- 3cm diameter with a beak 1-2cm long , brown to grey brown with a tough , strong fibrous wall usually showing irregular ribs and furrow due to shrinkage; fruits with 3 clusters of 45 – 65 seeds (Jansen, 2002).

Seeds subglobose in outline, usually somewhat angular 2-5 mm in diameter, with a glossy, light to dark-brown , glabrous, finely lined testa and circular, whitish hilum; aril thin, a bit fleshy, finely lined, completely covering the seed through the helium shows that the seed coat

is partly strongly thickened (mainly opposite the hilum) dividing the space within in to two distinict parts; the thickened, pale brown, somewhat spongy part of the seed-coat may constitute a varying fraction of the seed volume (up to 0.75), and shrinks considerably on drying, giving the seeds a wrinkled appearance on top; the other part is filled with an irregularly shaped, very white mass of perisperm; within this mass, more or less in the centre, a small, subovoid, dirty-white mass of endosperm can be observed; the embryo is small, ca 1.5 x 0.5 mm, erect, straight or slightly curved; its cotyledon is embedded in the endosperm; its reversedly funnel-shaped radical is situated near the hilum; the seed have strong spicy smell and taste (Jansen,1981, 2002 and Eyob *et al.,*2007).

Several important crop plants have their origin in Ethiopia, including coffee and korarima. Korarima is an important spice and medicinal plant. It is an indigenous spice of Ethiopia. The spice, know as korarima, Ethiopia cardamom, or false cardamom, is obtained from the plant's seeds (usually dried) and is extensively used in Ethiopia and Eritrean cuisine. The plant is native to western Ethiopia, south western Sudan, western Uganda, and Tanzania. It is widely distributed in southern and western Ethiopia (Provinces of Kefa, Gamo Gofa, Debub Omo, Sidamo, Illubabor and Wollega). Outside of these areas, it is cultivated in the vicinity of lake Tana and Gelemso and in Eritrea (Eyob *et al.,*2008)

The genus *Aframomum* comprises bout 50 species and is widely distributed in the wetter parts o tropical Africa. It is closely related to Amomum from tropical Asia and was formerly included in it. *Aframomum zambesiacum* occurs in similar habitats as *Aframomum corrorima*. The seeds of the former species, however, are not used, and in Ethiopia it is called 'monkey's korarima'. Two major differences with the real korarima are that its leaves are less aromatic upon crushing, and its inflorescences bear 25-50 flowers (korarima only up to 5) (Eyob *et al.,* 2007 and Eyob *et al.*, 2008).

2.2. Ecological Requirement and Crop Husbandry

In Ethiopia, korarima grows naturally at 1700-2000 m altitude on slighty shaded, more or less open places in forests. These areas have an annual rainfall of ca 1300 mm to more than 2000

mm, of which 50-60% falls in 'summer' (June-August) and 15-20% in 'spring' (March-May); there is no real dry season. The annual average temperature is ca 20°C Jansen (1981).

Korarima is a shade loving plant like cardamom (*Ellattaria cardamomum*) under natural forest condition. Shade level management is one of the key agronomic practices in korarima production. It was reported that shade level was 55-63%, which is suitable for korarima production (Jansen ,1981).

Shade is very important both for korarima and cardamom production since it creates suitable microclimate and regulates moisture and temperature, which facilitates optimum growth and root development particularly when korariam rhizomes produce very shallow roots at each nodes by (Jansen ,1981).

Korarima can be propagated by seed but planting rhizome parts is probably easier and quicker. Fruits mature about 2-3 months after flowering.The flowers are open for only one day. Perhaps people influence the wild population of korarima by some kind of protection and aid wider dispersal by planting (plant and environmental science, 2011).

2.3. Potential Use and Chemical Compostion of Korarima

Spices and herbs are the rich storehouses of different bioactive compounds and are well known for their beneficial effects on health (Ansari, *et al.,*2004). The use of korarima is only known from Ethiopia and Eritrea. It occurs as a cultivated crop only in Ethiopia. The seeds (usually dried, sometimes fresh) are used to flavour all kinds of sauces locally called ‘wot’, for which they are ground and usually mixed with other spices. Korarima is sold in all the markets in Ethiopia, and is daily used by most families in rural areas.

Korarima is used for adding flavour to local food, bread and butter. It is an ingredient in berbere, mitmita, awaze, and other spice mixtures, and is also used to flavor coffee.Additionally, the korarima seeds are widely used medicinally as a tonic, laxative, carminative and purgative drug, and is added to food for preserving purposes. The consumption of korarima as a spice may be used as source of antioxidants.

Strings of fruits are sometimes used as an ornament, or as rosaries (by the Arabs), and in the past the fruits have been used as money in Ethiopia. In addition, korarima is an important plant for soil conservation as the rhizomes and leaves spread on the ground covering and protecting the soil from erosion in hilly areas (Ansari *et al.,* 2004). It is primarily the red fruits that are being used, but also other parts of the plant. The taste of korarima is similar to Indian cardamom, and has been used as a substitute for this (Tefera and Wannakrairoj, 2006; Eyob, 2009).

Korarima seed has a mild, sweet flavour and is less peppery or pungent than seed of *Aframomum melegueta* K.Schum. (grain of paradise). The seeds contain essential oil which has a typical odour and is sometimes called 'nutmeg-cardamom'. After distillation of dried comminuted fruits, 3–3.5% of a pale yellow volatile oil with a flat cineolic odour can be obtained, in which the following compounds have been found (all monoterpenes, approximate amount of the major ones): 1,8-cineol 32–35%, limonene 7–14%, β-pinene 4–7%, sabinene 7–9%, terpinen-4-ol 3–5%, geraniol 5%, P-cymene 4%, α-pinene, α-terpineol and γ-terpinene 3% each. Sesquiterpenes were identified in another analysis; the total was dominated by about 75% monoterpenes including 1,8-cineol (38%) and terpinyl acetate (11%), and 17% sesquiterpenes including nerolidol (11–14%), β-caryophyllene (2%) and caryophyllene oxide 1% (Eyob *et al.*, 2007).

2.4. Harvest and Processing of Korarima

Maturity and harvesting time of korarima varies in different areas of Ethiopia but generally the plant flowers in May – August and harvesting is done in August – September. At the early stage, the color of capsules is green but when it matures and ready for harvest it turns to deep red color (Girma *et al.,* 2008).

To get quality product of korarima the capsules should be red ripe and the seeds when removed from the capsule should be dark brown that have pungent and appreciable taste when crushed by teeth (Eyob *et al.,* 2009).

There should be great care while harvesting the capsules of korarima not to create any opening on the capsules since through this opening important quality components (aroma and flavor) will be lost and it will serve as entrance for microorganisms(Girma *et al.,*2008).

Korarima capsules harvested from natural forests in the south and southwestern parts of the country are processed or dried in traditional ways. According to a survey conducted around Bonga the series of activities carried out by farmers in the preparation of korarima for market passes the following steps: (i) pre-drying: harvested capsules are stored in a warm place covered with straws, enset leaf or other materials for 10 to 15 days and (ii) drying: performed in two ways (a) sun drying (b) drying with smoke (Girma *et al.,* 2008).

2.5. Variability for Some Quantitative Traits in Korarima

Variation is the occurrence of differences among individuals due to differences in their genetic composition and/or the environment in which they are growing (Allard, 1999). The basic idea of studying variation is the partition of variability into its components that determine the genetic property of the population helps in formulating a sound crop-breeding program (Dudely and Moll, 1969).

Many of the characters that plant breeders seek to improve are physiologically and genetically complex. Yield, as a complex character, requires a detailed analysis of its components in improvement programs. Identification of major components and determination of their relative contribution to the variation of the complex character is the first objective of such analysis. The objective of analysis in majority of cases is to simplify selection for a complex character by replacing it through selection of one of its major components (Sparnaaij and Boss, 1993).

Genetic variability is of immense importance to the breeder because it could be transmitted to the progeny and proper management of this diversity could produce gain in the performance of the plant (Welsh, 1981).

Planning and execution of a breeding program for the improvement of quantitative attributes depend, to a greater extent, up on the magnitude of genetic variability existing in the germplasm (Kalloo, 1988). Determining the genetic variation among and within germplasm accessions facilitates reliable classification of accessions and identification of subset core accessions with possible utility for specific breeding purpose and to preserve maximum genetic diversity in germplasm sources (Mohammadi and Prasanna, 2003).

Selection for yield and yield related traits require an integral approach, since the nature of yield contributing characters is highly variable and significantly modified by external factors, which reduce the improvement of yielding ability. The effectiveness of selection depends on the amount of variability present in the genetic material for yield and yield related characters. Hence, the estimation of variability is of prime importance. The majority of traits including most of those important to crop productivity are controlled by the combined effects of a number of genes that influence the trait, each of which has a similar small influence (Pike, 1986).

Yield improvement is the ultimate goal in virtually every plant-breeding program. The character of yield reflects the performance of all plant components and might be considered as the final result of many others i.e. every plant contains an inherent physiological production capacity that operates on energy required for normal plant performance though all accessions do not have the same inherent physiological capacity to yield. Breeders commonly find yield to be a very complex array of plant component interactions and by the manipulation of these genetic systems yield is improved as the result of plant efficiency improvement (Welsh, 1981)

Some preliminary works done on ginger both local collections and introduced cultivars evaluated at Tepi for their rhizome yield and quality showed that there was a noticeable variation among accessions on morphological characteristics such as plant height, rhizome yield and quality of their produces (Girma and Digafie, 2004).

Senthil and Ganesan (2002) reported significant differences between the genotypes for nine traits viz., plant height, number of branches per plant, number of capsules on main stem, number of capsules on branches, total number of capsules, capsule length, number of seeds per capsule, 1000 seed weight and seed yield per plant.

2.5.1. Phenotypic (PCV) and genotypic coefficients of variation (GCV)

The two basic requirements for plant breeding are the presence of genetic variation and exploitation of this variation through selection (Acquaah, 2007). Phenotypic variability is the observable variation present in a character in a population; it includes both genotypic and environmental components of variation and as a result its magnitude differs under different environmental conditions. Genotypic variation, on the other hand, is the component of variation, which is due to the genotypic differences among individuals within a population, and is the main concern of planting breeding (Singh, 2003).

Genotypic and phenotypic coefficients of variation are measured to study the variability that exists in a given population (Kalloo, 1988). Genetic coefficient of variation, together with heritability estimates, the proportion of genetic variance to the total phenotypic variance, is considered to give the best picture of the amount of advance to be expected from selection (Johnson, and Hernandez, 1980). The gross or phenotypic variability has been reported to be useful in effective selection of promising plants from a population (Hailu, 1988).

Most of the economically important characters including yield are complex and polygenically controlled. Understanding of these characters would facilitate appreciation of genetic wealth available and paves a way to crop improvement for wider geographical adaptability and economic characters. However, the expression of these traits is likely to be affected to a great extent by environmental factors, which requires partitioning of environment and genetic components for a proper exploration (Adefris, 2004).

In a genetically mixed population of an asexually propagated species, a superior clone may be isolated and propagated as a cultivar (Poehlman and Sleper, 1995). Prasath *et al.* (2001) in

cardamom revealed that the GCV values were considerably high for characters such as yield/plant, number of capsules/plant and number of panicles. The above mentioned characters having higher range of variation have a better scope for improvement through selection. On the basis of GCV alone, it is not possible to -determine the amount of heritable variation.

The GCV and PCV for various agronomic and quality traits have been estimated in different crops. Momina *et al.* (2011) reported that number of plant per plot, fresh and dry rhizome yield ,fiber content and volatile oil content have high PCV and GCV value at two location in Ethiopia. Kandil *et al.(* 2012) reported low genotypic and phenotypic coefficient of variation for oil content in giger. Whereas high for plant height in flax genotypes. In addition to this Islam *et al.* (2008) revealed that moderate to high genotypic and phenotypic coefficients of variation for tiller per plant, plant height, leaves per tiller and rhizome yield per plant in ginger. Ahadu *et al*. (2008) reported that low GCV value for seed weight and oil content, medium for plant height, number of capsule per plant, yield per hectare and high for number of branch per plant in 64 sesame collections.

2.5.2. Heritability in the broad sense

Heritability is the proportion of the total variability that is due to genetic cause or the ration of genotypic variance to the total variance (Kalloo, 1988). It is indispensable to plant breeders in giving an indication of the effectiveness with which selection of the genotypes can be based on phenotypic performance of quantitative characters (Allard, 1964). Stoskopf *et al.* (1999) also reported that, the proportion of total variation caused by the genotype is heritable and can range from a value of one, where all variation is genetic, to zero, where all variations result from the environment.

According to Prasath *et al.* (2001) high heritability for characters like plant height, total tiller, bearing tiller, number of panicles, panicle length, number of capsule per plant and yield per plant in caradamom genotypes but low heritability for intenodal length. Sumathi and Muralidharan (2010) estimated high heritability for plant height, capsule length and oil

content in sesame. Rajaravindran *et al.* (2000) and Paramasivam (1980) also estimated high heritability and genetic advance for the number of capsules per plant, plant height and oil content in sesame genotypes.

2.5.3. Expected genetic advance

Genetic advance measures the expected genetic progress that would result from selecting the best performing genotypes for a character being evaluated (Allard, 1964). It is the function of the heritability of the trait, the amount of phenotypic variation and the selection differential that the breeder's use. Heritability value in itself provides no indication of the amount of genetic progress that would result from selecting the best individuals unless otherwise it is considered along with genetic advance (Allard, 1999).High heritability value could be obtained with accessions having small or large genetic variance but genetic progress would be larger with larger genotypic variance (Johnson *et al.,* 1955 and Allard, 1964). Genetic coefficient of variation together with heritability estimate is considered to give the best picture of the amount of advance to be expected from selection (Johnson and Hernandez, 1980).

High heritability coupled with high genetic advance under percent mean in cardamom genotypes for characters like number of panicle per plant, number of capsule per plant and yield per plant; whereas plant height, total tiller, bearing tiller panicle length and number of node per plant show high heritability in conjunction with low genetic advance as percent mean (prasath *et al.,*2001).

In sesame it is reported that plant height, number of branches per plant, number of capsules per plant, number of seeds per capsule, seed yield per plant has shown high heritability value and moderate genetic advance (Thangavel *et al.*, 2000).

The heritability estimates ranged from 28.13% for internodal length to 76.23% for yield/plant. High heritability values were observed for yield/plant, number of capsules/plant, panicle length and number of nodes/panicle indicating less influence of environment on these traits.

Moderate to low heritability for other characters indicating that environmental effects constitute a major portion of the total phenotypic variation and hence, selection for these characters will be less effective (Prasath *et al.,*2001).

Expected genetic advance and its estimated percentage mean for various characters revealed that yield/ plant and number of capsules/plant exhibited the highest genetic advance. Though characters like panicle length, number of nodes/panicles and total tillers exhibited' moderate to high heritability values, their GCV was comparatively less, resulting in less genetic advance (Korikanthimath *et al.*, 2000). The characters like yield/plant and number of capsules/ plant possessing high GCV, heritability and genetic advance could be effectively used in selection**,** as it has been suggested that characters with high heritability coupled with high genetic advance would respond to selection better than those with high heritability and low genetic advance.

2.6. Characters association

2.6.1. Correlation Analysis

The statistic, which measures the relationship between two or more variables, is known as correlation coefficient. Correlation coefficient analysis measures the mutual relationship between various plant characteristics and determines the component characters on which selection can be based for improvement in yield. Simple correlation is of three types: phenotypic correlation, genotypic correlation and environmental correlation (Singh, 2002). Phenotypic Correlation is the observable correlation between two variables; it includes both genotypic and environmental effects. Genotypic correlation, on the other hand, is the inherent association between two variables; it may be either due to a pleiotropic action of genes, linkage or, more likely both.

Environmental correlation arises entirely due to environmental effects. These three types of correlations can be estimated from replicated data only (Singh, 2002).

Knowledge of interrelationships between different traits is important in breeding for direct and indirect selection of characters that are not easily measured and those with low heritability (Patil *et al.*,1981). Mass selection has been used to improve grain yield through indirect selection for highly heritable traits, which are associated with yield.

Knowledge of correlations among traits is important for several reasons: it is possible to fully perceive the diversity of breeding material, to identify traits needed by genotype to grow successfully under certain ecological conditions, to identify and avoid characters that have little or no importance and use of some traits in the selection program, to define breeding target and cultivars model and to recognize impediments and benefits of a breeding process well in advance. With characters that exhibited positive correlations, simultaneous improvement in two or more characters is possible (Falconer and Mackay, 1996).

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The negative correlation of some important characteristics may lead to some undesirable selection based on these characters. The negative correlations of these character pairs were to impose problem in combining important yield components in one genotype. To improve the yield components with negative association, suitable recombination may be obtained through biparental mating, mutation breeding or diallel selective mating for breaking undesirable linkages. Correlation analysis, however, describes merely the mutual relationship between different pairs of characters without providing the nature of cause and effect relationship of each character (Batt, 1977).Many research indicated the existence of relationship between yield and other traits in cardamom and other related family crops of korarima.

From these Korikanthimath *et al.*(2000) reported that number of tiller per plant and number of bearing tiller per plant showed positive and significant correlation with number of capsule per plant. However the correlation between plant heights with number capsule per plant was not significant. They also reported the total number of tiller per plant had significant and positive correlation with fresh weight of capsule per plant.

Gopal *et al*. (1989) also reported similar results in cardamom and number of bearing tiller tillers per plant and height of the plant were positively correlated with fresh weight of capsules per plant but were not significant. Finding in sesame revealed that the number of capsules per plant had a highly positive and significant correlation with yield (Krishnamurthy *et al*., 1964., Krishnadoss and Kadambavanasundaram,1986). However, the oil content had a non significant association with yield and other characters. Adam (2006) in black cumin reported that essential oil content had negative genotypic correlation with seed yield and1000 seed weight.

2.6.2. Path coefficient analysis

Wright originally developed the concept of path coefficient analysis in 1921, but th technique was first used for plant selection by Dewey and Lu (1959). Path analysis is simply partial regression coefficient, which splits the correlation coefficients into the measures of direct and indirect effects of a set of independent variables on the dependent variable (Singh,2002).

If the cause and effect relationship is well defined, it is possible to represent the whole System of variables in the form of a diagram, known as a path diagram (Singh and Chaudhary, 2001).

The advantage of a path diagram is that a set of simultaneous equations can be written directly from the diagram and a solution of these equations provides information on the direct and indirect contribution of these causal factors to the effect (Singh and Chaudhary, 2001).

Sritharan *et al*. (1993) revealed that plant characteristics like tiller per plant, leaf length, number of panicle per plant, weight of fresh capsule and number of capsule per plant had higher direct effect on yield in cardamom. Therefore these characters could be used as selection criteria in a crop improvement programme for maximizing yield. Sandipan Chowdhury *et al.* (2010) and Singh *et al*. (1997) also obtained capsule per plant had highest positive direct effect on yield in sesame genotypes.

2.7. Genetic Divergence

Genetic diversity refers to the variation among alleles of genes in different individuals of population of a species (IPGRI, 1993). The genetic composition of a crop population is affected by mutation, migration, and recombination, which widen genetic variation. In contrast the genetic variation is reduced by natural and artificial selection and random genetic drift. Genetic diversity is also a raw material in plant breeding for developing high yielding varieties and for maintaining the productivity of such varieties by incorporating genes for disease and insect resistance as well as tolerance to abiotic stress as drought, cold and salinity (Allard, 1964).

Similarly, Van Hintum (1995) indicated that genetic diversity studies based on genetic markers and qualitative characters are used for many purpose:(1) for taxonomic studies, (2) to find the center of diversity of a species, (3) to trace the route of domestication, (4) to study the relationship between environment and diversity and (5) to study a complete crop gene pool or the diversity of infraspectific part of a gene pool.

Assessment of genetic variability in crop has a strong impact on plant breeding and conservation of genetic resources (Van Hintum, 1995). It is particularly useful in the characterization of individuals, accessions, and cultivars in order to determine the level of genetic diversity available in germplasm collections and for selecting parents. The prior knowledge of the nature, extent and distribution of genetic variation is crucial for successful conservation (*in-situ* and *ex-situ*) and sustainable utilization of germplasm. More over, the number of populations necessary to conserve genetic diversity within a species and choice of sites for *in-situ* conservation depend on the measure of diversity and its pattern of partition within and among populations (Kassahun, 2006).

2.7.1. Cluster Analysis

Cluster analysis is a multivariate statistical procedure whose primary purpose is to group individuals or objects based on the characteristics they possess, so that individuals with similar descriptions are mathematically gathered into the same cluster".

The resulting clusters of individuals should then exhibited internal (within cluster) homogeneity and high external (between clusters) heterogeneity, thus, if the classification is successful, individuals within a cluster shall be closer when plotted geometrically and different clusters shall be farther apart (Crossa *et al.,* 1995).

There are broadly two types of clustering methods: 1) Distance-based methods, in which a pair wise distance matrix is used as input for clustering analysis. The result can be visualized as a tree or dendrogram in which clusters may be identified. And 2) model-based methods, in which observation from each cluster are assumed to be random draws from some parametric model, and inference about parameters corresponding to each cluster and cluster membership of each individual are performed jointly using maximum-likelihood or Bayesian method (Johnson and Wichern,1988).

Another important aspect in cluster analysis is determining the optimal number of clusters or number of acceptable clusters. In essence, this involves deciding where to "cut" a dendrogram to find the true or natural groups. An " acceptable cluster" is defined as " group of two or more genotypes with a within-cluster genetic distance less than the overall mean genetic distance and between cluster distances greater than their within cluster distance of the two clusters involved" (Mohammadi *et al.,* 2003).

Prasath and Venugopal (2009) used 310 carefully selected cardamom genotype under the same environment condition and clustered into 39, 169 and 102 accessions in the first, second and third clusters. Accessions from the same cultivar group were scattered in different clusters. There is no definite clustering of accessions for Malabar, Mysore and Vazhukka. This indicates the possibilities of a common ancestral and close relationship of the genotypes of these three groups and also that geographical origin is not the single factor for genetic divergence in cardamom. The maximum inter-cluster distance existed between cluster 1 and 2 (4.32) followed by that between 2 and 3 (3.463). The inter-cluster distances were greater than intra-cluster distances, revealing considerable amount of genetic diversity among genotypes

Similar to this Radhakrishnan *et al*,(2006) used 90 cardamom germplasm accession and clustred them in to 8 group. Intercluster distance values also showed wide genetic divergence among accessions. Accessions belonging to the most distant clusters can be utilized for hybridization programmes to produce better and promising hybrids

2.8. Principal Component Analysis (PCA)

Principal component analysis is a multivariate techniques used for examining relationships among several quantitative variables (Crossa *et al.*, 1995). Principal component analysis can be used to drive a two dimensional scatter plot of individuals, such that the geometrical distances among them with minimal distortion. Aggregates of individuals in such a plot will reveal sets of genetically similar individuals (Warburton and Crossa, 2000).

Classification (grouping of entities with similar patterns) and ordination (description of spatial relationships among entities) methods are two multivariate techniques commonly used in such areas numerical taxonomy, plant breeding, genetic analysis and biotechnology to describe and analyze multivariate data sets (Crossa *et al*., 1995).

Many of these multivariate techniques such as cluster analysis and principal component analysis have been used alone or in combinations to study various aspect of diversity within crop germplasm (Rolf, 1992).Although, it is easy to make analysis in a multivariable case, inference pertaining to their results is not an easy task. In cluster analysis, there are many distance measures and methods based on these measures. Depending on either distance measure or selected method, the results of cluster analysis could be different and this can lead researcher into an uncertainty. That is why, in recent years, in cluster analysis and principal component analysis mostly used. By this way, on the one hand, the number of variables is reduced; on the other hand, the correlation pattern between variables, which is negatively affecting the multi-variable analysis methods, can be removed.

Furthermore, it is possible to derive detailed information from the plot of observations over the first two principal components. The resulting diagram can give the researcher an idea about the correctness and inference of cluster analysis results (Bensmail *et al.,* 1997).

This will allow visualization of the differences among the individuals and identify possible groups. The reduction is achieved by linear transformation of the original variables into a new set of uncorrelated variables known as principal components (PCs). The first step in PCA is to calculate eigenvalues, which define the amount of total variation that is displayed on the PC axes. The first PC summarizes most of the variability present in the original data relative to all remaining PCs. The second PC explains most of the variability not summarized by the first PC and uncorrelated with the first and so on (Jollife, 1986).

Patil *et al.*(2000) reported five principal components with eigenvalue greater than 1 explained 94.36% of the total variation by using 13 moroplogical traits and dry capsule yield per clump in large cardamom. Gupta et al.(2006) also reported three principal components explained 73% of total variation by using seven characters on large cardamom.

Furthermore, Ahadu,(2008) also revealed that four principal components with eigenvalue greater than one explained 75.59% of total variation by using 13 morpho agronomic characters in sesame.

In addition to these Momina *et al*.(2011) reported six principal components with eigenvalue greater than one explain 77.7% of total variation using 16 characters at Tepi and similarly at Bahirdar five principal components with eigenvalue greater than one explained 67.7% of total variation in ginger.

3. MATERIALS AND METHODS

3.1. Description of the Study Areas

The study was carried out at Jimma Agricultural Research Centre located at 363 km south west of Addis Ababa. The site is located at 7046' N and 360 E with an altitude of 1753 meters above sea level. It is situated in the tepid to cool humid-mid highlands of southwestern Ethiopia. The area is among the most conducive production areas for *aframomum corarima* in Ethiopia and the accessions were expected to fully express their genetic potential for the trait under consideration. The soil type of the experimental area is Eutric Nitosol (reddish brown) with a pH of around 5.2. The area receives mean annual rainfall of 1536 mm with a maximum and minimum temperature of 25.9 o C and 11.2 o C, respectively (IAR, 1997). The data on rainfall, temperature and relative humidity of the site during the study period and summary of long term data are presented in appendix 1.

3.2. Experimental Materials

The materials used for the study were 25 already established Ethiopian korarima germplasm accessions that are five years old and local checks. The korarima germplasm accessions were collected from the potential and representing areas. The list of geneotypes used in the study is given in Table 1.

3.3. Experimental Design, Management and Season

The study was conducted in 2011 from August to December. The experiment was superimposed on those which were planted in a 5x5 simple lattice design with two replications and five accessions per incomplete block. Nine plants per plot were planted with a spacing of 1.8m both between rows and plants. The genotypes were grown under Sesbania shade trees.

Table 1 germplasms used in the experiments

No	Accession	Region	Zone	Woreda	Altitude (m. a.s.l)
1	Jimma local	Oromia	Jimma	Jimma	1580
2	028/84	Oromia	Wollega	Arjo	1800
3	025/03	Oromia	Illubabor	Metu	1605
4	114/03	Oromia	Illubabor	Sombo	2229
5	059/03	Oromia	Wollega	Nekemte	2088
6	029/84	Oromia	Wollega	Gimbi	1930
7	016/84	Oromia	Illubabor	Sombo	2229
8	001/03	SNNPR	Sheka	Masha	1297
9	015/03	Oromia	Ilubabor	Sombo	2229
10	053/03	SNNPR	South Omo	Kemba	1850
11	045/03	SNNPR	Gamo gofa	Damot	2121
12	701/87	SNNPR	Kefa	Decha	2500
13	046/03	Oromia	Illubabor	algea	1500
14	105/03	Oromia	Illubabor	Yayu	1387
15	038/01	SNNPR	Sidama	Arero	2829
16	093/00	Amhara	Gojam	Debremarkos	2446
17	018/00	SNNPR	Kefa	Yeki	1097
18	010/00	SNNPR	Kefa	Chena	1972
19	009/00	Amhara	Gojam	Metekel	1525
20	068/87	Amhara	Gojam	Agew midir	500-3700
21	021/00	SNNPR	Bench maji	Bebeka	950-1285
22	686/87	Amhara	Gojm	Metekel	1525
23	001/84	Oromia	Bale	Genale	1000
24	011/00	SNNPR	Sidama	Sidama	2759
25	014/00	Amhara	Gojam	Metekel	1525

Source: Jimma Agricultural Research Center

3.4. Data Collected

1. **Plant height (cm):** The height of each of the five randomly taken plants from plot measured from soil level to the tip of the plant in cm and averaged to represent this character.

2. **Number of tillers per plant:** Total tiller per plant of five randomly selected plant from each plot were counted and averaged to represent this character.

3. **Number of bearing tillers per plant**: Bearing tiller per plant of five randomly selected plant from each plot were counted and averaged to represent this character.

4. **Internodal length (cm):** From second and third nodes from five randomly taken plants per plot were measured and averaged to get internodal length.

5. **Number of leaves per stem:** Number of five plant leaf from bottom to the upper portion of the plant were counted and averaged to represent this character.

6. **Leaf area /plant/LA/ (cm^2)***:* Was measured as the area of five randomly taken plant leaves using square pepper and the average recorded to represent this character.

7. **Number of capsules per plant:** All capsules borne on the five randomly taken plants were counted and averaged to represent this character.

8. **Yield per plant (g):** All the capsules borne on the five randomly taken plants were weighted and averaged to represent this character.

9. **Fresh weight of single capsule (g):** The fresh red ripe capsule of five plant randomly twenty five fruit selected from each plot before air drying were weighted and averaged as fresh fruit weight per plant.

10. **Fresh capsule length (cm)**: The length of the capsule from the base to the tip of each five randomly selected plant randomly twenty five red ripe fresh fruits of measured and the average taken to represent this character.

11. **Fresh capsule diameter (cm):** Average diameter (cm) at the widest point of five randomly selected plants of twenty five red ripe fresh fruits measured and the average taken to represent this character.

12. **Dry weight of single capsule (g):** Was recorded fruits of five plant from each which were fresh weight taken twenty five fruits are weighted after sun drying

13. **Dry capsule length (cm):** The length of the fresh length taken twenty five fruits were taken after sun drying from base to tip measured and averaged
14. **Dry capsule diameter (cm)):** Average diameter (cm) at the widest point of five randomly selected dry capsule which were fresh diameter taken randomly from five plants per plot after sun drying
15. **Hundred-seed weight (g):** Sample of 100 seeds was taken from the five randomly taken plants and weighted to represent this character.

16. **Volatile oil (v/w):** The essential oil isolation was carried out according to ASTA (1997). The amount of volatile oil was determined by modified Clevenger method. 100g of ground sample was weighed out and transferred quantitatively into a 500 ml round bottom flak of the volatile oil apparatus. Flask was filled with sufficient quantity of water. Then the trap was fixed on the flask and filled with water. Condenser was connected and the whole system was fixed onto a stand. Flask was heated to boiling and a reflux rate of 1-2 drops per second was maintained. Continuing the refluxing until two consecutive readings taken at one-hour interval shows no change of oil volume in the trap. It took about 3 hours to complete the process. The system was allowed to cool.

The percentage volatile oil content was calculated using the following equation,

$$\text{Volatile oil, \%(v/w)} = \frac{\text{volume of oil (ml) } 25^{o}C}{\text{Weight of sample (g)}} \times 100$$

17. **Oleoresin (w/w):** Oleoresin of korarima seeds was determined by acetone extract method using soxhlet apparatus. Hundred grams of ground sample was weighed and put into a paper extraction thimble, a cup made of whatman 1 filter paper. The thimble, containing sample was placed in the container of the extractor. Condenser was fixed on to it. The apparatus was assembled and started the extracting with acetone as solvent. Extraction was extended to 4-6 hours. After the process the extract was transferred in to a beaker. On a steam bath the solvent was evaporated completely. When the last traces of acetone were evaporated, the container was placed in a hot air oven at $110^{o}\pm2^{o}C$ until two consecutive weightings taken at $1^{1}/_{2}$-hour intervals didn't differ by more than 1mg. the dried residue was the non-volatile ethylene dichloride extract (oleoresin). (ASTA, 1997). Percentage of oleoresin was calculated using the following formula,

$$\text{Oleoresin, \%} = \frac{\text{weight of residue}}{\text{Weight of sample}} \times 100$$

18. **Dry Matter Content:** Dry matter percentage was determined by oven drying at $105^{o}C$ according to A.O.A.C (1990). The moisture in a sample is lost by volatilization caused by heat. An empty hot crucible (W1) is weighed and five grams of air dried sample transferred into it and placed in an oven at $105^{o}C$ overnight. The final weight (W2) was taken and dry mater content percentage is calculated as:

$$\text{Dry matter \%} = (W2-W1/W1) \times 100$$

19. **Total ash content (%):** The percentage of total ash content was determined by using furnace apparatus by procedure of A.O.AC (1990).It was determined by ignition of known weight (1g) of a sample at about $550^{o}C$ in muffle furnace till all the organic matter is oxidized and lost as CO_2.

    The residual represents inorganic constituents of total ash while the loss in weight was taken as the organic matter. Procedurally, weight of empty crucible (W2) was taken and one gram of sample transferred into it (W1). The crucibles with samples were placed in furnace and waited till the temperature reached $550\pm10^{o}C$.

Ash % = (W3-W2/W1) x 100

20. **Crude Fiber:** The crude fiber percent is the loss in weight on ignition of dried residue remaining after digestion /boiling of the fat free sample/ with 1.25% of H_2SO_4 and 1.25% of NAOH solutions in turn for 30 minutes. And the samples were then put into crucibles and placed in the furnace at 550^oC for 4 hours. For determination of crude fiber, the estimation was based on treating the moisture and fat free material with 1.25% diluted acid, then with 1.25% alkali. One gram of sample was added in a 400ml beaker marked at two hundred ml level. Two hundred ml of 1.25% H2SO4 and boiled for 30min. After filtration and washing, the residue was treated with 200ml 1.25% NaOH solution. It was filtered, washed with hot water. Ignite the residue to get the ash, and weighed. The loss in weight gave the weight of crude fiber A.O.AC (1990).

21. **Crude Fat Content:** The fat content of the korarima was determined using the A.O.A.C, (1990), and the extracted percentage fat content was calculated as follows:

$$\% \, Fat \; = \frac{\mathrm{W3} - \mathrm{W2}}{W1} \mathrm{X}\; 100$$

Where: W1 = initial weight of sample,
W2 = weight of beaker,
W3 = weight of beaker and fat

3.5. Statistical Analysis

3.5.1. Analysis of variance (ANOVA)

Data of quantitative characters were subjected to analysis of variance (ANOVA) using SAS version 9.2 (SAS, 2008) to examine the presence of statistically significant differences among genotypes for these characters. Least Significant Difference (LSD) at $p<0.05$ was employed to identify genotypes that are significantly different from each other

The model for lattice design:

$$Yil(j) = \mu + ti + rj + (b/r)\ l(j) + eil(j)$$

Where, $Yil(j)$ is the observation of the treatment $i(i = 1,....V, k^2)$, in the block $l(l = 1,..k)$ of the replication $j(j = 1,...,m)$;

μ is a constant common to all observations;

t_i is the effect of the treatment i;

rj is the effect of the replication j;

$(b|r)_{1(j)}$ is the effect of the block l of the replication j;

$e_{il(j)}$ is the error associated to the observation $Y_{il(j),}$

3.5.2. Estimation of Genotypic and Phenotypic Coefficient of Variation

The variability of each quantitative trait was estimated by simple measures such as mean, range, standard deviation, phenotypic and genotypic variances, and coefficients of variation. The phenotypic and genotypic coefficients of variation were computed using the formula suggested by Burton and de Vane (1953) as follows.

$$\sigma^2 p = \sigma^2 g + \sigma^2 e$$

Where, $\sigma^2 p$ = Phenotypic variance

$\sigma^2 g$ = Genotypic variance

$\sigma^2 e$ = Environmental variance

$$\sigma^2 g = (MSt - MSe)/r$$

Where, $\sigma^2 g$ = genotypic variance

MSt = mean square of treatment

MSe = mean square of error

r = number of replications

Phenotypic coefficient of variation (PCV), $PCV = \frac{\left(\sqrt{\sigma^2_p}\right)}{\overline{X}} X100$

Where, $\sigma^2 p$ = phenotypic variance

$\overline{x}$ = Population mean of the character being evaluated

Genotypic coefficient of variation (GCV), $GCV = \frac{\left(\sqrt{\sigma^2_g}\right)}{\overline{X}} X100$

Where, $\sigma^2 g$ = genotypic variance

$\overline{x}$ = Population mean of the character being evaluated

3.5.3. Estimation of heritability and genetic advance

3.5.3.1. Heritability in broad sense

Broad sense heritability values were estimated based on the formula of Falconer and Mackay (1996) as follows:

$$(h^2 b) = (\sigma^2 g / \sigma^2 ph) * 100$$

Where, $(h^2 b)$= heritability in the broad sense.

$\sigma^2 g$ = genotypic variance and

$\sigma^2 ph$ = Phenotypic variance

3.5.3.2. Expected genetic advance under selection (GA)

Expected genetic advance for each character at 5% estimated as per Allard (1964).

$$GA = k * \sigma ph * h^2$$

Where, σph = the phenotypic standard deviation on mean basis;

h^2 b = heritability in broad sense and k is selection Intensity.

3.5.3.3. Genetic advance as percent of mean

Genetic advance as percent of mean was estimated following the procedure of Johnson *et al.* (1955).

$$GAM = \frac{GA}{\overline{X}} * 100$$

Where, $\overline{x}$ =population mean of the quantitative character, GA =genetic advance as percent of mean.

3.5.4. Correlation Analysis

3.5.4.1. Phenotypic and genotypic correction coefficient analysis

Phenotypic correlation (r_p), the observable correlation between two variables, which includes both genotypes and environmental components between two variables, were estimated using the formula suggested by Johnson *et al*. (1955) and Singh and Chaudhury (1985).

$$rp = Pcovxy/\sqrt{(Vpx.Vpy)}$$

$$rg = Gcovxy/\sqrt{(Vgx.Vgy)}$$

Where, r_p = Phenotypic correlation coefficient

r_g = Genetoypic correlation coefficient

$Pcov_{xy}$ = Phenotypic covariance between variables x and y

$Gcov_{xy}$ = Genotypic covariance between variables x and y

$V_p x$= Phenotypic variance for variable x

$V_g x$ = Genotypic variance for variable x

$V_p y$ = Phenotypic variance for variable y

$V_g y$= Genotypic variance for variable

3.5.4.2. Path coefficient analysis

The direct and indirect effect of yield related traits on yield per plot were worked out through path coefficient analysis. The analysis was made following the method suggested by Dewey and Lu (1959). The formula was as follows.

$$rij = Pij + \Sigma rikpkj$$

Where: - rij = Mutual association between the independent character (i) and dependent Character (j) as measured by the correlation coefficient.

Pij = Component of direct effects of the independent character (i) on dependent character (j) as measured by the path coefficient and,

$\sum$ rikpkj = Summation of components of indirect effect of a given independent character (i) on the given dependent character (j) via all other independent character k).

Residual effect estimated by the formula

$\sqrt{1 - R2}$

Where: - $R2 = \Sigma pij\ rij$

3.5.5. Cluster analysis

Clustering was performed using the proc cluster procedure of SAS version 9.2 (SAS institute, 2008) by employing the method of average linkage clustering strategy of the observation. The numbers of clusters were determined by following the approach suggested by Copper and Miligan (1988) by looking in to three stastics namely Pseudo F, Pseudo t^2 and cubic clustering criteria.

3.5.6. Genetic divergence

Genetic divergences between clusters were calculated using the generalized Mahalanobis's D^2 statistics (Mahalanobis, 1936) using the equation:

$$D^2p = ((Xi - Xj)S - 1(Xi - Xj).$$

Where, D^2_p= the distance between any two groups i and j;

X_i and X_j = the p mean vectors of accessions $_i$ and $_j$, respectively.

S^{-1} = the inverse of the pooled covariance matrix.

The D^2 values obtained for pairs of clusters were tested for significance at 0.05nlevel of significance against the tabulated values for p degrees of freedom, where p is the number of variables considered as indicated by (Singh and Chaudhary, 1985).

3.5.7. Principal component analysis

Principal component analysis was performed using correlation matrix by employing SAS procedure (SAS, 2008). The objective of this analysis was to reduce the observed variables in smaller number of principal component that were accounted for most of the variance in the observed variables. Finally, it defines the pattern of variation between the accessions by summarizing data in to reduced number of traits (Corossa *et al*.,1995)

The principal components were derived as follows, suppose X^T = X1, Xp is a p dimensional random variable with mean μ and co - variance matrix ∑. Then

$Y1= a_{1j}x_{1+} a_{2j}x_{2+}$ ------- $a_{pj}x_{p} = a^T_j x$

Yj= Y1+Y2+Yp are principal components

$a_j^T = a_{1j}$……apJ are vector constants (Eigen vectors)

$a_j^T a_j = \sum a^2_{kj} = 1$

Var (yi) =Var $(a_1^T x)$= a ti $\sum a_1$

Where, X is a character trait, A is a coefficient (Eigen vector), Y is principal component, P is number of characters and J is number of principal component.

4. RESULTS AND DISCUSSION

4.1 Variability Assessments

4.1.1 Analysis of variance (ANOVA)

Mean squares of 21 characters from analysis of variance (ANOVA) presented in table 2. Significant difference among germplasm accessions ($p<0.05$) were observed for all traits expect for seed weight, internodal length and percent dry matter content of korarima seed. Significant difference indicates the presence of variability. Different authors reported significance difference on different characters of cardamom and other crop genotypes. From those Korikanthimath *et al.*(2000) reported significance difference among genotypes for number of capsule per plant, weight of fresh and dry capsule and oleoresin content. Ankegowda and Krishnamurthy (2008) also reported number of tiller, number of leaves and plant height show significant difference on six cardamom germplasm accessions under moisture stress condition which is in line with this finding.

Islam *et al.*(2008) reported significant difference for characters like plant height, tiller per plant, leaf length, number of leaves per plant, dry matter content and rhizome yield per plant by evaluating nineteen genotypes of ginger.

Another work done in India ginger evaluate the genotypes for yield and quality in 1997/98 showed significant variation among the genotypes for oil, oleoresin, crude fiber content. But they also reported significance difference among genotypes for dry matter percentage contradicting this finding (Tiwari, 2003b)

Table 2 Analysis of variance for 21 characters of 25 korarima germplasm accession studied at JARC in 2011/12

SV	REP	Treatments	B/REP	ERROR		R^2%	CV%
				Intra block	RCBD		
DF	1	24	8	16	24		
PH (cm)	383.09	669.76**	104.63	276.28	219.06	79.29	8.68
TT	0.5202	5.93**	2.87	2.293	2.48	82.42	19.89
BT	0.39	1.24**	0.56	0.22	0.33	88.42	20.93
INL (cm)	0.004	0.52^{NS}	0.23	0.45	0.38	60.28	13.35
NLPS	1.095	19.52**	9.49	7.27	8.01	81.78	9.32
LA (cm^2)	61.16	2826.66**	215.76	919.69	685.05	84.71	16.95
NCPP	0.08	4.06**	0.8	1.26	1.1	83.37	12.43
YPP(g)	244.3	5885.59**	1393.1	2014.88	1807.62	82.5	14.47
SW (g)	8.82	0.035^{NS}	0.014	0.023	0.02	69.29	7.03
WFC (g)	0.014	28.46*	16.12	12.54	13.73	75.81	14.49
LFC (cm)	0.03	6.065*	3.64	2.85	3.11	78.16	20.3
DFC (cm)	3.28	4.23**	2.08	0.95	1.33	83.48	9.81
WDC (g)	0.23	9.36*	6.45	3.32	4.36	77.16	15.78
LDC (cm)	1.4	1.24*	0.32	0.59	0.5	81.37	16.39
DDC (cm)	3.28	4.23**	2.08	0.95	1.33	83.48	15.48
DRM(%)	0.61	1.41^{NS}	0.203	1.41	1.62	62.04	1.37
CRFI (%)	0.0006	0.0048**	0.0014	0.0011	0.0011	86.41	15.79
VOC (v/w)	0.23	0.53**	0.23	0.19	0.21	87.53	17.93
OC (w/w)	1.48	1.147**	0.403	0.365	0.378	83.31	12.03
ASH (%)	0.021	0.48**	0.16	0.146	0.149	89.82	15.36
CRFAT(%)	0.027	0.051**	0.037	0.021	0.026	81.32	5.69

** and * indicates significant difference at 1 and 5% respectively, NS not significant

DF: degree of freedom, PH: plant height, TT:total tiller, BT: bearing tiller, IL: internodal length, NLPS: number of leaf per stem, LA: leaf area, NCPP: number of capsule per plant, YPP: yield per plant, SW: 100seed weight, WFC: weight of fresh capsule, LFC: length of fresh capsule, DFC: diameter of fresh capsule, WDC: weight of dry capsule, LDC: length of dry capsule, DDC: diameter of dry capsule, DRM%: dry matter percentage, CRFI%: crud fiber percentage, VOC: volatile oil content, OC: oleoresin content, %ASH: percent ash content, CRFAT%: crud fat percentage

4.1.2. Mean and range

Range and mean values of the 18 characters are presented in Table 4 and appendix Table1. The mean yield of capsule ranged from 541.3kg/ha to 1127.16kg/ha. Out of the 25 germplasm accession 52% gave above grand mean (857.67kg/ha). Similarly mean number of capsule per plant ranged from 15738.6 to 35711.6/ha and out of 25 germplasm accession studied 52% gave above grand mean which is 25058.32/ha. Volatile oil and oleoresin content ranged from 1.2 to 3.5v/w with 44% of accessions showing above grand mean value which is (2.23v/w) and oleoresin content ranged from 3.55 to 6.2w/w with 36% gave greater grand mean value which is 4.64w/w respectively

Plant height ranged from 118.2 to 221cm with grand mean of 173.1cm, while yield per plant ranged from 168.4 to 374.3gram with a grand mean of 277.92. Total tiller per plant showed variation from 4 to 13 with the grand mean valued of 7.12, Weight of fresh capsule and dry capsule ranged from 12.5 to 32.02 gram with mean of 23.06 gram and 6.5 to 17.1 gram with the grand mean of 11.69 gram respectively. Length of fresh and dry capsule also showed considerable variation with the range of 4 to 13.4 cm and 2 to 8.2cm with the mean value of 7.6cm and 4.28 cm respectively. Number of capsules per plant revealed relatively broad variation from 5 -10.8 with grand mean of 8.12 and crud fiber content from 10.1% to 37.85% with grand mean of 20.12.

The accessions revealed relatively narrow range of variation for bearing tiller and oleoresin content which ranged from 1 to 4 and 3.2 to 7.2 w/w% with the mean value of 2.49 and 4.64 w/w% respectively. Very narrow range of variation was observed in volatile oil content, ash and crude fat content of the seed which ranged from 1.1 to 3.5 v/w% , 1.2 to 3.6% and 2.12 to 2.9% with the mean value of 2.23 v/w% 2.23% and 2.38% respectively.

4.1.3. Variance components and coefficient of variation

Variance components and coefficients of variation estimate of characters considered in this study are presented in Table 3. PCV value were generally higher than their corresponding GCV values for all the characters considered indicating the higher influence of environment on germplasm accessions for expression of these characters.

Based on this delineation, PCV and GCV values were high for bearing tiller, leaf area, ash and crud fiber content. PCV values were high but GCV values were medium for diameter of dry capsule, total tiller per plant, length of dry capsule, volatile oil content, length of fresh capsule, weight of dry capsule and yield per plant. In addition PCV values were medium for number of leaves per stem and plant height whereas the GCV values were low for these characters. The GCV and PCV value were medium for number of capsule per plant, oleoresin content, and diameter of fresh capsule and weight of fresh capsule.

This medium to high GCV values of these characters existence of variability which can be exploited by selection. The PCV and GCV values were low for crud fat content indicating difficulty of improvement of these traits through selection.

This result is in harmony with the high volatile oil content, medium plant height and oleoresin content reported by Momina *et al*.(2011). However they found GCV and PCV value of medium leaf area and high PCV and GCV for number of leaves per stem which is low and medium for number of leaf per stem and high leaf area for both obtained in the present study. In contrast to this Yudhvir *et al*.(2003) also reported medium to high GCV and PCV values for plant height, leaf number and tiller number in turmeric.

The difference between PCV and GCV values was high for total tiller, weight of fresh capsule, length of fresh capsule, weight of dry capsule, length of dry capsule and volatile oil content; indicating influence of environment on these characters.

However, this difference was relatively low for plant height, bearing tiller, number of leaves per stem, leaf area, number of capsule per plant, diameter of fresh capsule, diameter of dry capsule, oleoresin content, ash, crud fiber and fat contents; showing minimum influence of environment on the expression of the characters. Konda *et al*.(2009) reported similar results for plant height, number of capsule per plant and crud fiber content in blackgram.

4.1.4. Heritability and genetic advance

Heritability and genetic advance estimate for all the characters are presented in Table 3. In this finding estimate of heritability in the broad sense ranged from 36.1% for length of fresh capsule to 69.9% for bearing tiller.

According to Verma and Agarwal (1982) heritability value greater than 50% are considered as high where as values less than 20% are low and values between 20% and 50% as medium. Accordingly high heritability was estimated for plant height (50.7%), bearing tiller (69.9%), leaf area (61%), number of capsules per plant (57.4%), yield per plant (53), diameter of fresh capsule (63.3%), diameter of dry capsules (64%), oleoresin content (51.7%), ash and crud fiber content with the values of (69.5 and 62.7% respectively). Whereas medium for total tiller (44.2%), number of leaves per stem (45.7%), weight of fresh capsule (38.8%), length of fresh capsule (36.1%), weight of dry capsule (47.3%), length of dry capsule (42.5%), volatile oil content (47.2%), crud fat (41.7%).These medium and high heritability values indicating the possibility of progress from selection.

This finding is in agreement with the finding of Prasath *et al.* (2009) for plant height, total tiller, bearing tiller and number of capsules per plant in cardamom. Yudhvir *et al*.(2003) also reported high heritability for tiller number, leaf number and plant height in turmeric. Similarly, Abraham (2008) reported high heritability for tiller per plant and yield in ginger collections. He also reported medium heritability value for plant height and rhizome length.

The genetic advance as the percentage of mean (GAM) at 5% selection intensity is presented in Table 3. According to Johnson *et al*. (1955) genetic advance is said to be high if its value is

greater than or equal to 20%, medium between 10-20% and low when it is less than 10%. Based on this criteria high genetic advance as percent of mean was observed for total tiller, bearing tiller, number of capsule per plant, length of fresh capsule, diameter of fresh capsule, length of dry capsule, diameter of dry capsule, volatile oil, oleoresin, ash, crud fiber and crud fat content. Genetic advance as percent of mean for number of leaves per stem and weight of fresh capsule was medium. Whereas genetic advance as percent of mean was low for plant height, leaf area and yield per plant.

According to Johnson *et al*. (1955) high heritability estimates along with high genetic advance is usually more helpful in predicting gain under selection than heritability estimates alone Therefore in this study most of the character had high genetic advance as percent of mean in conjunction with heritability such as; bearing tiller, ash, crud fiber, oleoresin content and number of capsule per plant: indicating the characters could be improved easily

On the other hand plant height, leaf area and yield per plant showed low genetic advance as percent of mean (< 5%) in conjunction with high heritability .This is because of these character are governed by non additive gene action indicating the character is under high influence of environment and that selection based on this character would be ineffective.

This finding is closely in agreement to the report of Baru *et al. (*1993) for plant height, number of leaf per stem and total tiller in turmeric. Abraham (2008) also reported high heritability in conjunction with high genetic advance as percent of mean for tiller per plant and yield. But he reported medium heritability with low genetic advance as percent of mean for leaves per plant and plant height.

Table 3 Estimate of mean, range, variance components, coefficients of variation, heritability in broad sense, genetic advance and genetic advance under percent mean of 18 characters of 25 germplasm accession studied at JARC 2011/12.

	Range			Genetic parameters						
Traits	Min	Max	Mean	$\sigma^2 g$	$\sigma^2 p$	GCV%	PCV%	H^2	GA	GAM%
BT	1	4	2.49	0.51	0.73	28.7	34.3	69.9**	8.4	337.34
ASH	1.2	3.6	2.23	0.332	0.48	25.8	31	69.5**	8	358.7
CRFI	10.1	37.85	20.12	18.95	29.7	21.6	27.1	63.9**	6.8	34
NCPP	5	10.8	8.12	1.48	2.58	15	19.8	57.4**	5.3	65.3
OC	3.2	7.2	4.64	0.391	0.76	13.5	18.7	51.7**	4.6	99.4
DFC	7.6	14.8	10.92	1.64	2.59	11.7	14.7	63.3**	5	45.9
DDC	3.6	10.8	6.92	1.69	2.64	18.7	23.5	64**	6.4	92
TT	4	13	7.12	1.82	4.1	18.9	28.5	44.2*	4.9	68.3
LDC	2	8.2	4.28	0.37	0.87	14.2	21.8	42.5*	4.1	96
VOC	1.1	3.5	2.23	0.17	0.36	18.5	26.9	47.2*	5	224.2
WFC	12.5	32.02	23.06	7.96	20.5	12.2	19.3	38.8*	3.5	15.4
LFC	4	13.4	7.6	1.61	4.5	16.7	27.8	36.1*	3.9	51.3
WDC	6.5	17.1	11.69	3.02	6.34	14.9	21.5	47.3*	4.6	39
NLPS	18	35.2	27.04	6.13	13.4	9.2	13.5	45.7*	3.5	12.8
PH	118.2	221	173.1	225.35	444.41	8.7	12.2	50.7**	3.6	2.1
LA	78.4	248.6	162.02	1070.81	1755.9	20.1	25.9	61**	6.4	3.9
CRFAT	2.12	2.9	2.38	0.015	0.04	5.1	7.97	41.7*	2.4	100.8
YPP	168.4	374.3	277.92	2038.99	3846.6	16.2	22.3	53**	5.16	1.9

** and * indicates high and medium heritability values respectively

GV:genetic variance , PV: phenotypic variance, GCV: genotypic coefficient of variation, PCV: phenotypic coefficient of variation, H^2:heritability in broad sense: GA: genetic advance, GAM%: genetic advance under percent mean, BT: bearing tiller, %ASH: percent ash content, , CRFI%: crud fiber percentage, , NCPP: number of capsule per plant, OC: oleoresin content, DFC: diameter of fresh capsule, DDC: diameter of dry capsule, , TT:total tiller, LDC: length of dry capsule, VOC: volatile oil content, WFC: weight of fresh capsule, LFC: length of fresh capsule, WDC: weight of dry capsule, NLPS: number of leaf per stem, PH: plant height, LA: leaf area, CRFAT%: crud fat percentage, YPP: yield per plant.

4.2. Association Among Characters

4.2.1. Correlation of yields with other traits

The genotypic and phenotypic correlation coefficients for yield and its related traits are presented in table 4. Total tiller, bearing tiller, number of leaves per stem, number of capsule per plant, weight of fresh capsule and length of dry capsule were positively and significantly correlated with yield per plant both at phenotypic and genotypic level. In addition length of fresh capsule was positively and significantly correlated with yield per plant at genotypic level only. This positive association of pairs of characters shows the possibility of correlated response to selection.

On the other hand oleoresin and crud fat content had negative and significant association with yield per plant at both phenotypic and genotypic levels indicating prevention of the simultaneous improvement of those traits along with each other. To improve these trait bi parental mating, diallel selective mating and mutuation breeding could be used which can break undesirable linkage. Yield per plant was not significantly correlated with the rest of the traits at both genotypic and phenotypic level.

Islam *et al.*(2008) reported positive and significant correlation of tiller per plant with yield per plant and crud fiber content had negative correlation with yield in turmeric. According to Abhay *et al.*(2011) pod per plant and pod length displayed positive correlation with yield per plant in fenugreek. Sumathi *et al*. (2010) reported that number of capsules per plant had significant and positive correlation with yield per plant. However they obtained negative correlation of capsule length and positive correlation of oil content with yield per plant in sesame which contradict this finding.

4.2.2. Correlations among other characters

Plant height exhibited positive and significant correlation with almost all capsule characters which are weight of capsule, length of capsule, diameter of capsule at fresh and dry basis at genotypic and phenotypic level. Total tiller also exhibited positive and significance correlation with bearing tiller, number of leaves per stem, number of capsules per plant. Length of dry capsule and bearing tiller correlated positively with number of capsule per plant and length of dry capsule. In addition to this, number of leaves per stem significantly and positively correlated with number of capsule per plant. Weight of fresh capsule also with length of fresh capsule, diameter of fresh capsule, weight of dry capsule, diameter of dry capsule and percent ash content positively and significantly correlated. The positive and significant association among these characters indicates that these traits can be improved simultaneously through selection.

This finding is in close agreement with Korikanthimath *et al.*(2000) which reported that number of tillers per plant and number of bearing tiller per plant showed positive and significant correlation with number of capsule per plant in cardamom. However, the correlation between plant heights with number capsule per plant was not significant. They also reported that total number of tiller per plant had significant and positive correlation with fresh weight of capsule per plant. (Gopal *et al.*, 1989) also reported similar results in cardamom. Number of bearing tillers per plant and height of the plant were positively correlated with fresh weight of capsules per plant but were not significant.

Adam (2006) in black cumin reported that essential oil content had negative genotypic correlation with seed yield and1000 seed weight. He also obtained negative correlation of oil content with plant height contradicting this finding. Contradicting this finding, evaluation in India indicated that plant height had significant positive association with rhizome yield in turmeric (Tamar *et al*., 2003). With regard to negative correlation, total tiller and bearing tillers negatively and significantly correlated with oleoresin and crud fat content. Beside this number of leaves per stem with volatile oil and oleoresin content, number of capsule per plant with oleoresin and crud fat content show negative and significant correlation.

Table 4 Genotypic Correlation (Above the Diagonal) and Phenotypic (Below the Diagonal) Coefficients of 18 characters of 25 korarima accessions studied at JARC 2011/12

Traits	PH	TT	BT	NLPS	NCPP	LA	WFC	LFC	DFC	WDC	LDC	DDC	VOC	OC	ASH	CRFI	CRFAT	YPP
PH		0.164	0.086	-0.138	0.007	0.272	0.723**	0.788**	0.836**	0.847**	0.458*	0.836**	0.166	0.31	0.289	0.225	-0.162	-0.146
TT	0.134		0.703**	0.423*	0.455*	-0.029	0.19	0.287	0.129	0.207	0.555**	0.129	0.209	-0.49*	-0.256	0.235	-0.347	0.41*
BT	0.135	0.625**		0.225	0.512**	-0.083	0.069	0.003	0.15	0.131	0.748**	0.15	0.321	-0.547**	-0.088	0.35	-0.647**	0.48*
NLPs	-0.073	0.364	0.175		0.722**	-0.085	0.013	0.102	0.004	0.012	0.507**	0.004	-0.312	-0.643**	0.091	-0.22	-0.199	0.69*
ncpp	0.003	0.436*	0.448*	0.66**		-0.019	0.046	0.016	0.24	-0.013	0.666**	0.24	-0.086	-0.854**	0.002	-0.178	-0.602**	0.97**
LA	0.229	-0.033	-0.097	-0.05	-0.018		0.02	0.235	0.239	-0.032	-0.18	0.239	-0.294	0.036	0.136	-0.196	-0.627**	-0.047
WFC	0.477*	0.176	0.07	-0.042	0.044	0.006		0.546**	0.773**	0.983**	0.13	0.773**	0.077	0.008	0.433*	0.266	-0.759**	0.563**
LFC	0.66**	0.26	0.054	0.15	0.006	0.224	0.458*		0.556**	0.663**	0.433*	0.556**	-0.241	-0.002	-0.18	0.344	-0.476*	0.456**
DFC	0.526**	0.108	0.145	0.052	0.16	0.166	0.618**	0.471*		0.707**	0.246	0.961**	0.267	-0.008	0.397*	-0.15	-0.765**	0.035
WDC	0.483*	0.181	0.056	-0.035	-0.003	-0.036	0.935**	0.474*	0.554**		0.109	0.707**	0.09	0.083	0.451*	0.451*	-0.554*	0.362
LDC	0.076	0.475*	0.406*	0.359	0.501**	-0.13	0.139	0.256	0.093	0.128		0.246	-0.131	-0.627**	-0.022	0.308	-0.338	0.593**
DDC	0.526**	0.108	0.145	0.052	0.16	0.166	0.618**	0.471*	0.589**	0.554**	0.093		0.267	-0.008	0.397*	-0.15	-0.706**	0.035
VOC	0.131	0.2	0.253	-0.298	-0.093	-0.284	0.104	-0.167	0.223	0.127	-0.122	0.223		-0.117	-0.307	0.094	-0.823**	-0.116
OC	0.225	-0.243	-0.174	-0.25	-0.485*	0.024	-0.006	0.05	-0.093	-0.017	*	-0.093	-0.005		-0.089	-0.146	-0.467*	-0.807**
ASH	0.232	-0.249	-0.075	0.082	0.003	0.129	0.377	0.147	0.285	0.379	-0.029	0.285	-0.28	-0.036		0.16	-0.488*	-0.069
Crfi	0.196	0.211	0.267	-0.145	-0.164	-0.159	0.207	0.322	-0.033	0.339	0.215	-0.033	0.086	-0.064	0.152		-0.422*	-0.184
Crfat	-0.086	-0.125	-0.153	-0.034	-0.165	0.129	-0.07	-0.11	-0.156	-0.128	-0.131	-0.156	-0.141	0.031	0.126	-0.161		-0.547**
YPP	-0.128	0.404*	0.433*	0.617**	0.957**	-0.055	0.411*	0.357	0.042	0.303	0.429*	0.042	-0.104	-0.47**	-0.067	-0.167	-0.566**	

* and ** Significant at probability level of 0.05 (r = 0.396) and 0.01 values (r = 0.505) respectively PH: plant height, TT:total tiller, BT: bearing tiller, NLPS: number of leaf per stem, LA: leaf area, NCPP: number of capsule per plant, YPP: yield per plant, WFC: weight of fresh capsule, LFC: length of fresh capsule, DFC: diameter of fresh capsule, WDC: weight of dry capsule, LDC: length of dry capsule, DDC: diameter of dry capsule, CRFI%: crud fiber percentage, VOC: volatile oil content, OC: oleoresin content, %ASH: percent ash content, CRFAT%: crud fat percentage

4.2.3. Path Coefficient Analysis

Path coefficient analysis was carried out to partition the correlation coefficients into direct and indirect effects. The direct and indirect effects of component traits on yield per plant are presented in Table 5. Number of capsules per plant which had significant and positive correlation with yield had the highest and positive direct effect on yield (1.104). This justifies that the correlation explains the true relationship and direct selection through this trait will be effective.

Diameter of dry capsule revealed positive direct effect. The correlation coefficient it had with yield was positive and the indirect effects via other traits were mostly negative and negligible. Thus the positive correlation it had with yield was mainly due to direct effect.

Weight of dry capsule and total tiller had positive direct effects. The magnitudes of the direct effects were equivalent to that of genotypic correlation coefficients. This justifies that the correlation explains the true relationship. Length of fresh capsule which had positive and significant association with yield had positive direct effect. Oleoresin content, crud fiber and crud fat had positive direct effects. The genotypic correlation they had with yield was negative. Their indirect effects via other characters were mostly negative. Therefore, their negative correlation coefficient with yield was mainly due to their indirect effect this implies the restricted simultaneous selection should be imposed to nullify the undesirable inderct effect.

Chowdhury *et al.(*2010) and Singh *et al*. (1997) also reported capsules per plant having the highest positive direct effect on yield. Similarly Velmurugan *et al*.(2008) obtained tiller number and rhizome per plant positive and significant direct effect on yield.

Diameter of fresh capsule and weight of fresh capsule had negative direct effects. The genotypic correlation these traits had with yield were positive. The indirect effects of most of other traits were negligible. Hence the genotypic correlations with yield were largely due to their direct effects. Volatile oil content and length of dry capsule also had negative direct

effects and the correlation coefficients these traits had with yield were positive and the indirect effects via other characters were mostly positive. Therefore the correlation they had with yield was because of their indirect effects. Leaf area and ash had negative direct effects and the correlation coefficients these traits with yield were negative and the indirect effects via other characters were mostly negative. Therefore the correlation they had with yield was because of the indirect effects. Number of leaves per stem had negative direct effect. The genotypic correlation of number of leaves per stem is positive and the indirect effect via most of other characters is negligible indicating the correlation with yield is due to direct effect.

The path analysis showed the residual value of 0.197which means the characters in the path analysis expressed the variability in yield by 80.3%.

Table 5 Estimates of direct (bold diagonal) and indirect effect (off diagonal) at genotypic level of different characters on yield of 25 korarima germplasm accession studied at JARC 2011/12

Traits	PH	TT	BT	NLPS	NCPP	LA	WFC	LFC	DFC	WDC	LDC	DDC	VOC	OC	ASH	CRFI	CRFAT	**Rg**
PH	**-0.08**	0.013	0.004	0.012	0.008	-0.045	-0.376	-0.205	-0.903	0.314	-0.098	0.913	-0.059	0.005	-0.077	0.042	-0.014	**-0.146**
TT	-0.013	**0.47**	0.029	-0.037	0.502	0.005	-0.099	-0.075	-0.138	0.077	-0.119	0.139	-0.074	-0.007	0.068	0.044	-0.03	**0.41***
BT	-0.007	0.055	**0.042**	-0.02	0.565	0.014	-0.036	-0.001	-0.163	0.048	-0.16	0.162	-0.113	-0.008	0.024	0.065	-0.057	**0.48***
NLPS	0.011	0.033	0.009	**-0.088**	0.797	0.014	-0.007	-0.027	-0.436	0.005	-0.109	0.438	0.11	-0.01	-0.024	-0.041	0.017	**0.693***
NCPP	-0.001	0.036	0.021	-0.064	**1.104**	0.003	-0.024	-0.004	-0.258	-0.005	-0.143	0.259	0.031	-0.013	-0.001	-0.033	-0.054	**0.97****
LA	-0.022	-0.002	-0.003	0.007	-0.021	**-0.165**	-0.01	-0.061	-0.256	-0.012	0.039	0.258	0.104	0.001	-0.036	-0.037	0.055	**-0.047**
WFC	-0.058	0.015	0.003	-0.001	0.05	-0.003	**-0.52**	-0.142	0.532	0.364	-0.028	0.513	-0.027	0.018	-0.116	0.05	-0.067	**0.563****
LFC	0.063	0.102	-0.128	-0.009	0.115	-0.039	-0.284	**0.26**	-0.599	0.245	-0.093	0.601	0.085	0.124	-0.248	0.264	-0.042	**0.456****
DFC	-0.067	0.01	0.006	0.013	0.265	-0.039	-0.402	-0.145	**-1.077**	0.261	-0.052	0.741	-0.094	-0.025	-0.106	-0.028	-0.062	**0.035**
WDC	-0.068	0.016	0.185	-0.001	-0.015	0.225	-0.511	0.073	-0.761	**0.37**	-0.023	0.764	-0.032	-0.002	0.12	0.084	-0.049	**0.362**
LDC	-0.037	0.043	0.11	-0.045	0.735	0.03	-0.068	-0.113	-0.264	0.04	**-0.214**	0.266	0.046	0.015	0.006	0.057	-0.03	**0.593****
DDC	-0.067	0.012	0.006	-0.165	0.265	-0.039	-0.402	-0.145	-0.108	0.261	-0.052	**0.752**	-0.082	-0.001	-0.106	-0.028	-0.062	**0.035**
VOC	-0.013	0.016	0.013	0.028	-0.095	0.048	-0.04	0.063	-0.287	0.033	0.028	0.288	**-0.353**	-0.002	0.082	0.018	-0.072	**0.116**
OC	-0.025	-0.038	-0.023	0.057	-0.942	-0.006	-0.004	0.001	0.889	0.031	0.134	-0.892	0.041	**0.015**	0.024	-0.027	-0.041	**-0.807****
ASH	-0.023	-0.02	-0.004	-0.008	0.003	-0.022	-0.225	-0.047	-0.427	0.167	0.005	0.429	0.108	-0.001	**-0.267**	0.03	0.042	**-0.069**
CRFI	-0.018	0.018	0.015	0.019	-0.196	0.032	-0.138	-0.09	0.161	0.167	-0.066	-0.162	-0.033	-0.002	-0.043	**0.187**	0.037	**-0.184**
CRFAT	0.131	-0.272	-0.47	-0.176	-0.682	-0.103	-0.894	0.224	0.561	-0.025	0.628	-0.324	0.029	-0.074	-0.012	0.892	**0.009**	**-0.547****

Residual effect : 0.197, * and ** Significant at probability level of 0.05 (r = 0.396) and 0.01 values (r = 0.505) respectively. PH: plant height, TT:total tiller, BT: bearing tiller, NLPS: number of leaf per stem, LA: leaf area, NCPP: number of capsule per plant, YPP: yield per plant, WFC: weight of fresh capsule, LFC: length of fresh capsule, DFC: diameter of fresh capsule, WDC: weight of dry capsule, LDC: length of dry capsule, DDC: diameter of dry capsule, CRFI%: crud fiber percentage, VOC: volatile oil content, OC: oleoresin content, %ASH: percent ash content, CRFAT%: crud fat percentage

4.3. Cluster Analysis

4.3.1. Cluster mean analysis

Cluster analysis grouped 25 accessions in to four distinct groups (Table 6 and appendix Figure 1) in which the first cluster (CL1) consisted of 9 accession which is (36%), the second cluster (CL2) 6 accessions (24%), the third cluster (CL3) 8 accessions (32%) and fourth cluster (CL4) containend 2 accession (8%).

Table 6 Distribution of germplasm accession in to four clusters based on D^2 analysis for 25 korarima accessions studied at JARC 2011/12

Clusters	Number germplasm accession	serial number	Region
Cluster I	9	015/03	Oromia
		053/03	SNNPRS
		068/87	Amhara
		701/87	SNNPRS
		010/00	SNNPRS
		028/84	Oromia
		105/03	Oromia
		001/03	SNNPRS
		046/03	Oromia
Cluster II	6	029/84	Oromia
		011/00	SNNPRS
		045/03	SNNPRS
		001/84	Oromia
		114/03	Oromia
		059/03	Oromia
Cluster III	8	Jimma local	Oromia
		093/03	Amhara
		025/03	Oromia
		009/00	Amhara
		016/84	Oromia
		038/01	SNNPRS
		021/84	SNNPRS
		686/87	Amhara
Cluster IV	2	018/00	SNNPRS
		014/00	Amhara

Collections from SNNP regional states were almost distributed in all clusters than Amhara and Oromia regional states indicating the existence of more genetic diversity in this region than Amhara and Oromia regional states and accession from the same origin might have different genetic background.

Cluster I characterized by having the tallest plant, highest weight of fresh capsule, length of fresh capsule, diameter of fresh capsule, diameter of dry capsule, oleoresin and ash contents. It also showed lowest number of total tiller and bearing tiller per plant, length of dry capsule and crud fiber content.

Cluster II was characterized by the highest volatile oil and crud fat content but with lowest number of leaves per stem, yield per plant diameter of fresh and dry capsule.

Cluster III exhibited by the highest total tiller, number of leaf per stem, weight of dry capsule, length of dry capsule and crud fat content. It also exhibited the lowest leaf area and number of capsule per plant.

Cluster IV was characterized by the highest yield, number of bearing tiller, leaf area and number of capsule per plant. It was characterized by shortest plant,the lowest weight of fresh capsule, length of fresh capsule, weight of dry capsule, volatile oil, oleoresin, ash and crud fat content.

Table 7 Mean value of 18 quantitative characters of the four clusters for 25 korarima germplasm accession studied at JARC 2011/12

Traits	clusters			
	I	II	III	IV
PH	185.6**	166.8	170.9	144.6*
TT	6.4*	7.4	7.7**	6.9
BT	2.2*	2.4	2.8	3**
NLPS	26.2	24*	30**	29
LA	194.4	132.5	131.6*	226.5**
NCPP	8.3	8.1	7.8*	9.1**
YPP	255.7	219.1*	330.3	345.3**
WFC	23.8**	22.3	23.5	20.4*
LFC	7.9**	7.8	7.4	6.6*
DFC	11.5**	10.1*	11.1	10.2
WDC	11.9	11.6	12.1**	9.5*
LDC	3.9*	4.1	4.7**	4.6
DDC	7.5**	6.1*	7.1	6.2
VOC	2.3	2.4**	2.2	1.5*
OC	5.1**	4.8	4.3	3.8*
ASH	2.4**	2.2	2.2	1.7*
CRFI	0.18*	0.24**	0.19	0.2
CRFAT	2.4	2.4	2.5**	2.3*

** and * : highest and lowest cluster mean values respectively

PH: plant height, TT: total tiller, BT: bearing tiller, NLPS: number of leaf per stem, LA: leaf area, NCPP: number of capsule per plant, YPP : yield per plant,WFC: weight of fresh capsule, LFC: length of fresh capsule, DFC: diameter of fresh capsule, WDC: weight of dry capsule, LDC: length of dry capsule, DDC: diameter of dry capsule, CRFI: crud fiber , VOC: volatile oil content, OC: oleoresin content, ASH: ash content, CRFAT: crud fat .

4.3.2. Genetic divergence among accessions

The squared distance was calculated and indicated in Table 8. Test of significance show significance difference between all cluster distances. The minimum squared distance was between cluster III and IV (67.75) followed by cluster I and II (82.12). Maximum squared distance was between cluster II and IV(408.27) followed by cluster II and III(240.57) and cluster I and IV (218.75). Generally this study revealed that germplasm accessions included in this study are moderately divergent. Radhakrishnan *et al*. (2006) using 90 caradmom genotypes reported diversity for growth and yield attributes among the accessions and they grouped into 8 clusters. According to them intercluster distance values also showed wide genetic divergence among accessions

According to Ghaderi *et al*.(1984) increasing parental distance implies a great number of contrasting alleles at the desired loci, and then to the extent that these loci recombine in the F_2 and F_3 generation following a cross of distantly related parents, the greater will be the opportunities for the effective selection for yield factors

Table 8 Generalized squared distance among four clusters in 25 korarima germplasm accession studied at JARC 2011/12

Clusters	II	III	IV
I	82.12**	111.42**	218.75**
II		240.57**	408.27**
III			67.75**

**: significant X^2 =28.87 and X^2 = 34.81 at 5 and 1% probability level

4.4. Principal Component Analysis

Principal component analysis is presented in Table 9 and it revealed that six principal components PCI to PCVII with eigenvalues, 4.69, 3.46, 1.84, 1.64, 1.52 and 1.32 respectively, have accounted for 80.51% of total variation. The first principal components PCI and PCII with values 26.1% , and 19.27% respectively contributed more to the total variation

According to Chahal and Gosal (2002), characters with the largest absolute values closer to unity with in the first principal component influence the clustering more than those with lower absolute values closer to zero.

Characters having relatively higher values in the first principal components (PCI) include plant height, weight of fresh capsule, length of fresh capsule, diameter of fresh capsule, weight of dry capsule and diameter of dry capsule. Total tiller, bearing tiller, number of leaf per stem, yield per plant, length of dry capsule and oleoresin content in the second principal components(PCII). Bearing tiller, number of leaf per stem, volatile oil content and crud fiber content in the third principal components. Leaf area, length of fresh capsule, volatile oil content and crud fat content in the fourth principal components(PCIV). Leaf area, weight of dry capsule, crud fiber and crud fat content in the fifth principal components (PC5) and Leaf area, number of capsule per plant and length of dry capsule in the six principal components.

Similarly Patil *et al*.(2000) reported five principal components with eigenvalues greater than 1 explaining 94.36% of the total variation by using 13 morphological traits and dry capsule yield per clump in large cardamom. Gupta *et al*.(2006) also reported three principal components explaining 73% of total variation by using seven characters on large cardamom.

Table 9 Eigenvectors and eigen values of the first six principal components (PCs) for 18 characters of 25 korarima accessions studied at JARC 2011/12

Traits	Eigenvectors					
	PC1	PC2	PC3	PC4	PC5	PC6
PH	0.359	0.199	-0.066	-0.124	-0.107	-0.18
TT	0.223	-0.314	-0.182	0.059	-0.095	-0.043
BT	0.2	-0.343	-0.334	0.1	-0.171	0.158
NLPS	0.07	-0.311	0.389	-0.01	0.053	-0.044
LA	0.066	0.079	0.095	-0.554	-0.301	0.335
NCPP	-0.025	-0.001	-0.123	-0.123	0.274	0.722
YPP	0.076	-0.418	0.298	0.093	-0.069	0.121
WFC	0.364	0.161	0.095	0.114	0.24	0.126
LFC	0.334	0.097	0.021	-0.309	0.125	-0.254
DFC	0.37	0.151	0.222	0.124	-0.191	0.11
WDC	0.364	0.17	0.011	0.106	0.318	0.106
LDC	0.22	-0.343	0.003	-0.023	0.051	-0.325
DDC	0.37	0.151	0.222	0.124	-0.191	0.11
VOC	0.073	0.059	-0.309	0.573	-0.279	0.125
OC	-0.076	0.355	-0.188	-0.117	-0.139	-0.216
ASH	-0.068	0.296	0.008	0.224	-0.169	0.004
CRFI	0.141	-0.047	-0.441	-0.051	0.506	-0.068
CRFAT	-0.173	0.143	0.392	0.306	0.381	-0.042
Eigenvalue	4.69	3.46	1.84	1.64	1.52	1.32
% variance	26.1	19.27	10.23	9.12	8.45	7.34
cumilative	26.1	45.37	55.6	64.72	73.17	80.51

PH: plant height, TT: total tiller, BT: bearing tiller, NLPS: number of leaf per stem, LA: leaf area, NCPP: number of capsule per plant, YPP : yield per plant,WFC: weight of fresh capsule, LFC: length of fresh capsule, DFC: diameter of fresh capsule, WDC: weight of dry capsule, LDC: length of dry capsule, DDC: diameter of dry capsule, CRFI: crud fiber , VOC: volatile oil content, OC: oleoresin content, ASH: ash content, CRFAT: crud fat .

5. SUMMARY AND CONCLUSIONS

Information on the extent and pattern of genetic variability in a population, interrelationship among different yield and its related characters and knowledge of the naturally occurring diversity are essential to design breeding strategies in crop improvement. To generate such information in korarima, twenty five germplasm acession including one local check were tested in a simple lattice design grown at Jimma Agricultural Research Center in 2011/12 main cropping season.

Results of analysis of variance showed statistically significant difference ($p<0.05$) among the tested germplasm accessions for all the characters considered except internodal length, seed weight and dry matter content. The range and mean values for most of the characters were large showing the existence of variation among tested germplasm accessions. Phenotypic coefficients variation (PCV) values ranged from 7.97 for crud fat content to 34.3% for bearing tiller per plant and genotypic coefficient variation (GCV) ranged from 5.7% for crud fat content to 28.7% for bearing tiller per plant. In addition, PCV value was generally higher than their corresponding GCV values for all the characters considered.

PCV and GCV values were high for bearing tiller, leaf area, ash and crud fiber content. PCV values were high but GCV values were medium for diameter of dry capsule, total tiller per plant, length of dry capsule, volatile oil content, length of fresh capsule, weight of dry capsule and yield per plant. In addition, PCV values were medium for number of leaves per stem and plant height whereas the GCV values were low for these characters. The GCV and PCV value were medium for number of capsule per plant, oleoresin content, diameter of fresh capsule and weight of fresh capsule.

Estimate of heritability ranged from 36.1% for length of fresh capsule to 69.9% for bearing tiller. The heritability value for the characters studied showed medium to high indicating good progress can be made if some of these traits considered as selection criteria.

The estimates of genetic advance as percent of mean was ranged from 1.9 % for yield per plant to 358.7% for ash content. In this study most of the characters showed high genetic advance as percent of mean in conjunction with high heritability. Characters with high heritability and genetic advance as percent of mean allow the improvement of these characters through selection.

Yield per plant manifested significant and positive association with total tiller, bearing tiller, number of leaf per stem, number of capsule per plant, weight of fresh capsule and length of dry capsule both at genotypic and phenotypic level. In addition to these length of fresh capsule was positively and significantly correlated with yield per plant at genotypic level only. By selecting these characters showing positive and significant association with yield there is a possibility to increase yield in korarima.

Path coefficient analysis based on yield as dependent variables showed that number of capsule per plant had the highest positive direct effect on yield. The correlation coefficient was also positive and significant. Diameter of dry capsule also showed positive direct effect. Since these traits had positive correlation with yield in the process of selection much attention should be given to them as these characters are helpful for indirect selection.

The cluster analysis based on D^2 analysis on means of germplasm accession classified the 25 germplasm accession in to four clusters which make them moderately divergent. There was statistically approved difference between all of the clusters

The maximum inter cluster D^2 was recorded between II and IV (x^2=408.27) followed by II and III (240.57) and I and IV (218.75) which revealed that these clusters were genetically more divergent from each other. The minimum squared distance was between cluster III and IV (x^2=67.75) followed by cluster I and II (x^2 = 82.2); implying that genotypes of these clusters were not much diverse. Thus, in this study crosses involving cluster II with cluster IV, II with III and I and IV are suggested to exhibit high heterosis and result in segregants with higher yield.

The principal component analysis revealed that six components (PCs) having eigenvalues between 1.32 and 4.69, explained 80.51% of the total variation. Quantitative traits such as plant height, weight of fresh capsule, length of fresh capsule, diameter of fresh capsule, total tiller, bearing tiller, number of leaf per stem, yield per plant and oleoresin content contributed to the variation in two PCs out of the six PCs. This result further confirmed the presence of genetic diversity for use in improvement program of korarima.

The present study generally implied the presence of significant genetic variability among the tested germpasm acessions. Thus, there is an excellent opportunity to bring about improvement through direct selection and hybridization which involves crossing of genotypes from different clusters. This finding, being the result of one year and one location using limited number of germplasm accessions, it is recommended that the experiment should be repeated at more location and years with more collections to confirm the obtained results.

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7. APPENDICES

Appendix A . Metrological data

Appendix A Table 1 Metrological data of 2011 cropping season at JARC

Month	Temperature in O_c							Humidity %	Sunshine/hr	Rainy day/ month	Wind speed	
	Air		Soil in depth								1min in km/hr	2min in km/hr
	min	max	5cm	10cm	20cm	50cm	100cm					
January	12.4	27.9	22.9	23.6	22.2	22.4	23	63	8.4	9	3.4	6.1
February	11.3	29.7	26	28	23.6	23	23.2	42	3.5	2	6.1	3.4
March	13.3	28.2	23.4	24.4	23.2	22.7	23.1	61	6.5	16	3.17	XX
April	13.1	28.4	24.1	24.2	23.4	23.2	23.9	66	6.2	18	3.6	3.8
May	14.2	26.7	23.6	24	23.4	23.3	24	73	5.4	18	XX	3.83
Jun	13	24.9	23.1	23.6	23.1	23.2	23.9	62	5.9	26	XX	XX
July	13	24.3	23.5	22	22	22.3	23.1	76	3.8	26	1.86	XX
July	13.3	23.3	22.1	23.1	22.8	22.2	21.6	65	3.8	28	2.74	3.1
Septemb	14.1	24.3	22.3	24	22.3	22.1	22.6	75	5.7	26	2.93	3.13
October	12.1	27.2	23.9	24	23.3	22.3	24.4	67	8	15	XX	0.21
Novemb	13.7	26.4	25	26.1	23.4	23.1	23.5	42	8.4	16	2.83	5.65
Decembe	11.5	27.3	23.6	24.9	22.6	22.2	23.1	64	7.1	12	5.6	2.4
Annual	155	318.6	283.5	291.9	275.3	272	297.4	714	72.7	212	15.43	31.68
Monthly	12.9	26.3	23.6	24.3	22.9	22.7	23.3	60	6.1	18	1.29	2.64

Appendix B. **Mean Separation**

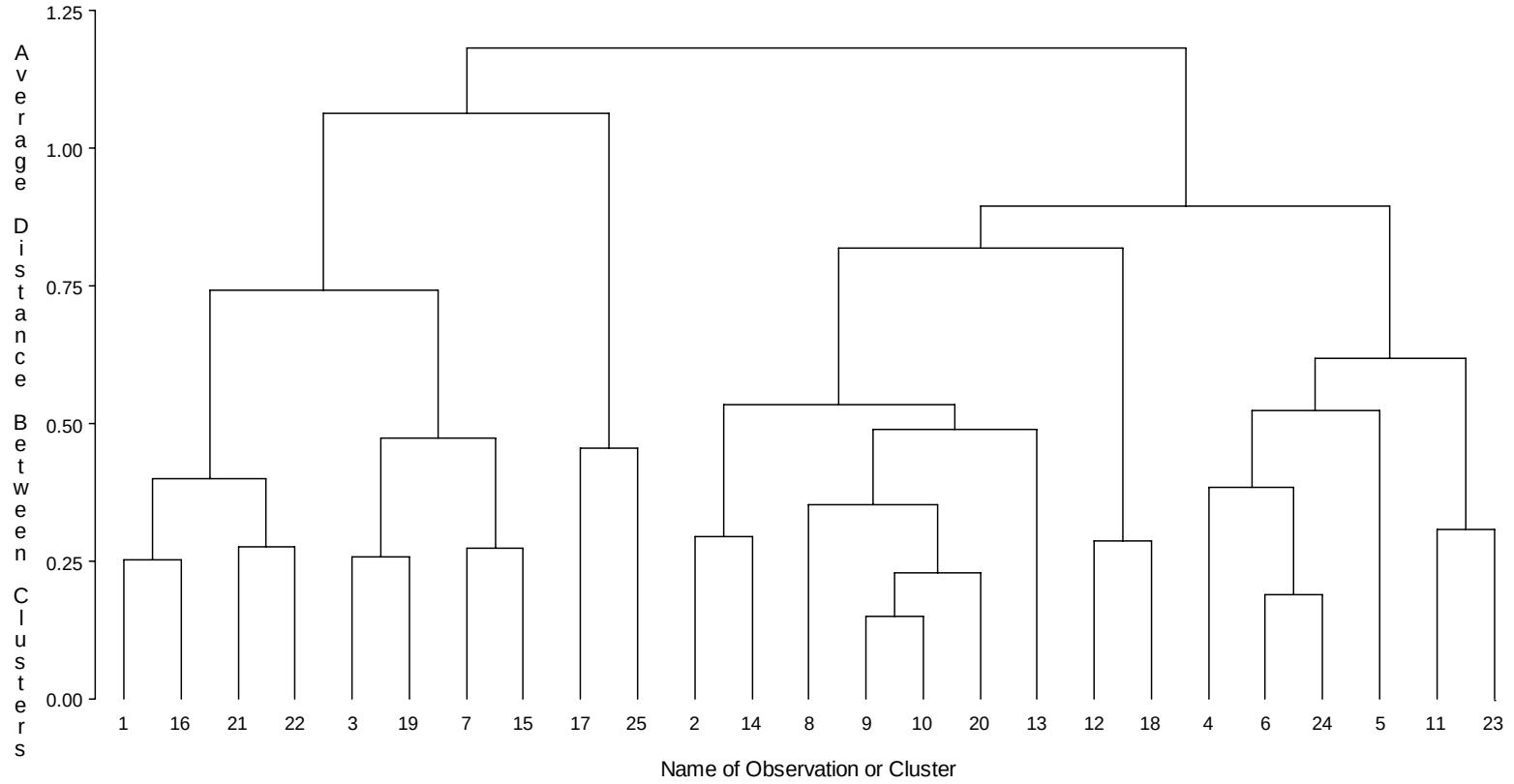
Appendix B Table 1 means for 25 accession studied at Jimma in 2011/2012

Accessions	PH	TT	BT	IL	NLPS	NCPP	YPP	LA	SW	WFC	LFC
1	171.05	9.7	3.4	5	32.6	10.3	349.1	183.65	2.255	21.35	8.45
2	172.65	6.3	2.0036	4.7	27	7.8	275.3	189.95	2.174	19	7.17
3	160.85	4.7	1.6735	4.8	32.05	8.5	301.05	110.55	2.09	24.66	7.05
4	164.1	6.1	1.8325	4.7	24.1	7.9	255	148.4	2.16	24.1	8.02
5	150.25	7	3.2289	4.5	23.2	6.9	224.45	98.55	1.7285	24.65	6.47
6	176.05	9.1	3.0193	4.7	24.6	7.2	227.9	138	2.16	25.56	8.87
7	169	6.2	3.1229	4.9	27.7	9	318.5	103.75	2.2535	20.21	5.56
8	192.5	7.7	3.3928	4.5	24.65	8.5	288.5	184.75	2.0375	27.19	7.13
9	180.1	8.7	1.3518	4.7	28.6	8.05	257	172.8	2.1895	25.8	7.8
10	177.55	6.05	1.8482	4.9	24.2	7.9	263	149.05	2.173	20.95	6.4
11	155	6.05	1.4313	3.8	22.6	5.05	183.2	149.9	1.975	17.2	5.85
12	206.6	5.5	1.3349	5.1	25.1	7.3	225.25	228.9	1.9	29.91	11
13	178.05	6.4	2.4048	5.3	26.4	7.05	230.1	188.55	2.105	25.2	6.275
14	186.65	7.6	3.7639	4.5	26.6	8.6	282.5	187.8	1.885	23.97	6.515
15	153.3	4.7	1.1602	4.44	31	8.4	301.3	105.8	2.09	22.73	6.634
16	177.75	9.05	2.9193	5.7	31.05	10.1	359	156.6	2.1	23.39	8.05
17	143.1	4.6	2.2229	5.1	22.6	8.95	333.4	245.45	2.15	17.9	5
18	202.7	5	1.3928	6	26.55	6.95	202.6	237.6	2	25.38	11.65
19	169.55	6.1	2.9518	4.55	27.7	9.2	318.25	100.55	2.21	23.6	5.95
20	179.25	6.7	2.2482	4	28.3	7.8	277.05	189.9	2.1745	17.25	7.72
21	195.1	11.6	3.8916	4.5	29.4	10.3	360.55	144.25	2.4	27.85	8.45
22	174.05	8.4	2.6952	4.1	30	9.7	334.1	172.8	2.175	24.565	7.96
23	146.6	6.2	1.9651	5	22.5	5.15	198.05	144.95	2.205	16.35	6.12
24	202.9	8.1	3.5241	5.2	24.8	7	225.75	135.45	2.16	25.16	10.75
25	142.6	10.5	3.4205	5.1	32.7	10.1	357.15	182.6	2.27	22.5	9.15
Grand mean	173.1	7.12	2.49	4.79	27.04	8.12	277.92	162.02	2.12	23.06	7.6
CV%	8.86	19.89	20.93	13.35	9.32	12.43	14.47	16.95	7.03	14.49	20.3
LSD5%	34.3	3.12	1.09	1.39	5.56	2.31	92.64	62.59	0.32	7.3	3.48
LSD1%	46.49	4.23	1.5	1.88	7.54	3.13	125.55	84.82	0.43	9.9	4.72

Appindix B table 1 continued

Accessions	DFC	WDC	LDC	DDC	VOC	OC	DRMA	ASH	CRFI	CRFAT
1	10.7742	9.907	4.25	6.7742	2.05	3.7	87.7	2.1	0.1884	2.3487
2	9.7411	8.5228	3.6	5.7411	1.5	5.4	86.9	1.625	0.1755	2.3091
3	10.0534	12.3201	4.35	6.0534	1.6	4.5	86.75	2.26	0.1904	2.7551
4	11.1008	12.5315	4.36	7.1008	2.85	4.9	89.75	1.75	0.1988	2.2951
5	10.6627	11.6096	4.05	6.6627	2.1	5	87.6	1.4	0.2033	2.2496
6	9.9734	14.698	5.95	5.9734	2.7	3.95	86.85	1.8	0.3508	2.4208
7	9.5404	10.4639	3.65	5.5404	3	4.8	86.15	2.75	0.1804	2.4662
8	10.4526	13.2111	4.35	6.4526	3.15	4.4	86.95	2.4	0.1974	2.1422
9	10.45	14.8225	3.5	6.45	3.05	4.9	86.7	3.3	0.1944	2.4522
10	12.4119	9.8506	3.4	8.4119	2.85	3.6	87.5	1.7	0.1977	2.4117
11	8.7313	8.7139	2.8	4.7313	2.55	6.4	86	3.4	0.1985	2.3396
12	13.5982	14.5798	4.05	9.5982	1.7	4.5	87.15	2.55	0.1521	2.585
13	10.7605	12.6271	3.8	6.7605	1.65	6.2	87	3	0.1987	2.3159
14	11.8579	12.7884	3.8	7.8579	3.15	5.6	86.8	2.5	0.1618	2.1509
15	9.8197	10.9166	4.45	5.8197	1.5	4.55	87.7	2.45	0.1966	2.7605
16	10.9313	12.3013	4	6.9313	1.6	4.65	86.45	1.6	0.194	2.4612
17	7.9482	7.7672	4.525	3.9482	1.2	3.75	87.45	1.4	0.1957	2.3116
18	13.4605	12.8644	3.9	9.4605	1.7	5.25	88.4	2.65	0.1542	2.1625
19	13.5579	12.8758	4.4	9.5579	3.05	3.8	87.6	2.75	0.1693	2.4425
20	9.8697	7.954	4.55	5.8697	1.5	4.9	86.7	1.63	0.2161	2.3271
21	13.2286	13.7237	7.25	9.2286	2.9	3.9	85.35	2.2	0.196	2.2657
22	10.8956	12.8395	4.7	6.8956	1.6	4.45	86.45	1.5	0.2036	2.3011
23	9.3079	8.4368	3.4	5.3079	2.6	4.5	87.9	3.5	0.1536	2.5871
24	11.8	14.9982	4.35	7.8052	2.25	4.75	87.2	1.75	0.3649	2.2921
25	12.06	10.8763	5.6	8.0671	1.9	3.65	87.75	1.9	0.1968	2.3666
Grand mean	10.92	11.69	4.28	6.92	2.23	4.64	87.1	2.23	20.12	2.38
CV%	9.81	15.78	16.39	15.48	17.79	12.03	1.37	15.36	15.79	5.69
LSD5%	2.24	4.16	1.59	2.24	0.91	1.25	1.02	0.79	0.067	0.33
LSD1%	3.09	5.73	2.16	3.09	1.23	1.69	1.38	1.07	0.091	0.46

APPINDIX C. FIGURE



Appendix C. Figure 1 Dendrogram depicting the genetic relationship of korarima germplasm based on yield and related character evaluated in 2011/12