# EFFECT OF PRIMING ON SEED GERMINATION AND GENETIC VARIATION IN KORERIMA [*Aframomum corrorima* (Braun) P.C.M. Jansen] GENOTYPES

**MSc THESIS**

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# Effect of Priming on Seed Germination and Genetic Variation in Korerima [*Aframomum corrorima* (Braun) P.C.M. Jansen] Genotypes

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## STATEMENT OF THE AUTHOR

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# BIOGRAPHICAL SKETCH

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ANOVA | Analysis of variance |
| CRD | Completely Randomized Design |
| EARO | Ethiopian Agricultural Research Organization |
| EIAR | Ethiopian Institute Of Agricultural Research |
| ETB | Ethiopian birr |
| $GA_3$ | Gibberellins Acid |
| $KH_2PO_4$ | Potassium di Hydrogen Phosphate |
| $KNO_3$ | Potassium Nitrate |
| m.a.s.l | Meter Above Sea Level |
| PEG | Polyethylene Glycol |
| RCBD | Randomized complete block design |
| UPGMA | Unweighted Pair-group Method with Arithmetic means |
| SAS | Statistical Analysis Software |
| SNNPR | Southern Nation Nationality Peoples Regional State |
| TNSRC | Tepi National Spices Research Center |

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# Effect of Priming on Seed Germination and Genetic Variation in Korerima [*Aframomum corrorima* (Braun) P.C.M. Jansen] Genotypes

## ABSTRACT

*This study was conducted to evaluate the effect of seed priming on seed germination and genetic variations among korerima genotypes. Twenty five korerima genotypes were evaluated for agro morphology characters and seed germination quality characters in a simple lattice and completely randomized (CRD) designs, respectively. Two genotypes were used to assess the effect of priming on seed germination in CRD with three replications in factorial arrangement of six priming materials (distilled, tap water, cow urine,* gibberellins acid, potassium di hydrogen phosphate , potassium nitrate) *and three durations of priming at Tepi National Spices Research Centre in 2016. Analysis of variance results revealed the presence of significant differences among genotypes for all characters. Moreover, the genotypes had dry capsule and pure seed yields ranged from 203.6 to 921.83, from 36.33 to 170.5 kg ha-$^{1}$, respectively. Unprimed seeds of genotypes seed germination percentage and speed of germination ranged from 48.33% to73.33% and 2.83 to 4.45, respectively. Priming had improved the seed germination potential significantly of the two korerima genotypes (093/00 and 059/03) with varied magnitude in which seed germination and speed of germination of primed seeds improved by about 11.62 to 41.99% and 1.16 to 3.57, respectively. The percentage of normal seedlings increased by about 5.61 to 18.24%, while fresh ungerminated and dead seeds significantly reduced by about 14.33 to 15.87 and 1.75% to 4.59%, respectively, as compared to unprimed seeds. Priming of seeds with* gibberellins acid *and cow urine significantly improved the seed quality of korerima than other priming materials. Most of the characters had low Phenotypic (PCV) and genotypic (GCV) coefficient of variations, heritability ($H^{2}$) and genetic advance (GAM) except number of capsule bearing sucker per plant, fresh capsule length, dry capsule diameter, dry capsule length, dry capsule yield in kg ha$^{-1}$ pure seed yield, and number of seed per capsule had high values. Number of capsule bearing suckers per plant, number of capsules per plant, dry capsule weight, total seed weight per capsule and dry capsule yield kg ha$^{-1}$ had positive and significant correlation with pure seed and dry capsule yield, respectively. Therefore, selection of genotypes for the mentioned characters could be used as simultaneous selection of genotypes for seed and dry capsule yield. The genetic distances estimated by Euclidean distance (ED) varied from 2.53 to 10.8 with a mean distance of 5.66 and standard deviation of 1.23. The clustering based on Euclidian distance matrix grouped the 25genotypes into seven distinct clusters. In conclusion, the genotypes were diverse with wide range of variations for most seed and dry capsule yield, yield related characters and seed quality that could be exploited to bring improve the crop either through direct selection and crossing of most distant genotypes from different clusters.*

***Keywords:*** *Association of characters, Euclidean distance, Dry capsule yield, germination and Speed of germination.*

# 1. INTRODUCTION

Korarima [*Aframomum corrorima* (Braun) P.C.M. Jansen] is herbaceous, perennial and aromatic species classified in the monocotyledonous family Zingiberaceae and belongs to the genus Aframomum. The chromosomes of korarima were observed to be small in size and their diploid number was found to be 2n= 2x=48 (Surawit and Wondyifraw, 2013). The plant consists of an underground rhizome, a pseudo stem, and several broad leaves and morphologically it resembles Elettaria species. Mature korarima plant can reach a height of 1-2 m. It sets seed after 3-5 years of planting depending on the planting materials used and it continue to bear seeds for a number of decades (Eyob, 2009).

Korerima is propagated both by seeds and rhizome Girma *et al.,* 2008). It grows in lower strata of natural forests and it needs 55 to 63% shade level for its proper development. It grows in areas located in altitudes ranging from 1000 to 2300 m.a.s.l. and receiving 1500 mm or more rainfall per year Girma *et al.,* 2008).

Korarima is indigenous to Ethiopia and important cash crop having a good export potential. The seed of korarima is mainly used as spices in traditional Ethiopian dishes. It is a source of income for growers as its seeds can fetches high prices in local and export markets. Korerima is used in traditional medicine for humans and cattle. Also korerima is important plant for soil conservation as the rhizomes and leaves spread on the ground covering and protecting the soil from erosion in hilly areas the year around (Eyob *et al*., 2009). However, it has been one of the most mishandled crops and it has been given less attention in research. A very few authors have addressed some issues of korerima such as indigenous practices of production and farm based biodiversity. Information is also available about essential oil yield and compositions from leaves, rhizomes, capsules and seeds (Eyob *et al*., 2009).

The formal survey carried out in southern Ethiopia indicated farmers are not encouraged to cultivate korerima due to seed germination takes prolonged time to emerge (one to two months), poor establishment of plants in the field due to large proportion of ungerminated seeds and lack of improved varieties with improved agronomic practices (Eyob *et al*., 2009).

The germination of korerima is not fast and/or many seeds do not germinate due to the presence of some kind of dormancy, possibly associated with its hard seed coat like the seeds

of Elettarias species. The presence of low food reserve in the seed endosperm might be a reason for the very slow growth of korarima seedlings. Korerima is also propagated by cutting of its clumps, but it results in the destruction of the productive garden, on top of the commonly associated shortage of planting materials to cover wider areas of land (Eyob *et al*., 2009).

Research is essential on way of shortening prolonged period of seed germination and increase the proportion of germinated seeds of korerima to increase the production the crop. Seed priming is a procedure that partially hydrates seed, followed by drying of seed, so that germination processes begin, but radicle emergence does not occur. It includes soaking seed in water or osmotic solution, and inter mixture with porous matrix material (Amarnath *et al.* 2015). The application of some seed treatments to make the hard seed coat of korerima permeable to water and/or gases was reported (Eyob, 2009).

The development of micro propagation methods may enable production of sufficient amounts of planting material of a desired clone for commercial productions, local cultivation and others, but the technology may not be utilized with short period of time to all producers. Improvement of seed quality by seed priming may be a simple and easy approach to enhance seed performance and agricultural productivity. For most crops, the mean yield increases due to priming range from zero to more than 200% with an overall average increase of 30% (Harris, 2009). Though, priming of seeds in most of crops has an advantage, but little work (one experiment) has been done on korerima seeds (Eyob, 2009). However, this study did not include all possible seed priming materials that could be easy accessible to farmers.

In the country where the crop is originated, the genetic diversity of the crop for yield, yield related characters and seed quality is expected. However, the extent of genetic variability among korerima genotypes for seed quality has not been studied. It has been suggested that the genotypes may have significant variation for seed quality that can be exploited to alleviate the seed germination problem (Eyob, 2009).

Assessment of genetic variability in crops has a strong impact on plant breeding and conservation of genetic resources. It is particularly useful in crops not well studied. The knowledge of the crop nature, extent and distribution of genetic variation is crucial for

successful selection of individual genotypes to be used as parents in hybridization program or to develop as variety. Very recently, Tepi National Spices Research Centre collected large numbers of korerima genotypes from major growing regions of Ethiopia to assess the genetic variations among genotypes and thereby to develop to varieties. However, characterization and genetic diversity study has not been studied in korerima. Therefore, this research was initiated with the following objectives.

**Objectives:**

- To assess the effect of priming on seed germination of korerima.
- To assess the genetic variability and association of characters in korerima genotypes for seed yield and related characters.

# 2. LITERATURE REVIEW

## 2.1. Botanical Description of Korerima

Korerima [*Aframomum corrorima* (Braun) P.C.M. Jansen] is herbaceous, perennial and aromatic species classified in the monocotyledonous family Zingiberaceae and belongs the genus Aframomum. The chromosomes of korerima were observed to be small in size and their diploid number was found to be 2n = 2x = 48 (Surawit and Wondyifraw, 2013).

Korerima, is a perennial, tropical shade loving, aromatic herb, often of large size, bearing flowers either terminally on aerial leaf shoots or from the ground level. The plant consists of an underground rhizome, a pseudo stem, and several broad leaves and resembles Elettaria species morphologically. It grows usually with strong fibrous subterranean scaly rhizomes and with leafy stems reaching 1–2 m height. It sets seed after 3-5 years of planting depending on the planting materials used and it continue to bear seeds for a number of decades (Eyob, 2009).

It is usually self-pollinated crop, the position of the stigma is below or against the base of the anther. Most probably the flower open for one day only, but there is no experimental evidence. Occasionally cross-pollination by insect is possible due to the presence of large nectarines at the top of ovaries (Jansen, 2008).

It grows in south and south western part of the country such as Gamo Gofa, Kaffa, Jima and Bale zones (Girma *et al.*, 2008). Ethiopia is a homeland for many spices, such as korerima, long pepper, black cumin, bishops weed or '*nech azmud'*, coriander, etc. Wild ginger is also abundant in many parts of the country. Korerima grows naturally at altitude ranging from 1000 - 2000 m. a.s.l. (Girma *et al*., 2008).

The flowers are covered by imbricate, purplish-brown, sub ovate scales of 2.5 cm × 1.5 cm and each flower is surrounded by a scarious, sub oblong bract up to 6 cm×2 cm, bidentate, ciliate. The fruit is an indehiscent and subconical berry up to 6 cm × 3.5 cm in size usually it shows 3 longitudinal furrows, but sometimes it gives more shiny green when immature, turning bright red at maturity, with three cells containing 45–65 seeds for each. Seeds are sub globose in outline but usually somewhat angular from 2–5 mm in diameter. The seed testa is

finely lined, glossy brown and its hilum is circular, whitish, aril thin and a bit fleshy (Jansen, 2008).

## 2.2. Importance of Korerima

The use of korerima is so diverse, where seeds (usually dried, sometimes fresh) are used to flavor all kinds of sauces, for which they are ground and usually mixed with other spices; occasionally they are also used to flavor coffee, tea, bread and butter. The seed of korerima is mainly used as sources of spices in traditional Ethiopian dishes. It is a source of income for growers as its seeds fetches high prices in local and export markets (Girma *et al*., 2008).

Korerima is a milder spice similar to coriander, and is also highly popular for the preparation of stews in Ethiopia. It is considered as one of the few spices and is an important culinary and medicinal plant species native to Ethiopia, where it is found and growing in the rainforests of the Southern and Southwestern parts of the country (Piem, 2010).

Korerima is said to aid the digestive tract and to cure common colds and upper respiratory infections (Piem, 2010). The seeds are also important ingredients in the preparation of *berbere, mitmita, awaze,* and other spice mixtures, and are also used to flavor coffee (Jansen, 2008).

Korerima is mainly harvested from wildly grown plants within the forests in many parts of the country, but mainly from the southern and south western region of the country. The dried fruits (capsules) of korerima had long been marketed throughout the country, and the fresh fruits are also sold at local markets in the major producing areas. They are relatively expensive than other spices and were commonly used as a currency during local transactions (Jansen, 2008).

Dried capsule of *Aframomum corrorima* has highly significant economic importance for local and as export commodity in addition to various uses. Previously, Ethiopia was well-known for its considerable exports of *Aframomum corrorima* capsules to the world market, mainly as a substitute for the Indian small cardamom (Eyob, 2009). Currently (2015) farm gate prices of dried and locally processed *Aframomum corrorima* capsules is 80 to 110 (ETB) per kg and

when it come to the central market more than 40% price increase is very common (Eyob, 2009).

Also korerima is important plant for soil conservation as the rhizomes and leaves spread on the ground covering and protecting the soil from erosion in hilly areas the year around (Eyob *et al.,* 2009). In addition, ethno-botanical surveys were also conducted in Gamo Gofa, Debub Omo and Kaffa, which are the three major korerima growing regions of Southern part of Ethiopia. Hence, plant parts used as a source of medicine against different aliments were documented.

About 83% of the interviewed key informants had asserted the seeds to be the most widely used parts in the traditional medicine, followed by leaves (75%) and rhizomes (72%). Its antioxidant ability of different plant parts and seed oils extracts showed the highest anti-fungal activity followed by pod extracts. However, the inhibitory effect of leaf and rhizome is lower and has no activity towards tested organisms at the lowest concentrations. The study on antimicrobial (antifungal) properties in korerima partly supports the use of this medicinal plant as traditional remedies for different aliments (Eyob *et al*., 2009).

Korerima oil has a similar chemical composition to that of the Indian cardamom (*Elettaria cardamomum*), except for its reduced content of α-terpinyl acetate, which is the major component in the latter. The major components of dried seed and pod oils of korerima were found to be 1,8-cineole (44.3%) and E-nerolidol (17.2%), respectively, while 32.6% of 1,8-cineole was recorded from dried seed. The essential oil yield of fresh leaves, rhizomes, pods and seeds were 0.46, 0.69, 0.83 and 4.30% on a w/w dry basis, and 0.09%, 0.07%, 0.15% and 3.57% on a w/w wet basis, respectively (Eyob *et al*., 2009).

## 2.3. Ecological Requirement

Korerima can grow well in areas with mean annual rainfall of 1,300 mm to more than 2,000 mm, but with no distinct dry season. However, the crop thrives well where the main rainy season lies in the months of June to August, where 50–60% of the total rainfall is availed to the plant (Girma *et al*., 2008).

The crop is commonly found in the wild habitats where wild coffee is commonly found. On top of this, it is not uncommon to find korerima in wider agro ecologies of Ethiopia; between 1350 to 2300 m.a.s.l. availing the optimal environmental conditions essential for the proper growth and development of korerima is important to achieve the best economic benefits (Girma *et al*., 2008).

The crop requires average temperature ranging between 16 to 24$^{o}$C, a moderate shade of 55-63% (Girma *et al.*, 2008) and a photoperiod with <12 hours of light, i.e. a short day plant. With regard to soils, it thrives well on acidic soils (i.e. 5.5 - 6.5 PH), deep to medium soils (50-150 cm), high to moderate organic matter and fertility status, well drained but with high water holding capacity. In general, the crop does better as undergrowth within the forest habitat, where the soil is so porous and fertile without any compaction due to high accumulation of humus (Girma *et al*., 2008).

As korerima will probably remain some of the most important spices due to its presence of aromatic seeds, it will continue to be attractive to customers/consumers. However, till now large-scale cultivation for its seeds production is not expected as good. Although not yet in direct danger of extinction, like all Aframomum species, deserves to be part of germplasm collections. Unreservedly, there is no a serious diseases or insect pests known for korerima except the natural enemies like, ape, monkey and mice, but current reports that the rust *Puccinia aframomi* has been observed on korerima leaves in Ethiopia (Jansen, 2008).

## 2.4. Propagation

Korerima can be propagated by seed and clumps/vegetative methods. Propagation of korerima by seed is quite difficult by traditional breeding methods, but planting rhizome parts is probably easier and quicker than seeds.

The development of micro propagation methods does not only enable production of sufficient amounts of planting material of a desired clone for commercial productions, local cultivation and others but also it is the base for the future improvement of the crop through tissue culture, genetic engineering as well as for modern germplasm conservation tasks. Among the most

prominent members of the family *Zingiberaceae* like, cardamom, large cardamom, ginger and turmeric have been so far successfully carried out their micro propagation (Eyob, 2009).

The vegetative propagation of korerima through splitting of rhizome with one year old and another young sucker is the conventional technique used on its propagation. Even if propagation by using rhizome shortens the juvenile stage of the stand plant and also enables to produce true-to-type ones, it is always come with shortage of planting materials to cover large areas of land and it involves sacrifice of potentially productive stands (Eyob, 2009).

The slow seed germination and growth of the subsequent seedlings were concerns of korerima growers. The germination of korerima seeds faces certain problems and it takes a prolonged time to emerge after the seed sown in the nursery. This is due to with the presence of some kind of dormancy, possibly associated with the hard seed coat and low food reserve in the seed endosperm might be a reason for the very slow growth of the seedlings (Eyob, 2009)..

Enhancement of korerima seed germination is important in propagation and breeding program as well as for testing and using germplasms. Currently, there was a study in breaking of korerima seed dormancy due to its impermeability of hard seed coat. One of these studies was to explore the effect of different treatments on germination and seedling growth attributes of high land korerima cultivar namely Mume and the result was obtained by soaking korerima seeds in 50% H2SO4 for 60 min followed by soaking in 250 mg/l $GA_3$ for 24 hrs had recorded 83.3% germination (Eyob, 2009).

## 2.5. Seed Priming

Priming in its traditional sense, is soaking of seeds in water before sowing, has been the experience of farmers in India in an attempt to improve crop stand establishment but the practice was without the knowledge of the safe limit of soaking duration. Moreover, Harris *et al*. (2009), promoted a low cost, low risk technology called ‘on-farm seed priming’ that would be appropriate for all farmers, irrespective of their socio-economic status.

Seed priming is basically a pre-sowing seed treatment. However, primed seeds may be dried back to their initial moisture content and stored for variable periods of time depending on the species. Primed and dried seeds normally have a more rapid and uniform germination when

subsequently re-hydrated, especially under adverse environmental conditions (Amarnath *et al*., 2015).

The mechanism of seed drying after bio-priming is known as the hydration-dehydration process or dry back and is used to reduce the degree of moisture in seeds to levels compatible with storage and maintaining the beneficial effects of the treatment, without quality loss caused by rapid seed deterioration. However it's the investigated research, effect of priming treatments viz., Neem Leaf Extract, Parthenium Leaf Extract, Cow Urine and Coconut Water, Lantana Camera Extract improve seed quality parameters viz., germination per cent, shoot length, root length, seedling length, seedling dry and fresh weight of sorghum (Amarnath *et al*., 2015).

Seed germination is a complex physiological process that is actually a response to environmental signals such as temperature, water potential, light, nitrates and other factors. Unfavorable environmental conditions are for germination and seedling emergence in arid and semiarid regions of the main causes of poor seedling emergence and establishment. One of the limiting factors is the incidence of drought stress on plant that is the occurrence of severe drought due to evaporation, high osmotic potential of the soil and the soil pest salt and ice on the thermodynamic equilibrium conditions and reduced availability of drinking water. Basically, the germination and establishment of seedlings to drought stress is very sensitive so that drought stress decreased seed germination and seedling and non-uniform establishment (Amarnath *et al*., 2015).

Mahmoudi *et al*. (2012) in their study investigated the effect of hormone primed on germination and seedling growth of lettuce seedlings and then reported that between different concentrations of $GA_3$ there was a statistically significant difference. Bahari *et al.* (2012) investigated effect of hydro-priming, osmo-priming salicylic acid on germination and seedling establishment of *Bromus tumentlus* and showed that the treatment improved seed germination under drought stress.

Recently many types of seed treatments such as, hydration pre-sowing, seed priming, seed coating with bio control agents and bio-priming seed treatments have been considerable and environmentally acceptable alternatives to the existing fungicide seed treatment. Thus many

different primers have been used for treatment of diseases and yield improvement (Amarnath *et al*., 2015).

## 2.6. Genetic Variability in Korerima

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). 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.

Determining the genetic variation among and within genotypes facilitates reliable classification of genotypes and identification of subset core genotypes with possible utility for specific breeding purpose and to preserve maximum genetic diversity in germplasm sources (Sharama, 2010).

### 2.6.1. Phenotypic and genotypic coefficients of variations

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.

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 characters 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, 2014).

In a genetically mixed population of an asexually propagated species, a superior clone may be isolated and propagated as a cultivar Prasath and Venugopal (2009) 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 characters 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 ginger, whereas high for plant height in flax genotypes. In addition to this Islam *et al.* (2010) 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. Hikmat *et al*. (2012) reported that the largest variation was observed for plant height, leaf length, leaf width, and number of leaves in turmeric.

### 2.6.2. Heritability

According to Falconer and Mackay (1996), heritability is defined as the measure of the correspondence between breeding values and phenotypic values. Heritability is classified into broad and narrow sense. Heritability in the broad sense is defined as the proportion of phenotypic variance that is attributable to an effect for the whole genotype, comprising the sum of additive, dominance and epistatic effects (Falconer and Mackay, 1996).

For rational approach towards the improvement of seed yield, selection has to be made for the components of yield. However, the heritable variation is often masked by non-heritable variation, which creates difficulty in selection program. This suggests the need for partitioning the overall variability in to heritable and non-heritable components, which enables the breeder to evolve suitable breeding procedures (Savita, 2006).

Heritability indicates how much the phenotypic variability has a genetic origin, gives objective information for the genetic selection process (Veershey, 2009). The precision of this parameter depends on an adequate estimation of the associated variance components. In general the prediction of the breeding value of genotypes (families, clones origins, etc.) and the identification of those that are genetically superior, depend on the correct estimation of the genetic parameters. The value observed when a quantitative character is measured on an individual, is the phenotypic value.

Simegn *et al.* (2012) reported that 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%).These medium and high heritability values indicating the possibility of progress from selection.

**2.6.3. Genetic advance**

Genetic advance measures the expected genetic progress that would result from selecting the best performing genotypes for a character being evaluated (Allard, 1999). The estimate of genetic advance as per cent of mean provides more reliable information regarding the effectiveness of selection in improving the characters.

According to Allard (1999), genetic advance under selection is a genotypic value, which depends on three things such as genetic variability, heritability or masking effect of non-genetic variability on the genetic variability and the selection intensity applied. Genetic progress would increase with increase in the variance. Generally, genetic advance gives clear picture and precise view of segregating generations for possible selection. Higher estimates of heritability coupled with better genetic advance confirms the scope of selection in developing new genotypes with desirable characteristics (Allard, 1999).

The ultimate goal of plant breeder is to have higher genetic advance for the characters selected, since it is an indicator for the genetic improvement made in a population under

selection. The genetic gain that can be expected for a particular character through selection is the product of heritability, phenotypic standard deviation and selection differential (Cvikic *et al.*, 1999).

The estimate of genetic advance help in understanding the type of gene action involved in the expression of various polygenic characters. Knowledge of association between yield and its attributes obtainable through estimation of genotypic and phenotypic correlation helps a great deal to formulate selection strategies to develop suitable genotypes (Sharma, 2010).

Simegn *et al*. (2012) reported that 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, crude fiber and 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.

### 2.6.4. Association of characters

2.6.4.1. Correlation coefficient

The degree of association between two characters is measured by the correlation coefficient. Therefore, correlation is helpful in determining the component characters of a complex character like yield. Such studies are useful in disclosing the magnitude and direction of these relationships between the different characters and grain yield as well as among characters themselves (Falconer and Mackay, 1996).

Association of economically important quantitative characters which is statistically determined by correlation coefficient has been quite useful as a basis of selection. Correlation studies provide information that the selection for one character will result in progress for all correlated characters. Correlation coefficient is a measure of the degree for linear association between two variables (Singh ., 2009).

Estimation of genotypic and phenotypic correlation between various agronomic characters may provide information necessary to show the relationship between characters. When selection is based on two or more characters simultaneously, combined effect of genotype and

environment gives us the phenotypic correlation while the genotypic correlation may result from linkage, epistasis and pleiotropy (Singh, 2009).

The correlations between observed characters may exist due to various reasons; because of pleiotropy, genetic linkage, the association of loci or blocks of loci governing variability for different characters located on same chromosomes. Such kind of non-random segregation will result only in temporary correlations. The association of characters can be measured as the co-efficient of correlation (Ashok and Patil, 2008).

Correlation coefficient measures the strength and direction of a linear association between two variables. It ranges from -1 to +1. Correlation value (r=1) implies perfect (100%) correlation, where both characters vary hand in hand, (r = -1) means there is 100 % correlation between two characters, but they vary in opposite direction, and (r= 0) carries the implication that there is no correlation at all between the two characters (Falconer and Mackay, 1996).

Simegn *et al.* (2012) reported that 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.

2.6.4.2. Path coefficient analysis

Path analysis was first suggested by (Dewey and Lu, 1959). It is standardized partial regression analysis based on cause and effect relationship and it is useful for analysis by subdividing correlation in a causal scheme. The computed correlation coefficient values are partially useful in explaining the nature and extent of association existing between pairs of characters. The economic character like fruit yield is dependent on several component characters, which are mutually related.

Correlation explains the true association existing between the component characters with dependent character (fruit yield). Slight change in any one component will ultimately disturb

the complex, hence character has to be analyzed for its action which is done through path analysis, where the two types of action namely direct effect of component character on fruit yield and the indirect effect through other component characters on fruit yield are obtained which cannot be recovered by the correlation studies (Savita, 2006).

Path coefficient analysis is a very important statistical tool that indicates which variables (causes) exerts influence on other variables (effects), while recognizing the impacts of multi colinearity (Akanda and Mundt, 1996). Path coefficient analysis is simply a standardized partial regression coefficient and as such measures the direct and indirect effect for one variable upon another and permits the separation of the correlation coefficient into components of direct and indirect effect (Dewey and Lu, 1959). Moreover, using path coefficient analysis, it is easy to determine which yield component is influencing the yield substantially.

### 2.6.5. Genetic divergence

Genetic divergence is the statistical distance between genotypes. It is determined by using cluster analysis in to different groups (Singh and Chaudhary, 2001). It is the major tool that used in estimating genetic distances in multivariate analysis. Genetic distance measures based on phenotypic characters are one of the main multivariate techniques used to provide criteria for choosing parents. Genetic divergence is an efficacious tool for an effective choice of parents for hybridization and breeding program. In addition, it is a source of variation, the raw material for crop improvement work, essential to decrease crop vulnerability to a biotic and biotic stresses, ensure long term selection gain in genetic improvement and promote rational use of genetic resources (Singh and Chaudhary, 2001).

Genetic similarity is the converse of genetic distance that is the extent of gene similarity among cultivars. The measurement of distance or similarity among cultivars is the covariance of the allele frequencies summed for all characters (Singh and Chaudhary, 2001). Several genetic distance measures have been used to quantify genetic relationships among cultivars or genotypes.

One of the most useful genetic distance formulae is that of Euclidean distance, which is the square root of the sum of squares of the distances between the multidimensional space values

of the distance for any two cultivars (Kaufman and Rousseun, 1990). In addition, the pattern of genetic relationship or proximity among cultivars can be conveniently shown by other multivariate techniques such as cluster analysis

### 2.6.6. 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 two types of clustering methods: (1) distance-based methods, in which a pair wise distance matrix is used as an 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 methods (Johnson and Wichern, 1992).

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*., 2012).

Simegn *et al*. (2016) classified 25 korerima genotypes with 21 morphological characters clustered into four main clusters and those genotypes showing wide genetic diversity among the tested genotypes.

# 3. MATERIALS AND METHODS

## 3.1. Description of the Study Area

The experiment was conducted at Tepi National Spices Research Center. Tepi National Spices Research Center is located in South Nation and Nationalities People (SNNP) Regional State at an elevation of 1200 meter above sea level. The research center is situated at Latitude of 70 10' 54.5'' N and with a Longitude of 350 25' 04.3-28.2' E in the hot humid low land area of south western Ethiopia. The mean annual rain fall recorded at the station is 1559 mm and mean minimum and maximum temperatures were 15.5$^{o}$ C and 29.7$^{o}$C, respectively (TNSRC, 2016).

## 3.2. Experimental Materials, Treatments and Design

### 3.2.1. Genetic variability study

3.2.1.1. Experimental materials and design

The genetic variability study was conducted using 25 Korerima genotypes that were collected from Kaffa, Bench-Maji, Sheka, Gamo Gofa, Sidamo,Wollega, Illubabor, Bale, Jimma, South Omo and northwestern Ethiopia growing regions for variety development and the collections were maintained at Tepi National Spices Research Center. The descriptions of the genotypes is presented in (Table 1).

The experiment was superimposed on those which were planted in a simple lattice design with two replications and five genotypes per incomplete block. Twenty plants per plot were planted with a spacing of 2 m both between rows and plants. The genotypes were grown under well managed natural forest shade trees ( Albizia species) and the shade trees are managed yearly as required in order to maintain the desired shade level for normal development of korerima. Each genotype was assigned to one plot in each replication where each plot was with width and length of 8 x 10 m. The data collected from the three central rows were analyzed as per simple lattice design while the seed physiological quality was analyzed using completely randomized design (CRD).

Table 1. Twenty five korerima genotypes maintained at TNSRC

| No. | Genotypes code | Region | Zone | Wereda | Altitude |
|---|---|---|---|---|---|
| 1 | 053/03 | SNNPR | South Omo | Kemba | 1850 |
| 2 | 046/03 | Oromiya | Illubabor | Algea | 1500 |
| 3 | 114/03 | Oromia | Illubabor | Sombo | 2229 |
| 4 | 029/84 | Oromia | Wollega | Gimbi | 1930 |
| 5 | 038/01 | SNNPR | Sidamo | Arero | 2829 |
| 6 | 045/03 | SNNPR | Gamogofa | Damot | 2121 |
| 7 | 021/00 | SNNPR | Benchi maji | Bebeka | 1285 |
| 8 | 015/03 | Oromiya | Illubabor | Smbo | 2229 |
| 9 | Jimma local | Oromia | Jimma | Jimma | 1580 |
| 10 | 686/87 | Amhara | Gojam | Metekel | 1525 |
| 11 | 001/00 | Oromia | Bale | Genale | 1000 |
| 12 | 093/00 | Amhara | Gojam | Debre markos | 2446 |
| 13 | BM31/03 | SNNPR | Kafa | Chena | 1500 |
| 14 | 028/84 | Oromia | Wollega | Arjo | 1800 |
| 15 | 701/87 | SNNPR | Kafa | Decha | 2500 |
| 16 | 68/87 | Amhara | Gojam | Agew midir | 1500 |
| 17 | 25/03 | Oromia | Illubabor | Metu | 1605 |
| 18 | BM34/03 | SNNPR | Kafa | Chena | 1972 |
| 19 | 059/03 | Oromia | Wollega | Nekemte | 2088 |
| 20 | 018/00 | SNNPR | Sheka | Yeki | 1097 |
| 21 | 016/84 | Oromia | Illubabor | Sombo | 2229 |
| 22 | 009/00 | Amhara | Gojam | Metekel | 1525 |
| 23 | 105/03 | Oromia | Illubabor | Yayu | 1387 |
| 24 | 010/00 | SNNPR | Kafa | Chena | 1972 |
| 25 | 011/00 | SNNPR | Sidamo | Sidama | 2759 |

Source: Tepi National Spice Research Centre

3.2.1.2. Experimental procedure for field data collection

Data from the experimental field was collected on sample plants on net plot basis. The dried capsule yield (kg $ha^{-1}$) was estimated on net plot basis while other parameters were estimated from sample plants. For this purpose, ten red ripe capsules were collected from ten randomly taken plants from net plot for each genotype and replication. Fresh and dried capsules characters were measured and the mean value was registered for analysis. The seeds were extracted after drying of the sample capsules and seeds physical quality parameters were

measured. All the data collected for capsules, seed physical quality and capsule yield (kg $ha^{-1}$) from the experimental field were analyzed using the simple lattice design where the genotypes were maintained.

After recording the seeds physical quality parameters, seeds extracted from ten sampled capsules from each replication for each genotypes was bulked together to produced one homogenous sample for each genotype. Then after, 50g of sample seeds was taken from each genotype seeds after bulked and subdivided into four sub group each considered as one replication. These four sub sample seed were used to evaluated the physiological seed quality of genotypes at laboratory with CRD.

### 3.2.2. Seed priming experiment

3.2.2.1. Experimental treatments and design

The genotypes that exhibited highest and lowest seed quality was used for this experiment. One hundred (g) seeds of each genotype for each replication was subjected for six priming treatments viz., Distilled water; $KNO_3$ (0.2%); $KH_2PO_4$ (0.5%); $GA_3$ 200 ppm; Cow urine 10%; Tap water and three priming durations (3 hrs., 6 hrs. and 9 hrs.). The experiment was conducted as 2 (genotypes) x 6 (priming materials) x 3 (priming durations) factorial using 1completely randomized design (CRD) with three replications and a total of 36 treatments. Since korerima seed is a medium sized seed, after the completion of the required seed treatments, for each treatment 100 seeds was sown on top of the blotter paper using germinating box and kept at room temperature in seed technology laboratory TNSRC.

Treatments:

1. Distilled water
2. $KNO_3$ (0.2%);
3. $KH_2PO_4$ (0.5%)
4. Gibberellins acid ( $GA_3$) 200 ppm;
5. Cow urine (10%)
6. Tap water

3.2.2.2. Preparation of priming solution

1. Soaking dried seed in distilled water: (50 g of korerima seeds was taken and soaked in 200 ml of tap water
2. $GA_3$ (200 ppm): It was prepared by dissolving 500 mg of $GA_3$ in distilled water and volume was made up to 1000 ml
3. $KNO_3$ (0.2%): It was prepared by dissolving 2 g of $KNO_3$ in distilled water and volume was made up to 1000 ml
4. $KH_2PO_4$ (0.5%): It was prepared by dissolving 5 gm of $KH_2PO_4$ in distilled water and volume was made up to 1000 ml
5. Cow urine (10%): It was prepared by dissolving 25 ml of cow urine in distilled water and volume was made up to 225 ml
6. Soaking dried seed in tap water: (50 g of korerima seeds was taken and soaked in 200 ml of tap water.

### 3.2.3. Data collection

**Plant height (cm)**: Plant height was measured from ten randomly taken plants in centimeters from ground level to the plant tip and the average measurement was taken.

**Number of suckers per plant**: Number of suckers produced from ten randomly taken plants in each net plot was counted and the average measurement was taken.

**Number of capsule bearing suckers per plant**: Number of capsule bearing suckers produced from ten randomly taken plants in each net plot was counted and the average measurement was taken

**Internodes length (cm):**It was measured in centimeters the length that was found between two consecutive nodes at physiological maturity using ten randomly taken plants.

**Number of leaves per stem:** Number of leaves produced from ten randomly taken plants in each net plot was counted and the average measurement was taken.

**Leaf area ($cm^2$)**: Leaf area was taken using (cm) from ten randomly taken plants in each net plot and the average measurement was taken.

**Number of capsules per plant**: Number of capsules produced from ten randomly taken plants in each net plot was counted and the average measurement was taken.

**Fresh capsules diameter (cm)**: Ten capsules was randomly taken from capsules collected from ten plants and each capsule girth was measured to the widest portion using caliper and the average of the ten capsules measurement was taken.

**Fresh capsules length (cm):** It was measured from ten capsules that were used for measurement. Each capsule length was measured from the top to the lower end of capsule and the average of 10 capsules was calculated to register mean fresh capsules length in (cm).

**Dry capsules diameter (cm):** Ten capsules were randomly taken from capsules collected from five plants and dried, each dried capsule girth was measured at widest portion using caliper and the average of the ten capsules measurement was taken.

**Dry capsules length (cm):** It was measured from 10 dried capsules that were used for girth measurment. Each dried capsule length was measured from the top to the lower end of capsule and the average of 10 capsules was calculated to register dried capsules length in (cm).

**Fresh capsules weight (g):** It was calculated from capsules collected from ten randomly taken plants in each net plot by weighing the total capsules collected and dividing by the number of capsules.

**Dry capsule weight (g):** It was calculated from capsules collected from ten randomly taken plants after drying, weighed and divided by the total number of capsules.

**Dried capsules yield (kg per plot):** All red ripe capsules produced by plants in each net plot were harvested, dried under open sun on raised mesh wire , weighed and calculated the dried capsule yield (kg per plot basis).

**Dried capsules yield (kg ha$^{-1}$):** All red ripe capsules produced by plants in each net plot were harvested, dried under open sun, weighed and calculated the dried capsule yield (kg ha-1 basis).

**Number of seeds per capsule:** Number of seed(s) per capsule was recorded by taking the mean number of seeds obtained from ten sampled capsules

**1000 seeds weight (g):** It was taken by weighing 1000 seeds drawn randomly from the yield obtained from each experimental plot.

**Seed weight per capsule (g):** It was registered the pure seed obtained from ten capsules weight in gram and taking the mean value.

**Seed yield (kg per plot):** It was calculated from pure seeds weight per capsule considering the plant population per plot and number of capsules collected per plant.

**Standard germination (%):-**

Standard germination test was done for collected korerima genotypes seed using completely randomized design (CRD) under laboratory condition. As the germination standard are not available for this crop, hence the seed were tested in the laboratory as per procedure of *Coriandrum sativum* because korerima have similar seed size with *Coriandrum sativum*. Based on *Coriandrum sativum* seed testing standard, four hundred seeds of korerima were tested into four replications. The first count and the final count was taken on $7^{th}$ and $21^{st}$ days, respectively. The result of the germination test is calculated as the average of four replicate. The percentage of abnormal seedlings, hard, fresh and dead seed is calculated. The seed size of korerima is indicated in the appendix table 2.

**Speed of germination:**

Speed of germination is another method which is used for assessing the vigor of seeds. Hundred seeds were counted and taken from each genotypes. The seeds were divided into four replicates of 25 seed each. The seeds were planted top of germination paper adjusted at $25^{o}$C for 21 days. The normal seedlings were counted starting from the $7^{th}$ day after planting and final count was taken $21^{th}$ day after planting. Germination was counted every day, and the germinated seedlings on each day divided by the number of days that the test has been run in order to compute the mean daily germination for that day. The normal seedlings were counted and removed from each germinator paper each day. The speed of germination (SG) was then calculated according to Maguire (1962) as:

$$\frac{n1}{1} + \frac{n2}{2} + \cdots + nx/x = N$$

Where: $n1 \ldots nx$ are the number of seed germinated on day $1$ to day $x1 \ldots\ldots x$ is the number of days. High value of N indicates high seed vigor. Seed is considered as germinated when the radical has appeared hence, it should be removed.

**Seedling Vigor Test:-**

**Vigor index I**; Seedling Shoot and Root Length were assessed after the final count in the standard germination test. Ten normal seedlings were randomly selected from each replicate. The shoot length was measured from the point of attachment to the cotyledon to the tip of the seedling. Similarly, the root length was measured from the point of attachment to the cotyledon to the tip of the root. The average shoot or root length was divided to the total shoot or root lengths by the total number of normal seedlings measured (Fiala, 1987). Seedling Vigour Index I was calculated by multiplying the standard germination with the average sum of shoot length and root length after the final count of standard germination test.

**Vigour index II**: The seedling dry weight was measured after the final count in the standard germination test. Ten seedlings randomly selected from each replicate were cut free from their cotyledons and placed in envelopes and dried in an oven at 80 ± 1 °C for 24 hours. The dried seedlings were calculated to the nearest decimal using sensitive balance. Vigour Index II was calculated by multiplying the standard germination with mean seedling dry weight (Fiala, 1987).

## 3.3. Data Analysis

### 3.3.1. Analysis of variance and treatment mean comparison

Data collected from the two experiments were subjected to analysis of variance for the design and treatment arrangement of each experiment as the procedure indicated by Gomez and Gomez (1984) using Statistical Analysis System (SAS, 2001) computer software version 9.2. Data collected on the basis of percentage was analyzed after angular transformation (arcsine) conducted. Where significant differences were detected, the means separation was carried out using the least significant differences (LSD) at 0.05 level of probability. In addition, data collected for genotypes capsules and seeds quality parameters were subjected for genetic variability analyses as indicated below.

### 3.3.2. Phenotypic and genotypic variations

The variability of genotypes was estimated by simple measures, namely range, mean, standard error, phenotypic and genotypic variance and coefficient of variations. The phenotypic and genotypic variance was estimated according to the methods suggested by Burton and De Vane (1953).

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

$\sigma^2 g = \frac{Mg - Me}{r}$

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

$\sigma^2$ g = Genotypic variance

$\sigma^2$ e = Environmental (error) variance

(Error mean square)

*Mg*= mean sum square of genotypes

*Me*= mean sum square of error

*r*=Number of replications

### 3.4.3. Genotypic and phenotypic coefficient of variations

The phenotypic and genotypic coefficients of variations were estimated according to the methods suggested by Burton and De Vane (1953).

Phenotypic coefficient of variation, PCV = $\frac{\sqrt{\sigma^2 p}}{\bar{x}} * 100$

Genotypic coefficient of variation, GCV = $\frac{\sqrt{\sigma^2 g}}{\bar{x}}$*100

Where $\bar{x}$ = population mean

### 3.4.4. Heritability and genetic advance

Broad sense heritability was computed for each pod and seed quality parameter based on the formula developed by Allard(1960) as:

$H^2 = \frac{\sigma 2g}{\delta 2p}$*100

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

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

$\sigma^2 e$ = Environmental (error) variance

Heritability will be classified as suggested by Verma and Agarwal (1982) into low (0-20%), moderate (20-50%) and high (>50%).

The genetic advance (GA) for selection intensity (K) at 5% was calculated by the formula suggested by Allard (1960) as:

$$GA = (K)\ (\delta P)\ (h^2)$$

Where, GA= Expected genetic advance, $\delta$P = the phenotypic standard deviation, h2 = the heritability, K= Selection differential (K=2.06 at 5% selection intensity).

GA (as % of the mean) = $\frac{GA}{\bar{x}}$*100

Where, $\bar{x}$= population mean.

The GA as percent of mean was categorized as low, moderate and high as suggested by Johnson *et al*.(1955) as follows: 0 - 10% = Low, 10 – 20 = Moderate and > 20 = High

**3.4.5. Association of characters and path coefficient analysis**

3.4.5.1. Correlation coefficient (r)

Estimation of genotypic and phenotypic correlation coefficients were done based on the procedure of Dabholkar (1992).

Genotypic Correlation Coefficient ($r_g$) = $(COVg\ (xy))/(\sigma g\ (x) * \sigma g\ (y)$

Phenotypic Correlation Coefficient t ($r_{ph}$) = $\frac{COVph\ (xy)}{\sigma ph\ (x) * \sigma ph\ (y)}$

Where, COVg (xy) and COVph (xy) were the genotypic and phenotypic covariance of two variables (X and Y), respectively. σg (x) and σg (y) were the genotypic standard deviations for variables X and Y respectively. σph (x) and σph (y) were the phenotypic standard deviations of variables X and Y, respectively.

The calculated phenotypic correlation value was tested for its significance using t-test:

t = rph/SE (rph)

Where, rph = Phenotypic correlation; SE (rph) = Standard error of phenotypic correlation obtained using the following formula (Sharma, 1998).

SE (rph) = $\sqrt{\frac{1 - r2\ ph}{n - 2}}$

Where, n is the number of genotypes tested, $r^2$ph is phenotypic correlation coefficient.

The coefficients of correlations at genotypic levels were tested for their significance by the formula described by Robertson, (1959) as indicated below:

t = rgxy/SErgxy

The calculated "t" value was compared with the tabulated "t" value at (n-2) degree of freedom at 5% level of significance. Where, n is number of genotypes.

SErgxy = $\sqrt{\frac{1 - r2gxy}{h2x} . h2y}$

Where, $h^2$x = Heritability of character x

$h^2y$ = Heritability of character y

3.4.5.2. Path coefficient analysis

The path coefficient analysis was done using the formula of Dewey and Lu (1959)

rij = Pij + Σrik Pkj

Where, rij is association between the independent variable (i) and dependent variable (j) as measured by correlation coefficient; Pij was component of direct effect of the independent variable (i) on the dependent variable (j) as measured by path coefficient; and Σrik Pkj was summation of components of indirect effects of a given independent variable (i) on a given dependent variable (j) via all other independent variables. The residual factor ($P^2R$) was estimated as described in Dewey and Lu (1959):

$1 = P^2R + \Sigma Pij\ rij$

Capsule yield kg $ha^{-1}$ was used as dependent characters for path coefficient analysis and other characters were used as independent variables as required.

**3.4.6. Genetic diversity**

The genetic distance of genotypes was estimated using Euclidean distance (ED) calculated from the data collected for Capsules and seed quality parameters of genotypes. Each parameter for each genotype were estimated using Euclidean distance after standardization (subtracting the mean value by the standard deviation) as established by Sneath and Sokal, (1973) as follows:

$$EDjk = \sqrt{\sum_{i=1}^{n} (Xij - Xik)^{\frac{2}{2}}}$$

Where, EDjk = distance between genotypes j and k; xij and xik= capsules and seed quality parameters mean values of the $i^{th}$ parameter for genotypes j and k, respectively; and n=number of parameters used to calculate the distance. The distance matrix from capsule and seed quality parameters was constructed dendrograms based on the Unweighted Pair-group Method with Arithmetic means (UPGMA). The result of the cluster analysis was presented in the form of dendrogram.

# 4. RESULTS AND DISCUSSION

This research had two major components. The first component was effect priming on seed germination quality of korerima and the second research component was focusing on assessment of genetic variation in korerima genotypes for yield, yield related characters. The results obtained from the laboratory and field experiments are presented in subsequent sub-chapters.

## 4.1. Seed Germination Test

In the present study, 25 korerima genotypes were evaluated for germination and other physiological quality parameters. The experiment was conducted in laboratory using seeds collected from capsules harvested at full red ripen stages or capsules maturity.

### 4.1.1.Analysis of variance

Analysis of variance conducted for seed germination quality parameters revealed significant differences ($P<0.05$) among all korerima genotypes except abnormal seedling (Appendix Table 4).

The results of the present study indicated that primed korerima seeds had higher germination percentage than unprimed ones, The current finding is in agreement with results reported by Amarnath *et al* (2015) that 36 cardamom genotypes had significant difference for germination percentage (%), speed of germination, seedling vigor index II, seedling dry weight (g),and normal seedling.

### 4.1.2. Physiological seed quality

The standard germination of genotypes ranged from 46.67 to 73.33% with mean values of 57.37%. Genotype 093/00 had significantly the highest germination percentage while genotypes 059/03, Jimma local, 029/84, 001/00 and 686/87 had significantly lowest germination percentage (Appendix Table 4). Speed of germination of genotypes varied from 2.83 to 4.45 with mean value of 3.45. The genotype 093/00 had significantly the highest speed of germination while the genotype 059/03 had significantly lowest rate of germination.

Seedling length of genotypes varied from 2.38 to 6.11 (cm) with mean values of 4.35 (cm). Meanwhile, the genotypes 093/00,038/01 and 010/00 had significantly the long seedlings while 059/03 had significantly short seedlings (Appendix Table 5). Seedling dry weight of genotypes ranged from 0.84 to 0.94 (g) with mean values of 4.35 (g). The genotype 046/03 had significantly highest seedlings dry weight while 029/84, 001/00, Jima local and 009/00 had significantly lowest seedling dry weight (Appendix Table 5).

Seedling vigor index I ranged from 111.65 to 448.55 with mean value of 256.13. The genotype, 093/00 exhibited seedling vigor index I significantly highest while 029/84 and 001/00 showed significantly lowest vigor index I. Seedling vigor index II varied from 39.79 to 64.29 with mean value of 49.93. The genotypes, 093/00 exhibited significantly highest the seedling vigor index II while 093/00 and 059/03 showed significantly lowest vigor index II. Normal seedling of genotypes ranged from 24 to 54.33 with mean values of 38.37. The genotypes 093/00 and 045/03 exhibited significantly highest number of normal seedlings, while genotype 059/03 recorded significantly the lowest number of normal seedlings. Fresh ungerminated seed of genotypes ranged from 23.37 to 48.06 with mean values of 35.49. Genotypes 029/84 had significantly highest number of fresh ungerminated seeds, while 045/03 had significantly lowest number of fresh ungerminated seeds. Dead seed of genotypes varied from 2.65 to 12.35 with mean values of 7.09. Genotypes 028/84 revealed significantly highest number of dead seeds while 093/00 had significantly lowest number of dead seeds (Appendix Table 5).

The current finding results indicated that significant differences were observed in all vigor indices among various unprimed korerima genotypes tested and also unprimed korerima seed tested result showed that significant value for standard germination (%), speed of germination, seedling length, vigor index I and II ,and normal seedling was observed for genotypes 093/00 while genotype 59/03 revealed the lowest value for these characters.

The present study is in agreement with Brikti (2011) who reported that the root length, shoot length, seedling dry weight and seedling vigor indices had significantly differences among varied groundnut varieties.

### 4.2.2. Effect of priming on seed quality of korerima

4.2.2.1. Analysis of variance

Standard germination (%), speed of germination, seedling length(cm), seedling dry weight (g), seedling vigor index I, seedling vigor index II, normal seedling, abnormal seedling, fresh ungerminated and dead seed were considered to assess the effect of priming on seed quality of two korerima genotypes.

The priming of seeds had significant effect on all the seed quality characters, and also, duration of priming had significant effect on all the seed germination quality characters except seedling length, seedling dry weight, seedling vigor index I and seedling vigor index II. However, the effect of genotype was significant only on seedling length and , seedling vigor index I. The interaction effects of genotype x priming material had significant effects on all the seed germination quality characters except seedling vigor index I and seedling vigor index II. Interaction effects of priming material x duration of priming had significant effects on all the seed germination quality characters except seedling length and seedling dry weight which was insignificant. However, the genotype x duration of priming interaction had significant effect on seedling vigor index I and seedling vigor index only. The three way interaction (genotype x priming x duration of priming) had significant effect on standard germination percentage, speed of germination, seedling vigor index I and seedling vigor index II (Appendix Table 5).

The results of the present study indicated that seed priming had significant and positive effect on different aspects vigor indices improvements, such as seed germination, growth and biochemical parameters. Seed priming significantly enhanced seed germination quality of korerima irrespective of genotypes. The response of crop for different seed treatments were interpreted in terms of germination percentage, seedling dry weight, speed of germination, seed vigor, seedling length, root length, shoot length test. The results of the present study is in agreement with Amarnath *et al*. (2015) stated that seed priming increase the percentage, germination rate, and decreased abnormal seedlings in sunflower plants. Mahmoodi *et al.* (2012) pointed out gibberellic acid had the effect of improving germination that are in agreement with the results of this study.

4.2.2.2. Interaction effect of genotype x priming x duration of priming

The genotype, 59/03 interacted with $GA_3$ of priming for six hours duration and the same genotype interacted with priming of CU (cow urine) for three hours exhibited significantly highest seed germination percentage of 91.66 and 86.67%, respectively. However, this genotype interacted with CU for nine hours duration gave significantly highest speed of germination (6.48). In contrast, 093/00 interacted with $KH_2PO_4$ for nine hours duration had significantly lowest seed germination percentage (56.6%) and speed of germination (3.64), respectively, (Table 2).

The results of the present study indicated that seed priming improved seed physiological quality significantly, meanwhile, korerima seed primed with $GA_3$ and cow urine showed better seed germination percentage than other seed treatments on two korerima genotypes. In addition, seed priming with cow urine showed the highest speed of germination than other priming materials and the unprimed ones.

Amarnath *et al*. (2015) reported that significantly maximum increase in total germination percentage and speed of germination occurs by treating seeds with coconut water followed by cow urine, while lowest germination was observed with unprimed control treatment.

Genotype, 93/00 interacted with cow urine of priming for three hours duration revealed significantly highest seedling vigor index I of 579.3, but the same genotype interacted with priming of $KH_2PO_4$ for nine hours duration had significantly lowest seedling vigor index I of 324.03 (Table 2).

The results of the present study indicated that seed priming improved seedling vigor I significantly, meanwhile, korerima seed primed with cow urine and $GA_3$ showed better seedling vigor I than other seed treatments of the two korerima genotypes. The current finding is in close agreement with Amarnath *et al.* (2015) also confirmed that, maximum increase in seedling length, seedling fresh and dry weight, and vigor index I and II occurs by Coconut water (40.28 cm) followed by Cow Urine (39.53 cm) while lowest seedling length (28.16 cm) was observed with unprimed control treatment in sorghum. Ansari *et al.* (2013) reported that all the priming treatments showed improved vigor index I as compared to non-primed seeds

which was due to increased shoot and root length of seedlings from primed seeds and so much more vigorous than from un primed seeds, which support this finding positively.

The highest vigor index II (79.57) was obtained from genotypes 059/03 primed with cow urine for three hours, while the lowest vigor index II (66.36) was recorded from genotype 093/00 seeds primed with $KH_2PO_4$ for nine hours. Seeds of 059/03 primed with $GA_3$ also resulted the second highest vigor index II (78.95) value next to cow urine (Table 2).

The present result indicated that seed priming significantly improved vigor index II of korerima seeds as compared with unprimed ones (Table 15). The present study is in agreement with the results of Ansari *et al.* (2013) reported that highest seedling vigor index II, were attained from treated seeds with 25 ppm of $GA_3$.

Table 2. Interaction effect of genotype x priming x duration of priming on seed germination in korerima

| Genotype | Priming | Duration of priming (hrs.) | Standard Germination (%) | Speed of germination | Seedling vigor index I | Seedling vigor index II |
|---|---|---|---|---|---|---|
| 093/00 | Distilled water | 3 | 71.60f-h | 4.64g-k | 462.42c-i | 71.37f-k |
| | | 6 | 73.30e-h | 4.56g-k | 437.25e-k | 70.77f-m |
| | | 9 | 73.30e-h | 4.64g-k | 436.77e-k | 71.90e-k |
| | Potassium nitrate | 3 | 81.60b-d | 5.40b-e | 513.97a-d | 73.7c-j |
| | | 6 | 70.00g-j | 5.42b-e | 476.38b-h | 73.27c-j |
| | | 9 | 60.00kl | 4.83f-j | 380.55h-l | 67.95k-m |
| | Potassium di hydrogen phos phate | 3 | 66.60h-k | 4.50g-l | 411.20e-k | 70.27g-m |
| | | 6 | 60.00kl | 4.05l-n | 378.70i-l | 67.40km |
| | | 9 | 56.60 l | 3.64n | 324.03l | 66.36m |
| | Gibberellins acid | 3 | 81.60b-d | 5.24b-f | 544.77a-d | 74.04c-i |
| | | 6 | 85.00a-c | 5.68b | 525.68a-d | 74.67b-g |
| | | 9 | 83.33bc | 5.61bc | 564.67ab | 76.33a-d |
| | Cow urine | 3 | 85.00a-c | 5.61bc | 579.30a | 77.57a-c |
| | | 6 | 83.33bc | 5.70b | 553.67a-c | 77.81a-c |
| | | 9 | 80.00b-e | 5.31b-f | 527.60a-d | 76.09a-e |
| | Tap water | 3 | 65.00i-k | 4.24j-m | 439.67e-k | 69.50h-m |
| | | 6 | 68.30g-j | 4.51g-l | 442.45e-j | 73.62c-j |
| | | 9 | 80.00b-e | 5.36b-e | 514.38a-d | 74.39b-h |
| 059/03 | Distilled water | 3 | 66.60h-k | 4.05l-n | 385.57h-l | 69.94h-m |
| | | 6 | 70.00g-j | 4.40i-ml | 393.17h-l | 70.63g-k |
| | | 9 | 78.33c-f | 4.83f-j | 450.20d-j | 73.49c-j |
| | Potassium nitrate | 3 | 75.00d-g | 5.01d-h | 452.80d-j | 72.15d-k |
| | | 6 | 81.60b-d | 5.50b-e | 532.17a-d | 73.78c-j |
| | | 9 | 66.60h-k | 4.38i-m | 392.00h-l | 69.83h-m |
| | Potassium di hydrogen phos phate | 3 | 71.60f-h | 4.56g-k | 409.23f-k | 61.54e-k |
| | | 6 | 73.30e-h | 4.93e-i | 406.00g-l | 71.36f-k |
| | | 9 | 63.30kl | 3.91l-n | 365.52j-l | 68.23k-m |
| | Gibberellins acid | 3 | 85.00a-c | 5.59b-d | 505.18a-f | 77.71a-c |
| | | 6 | 91.66a | 6.40ab | 564.85ab | 78.95ab |
| | | 9 | 81.60b-d | 5.60b-d | 493.07a-f | 76.26a-d |
| | Cow urine | 3 | 86.67ab | 5.75b | 544.75a-d | 79.57a |
| | | 6 | 68.30g-j | 5.06c-g | 474.67b-i | 75.32b-f |
| | | 9 | 71.60f-h | 6.48a | 467.98c-i | 74.10c-h |
| | Tap water | 3 | 60.00kl | 3.90mn | 344.99kl | 69.37j-m |
| | | 6 | 66.60h-k | 4.310j-m | 409.33f-k | 71.08f-k |
| | | 9 | 73.30e-h | 4.60g-k | 438.82e-k | 73.61c-j |
| CV (%) | | | 6.18 | 4.18 | 9.83 | 9.84 |
| LSD P<(5%) | | | 7.59 | 0.59 | 96..001 | 4.59 |

Means with the same letter are not significantly different, LSD = least significant difference

4.2.2.3. Interaction effect of genotype x priming on seed quality

The genotype 93/00 interacted with cow urine revealed significantly highest seedling length of 6.67 (cm), in contrast genotype 59/03 interacted with distilled water had significantly lowest seedling length of 5.57 (cm). In addition, priming of 059/03 seeds interacted with cow urine increased significantly seedling dry weight 0.33 (g), while seeds of korerima treated with $KH_2PO_4$ of the same genotype gave lowest seedling dry weight of 0.28 (g). The priming of 059/03 seeds with $GA_3$ gave significantly highest normal seedling but significantly lowest normal seedling obtained from priming of 093/00 seeds with $KH_2PO_4$ (Table 3).

The present study indicated that, seed priming improved seed germination as compared to unprimed seeds in both genotypes. Normal seedlings were highly increased in korerima genotypes in all seed treatments in which seeds primed with $GA_3$ followed by cow urine gave the maximum number of normal seedlings. In korerima genotypes, untreated seeds had lower proportion of normal seedlings which revealed seeds were less vigorous to be used for planting (Table 16). The current finding is in close agreement with Amarnath *et al.* (2015) reported that maximum increase in seedling length occurs by Coconut water followed by Cow Urine while lowest seedling was observed with unprimed control treatment on sorghum. Mahmoudi *et al*. (2012) also investigated the effect of hormone primed on germination and seedling growth of lettuce in which significant differences were evident among seed samples treated with different concentrations of $GA_3$. The seeds of mountain rye primed with 25 ppm of $GA_3$ had highest normal seedling percentage (NSP) and seedling vigor index (Ansari *et al.*, 2013).

The priming of 059/03 seeds interacted with cow urine significantly lower the number of abnormal seedling while the priming of the same genotype seeds with $KH_2PO_4$ gave significantly highest number of abnormal seedlings (Table 3).

The current study showed that, seed priming potentially decreased the number of abnormal seedling occurrence but its effect depends on the interaction of genotypes and the priming material types used. It was observed a general trend that the amounts of abnormal seedlings were reduced in seeds primed with cow urine and $GA_3$ as compared to other seed treatments.

This result is in agreement with Amarnath *et al* (2015) in sorghum observed that seed priming with $GA_3$ and cow urine minimized the occurrence of abnormal seedling.

Fresh ungerminated seeds were highly reduced when seeds of 093/00 and 059/03 korerima genotypes were primed with cow urine and $GA_3$, respectively, whereas, maximum number of fresh ungerminated seeds was observed in primed seeds of 093/00 with $KH_2PO_4$, (Table 16). The lowest numbers of dead seeds were obtained from the primed seeds of 059/03 with $GA_3$ and cow urine but the same genotype seeds primed with $KH_2PO_4$ had significantly highest number of dead seed (Table 3).

From this finding it is possible to conclude that seed priming was significantly reduced the occurrence of number of fresh ungerminated and dead seeds in which the magnitude of priming effect depends on the interaction of genotypes and the priming material types. Satish and Basave(2005) suggested seed priming minimized the proportion of fresh ungerminated and dead seeds during seed germination by shorting the dormancy period of the eggplant seeds. Amarnath *et al.* (2015) observed the low occurrence of fresh ungerminated and dead seeds in seeds of sorghum treated with $GA_3$.

Generally, seed priming significantly improved the seed quality of the two korerima genotypes (093/00 and 059/03) with varied magnitude of improvement in which the germination and speed of germination of seeds improved by about 11.62% to 41.99% and 1.16 to 3.57, respectively. The normal seedlings increased by about 5.61% to 18.24%, while fresh ungerminated and dead seeds significantly reduced by about 14.33 to 15.87%% and 1.75% to 4.59%, respectively, as compared to unprimed ones (Table 3).

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Table 3. Interaction effect of genotype x priming on seed germination in korerima

| Genotype | Priming | Seedling length (cm) | Seedling dry weight (g) | Normal seedling | Abnormal seedling | Fresh ungerminated seed | Dead seed |
|---|---|---|---|---|---|---|---|
| 093/00 | Distilled water | 6.12b | 0.29bc | 50.94b-d | 22.00b-d | 17.77a-c | 11.44abc |
| | Potassium nitrate | 6.13b | 0.29bc | 52.10b-d | 22.33b-d | 15.44b-e | 10.11b-d |
| | Potassium di hydrogen phosphate | 6.02bc | 0.29bc | 42.77e | 23.66a-c | 21.66a | 16.55a |
| | Gibberellins acid | 6.56ab | 0.29bc | 58.33ab | 19.00de | 12.10de | 4.66de |
| | Cow urine | 6.67a | 0.32ab | 59.94ab | 19.03de | 10.07de | 4.44de |
| | Tap water | 6.55ab | 0.31ab | 49.77c-e | 21.33c-e | 18.10a-c | 10.73a-d |
| 059/03 | Distilled water | 5.57d | 0.30bc | 50.16c-e | 21.50c-e | 18.27a-c | 9.88b-d |
| | Potassium nitrate | 6.13b | 0.29bc | 52.10b-d | 22.66a-d | 16.44a-d | 8.10b-e |
| | Potassium di hydrogen phosphate | 5.66cd | 0.28c | 48.60c-e | 25.83a | 18.99a-c | 11.55ab |
| | Gibberellins acid | 6.03bc | 0.31ab | 60.27a | 20.83c-e | 10.40e | 3.21e |
| | Cow urine | 6.27ab | 0.33a | 58.21ab | 18.33e | 13.77c-e | 7.33c-e |
| | Tap water | 5.95bcd | 0.31ab | 46.66de | 20.00de | 20.55ab | 12.77ab |
| CV (%) | | 7.63 | 8.34 | 9.33 | 9.33 | 7.89 | 7.33 |
| LSD (P<0.05) | | 0.41 | 0.018 | 7.63 | 3.28 | 5.23 | 6.19 |

Means with the same letter(s)are not significantly different, LSD = least significant difference , CV (%)= coefficient of variation

4.2.2.4. Interaction effect of priming x duration of priming on seed quality

Interaction effects of priming materials with duration of priming had significantly increased normal seedlings proportions and reduced the amount of abnormal seedlings proportions. The maximum number of normal seedlings were recorded from seeds primed with both $GA_3$ (73%) and cow urine (72.5%) for six and three hours priming durations, respectively. In contrast, the minimum number of normal seedlings were registered from seeds primed with both $KH_2PO_4$ (43%) and tap water (45%) for nine and three hours priming, respectively. The minimum number of abnormal seedlings were registered from seeds primed with $GA_3$ (17%) and cow urine (17%) for six and three hours durations, respectively. In contrary, the maximum number of abnormal seedlings (35.5%) was observed when korerima seeds primed with tap water for nine hours duration (Table 4).

The present finding is in accordance with Amarnath et *al*. (2015) in sorghum and Ansari et *al.* (2013) in mountain rye reported normal seedling percentage (NSP) and seedling vigor index (SVI) were increased in seeds treated with cow urine and 25 ppm of $GA_3$. The latter authors also reported the amounts of abnormal seedlings were reduced from treatment cow urine and 25 ppm of $GA_3$.

The minimum numbers of fresh ungerminated and dead seeds were registered from seeds primed with $GA_3$ for six hours. In contrast, the maximum number of fresh ungerminatedand dead seeds were observed when korerima seeds primed with $KH_2PO_4$ (23) for nine hours duration. Generally, priming with $GA_3$ and cow urine had reduced the amount of fresh ungerminated and dead seeds as compared to other seed priming treatments. Umair*et al.* (2010) observed that osmo priming like $KH_2PO_4$ has reduced germination percentage while it increased the amount of fresh and dead seed in mung bean. Amarnath *et al*. (2015) similar result reported in sorghum (sorghum.

Table 4. Interaction effect of priming x duration of priming on seed germination

| Treatment | | Seed germination test parameter | | | |
|---|---|---|---|---|---|
| Priming material | Duration of priming (hours) | Normal seedling | Abormal seedling | Fresh ungerminating seed | Dead seed |
| Distilled water | 3 | 49.00fg | 22.00b | 21.00a-c | 12.00cd |
| | 6 | 51.00f | 22.00b | 19.00c-e | 12.00cd |
| | 9 | 54.00e | 24.00b | 18.00d-f | 8.00ef |
| Potassium nitrate | 3 | 56.00de | 24.00b | 16.00fg | 8.00ef |
| | 6 | 58.00cd | 25.00ab | 14.00gh | 7.00e-g |
| | 9 | 48.00g | 20.00b | 21.00a-c | 15.00a-c |
| Potassium di hydrogen phosphate | 3 | 49.00fg | 22.00b | 20.00b-d | 12.00cd |
| | 6 | 48.00g | 21.00b | 20.00b-d | 14.00bc |
| | 9 | 43.00h | 19.00b | 23.00a | 18.00a |
| Gibberellins acid | 3 | 59.00bc | 26.00ab | 14.00gh | 5.00fg |
| | 6 | 73.00a | 17.00bc | 10.00j | 4.00g |
| | 9 | 59.00bc | 26.00ab | 13.00hi | 6.00fg |
| Cow urine | 3 | 72.50a | 17.00bc | 11.00ij | 5.00fg |
| | 6 | 57.00cd | 25.00ab | 13.00hi | 8.00ef |
| | 9 | 54.00e | 24.00b | 17.00ef | 8.00ef |
| Tap water | 3 | 45.00h | 20.00b | 22.00ab | 16.00ab |
| | 6 | 54.00e | 24.00b | 16.00fg | 9.50de |
| | 9 | 48.00g | 35.5.00a | 22.00ab | 12.00cd |
| CV (%) | | 9.8 | 8.5 | 7.85 | 8.66 |
| LSD (P>0.05) | | 2.97 | 11.23 | 2.97 | 3.07 |

Means with the same letter are not significantly different, LSD = least significant difference, CV (%)= coefficient of variation

## 4.3. Genetic Variability in Korerima Genotypes

### 4.3.1. Analysis of variance

Mean sum of squares of 17 characters from analysis of variance (ANOVA) presented in Table 5. The result revealed that the presence of significant differences among genotypes ($P<0.05$) for all characters of korerima genotypes. This significance differences among genotypes indicated the presence of variability among the genotypes for all characters. The presence of variability among genotypes was a good opportunity for breeders to improve characters of interest through selection.

The current finding is in agreement with the finding of Simegn *et al*. (2012) that the presence of enormous amount of genetic variability in korerima. Information is scarce in korerima diversity; however, different authors reported significance difference on different characters of other spices crops such as cardamom and other crop genotypes. Hikmat *et al*. (2012) reported significant difference among 20 turmeric genotypes for number of tiller, number of leaves and plant height.

Table 5. Analysis of variance for different characters of various korerima genotypes at Tepi

| Characters | Repl. | Blocks within rep.(Adj) | Treatment | | Error | | | Efficiency relative to RCBD | CV (%) |
|---|---|---|---|---|---|---|---|---|---|
| | | | (unadj.) | (adj.) | Intra | RCBD | Total | | |
| | (1) | (8) | (24) | (24) | (16) | (24) | (49) | | |
| Plant Height (cm) | 120.4 | 248.24 | 284.2 | 284.24** | 233.9 | 238.7 | 258.9 | 100.11 | 4.47 |
| Number of capsule bearing sucker per plant | 0.098 | 0.024 | 0.929 | 0.929** | 0.05 | 0.043 | 0.068 | 81.67 | 19.9 |
| Internodes length | 3.95 | 0.93 | 3.84 | 3.81** | 3 | 3.65 | 3.26 | 100.08 | 7.08 |
| Number of leaves per plant | 0.34 | 0.11 | 0.2 | 0.2* | 0.12 | 0.11 | 0.11 | 98.48 | 9.58 |
| Leaf area ($cm^2$) | 768 | 182.43 | 441.3 | 441.35** | 253.8 | 230 | 344.5 | 90.62 | 6.24 |
| Number of capsule per plant | 0.32 | 0.02 | 0.25 | 0.25* | 0.15 | 0.019 | 0.02 | 101.41 | 8.2 |
| Fresh capsule diameter (cm) | 1.15 | 0.18 | 0.24 | 0.23** | 0.15 | 0.16 | 0.22 | 101.04 | 14.2 |
| Fresh capsule length (cm) | 0.29 | 0.066 | 0.12 | 0.12** | 0.1 | 0.091 | 0.11 | 85.3 | 14.4 |
| Dry capsule length (cm) | 0.043 | 0.37 | 0.9 | 0.9** | 0.77 | 0.63 | 9.8 | 98.98 | 5.83 |
| Dry capsule diameter (cm) | 0.78 | 0.085 | 0.82 | 0.82** | 0.067 | 0.073 | 0.77 | 101.6 | 15.1 |
| Fresh capsule weight (g) | 43.09 | 11.41 | 12.55 | 12.55** | 11.77 | 11.65 | 0.75 | 82.59 | 5.86 |
| Dry capsule weight (g) | 1.31 | 0.49 | 1.02 | 1.02** | 0.86 | 0.74 | 0.89 | 85.69 | 6.36 |
| Dry capsule yield (kg per plot) | 0.056 | 0.25 | 0.255 | 0.255** | 0.17 | 0.203 | 0.014 | 86.02 | 16.5 |
| Dry capsule yield (kg $ha^{-1}$) | 10.79 | 15.74 | 29.7 | 29.7** | 17.26 | 16.75 | 0.61 | 72.45 | 16.6 |
| Number of seed per capsule | 514.5 | 216.82 | 623.5 | 623.51** | 0.1 | 0.08 | 359.8 | 87.02 | 5.82 |
| Total seed weight per capsule (g) | 0.11 | 0.083 | 0.1 | 0.1** | 0.07 | 0.08 | 0.22 | 98.1 | 7.63 |
| Seed yield (kg per plot) | 0.19 | 0.105 | 0.16 | 0.16** | 0.088 | 0.094 | 22.97 | 97.06 | 17.8 |

* and **, significant at $P<0.05$ and $P<0.01$, respectively, numbers in parenthesis represented degree of freedom, blocks within rep.(Adj.)= adjusted blocks mean squares within replication, Treatments (Unadj.)= unadjusted treatment mean squares, Treatments (adj.)= adjusted treatment mean square, CV (%) = coefficient of variation in percent, RCBD= randomized complete block design

### 4.3.2. Range and mean values

4.3.2.1. Mean value of genotypes for growth characters

Range and mean values of the 17 characters are presented in Table 6. Plant height of 25 korerima genotypes ranged from 92 to 136 (cm) with overall mean of 118.5 (cm), while internodes length (cm) varied from 5.38 to 10.85 with mean values of 8.25 (cm). Similarly capsule bearing suckers per plants varied from 2.54 to 3.33 with a mean values of 3.01. Leaf area ranged from 110.45 to 179.3 ($cm^2$) with a mean valued of 152.11 ($cm^2$), while numbers of leaves per plants ranged from 12.84 to 13.81 with mean values of 13.37 (Table 6).

The genotypes BM34/03 and BM31/03 collected from SNNPR showed the highest mean value for plant height but the genotype 015/03 collected from Oromia showed lowest mean value for plant height, internodes length, number of leaves per suckers and leaf area. Genotypes 001/10 collected from SNNPR showed lowest number of suckers per plants. The highest and lowest mean value of capsule bearing suckers per plants was observed for genotypes105/03 and 009/00 (Appendix Table 1).This finding is in agreement with the finding of Hikmat *et al*. (2012) in turmeric, Simegn *et al*. (2012) in korerima.

4.3.2.2. Mean value of genotypes for capsule yield and yield components

Number of capsules per plant showed variation from 2.32 to 2.77 with the mean value of 2.55, while fresh capsule diameter (cm) ranged from 2.4 to 4.28, with a mean value of 2.74. The overall fresh capsule weight varied from 15.55 to 22.22 (g) with mean value of 18.21 (g). Fresh capsule length varied from 3.83 to 4.84 (cm) with mean value of 4.37 (cm). Dry capsule weight varied from 1.71 to 4.86 (g) with mean value of 3.35 (g). Dry capsule diameter ranged from 1.40 to 2.12 (cm) with the mean value of 1.71 (cm), while dry capsule length ranged from 1.23 to 4.09 (cm) with the mean value of 3.41 (cm). Total weight of dry capsule yield kg $ha^{-1}$ ranged from 203.6 to 921.83 (kg) with mean valued of 516.1 (kg) (Table 6).

The genotypes 059/03 which was collected from Oromia had revealed highest mean value for fresh capsule length, dry capsule weight, dry capsules yield in kg per plot and dry capsules yield in kg $ha^{-1}$ but genotype 025/03 obtained the same region had showed lowest mean value

for number of capsules per plant, dry capsule length, dry capsules diameter, dry capsules yield in kg per plot and dry capsules yield in kg $ha^{-1}$. Generally, genotypes 059/03 and 025/03 showed a wide range of variability which gives a good information for future breeding (Appendix Table 2).The current finding has close agreement with Simegn *et al.* (2012).

4.3.2.3. Mean value of genotypes for seed characters and seed yield

Number of seed per capsule ranged from 96 to 176.81 with the mean value of 153.4, while total seeds weight per capsule varied from 0.91 to 3.26 (g) with mean value of 2.07 (g). Similarly pure seed yield kg per plot ranged from 0.30 to 1.34 (kg) with mean value of 0.56 (kg). (Table 6).

The genotype 059/03 which was collected from Oromia revealed highest mean value for total seed weight per capsule, pure seed yield per plot and number of seed per capsule but the lowest mean value for total seed weight per capsule and pure seed yield per plot were recorded by BM31/03. Korerima genotypes revealed relatively narrow range of variation for number of seed per capsule (Appendix Table 3).This finding is in agreement with the finding of Simegn *et al*. (2012) in korerima.

**4.3.3. Genotypic and phenotypic coefficients variations**

Variance components and coefficients of variation estimate of characters are presented in Table 3. The genotypic coefficient of variation (GCV) ranged from 0.49 for dry capsule yield kg $ha^{-1}$ to 35.57% for dry capsule diameter, while phenotypic coefficient of variation (PCV) ranged from 0.93 for dry capsule yield kg $ha^{-1}$ to 64.38% for pure seed yield kg per plot (Table 6). .

Phenotypic coefficient of variation values were generally higher than their corresponding GCV values for all characters indicating the higher influence of environment on the expression of these characters in genotypes. Simegn *et al.* (2012) reported the magnitude of PCV was higher than GCV for all characters in korerima which support the current finding**.**

According to Deshmukh *et al.* (1986) PCV and GCV can be categorized as low (<10%), moderate (10-20%) and high (>20%). Accordingly, both PCV and GCV values were high for

number of capsule bearing suckers per plant, dry capsule diameter, and pure seed yield in (kg) per plot, while, internodes length (cm), dry capsule length (cm) and dry capsule weight (g) had high PCV values but GCV were moderate for these characters. The result suggested that selection based on phenotypic expression of genotypes is effective in improving these characters. Similar results was reported by Simegn *et al.* (2012), dry capsule diameter (cm) showed both PCV and GCV values was high (Table 6).

Both PCV and GCV values had moderate value for number of capsule per plant. whereas, plant height (cm), number of leave per plant, fresh capsule diameter (cm), dry capsule yield kg per plot and total seed weight per capsule had moderate PCV value , and also dry capsule length (cm) and dry capsule weight (g) had moderate GCV value (Table 2). This indicated the considerable influence of the environment on the expression of these characters and suggested the possibility of improvement of these characters through repeated selection based on the phenotype of genotypes (Simegn *et al.*, 2012). Hikmat *et al*. (2012) reported moderate phenotypic coefficients of variation for plant height and leaf area in turmeric which is support the current finding.

Both GCV and PCV values were low for leaf area ($cm^2$), fresh capsule length (cm), fresh capsule weight (g), dry capsule yield kg $ha^{-1}$ and number of seed per capsule, and also, plant height (cm), internodes length (cm), number of leave per plant, leaf area ($cm^2$), fresh capsule length (cm), fresh capsule length, fresh capsule weight (g), dry capsule yield kg per plot, dry capsule yield kg $ha^{-1}$, number of seed per capsule and total seed weight per capsule had low GCV value. This indicates the presence of high influence of environmental factors on these characters and selection based on phenotypic performance of genotypes for these characters would be ineffective to bring about considerable improvement . Islam *et al*. (2012) reported leaf area, capsule length and fresh capsule weight were showed low GCV and PCV value which support the current finding. Selection is not appropriate breeding method to improve these characters because of the high masking of environmental factors on the expression of characters).

### 4.3.4. Estimate of heritability ($H^2$)

Heritability estimate for all the characters were computed in Table 6. The estimate of heritability in the broad sense ranged from 2.67 (cm) for internodes length to 92.31% for number of capsule per plant. According to Verma and Agarwal (1982) heritability of a character is classified as high if it is 50% or more and moderate for the values between 20% and 50% and low for values less than 20%. Accordingly, heritability values were high for number of capsule bearing suckers per plant (89.8%) , number of capsule per plant (92.31%), dry capsule diameter (82.22%) and number of seed per capsule (80%). Selection for such characters could be easy and effective to improve the characters on the phenotypic expression of the genotypes. Simegn *et al.* (2012) reported high heritability for bearing tiller and diameter of dry capsules which support this finding.

Medium heritability estimates were observed for number of leaves per suckers (31.25%), leaf area (31.49), fresh capsule diameter (20%), dry capsule length (22.39%), dry capsule yield kg $ha^{-1}$ (27.89%) and pure seed yield in (kg) per plot (23.08%). This indicates that selection may not be rewarding in one cycle of selection due to considerable masking effect of environmental factors on the expression of these characters in korerima genotypes

The low estimates of heritability (<20%) were observed for plant height, internodes length, fresh capsule length, fresh capsule weight, dry capsule weight, dry capsule yield in (kg) per plot and total seed weight per capsules. This implies that selection may be difficult or virtually impractical due to the masking effect of the environment. This is because the low heritability of characters is due to the higher influence of environment factors than genetic factor which limit the scope of improvement using selection.

**4.3.5. Estimation of expected genetic advance**

The calculated genetic advance as the percent of the mean (GAM) at 5% selection intensity is presented in Table 6. Estimates of genetic advance ranged from 0.02% for dry capsule yield in kg per plot to 81.4% for dry capsule yield in kg $ha^{-1}$. The genetic advance as percent of mean was categorized as low (<10%), moderate (10-20) and high (> 20%) as suggested by Johnson *et al.* (1955). Accordingly, high genetic advance as percent of mean were observed for number of capsule bearing suckers per plants (40.02), number capsule per plant (26.89%),

dry capsule diameter (66.45%) and pure seed yield in kg per plot (30.61). In addition Genetic advance as percent of mean were showed moderate for dry capsule length (19.17%) and number of seed per capsule (15.33%). It was suggested that the importance of considering both the genetic advance and heritability of character rather than considering separately in determining how much can progress be made through selection (Sharma, 2012).

Higher estimates of heritability coupled with better genetic advance confirms the scope of selection in developing new genotypes with desirable characteristics (Sharma 2012). This indicated that these characters were highly heritable and selection of high performing genotypes is possible to the improvement of the characters. These characters were less influenced by environmental changes. Most of the variations are due to genetic factor and improvement in these characters would be more effective through selection owing to their additive gene action (Sharma, 2012). The current finding is in agreement with the finding of Simegn *et al.* (2012) that high heritability coupled with high expected genetic advance as percent for dry capsule diameter and leaf area revealed.

Genetic advance as percent of mean was low for plant height, number of leaves per sucker, leaf area, fresh capsule diameter, dry capsule weight, dry capsule yield kg per plot, and total seed weight per capsule. However, genetic advance as percent of mean were very low (<2%) for internodes length, fresh capsule length, fresh capsule weight and dry capsule yield kg $ha^{-1}$. This implies that the selection of high performing genotypes may not lead to improvement of the characters in the selected generation as compared to the base population due to the higher influence masking of non-genetic factors on the expression of these characters in the population under selection. Genetic advance under selection is a genotypic value, which depends on genetic variability, heritability, masking effect of non-genetic variability and the selection intensity applied (Sharma, 2010) . Therefore, genetic progress would increase with increase in the genetic variance and reduced non-genetic variability. The current study results are in harmony with the results reported by Simegn *et al*. (2012) that genetic advance as percent of mean was low for plant height, leaf area, number of leaves per sucker and dry capsule yield in korerima.

Table 6. Estimates of variability components for different characters of various korrema genotypes at Tepi

| Character | Range | Mean | SE | $\sigma^2$ph | $\sigma^2$g | PCV (%) | GCV (%) | $H^2$ (%) | GA | GAM (5%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Plant Height (cm) | 92-136 | 118.8 | 2.27 | 261.47 | 22.77 | 13.61 | 4.02 | 8.71 | 2.90 | 2.44 |
| Number of capsule bearing sucker per plant | 2.54-3.33 | 3.01 | 0.037 | 0.49 | 0.44 | 23.26 | 22.04 | 89.80 | 1.29 | 43.02 |
| Internodes length | 5.38-10.85 | 8.25 | 0.256 | 3.75 | 0.10 | 23.47 | 3.83 | 2.67 | 0.11 | 1.29 |
| Number of leaves per plant | 12.84-15.81 | 13.37 | 0.047 | 0.16 | 0.05 | 11.87 | 6.64 | 31.25 | 0.26 | 7.64 |
| Leaf area ($cm^2$) | 110.45-179.3 | 152.1 | 2.625 | 33.57 | 10.57 | 3.81 | 2.14 | 31.49 | 3.76 | 2.47 |
| Number of capsule per plant | 2.32-2.77 | 2.55 | 0.024 | 0.13 | 0.12 | 14.14 | 13.58 | 92.31 | 0.69 | 26.89 |
| Fresh capsule diameter (cm) | 2.4-4.28 | 2.74 | 0.066 | 0.20 | 0.04 | 16.32 | 7.30 | 20.00 | 0.18 | 6.72 |
| Fresh capsule length (cm) | 3.83-4.84 | 4.37 | 0.047 | 0.11 | 0.01 | 7.59 | 2.29 | 9.09 | 0.06 | 1.42 |
| Dry capsule length (cm) | 15.55-22.22 | 18.21 | 0.44 | 0.77 | 0.14 | 4.82 | 2.05 | 18.18 | 0.33 | 1.80 |
| Dry capsule diameter (cm) | 1.40-2.12 | 1.71 | 0.039 | 0.45 | 0.37 | 39.23 | 35.57 | 82.22 | 1.14 | 66.45 |
| Fresh capsule weight (g) | 1.23-4.09 | 3.41 | 0.12 | 2.01 | 0.45 | 41.58 | 19.67 | 22.39 | 0.65 | 19.17 |
| Dry capsule weight (g) | 1.71-4.86 | 3.35 | 0.13 | 0.88 | 0.14 | 28.00 | 11.17 | 15.91 | 0.31 | 9.18 |
| Dry capsule yield (kg per plot) | 1.63-7.37 | 4.13 | 0.067 | 0.23 | 0.03 | 11.61 | 4.19 | 13.04 | 0.13 | 3.12 |
| Dry capsule yield (kg $ha^{-1}$) | 203.6-921.83 | 516.1 | 0.67 | 23.23 | 6.48 | 0.93 | 0.49 | 27.89 | 2.77 | 0.54 |
| Number of seed per capsule | 96-176.8 | 153.4 | 0.017 | 0.1 | 0.08 | 9.30 | 8.32 | 80.00 | 0.52 | 15.33 |
| Total seed weight per capsule (g) | 0.91-3.26 | 2.07 | 0.043 | 0.09 | 0.01 | 14.49 | 4.83 | 11.11 | 0.07 | 3.32 |
| Seed yield (kg per plot) | 0.30-1.34 | 0.56 | 0.05 | 0.13 | 0.03 | 64.38 | 30.93 | 23.08 | 0.17 | 30.61 |

$\sigma^2$g=Genotypic variance, $\sigma^2$ph= Phenotypic variance, GCV= Genotypic coefficient of variation, PCV= Phenotypic coefficient of variation, $H^2$ = Broad sense heritability, GA = genetic advance, GAM (%)=Genetic advance as percent of mean

## 4.4. Genotypic and Phenotypic Correlation Coefficients

Genotypic and phenotypic correlation estimates between the different characters are presented in Table 7. The results are presented and discussed in to three categories viz. correlation coefficient of pure seed with other characters, correlation coefficient of dry capsule yield with other characters and correlation coefficients among other characters. Yield is a complex character associated with many characters. Therefore, estimates of correlation between yield and other characters as well as among other characters is generating important information on which the selection of genotypes based in breeding programs. Correlation coefficient measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for the improvement in yield as an associated complex characters (Mohammadi *et al*., 2012).

### 4.4.1. Correlation coefficient of pure seed yield with other characters

Pure seed yield per plot showed positive and significant correlation both at genotypic and phenotypic levels with number of capsule bearing suckers per plant, number of capsules per plant, dry capsules weight, number of seeds per capsule, total seeds weight per capsule, dry capsule yield per plot and dry capsule yield $ha^{-1}$. In addition, pure seed yield had positive and significant phenotypic correlation with dry capsules length (Table 7). This suggested that the selection of genotypes for high mean values for these characters is the simultaneous selection of genotypes for high seed yield.

The results of present investigation is in confirmation with the results of Simegn *et al.* (2012) that number of capsule per plant and dry capsules weight showed positive and high significant correlation with seed yield in korerima.

### 4.4.2. Correlation coefficient of dry capsule yield with other characters

Dry capsule yield kg $ha^{-1}$showed positive and significant correlation both at genotypic and phenotypic levels with number of capsule bearing suckers per plant, number of capsules per plant, dry capsule weight, total seed weight per capsule and dry capsule yield per plot. In addition, dry capsule yield kg $ha^{-1}$ showed positive and significant phenotypic correlation with dry capsules length and number of seed per capsule (Table 7).

This positive and significant association of pairs of characters shows the possibility of correlated response to selection is high. Therefore, any improvement of these characters would result in a considerable increment on dry capsule yield kg $ha^{-1}$. This finding is in close agreement with Simegn *et al.* (2012) in korerima.

### 4.4.3. Correlations among other characters

Plant height showed positive and highly significant genotypic and phenotypic association with internodes length, number of leaf per sucker, leaf area, dry capsule length and dry capsule diameter (Table 4). The result indicated that the higher chance of improving these characters simultaneously by selection of genotypes with high mean values. Number of capsule per plant showed positive and significant phenotypic association with number of capsule bearing suckers per plant and dry capsule weight. Dry capsule weight showed positive and significant phenotypic association with internodes length and dry capsule length.

The result indicated higher chance of improving these characters simultaneously by selection of genotypes with high mean values. The current findings is in close agreement with the results reported by Simegn *et al.* (2012) positive and significant association was registered with dry capsule length and internodes length.

Table 7. Estimates of correlation coefficients at phenotypic (above diagonal) and genotypic (below diagonal) levels of different characters in various korerima genotypes grown at Tepi

| Characters | Plant Height (cm) | No. of capsule bearing sucker / plant | Internodes length | No. of leaves/ plant | Leaf area ($cm^2$) | No. of capsule/ plant | Fresh capsule diameter (cm) | Fresh capsule length (cm) | Fresh capsule weight (g) |
|---|---|---|---|---|---|---|---|---|---|
| Plant Height (cm) | | 0.063 | 0.638** | 0.59** | 0.63** | 0.261 | 0.039 | -0.005 | -0.001 |
| No. of capsule bearing Sucker/ plant | 0.035 | | 0.102 | -0.357 | -0.376 | 0.324 | 0.033 | 0.241 | 0.074 |
| Internodes length | 0.496* | 0.087 | | 0.171 | 0.381 | 0.099 | 0.170 | -0.308 | -0.030 |
| No. of leaves/ plant | 0.530** | -0.090 | 0.089 | | 0.58** | 0.016 | -0.090 | -0.155 | -0.094 |
| Leaf area ($cm^2$) | 0.464* | -0.165 | 0.284 | 0.290 | | -0.10 | 0.237 | -0.303 | 0.078 |
| No.of capsule/ plant | 0.173 | 0.330 | 0.048 | 0.158 | -0.053 | | -0.053 | 0.254 | 0.113 |
| Fresh capsule diameter (cm) | 0.076 | -0.003 | -0.013 | 0.168 | 0.295 | -0.220 | | -0.227 | 0.171 |
| Fresh capsule length (cm) | 0.032 | 0.133 | -0.026 | -0.280 | -0.201 | 0.115 | 0.071 | | 0.139 |
| Fresh capsule weight (g) | -0.056 | 0.085 | -0.157 | 0.032 | 0.091 | -0.055 | 0.189 | 0.302 | |
| Dry capsule diameter(cm) | 0.128 | -0.005 | 0.074 | -0.106 | 0.265 | -0.231 | 0.492* | -0.091 | 0.063 |
| Dry capsule length (cm) | 0.328 | 0.081 | 0.193 | 0.240 | 0.167 | 0.260 | -0.086 | -0.085 | 0.008 |
| Dry capsule weight (g) | 0.356 | 0.126 | 0.412* | 0.032 | 0.151 | 0.307 | -0.124 | 0.047 | -0.035 |
| No. of seed/ capsule | -0.027 | 0.149 | -0.091 | -0.195 | 0.047 | 0.134 | 0.096 | 0.124 | 0.318 |
| Total seed weight/ capsule (g) | 0.264 | -0.016 | 0.306 | 0.071 | 0.106 | 0.032 | -0.152 | -0.083 | -0.142 |
| Seed yield (kg / plot) | 0.267 | 0.57** | 0.240 | 0.083 | 0.027 | 0.640** | -0.181 | 0.037 | -0.097 |
| Dry capsule yield (kg/ plot) | 0.345 | 0.54** | 0.309 | 0.018 | 0.134 | 0.535** | -0.149 | 0.056 | -0.054 |
| Dry capsule yield (kg $ha^{-1}$) | 0.395 | 0.60** | 0.332 | 0.036 | 0.010 | 0.642** | -0.150 | 0.123 | -0.017 |

Table 7. Continues…

| Characters | Dry capsule diameter (cm) | Dry capsule length (cm) | Dry capsule weight (g) | No. of seed/ capsule | Total seed weight/ capsule (g) | Seed yield (kg / plot) | Dry capsule yield (kg/plot) | Dry capsule yield (kg $ha^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| Plant Height (cm) | 0.051 | 0.397* | 0.361 | -0.176 | 0.370 | 0.296 | 0.416* | 0.382 |
| No. of capsule bearing sucker/ plant | 0.164 | 0.128 | 0.231 | 0.368 | 0.151 | 0.628** | 0.588** | 0.654** |
| Internodes length | 0.166 | 0.425* | 0.480* | -0.188 | 0.511** | 0.273 | 0.396* | 0.356 |
| No. of leaves/ plant | -0.087 | 0.280 | -0.021 | -0.264 | 0.127 | -0.065 | -0.127 | -0.158 |
| Leaf area ($cm^2$) | 0.173 | 0.137 | 0.128 | -0.159 | 0.044 | -0.043 | 0.095 | -0.075 |
| No. of capsule/ plant | -0.156 | 0.377 | 0.535** | 0.285 | 0.146 | 0.674** | 0.572** | 0.720** |
| Fresh capsule diameter (cm) | 0.549** | -0.121 | -0.152 | 0.077 | -0.134 | -0.102 | -0.130 | -0.094 |
| Fresh capsule length (cm) | -0.437* | -0.176 | -0.017 | 0.067 | -0.064 | 0.117 | 0.043 | 0.144 |
| Fresh capsule weight (g) | -0.304 | -0.453* | -0.079 | -0.003 | -0.249 | -0.024 | -0.116 | 0.020 |
| Dry capsule diameter (cm) | | 0.003 | 0.083 | 0.277 | 0.131 | 0.146 | 0.219 | 0.078 |
| Dry capsule length (cm) | -0.044 | | 0.456* | 0.054 | 0.436* | 0.433* | 0.441* | 0.420* |
| Dry capsule weight (g) | 0.213 | 0.273 | | 0.301 | 0.664** | 0.754** | 0.788** | 0.854** |
| No. of seed/ capsule | 0.467* | 0.206 | 0.304 | | 0.240 | 0.507** | 0.422* | 0.396* |
| Total seed weight/capsule (g) | 0.278 | 0.255 | 0.679** | 0.190 | | 0.674** | 0.524** | 0.497* |
| Seed yield (kg/ plot) | 0.115 | 0.277 | 0.696** | 0.398* | 0.559** | | 0.891** | 0.908** |
| Dry capsule yield (kg/ plot) | 0.022 | 0.281 | 0.723** | 0.272 | 0.483* | 0.896** | | 0.899** |
| Dry capsule yield (kg $ha^{-1}$) | 0.058 | 0.278 | 0.814** | 0.269 | 0.441* | 0.902** | 0.882** | |

* and **, significant at $P<0.05$ and $P<0.01$ level (for $r > 0.396$ and $r > 0.505$) respectively.

## 4.5. Path Coefficient Analysis

### 4.5.1. Genotypic path analysis of pure seed yield with other characters

The genotypic direct and indirect effect of different characters on pure seed yield per plot is presented in Table 8. Number of seeds per capsule, total seed weight per plot, dry capsule yield per plot and dry capsule yield had high and positive direct effects on pure seed yield, however, number of capsule bearing sackers per plant, dry capsule weight and number of capsule per plant had negative direct effects on pure seed yield at genotypic level. The result indicated that the positive and significant correlation of number of capsule bearing sackers per plant, dry capsule weight, total seed weight per plot, dry capsule yield per plot and dry capsule yield kg $ha^{-1}$ with pure seed yield per plot were due to the high direct effect of the characters. But the positive and significant genotypic correlation of number of capsule bearing suckers per plant, dry capsule weight and number of capsule per plant with pure seed yield per plot were due to the high and positive indirect effects of other characters via this characters. For instance the positive and significant genotypic correlation of number of capsule per plant with pure seed yield per plot was due to the positive and high indirect effect of this character via dry capsule yield kg $ha^{-1}$ and dry capsule yield per plot. The current finding is in agreement with the finding of Simegn *et al.* (2012) that high and positive direct effects of capsule bearing tiller, dry capsule weight, and number of seed per capsule on pure seed yield of korerima.

Genotypic path analysis residual value was 0.052. This indicated that 94.8% of the variability in seed yield was explained by the component factors/characters included in genotypic path analyses. This suggested that the choice of seed yield attributing characters in the study was quite good.

Table 8. Genotypic direct effects (bold and diagonal) and indirect effects (off-diagonal) of different characters on seed yield in various korerima genotypes evaluated at Tepi

| Characters | No. of capsule bearing sucker /plant | No. of capsule/ plant | Dry capsule weight (g) | No. of seed / capsule | Total seed weight/ capsule (g) | Dry capsule yield (kg/ plot) | Dry capsule yield (kg $ha^{-1}$) | $r_g$ |
|---|---|---|---|---|---|---|---|---|
| No. of capsule bearing sucker / plant | **-0.481** | -0.058 | -0.147 | 0.034 | -0.006 | 0.154 | 1.061 | 0.571** |
| No. of capsule/ plant | -0.159 | **-0.175** | -0.359 | 0.031 | 0.012 | 0.152 | 1.130 | 0.640** |
| Dry capsule weight (g) | -0.061 | -0.054 | **-1.170** | 0.070 | 0.261 | 0.205 | 1.433 | 0.696** |
| No. of seed/ capsule | -0.072 | -0.023 | -0.356 | **0.230** | 0.073 | 0.077 | 0.473 | 0.398* |
| Total seed weight/ capsule (g) | 0.008 | -0.006 | -0.794 | 0.044 | **0.385** | 0.137 | 0.776 | 0.559** |
| Dry capsule yield (kg / plot) | -0.260 | -0.094 | -0.846 | 0.063 | 0.186 | **0.284** | 1.552 | 0.896** |
| Dry capsule yield (kg $ha^{-1}$) | -0.290 | -0.112 | -0.952 | 0.062 | 0.170 | 0.250 | **1.76** | 0.902** |

Residual effect=0.052

* and ** Significant at probability level of 0.05 (r= 0.396) and 0.01 values (r= 0.505), respectively, $r_g$= genotypic correlation

### 4.5.2. Phenotypic path analysis of pure seed yield with other characters

The phenotypic direct and indirect effect of different characters on pure seed yield per plot is presented in Table 9. Dry capsule yield kg $ha^{-1}$ followed by total seed weight per capsule, dry capsule yield per plot and number of capsules per plant had exerted positive direct effect on pure seed yield. But number of capsule bearing sackers per plant and dry capsule weight had negative direct effect on pure seed yield at phenotypic level. Whereas, via dry capsule yield kg $ha^{-1}$and dry capsule yield kg per plot showed considerable positive indirect effect on pure seed yield and the total correlation was significant and positive.

The current result clearly showed that the positive and significant correlation of number of capsule per plant, number of seed per capsule, total seed weight per plot, dry capsule yield per plot and dry capsule yield kg $ha^{-1}$ with pure seed yield per plot was due to the high direct effect of the characters. But the positive and significant phenotypic correlation of number of capsule bearing suckers per plant and dry capsule weight with pure seed yield per plot was due to the high and positive indirect effects of other characters via dry capsule yield per plot and dry capsule yield kg $ha^{-1}$.So direct selection based on high direct effect of the characters could be effective for increasing pure seed yield. Simegn *et al*. (2012) in korerima.

The path analysis showed the residual value of 0.014 which means the characters in the path analysis expressed the variability in seed yield by 98.6%.

Table 9. Phenotypic direct effects (bold and diagonal) and indirect effects (off-diagonal) of different characters on seed yield in various korerima genotypes evaluated at Tepi

| Characters | No. of capsule bearing sucker/ plant | No. of capsule/ plant | Dry capsule weight (g) | No. of seed/ capsule | Total seed weight / capsule (g) | Dry capsule yield (kg / plot) | Dry capsule yield (kg $ha^{-1}$) | $r_{ph}$ |
|---|---|---|---|---|---|---|---|---|
| No. of capsule bearing sucker per plant | **-0.146** | 0.047 | -0.147 | 0.043 | 0.071 | 0.163 | 0.602 | 0.628** |
| No. of capsule per plant | -0.047 | **0.145** | -0.341 | 0.034 | 0.069 | 0.159 | 0.662 | 0.674** |
| Dry capsule weight (g) | -0.034 | 0.078 | **-0.637** | 0.036 | 0.313 | 0.219 | 0.786 | 0.754** |
| No.of seed per capsule | -0.054 | 0.041 | -0.192 | **0.118** | 0.113 | 0.117 | 0.364 | 0.507** |
| Total seed weight/ capsule (g) | -0.022 | 0.021 | -0.423 | 0.028 | **0.471** | 0.146 | 0.457 | 0.674** |
| Dry capsule yield (kg/ plot) | -0.086 | 0.083 | -0.502 | 0.050 | 0.247 | **0.278** | 0.827 | 0.891** |
| Dry capsule yield (kg $ha^{-1}$) | -0.095 | 0.104 | -0.544 | 0.047 | 0.234 | 0.250 | **0.92** | 0.908** |

Residual effect=0.0142

* and ** Significant at probability level of 0.05 (r= 0.396) and 0.01 values (r= 0.505), respectively, $r_g$= genotypic correlation

### 4.5.3. Genotypic path analysis of dry capsule yield with other characters

The genotypic direct and indirect effect of different characters on dry capsule yield kg $ha^{-1}$ is presented in Table 10. The maximum positive genotypic direct effect on dry capsule yield kg $ha^{-1}$ was exerted by dry capsule weight followed by number of capsule bearing sackers per plant, number of capsules per plant and dry capsule length, in contrast, number of seed per capsule, total seed weight per capsule and dry capsule yield per plot had negative direct effects on dry capsule yield at genotypic level.

The result indicated that the positive and significant correlation of dry capsule weight, number of capsule bearing suckers per plant, dry capsule length and number of capsule per plant with dry capsule yield kg $ha^{-1}$was due to the high direct effect of these characters. But the positive and significant genotypic correlation of number of seed per capsule, total seed weight per capsule and dry capsule yield per plot with dry capsule yield kg $ha^{-1}$ was due to the high and positive indirect effects of via dry capsule weight. So direct selection based on high direct effect of the characters could be effective for increasing dry capsule yield. It also suggested the possibility of indirect selection for high capsule yield via dry capsule weight could be effective for increasing dry capsule yield. Maximum positive direct effect of number of capsule bearing suckers per plant on dry capsule yield was also reported by Simegn *et al.* (2012) in korerima.

The residual effect was found 0.149 which means the characters in the path analysis expressed the variability in dry capsule yield by 85.1%., indicated that there were other contributors which were responsible for capsule yield but not taken into consideration in the present investigation.

Table 10. Genotypic direct effects (bold and diagonal) and indirect effects (off-diagonal) of different characters on seed yield in various korerima genotypes evaluated at Tepi

| Characters | No. of capsule bearing sucker / plant | No. of capsule/ plant | Dry capsule length (cm) | Dry capsule weight (g) | No. of seed/ capsule | Total seed weight / capsule (g) | Dry capsule Yield (kg/ plot) | $r_g$ |
|---|---|---|---|---|---|---|---|---|
| No. of capsule bearing | **0.361** | 0.073 | 0.000 | 0.085 | -0.011 | 0.0001 | -0.011 | 0.603** |
| Sucker/ plant | | | | | | | | |
| No. of capsule/ plant | 0.119 | **0.222** | 0.002 | 0.208 | -0.010 | 0.0001 | -0.011 | 0.642** |
| Dry capsule length (cm) | 0.029 | 0.058 | **0.006** | 0.185 | -0.015 | 0.0001 | -0.006 | 0.378* |
| Dry capsule weight (g) | 0.045 | 0.068 | 0.002 | **0.677** | -0.022 | 0.0003 | -0.015 | 0.814** |
| No. of seed per capsule | 0.054 | 0.030 | 0.001 | 0.206 | **-0.074** | 0.0002 | -0.006 | 0.369* |
| Total seed weight/capsule (g) | -0.006 | 0.007 | 0.002 | 0.460 | -0.014 | **-0.096** | -0.010 | 0.441* |
| Dry capsule yield (kg/ plot) | 0.195 | 0.119 | 0.002 | 0.489 | -0.020 | 0.0003 | **-0.021** | 0.882** |

Residual effect=0.149

* and ** Significant at probability level of 0.05 (r= 0.396) and 0.01 values (r= 0.505), respectively, $r_g$= genotypic correlation.

### 4.5.4. Phenotypic path analysis of dry capsule yield with other characters

The phenotypic direct and indirect effect of different characters on dry capsule yield is presented in Table 11. Number of capsule bearing suckers per plant, number of capsule per plant, dry capsule weight and dry capsule yield per plot had exerted positive direct effect on dry capsule yield. But dry capsule length, number of seeds per capsule and total seed weight per plot had negative direct effect on dry capsule yield at phenotypic level. Whereas, via dry capsule weight showed considerable positive indirect effect on dry capsule yield and the total correlation were significant and positive.

The result showed that the positive and significant correlation of number of capsule bearing sackers per plant, number of capsule per plant, dry capsule weight and dry capsule yield per plotwith dry capsule yield was due to the high direct effect of these characters. But the positive and significant phenotypic correlation of dry capsule length, number of seed capsule and total seed weigh with dry capsule yield was due to the high and positive indirect effects of other characters via dry capsule weight. So direct selection based on high direct effect of the characters could be effective for increasing pure seed yield. Simegn *et al*. (2012) in korerima.

The residual effect was found 0.015, which means the characters in the path analysis expressed the variability in dry capsule yield by 98.5%., indicated that there were other contributors which was responsible for yield but not taken into consideration in the present investigation.

Table 11. Phenotypic direct effects (bold and diagonal) and indirect effects (off-diagonal) of different characters on seed yield in various korerima genotypes evaluated at Tepi

| Characters | No. of capsule bearing Sucker/ plant | No. of capsule/ plant | Dry capsule length (cm) | Dry capsule weight (g) | No. of seed/ capsule | Total seed weight/ capsule (g) | Dry capsule yield (kg/plot) | $r_{ph}$ |
|---|---|---|---|---|---|---|---|---|
| No. of capsule bearing Sucker/plant | 0.397 | 0.075 | -0.003 | 0.138 | -0.011 | -0.005 | 0.056 | 0.654** |
| No. of capsule/plant | 0.129 | 0.231 | -0.009 | 0.319 | -0.008 | -0.004 | 0.054 | 0.720** |
| Dry capsule length (cm) | 0.051 | 0.087 | -0.024 | 0.272 | -0.002 | -0.013 | 0.042 | 0.420* |
| Dry capsule weight (g) | 0.092 | 0.124 | -0.011 | 0.597 | -0.009 | -0.020 | 0.075 | 0.854** |
| No. of seed per capsule | 0.146 | 0.066 | -0.001 | 0.180 | -0.029 | -0.007 | 0.040 | 0.396* |
| Total seed weight/capsule (g) | 0.060 | 0.034 | -0.010 | 0.396 | -0.007 | -0.030 | 0.050 | 0.497* |
| Dry capsule yield (kg/plot) | 0.233 | 0.132 | -0.011 | 0.470 | -0.012 | -0.016 | 0.095 | 0.899** |

Residual effect=0.015

* and ** Significant at probability level of 0.05 (r= 0.396) and 0.01 values (r= 0.505), respectively, $r_g$= genotypic correlation

## 4.6. Genetic Divergence

### 4.6.1. Genetic distance analysis

The 25 korerima genotypes exhibited significant differences for 17 morphological characters studied. The genetic distances of 300 pairs of genotypes were estimated by Euclidean distance (ED) from 17 characters for which the genotypes exhibited significant differences. The Euclidean distance calculated for pairs of genotypes is presented in (Table 12). The highest genetic distance >9.36 was computed between genotypes 25/03 and 059/03 (10.8), BM31/03 and 059/03 (9.9), which were collected from Oromia and SNNP Regional States. The low genetic distance less than three were observed between 045/03 and 686/87 (2.53), 114/03 and 009/00 (2.84), 114/03 and 011/00 (2.63, 045/03 and 105/03 (2.92), 016/00 and 009/00 (2.82), 016/00 and 010/00 (2.84), 016/84 and 011/00 (2.93), 686/87 and 105/03 (2.76).

Among 300 pairs of genotypes, 64 (21.33%) had <4.5, 109 (36.33%) and 79 (26.33%) had, 4.51 to 5.74 and 5.75 to 6.98 distances, respectively. On the other hand, 36 (12%) and 12 (4%) had distances in the range between 6.99 to 8.12 and 8.13 to 9.36, respectively.

The Euclidean distance of 25 korerima genotypes varied from 2.53 to 10.8 with a mean distance of 5.66 and a standard deviation (SD) of 1.23 (Table 10). The mean Euclidean distance was calculated for each genotype to other 24 genotypes to identify which genotypes were closest and distant to others. The results showed that the most distant genotypes to others were 25/03 (7.01), 059/03 (6.89), 701/87 (6.72) and 029/84 (6.7). On the other hand, 011/00 (4.38), 114/03 (4.79) and 686/87 (4.98) were the more the close to other genotypes. Among the 25 genotypes 60 (%) and 40 (%) had mean genetic distances of <5.66 and >5.66, respectively (Table 7). The mean distances results were in harmony with the clustering pattern of the genotypes that the two most distant genotypes were from two different clusters and the most genetically related cultivars were from same cluster.

The information presented here suggestes that the korerima genotypes could be a good source of parents for improvement of the crop through hybridization and selection.

Table 12. Euclidean distance of various korerima genotypes measured from different characters

| | 046/03 | 114/03 | 029/84 | 038/01 | 045/03 | 021/00 | 015/03 | Jima | 686/87 | 001/00 | 093/00 | BM31/03 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 053/03 | 5.95 | 4.20 | 6.40 | 4.70 | 4.34 | 5.57 | 6.56 | 4.60 | 4.69 | 3.50 | 4.97 | 7.14 |
| 046/03 | | 4.59 | 6.43 | 4.71 | 3.90 | 4.66 | 6.89 | 5.67 | 4.19 | 4.98 | 4.45 | 4.83 |
| 114/03 | | | 6.14 | 3.46 | 4.69 | 4.63 | 6.48 | 5.17 | 3.95 | 4.30 | 5.80 | 6.99 |
| 029/84 | | | | 7.01 | 6.04 | 6.54 | 7.87 | 5.66 | 6.19 | 5.56 | 5.87 | 6.96 |
| 038/01 | | | | | 4.48 | 4.11 | 4.89 | 6.18 | 4.62 | 3.97 | 5.13 | 6.89 |
| 045/03 | | | | | | 4.44 | 6.42 | 4.65 | 2.53 | 3.25 | 4.75 | 3.83 |
| 021/00 | | | | | | | 3.78 | 6.22 | 4.43 | 5.39 | 4.81 | 5.58 |
| 015/03 | | | | | | | | 7.91 | 6.97 | 6.42 | 5.09 | 7.32 |
| Jima | | | | | | | | | 4.69 | 3.61 | 5.43 | 5.35 |
| 686/87 | | | | | | | | | | 3.50 | 5.56 | 5.01 |
| 001/00 | | | | | | | | | | | 4.42 | 5.61 |
| 093/00 | | | | | | | | | | | | 5.56 |

Table 12. Continues…

| | 028/84 | 701/87 | 68/87 | 25/03 | BM34/03 | 059/03 | 018/00 | 016/84 | 009/00 | 105/03 | 010/00 | 011/00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 053/03 | 6.12 | 7.40 | 5.26 | 7.70 | 5.42 | 6.80 | 6.55 | 4.62 | 5.63 | 5.07 | 6.47 | 4.04 |
| 046/03 | 6.79 | 7.28 | 5.00 | 6.60 | 3.75 | 7.00 | 3.32 | 6.18 | 5.49 | 5.00 | 7.31 | 4.58 |
| 114/03 | 6.46 | 5.07 | 5.45 | 7.60 | 3.26 | 5.10 | 4.15 | 3.59 | 2.84 | 4.05 | 4.28 | 2.63 |
| 029/84 | 6.99 | 8.39 | 5.64 | 6.70 | 6.36 | 8.80 | 6.95 | 7.31 | 7.59 | 6.53 | 7.33 | 5.57 |
| 038/01 | 5.96 | 5.76 | 5.84 | 7.20 | 4.80 | 5.60 | 4.05 | 3.59 | 4.10 | 4.69 | 4.59 | 3.77 |
| 045/03 | 6.28 | 7.28 | 5.40 | 5.20 | 4.42 | 7.70 | 4.80 | 5.65 | 6.27 | 2.92 | 6.95 | 4.01 |
| 021/00 | 4.92 | 6.87 | 4.88 | 6.00 | 4.92 | 7.80 | 4.12 | 4.80 | 5.71 | 4.64 | 6.04 | 4.51 |
| 015/03 | 4.95 | 7.61 | 6.64 | 7.30 | 6.96 | 8.10 | 5.52 | 5.15 | 6.88 | 6.66 | 6.41 | 5.77 |
| Jima | 5.99 | 8.46 | 4.17 | 6.40 | 5.69 | 8.30 | 6.10 | 6.37 | 6.76 | 5.42 | 7.28 | 4.08 |
| 686/87 | 6.62 | 6.72 | 5.39 | 5.70 | 3.45 | 7.20 | 4.70 | 5.24 | 5.53 | 2.76 | 6.33 | 3.62 |
| 001/00 | 6.19 | 7.46 | 5.30 | 6.10 | 4.80 | 6.90 | 5.13 | 5.12 | 5.89 | 4.38 | 6.26 | 3.42 |
| 093/00 | 5.00 | 8.00 | 4.69 | 6.40 | 5.71 | 7.20 | 5.05 | 5.95 | 6.53 | 6.05 | 7.53 | 4.62 |
| BM31/03 | 6.60 | 8.93 | 5.66 | 4.10 | 6.35 | 9.90 | 5.26 | 7.85 | 8.38 | 5.21 | 8.83 | 5.85 |
| 028/84 | | 6.94 | 4.38 | 6.00 | 7.17 | 8.10 | 5.93 | 5.92 | 7.07 | 6.33 | 7.11 | 5.25 |
| 701/87 | | | 7.70 | 8.80 | 5.66 | 4.90 | 5.79 | 5.39 | 4.90 | 5.44 | 5.16 | 5.36 |
| 68/87 | | | | 5.70 | 5.74 | 8.40 | 5.63 | 6.29 | 6.68 | 6.29 | 7.20 | 4.89 |
| 25/03 | | | | | 7.54 | 10.80 | 6.28 | 8.55 | 9.34 | 6.41 | 9.04 | 6.83 |
| BM34/03 | | | | | | 5.70 | 3.81 | 4.96 | 4.37 | 3.85 | 5.74 | 3.54 |
| 059/03 | | | | | | | 6.36 | 4.66 | 3.34 | 6.47 | 5.39 | 5.00 |
| 018/00 | | | | | | | | 5.41 | 5.03 | 4.69 | 6.16 | 4.06 |
| 016/84 | | | | | | | | | 2.82 | 4.66 | 2.84 | 2.93 |
| 009/00 | | | | | | | | | | 5.19 | 3.50 | 3.32 |
| 105/03 | | | | | | | | | | | 5.66 | 3.33 |
| 010/00 | | | | | | | | | | | | 4.02 |

Table 13. Mean genetic distances of various korerima genotypes

| Genotypes | Minimum | Maximum | Mean | SD | CV (%) |
|---|---|---|---|---|---|
| 053/03 | 3.50 | 7.73 | 5.57 | 1.14 | 20.52 |
| 046/03 | 3.32 | 7.31 | 5.40 | 1.18 | 21.91 |
| 114/03 | 2.63 | 7.63 | 4.79 | 1.30 | 27.11 |
| 029/84 | 5.56 | 8.84 | 6.70 | 0.87 | 13.01 |
| 038/01 | 3.46 | 7.19 | 5.00 | 1.08 | 21.55 |
| 045/03 | 2.53 | 7.73 | 5.01 | 1.35 | 27.01 |
| 021/00 | 3.78 | 7.77 | 5.22 | 0.97 | 18.55 |
| 015/03 | 3.78 | 8.14 | 6.44 | 1.09 | 16.96 |
| Jima | 3.61 | 8.46 | 5.84 | 1.27 | 21.79 |
| 686/87 | 2.53 | 7.16 | 4.98 | 1.30 | 26.05 |
| 001/00 | 3.25 | 7.46 | 5.06 | 1.18 | 23.32 |
| 093/00 | 4.42 | 8.00 | 5.61 | 0.97 | 17.26 |
| BM31/03 | 3.83 | 9.90 | 6.42 | 1.56 | 24.29 |
| 028/84 | 4.38 | 8.08 | 6.21 | 0.86 | 13.92 |
| 701/87 | 4.85 | 8.93 | 6.72 | 1.32 | 19.68 |
| 68/87 | 4.17 | 8.38 | 5.76 | 1.01 | 17.52 |
| 25/03 | 4.10 | 10.8 | 7.01 | 1.48 | 21.15 |
| BM34/03 | 3.26 | 7.54 | 5.16 | 1.21 | 23.49 |
| 059/03 | 3.30 | 10.8 | 6.89 | 1.76 | 25.54 |
| 018/00 | 3.32 | 6.95 | 5.20 | 0.97 | 18.56 |
| 016/84 | 2.82 | 8.55 | 5.24 | 1.48 | 28.20 |
| 009/00 | 2.82 | 9.34 | 5.55 | 1.72 | 31.02 |
| 105/03 | 2.76 | 6.66 | 5.07 | 1.14 | 22.40 |
| 010/00 | 2.84 | 9.04 | 6.14 | 1.54 | 25.11 |
| 011/00 | 2.63 | 6.83 | 4.38 | 1.03 | 23.60 |
| Overall mean | 2.53 | 10.8 | 5.66 | 1.23 | 21.98 |

SD = standard deviation and CV (%) = coefficient of variation in percent.

### 4.6.2. Cluster analysis

The dendrogram constructed from Euclidean distance matrix using UPGMA clustering method presented in Appendix Figure 1. The cut point of dendrograms (4.5) was established by mean genetic distance and standard deviation in which the cut point was greater than mean distance of collections minus standard deviation. Accordingly, the 25 korerima genotypes were grouped into seven distinct clusters.

The two clusters (Cluster II and VI) were constructed with single genotype obtained from SNNPR and Oromia regions, while Cluster IV and VII consisted of each two genotypes. Cluster I was the largest which was constructed with 11 (44%) genotypes which were collected from SNNPR(6), Oromia (5) and Amhara (1) Regional States, while Clusters II and V were the second and third largest which were constructed with 5(20%) and 3(12%) members, respectively.

Generally, this clusters analysis revealed that Ethiopian korerima genotypes originated from different sources were distributed to the different groups based on their genetic distance with no definite regional pattern. Korerima genotypes collected from SNNP and Oromia regional states were distributed in six of the seven clusters, while the genotypes collected from Amhara were distributed in four of the seven clusters. This indicates the existence of more genetic variability of genotypes obtained from the first of two regions than Amhara and genotypes from the same origin might have different genetic background (Table 14). Simegn *et al*. (2016) reported that the 25 korerima genotypes were grouped in to four distinct clusters. The same authors also reported that korerima genotypes collected from SNNP regional states showed more genetic diversity than Oromia regional states.

Table 14. Genotypes in seven clusters with collection region, zones, districts and altitudes

| Clusters | Genotypes code | Collection | | | |
|---|---|---|---|---|---|
| | | Region | Zone | District | Altitude |
| I (44%) | 053/03 | SNNPR | South Omo | Kemba | 1850 |
| | 001/00 | Oromia | Bale | Genale | 1000 |
| | Jima | Oromia | Jima | Jima | 1580 |
| | 046/03 | Oromia | Illubabor | Algea | 1500 |
| | 018/00 | SNNPR | Kafa | Yeki | 1097 |
| | 114/03 | Oromia | Illubabor | Sombo | 2229 |
| | 011/00 | SNNPR | Sidamo | Sidama | 2759 |
| | BM34/03 | SNNPR | Kafa | Chena | 1972 |
| | 045/03 | SNNPR | Gamogofa | Damot | 2121 |
| | 686/87 | Amhara | Gojam | Metekel | 1525 |
| | 105/03 | Oromia | Illubabor | Yayu | 1387 |
| II (20%) | 038/01 | SNNPR | Sidamo | Arero | 2829 |
| | 016/84 | Oromia | Illubabor | Sombo | 2229 |
| | 009/00 | Amhara | Gojam | Metekel | 1525 |
| | 010/00 | SNNPR | Kafa | Chena | 1972 |
| | 059/03 | Oromia | Wollega | Nekemte | 2088 |
| III (4%) | 701/87 | SNNPR | Kafa | Decha | 2500 |
| IV (8%) | 021/00 | SNNPR | Benchi maji | Bebeka | 1285 |
| | 015/03 | Oromia | Illubabor | Smbo | 2229 |
| V (12%) | 093/00 | Amhara | Gojam | Debre markos | 2446 |
| | 028/84 | Oromia | Wollega | Arjo | 1800 |
| | 68/87 | Amhara | Gojam | Agew midir | 1500 |
| VI (4%) | 029/84 | Oromia | Wollega | Gimbi | 1930 |
| VII (8%) | BM31/03 | SNNPR | Kafa | Chena | 1500 |
| | 25/03 | Oromia | Illubabor | Metu | 1605 |

### 4.6.3. Cluster mean analysis

The range, mean, standard deviation and coefficient of variation of seven clusters mean values for 17 characters are shown in Table 15. Cluster I was characterized by containing genotypes which had highest mean values for plant height (126.79 cm) and internodes length, while lowest mean values revealed for fresh capsules length (4.32). Simegn *et al*. (2012) also reported that Cluster I had tallest plant in korerima genotypes they studied.

Cluster II characterized by having the highest mean values for number of capsule bearing suckers per plant (3.22) and total seed weight per capsules (2.89 g), than other clusters.

Cluster III characterized by having the highest mean values of number of suckers per plant (4.47), number of capsules per plant (2.69), fresh capsules length (4.82 cm), fresh capsules diameter (2.96 cm), dry capsules weight (4.63g),pure seed yield per plot (7.12 kg) and dried capsule yield kg $ha^{-1}$ (889.85) and the lowest mean value for dry capsule length (1.68 cm) than other clusters. Simegn *et al*. (2012) reported that Cluster III was identified by having high mean value of dry capsules weight and dried capsules yield per plot in korerima.

Cluster IV was characterized by lowest mean values for plant height (98 cm), number of leaves per sucker (3.00), leaf area (120.06 $cm^2$) and fresh capsule diameter (2.54 cm) than other clusters.

Cluster V characterized by having the highest mean values for dry capsules diameter (1.92 cm) than other clusters.

Cluster VI characterized by the highest mean values for leaf area (164.5 cm2), fresh capsules diameter (4.28 cm) and lowest mean value for fresh capsule length (3.88cm) and 1000 seeds weight (10.97g) than other clusters.

Cluster VII was characterized by having the highest mean value only for number of leaves per suckers (3.55). This cluster had lowest mean values for most of the characters viz. for number capsule bearing suckers per plant, number capsules per plant, dry capsules diameter, dry capsules weight, dry capsules yield per plot, dry capsules yield kg $ha^{-1}$, number of seeds per capsule, total seed weight per capsule, pure seed yield per plot than other clusters.

The cluster mean analysis results suggested that selection could be made in Cluster II where the breeding objective is targeted to obtain genotypes with highest seed yield and seed related characters. Selection of genotypes from Cluster III could be to select genotypes for dried capsule yield kg $ha^{-1}$and dry pod related characters such as number of suckers per plant, number of capsules per plant, fresh capsules length, fresh capsules diameter, dry capsules weight and dried capsules yield per plot. The crossing of genotypes from these two clusters might produce hybrids with high dried capsule yield and seed yield. In general, each cluster

had highest mean value at least for one character that gave an option to breeders to select genotypes which fit the objective(s) of the breeding program. It is also possible to bring improvement by selection of genotypes with desirable characters from different clusters and crossing of genotypes with all possible combinations.

Table 15. Mean values of seven korerima clusters for different characters

| characters | Cluster | | | | | | |
|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII |
| Plant Height (cm) | 126.79 | 116.72 | 116 | 98 | 110.36 | 120.5 | 113.50 |
| Number of capsule bearing sucker per plant | 2.91 | 3.22 | 2.91 | 3.11 | 3.11 | 2.98 | 2.82 |
| Internodes length | 9.27 | 9.02 | 8.33 | 6.42 | 8.01 | 8.77 | 8.35 |
| Number of leaves per plant | 3.48 | 3.31 | 3.12 | 3.00 | 3.25 | 3.29 | 3.55 |
| Leaf area ($cm^2$) | 159.67 | 143.63 | 155.3 | 120.06 | 147.95 | 164.5 | 162.32 |
| Number of capsule per plant | 2.55 | 2.57 | 2.69 | 2.58 | 2.54 | 2.55 | 2.38 |
| Fresh capsule diameter (cm) | 2.65 | 2.64 | 2.96 | 2.54 | 2.78 | 4.28 | 2.79 |
| Fresh capsule length (cm) | 4.32 | 4.36 | 4.82 | 4.39 | 4.53 | 3.88 | 4.38 |
| Fresh capsule weight (g) | 17.67 | 18.41 | 19.9 | 14.3 | 13.39 | 16.5 | 11.54 |
| Dry capsule diameter (cm) | 1.70 | 1.76 | 1.64 | 1.60 | 1.92 | 1.8 | 1.43 |
| Dry capsule length (cm) | 3.80 | 3.88 | 1.68 | 3.71 | 2.31 | 3.28 | 2.39 |
| Dry capsule weight (g) | 3.47 | 4.36 | 4.63 | 2.54 | 2.43 | 3.07 | 1.89 |
| Dry capsule yield (kg/ plot) | 4.06 | 6.08 | 7.12 | 3.08 | 2.73 | 3.25 | 1.70 |
| Dry capsule yield (kg $ha^{-1}$) | 507.72 | 760.31 | 889.85 | 384.72 | 341.79 | 406.68 | 212.54 |
| Number of seed per capsule | 3.36 | 3.48 | 3.32 | 3.39 | 3.51 | 3.4 | 3.24 |
| Total seed weight per capsule (g) | 2.03 | 2.89 | 2.83 | 1.74 | 1.61 | 1.73 | 1.04 |
| Seed yield (kg per plot) | 0.72 | 1.08 | 1.27 | 0.55 | 0.49 | 0.58 | 0.32 |

# 5. SUMMARY AND CONCLUSIONS

Korerima [*Aframomum corrorima* (Braun) P.C.M. Jansen] is an indigenous and important cash crop having a good export potential. However, the genetic diversity of this crop is less studied. In addition, korerima is known as having slow seed germination and subsequent seedlings growth and most of seeds not germinate due to the presence of some kind of dormancy, possibly it associated with the hard seed coat and low food reserve in the seed endosperm.

Effect of priming on seed germination of korerima and genetic variation among genotypes and have not been well studied. Therefore, this study was conducted with the objectives to evaluate the effect of seed priming on seed germination and genetic diversity, heritability, genetic advance, associations characters, yield and yield related characters

The data generated from the two set experiments were subjected to analysis of variance and genetic analyses. The analysis of variance showed significant differences among genotypes for seed germination quality characters and genetic variability parameters.

The unprimed seed germination ranged from 46.67 to 73.33% with mean values of 57.37% and the speed of seed germination for 25 genotypes varied from 2.83 to 4.45 with mean value of 3.45. The genotypes also exhibited wide variation for other seed germination quality parameters.The genotype,093/00 had significantly highest seed germination percentage and speed of germination, whereas 059/03 had significantly lowest seed germination percentage and speed of germination.

Seed priming experiment conducted using 093/00 and 059/03 showed that the interaction of genotype x priming x priming duration had significant effect on seeds germination in percent, speed of germination, seedling vigor index I and II. The possible two factors interactions (genotype x priming, genotype x duration of priming and priming x duration of priming) had significant effects on varied number of seed quality parameters. Generally the priming of

seeds had significant effect on all the seed quality characters and the two genotypes respond differentially for priming materials and duration of priming.

Generally, seed priming significantly improved the seed quality of the two korerima genotypes (093/00 and 059/03) with varied magnitude of improvement in which the germination and speed of germination of seeds improved by about 11.62% to 41.99% and 1.16 to 3.57, respectively. The normal seedlings increased by about 5.61% to 18.24%, while fresh ungerminated and dead seeds significantly reduced by about 14.33 to 15.87%% and 1.75% to 4.59%, respectively, as compared to unprimed ones. Priming seeds with $GA_3$ and cow urine significantly improved the seed quality of korerima more than priming seeds with distilled water; $KNO_3$ (0.2%); $KH2PO_4$ (0.5%), tap water.

The genotypic coefficient of variation (GCV) ranged from 0.49% to 35.57% while phenotypic coefficient of variation (PCV) ranged from 0.93% to 64.38%. Phenotypic coefficient of variation values were generally higher than their corresponding GCV values for all characters indicating the higher influence of environment on the expression of these characters in genotypes. Both PCV and GCV values were high for number of capsule bearing suckers per plant, dry capsule diameter, and pure seed yield in (kg) per plot, while, internodes length (cm), dry capsule length (cm) and dry capsule weight (g) had high PCV values.

Heritability values were high for number of capsule bearing suckers per plant (89.8%) , number of capsule per plant (92.31%), dry capsule diameter (82.22%) and number of seed per capsule (80%), while genetic advance as percent of mean were also high for leaf area (46.6%), number capsule per plant (23.65%), dry capsule diameter (33.77%), dry capsule yield kg $ha^{-1}$(81.4) and pure seed yield in kg per plot. The estimates of genetic variability components suggested selection will be fairly easy and efficient to this characters.

Pure seed yield per plot had positive and significant correlation both at genotypic and phenotypic levels with number of capsule bearing suckers per plant, number of capsules per plant, dry capsules weight, number of seeds per capsule, total seeds weight per capsule, dry capsule yield per plot and dry capsule yield $ha^{-1}$. The results suggested the selection of

genotypes for high mean values for these characters is the simultaneous selection of genotypes for dry capsule yield.

The genetic distances of 25 korerima of genotypes varied from 2.53 to 10.8 with a mean distance of 5.66 and standard deviation of 1.23. The genetic distances have been used to construct dendrograms based on UPGMA clustering method in which the genotypes were grouped into seven distinct clusters

Priming with $GA_3$ and cow urine significantly improved the seed germination of korerima and the magnitude of improvement was depending on the genotypes response to the priming material types and duration of priming. The conclusion could be made based on the results obtained from the two sets of experiments that priming with GA3 and cow urine improve seed germination and genotypes tested during this experiment had showed wide range of variation for yield and yield related characters. The genotypes were diverse with wide range of genetic distances and distinguished by one or more characters than others.

However, it is hardly possible to consider this recommendation is conclusive since the experiments were conducted for one season at one location. The seed priming experiment was conducted using only two genotypes having contrasting mean performances for seed quality parameters. Therefore, it is recommended to evaluate the genotypes for more one season before to progress the genotypes to the next step breeding activity. It is also necessary to conduct the seed priming experiment once more by including genotypes with varied seed quality performance to make a final recommendation for korerima growers.

# 6. REFERENCES

Abebe sori, R.P.S.Tomer and Asnake Fikre. 2011.Effect of hydro and osmo priming on seed quality and yield of chickpea (*Cicer arietinum* **l.).** MSc. Thesis, Haramaya University, Haramaya, Ethiopia.

Abraham Tesema. 2012. The effects of different stages of harvesting and seed priming on seed quality of pepper (*capsicum annuum* l.). MSc. Thesis, Haramaya University, Haramaya, Ethiopia.

Adefris Teklewold. 2012. Diversity study based on quality characters and RAPD markers and investigation of heterosis in Ethiopian mustard. Doctoral Dissertation, George-August University, Germany.

Adityal, J.P., Pushpendra,P., Bhartiya, B., Anuradha H., Bhartiya. 2011. Genetic variability, heritability and character association for yield and component characters in soybean (*G. max* (L.). *Journal of central European*, 12(1), p.27-34.

Akanda, S.I. and. Mundt, C.C. 1996. Path coefficient analysis of the effects of strip rust and cultivar mixtures on yield and yield components of winter wheat. Theory andAppllication Genet. 92: 666-672.

Allard, R.W.1999. *Principles of Plant Breeding, 2nd ed.* John Willey and Sons Inc, New York, London, 96p.

Allard, R.W. 1960. Principles of Plant breeding. John Wiley and Sons inc., New York. 485p.

Amarnath, B. H., Chaurasia A. K., Arvind, K., Niranjana, C., Vivekanad, V. and Ashish, K. 2015. Effect of priming with botanicals and animal waste on germination and seedling vigour in sorghum (*Sorghum bicolor* L.) seeds. *Advances in Applied Science Research*, 6(10):73.

Ansari, O., Azadi, M.S., Sharif-Z., F., Younesi, E. 2013. Effect of hormone priming on germination characteristics and enzyme activity of mountain rye (*Secale montanum*) Seeds under drought stress conditions. *Journal of stress physiology & biochemistry*, vol. 9 no. 3 2013, pp. 61-71 ISSN1997-0838.

Armin, M. Asgharipour M. and M. Razavi-Omrani. 2010. Effect of seed priming on the Germination and Seedling growth of watermelon (*Citrullus lanatus). Advances in Environmental Biology.* 4(3):501-505.

Ashok, A. Patil. 2008. Studies on correlation, path analysis, genetic divergence, heterosis and combining ability in ten parent diallel cross of tomato (*Lycopersicum esculentum* Mill.). Ph.D. Thesis, Uni. Agric. Sci., Dharwad (India).

Bahari, A., Sharif-Zadeh, F., Ardekani, M.2012.Effect of priming treatments on germination characteristics and seedling establishment *Bromuvs tumentlus* germination under drought and cold. finishing a master 260 pages.

Brikti Ferede. 2011. Seed system and quality analysis of groundnut (*Arachis hypogaea* l.), in Babile woreda,Eastern Ethiopia. M.Sc. Thesis, Haramaya University, Haramaya, Ethiopia.

Burton, G.W. and E.H., De Vane. 1953. Estimating heritability in Tall Fescue (*Festuca arundinacea*) from replicated clonal material. *Agronomy Journal*, 45: 481-487.

Crossa, J.D. and S., Taba.1995. The use of multivariate methods in developing a core collection.Pp.77-92 In: Hodgkm, J., Brown, A .H.D., Van Hintum, and Morals, E.A.V (eds.) Core Collections of Plant Genetic Resources. John Wiley and Sons, Chinchester.

Cvikic, D., Zdravkovic, J. Momirovic, G.S. Susic, Z. and Dordevic, R. 1999. Inheritance mode and phenotypic variability for fruit firmness in nor and rin tomato genotypes. Genetica 31(2): 107-114.

Dabholkar, A.R. 1992. Elements of Biometrical Genetics. Shock Kumar Mittal Concept publishing company. New Delhi, India. 213p.

Deshmukh, S.N., Basu, M.S. and P.S. Reddy.1986. Genetic variability, characterassociation and path coefficient analysis of quantitative characters in Virginia bunch varieties ofgroundnut. *Indian Journal of Agricultural science* 56:816-821.

Dewey, D.R and K.H. Lu.1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Journal of Agronomy*. 51: 515-558.

Eyob Seyifu, 2009. Promotion of seed germination, subsequent seedling growth and in vitro propagation of korerima*(Aframomum corrorima* (Braun) P.C. M. Jansen). *Journal of Medicinal Plant Resources*, 3: 652-659.

Eyob Seyifu, Tsegaye A. and Appelgren, A. 2009. Analysis of korerima (*Aframomum corrorima* (Braun) P.C.M. Jansen) indigenous production practices and farmbased biodiversity in southern Ethiopia. Genetic Resources Crop Evolution, 56: 573-585.

Falconer, D.S., Mackay, T.F.C.1996. *Introduction to Quantitative Genetics. 4th ed*. Longman, Susex, England.

Fiala, F. 1987. *Handbook of vigour test methods, ISTA publication, and second edition*. Zuerich, Swzerland.

Girma Hailemichael, Digafie Tilahun, Edossa Etissa, Belay Yemanebirhan and Weyessa Garedew. 2008. Spices research achievements, revised edition, Ethiopian Institut of Agricultural Research, Addis Ababa, Ethiopia.

Gomez, A.K. and A. A. Gomez. 1984. *Statistical procedures for agricultural research. 2nd ed.* Wilney Int. Sci., New York. 680p.

Gopal, R., Chandramony, D. and Nayar, N.K. 1989. Genetic basis of yield and yield component in Cardamom (*Elettaria cardamom* maton). *Journal of Plantation Crops*, 20:230-232.

Hikmat, U.J., Malik, A. and Zabta, K.S. 2012. Estimation of Genetic Variability In Turmeric (*Curcuma Longa* L.) Germplasm Using Agro-Morphological characters. *Pakistan Journal Botany*. 44: 231-238.

Islam, K. M. A., M. G. Rasul., N. Sultana. and M. A. Mian. 2008. Genetic Variability and Character Association in Ginger (*Zingiber officinale* Rosc.). Ann. Bangladesh Agric. (2008) 12(1):3-6.

ISTA. 2014. International Seed Testing Association. International rule for seed testing. Bassersdorf, Switzerland.

Jansen, P.C.M. 2008. *Aframomum corrorima* (Braun). *South African Journal of Botany*,74(I): 181-185.

Johnson, R. and Wichern, D.W. 1992. *Applied Multivariate Statistical Analysis, 2nd ed*. Prentice Hall. New York.Pp:607.

Kandil, A.A., Shareif. A.E, Abu Zaied,T.A. and Moussa A.G.T. 2012. Multivariate Analysis of Some Economic Characters in Flax. *Pakistan Journal of Biological Science*, 15(2): 85- 91.

Kaufman, L. and P.J. Rousseun. 1990. Finding groups in data. An introduction to cluster analysis. A Wiley-Interscience Publication, New York.

Kausar, M., T. Mahmood, S.M.A. Basra and M. Arshad. 2009. Invigoration of low vigor sunflower hybrids by seed priming. *International Journal of Agricultural Biology.* 11: 521–528.

Liopa, A., Zakynthinos, G., Varzakas, T., Nickolaos Xynias. 2011. Effect of NaCl and GA3 on seed germination and seedling growth of eleven medicinal and aromatic crops. *Journal of Medicinal Plants Research* 5(17): 4065-4073.

Maguire, J.D. 1962. Speed of germination aid in selection and evaluation for seedlingsemergence and vigor. Crop Science, 2: 176-177. Mg (NO3)2. Annual Agricultural Research. 5:11-16.

Mahmoudi, H., Zargouni, H., Tarchoune, I., Baatour, O., Nasri, N., Ben Massoud, R., Zaghdoudi, M., Abidi, W., Huang, J., Hannoufa, A., Lachaâl, M., Ouerghi, Z. 2012. Combined effect of hormonal priming and salt treatments on germination percentage and antioxidant activities in lettuce seedlings. African *Journal of Biotechnolog*y, 11(45): 10373-10380.

Momina Argaw, Sinatayew A, Girma Hailemichael and Abush Tesfaye. 2011. Variability of ginger (Zingibir *officinal*e Rosc.). Genotypes for Some Morphological and Quality Cs in Ethiopia. *International Journal of Agricultural Research*, 6(6): 444-457.

Nasri, N., Mohamoudi, H., Baatour, O., Mrah, S., Kaddor, R. and Lacha, M. 2012. Effect of exogenous gibberellic acid on germination, seedling growth and phosphatase activities in Lettuce under salt stress. *Africa Journal Biotechnology* 11:11967-11971.

Nei, M. 1978. Estimation of average heterozygosity and genetic distance from small number of individuals. Genetics 89: 583-590.

Piem, K. 2010. Top three Ethiopian spices. Internet document: www.ehow.com › Food & Drink › Herbs and Spices › Blend Spices, accessed on February 11, 2010.

Sandipan Chowdhury, Animesh K., Datta V., Aditi Saha, Sonali Sengupta, Rita Paul, SusmitaMaity and Ananya Das. 2010. Characterss influencing yield in sesame (*Sesamum indicum*. L.) andmultilocational trials of yield parameters in some desirable plant types. *Indian Journal Science Technology*,3: 163-166.

SAS Institute Inc. 2001. Statistical Analysis Systems, version 9.1.Cary, North Carolina, USA.

Sharma, H.R. 2010. Genetic variability, correlation and path coefficient studies in tomato *(Lycopersicon esculentum* Mill.) under cold arid region. *Progress Horticulture.*37 (2): 437-443.

Sharma, H.R., Sharma, D. and Thakur, A.K. 2009. Studies on analysis of genetic divergence in tomato (*Lycopersicon esculentum* Mill.). *Jounal of Horticultural Sciences*1 (1): 52-54.

Simegn Kinfu, Sentayehu Alamerew and Melaku Addisu. 2016. Genetic diversity studies on yield and its related characters in korerima [*Aframomum corrorima* (Braun) Jansen], germplasms. *Journal of Biology, Agriculture and Healthcare,* Vol.6, No.3.

Simegn Kinfu, Sentayehu Alamerew and Melaku Addisu. 2012. Genetic diversity studies on yield and its related traits in korarima [*Aframomum corrorima* (Braun) Jansen], germplasms. M.Sc. Thesis. Ambo University, Ambo, Ethiopia

Singh, A.K. 2009. Genetic variability, correlation and path coefficient studies in tomato *(Lycopersicon esculentum* Mill.) under cold arid region. *Progress Horticulture.*37 (2): 437-443.

Singh, R.K. and B.D. Chaudhary. 2001. *Biometrical Methods in Quantitative Genetic Analysis. 3rd Edition.* Kalyani Publishers, New Delhi. pp. 135-255.

Singh, R.K. and B.D. Chaudhary. 1985. Biometrical Methods in Quantitative Genetics Analysis, Kalyani publishers, New Delhi. 318p.

Surawit, W. and Wondyifraw Tefera. 2013. In Vitro Chromosome Doubling in Korerima [*Aframomum corrorima* (Braun) P.C.M. Jansen] Using Colchicine and Oryzalin. Asetsart J. (Nat. Sci.) 47: 684 - 694.

TNSRC (Tepi National Spices Research Centre). 2016. National research strategy for spices plants. Tepi, Ethiopia. Ethiopia.

Umair, M., Ali, S., Bashir, K. and Hussein, S. 2010. Evaluation of different seed priming techniques in mung bean (*Vigna radiata* L.). *Soil and Environment*. 29(2):181-186.

Verma, P.S and Agrawal, V.K. 1982. Genetics. South Chanda and Co.Ltd; Ram Nagar, New Delihi, pp: 555.

# 7. APPENDICES

Table 1. Mean values of various korerima genotypes for different growth characters as evaluated at Tepi

| Genotypes code | PH | Number of capsule bearing sackers per plant | Internodes length | Number of leaf per plant | Leaf area | Number of sacker per plant | Fresh capsule diameter |
|---|---|---|---|---|---|---|---|
| 053/03 | 118.40 | 2.65 | 8.02 | 3.46 | 155.20 | 2.49 | 2.60 |
| 046/03 | 135.50 | 3.26 | 7.52 | 3.81 | 151.50 | 2.71 | 2.78 |
| 114/03 | 128.30 | 3.04 | 9.25 | 3.31 | 160.40 | 2.60 | 2.73 |
| 029/84 | 120.50 | 2.98 | 9.25 | 3.29 | 164.50 | 2.55 | 4.28 |
| 038/01 | 121.50 | 3.16 | 8.71 | 3.42 | 127.00 | 2.44 | 2.61 |
| 045/03 | 117.50 | 2.67 | 7.25 | 3.76 | 155.20 | 2.50 | 2.67 |
| 021/00 | 104.00 | 3.03 | 8.20 | 3.16 | 129.600 | 2.68 | 2.50 |
| 015/03 | 92.00 | 3.19 | 5.38 | 2.84 | 110.40 | 2.48 | 2.59 |
| Jimma local | 132.50 | 2.82 | 8.80 | 3.43 | 179.30 | 2.37 | 2.61 |
| 686/87 | 123.80 | 2.82 | 7.55 | 3.60 | 165.00 | 2.61 | 2.40 |
| 001/00 | 132.60 | 2.89 | 10.85 | 3.46 | 157.40 | 2.33 | 2.73 |
| 093/00 | 114.60 | 3.24 | 7.95 | 3.36 | 152.90 | 2.56 | 2.95 |
| BM31/03 | 118.50 | 2.77 | 6.78 | 3.70 | 165.60 | 2.44 | 2.64 |
| 028/84 | 97.50 | 2.99 | 6.05 | 3.00 | 133.90 | 2.50 | 2.67 |
| 701/87 | 116.00 | 2.91 | 7.95 | 3.12 | 155.30 | 2.69 | 2.96 |
| 68/87 | 119.00 | 3.11 | 9.00 | 3.40 | 157.00 | 2.57 | 2.73 |
| 25/03 | 108.50 | 2.87 | 7.25 | 3.40 | 159.00 | 2.32 | 2.95 |
| BM34/03 | 136.00 | 3.04 | 8.78 | 3.41 | 164.70 | 2.77 | 2.66 |
| 059/03 | 131.00 | 3.31 | 8.30 | 3.34 | 155.50 | 2.73 | 2.75 |
| 018/00 | 135.80 | 3.28 | 10.30 | 3.25 | 145.10 | 2.59 | 2.63 |
| 016/84 | 106.40 | 3.08 | 8.05 | 3.25 | 137.60 | 2.55 | 2.43 |
| 009/00 | 120.50 | 3.33 | 8.90 | 3.41 | 152.60 | 2.68 | 2.58 |
| 105/03 | 115.90 | 2.54 | 9.05 | 3.50 | 158.60 | 2.61 | 2.62 |
| 010/00 | 104.20 | 3.24 | 8.70 | 3.15 | 145.20 | 2.46 | 2.85 |
| 011/00 | 118.40 | 3.04 | 8.50 | 3.33 | 163.60 | 2.52 | 2.70 |
| Mean | 118.75 | 3.01 | 8.25 | 3.37 | 152.10 | 2.55 | 2.74 |
| LSD (p<5%) | 31.57 | 0.47 | 4.61 | 0.71 | 32.88 | 0.28 | 0.8 |

LSD (p<5%) =least significant difference at P<0.05

Table 2. Mean values of various korerima genotypes for capsule yield and yield component as evaluated at Tepi

| Genotypes | Fresh capsules length | Fresh capsule weight | Fresh capsule weight | Dry capsule length | Dry capsules weight | Dried capsule yield (kg per plot) | Dried capsule yield kg $ha^{-1}$. |
|---|---|---|---|---|---|---|---|
| 053/03 | 4.30 | 22.22 | 1.93 | 3.55 | 3.96 | 3.73 | 466.05 |
| 046/03 | 4.53 | 18.97 | 1.67 | 3.84 | 2.65 | 2.90 | 362.84 |
| 114/03 | 4.25 | 19.11 | 1.83 | 3.77 | 4.47 | 4.45 | 555.78 |
| 029/84 | 3.88 | 17.82 | 1.80 | 3.28 | 3.07 | 3.25 | 406.68 |
| 038/01 | 4.47 | 16.45 | 1.70 | 3.70 | 3.23 | 4.42 | 552.2 |
| 045/03 | 4.39 | 16.61 | 1.56 | 4.00 | 2.92 | 3.37 | 421.74 |
| 021/00 | 4.23 | 18.19 | 1.66 | 3.64 | 2.45 | 2.64 | 329.79 |
| 015/03 | 4.55 | 17.42 | 1.54 | 3.78 | 2.63 | 3.52 | 439.66 |
| Jimma local | 4.11 | 15.55 | 2.09 | 3.67 | 3.09 | 3.06 | 382.09 |
| 686/87 | 4.10 | 18.11 | 1.52 | 3.47 | 3.41 | 4.00 | 500.05 |
| 001/00 | 4.27 | 16.63 | 1.67 | 3.93 | 3.19 | 3.96 | 495.43 |
| 093/00 | 4.73 | 20.38 | 1.69 | 3.76 | 1.95 | 2.49 | 311.30 |
| BM31/03 | 4.43 | 17.46 | 1.47 | 3.55 | 1.71 | 1.77 | 221.44 |
| 028/84 | 4.71 | 15.68 | 1.97 | 1.66 | 3.14 | 3.10 | 387.48 |
| 701/87 | 4.82 | 21.66 | 1.64 | 1.68 | 4.63 | 7.12 | 889.85 |
| 68/87 | 4.17 | 17.98 | 2.12 | 1.52 | 2.21 | 2.61 | 326.59 |
| 25/03 | 4.33 | 20.44 | 1.4 | 1.23 | 2.08 | 1.63 | 203.6 |
| BM34/03 | 4.29 | 19.16 | 1.65 | 3.95 | 3.63 | 5.62 | 702.49 |
| 059/03 | 4.84 | 18.97 | 1.73 | 3.91 | 4.86 | 7.37 | 921.83 |
| 018/00 | 4.66 | 18.53 | 1.54 | 3.66 | 3.12 | 3.73 | 466.45 |
| 016/84 | 4.19 | 17.52 | 1.75 | 3.96 | 4.41 | 5.82 | 727.08 |
| 009/00 | 4.34 | 16.37 | 1.84 | 4.09 | 4.85 | 5.79 | 723.44 |
| 105/03 | 4.36 | 15.98 | 1.52 | 4.00 | 3.67 | 4.94 | 617.00 |
| 010/00 | 3.97 | 20.60 | 1.79 | 3.75 | 4.47 | 7.02 | 877.04 |
| 011/00 | 4.30 | 17.48 | 1.76 | 3.94 | 4.02 | 4.92 | 615.00 |
| Mean | 4.37 | 18.21 | 1.71 | 3.41 | 3.35 | 4.13 | 516.12 |
| LSD(P<0.05) | 0.66 | 7.08 | 0.53 | 1.81 | 1.92 | 0.87 | 8.57 |

LSD (p<5%) =least significant difference at P<0.05

Table 3. Mean values of various korerima genotypes for seed yield and related traits

| Genotypes | Total seeds weight per capsule (g) | seed yield per plot (kg) | Number of seeds per capsule (g) |
|---|---|---|---|
| 053/03 | 2.39 | 2.25 | 3.57 |
| 046/03 | 1.67 | 1.88 | 3.34 |
| 114/03 | 2.78 | 2.83 | 3.35 |
| 029/84 | 1.73 | 1.85 | 3.40 |
| 038/01 | 2.65 | 3.64 | 3.34 |
| 045/03 | 1.73 | 2.00 | 3.30 |
| 021/00 | 1.95 | 2.10 | 3.30 |
| 015/03 | 1.54 | 2.06 | 3.49 |
| Jimma local | 1.79 | 1.77 | 3.44 |
| 686/87 | 2.09 | 2.45 | 3.24 |
| 001/00 | 2.08 | 2.58 | 3.41 |
| 093/00 | 1.55 | 2.03 | 3.59 |
| BM31/03 | 0.91 | 0.93 | 3.33 |
| 028/84 | 1.88 | 1.85 | 3.48 |
| 701/87 | 2.83 | 4.34 | 3.32 |
| 68/87 | 1.41 | 1.67 | 3.46 |
| 25/03 | 1.17 | 0.91 | 3.15 |
| BM34/03 | 1.53 | 2.57 | 3.31 |
| 059/03 | 3.26 | 4.94 | 3.60 |
| 018/00 | 1.80 | 2.16 | 3.29 |
| 016/84 | 2.69 | 3.57 | 3.56 |
| 009/00 | 3.10 | 3.80 | 3.48 |
| 105/03 | 2.23 | 2.97 | 3.29 |
| 010/00 | 2.76 | 4.35 | 3.43 |
| 011/00 | 2.29 | 2.80 | 3.47 |
| Mean | 2.07 | 2.56 | 3.40 |
| LSD(P<0.05) | 0.58 | 0.61 | 0.29 |

LSD (P<0.05) =least significant difference at P<0.05

Table 4. Mean squares from analysis of variance for ten seed physiological quality characters of various korerima genotypes evaluated at Tepi

| Seed quality character | Genotype (24) | Error (50) | CV (%) |
|---|---|---|---|
| Standard germination (%) | 0.77* | 0.70 | 11.08 |
| Speed of germination | 0.48* | 0.039 | 10.73 |
| Seedling length (cm) | 4.76** | 0.11 | 7.67 |
| Seedling dry weight (g) | 0.012* | 0.011 | 5.83 |
| Seedling vigor inde I | 29.1** | 2.96.73 | 10.98 |
| Seedling vigor inde II | 0.677* | 0.365 | 12 |
| Normal seedling | 0.027* | 0.026 | 5.96 |
| Abnormal seedling | $0.038^{ns}$ | 0.05 | 11.27 |
| Fresh ungerminating seed | 0.044* | 0.030 | 7.49 |
| Dead seed | 0.051* | 0.038 | 12.38 |

ns, * and **, insignificant, significant at $P<0.05$ and $P<0.01$, respectively, CV (%) = coefficient of variation in percent, Numbers in parenthesis represent degree of freedom

Table 5. Mean performance value of various unprimed korerima genotypes seed quality test result at Tepi

| Genotype | standard germination (%) | speed of germination | seedling length (cm) | seedling dry weight (g) | seedling vigor index I | seedling vigor index II | normal seedling | abnormal seedling | fresh ungerminated se | dead seed |
|---|---|---|---|---|---|---|---|---|---|---|
| 053/03 | 63.33ab | 3.75a-d | 3.92hi | 0.87bc | 248.2e-h | 55.29a-e | 44.33a-d | 19.40ab | 28.89c-f | 7.34a-e |
| 046/03 | 51.33ab | 3.01cd | 5.04de | 0.94a | 2.58efgh | 48.64b-f | 32.33b-e | 19.46a | 42.2a-c | 6.00b-e |
| 114/03 | 56.67ab | 3.37a-d | 4.11gh | 0.85bc | 258.61f-j | 48.54b-f | 37.66a-e | 18.70ab | 37.27a-f | 6.34a-e |
| 029/84 | 48.33b | 2.91b | 3.10de | 0.85c | 116.1 1 | 41.25d-f | 29.33c-e | 18.6ab | 48.06a | 4.00c-e |
| 038/01 | 59.33ab | 3.53a-d | 6.07a | 0.88bc | 360.2b-d | 52.21a-f | 40.33a-e | 19.40ab | 34.64a-f | 5.66b-e |
| 045/03 | 69.33ab | 4.10ab | 5.30ed | 0.87bc | 371.62bc | 60.6ab | 50.33a | 18.27b | 23.37f | 8.01a-e |
| 021/00 | 58.67ab | 3.57a-d | 3.78kl | 0.87bc | 161.64j-l | 51.06a-f | 39.66a-e | 18.68ab | 33.98a-f | 7.66a-e |
| 015/03 | 50.67ab | 3.07bcd | 3.40hij | 0.85bc | 173.14i-l | 43.06c-f | 31.66b-e | 19.24ab | 40.41a-d | 8.67a-e |
| Jima local | 48.67b | 2.92cd | 4.82ef | 0.84c | 236.54f-i | 41.36d-f | 29.66d-e | 19.24ab | 41.42a-d | 9.66a-d |
| 686/87 | 49.70b | 2.97cd | 3.13jk | 0.86bc | 156.53kl | 42.71c-f | 30.66b-e | 19.29ab | 39.05a-d | 10.90ab |
| 001/00 | 50.00 b | 2.97cd | 5.26l | 0.85c | 111.65l | 42.5c-f | 31.00b-e | 18.99ab | 39.35a-d | 10.7a-c |
| 093/00 | 73.33a | 4.45a | 6.11a | 0.87bc | 448.55a | 64.29a | 54.33a | 18.57ab | 24.43ef | 2.65e |
| BM31/03 | 62.67ab | 3.77a-d | 5.86abc | 0.87bc | 368.6bc | 54.52a-f | 43.66a-d | 18.48ab | 31.51b-f | 6.33a-e |
| 028/84 | 52.00ab | 3.02bcd | 3.80kl | 0.91ab | 237.95e-i | 40.42e-f | 27.66de | 19.29ab | 44.35ba | 12.35a |
| 701/87 | 56.67ab | 3.29bcd | 3.87hi | 0.88bc | 220.1f-k | 49.86a-f | 37.66a-e | 19.03ab | 34.96a-f | 8.33a-e |
| 68/87 | 64.00ab | 3.84a-d | 5.33cde | 0.87bc | 345.6b-d | 56.4a-d | 45.66a-c | 19.15ab | 27.84d-f | 7.34a-e |
| 25/03 | 62.67ab | 3.81ab | 5.88abc | 0.86bc | 371.42bc | 54.12a-f | 43.66a-d | 19.29ab | 30.35c-f | 6.68a-e |
| BM34/03 | 57.33ab | 3.43a-d | 5.38bcd | 0.86bc | 307.9c-e | 49.48a-f | 38.33a-e | 18.96ab | 38.04a-d | 4.66c-e |
| 059/03 | 46.67b | 2.83d | 2.38l | 0.86bc | 122.96i | 39.79f | 42.00a-d | 19.07ab | 26.27df | 8.99a-d |
| 018/00 | 65.33ab | 3.95abc | 5.10de | 0.87bc | 333.6b-d | 57.06a-c | 46.33a-c | 18.96ab | 31.04b-f | 3.66de |
| 016/84 | 64.00ab | 3.84a-d | 4.49fg | 0.86bc | 287.4d-f | 55.24a-e | 45.00a-c | 18.75ab | 29.57c-f | 6.67a-e |
| 009/00 | 57.30ab | 3.46a-d | 3.16jk | 0.85c | 182.2h-l | 48.73b-f | 38.33a-e | 19.17ab | 35.48a-f | 7.01a-e |
| 105/03 | 50.67ab | 2.99cd | 2.97jk | 0.88bc | 156.45kl | 43.80c-f | 31.66b-e | 19.34ab | 42.30a-c | 6.68a-e |
| 010/00 | 66.00ab | 3.96abc | 5.96a | 0.87bc | 393.8ab | 57.40a-c | 47.00ab | 19.26ab | 27.72d-f | 6.01b-e |
| 011/00 | 58.00ab | 3.47a-d | 3.47hi | 0.86bc | 198.8g-k | 49.88a-f | 39.00a-e | 19.07ab | 36.92a-f | 56.00b-e |
| CV (%) | 6.26 | 7.48 | 9.79 | 8.97 | 12.83 | 12.33 | 9.27 | 8.33 | 9.36 | 7.70 |
| LSD(P<0. | 18.61 | 1.08 | 1.05 | 0.05 | 0.77 | 0.16 | 1.17 | 1.17 | 1.30 | 1.07 |

Means with similar letter(s) in a column are not significantly different, LSD (P<0.05) =least significant difference at P<0.05

Table 6. Mean squares from analysis of variance for seed quality characters as affected by seed priming of two korerima genotypes evaluated at Tepi

| Seed quality character | Genotype (1) | Priming (5) | duration (2) | Genotype*Priming (5) | Genotype *Duration (2) | Priming * duration (10) | Genotype *priming *duration (10) | Error (72) | CV (%) |
|---|---|---|---|---|---|---|---|---|---|
| Standard germination (%) | 2.1$^{ns}$ | 958** | 129** | 101*** | 17.4ns | 233** | 39.3** | 21.75 | 6.26 |
| Speed of germination | 0.04ns | 5.4*** | 1.15** | 0.6*** | 0.18ns | 1.18** | 0.26** | 0.13 | 7.48 |
| Seedling length (cm) | 3.83** | 0.99** | 0.11ns | 0.19* | 0.34ns | 0.06ns | 0.20ns | 0.36 | 9.79 |
| Seedling dry weight (g) | 0.001ns | 0.004** | 0.001ns | 0.0003* | 0.002ns | 0.003ns | 0.002ns | 0.007 | 8.97 |
| Seedling vigour index I | 19460.8* | 62610.9** | 4738.2ns | 537.1$^{ns}$ | 4804.4** | 9072.7** | 2281.2* | 3478.7 | 12.83 |
| Seedling vigour index II | 8.18ns | 161** | 7.21ns | 11.2$^{ns}$ | 0.12** | 22.1** | 6.10* | 7.97 | 12.33 |
| Normal seedling | 1.02ns | 469.7*** | 63.4** | 4.7*** | 8.5.ns | 114.2** | 19.3* | 10.66 | 9.27 |
| Abnormal seedling | 0.18ns | 86.3*** | 11.6** | 9.1*** | 1.56ns | 20.9** | 3.53ns | 1.95 | 12.83 |
| Fresh ungerminating seed | 2.67ns | 241.4*** | 33.1** | 18.3*** | 2.39ns | 51.58** | 11.24ns | 7.15 | 15.36 |
| Dead seed | 1.61ns | 31.2** | 3.65* | 4.3*** | 1.15$^{ns}$ | 8.34** | 1.98ns | 7.61 | 7.7 |

ns, * and **, insignificant, significant at P<0.05 and P<0.01, respectively, CV (%) = coefficient of variation in percent, Numbers in parenthesis represent degree of freedom.

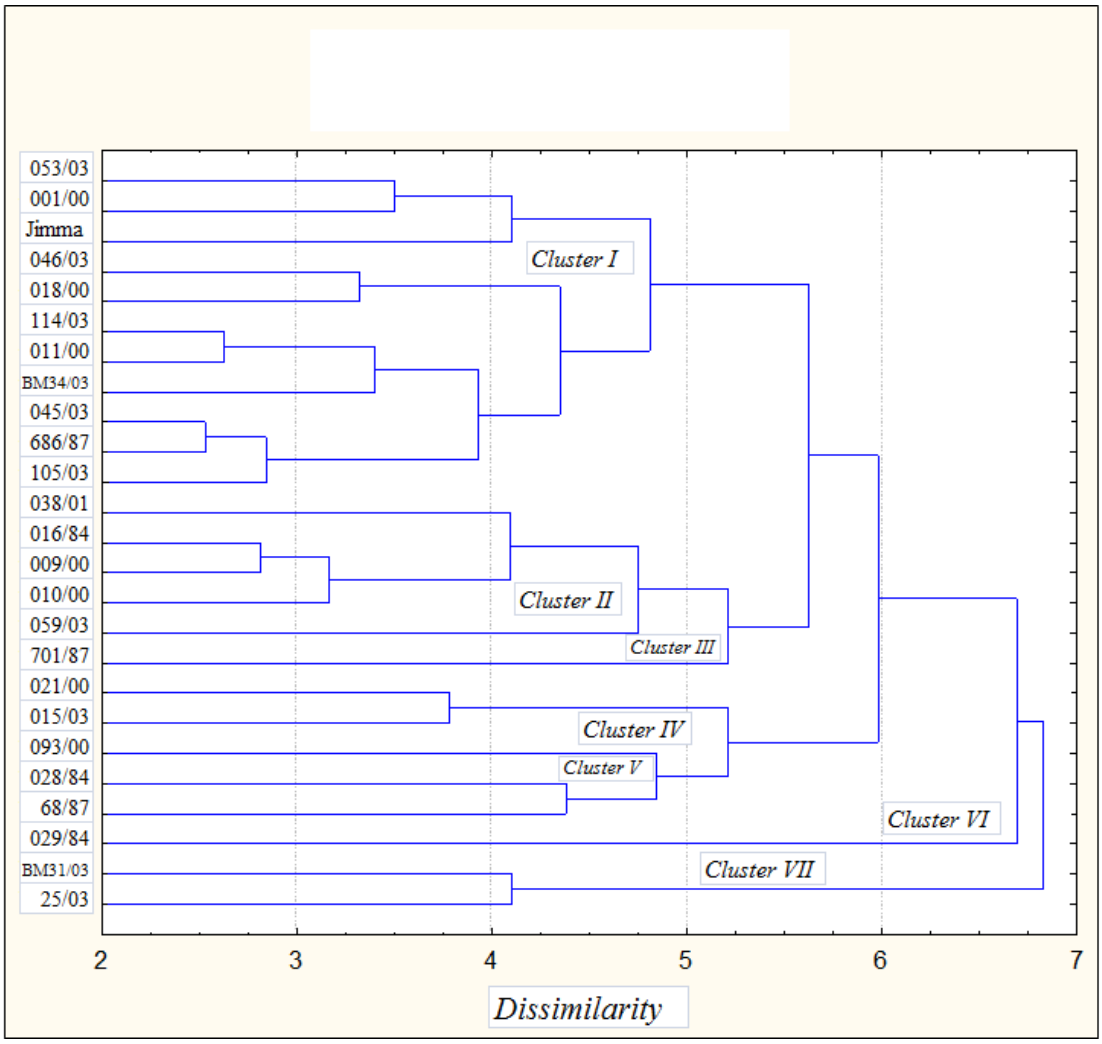
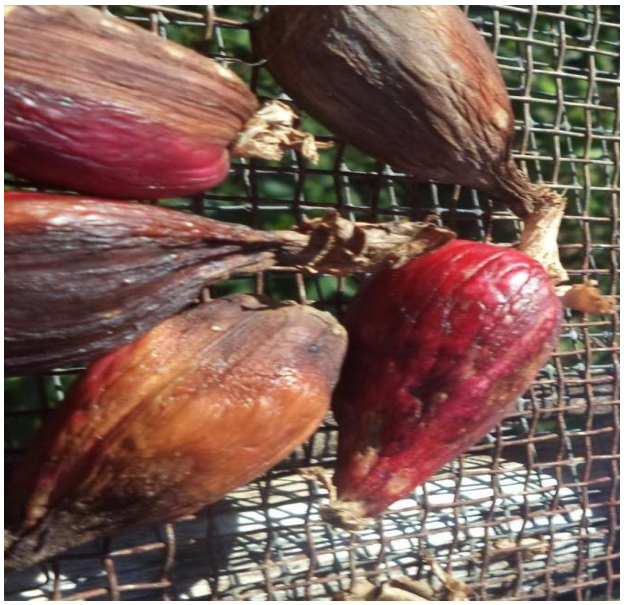



Figure 1. Dendrogram generated based on UPGMA clustering method depicting genetic relationships among various krerima collections based on different characters.

a) Dried korerima seed



b) Korerima capsule during drying

c) korerima seed in its capsule

Figure 2. Korerima capsule and seed pictures