ADDIS ABABA UNIVERSITY
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Morphological and biochemical diversity of emmer wheat (*Triticum dicoccum* (Schrank) Schub.) in Ethiopia

By

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Abstract

Morphological and isozyme diversity study of 55 emmer wheat (Triticum dicoccum (Schrank) Schub.) populations and the associated ethnobotanical knowledge in Arsi and Bale have been undertaken in this study. A total of 55 landrace populations (25-45 single plant per population which is a total of 1885 entries) were considered for morphological study. Protein content was determined for the 37 emmer wheat populations following the standard procedure. The dry matter, ash, organic matter and Ca were done for 55 emmer wheat population following the standard protocol. The isozyme variations in the three enzyme systems: esterase (EST), acid phosphatase (ACP) and aspartate aminotransferase (AAT) were investigated for 12 emmer wheat populations selected after clustering them on morphological characters.

Mean, coefficient of variations, heritability, genetic advance, correlation coefficients, cluster analysis, chi- square test, multidimensional scaling, and discriminant analysis were done for each morphological character. Correspondence analysis and Shannon's diversity index (H') were used to estimate the morphological variation. The coefficient of variation was large for most traits in Shewa indicating more diversity in this region. This was further confirmed by Shannon's diversity index where the mean diversity (H') was the highest in this region (0.78) followed by Harerghe and Gonder, the least diversity index was shown by Tigray region. H' at population level ranged from 0(monomorphic) to 1 (Polymorphic) for some traits. The overall mean diversity for Ethiopia was estimated to be H' = 0.75. Farmers in the study area assert that emmer wheat is morphologically uniform and this was confirmed through field observation. This crop has important traits in disease resistance, stress tolerance and traditional use values. Farmers in Arsi and Bale regions have their own folklore, songs, and sayings on this particular crop to indicate its use value *and problems related with its hulledness. Phenotypic polymorphism was observed for the three enzymes. Relatively higher variation was observed for esterase enzyme system and no variation was detected for enzyme system aspartate amino transferase (AAT). Positive (though not significant) correlation was observed between morphological diversity index and mean heterozygosity based on isozyme data.*

The Arsi and Bale area makes an important in-situ conservation site for emmer wheat because of the specialty of the crop to the society.

Key words: *Triticum dicoccum, emmer wheat diversity, morphological character, protein, isozyme, ethnobotany*

1. Introduction

A wide genetic base of germplasm is a prerequisite for the success of a plant-breeding program, and to cope with unforeseen challenges in a changing environment (Bechere *et al.*, 1996). Man's dependence on centers of genetic diversity for his plant and animal germplasm resources is becoming very acute because of the high rate of erosion of genetic variability and structure of landrace population (Bekele, 1983).

The valuable genetic diversity of several crops is under constant danger of being irretrievably lost due to natural calamities such as drought, replacement of the landrace by genetically uniform crop varieties and change and development in land use (Bekele 1985; Worede, 1988).

Emmer wheat (*Triticum dicoccum*) was domesticated in the Near East somewhere in the Fertile Crescent (Helbaek, 1959; Nesbitt and Samuel, 1996) and later was introduced to Ethiopia by early immigrants of Hamites, some 5,000 years ago (Helbaek, 1959).

Ethiopia has an amazing diversity of field crop varieties and the diversity expresses itself relatively under uniform ecological condition. In addition, there is a good wealth of botanical varieties of wheat (Vavilov, 1951). Even though emmer wheat was one of the ancient domesticated wheat, there was a decline of the production of emmer in areas of domestication. According to historians, archeologists and archeobotanists the decline was due to increase in salinization of irrigated fields, and replacement by barley and free threshing wheat (Nesbitt and Samuel, 1996).

Today, emmer is grown on a limited scale and comprises about 7 percent of Ethiopia's entire wheat production (BOSTID, 1996). But the broad genetic diversity of wheat is under the greatest threat due to new varietal influx (Mengesha, 1975).

The problem of threshability in emmer wheat remained a discouraging factor for its production. Furthermore, as indicated in the case of many crops, the cereal (bread wheat) extension program coupled with the absence of improved varieties for emmer wheat production is another factor leading to reduction of emmer production and improved varieties released actually reduce genetic resources. Thus, it becomes extremely important to maintain and conserve emmer wheat germplasm for further use in breeding program and genetic conservation of the crop.

Choice of sites for *in-situ* conservation may be dependent on high diversity estimate based on different markers. In addition, prior knowledge of the nature and extent of genetic variation is crucial for successful conservation (*in-situ* and *ex-situ*) and utilization of germplasm (Demissie, 1996; Tesemma and Belay, 1991). However, such data are not available for emmer wheat in Ethiopia. Hence, the study was carried out with the following objectives:

Objectives

The general objective of the study is to generate basic information on diversity covering various morphological and biochemical characters of emmer wheat landrace of Ethiopia and to document the associated farmers knowledge and perception in Arsi and Bale zones.

Specific objectives

- To make an inventory for the identification and description of each distinct landraces of emmer wheat and to compile the special agronomic and nutritional features based on farmer perceptions.
- To compile the special features of the crop in general and the specific landrace from collection of folklore (Songs, sayings, beliefs, myths, poems, ethos) referring to emmer wheat
- To study the diversity of emmer wheat using morphological and biochemical markers and to see their geographic and provenance distribution.
- To identify sites of high genetic diversity which could be recommended for on farm *in-situ* conservation of the crop.
- To study the relation between morphological and biochemical characters
- To generate information for further emmer wheat collection
- To compare the variation between the gene bank material and the material cultivated by farmers in Arsi and Bale.
- To assess the conditions that probably led to the reduction of emmer wheat cultivation over time and suggest future enhancement of the crop.

2. Literature Review

2.1.Origin and Taxonomy of Wheat (*Triticum* spp.)

The genus *Triticum* belongs to the tribe Triticeae in the family Poaceae (Gramineae) and subfamily Pooideae. The Triticeae is economically the most important tribe, which comprises barley (*Hordeum* spp.), rye (*Secale cereale*) as well as other important perennial forage grasses. The tribe is a temperate taxon and distributed in most areas in the world with main concentration regions in the Central and Southwestern Asia (Purseglove, 1975; Feldman, 1979; Bothmer, 1992).

Wheat is one of the earliest domesticated crop species together with barley and pulses. It was domesticated at least as early as 7500 B.C in the Near East, some where in the Fertile Crescent (Which comprises the mountain chains flanking the plains of Mesopotamia and Syrian desert) and also in Anatolia and the Balkans. This area coincides with the geographical distribution of the wild progenitors of wheat (Helbeak, 1959; Feldman, 1979; Langer and Hill, 1982).

The wild species of *Triticum* and the closely allied genus *Aegilops* and the primitive cultigens are the pioneer plants, which have contributed to the evolution of modern wheat (Purseglove, 1975).

Wheat (*Triticum* spp.) is an allpolyploid plant consisting of diploid (2n = 2x = 14), tetraploid (2n = 4x =28) and hexaploid (2n=6x=42) species having basic chromosome set of x = 7. The allopolyploidy nature of the genus *Triticum* which is a "young" complex without clear cut morphology makes it difficult for offering adequate species borders since it belongs to a tribe of plants which is sufficiently young to allow hybridization between different genera (Berrie, 1977; Porceddu and Lafiandra, 1986).

The most recent groupings are largely based on cytogenetic affinities (Hancock, 1992). There are three major kinds of wheat: diploid, tetraploid and hexaploid. The diploids are represented by a single cultivated species *T. monococcum* or Einkorn, which derives its name from the fact that it produces only one grain per spikelet. In the threshed material the seed is still enclosed by the tough glumes and further processing is required to extract the naked grains (Harlan and Zohary, 1966; Langer and Hill 1982; Hancock, 1992).

A complex of several subspecies represents the tetraploid group. The most important cultivated types are *Triticum diccocum* (Emmer) and *Triticum durum*. *Triticum dicoccoides*, the most likely progenitor of emmer, may be a chromosome-doubled hybrid of *T. boeoticum* and a species of *Aegilops* (Helbaeck, 1959; Hancock, 1992). Emmer was widely grown in the Mediterranean region until Greco-Roman times and makes good bread and pastry. *Triticum durum* was derived from the hybridization of wild Einkorn (AA) (*T. boeoticum*) and another diploid species with the B genome. There is also another tetraploid species; *T. timopheevi*, but it is only cultivated in a very restricted region of Russia and the donor of its G genome is ambiguous (Hancock, 1992).

The most widely grown species of wheat is the hexaploid *T. aestivum* that is divided into several subspecies. This hexaploid species from which most modern wheats have been developed, is not known in a wild state. With an exception of T. *spelta*, the bread wheats have tough inflorescent that does not shatter when harvested, and the seeds are easily threshed after gathering. Some of the varieties are hulled (*spelta, macha and varilouii*), while others are free threshing (*aestivum*, *compactum*, and *sphaeroccum*). All hexaploid seeds are high in the protein gluten content, which is an important agent in making the leavened bread fluffy (Purseglove, 1975; Hancock, 1992).

There are three genomes designated as A, B, (G) and D, involved in the formation of the polyploid series (Purseglove, 1975; Langer and Hill, 1982). The origins of the cultivated wheat and its evolutionary relationships for the different wheat types have been summarized as suggested by Croston and Williams (1981).

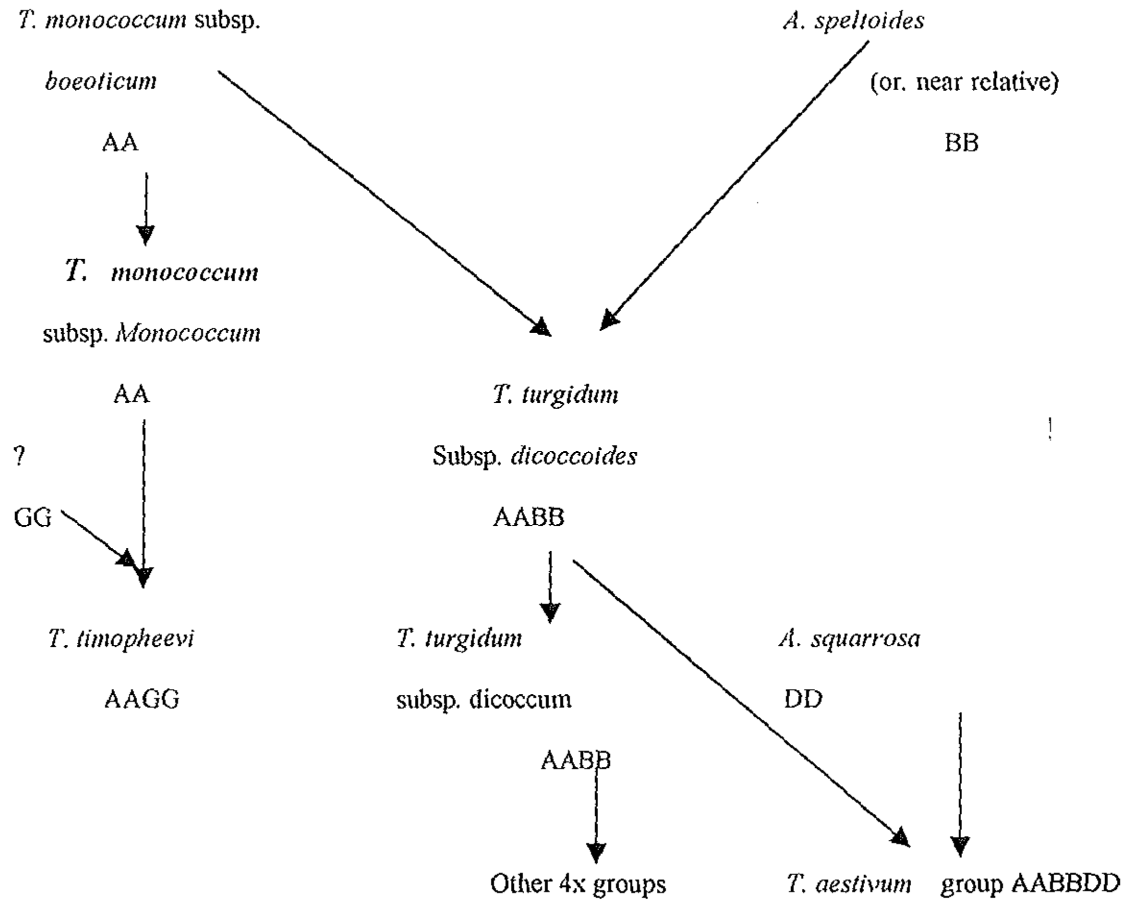


Fig 1. The probable origin and accepted relationships of the different *Triticum* spp. based on cytogenetic evidence. Each capital letter shows a genome composed of seven chromosomes (Croston and Williams, 1981).

2.2 Distribution and production of wheat (*Triticum* spp.) in Ethiopia

Plants constitute 93 percent of the world's diet. Cereals contribute two-third of all food. Among the cereals, wheat is the most important major crop of the world on which the livelihood of millions of people depends (Hanson, *et al.*, 1982; Negassa, 1986). Its nutritional value and the possibility of storing and transporting the seeds facilitated its utilization and the expansion of this crop in its area of cultivation. Today, it is the most widespread crop in the world and the staple food of over a third of the world's population (Porceddu and Lafiandra, 1986).

It is speculated that early immigrants of Hamites, some 5,000 years ago introduced wheat to Ethiopian highlands and emmer wheat (*T. dicoccum*) was the first to arrive (Helbaeck, 1959; Feldman, 1979). The origin of naked tetraploid wheat is not clear, but it is assumed that *T. durum* originated from *T. dicoccum* by an accumulation of mutations that reduced the toughness of the glumes until free threshing was attained (Feldman, 1979; Tesemma and Belay, 1991). The introduction of bread wheat (*T. aestivum*) was believed to be recent, perhaps brought by an European explorers (Harlan, 1969; Hailemariam, 1991).

In Ethiopia, wheat is one of the major cereal crops that rank fifth in acreage after tef, maize sorghum and barley. Ethiopia is the largest wheat producing country in Sub- Saharan Africa (Engles and Hawkes, 1991; Hailemariam, 1991; CSA, 1996). Tetraploid wheats occupy about 60% of the total area under wheat cultivation and the rest by the hexaploid bread wheat (*T. aestivum* L.) (Tesemma and Mohammed, 1982; Tesemma and Belay, 1991).

The first attempt to study and classify Ethiopian wheat dates back to 1885. Since then, several explorers, including N. I. Vavilov, Russian botanist and geneticist, have also tried to describe Ethiopian wheats (Hailmariam and Worede, 1986; Tesemma and Belay, 1991). Reviews by Demisse and Hailmariam (1991) indicate that the genus *Triticum* in Ethiopia is represented by 7 species, including *T. dicoccum*, *T. durum*, *T. turgidum*, T. *polonicum*, *T. aestivum*, *T. compactum*, and *T. pyrimidale*.

2.3. Tetraploid wheat in Ethiopia

Vavilov (1951) considered Ethiopia as the center of origin for cultivated tetraploid wheat since he encountered tremendous diversity of tetraploid wheat. However, Harlan (1971) argued that due to the absence of wild progenitors and near relatives, Ethiopia is considered as center of diversity for tetraploid wheats rather than center of origin. Tetraploid wheat is one of the most important wheat species and has proved to harbor a substantial wealth of genetic variation (Harlan, 1969; Harlan, 1971).

Agriculture in Ethiopia is still predominantly traditional thus the tetraploid wheat grown by farmers are landraces, consisting of mixture of genetic lines, which vary, in botanical form and morphological character. All the known tetraploid wheats in Ethiopia belong to the AABB genomic group (Tesemma and Belay, 1991). Some species can be readily distinguished from the group, while others exhibit morphological overlap. For instance, the *turgidums* differ little from the *durums* and there are transitional forms between the two types (Cf Tesemma and Belay, 1991).

2.4 Importance and utilization emmer wheat in Ethiopia

Emmer wheat must have arisen from wild emmer wheat (*T. dicoccodies*) by mutations, domestication and selection (Pursglove, 1975). It was domesticated in the Near East somewhere in the Fertile Crescent (Helback, 1959; Nesbitt and Samuel, 1996). Emmer was the only or by far the principal wheat until the emergence of the tetraploid naked species in the 1st millennium BC and in most of Europe competition from other wheat species was significant up to about the birth of Christ (Helback, 1959). After its introduction by early immigrants of Hamites emmer became a major cereals and it is still cultivated to a limited extent in Ethiopia, Iran, Eastern Turkey and Transcaucasia (Purseglove, 1975).

Emmer wheat is a minor crop in most parts of the Ethiopian highlands but has been replaced by tetraploid and hexaploid free threshing wheat. Today, emmer is grown on a limited scale and comprises about 7 percent of Ethiopia's entire wheat production (Purseglove, 1975; BOSTID, 1996). Emmer wheat is produced mostly in the highlands of Ethiopia, Bale, Arsi, Shewa, Hararge, Wello, Gojam and Gonder. There is a significant amount of emmer in the Bale zone during "Belg" and "meher" production seasons and it is one of the major crops in the region and contributes more than *T.durum* (Demissie and Hailegiorgis, 1985, Hailemariam and Mekibib 1988, Guta *et al.*, 1997). Recently, according to 5 years (1995-19991) data report of Ministry of Agriculture office of Bale Zone emmer ranks fifth in acreage after bread wheat, barley, maize and tef.

In Ethiopia emmer wheat is known by different local name as `Aja or Agga' in Amharic, `Arras' in Tigringa, 'Hyssa or Matajebo' in Oromiffa (Phillips, 1995; BOSTID, 1996). The spikes are dense, bearded and laterally compressed and the spikelets are mostly two grained. Hulledness in emmer wheat causes difficulty in threshing but it had advantageous characteristics. The grains in both field and storage are protected well by thick, tough glumes. Difficulty in threshability is one of the reasons, which contributes to the decreasing acreage of emmer in some locality (Nesbitt and Samuel, 1996).

The major genes present on chromosome 2^{nd} B chromosome's short arm (2BS) and 5^{th} A chromosome's arm (5AL) govern hulledness in wheat genetic system. Several minor genes, which are scattered through out the genomes of wheat, have also effect, some of which are identified by *Qft. Mgb-5A* and *Qft. Mgb-6A*. Polygenic systems are involved in the evolution of free threshable (FT) wheat. When this locus is either hemizygous as in monosomic 5A or absent, as in nullisomic 5A, the spike is longer and laxer, the rachis tends to be brittle and the spikelets are non-free threshing due to the tough tenacious glumes. All free threshable hexaploid carry this dominant factor but the non-free threshabele wheats evidently carry the recessive q allele. Another genetic system governing threashability is associated with D genome. This gene is derived from *Aegilops tauschii* Coss. (2n = 2x= 14, DD) inhibited the expression of Q (Mackey, 1966; Simonetti, *et al.*, 1999).

Apart from threshability constraint, it has the ability to grow in poor soil condition (marginal land) and it is resistant to a range of fungal diseases except leaf rust to which emmer is susceptible, and is drought resistant (BOSTID, 1996; Nesbitt and Samuel, 1996). Emmer wheat possesses considerable morphological variation, which can be used for breeding varieties more adapted to dry areas, where abiotic stress play a major role reducing yield (Damania, *et al.*, 1992). In addition other economically useful traits such as disease resistant, earliness and frost tolerance can be exploited for wheat improvement (ICARDA, 1991).

In Ethiopia emmer is used in various ways in the farming community. Some are ground in to flour and baked into unfermented bread (*kita*). Some are crushed and cooked with milk or water to make porridge; split grains of emmer are worked with boiling water and butter to produce gruel (BOSTID, 1996). Farmers in most areas of the country assert that they produce emmer wheat for its special medicinal and nutritional values. Traditionally, it is believed that broken bones heal faster when emmer is consumed in the form of porridge. As a result it is recommended for mothers as special diet in maintaining their health and strength after childbirth (Tesemma and Belay, 1991).

Recently, the discovery that its consumption reduces risk of colon cancer and heart disease led to its being promoted as a healthy food in Italy and elsewhere (ICARDA, 1991). In addition the elderly and the sick were served Farro (emmer, einkorn and spelta) because it is light and easily digestible. Now these qualities are beginning to be widely appreciated. Its efficiency to reduce risks of these two major human diseases may be due to its high fiber content compared with other modern wheat (ICARDA, 1991; Catarci, 1998).

2.5 Role of genetic diversity

Biodiversity is the term used to describe the total variety of living organisms (plant, animals, fungi and microbes) that exist on our planet (Stuart *et al.*, 1990). It provides humans with a wide array of materials essential for food, fiber, medicine and industry. Because of human reliance on biological diversity, scientists and policy makers must understand the factors involved in the generation and maintenance of diversity in order to reduce the risk of reduction of diversity and extinction of valuable genetic resources (Teshome *et al.*, 1999).

Plant genetic resource constitute the building blocks of all modern plant breeding: they form the raw material from which new, more resistant and high yielding varieties have been systematically bred to meet the growing need for improved variety. These traditional gene pools are an invaluable asset to the welfare of mankind and should be preserved, both for current use and posterity (Worede, 1988; Engels and Hawkes, 1991).

Plant genetic resources, which include the genetic diversity of cultivated species and their wild relatives, are highly prized for their potential value as sources of important variations for crop improvement programs. Populations of these various forms of plant species also represent sources having the greatest potential for genetic diversity and can, therefore, serve as invaluable means to fill the gaps that still exist in the available base of genetic diversity in the world collection of many major crop species. Among the most important traits, which are believed to exist in these materials are earliness, disease and pest resistance, nutritional quality, resistance to drought and other stress conditions and characteristics especially useful in low input agriculture. Other important sources of germplasm include obsolete cultivars, varieties or cultivars in current use, breeding lines and special genetic stocks normally maintained by breeders (Worede, 1988).

The existence of such genetic diversity in Ethiopia has great significance and risk reducing for long term food security of the country and the rest of the world because it provides the resource base on which sustained development of high yielding and stable varieties depends (Worede, 1988; Hardon and de Boef, 1992).

In many areas of the tropics and subtropics including Ethiopia, especially in areas with marginal conditions and resource poor farmers landraces consisting of mixture of genetic lines, which have variation, are still an integral part of the farming system. The local plant genetic resources are maintained in a dynamic system with continuous farmers selection and environmental adaptation. Resource poor farmers families and communities are the custodians of pools of important germplasm of many crops, especially those of local importance in the dynamic system (Tesemma and Belay, 1991; Harden and de Boef, 1992).

Not only does Ethiopia possess important diversity in crops domesticated elsewhere, such as wheat, barley, grain legumes and several oil plants, but it also has developed its indigenous cultigens such as tef, sorghum, noug, enset, *Brassica carinata*, and coffee many of which are now of great international importance. It has an amazing diversity of field crops varieties and the diversity expresses itself relatively under uniform ecological condition. In addition, there is a good wealth of botanical varieties of wheat (Vavilov, 1951). Vavilov (1951) also indicated that the Ethiopian region is an important primary or secondary center for some 38 crop species.

According to Harlan (1971), there is far more variation in both barley and Emmer wheat in Ethiopia than in their centers of origin. This idea is confirmed by Worede (1988) and Hailemariam and Mekbibe (1988), and high genetic diversity of wheat is found in Arsi, Bale and Shewa while its diversity is medium in Gojam, Gonder, Tigray and Wello. Lately, Belay (1997) confirmed the presence of high diversity of tetraploid wheat in Shewa and Gojam.

2.6 Genetic erosion and variation

The changes in biodiversity are influenced by evolutionary processes, social needs, cultural practices of human, and hence, biodiversity is the outcome of more than three billion years of evolutionary histories and it will be difficult to reclaim back if once they are lost. Plant genetic resource is a critical portion of global biodiversity (Hardon and de Boef, 1992; Wilson, 1992; Feyissa, 1999).

Man's dependence on centers of genetic diversity for his plant and animal germplasm resources is becoming very acute because of the high rate of erosion of genetic variability and structure of landrace populations (Bekele, 1985). In Ethiopia, the existing broad range of genetic diversity, particularly that of primitive and wild gene pools, is being rapidly depleted, displaced, or abandoned due to causes that are many and complicated. According to Worede (1988) and Stuart *et al.* (1990), various factors have interplayed in posing such threat, which is progressing at an alarming rate. The most important ones include, displacement of native cultivars by improved cultivars, loss of wild gene pools and habitat disappearance, drought and genetic vulnerability (Bekele, 1985; Mooney 1985).

In the developed world, most of the original landrace varieties have long been replaced by genetically similar monoculture cultivars. The recent advance in genetic engineering also aggravates the destruction of biodiversity in general and plant genetic resource in particular (Kessler *et al.*, 1992).

2.7 Maintenance of genetic diversity

A landrace is a plant population with a limited range of genetic variation, which is adapted to local agroclimatic conditions and which has been generated, selected, named and maintained by traditional farmers. These landraces have been used by plant breeders as the source for specific agronomic and other traits in the development of the improved cultivars than is Modern High Yielding Varieties (HYV's) (Frankel, 1974). Conventional plant breeders employ very few selection criteria and seek to develop varieties for widespread production in favorable agricultural habitats (Teshome *et al.*, 1999). Plant genetic resources with highest potential for genetic diversity are represented primarily by landraces, wild relatives of cultivated species and wild/weedy species that often contain genes for disease and pest resistance, and characters of adaptation to changing environments. Genetic diversity has been associated with environmental heterogeneity (Bekele 1984; Hawthin *et al.*, 1996).

It is important to conserve plant genetic resources for their sustainable and effective utilization. The ultimate objective of conservation is to keep the genetic potential of a species by maintaining the maximum intra-specific diversity existing in it. Two major strategies have been developed for the conservation of plant genetic resources, namely *ex-situ* and *in-situ*.

Ex-situ conservation refers to methods of conservation that entail the removal of germplasm resource (seed, pollen or the whole plant) from their original habitats or natural environments and preserving them in other environments in order to ensure their safety. The strategy involves collection, storage, regeneration, documentation and information systems, evaluation and enhancement. *Ex-situ* conservation can include the use of botanical gardens, arboreta, and gene banks (Seme, 1994).

In-situ conservation of biological resources refers to their maintenance in the natural habitats where they occur, whether as wild/weedy forms of plant communities or in farmer's fields. *In-situ* conservation links conservation at the species level of biodiversity with the ecosystem level. Since the beginning of the modern conservation effort for PGR, *in-situ* conservation strategies have been identified as important elements in the overall conservation effort (Iwanaga, 1994).

Both *in-situ* and *ex-situ* methods of conservation have their own problem and drawbacks. The drawback in *ex-situ* conservation strategy is that seed storage freezes the evolutionary process by preventing the evolution of new types or levels of adaptations. There may be a loss of the conserved material due to degeneration and it is associated with high cost, which is not affordable by developing countries.

The major problem of *in-situ* conservation strategy is the absence of controlled monitoring and security, since natural habitats are lost and replacement of landraces by other landraces and modern varieties takes place as a normal part of cropping systems. The cost that is needed for implementation of *in-situ* conservation is also one of the drawbacks. The low yielding potential of landraces is also a problem in case of local/ community conservation strategy, and farmers might need modern variety for better yield (Hardon and de Boef, 1992).

Many authorities have pointed out that the combination of the two approaches is important for sustainable conservation of genetic resources (Altieri and Merrick, 1987; Worede, 1990). However in Ethiopia, to minimize the rapid genetic erosion, *ex-situ* conservation is the major method of conservation strategy (Feyissa, 1999; Worede, 1988). The Institute of

Biodiversity Conservation and Research since its establishment, carried out a series of plant exploration expeditions to collect, conserves and evaluates these dwindling resources.

To date, a total of 2726 accessions of *Triticum* spp. have been collected from various agro-ecological zones by IBCR. The gene bank possesses a total 11069 accessions which included material obtained through donations, repatriation, selection and previous collection. The total number of emmer wheat in the possession of IBCR is close to 7-8% of the total *Triticum* material. In the past no specific collection operation was launched for emmer wheat in Ethiopia, but all the accessions were assembled as part of general collecting exercises. A total of 500 population samples were collected from various regions such as Bale, Arsi and Shewa. But, recently in collaboration with Sinana Agricultural Research Center (the only agricultural research center working in improvement research on emmer wheat in Ethiopia), specific collection operation was conducted on emmer wheat in Arsi and Bale region where the crop has important cultural and use values for local farmers (Demissie and Hailemariam, 1991; Personal observation).

2.8 Marker systems used for diversity study

Over the years, the methods of detecting and assessing genetic diversity have extended from analysis of discrete morphological traits to biochemical and molecular traits (Bekele, 1983; Tsegaye and Tesemma, 1995; Demisse, 1996; Belay, 1997; Ayana and Bekele, 1998).

2.8.1 Morphological Markers

According to preliminary evaluation of Demissie and Hailemariam (1991) on PGRC/E emmer wheat collections at Deber Zeit, high variation was recorded for the number of spikelet per spike and kernel number per spike. Little variation was observed at each location between accessions, except for spike color, plant height, days to flowering and maturity, spike length and width, and kernel size. In addition to this preliminary investigation, the population of emmer wheat landrace of Ethiopia is uniform.

The information generated from genetic diversity study using morphological characters can be exploited for crop improvement programs, further germplasm collection and choice of appropriate site for *in-situ* conservation. Such type of diversity study is relatively cheaper and simple. However, morphological markers have also drawbacks since many of such traits are controlled by many genes (polygenic) and they are influenced by environment.

2.8.2 Isozyme marker

The characterization and identification of isozymes is carried out on the basis of the phenotype electrophoretic band patterns. These patterns can usually be interpreted in terms of loci and alleles. These qualities make isozymes one of the most ideal marker systems in population studies especially in assessing variation within and among population (Demisse, 1996). The capacity to see allelic variation at isozyme loci has revolutionalized research in the field of biochemical genetics and evolution. This variation, called allozymic polymorphism, has been used in plants to examine genetic processes at every stage of the life cycle and ascertain genetic diversity in all major crops as well as many other species. Allelic variants of genes that encode isozymes are useful in many basic and applied investigations of crop species (Martinez- Zapater and Olivers, 1984; Wendel and Weeden, 1990; Tsegaye and Tesemma, 1995).

This marker system has advantage in that it is not affected by environmental condition; allelic differences are always reflected in terms of mobility difference. Like other marker system, isozymes have some shortcomings. Not all genetic changes occurring at DNA level are detected at protein (isozyme) level and polyploidy is quite a common phenomena in plants and caution is required when interpreting patterns resulting from gene duplication in polyploid species (Martinez -zaparter, 1984; Pedersen *et al.*, 1990).

Different investigations of isozyme variation in Ethiopian tetraploid wheat have revealed that esterase; acid phophatase and aconitase have variability and are monomers or dimers (Tsegaye, 1994; Tsegaye and Tesemma, 1995; Tsegaye *et al.*, 1996)

2.9 Ethnobotanical study

Agroethnobotany is a specific branch of ethnobotany that deals with the ethnobotany of crop plants and related aspects. It relies on farmer perception and knowledge systems around traditional crop cultigens and their use and management. Because of its special features, knowledge held by farmer conservators, skilled farmers, women farmers or women members of farmer conservators are very important (Martin, 1995; Maundu, 1995). Ethnobotanical studies on traditional crops allow gathering useful information about its agronomic, use, management and germplasm characteristics of the crop.

Crop specific ethnobotany as attempted by Asfaw (1990) on barley (*Hordeum vulgare*) and Teshome *et al.* (1999) would help to record the specific knowledge that has accumulated during its long cultivation history and to make sustainable use of the crops. Indigenous knowledge of the farming community must be incorporated in the study of crop genetic resources. *In-situ* conservation efforts should be linked to rural development by taking into account the traditional agricultural knowledge and practices of farmers (Altieri and Merrick, 1987).

Agroethnobotanical studies on Ethiopian cultivated crops is very minimal and only that of Asfaw (1990) on barley (*Hordeum vulgare* L.) and Teshome *et al.* (1999) on sorghum (*Sorghum bicolor* (L.) Monech, Kebebew *et al.*, (1997) and Tamiru (1999) on durum wheat are known. But there is no ethnobotanical study conducted on Ethiopian emmer wheat landraces.

3. Material and Methods

3.1 Morphological study

3.1.1 The study area

Description of the Experimintal Site

The study was carried out at Sinana Agricultural Research Center, which is located at 7^0 7'N latitude and 40^0 10' E longitudes in the Oromia Regional State. Sinana Agricultural Research Center is specifically located at 463km south east of Addis Ababa and 33km from Robe, capital of Bale zone, on the way to Goro and Sofumar cave. The elevation is 2400m a.s.l and characterized by gentle slope. The soil type is vertisol like and with slight acidity (pH 6.2). A total N content of 0.243%, available P 30 ppm, K value of 240 mg/1kg soil and CEC of 64 Meq/kg of soil (Ethicha, *et al.*, 1998). The experimental site is located in the area where emmer wheat is important and the center is the only center, which carries different research activity on it.

Weather condition of the season

Sinana Research Center represents a high altitude with high rainfall distributed bimodally. Total annual rainfall amount over ten years ranges from 750-1000mm (average 860mm). The weather condition in Sinana area is mild. Average annual maximum temperature is 21^{0}C while that of minimum temperature is 9^{0}C (Ethicha, *et al.*, 1998). In the experimental season, (August, 1999 – January, 2000) the rainfall amount ranged from 144 (August, 1999) to 0.00 (December, 1999), and the average minimum and maximum temperatures were 6.6^{0}C and 22.95^{0}C respectively (Appendix 2). As a result of favorable weather conditions, the site is potential and ideal place to undertake research on emmer wheat.

Germplasm acquisition

The Emmer wheat germplasm materials for this study were kindly provided by the Institute of Biodiversity Conservation and Research. According to the Institute, original samples were collected using the random method of Hawkes (1976). The accessions are representing the whole Ethiopia having altitudinal ranges between 1550 to 2890m a.s.l. A total of 55 emmer wheat populations including one local check (PGRC/E 215407) were used for this study. Selection of the populations for this study was based on altitude and administrative region. Appendix 1 shows the list of accessions, origin and altitude of the populations used for this study.

3.1.2 Experimental procedures

The experiment was laid out in randomized complete block design with four replications in single row of 3.4m lengths. The spacing between plants was 0.2m and the spacing between rows and replication were 0.4m and 1.5m, respectively. Twenty five to forty five individuals plant per population, and a total of 1850 individual plants were evaluated for the following agronomic characters using International Board of Plant Genetic Resource descriptor of wheat (IBPGR, 1981).

1. **Days to Heading (DH)**:- the number of days from planting up to heading
2. **Grain filing (GFL)**:- the number of days from heading up to physiological maturity
3. **Days to maturity (DM)**:- the number of days from planting up to physiological maturity
4. **Tiller number (TN):-** The actual count of the fertile number of tillers (spike bearing)
5. **Node number (NN)**:- the actual count of the number of node of mother plant

6. **Plant height (PHT):-** Height of mother plant before maturity, the distance between the ground level to the tip of the terminal spikelet in cm

7. **Spike length (SPL)**:- Distance from the base of the spike to the tip of the highest spikelet (excluding own) in cm

8. **Awn length (ALG)**:- Distance from the tip of the spike to the end of the awn

9. **Number of spikelets per spike (NSpl/s)**:- the actual count of the number of spikelet of the mother spike

10. **Number of kernels per spike (NKPS) :-** the actual count of the number of seeds (kernels) of the mother spike

11. **Spike density (SD)**:- visual measurement according to the key given in IBPGR descriptor list and this was rated as 1 for dense, 2 for medium dense and 3 as lax

12. **Glume hairiness(GH)**:- Measured on outer side of sterile glume and this was rated as 1 for pubescent and 2 for glabrous.

13. **Glume color (GC) :-** observed on the outer glume and this was rated as 1 for White, 2 for pale yellow, 3 pale red and 4 dark reddish gray

14. **Kernel color (KC)**:- Observed on the harvested seeds of each individual plant and recorded as 1 for white, 2 for pale yellow, 3 for pale red

15. **Beak length (BK)**:- Observed on the tip of glume of the mother spike and recorded as 1 for short beak, 2 for medium beak and 3 for long beak (> 3 mm)

16. **Ear shape**:- The shape of the mother spike was taken and recorded as 1 for tapering ,2 for parallel ear shape.

17. **Seed yield per plant with hull (SYWH)**:- The dried weight of seeds with its hull from each individual plant in g (g/plant)

18. **Seed yield per plant dehulled (SYWOH)**:- The dried weight of dehulled seed from each individual plant in g.

19. **Thousand seed weight (TSW)**:- 1000 seeds were randomly taken from each single plant and weighed

20. **Biomass (BM)**:- The weight of the individual plant (with its tiller) material above the ground (Biological yield)

21. **Harvest index (HI)**:-The ratio of seed yield (dehulled) per plant to the biological yield per plant multiplied by 100.

3.2 Biochemical Studies

3.2.1 Isozyme study

Isozyme analysis was carried out on twelve accessions of emmer wheat selected from six clusters based on morphological diversity. Two populations from cluster A, B, F and D and one from cluster E and three populations from cluster C were used. The selection of the two populations from each cluster was based on diversity index, regions of origin, and dendrogram distance matrix (cluster distance).

The method of extraction and running electrophoresis procedure is that of Chamberain (1998).

The enzyme systems studied were Aspartate amino transferase (AAT; EC 2.6.1.1), Esterase (EST; EC 3.1.1.-) and Acid phosphatase (ACP; EC 3.1.3.2). The staining procedure followed was that of Chamberain (1998).

An assessment of isozyme phenotype polymorphism was made using the overall banding patterns. Phenotypic polymorphism, genetic distance and heterozygosity were determined using Biosys software (Nei, 1978; Swofford and Selander, 1981). A genetic interpretation of the banding patterns was made based on the reported structure of each enzyme in different plant species (Wendel and Weeden, 1990) and particularly in related species, barley, *T. durum* and *T.polonicum*, were the information available (Hvid and Nielsen, 1977; Tsegaye *et al.*, 1994; Tsegaye and Tesemma, 1995; Tsegay *et al;* 1996; Jaaska, 1997).

3.2.2 Protein Analysis

37 accessions out of the 55 accessions, which were studied for morphological diversity at Sinana, were subjected to protein analysis. Protein analysis was carried out using the Kjeldahl method. Organic nitrogen is converted into ammonium ions by digestion with concentrated sulphuric acid in the presence of a catalyst such as a mixture of potassium sulphate with copper sulphate. Following Kjeldahl digestion, the digests were made alkaline and ammonium was determined by steam distillation of ammonia, which involved trapping in boric acid and titration (AOAC, 1990).

When using the steam distillation method the distillate was titrated against a standard acid (0.1 N HCl). From this titration the amount of nitrogen was determined, and multiplied by 6.7 to convert to crude protein (AOAC, 1990).

3.2.3 Analysis of dry matter, Ash and Mineral

Dry matter, ash and mineral analysis were done for each landrace using AOAC (1990) protocol. Percent measurement of calcium was determined by atomic absorption spectrophotometer (AAS) using the standard procedure of AOAC (1990).

3.3 Ethnobotanical survey

3.3.1 Geographical location

The study was carried out in Arsi and Bale zone of Oromia Regional State in southeastern Ethiopia. Arsi and Bale are located at 7^0,30`N and $39^0$, 30`E and 7^0,00`N and $39^0$45`E of latitude and longitude, respectively (Ethiopian Mapping Authority, 1988). The study concentrated in the mid and high altitude areas of the major emmer wheat growing weredas of the zones, which included: Hitosa. Tiyo, Munesa, Digelu fi Tijo, Lemu fi Bilibilo, Shirka, Tena, Robe, Aminage, from Arsi zone and Dodolla, Adaba, Sinana-Dinsho, Goba, Agarfa, Gassera-Gollolcha, Ginire and Goro from Bale Zone. A map of the area is shown in Fig 2. The two zones have an extensive chain of highland systems.

3.3.2 Survey Procedure

First the existing secondary information was gathered from different governmental institutions (especially MOA office) and discussions were made to identify emmer wheat producing pocket areas. Thereafter, individual farmer interviews were made to generate primary information. The data collection procedure is following a format developed for this purpose (Appendix 14) and included interviews and observations. The domain of informants included in the study was diverse, participating most members of the community including men, women, elders, youth, religious people and others so as to get maximum information. The method of extracting the information was individual and group discussions.

Totally, about 75 farmers were interviewed using a pre-formulated semi-structured data collection format (Appendix 13). During the survey, discussions were made with 110 people about the crop emmer wheat. In all localities farmers explained the importance of emmer wheat in both home consumption and for sale. They mentioned different activities of emmer wheat production, like site selection, land preparation, till harvesting and utilization of the crop. In addition, the discussion included different sayings, songs, poems and other traditions released by community members.

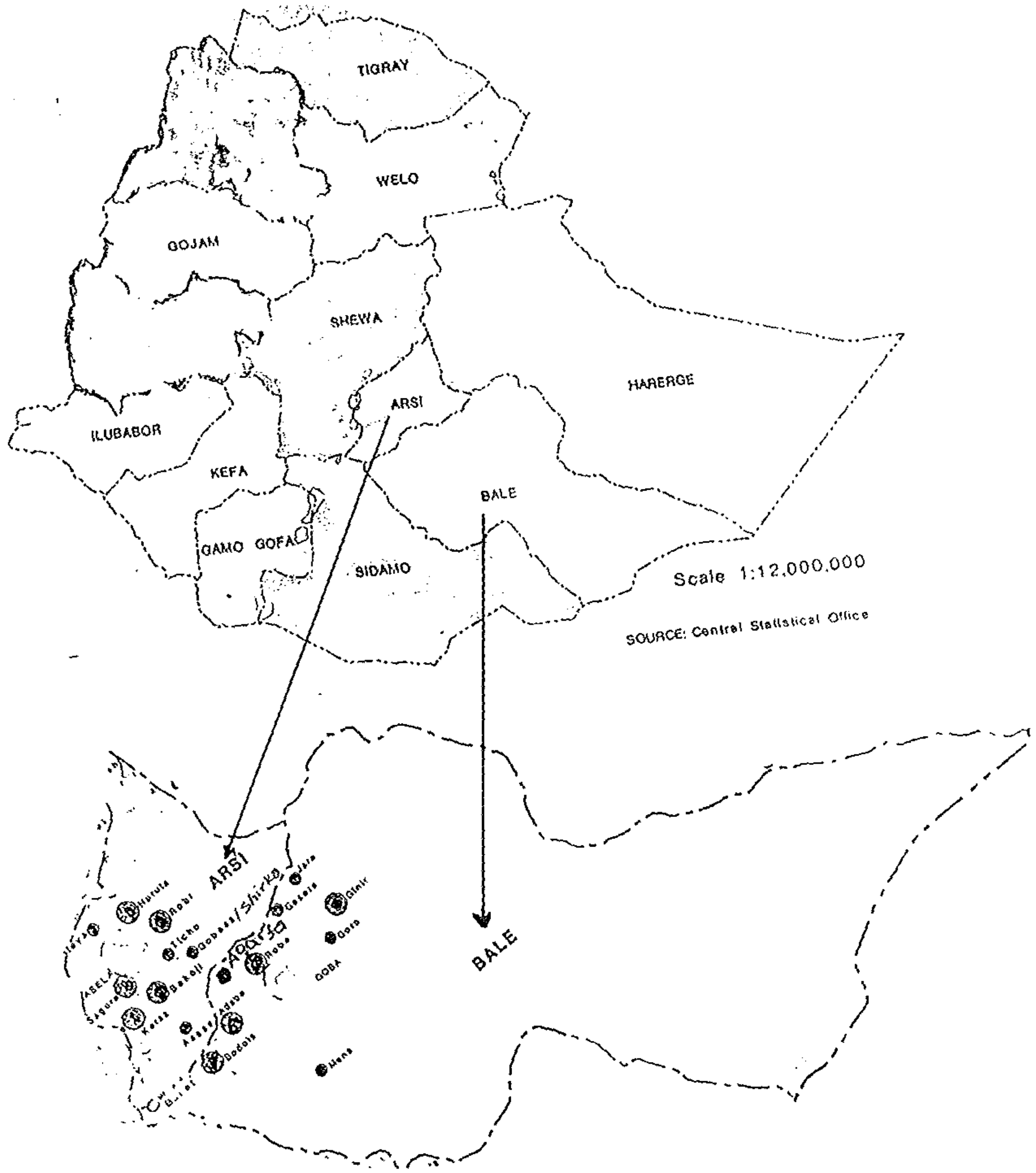


Fig 2 The map of the survey area of the two zones- Arsi and Bale

3.4 Statistical Analysis

Analysis of variance (ANOVA) for each quantitative trait data was carried out in a randomized complete block model with four replications using the MSTAT computer program (Michigan University, 1991). Mean values were in turn used to estimate broad sense heritability and the expected genetic advance.

The following steps were followed to calculate genetic advance, phenotypic and genotypic variance:-

Phenotypic variance (Vp) = Genotype MS/r

Error variance (Ve) = Error MS/r

Genotypic variance (Vg) = Vp-Ve

Where r = number of replications

Phenotypic coefficient of variation (PCV) = 100 (VP) /M

Genotypic coefficient of variation (GCV) = 100 (Vg)/M

Where M = the mean value

Heritability (h) = Vg/Vp

Genetic advance (Gs) = (I) (h) (vp)

Where I = selection differential (2.06 for selecting 5% of the genotypes)

GS (% of the mean) = GS/M) 100.

Simple correlation coefficients between all possible traits were carried out using SPSS for MS windows 6.1. The percentage frequencies of the phenotypic classes of each character population, region and altitude group were calculated for the qualitative characters by cross tabulation. Shannon-Weaver diversity index, H', which has been widely used in measuring the diversity of germplasm collections (Negassa, 1985; Bekele, 1984; Demissie, 1996;

Belay, 1997) were estimated on the frequency data. The Shannon Weaver diversity index, H, is defined as follows:

$$H = - \sum^{n}_{i=1} Pi \ln e Pi$$

Where pi is the proportion of the total number of individuals (genotypes) in the i^{th} class and n is the number of phenotypic classes for a given character. Each value of H was calculated for each character, region and altitude group, because it is sensitive to very small fractions (Hennink and Zeven, 1991). A one-way analysis of variance of non-normalized H' was carried out for each traits using region and altitude classes. Hierarchical ANOVA pooled across character was also performed to estimate the contribution of the different variance components like region and altitude to the level of diversity. Chi-square analysis was performed on the frequency data distribution of characters.

In order to group the emmer wheat growing regions through an ordination technique, the region contingency table was assessed in terms of row profiles (regions) and column profiles (traits) by a correspondence analysis using the simple correspondence procedure as devised by MINITAB (1998).

As with principal components, variability is partitioned, but rather than partitioning the total variance, it partitions the Pearson chi square statistic which is termed as inertia (chi-square/n accounted for each component) (du Toit *et al.*, 1986).

Hierarchical agglomerative clustering was performed using wards criterion, i.e. minimizing the total sum of squared distances of object to cluster centers and stopping just before dramatic increase in criterion value or decrease of R-squared. Ward's criterion was preferred because it tends to produce compact clusters (Zewdie and Zeven, 1997) clustering were computed based on mean quantitative data alone and both quantitative and frequency data of qualitative data using MINITAB (1998) computer program. To eliminate the possible impact of different magnitude of units for the different data were standardized by subtracting the mean over populations of each character, and dividing by the standard deviation of each character over all populations, $Z = x - \bar{x}/s$.

Canonical discriminate analysis repeatedly used in germplasm evaluation (Pecetti and Damania, 1996; Spagnoletti and Qualset, 1987) was undertaken to assess on multivariate basis using quantitative trait differences and hence distinctiveness between the different emmer wheat growing regions. Distance matrix, i.e. square euclidean Distances, computed from means of sixteen quantitative characters of the 55 populations were used as the input for multidimensional scaling.

4. Result

4.1 Morphological Diversity

4.1.1 Mean, Range and coefficient of variation for quantitative characters

The mean and coefficient of variations by region and altitude over the entire individuals of the 55 emmer wheat populations are presented in Tables 1 and 2. According to the result presented in the two Tables (1 and 2), the characters in both tables showed the highest coefficient of variations is not the same for all altitude and region. But tiller number and thousand-grain weight showed highest coefficient of variations in all the regions and altitudes. The highest mean tiller number was recorded from the population collected from Shewa (29), Gojam (29) and Gonder (28) while population collected from Hararge showed least mean tiller number (19).

The highest coefficient of variation for biomass was recorded from population collected from Shewa (24.8) and also they have highest mean value (123 gm). Population collected from Arsi showed high coefficient of variation for Harvest index (31.4%). In the case of seed yield with and without hull, populations collected from Bale and Shewa showed highest coefficient of variation, 16.4% and 15.7%, respectively. The highest mean seed yield per plant was recorded from the population collected from Shewa (37g/plant) and Gonder (39 gm/plant). The mean seed yield per plant with and without hull is 31g and 20g, respectively. Phenological traits didn't show high coefficient of variation. The same was true for number of node per plant, number of kernels per plant and plant height.

Variations in the various morphological traits were also observed by altitude groups (Table 2). Thousand grain weight showed high coefficient of variation in all altitude groups except in 2800 and above, seed yield per plant with and without hull also showed high coefficient of variation for all altitude group but the highest was in altitude group below 2000m (41.9% with and 37.1 without hull). The highest altitude group (> 2801 m) showed lower coefficient of variation for all morphological traits studied except for days to head and harvest index. The highest mean seed yield per plant with and without hull was obtained from the highest altitude group (>2401m asl) 35g for both altitude group with hull and 22g, 23g without hull, respectively.

Analysis of variance over the entire data showed that highly significant difference between populations were observed regarding days to head, days to maturity, grain filling period, flag leaf length, tiller number, number of kernels per spike, spike length, number of spikelete per spike, biomass, plant height, thousand grain weight, harvest index, seed yield with hull and seed yield without hull (Table 3).

Table 1. Mean (M) and coefficient of variations (CV) by regions and over the entire data

	DH		DM		GFP		FLG		TN		AWL		TGW		NK/S		SpL		NSpl/S		BM		PHT		HI		SYWH		SYWOH	
Region	M	CV	M	CV	M	CV	M	CV	M	CV	M	CV	M	CV	M	CV	M	CV	M	CV	M	CV	M	.CV	M	CV	M	CV	M	CV
Bale	89	3.2	140	5.5	52	14.5	25	3.8	20	24.3	12	14.3	34	27.8	42	4.8	8	15.9	22	12.0	99	19.5	92	4.1	20	9.5	30	16.4	30	16.4
Arsi	89	1.2	142	1.9	53	5.6	24	6.5	22	15.3	11	10.9	28	44.5	43	4.7	8	8.8	22	3.9	108	12.2	93	3.5	20	31.4	32	8.5	32	8.5
Shewa	92	3.4	144	2.4	52	6.2	24	10.6	29	30.8	11	11.5	24	33.9	44	5.3	9	7.4	23	6.5	123	24.8	88	5.9	19	9.3	37	15.7	37	15.7
Harer	89	1.5	142	1.7	54	7.4	24	4.4	19	12.9	11	10.2	28	35.9	42	4.9	8	11.1	22	4.4	96	15.5	95	4.4	18	11.6	27	14.0	27	14.0
Sidamo	93	-	137	-	44	-	26	-	23	-	10	-	23	-	45	-	9	-	23	-	112	-	88	-	20	-	33	-	33	-
Gojam	96	-	139	-	43	-	23	-	29	-	10	-	36	-	45	-	8	-	23	-	111	-	89	-	16	-	29	-	29	-
Gonder	92	0.8	142	1.0	50	4.2	24	3.0	28	5.0	11	0	21	6.7	45	1.6	8	0	23	0	116	12.2	88	4.8	22	0	39	9.1	39	9.1
Tigray	87	0	139	4.6	52	12.2	21	3.4	20	10.6	11	19.3	39	7.3	30	0	7	0	16	0	74	3.9	81	0.8	17	12.5	24	8.8	24	8.8
Ethiopia	90	0.4	142	0.4	53	1.1	24	1.0	22	3.6	11	1.6	28	5.1	43	1.1	8	1.5	22	1.1	105	2.6	92	0.7	19	2.9	31	3.1	20	3.2

- = No CV since it has only 1 popu

Table 2. Mean (M) and coefficient of variations (CV) by altitude group and over the entire data

	DH		DM		GFP	FLG		TN		AWL	NDN	NK/S		SpL		NSpl/S	BM		PHT		HI	TGW		SYWH		SYWOH
Altitude	M	CV		CV	M	CVM	C	M	CV	MCV	M	CVM	C	M	CVM	C	M	CVM	CV	M	CV	M	CV	M	CVM	CV
1	89	1.9	14	2.2	53	6.424	4.	17	29.2	1119.2	4	9.542	7.	8	16.122	7.	90	28.393	5.0	17	16.9	39	35.4	25	41.916	37.1
2	89	2.4	14	2.2	53	8.124	5.	21	18.8	1111.4	4	4.642	8.	8	8.322	7.	103	15.093	5.4	19	26.4	29	33.0	30	17.019	18.5
3	91	4.1	14	4.5	51	11.525	10.	25	33.6	118.3	4	043	9.	9	11.523	9.	114	22.690	5.7	20	7.5	23	30.8	35	21.522	20.5
4	90	2.1	14	0.8	52	5.024	2.	24	14.8	104.5	4	044	4.	9	6.123	2.	116	8.893	4.9	20	12.3	20	2.7	35	13.623	19.6

Altitude group1= < 2000, 2= 2001-2400, 3 = 2401-2800, 4= >2801

Table 3. Mean squares for 16 quantitative morphological traits of 55 emmer wheat population

Character	Mean squares			CV	SE
	Replication	Landrace	Error		
DH	8.65	32.12**	4.63	2.41	0.29
DM	453.51**	63.40**	38.38	4.37	0.84
GFP	546.78**	77.45**	42.63	12.48	0.88
FLG	0.00	11.18*	7.85	11.77	0.38
TN	141.13**	138.04**	37.95	28.01	0.83
AWL	125.59*	31.84	36.58	55.21	0.82
NDN	8.24**	0.23	0.19	11.20	0.06
NK/S	75.96**	49.95**	8.92	7.02	0.40
SpL	9.22**	1.60**	0.44	8.13	0.09
NSpl/S	13.10**	12.24**	2.09	6.59	0.19
BM	9351.36**	1542.88**	707.56	25.51	3.59
PHT	113.44**	98.25**	28.67	5.83	0.72
TGW	2637.47**	344.94**	35.74	21.54	0.81
HI	100.61**	15.91*	11.20	17.93	0.45
SYWH	342.15*	171.32**	98.82	32.54	1.34
SYWOH	132.59*	83.05**	39.97	32.31	0.85

*: P< 0.05, ** : P< 0.01

4.1.2 Heritability (broad sense), Genetic advance and Estimates for components of variance

Phenotypic (PCV) and genetic (GCV) coefficients of variation estimates of the components of variance, broad sense heritability (H), expected genetic advance and genetic advance as percent of mean are presented in Table 4. Generally, only slightly higher PCV values than GCV were obtained for all the characters signifying the genetic factors exerted the major effect in estimating the variation.

Phenotypic coefficients of variation (PCV) were high for thousand-grain weight (33.45%), tiller number (26.7%), seed yield with and without (21.42, 23.28%) and moderatly high for Biomass (18.83%) and Harvest index (10.69). GCV showed a similar trend as PCV and ranged between 1.76%, for days to maturity and 31.67% thousand-grain weight.

Heritability estimates in broad sense (Table 4) showed high value for thousands grain weight (89.45%), days to head (85.55), number of kernels per spike (82.15%), number of spikelate per spike (83.01%). Spike length (72.5%), tiller number (72.5%), and plant height (70.81%), showed moderately higher heritability estimate. The heritability values were low for days to mature, grain filing period, flag leaf length, node number, biomass, harvest index, seed yield with and without hull.

Table 4 Summary statistics and estimates of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GVC), broad sense heritability (H) and genetic advance (Gs) in 55-emmer wheat population for 16 quantitative morphological traits

Traits	M	Range	Vp	Ve	Vg	PCV %	GCV %	H^2	GA	GA% of the M
DH	89.48	83-96	8.03	1.16	6.87	3.17	2.93	85.55	4.96	5.54
DM	141.3	124-152	15.85	9.60	6.25	2.81	1.76	39.43	3.23	2.28
GFP	52.33	35-64	19.36	10.66	8.90	8.41	5.70	45.97	4.17	7.97
FLG	23.81	20-40	2.81	1.96	0.84	7.04	3.85	29.89	1.03	4.33
TN	22.00	12-44	34.51	9.49	25.02	26.7	22.74	72.50	8.77	39.86
NDN	3.88	3-5	0.06	0.05	0.01	6.31	2.58	16.67	0.08	2.06
NK/S	42.53	30-47	12.49	2.23	10.26	8.31	7.53	82.15	5.98	13.74
SpL	8.19	6-10	0.4	0.11	0.29	7.72	6.58	72.5	0.95	11.6
NSpl/S	21.91	16-25	3.06	0.52	2.54	7.98	7.27	83.01	2.99	13.65
BM	104.3	55-160	385.72	176.9	208.83	18.83	13.86	54.14	21.9	21.00
PHT	91.91	79-100	24.56	7.17	17.39	5.39	4.54	70.81	7.23	7.87
TGW	27.76	19-66	86.24	8.94	77.3	33.45	31.67	89.45	17.1	61.64
HI	18.67	12-44	3.98	2.8	1.18	10.69	5.82	29.65	1.22	6.54
SYWH	30.55	10-47	42.83	24.71	18.12	21.42	13.93	42.31	5.70	18.66
SYWOH	19.57	7-29	20.76	9.99	10.77	23.28	16.77	48.99	4.60	23.51

Expected genetic advance as percent of the mean was generally not high for most of the characters. The values ranged between 2.06% for node number and 61.64% for thousand-grain weight.

4.1.3 Correlation analysis of quantitative characters

Correlations of the different characters by region and over the entire data in emmer wheat are indicated in Table 5 and Appendix 3-6. In correlation study of entire data seed yield with and without hull was significantly and positively correlated with, day to head, days to maturity, number of kernel per spike, number of spikelets per spike, spike length, biomass, tiller number, and harvest index. Kernel per spike is significantly positively correlated with days to head, plant height, spikelets per spike, spike length, biomass, tiller number and seed yield, but it has negative correlation with grain filling period and thousand grain weight. Tiller number was significantly positively correlated with days to head, days to maturity, number of kernel per spike, spike length, biomass and seed yield. Correction analysis by region indicated there were significant positive correlation between seed yield and biomass and tiller number for Bale, Arsi, Shewa, and Harerghe. For the population collected from Bale and Shewa all traits correlated positively with the seed yield (Appendix 3 and 5).

Table5. Correlation among 16 different characters of emmer wheat populations in Ethiopia

	DH	DM	GFP	FLG	AW	ND	PH	K/S	Spl/S	SL	BM	TN	TGW	SY		HI
														WH	WHO	
DH		0.19	-0.42**	0.21	-0.06	0.00	-0.21	0.42**	0.41**	0.49**	0.54**	0.86**	-0.09	0.49**	0.47**	0.03
DM			0.79	-0.07	0.13	-0.1	0.15	0.18	0.18	0.21	0.37**	0.37**	0.12	0.31*	0.31*	-0.01
GFP				-0.19	0.12	-0.09	0.27*	-0.08	-0.08	0.03	-0.01	-0.08	0.15	-0.03	-0.02	-0.04
FLG					0.02	-0.11	0.09	0.40	0.30*	0.29*	0.30*	0.16	-0.12	0.32*	0.35**	0.06
AWL						0.0	0.09	0.0	0.06	0.09	0.04	0.04	0.11	0.1	0.07	0.04
ND							0.08	0.0	0.0	0.11	-.04	0.03	0.02	0.03	-0.02	0.58**
PH								0.43**	0.39**	0.26	0.1	-0.21	0.16	0.04	0.08	0.07
K/S									0.95**	0.55**	0.55**	0.28**	-0.19	0.5**	0.57**	0.23
Spl/S										0.53**	0.49**	0.21	-0.19	0.45**	0.52**	0.24
SL											0.58**	0.35**	0.08	0.62**	0.57**	0.26
BM												0.86**	-.09	0.92**	0.89**	0.07
TN													-0.15	0.82**	0.76**	0.07
TGW														-0.05	-0.17	0.0
SYWH															0.94**	0.28*
SYWOH																0.31*
HI																

significance levels** =p < 0.01,*= p < 0.05

4.1.4. Cluster analysis

In Fig.3, six different clusters are formed on the basis of qualitative and quantitative morphological characters.

Cluster A consisted of two populations from Harerghe and Tigray and one population from Shewa and Bale. Three of the populations in this cluster are from the same altitude group (2001-2400m a.s.l), while from the rest theer, two were from lower altitude group (< 2000 m a.s.l) and one from the highest (> 2801 m a.s.l)

Cluster B consisted the maximum number of populations (18) collected from Harerghe, Bale and Arsi. In this cluster group the populations from Sidamo, Gojam, Gonder and Tigray were not included.

Cluster C consisted sixteen populations collected from Arsi, Shewa, and Harerghe but populations from Bale, Sidamo, Gojam, Gonder and Tigray were not included.

Cluster D This cluster consisted five populations from Shewa, Gojam, Sidamo and Bale.

Cluster E only one population, which is an outlier, was distinctly grouped in this cluster. The population was collected from Shewa (2800 m a.s.l.).

Cluster F consisted nine populations from Gonder, Shewa, Arsi and Harerghe.

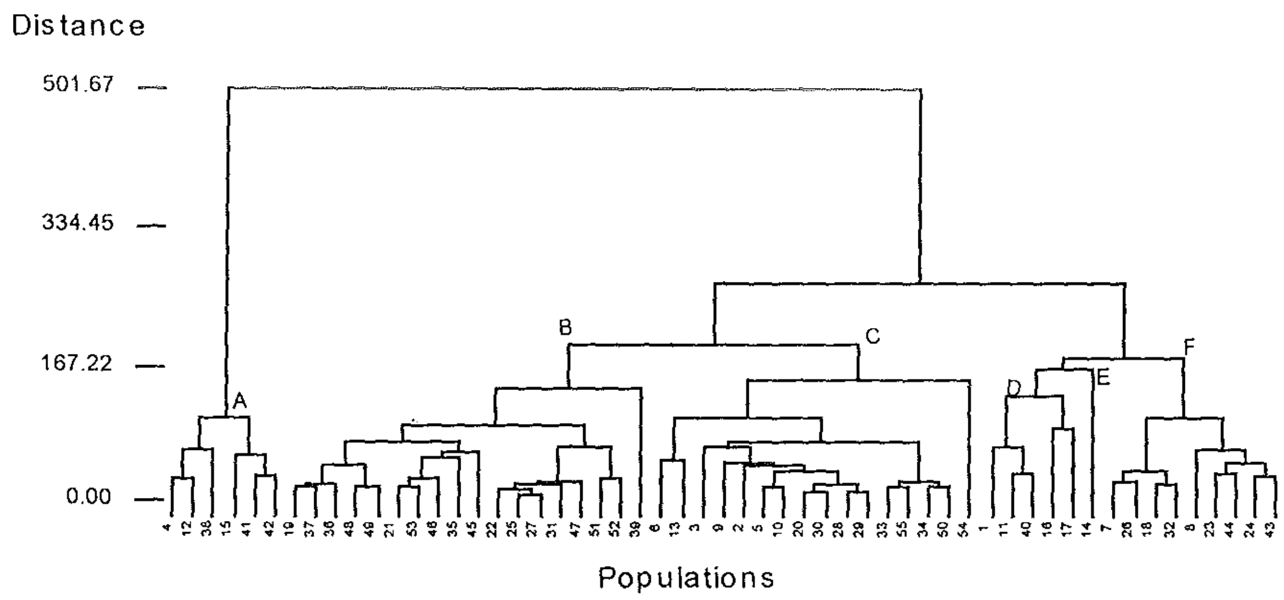


Fig 3. Dendrogram constracted using Ward methods on 55 emmer wheat populations based on

quantitative and qualitative morphological characters

Clustering of population based on quantitative characters is indicated in the denderogram given in Fig. 4. Six major clusters A, B, C, D, E and F were formed. The summaries of mean agronomic traits for each cluster group are presented in Table 6.

Cluster A is characterized by having lower biomass, shorter flag leaf length, lower harvest index, smaller kernels per spike and spikelete per spike and lower seed yield per plant.

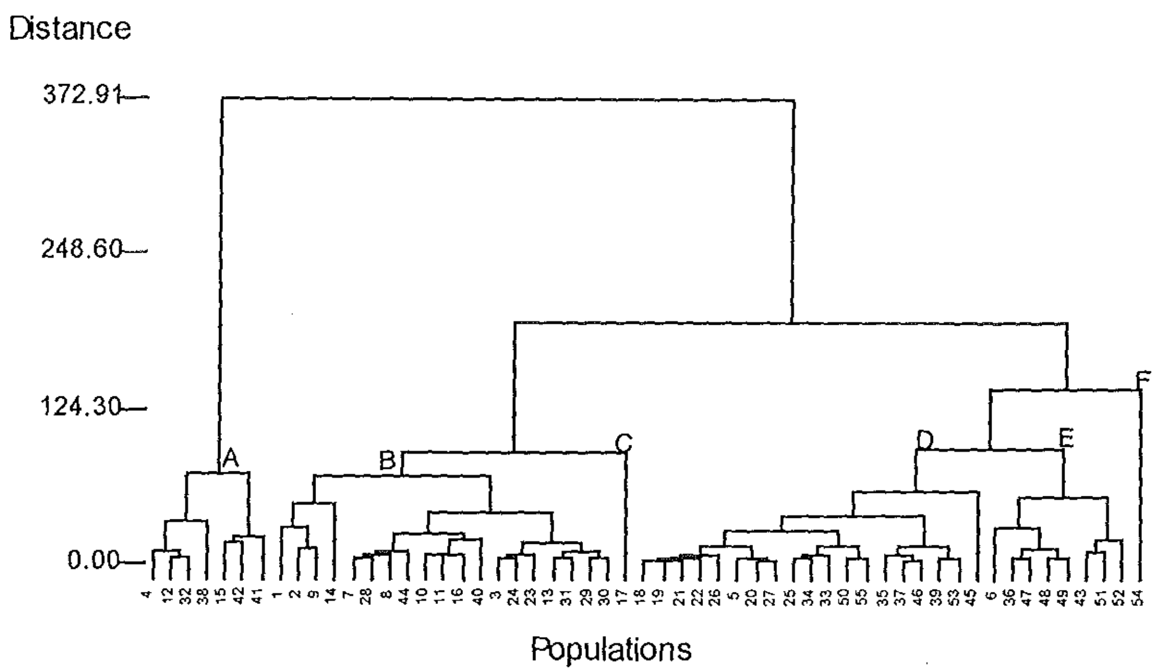


Fig4. Dendrogram constracted using Ward method on 55 emmer wheat populations based on sixteen quantitative morphological characters

Cluster B was mainly characterized by higher biomass, high seed yield and high tillering capacity.

Cluster C had only one accession characterized by higher flag leaf length, shorter grain filling period, early maturing type, higher number of kernel per spike, lower thousand grain weight and lower tillering capacity.

Cluster D contained the largest number of accessions (19 accessions) and was mainly characterized by having longer grain filling period. Actually the accessions of cluster D do not possess extremes for most traits.

Cluster E consists of 8 accessions mainly characterized by higher biomass, late maturing, long plant height, higher thousand of grain weight.

Cluster F consist only one outlier characterized by higher harvest index, higher number of spikelete per spike, high thousand grain weight and it had moderate value for the other traits.

Table 6. Summary of mean agronomic character over the six cluster of emmer wheat populations

Cluster	DH	DM	GFP	FLG	AWL	PH	K/S	Spl/S	SL	BM	TN	TGW	SY		HI
													WH	WHO	
Cluster-A	88	139	52	22	11	86	35	19	7	71	17	27	19	11	16
Cluster-B	92	142	51	24	10	91	44	23	9	122	28	22	36	23	19
Cluster-C	90	124	35	27	10	91	45	23	9	92	15	21	27	17	19
Cluster-D	88	143	55	24	11	93	43	22	8	98	19	29	28	18	19
Cluster- E	90	144	54	25	12	96	44	23	9	114	22	41	35	22	20
Cluster- F	89	140	51	23	10	94	44	23	9	88	19	39	30	18	44
Entire pop	90	142	52	24	11	92	43	22	8	105	22	28	31	20	19

4.1.5 Discriminant analysis

Discriminant analysis, using the regions of origin or the accessions as a grouping variable, revealed that 26 of the 55 (47.3%) accessions were correctly classified to their respective regions of origin (Table 7). The percent of accessions correctly classified was higher for Sidamo and Tigray followed by Arsi and Hararghe but in case of Sidamo and Gojam the number of accessions were one. This may have affected the power to discriminant analysis and makes the result exaggerated.

Table 7 Summary of discriminate analysis for 55 emmer wheat accessions by place of origin

Region	Percent of accessions correctly classified (%)							
	Bale	Arsi	Shewa	Harerghe	Sidamo	Gojam	Gonder	Tigray
Bale	15	43	14	14	0	0	0	14
Arsi	0	67	5	28	0	0	0	0
Shewa	11	22	11	0	22	23	11	0
Harerghe	27	13	7	53	0	0	0	0
Sidamo	0	0	0	0	100	0	0	0
Gojam	0	0	0	0	100	0	0	0
Gonder	0	0	50	0	50	0	0	0
Tigray	0	0	0	0	0	0	0	100

Discriminant analysis was further made using the means of regions of origin for the 16 quantitative characters in order to study the regional pattern of variation. The analysis was effective in that the first two canonical variables explained 96.2% of the total variation among 55 emmer wheat accessions for 16 quantitative character studied (Table 8). The first and the second canonical variables had significant contribution for the discrimination of regions and the first canonical variable accounted for 54.7% of the total variation. CAN-1, which maximized the differentiation among landrace populations was closely related to heading time. Tiller number and flag leaf length showing strong positive correlation. But grain filling period and node number showed a strong negative correlation with CAN-1.

Table 8. Eigen value, percent of variance and cumulative variance of the first three canonical variables (CAN-) and correlation coefficients of the CANs for 16 quantitative traits in emmer wheat landraces

Characters	CAN-1	CAN-2	CAN-3
DH	0.84*	0.09	0.54
DM	0.02	0.10	0.22*
GFP	-0.36*	0.07	-0.06
FLG	0.26*	0.13	-0.04
TN	0.34*	0.12	0.30
AWL	-0.08	0.22*	0.09
NDN	-0.09	0.00	0.09
NK/S	0.39	0.91*	-0.12
SpL	0.12	0.50*	0.09
NSpl/S	0.38	0.81*	-0.12
BM	0.28	0.41*	0.22
PHT	-0.43	0.69*	0.58
TGW	-0.10	0.04	0.32*
HI	-0.01	0.18	-0.06
SYWH	0.25	0.43*	0.16
SYWOH	0.23	0.42*	0.12
Eigenvalues	1.42	1.08	0.10
% of total variance	54.7	41.51	3.8
% of cumulative variance	54.7	96.2	100

*: P< 0.05

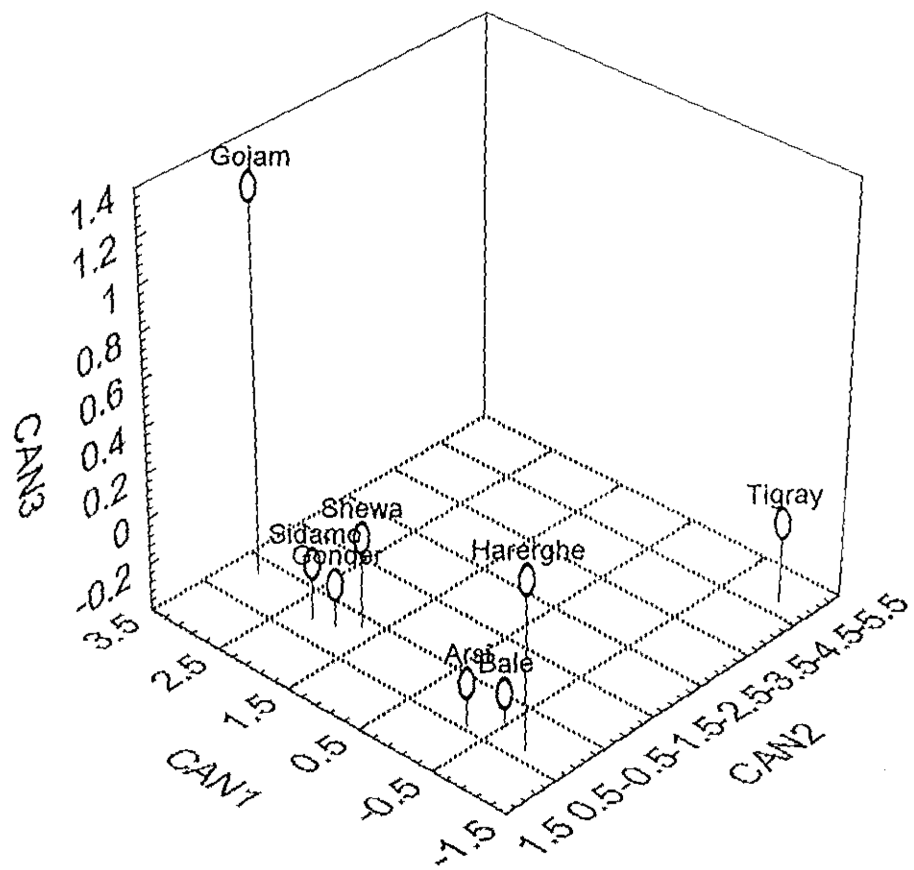


Fig5. 3D representation of the first three canonical variables (CAN) resulting from discriminant analysis of region mean of quantitative traits of 55 emmer wheat landraces.

Figure 5 shows the distribution of the eight regions of origin of the accessions along the three axes of the canonical variables. Gojam and Sidamo materials with high positive canonical scores occupied the extremes of the first axis and Harerghe and Tigray materials had low negative scores. The second canonical axis made differentiation among landrace populations, based on yield and yield components and this axis showed high correlation with these traits. The extremes occupied by Tigray materials with high negative and lower yield per plant, lower biomass, number of kernels per spike and spikelate per spike. In the figure it is clearly seen that Arsi and Bale were sketched within the same square, which indicates the similarity of the materials due to may be material exchange because of proximity effect.

4.1.6 Correspondence analysis

Further analysis of the patterns of diversity among accessions from different regions was carried out by correspondence analysis of qualitative data (Appedix 11). The calculated inertia, percent of variance and cumulative variance are reported in Table 9. The first two components (variables) accounted for 73.7% of the total variance and out of this component; C1 covered 44.5% of the variation.

Table 9. Correspondence analysis ordinate scores, inertia, proportion of variance and cumulative variance for the first two components for the eight region.

Region	C1	C2
Bale	0.153	0.065
Arsi	0.044	0.084
Shewa	-0.010	-0.025
Harerge	0.015	0.056
Sidamo	-0.540	-0.071
Gojam	0.027	0.332
Gonder	0.115	-0.307
Tigray	0.198	-0.135
Inartia	0.046	0.03
Proportion of variance	0.445	0.292
Cumulative variance	0.445	0.737

Bale, Tigray and Gonder showed higher positive correlations with component 1 but Sidamo only had negative correlation. In line with this column contribution (data not shown) indicated short beak length and dark reddish gray glume color had high negative correlation with compenent1.

Component 2 was negatively associated with Tigray and Gonder but strong positive correlation observed with Gojam. In component 2, traits like lax spike density, white kernel color and white glume color had big contribution for the separation of regions and these traits showed strong negative correlation and highest contribution in C 1.

Figure 6 shows the distribution of the eight regions of origin of the accessions along the two axes of the component variables. The distinctiveness of Sidamo, Tigray and Bale on the component 1 was due to lower frequency of short beak length (Bale and Tigray) and high frequency of short beak length and dark reddish gray glume color (Sidamo). The isolation of Gojam, Gonder and Tigray was due to higher frequency of white kernel color and lax spike density and white glume color.

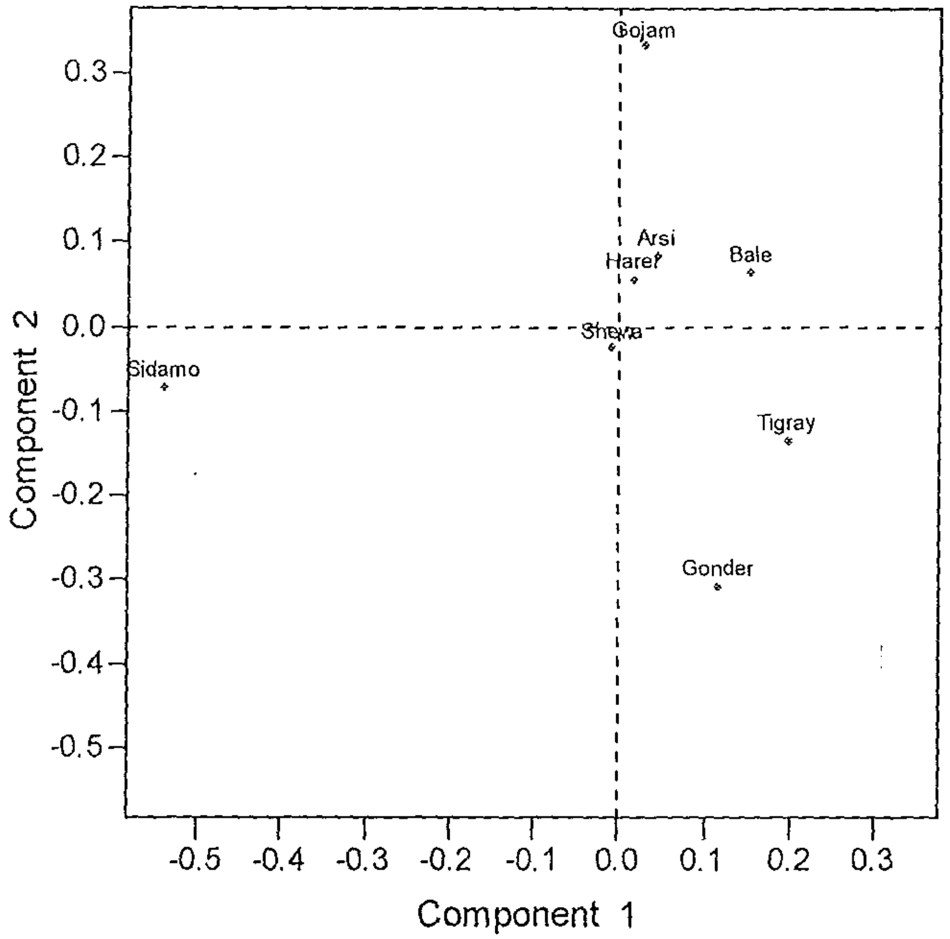


Fig.6 Distribution of the eight regions of origin of the population along the two axes of the component variables using qualitative characters

4.1.7 Multidimensional scaling

A representation of the Square Euclidean Distance Matrix computed from 55 populations using sixteen quantitative characters was made using the multidimensional scaling procedure (STASTICA, 4.1 computer program). Plotting the first two dimensions indicated that the populations collected from the different regions had distinct agro-morphological attributes. Most of the accessions had neither negative nor positive loading in both axis and there is an overlap to some degree. Most of the populations collected from Shewa had negative loading in the first axis unlike the populations collected from Harerghe and Tigray (Fig. 7).

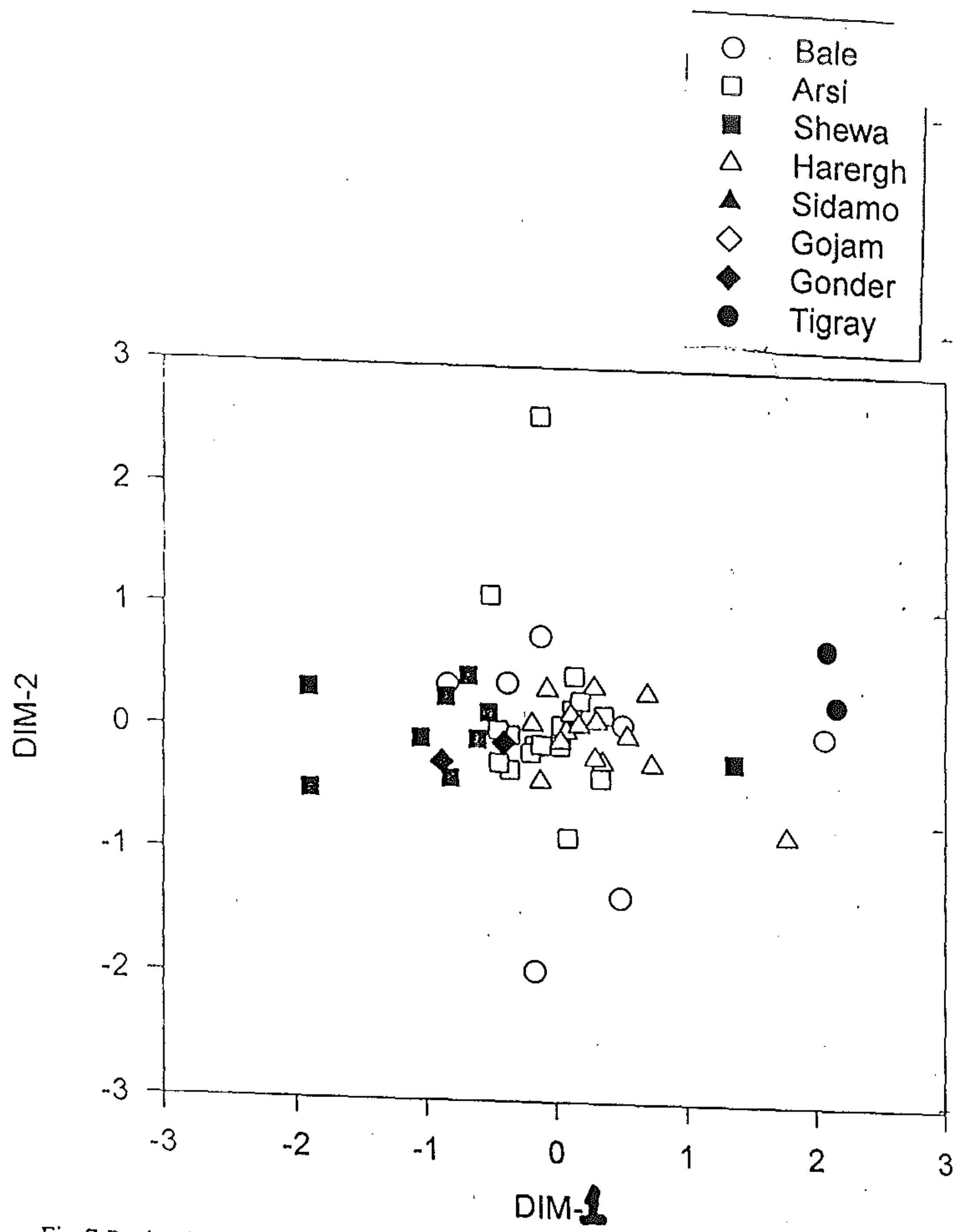


Fig.7 Projection of emmer wheat populations according to the first two dimensions of multidimensional scaling

4.1.8 Frequency Distribution and Diversity index for Morphological characters

4.1.8.1.Regional trait distribution

Frequencies in phenotypic classes expressed in percentage for characters by regions and the results of chi-square tests for each region is summarized in Table 10. The predominant phenotypic class in all geographical regions is the medium beak length types except in the case of Sidamo where the short beak length (60 %) is dominant. The highest frequency of medium beak length was recorded for Tigray (98%) followed by Bale (91%).

Tapering and parallel ear shapes were observed in all the regions and its distribution is nearly equal. White, pale-yellow, pale-red and dark- reddish gray were found in the entire region except white and dark reddish gray were absent in Gojam. Pale yellow glume color was predominant over the entire regions unlike the rarely observed- dark-reddish gray one. Glume pubescence is a monomorphic trait and only glabrous was observed in all the regions. White kernel color was completely absent in populations collected from Bale, Sidamo, Gojam and Tigray. Pale yellow and pale red seed colors were equally predominant in all regions with different proportion.

Medium spike density was predominating character of spike in all the regions and it ranges from 77% (Tigray) to 53% (Sidamo). Lax spike type was absent in Sidamo and Gojam material. Erect and intermediate type of spike bending tendency were frequently observed in the entire geographical regions but completely bent down spike was not frequent as such. Only four regions, Sidamo, Gojam, Gonder and Tigray displayed a deviation from the expected chi-square distribution so that they had significant chi-square distribution ($P < 0.05$). The lower sample from these regions may account for high chi-square deviation.

4.1.8.2 Altitudinal trait distribution

The phenotypic frequencies for individual characters and altitude classes as percentages of the number of genotypes from each altitude class by pooling populations together is summarized in Table 11. Except the upper altitude class (> 2801 m a.s.l), which had only 5 accessions, the rest were represented well. In all altitude classes medium beak length was predominant. Pale yellow glume color was the predominant glume color and its frequency increased as the altitude increases and the bending tendency of the spikes also showed somewhat increasing trends with altitude. But all the traits didn't show any deviation from chi- square distribution and the variation of the traits considered were less variable by altitude group than by regions.

Table10. Percentage of phenotypic classes and Chi- square values for qualitative trairs of each region

Region	Beak Length				Ear Shape			Glume Color					Glume Pubescence			Kemel Color				Spike Density				Spike Bending Tendency			
	S	M	L	X	T	P	X^2	W	P-Y	P-r	D-R-G	X	G	H	X^2	W	P-Y	P-r	X^2	D	M	L	X^2	E	IM	B Dn	X2
Bale	9	91	0	10.7	45	55	0.20	8	53	37	2	10.2	100	0	0		53	47	2.43	40	59	1	0.76	55	39	6	3.13
Arsi	21	79	0	0.2	47	53	0.003	10	52	37	1	9.9	100	0	0		43	56	1.85	38	61	1	0.60	47	43	10	0.77
Shewa	31	69	0	4.1	50	50	0.3	15	54	29	2	2.5	100	0	0		48	46	9.34	38	59	3	0.39	46	47	7	0.13
Harer	23	76	1	6.1	42	58	1.11	10	49	38	3	8.5	100	0	0		44	54	0.81	43	56	1	1.65	47	47	6	0.49
Sidamo	60	40	0	79.83*	40	60	2.11	22	40	15	23	66.16**	100	0	0		45	55	2.71	48	53	0	5.76	25	58	18	23.5*
Gojam	13	87	0	5.4	50	50	0.3	0	83	17	0	42.18*	100	0	0		46	54	2.39	38	63	0	2.22	21	66	13	25.95*
Gonder	22	78	0	0.1	55	45	2.41	22	42	27	9	6.9	100	0	0		56	38	12.96	38	55	7	11.7	78	22	0	42.1**
Tigray	2	98	0	24.5	49	51	2.12	38	47	11	4	41.99*	100	0	0		53	47	2.43	19	77	4	15.6	51	45	4	2.41

S = small; M =medium; L = Long; T= tapering; P = parallel; W =white; P-Y= pale yellow; P-r = pale red; D-R-G = dark reddish gray ; G=glabrous; H= hairy; D= dense ; M= medium; L= long ; E= erect ; IM = intermediate; BDn= completely bent down, Significance levels** = $p < 0.01$, * = $p < 0.05$

Table11: Percentage of phenotypic classes and Chi- square values for qualitative trairs of each altitudinal class

Altitud	Beak Length				Ear Shape			Glume Color					Glume Pubescence			Kernel Color				Spike Density				Spike Bending Tendency			
	S	M	L	X^2	T	P	X^2	W	P-Y	P-r	D-R-G	X^2	G	H	X^2	W	P-Y	P-r	X^2	D	M	Lax	X^2	E	I M	B Dn	X2
1	10	90	0	6.1	49	51	0.4	13	51	33	3	0.48	100	0	0	2	52	46	0.7	34	65	1	1.43	43	54	3	5.4
2	23	76	1	3.1	45	55	0.1	12	50	36	2	0.81	100	0	0	1	44	55	1.2	41	58	1.3	0.27	49	44	7	0.11
3	22	78	0	0.6	43	57	0.4	9	53	33	5	2.20	100	0	0	2	46	52	0.4	40	57	3	1.60	50	42	8	0.25
4	23	77	0	1.0	47	53	0.1	10	59	29	1	2.27	100	0	0	1	53	46	0.8	42	57	1	0.44	49	38	13	4.54

S = small; M =medium; L = Long; T= tapering; P = parallel; W =white; P-Y= pale yellow; P-r = pale red; D-R-G = dark reddish gray ; G=glabrous; H= hairy; D= dense ; M= medium; L= long ; E= erect ; IM = intermediate; BDn= completely bent down

1= < 2000m a.s.l.; 2 = 2001 – 2400m a.s.l.; 3= 2401-2800m a.s.l ; 4 = > 2801m a.s.l

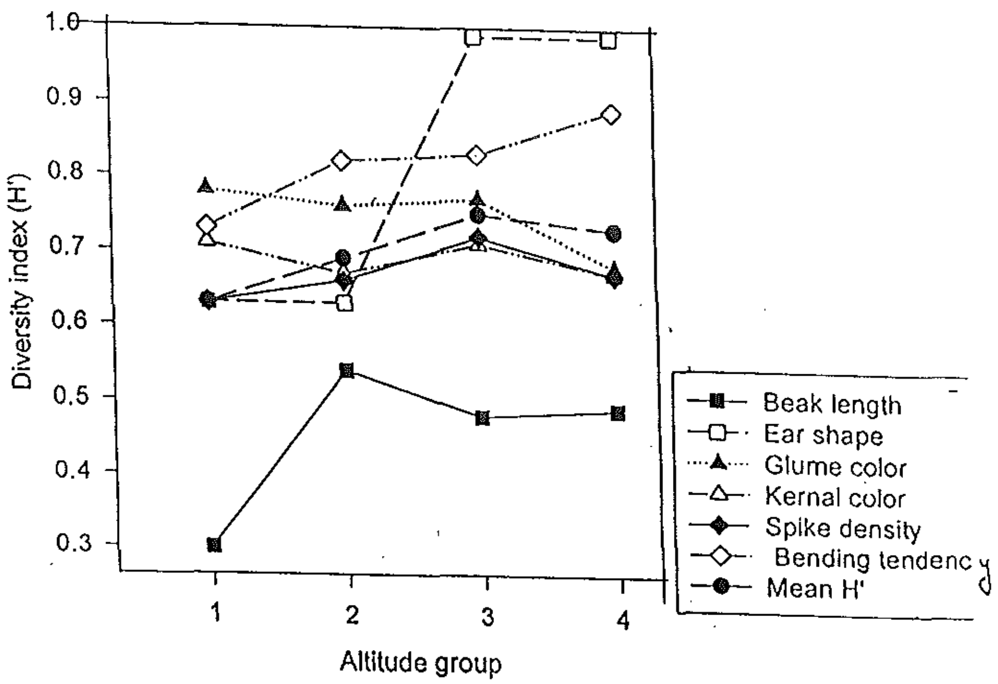
4.1.8.3 Diversity index

Estimate of diversity for individual characters, regions, populations and altitude classes are shown in Table 14 and 15 and Appendix 6, respectively. Polymorphism was common in populations for ear shape indicating the existence of ear shape variation in the populations studied. The highest mean diversity indeces (0.78 and 0.77) were observed in two populations collected from Sidamo (PGRC/E 213038) and Arsi (PGRC/E 6052) followed by another collection from Arsi (PGRC/E 219078). However, a collection from Harerghe (PGRC/E 7920) showed lower H' (0.54). On altitude bases, all the traits showed from lower H' 0.3 for beak length in altitude class one (> 2401 m a.s.l.) ranges to 0.99 for ear shape (Appendix 7). The diversity index for ear shape showed exponential sharp increase in the first three altitude group and then stabilized. Spike bending tendency showed a gradual increase and spike density and mean diversity showed gradual increase in then gradual decrease after the third altitude group with increasing altitude. Beak length showed sharp increment then gradual decrease with increasing altitude. Glume color and kernel color showed gradual decrease (Fig. 8). At altitudinal group 3 all the morphological traits tend to decline or stabilize but bending tendency showed gradual increase because of the effect of frost after the altitude group 3 and the bent type had the trait which can avoid the moisture from it spike.

Pooled diversity index over entire data and region indicated high diversity, and this recorded by collection from Shewa (0.78) and followed by Hararghe (0.74), Gonder (0.74) and Arsi (0.73) (Table 12). The present data showed that the overall mean H' for Ethiopia was 0.75 ± 0.07 which is high (Table 12).

Table 12. Mean diversity indices (H') for each of six qualitative traits across regions

Region	BL	ES	GC	KC	SD	BT	Mean ± SE
Bale	0.28	0.99	0.71	0.63	0.66	0.79	0.68 ± 0.1
Arsi	0.47	0.99	0.71	0.67	0.65	0.86	0.73 ± 0.07
Shewa	0.56	1.00	0.76	0.80	0.71	0.82	0.78 ± 0.06
Harergh	0.54	0.98	0.76	0.70	0.67	0.80	0.74 ± 0.06
Sidamo	0.61	0.34	0.95	0.63	0.63	0.89	0.68 ± 0.09
Gojam	0.35	1.00	0.33	0.63	0.61	0.79	0.62 ± 0.1
Gonder	0.48	0.99	0.91	0.78	0.80	0.48	0.74 ± 0.09
Tigray	0.09	1.00	0.79	0.63	0.59	0.76	0.63 ± 0.12
Ethiopia	0.52	1.00	0.77	0.71	0.66	0.83	0.75 ± 0.07



1 = < 2000m a.s.l ; 2 = 2001-2400m a.s.l ; 3 = 24001-2800m a.s.l 4 = > 2801m a.s.l

Fig.8 Mean diversity indices for traits and overall mean across traits in four altitude groups

The analysis of variance of H for individual traits by region is presented in Table 13 For all characters most of the variance was due to the variation within populations rather than regions and altitudinal classes. However, beak length and glume color showed significant variation ($P < 0.05$) among regions. Beak length also differed significantly ($p < 0.05$) between altitude groups.

Table 13. Mean squares for the different levels of grouping involving regions and altitudes from the ANOVA of H for individual character

Character	Between		Between population within	
	Region (df=7)	Altitude (df=3)	Region (df=47)	Altitude (df=51)
Beak Length	0.106**	0.091**	0.013	0.021
Ear Shape	0.001	0.001	0.002	0.002
Glume Color	0.084**	0.01	0.023	0.032
Kernel Color	0.012	0.00	0.009	0.01
Spike Density	0.011	0.007	0.009	0.009
Spike bending tendency	0.039	0.013	0.027	0.029

Significance levels ** = $p < 0.05$

A further analysis of the data by hierarchical analysis of variance in order to partition the within region and altitude variance, based on normalized data, showed that there were no significant differences within region and altitude (Table 14).

Table14. Hierarchical analysis of variance of H' across the six qualitative traits

Source of Variation		df	Sum of square	Mean square	F-ratio
Between	Regions	7	0.2033	0.029	2.16ns
	Population within region	47	0.6308	0.0134	0.33ns
	Altitude groups	3	0.048	0.016	1.04ns
	Population within altitude group	51	0.786	0.0154	0.38ns
Characters within populations		275	11.273	0.041	
Total		329	12.107		

Table 15 Diversity index for each population

Landrace	LANDRACE(Acc.No)	BLH'	ESH'	GCH'	KCH'	SDH'	BTH'	Mean H' ± SE
1	PGRC/E 5999	0.5	0.99	0.45	0.61	0.53	0.58	0.62 ± 0.08
2	PGRC/E 6018	0.6	1	0.6	0.79	0.62	0.82	0.74 ± 0.06
3	PGRC/E 6052	0.5	0.9	0.66	0.68	0.83	0.98	0.77 ± 0.07
4	PGRC/C 6054	0.2	0.97	0.73	0.89	0.7	0.56	0.68± 0.11
5	PGRC/E 6055	0.5	0.99	0.65	0.62	0.78	0.91	0.75 ± 0.07
6	PGRC/E 6068	0.5	1	0.69	0.44	0.8	0.56	0.67± 0.11
7	PGRC/E 6843	0.4	0.99	0.93	0.79	0.82	0.55	0.75 ± 0.09
8	PGRC/E 7278	0.5	0.91	0.85	0.5	0.78	0.35	0.65 ± 0.09
9	PGRC/E 7884	0.4	0.84	0.65	0.82	0.62	0.96	0.72 ± 0.08
10	PGRC/E 7885	0.4	0.98	0.72	0.72	0.67	0.81	0.73 ± 0.07
11	PGRC/E 7886	0.5	0.99	0.61	0.55	0.69	0.82	0.70 ± 0.07
12	PGRC/E 7913	0.5	0.99	0.68	0.72	0.81	0.73	0.75 ± 0.06
13	PGRC/E 7920	0.1	0.79	0.32	0.63	0.62	0.68	0.54 ± 0.1
14	PGRC/E 8010	0.	0.99	0.74	0.9	0.62	0.61	0.73 ± 0.08
15	PGRC/E 204345	0.2	0.99	0.72	0.62	0.7	0.85	0.69 ± 0.11
16	PGRC/E 213038	0.6	0.97	0.95	0.63	0.63	0.89	0.78 ± 0.07
17	PGRC/E 215407	0.3	0.77	0.55	0.62	0.63	0.89	0.63 ± 0.08
18	PGRC/E 216831	0.5	0.97	0.76	0.79	0.62	0.54	0.71 ± 0.07
19	PGRC/E 216835	0.5	0.85	0.83	0.62	0.63	0.85	0.72 ± 0.06
20	PGRC/E 216836	0.4	0.95	0.64	0.76	0.76	0.91	0.75 ± 0.07
21	PGRC/E 216838	0.	0.98	0.64	0.62	0.7	0.44	0.63 ± 0.08
22	PGRC/E 219074	0.5	1	0.52	0.63	0.47	0.57	0.62 ± 0.08
23	PGRC/E 219078	0.	0.98	0.76	0.6	0.74	0.85	0.76 ± 0.06
24	PGRC/E 219079	0.4	0.98	0.68	0.71	0.63	0.78	0.70 ± 0.07
25	PGRC/E 219080	0.4	1	0.7	0.63	0.59	0.78	0.69 ± 0.08
26	PGRC/E 219081	0.4	1	0.95	0.59	0.59	0.49	0.68 ± 0.1
27	PGRC/E 219082	0.5	0.99	0.49	0.63	0.6	0.77	0.67 ± 0.08
28	PGRC/E 219083	0.5	0.99	0.66	0.63	0.6	0.84	0.71 ± 0.07
29	PGRC/E 219084	0.4	0.96	0.69	0.62	0.63	0.95	0.72 ± 0.08
30	PGRC/E 219085	0.4	0.98	0.57	0.8	0.63	0.99	0.73 ± 0.1

Table 15 Continued

31	PGRC/E 219253	0.4	0.98	0.65	0.61	0.57	0.73	0.67 ± 0.07
32	PGRC/E 219254	0.5	0.99	0.88	0.8	0.63	0.55	0.73 ± 0.08
33	PGRC/E 219255	0.5	0.99	0.62	0.62	0.58	0.89	0.71 ± 0.08
34	PGRC/E 219256	0.5	0.96	0.73	0.71	0.69	0.73	0.72 ± 0.06
35	PGRC/E 219259	0.5	0.88	0.84	0.66	0.54	0.92	0.73 ± 0.07
36	PGRC/E 219260	0.5	0.82	0.68	0.63	0.57	0.62	0.65 ± 0.04
37	PGRC/E 219263	0.	0.91	0.79	0.58	0.63	0.58	0.67 ± 0.06
38	PGRC/E 219272	0.3	0.99	0.79	0.7	0.56	0.67	0.68 ± 0.09
39	PGRC/E 219275	0.	0.99	0.67	0.63	0.65	0.8	0.71 ± 0.07
40	PGRC/E 219510	0.3	1	0.33	0.63	0.6	0.78	0.62 ± 0.1
41	PGRC/E 221736		0.98	0.75	0.62	0.57	0.86	0.63 ± 0.14
42	PGRC/E 221741	0.1	0.99	0.8	0.63	0.61	0.61	0.63 ± 0.11
43	PGRC/E 229266	0.5	0.99	0.72	0.57	0.57	0.57	0.67 ± 0.07
44	PGRC/E 229268	0.5	0.84	0.74	0.62	0.73	0.7	0.70 ± 0.04
45	PGRC/E 230675	0.4	0.99	0.8	0.62	0.7	0.76	0.71 ± 0.08
46	PGRC/E 230679	0.1	0.97	0.62	0.63	0.6	0.79	0.63 ± 0.11
47	PGRC/E 230686	0.3	0.99	0.68	0.61	0.6	0.55	0.64 ± 0.08
48	PGRC/E 230690	0.1	0.96	0.67	0.56	0.62	0.51	0.57 ± 0.11
49	PGRC/E 231233	0.3	0.94	0.66	0.63	0.58	0.68	0.65 ± 0.07
50	PGRC/E 231235	0.	0.98	0.8	0.6	0.61	0.74	0.67 ± 0.09
51	PGRC/E 231238	0.1	0.94	0.63	0.63	0.69	0.84	0.64 ± 0.12
52	PGRC/E 232230	0.4	0.98	0.64	0.62	0.44	0.62	0.62 ± 0.08
53	PGRC/E 232231	0.3	0.96	0.6	0.61	0.63	0.6	0.62 ± 0.08
54	PGRC/E 232232	0.4	0.99	0.74	0.61	0.48	0.83	0.68 ± 0.09
55	PGRC/E 232233	0.5	0.97	0.69	0.63	0.52	0.89	0.71 ± 0.07

BLH' = H' of beak length; GCH' = H' of glume color; KCH' = H' of kernale color; SDH' = H' of spike density; BTH' = H' of spike bending tendency

4.2 Biochemical Diversity

4.2.1 Isozyme study

The summary of allele frequencies of six polymorphic loci and their genetic variability in the twelve populations are given in Tables 16 and 17. The mean number of alleles and percent of polymorphic loci for the populations ranged from 1.4 to 1.7 and from 44.4 to 66.7, respectively. Heterozygosity estimates show that the mean for the populations is 0.369 and ranges from 0.311 to 0.489. Most of the populations showed lower frequency of allele per locus and only three populations got highest ranges. Most of the population showed lower percentage polymorphic loci. But two populations, PGRC/E 221736 and 213038, collected from Tigray and Sidamo showed higher percentage of polymo

Table 16 Summary of allele frequencies for 6 polymorphic loci among populations of emmer

	Population											
Locus	1	2	3	4	5	6	7	8	9	10	11	12
EST-1												
A	.500	.800	.600	.900	.500	.500	.500	.625	.500	.500	.600	.500
B	.500	.200	.400	.100	.500	.500	.500	.375	.500	.500	.400	.500
EST-2												
A	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
EST-3												
A	.300	.300	.100	.000	.000	.500	.000	.100	.000	.000	.100	.300
B	.700	.700	.900	1.000	1.000	.500	1.000	.900	1.000	1.000	.900	.700
AAT-1												
A	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500	.50
B	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500	.50
AAT-2												
A	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.00	1.000
AAT-3												
A	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.00	1.000	1.000
ACP-1												
A	1.00	.625	.778	.900	.800	.800	.000	.200	.000	.200	.200	.00

Table 16 Continued

B	.000	.375	.167	.100	.200	.200	1.000	.800	.125	.800	.800	1.00
C	.000	.000	.056	.000	.000	.000	.000	.000	.875	.000	.000	.000
ACP-2												
A	.000	.400	.000	.000	.000	.000	.100	.100	.000	.000	.000	.000
B	1.000	.600	1.000	1.000	1.000	1.000	.900	.900	1.000	1.000	1.00	1.00
ACP-3												
A	.500	.500	.500	.500	.500	.500	.300	.500	.500	.500	.500	.500
B	.500	.500	.500	.500	.500	.500	.700	.500	.500	.500	.500	.500

1= PGRC/E6054 (Shewa), 2 = PGRC/E221736 (Tigray), 3 = PGRC/E230690 (Bale), 4 = PGRC/E232230 (Arsi), 5 = PGRC/E216838 (Hararghe), 6 = PGRC/E232232 (Arsi), 7 = PGRC/E7920 (Harerghe), 8 = PGRC/E213038 (Sidamo), 9 = PGRC/E 219510 (Gojam), 10=PGRC/E8010(Shewa),11=PGRC/E6843(Gonder),12=PGRC/E219254(Harerghe)

Table 17. Measures of genetic variability, averaged over 6 isozyme loci in population of 12-emmer wheat landrace.

Population	Mean no. of alleles per locus	% of polymorphic loci	Mean heterozygosity Observed	Mean heterozygosity expected
1. P-6054	1.4	44.4	.400	.237
2. P-221736	1.7	66.7	.417	.334
3. P-23069	1.7	55.6	.383	.248
4. P-232230	1.4	44.4	.267	.168
5. P-216838	1.4	44.4	.378	.225
6. P-232232	1.6	55.6	.489	.286
7. P-7920	1.4	44.4	.311	.198
8. P-213038	1.7	66.7	.350	.267
9. P-219510	1.4	44.4	.361	.213
10. P-8010	1.4	44.4	.333	.225
11. P-6843	1.6	55.6	.333	.244
12. P-219254	1.4	44.4	.400	.237

P = PGRC/E

A comparison of F statistics for 12 populations is given in Table 18. The values of F_{ST} indicate differentiation between populations (Biosis, 1998). The degree of differentiation (F_{ST}) of the individual loci ranged from 0.00 for AAT 1 to 0.505 for ACP-1. The populations were differentiated among themselves markedly for EST- 3, ACP- 1 and ACP-2. The mean value for F_{ST} indicates a moderate level of differentiation between populations.

Table 18. Summary of F-statistics at 6 isozyme loci among 12 populations of emmer wheat

Locus	F(IS)	F(IT)	F(ST)
EST-1	-.833	-.708	.068
EST-3	-.478	-.165	.212
AAT-1	-1.00	-1.00	.000
ACP-1	.137	.642	.585
ACP-2	.524	.649	.263
ACP-3	-.959	-.935	.012
Mean	-.706	-.387	.187

F(IS) = indicates variability within population, F(IT) = total genetic variability, F(ST) = variability among population

The unbiased genetic identify and genetic distance estimates between the population ranged from 0.999 to 0.843 and 0.105 to 0.00, respectively. These data confirm that there were moderate degrees of differentiation among the populations.

Table19. Matrix of Nei's (NEI, 1978) genetic similarity and/or distance coefficients for pairwise comparisons of populations of emmer wheat over 6 isozyme

Population	1	2	3	4	5	6	7	8	9	10	11	12
P-6054	*****	.943	.987	.965	.982	.989	.843	.899	.864	.898	.902	.85
P-221736	.014	*****	.960	.956	.947	.951	.901	.949	.863	.925	.938	.906
P-23069	.000	.002	*****	.986	.997	.975	.900	.945	.908	.945	.947	.900
P-232230	.009	011	.000	*****	.978	.943	.864	.921	.873	.913	.920	.857
P-216838	.000	.013	.000	.000	*****	.965	.905	.944	.902	.950	.947	.898
P-232232	.000	.004	.000	.024	.002	*****	.868	.919	.864	.913	.923	.902
P-7920	.105	.051	.059	.095	.056	.080	*****	.986	.889	.988	.985	.981
P-213038	.052	.006	.017	.043	019	.032	.000	*****	.906	.995	.999	.985

Table 17 Continued

P-219510	.086	.077	.051	.086	.056	.081	.070	.049	*****	.913	.909	.881
P-8010	.058	.029	.021	.053	.018	.042	.000	.000	.048	*****	.997	.982
P-6843	.053	.017	.017	.045	.019	.032	.000	.000	.049	.000	*****	.987
P-219254	.087	.042	.055	.098	.058	.049	.000	.000	.072	.000	.000	****

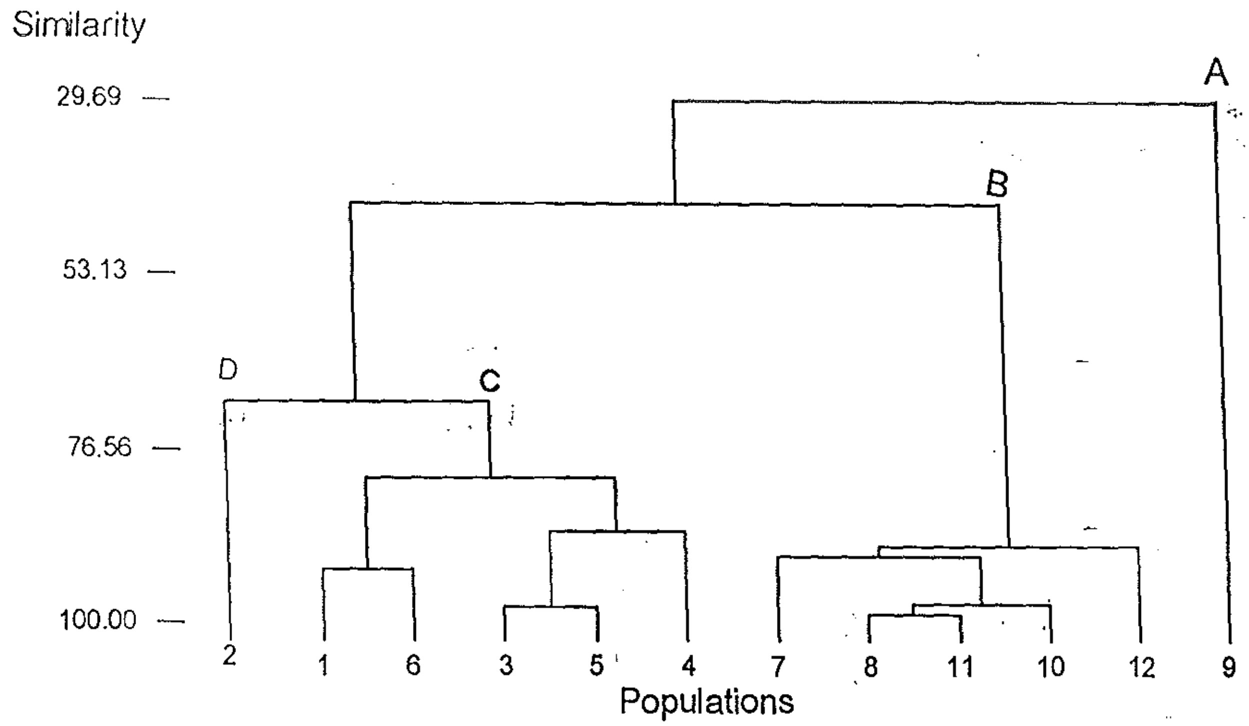
*Left ****: indicates unbiased minimum distance* *right of ****: indicats genetic identity P = PGRC/E*

1= PGRC/E6054 (Shewa), 2 = PGRC/E221736 (Tigray), 3 = PGRC/E230690 (Bale), 4 = PGRC/E232230 (Arsi), 5 = PGRC/E216838 (Harerghe), 6 = PGRC/E232232 (Arsi), 7 = PGRC/E7920 (Harerghe), 8 = PGRC/E213038 (Sidamo), 9 = PGRC/E 219510 (Gojam), 10 = PGRC/E 8010 (Shewa), 11=PGRC/E6843(Gonder),12=PGRC/E219254(Harerghe)

The highest genetic distance observed was between populations collected from Harerghe (PGRC/E 7920) and populations collected form Shewa (PGRC/E 6054). These two populations were from different regions and altitude classes. The highest genetic similarly were observed between populations collected from Sidamo and Gonder which is far apart from each other, but with little differences.

Clustering of populations using unbiased minimum distance was carried out using unweighted pair group method (Fig 9). The populations were grouped in to four clusters.

Cluster A contains only one outlier population of Gojam collection. Clusters B and C contain five populations each and cluster C contains one population from Shewa, and Bale, two from Arsi and Hararghe. Cluster B contains a dispersed population one from Sidamo, Shewa, Gonder and two from Hararghe. Cluster D contains one population which is an outlier collected from Tigray.



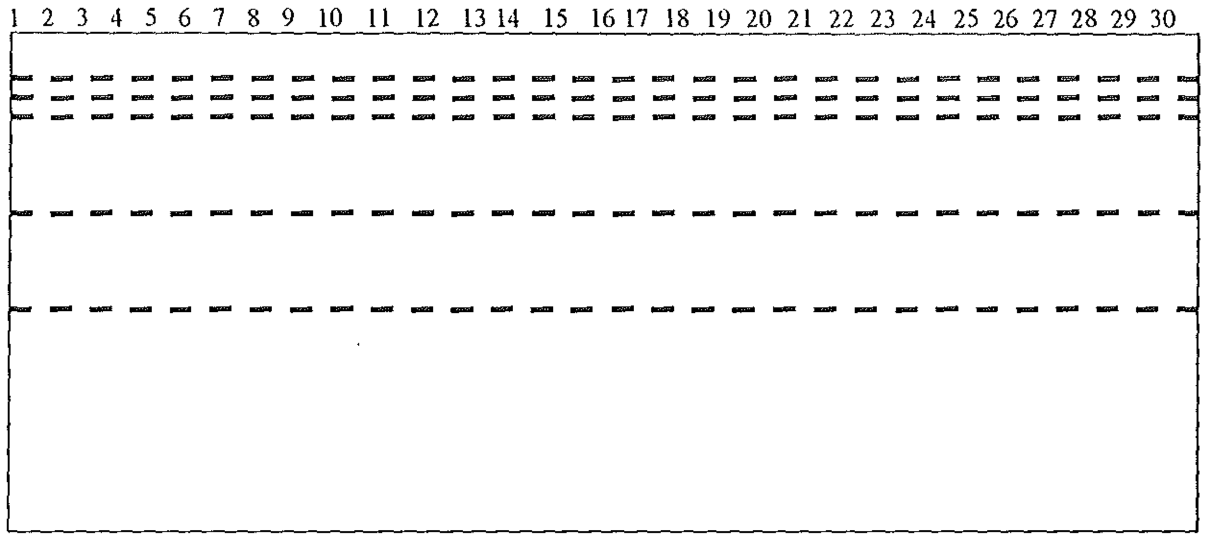
1= PGRC/E6054 (Shewa), 2 = PGRC/E221736 (Tigray), 3 = PGRC/E230690 (Bale),

4 = PGRC/E232230 (Arsi), 5 = PGRC/E216838 (Harerghe), 6 = PGRC/E232232 (Arsi), 7 = PGRC/E7920 (Harerghe), 8 = PGRC/E213038 (Sidamo), 9 = PGRC/E 219510 (Gojam), 10 = PGRC/E 8010 (Shewa), 11= PGRC/E6843 (Gonder), 12 = PGRC/E 219254 (Harerghe)

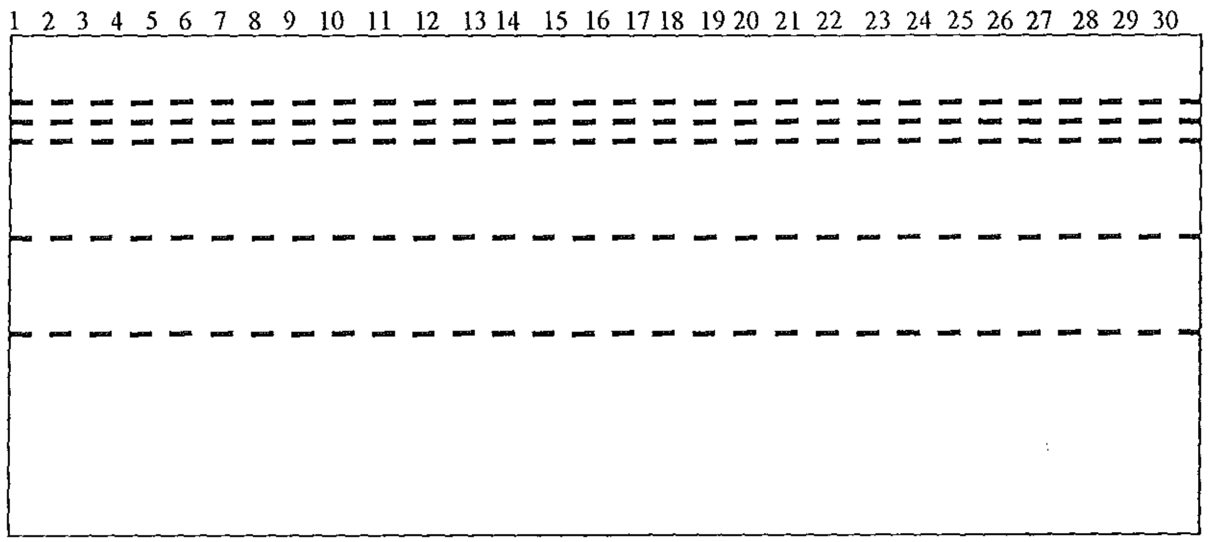
Fig. 9 Dendrogram showing the clustering of 12 emmer wheat populations based on isozyme data

Below is given the schematic representation of the zymogram banding pattern of the different emmer wheat populations studied. The sequence of loading (for all gels) was (each represented by five wells, i.e. five plants per landrace) 1= PGRC/E6054 (Shewa), 2 = PGRC/E221736 (Tigray), 3 = PGRC/E230690 (Bale), 4 = PGRC/E232230 (Arsi), 5 = PGRC/E216838 (Harerghe), 6 = PGRC/E232232 (Arsi), 7 = PGRC/E7920 (Harerghe), 8 = PGRC/E213038 (Sidamo), 9 = PGRC/E 219510 (Gojam), 10 = PGRC/E 8010 (Shewa), 11= PGRC/E6843 (Gonder), 12 = PGRC/E 219254 (Harerghe).

Gel-1



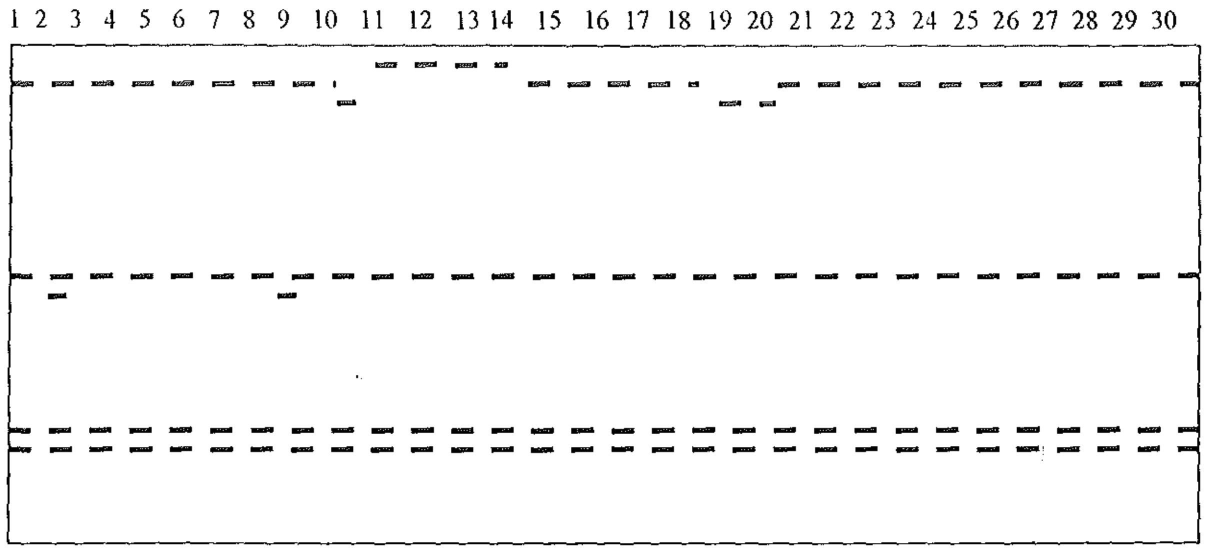
Gel-2



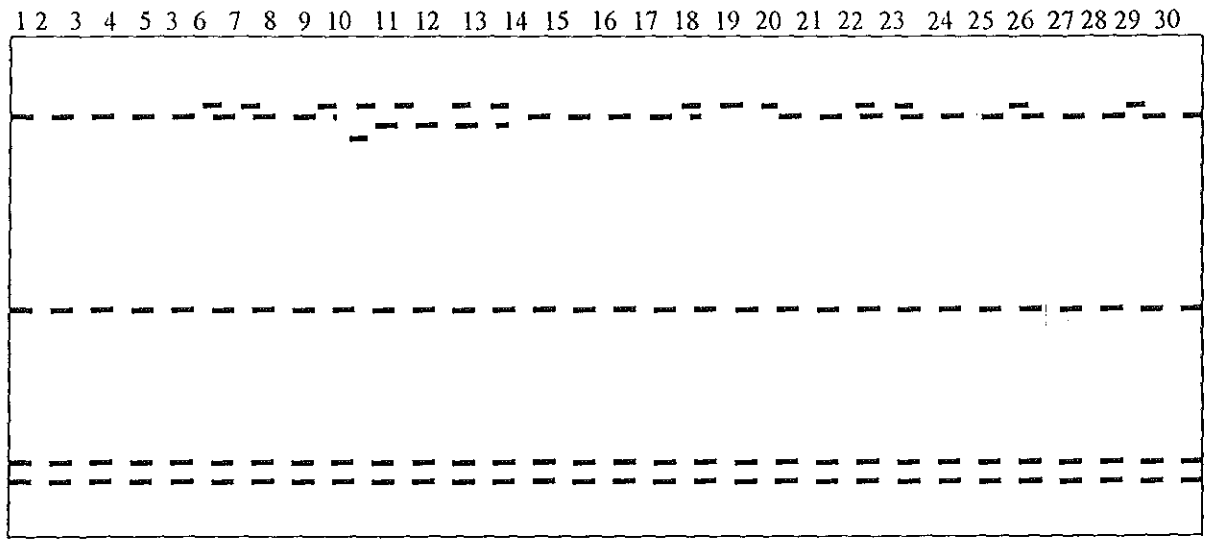
Population1-6 were loaded in the first gel and each population each represented by five wells, i.e. five plants per landrace, accordingly the data was collected (Appendix 12)

Fig. 10. Schematic illustration of the zymogram banding pattern of emmer wheat population for enzyme system AAT

Gel-1



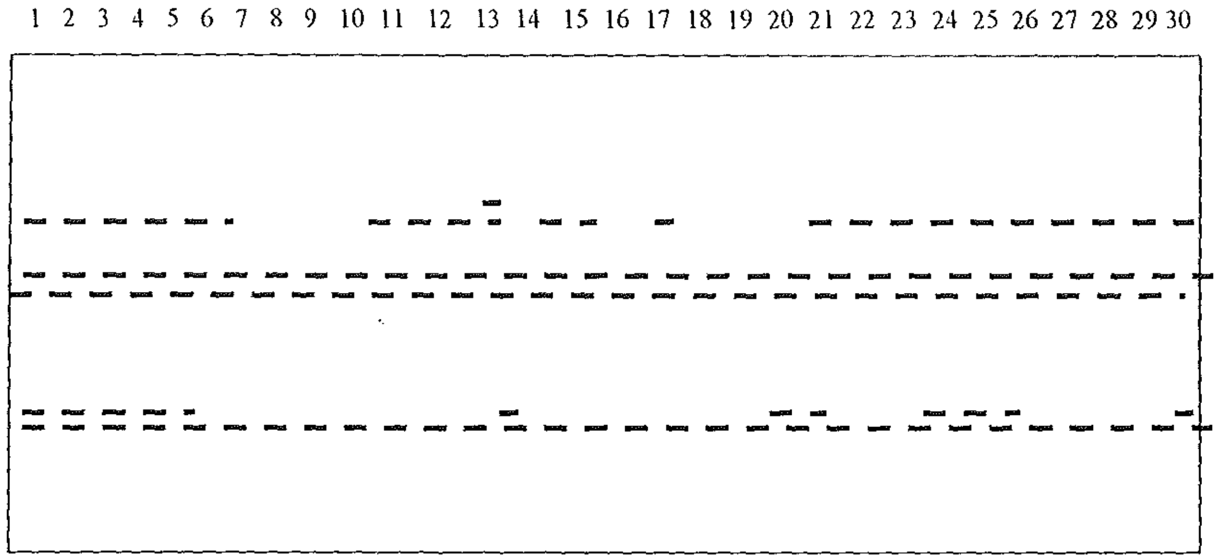
Gel-2



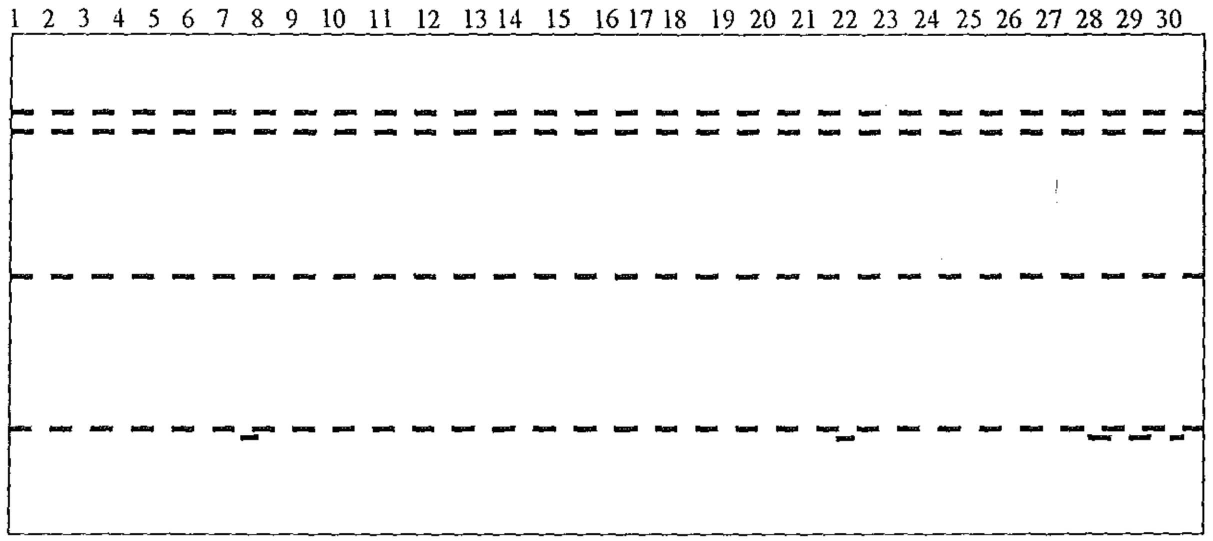
Population1-6 were loaded in the first gel and each population each represented by five wells, i.e. five plants per landrace, accordingly the data was collected (Appendix 12)

Fig.11. Schematic illustration of the zymogram banding pattern of emmer wheat population for enzyme system ACP

Gel-1



Gel-2



Population1-6 were loaded in the first gel and each population each represented by five wells, i.e. five plants per landrace, accordingly the data was collected (Appendix 12)

Fig. 12. Schematic illustration of the zymogram banding pattern of emmer wheat population for enzyme system EST

4.2.2 Protein Analysis

Protein contents of 37 populations of emmer wheat are given in Table 20. One-way analysis of variance for populations showed no significant variation at $P < 0.05$ (Table 21). However, there was significant difference in altitude groups ($p < 0.05$). There was no significant variation detected between regions. The covariance analysis showed a strong negative correlation between altitudes and region in protein content. The highest regional mean was scored by Bale (14.58) and followed by Harerghe (14.085). The highest protein content was scored by accession PGRC/E 7920 (15.33) collected from Hararghe and this accession showed highest genetic distance in isozyme analysis. The lowest was scored by accession PGRC/E 7886 (11.95) from Shewa.

Table 20. Protein contents of 37 populations of emmer wheat

Landrace	%Protein	Landrace	%Protein	Landrace	%Protein
PGRC/E 5999	12.93	PGRC/E 213038	13.54	PGRC/E 219253	12.50
PGRC/E 6018	12.74	PGRC/E 215407	13.90	PGRC/E 219254	13.60
PGRC/E 6052	14.21	PGRC/E 216831	13.89	PGRC/E 219255	13.01
PGRC/C 6054	13.19	PGRC/E 216835	14.00	PGRC/E 219256	13.05
PGRC/E 6055	13.17	PGRC/E 216836	14.43	PGRC/E 219259	12.99
PGRC/E 6068	13.02	PGRC/E 216838	13.39	PGRC/E 219260	12.89
PGRC/E 6843	12.39	PGRC/E 219074	15.14	PGRC/E 219263	12.68
PGRC/E 7278	12.23	PGRC/E 219078	14.62		
PGRC/E 7884	12.24	PGRC/E 219079	13.82		
PGRC/E 7885	12.79	PGRC/E 219080	13.46		
PGRC/E 7886	11.95	PGRC/E 219081	13.55		
PGRC/E 7913	13.47	PGRC/E 219082	13.04		
PGRC/E 7920	15.33	PGRC/E 219083	12.25		
PGRC/E 8010	13.32	PGRC/E 219084	11.99		
PGRC/E 204345	15.26	PGRC/E 219085	12.95		

Table 21. Analysis of variance and covariance for protein content of populations of emmer wheat using different regions and altitude groups (*significant at P < 0.05)

Source	D.f	Sum of square	Mean square	Region (Covariance)	Altitude (Covariance)
Between regions	5	11.44	2.228ns		
Within region	22	11.47	0.521ns		
Between altitude	3	7.767	2.589*		
Within altitude	24	15.14	0.631		
Between landrace	27	22.907	0.848		
Total	27	22.907			
Region				0.848	-0.341
Altitude				-0.341	0.550

Table 22. Mean protein content of the population over region and altitude groups

Region/Altitude	Mean ± SE
Bale	14.58 ± 0.68
Arsi	13.63 ± 0.27
Shewa	12.74 ± 0.19
Harerghe	14.085 ± 0.29
Sidamo	13.54 ± 0.09
Gonder	12.31 ± --
< 2000m asl	13.19 ± --
2001- 2400m asl	14.00 ± 0.24
2401- 2800m asl	13.14 ± 0.27
> 2801	12.51 ± 0.27
Mean	13.47 ± 0.17

4.2.3 Dry Matter, Ash, Organic Matter and Mineral Analysis

The analysis of percent dry matter, ash, organic matter and mineral analysis showed that there is no significant variation over region and altitude. It can be observed from Table 23 that ash has got increasing trend with increment in altitude, but the other analyses done show an increasing trend to a certain altitudinal level, beyond which they tend to decrease.

Table 23. Mean data of Ash, Calcium (Ca), Dray matter (DM) and Organic matter (OM) of 55 emmer wheat landrace over altitude

ALT		ASH	CA	DM	OM
1.00	Mean	1.2538	6.375E-02	88.7063	98.7463
	SE	6.000E-02	1.000E-02	5.000E-02	6.000E-02
2.00	Mean	1.3610	6.500E-02	88.6507	98.6723
	SE	5.000E-02	3.000E-03	4.000E-02	4.000E-02
3.00	Mean	1.3550	7.083E-02	88.5758	98.6450
	SE	5.000E-02	.0000	4.316E-02	5.000E-02
4.00	Mean	1.5180	6.600E-02	88.6340	98.4820
	SE	.1100	1.000E-02	.1202	.1100
Total	Mean	1.3584	6.618E-02	88.6409	98.6598
	SE	3.000E-02	.0000	2.519E-02	3.000E-02

Altitude group (ALT) 1 = < 2000m asl, 2 = 2001-2400m asl, 3 = 2401-2800m asl, 4 = > 2801m asl

Analysis was also done at a region level. Tigray scored the highest ash content while the lowest ash content observed was that of Sidamo (Table 24). The different emmer wheat accessions were also compared for their calcium content at region level. The result indicates that Shewa and Gondar scored the highest calium content while Sidamo and Gojam were the lowest. For dry matter and organic matter content, Gojam and Sidamo collections showed the highest contents, respectively.

Table 24. Mean ash, Ca, Dry matter and organic matter content for the 55 different accessions of emmer wheat over regions.

REG		ASH	Ca	DM	OM
Bale	Mean	1.1886	6.429E-02	88.6314	98.8114
	SE	5.000E-02	1.000E-02	5.000E-02	5.000E-02
Arsi	Mean	1.3456	6.889E-02	88.6739	98.6544
	SE	5.000E-02	3.782E-03	4.592E-02	5.000E-02
Shewa	Mean	1.4367	7.000E-02	88.6233	98.5633
	SE	5.000E-02	2.887E-03	3.371E-02	5.000E-02
Harerghe	Mean	1.4173	6.200E-02	88.6320	98.6493
	SE	8.000E-02	1.000E-02	6.000E-02	7.000E-02
Sidamo	Mean	1.1000	6.000E-02	88.5400	98.9000
	SE	.	.	.	.
Gojam	Mean	1.1600	6.000E-02	88.7600	98.8400
	SE	.	.	.	.
Gonder	Mean	1.3250	7.000E-02	88.4800	98.6750
	SE	.1200	.0000	5.000E-02	.1100
Tigray	Mean	1.5350	6.500E-02	88.6750	98.4650
	SE	5.000E-02	5.000E-03	.2150	5.000E-02
Ethiopia	Mean	1.3584	6.618E-02	88.6409	98.6598
	SE	3.000E-02	.0000	3.000E-02	3.000E-02

4.3. Studies on Cultural practices and Ethnobotanical studies

4.3.1 Ecogeographical distribution and production system of emmer

The ethnobotanical data was taken along with agronomic, management and cultural practices of the farmers. In both zones (Arsi and Bale) farmers have more or less similar cultural practices regarding emmer wheat production. Crop production and animal husbandry are the main agricultural practices in the zones. Present day distribution of emmer wheat is in mid and high altitudes of the two zones. In areas where bimodal rainfall pattern is common both seasons are used to produce emmer wheat.

Site selection and allocation of lands

Farmers allocate their farm plots mainly based on their suitability for a given crop. In so doing, they consider enormous factors like soil type, topography of the land, fertility and depth of the soil, etc.., which can affect the performance of their crop. A given site is selected only for those crops, which tolerate or resist some major yield-limiting factor in it. Farmers do not give priority for emmer wheat during site selection. The reason is that emmer wheat is a hardy crop and in spite of the low yield it has high adaptability and tolerance to poor soil condition where no other crops can be grown with the same degree of success. According to most of emmer wheat farmers, they used to plant emmer after finishing the activity of planting other crops. Consequently, marginal land, water logged land, frost prone areas, shade area, roadside land, rocky and mountainous land is given to emmer wheat cultivation.

Land preparation and planting

The process of tilling is done by an oxen drown wooden implement which have sharp edage of metal called '*maresha*'. For most farmers plowing frequency for emmer land preparation is at most three times which is lower than the other cereals. According to explanation given by farmers, this is because of three main reasons. The first one is, farmer plant emmer wheat on the '*genna*'season (March-August, according to Bale farmer) harvest and hence they don't have enough time to prepare its land well. The other two reason are related to the fact that emmer will lodge if planted on well-prepared farmland and its tolerance to any natural hazard. Most of the time farmers used to plant emmer in virgin or marginal lands so the virgin land will be well prepared for the coming seasons for the other cereal crops. The local people have old saying in their language- Oromiffa *"Hayisaa fi garbichi xiqquma biyyee mataarratti rarni"* in English *"Hayisa fi garbecha tikkuma biys matarati rarane"* meaning emmer wheat and a low profile person need small soil to be buried which indicate its requirement of minimum tillage or shallow soil.

Farmers used to plant emmer with its hull and also they do not use fertilizers. Some of the interviewed formers reported that they are forced to plant emmer wheat and pulse crop in case of shortage of fertilizer and fear of credit since the price of fertilizer is becoming unaffordable by poor farmers.

Disease and weed management

According to most interviewed farmers idea there is no serious disease and pest seen in emmer wheat. But some farmers mention leaf rust as problem. Farmers report and observations of the actual fields indicate that there is weed infection in both seasons in emmer wheat fields. For this serious weed infestation minimum tillage may be major reason.

According to farmers report and visual assessment the major weed flora of the survey area include, *hadda* (*Guizotia scabra*), *asendabo* (*Phalaris paradoxa*), mergaserrei (*Setaria* spp.), *shabbe (Rumex* spp.) and *banggi (Datura stramonium*). Farmers do not give priority in weeding emmer wheat. They indicated that there is a critical labor shortage to weed all crops and the limited labors is used to weed the other cereals especially bread wheat, since emmer is relatively more tolerant and competent to weed infestation and competition.

Harvesting and threshing

Harvesting of emmer wheat is done manually using sickles, but currently some farmers use combine harvester. The manual harvesting of emmer is done before the crop is completely dry because the rachis is fragile and the ears break easily when completely dry up. For the *genna* (March - August) crop harvesting in areas, which receive bimodal rainfall, farmers are too busy, due to harvest of *genna* crop and also because of land preparation for the following *bonna* crops. Thus they leave crops piled on their farms till they get time for threshing. Mostly farmers plant barley and emmer in *genna*. Threshing activity is similar with the other crops, and is usually using animal trampling method on a leveled and cleaned ground.

The grain yields of emmer wheat vary from year to year depending on rainfall and other natural occurrences and from farm to farm depending on soil fertility and weed infestation. Keeping this fact in mind, the average and range of grain yield of local (landrace) emmer wheat under farmers' management practices is 24 q /ha and 20-35 q/ha respectively for hulled grains.

4.3.2. Emmer wheat variety and diversity in farmers' fields

Except Sinana Agricultural Research Center there is no other center currently working on emmer wheat improvement and accordingly, till now, there is no improved variety of emmer wheat. Therefore, the existing variety of emmer wheat in the area is the local one, which is farmers' variety.

Visual observation and farmers assertion indicates that there is only one morphotype and the local people know it by the name *'Hayisaa'* (In some pocket area call it Aja, *Gardama, Issaa,* and *Mattajabo*). The reason for the variation in naming is related to immigrants from different part of Oromia and Amahar region who tend to adopt its name in their previous locality. Accordingly, emmer wheat is called by different names among immigrants, those who came from Shewa and Amhara region call it *Aja*, in (Amharic) those from Hararghe call it *Issaa* (Oromiffa) , *Matajaboo* and *Umburii* (Oromiffa) called by West and Central Oromia but *Hayisaa* in Oromiffa and Aja' in Amharic are the two common and frequent names in use in the two zone.

The farmers' field is uniform in all traits when it is compared within farmland and between farmland of emmer. The number of seeds per spike is commonly two but depending on the size of the spike, there are cases in which one can find three or one. There is no variation in the farmers' field in resistance to leaf rust and stem rust, most of the plant being equally susceptible for leaf rust and resistant to stem rust. However, in the case of yellow rust there is probably clear diversity, some of the plants are more attacked than others.

4.3.3. Informal seed system and marketability of emmer wheat

Emmer wheat is one of the traditional crops for the indigenous people. It is preferred and needed by farmers because of its classified good food value. The crop has relation with culture of the Oromo people of the area. In previous year emmer wheat did not have commercial value in the area. The reason for lower or no market value is due to strong social influnce for the marketing of emmer wheat. According to the elderly local people there is a strong negative attitudes for the sale of emmer. The local people have a saying in relation to their culture, in Oromiffa "*Hayisaan silga loonit*", *Hayisaan korma*" '*Oromani silga loon fi korma hin gurguru*' English – " Hyissan silga loniti" 'Hyissni korm, Oromoni silga loni fi korm hingurguru" meaning, emmer wheat is the maiden first milk and bull and the Oromo ethnic group will never sale maiden milk and bull. The Oromo ethnic group especially indigenous people of Arsi and Bale previously they were pastoralists and their cultures are strongly attached with livestock and livestock products. Here, also they consider emmer wheat as bull and, maiden milk, which is restricted only for home consumption, but forbidden for sale. If any one who is selling emmer wheat, in the past, was considered by the people as evil willed man and out castled from the society. Due to unavailability of emmer in the market and its importance most farmers, in general, old people in particular still maintain a small farm for emmer production. Therefore, this strong cultural influence hinders both production and commercialization of emmer wheat on a large large scale.

According to local merchants, now a days, due to increasing demand of emmer wheat by urban dwellers and reduction of cultural influence, emmer is seen in Arsi and Bale markets but the amount is still small. The price of a quintal (1quintal = 60-75 kg) of emmer in the local market varies from place to place and from time to time but most of the time it ranges from 70 - 130 Birr/quintal. According to elderly farmers, in pervious years and in some areas where there is strong social and cultural taboo for sales of emmer, farmers get emmer seed as gifts, through loans and exchange.

4.3.4.Emmer Wheat processing and Gender roles

Emmer wheat is preferred and appreciated by all the local people. All farmers especially in Bale allocate at least a small farmland for home consumption. Some farmers produce more emmer for sale in the local market. In contrast to its importance it's processing is one of the difficult tasks for emmer what producing farmers. Threshing is not different from the other cereals but emmer needs to be further processed in orders to free the grain from the husk for human consumption. The difficulty of de-hulling is one of the major factors, which contributes to the decrease in production of emmer in some families.

Time and labor is spent in dehulling emmer wheat particularly, de-hulling and milling is a very tiresome job for mothers in the past and still is in some areas. Women clean the spikelete for dehulling and milling process. The hull is not usually completely removed before grinding. Grinding is usually done using traditional milling (grinding) stone in their homes. They blow the grounded grains to the air in order to completely clean the grains, and sieve it to discriminate by size. The process of grinding is repeated based on the type of food to be prepared. The coarse part of the seeds is used to make *shuffisa* and *hanga* (hard porridges) and the powdered / fine flour is used to make '*Merka*' (soft porridge), *haphi* (pancake) and other foodstuffs, which need fine flour.

All the above processing for pre-food preparation and food preparation process itself is left for mothers and their daughters, which is a heavy task. The local people have different sayings, which indicate problems associated with dehulling, which is a burden on female members of the society (Table 25 and Appendix 8). Now a days in most partsthere are milling houses that are used to mill other crops so that with some modification people are using it for dehulling and milling.

4.3.5 Farmers Food habit and emmer wheat utilization

In the survey area there are different food habits among the migrant Christians and local Muslims. Generally, in Christian families the staple food is *injera*, prepared from barley, wheat, tef, emmer wheat, solely or mixed in various proportions. Porridge (*Merkka* and *Suffisa*) usually prepared from barely, emmer wheat and/or wheat, is the staple food of Muslims in the area. Dairy products (milk and butter) are the major relishes of porridge. Nowadays, however dairy products (as porridge relishes) are supplemented in some areas by linseed oil, as the latter are less available.

In addition to different foodstuffs emmer also used in the preparation of soft drinks. In some areas of Arsi, farmers reported that, depending on the availability of emmer; they even used it as '*asharro*', malt (bi*kill*) and '*kita*' (pancake) for preparing local alcoholic drinks like '*katikala*' and '*Ferrso*' (local beer). Some farmers also give emphasis the feed value of emmer wheat straw and also the taller stem left after harvesting the top is used in thatching roofs.

Local food recipes made with emmer wheat

The production system of the local people is totally depending on cultivation of field crops and livestock production. Their food habit is directly depends on their production system as a source of food. The food recipe of the local people directly depends on what they have and they produce. Accordingly, their emmer recipes are collected from women and males are documented here.

'Merka' (soft porridge)

Though the flour of barley, wheat and emmer wheat can be used for *merka* preparation, the later is most preferred. Since emmer wheat cultivation is restricted to small farmlands, farmers do not produce surplus grains as the major cereals. Due to the limited grains they usually have, the local people used to prepare emmer wheat porridge on special occasions for home consumption and for honored guests.

Emmer wheat *merka* is preferred and recommended by the local people as special dish for women giving birth, unhealthy people, weak people and children for maintaining their health and strength. Emmer wheat *merka* appears mostly in the morning, lunch and diner, but in case of emergency in which respected guests comes to their home, mothers prepare emmer porridge (Table 24). Merka appears in all mealtimes, except snacks (Table 23).

Hango and shuffisa (Hard porridge)

Hango and *shuffisa* (hard porridge) is commonly prepared from barley, wheat and emmer wheat but the preferred *hango* and *shuffisa* is prepared from emmer. *Shuffisa (Kinche)* mostly appeared in the daily meal during break fast but h*ango* is prepared on special occasion and courser grains during milling is used for making it (Table 24). *Shuffisa (Kinche)* is mostly prepared and used for childen and prepared. *Hango* is mostly prepared a week before the date of marking ceremonies called '*hark dhaa*' in the male house.

Table 25. Meal time and type of dishes served in the study area.

Mealtime	Type of dish served
Break fast	*merka, shuffisa, haphi, dabboo*
Lunch	*Merka, bedden, shuffisa*
Snack	*Haphi (Kita)*
Dinner	*Merka, shuffisa, Muzz/ bulluka, shorba, bedden, cankita*
Special occasion	*Hango, shorba,*

Shorba (Soup) and Muzze

Shorba preparation doesn't need fine flour but like that of the *shuffsa* and *hango,* it need coarsely splited dehulled grains. *Muzze* is used for children whose mothers have died or are not with them any longer and/or at the time of livestock milk shortage and for unhealthy family member. But *shorba* is mostly restricted for the fasting time of Muslims.

*Cankita (*Local spaghetti)

In Bale zone some women commonly prepare *cankita* (local spaghetti) manually or with a small machine for home consumption. Both emmer wheat and bread wheat are used for preparation of *cankita* locally but due to its availability, bread wheat is common, with regards to its preference emmer is more selected.

Haphi (Kita) and other minor food stuff

Haphi (unfermented bread) prepared from barley, wheat and emmer wheat. *Haphi* made from emmer wheat is preferred and it is believed to strengthen body when it is eaten together with milk and it is taster than barley and wheat. *Most households in both zone commonly prepare haphi* and is served at breakfast, snack for child and side dish during coffee ceremonies. *Dabbo* (bread) and *injera* are also prepared from emmer but due to the need of more flour of emmer and the shortage of emmer flour, most of the time people use emmer to mix it at different proportion with barley, wheat and tef.

Local Drinks

Emmer wheat is also important in the preparation of different local drinks among both local Muslims and Christians. Mostly Muslims use it for the preparation of soft drinks. In the survey area two types of soft drinks are prepared and used, that is, '*Karribbo*' and '*Lila*'.

Karribbo and *Lila*

In Arsi and Bale, *karribbo* is commonly prepared from barley and wheat and in rear case emmer is used. The utilization of emmer for *karrribbo* is restricted in special occasions and holidays. Farmers consider such drinks as alcoholic free drinks but the fermentation proceedes and the amount of alcohol is increased through time, and thus, they drink it with in a short time. *Lila* is prepared during holidays in some parts of Arsi. It is similar to *Kerribbo* but it is different in that its preparation doesn't need *haphi/kita*.

Table 26. Traditional dishes and drinks prepared from emmer or mixture of emmer

Type of dishes and drinks in Oromiffa	Description
Marqaa	Stiff porridge
Shuffisa (Qincee)	Coarsely grounded and boiled and drained meal which is hard porridge
Hangoo	Soup like liquid food
Muuzee (buuqa)	" " " "
Shoorbaa	Soup
Saankitaa	Home made spaghetti
Haphii (Qixxaa)	Thin pan cake un leavened
Daabboo	Thick bread well leavened
Beddeena	Thin pan cake like sour bread
Qariboo	Home made soft drink
Liillaa	Home made soft drink

4.3.6. Emmer and its medicinal value (food medicine)

According to the local people, emmer has medicinal value for different diseases. The local people generally agree that, emmer is important in maintaining broken bones. They said that broken bones heals faster when emmer is consumed in different forms of local dish like *Merka, hango, shuffisa muzze (bulka) and shorba*. Such preparation of emmer is important for any spinal cord related problems. For healthiness and purity of the skin, common cold for child strength and healthy growth emmer is recommended. In addition emmer wheat dish is mentioned as special effect for boils and some venereal diseases like Gonorrhea and Syphilis, if it is consumed as *muzze (bulka)*. Local people appreciate emmer as compared to wheat in that emmer doesn't affect stomach when consumed in any form- considered as healthy food.

The medicinal value of emmer is not only used for human diseases, but also for animals, like broken livestock, calf possessed by pest (*'kichame'*) and wounded animal. It is also important for milk cow to increase milk and calf to maintain their weight during dry season. During the early years in the culture of the Oromo people live in the two-zone horse has greater value for transporting, fighting and other related things. The horse, which are maintained, for the above activities and for holyday riding are continuously fed emmer. Generally, elder people of the society recommend and prefer emmer for any kind of disease and hurted man and animals.

4.3.7. Trends in emmer wheat cultivation

The trends in emmer wheat production are different in the two zones. Accordingly, the farmers in Arsi indicated the decreasing trends of emmer wheat production due to different factors. According to farmers the reasons are: Higher pressure of bread wheat through extension package program, low market value, poor yield obtained after dehulling, pre-harvesting sprouting.

In some Weredas of Bale zone, emmer wheat shows increasing trend. Farmers in Dinsho, Selka and Meluu areas mentioned different advantage of emmer in which they forced to increase their emmer land. Because of its food value, the improvement of market value, tolerance of abiotic and biotic factor and good for mechanization.

Therefore, the status and trend of emmer at different district is different and dynamic since the above (single or cumulative) factors contributed for the decrease or the increase of its production.

4.3.8.Cultural significance

Farmers assert that barley has more cultural significance for Oromo society than emmer. But in some case mothers use emmer wheat as *kinche* for *attete*. *Attete* is one of widely celebrated Oromo practice in which rituals wishing healthy life and prosperity for the family members are made (Asfaw, 1990). A special emmer wheat *kinche* or *shuffisa* (hard porridge) is prepared for this ceremony.

4.3.8.1.Marriage tradition

Hango, which is made of splited emmer grain, commonly prepared for *'hark-dha'* ceremony before a week of the exact date of the marriage day. Any dish of emmer is preferred and selected for respected and honored guests. But, the frequency and availability of emmer is not as such common in any wedding ceremonies but depending up on the amount and the will of the farmer may prepare emmer dish especially porridge on the wedding day.

4.3.8.2 The role of emmer dish in time of fasting

The Muslim society in general, and Arsi and Bale local people in particular, has a one month fasting and special prayer time annually. During this time of searching the will and face of God emmer has a special position in their foodstuff. For this special one-month fasting time every farmer will produce and store some amount of emmer wheat since the price of emmer in the local market is un affordable and influenced by a social taboo. During this fasting period, they give preferance for emmer wheat *shorba*. Emmer wheat *shorba* is chosen due to its nutritional value in order not to loss their weight and resistance in fasting period. During this time, the demand of emmer by the rural and local people is increased and therefore, its market value riches its maximum.

4.3.8.3.Songs and saying

The Oromo ethnic groups have many traditional songs and sayings in relation with his crop growing condition, crop type, crop quality, crop preference, and crop problems (Asfaw, 1990). Here also the local people have many saying on emmer, which indicates its medicinal value, dehulling problem, food quality, and tolerance to different stresses.

The quality of emmer is appreciated in Amharic *Kehile aja keneger engja* meaning from all the crop emmer is the best. In Oromiffa the good food quality of emmer is appreciated with its threshing problem in *Hayisaan kan nyaatuf tolee, Haadhaf Intale qolle* saying which means emmer wheat is good for food but mothers and daughters suffer a lot. The detail for song and saying is indicated in Table 25 and Appendix 9.

Table 27. Different songs and sayings on emmer wheat collected from Arsi and Bale Zones

Oromiffa	Meaning	Implication
Hayisaan nyaattee burraqxii hin nyaatuu doobbi guratti	A man who eats emmer jumps but a man who does not consume emmer is week	It indicates it is top quality food which is prefered for strength
Kehile aja keneger engja (Amharic)	From all crops emmer is the best but from disagremetns noting is prefered	Indicates preference for emmer wheat
Hayisaan kan nyaatuf tolee, Haadhaf Intale qolle	Emer wheat which is good for eating but trubles mother and her daughter in processing	Indicates its preference as food but difficulty in threshing
Hayisaani lafee cakde deebisa/fayyisa	Emmer wheat will maintain (return) broken bones	It indicates its preference as soup for broken bones
Korma jechuun dhiirra nama qarbuufi hayisaa qote nama arbean loles	Bold farmer is a farmer who produces emmer and barley and a man who kills elephant	It indicates the high value of the crop emmer in the society
Namni hayisaa nyaatu haadha fi intala hin laallatu	A man who consumes emmer wheat is sexually strong and doesn't discriminate mother and daughter	It indicates its nutritional value and makes man active & tough

5. Discussion

5.1 Morphological character

5.1.1 Character distribution

The four and three-color groups of glume and kernel, respectively are not evenly distributed in the entire collection. In some regions, dark reddish gray for glume color and white for kernel color were absent. But the predominant seed color was pale-yellow and pale-red. Farmers prefer reddish and reddish-yellow colored grain and they say that the grain develops reddish color when the seed is plumped, which indicates that the growing conditions and the land are appropriate. This indicates, that there may be a directional selection towards reddish seed color.

Tapering and parallel ear types are evenly distributed in the entire collection. Lax spike is not typical of tetrapioid wheats with the exception of *T. carthlicum*, which could be one reason for its low frequency in the populations as a whole. It is concentrated in Gonder, Tigray and Shewa only and common in altitude third group (2401-2800m a.s.l). The association of lax spikes with the third altitude group appears to be associated with high rainfall without frost. Belay, (1997) also found similar result in Ethiopian durum wheat in that lax spike is concentrated in Shewa. Glume pubescence was a monomorphic character and all the collections showed glabrous glumes types. Spike bending tendency shows an increasing trend with altitude, but across regions completely bent spikes are predominant in Sidamo and Gojam. According to the local knowledge, bending of spike is an important character for high rainfall area with extended rainfall since it avoids raindrops from their spike so that it protects pre-harvesting sprouting. In addition, bent spike has an advantage in resisting frost in the frosty area (Kebebew *et al.*, 1997).

Correspondence analysis of qualitative data of 55-emmer wheat populations distinctly separated Sidamo, Gojam, Tigray and Gonder into different corners (Fig. 6). In contrast, Shewa, Hararghe, Arsi and Bale were concentrated at the center indicating the similarity of materials. These may be explained, as the possibility of germplasm exchange and similarity of agroecological zones. In Bale, people started crop production after Shewa and Arsi so that there is interaction in seed exchange (Mamo and Franzel, 1987) .The similarity of their material is also shown by discriminant analysis, in which most of the material from Bale is of Arsi type (43%).

The highest mean seed yield per plant was recorded from populations collected from Shewa, Gonder, Arsi, Bale and Sidamo. Most of these regions receive relatively high rainfall and the trial site Sinana Agricultural Research Center is a major emmer wheat producing area, which grossly shares a similar agro-ecological condition with these regions. The discriminant analysis of quantitative data also as that of correspondence analysis discriminate Tigray and Gojam from the other regions, this showed that the material from the two regions are very distinct.

The discriminant analysis showed the materials from Gonder and Gojam were totally misclassified (100%) and in addition materials from Bale, Shewa and Harerghe also showed more percent of misclassification (Table 7). Jaradat (1991) found that the correct classification in a discrminant analysis of durum wheat landrace genotype from Jordan was highest in the driest district of collection. This was the case in the present study, as Tigray and Harerghe have relatively moisture stressed area the rest area. These regions showed higher diversity indexes. These results are supported by the hypothesis of Holcobe *et al.*

(1977), Pecetti and Damania (1996) and Ayana and Bekele (1999) that the higher the diversity of the group, the higher is the probability of misclassification and vise versa. The H' also showed relatively high diversity index for the above-mentioned regions. Close examination of the predicted membership for the misclassified accessions of each region revealed that most of such accessions were either placed in the adjacent regions or in regions having similar climatic conditions.

5.1.2 Diversity index

Summary of mean diversity indexes for individual characters, population and region doesn't show clear pattern but there is a clear increase of diversity as altitude increases in traits like beak length, ear shape, kernel color, spike density, and bending tendency. The reduction of over-all mean diversity index at above 2401 is due to the selection pressure of frost at higher altitude. According to Belay (1997) in durum wheat also there is no clear pattern obtained regarding regional the diversity index. This may be due to gene flow/germplasm exchange similarity in origin of the population. Maximum morphological diversity occurred in Shewa, Arsi, Gonder and Hararghe and the maximum diversity occurred in the altitudinal range of altitude group 2401-2800m asl. Most of the above regions have good agroclimatic conditions for emmer

The higher diversity in Shewa is also supported by Negassa (1986), Pecetti and Damania (1996), Belay (1997) and recently by Tamiru (1999) in durum wheat, which is the same family and /or may be progenitor of durum. The mean diversity index of Tigray and Gojam were the least. In Tigray, civil unrest and drought have resulted in genetic erosion, and replacement of land races by modern bread wheat variety may be the cause for low

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The multidimensional scaling projection, the 55 emmer wheat populations also showed the distinctiveness of Tigray material supported by Pecetti and Damania (1996) in durum wheat and high dispersion of Shewa material across the two dimensions.

Correlation between characters, showed that seed yield without hull were strongly correlated with days to head, days to mature, kernel number per spike, number of spikelate per spike, spike length, biomass and thousand-grain weight and most of these traits showed strong positive correlation.

Other researchers have investigated the relationships between grain yield, number of effective tillers, and kernel per spike and kernel weight. Accordingly, Grafius and Okoli (1974) found that 72% of the variation in grain yield was explained by the three yield components namely, number of effective tillers, and kernel per spike and kernel weight the same results were obtained in durum wheat by Belay, (1997) in that he has positive correlation between seed yield and tiller number, number of kernels per spike, seeds per spike, thousand seed weight, biomass.

Heritability estimate in broad sense showed high value for days to head, thousands of grain weight, number of spikelet per spike and number of kernel per spike, indicating that these characters are predominatly controlled by genetic factors. The heritability values were low for seed yield, harvest index, node number, flag leaf length, grain filling period and days to maturity. Therefore, improvements of this traits through selection may not be effective, eventhough heritability estimates provides the basis for selection on phenotype performance. Joharison *et al.* (1955) suggest that estimates of heritability and genetic advance should always be considered simultaneously because high heritability will not always associated with high genetic advance. According to (Cf Amin *et al.*, 1992), high heritability associated with equally high genetic advance is mainly due to the additive gene effect but if the heritability were due to dominance and epistasis, the genetic gain would be low. This study revealed that thousand-grain weight and tiller number were predominantly controlled by additive genet effect. The same results were observed by Belay (1997) in drum that is only tiller number, kernels per spike and thousands grain weight had higher genetic advance.

5.1.3 Cluster Analysis

Clustering based on quantitative and qualitative characters resulted in six major clusters having different number of accessions. Cluster B and C had maximum number of accessions, 16 and 18, respectively. All of the materials in cluster B are Arsi, Bale and Hareghe collections. This may be due to the proximity effect, which facilitate different socioeconomic interactions in material exchange and gene flow. Materials colleted from Arsi, Hareghe and Shewa dominate in Cluster C (Fig.4). Cluster E is represented by a single accession collected from Shewa (PGRC/E 8010). This accession was characterized by having high biological yield, seed yield and tiller number. It is also a late maturing type, has a shorter plant height and has lower thousand-grain weight with moderate diversity (0.5). Cluster F was represented by a single accession PGRC/E 232238 collected from Arsi and characterized by having high diversity index (0.83). These results were also supported by a multidimensional scaling projection of the 55 accessions of emmer wheat.

5. 2 Biochemical Analysis

5.2.1 Isozyme Analysis

There is considerable genetic variation within populations of emmer wheat PGRC/E 22 1736 and PGRC/E 213038 as characterized by higher percentage of polymorphic loci, the average number of alleles per locus and the mean heterozygosity. These two populations relatively had lower minimum distance and the later population has higher morphological diversity index. The mean F_{ST} value is low (0.187) as compared to the average F_{ST} value for inbeeding species (0.51) reported by Hamrick and Godt (1990) and similars result were observed by Tadesse (1999) in grasspea.

Nei's genetic distances among 12 populations of emmer wheat studied shows that there are only moderate differences between populations collected from different regions. But, a population which shows, high minimum distance i.e. PGRC/E 7920 collected from Hararghe showed high dissimilarity with the rest of populations.

Clustering based on allelic frequency data showed some over lap with the multi-dimensional scaling projection in that, Tigray material (PGRC/E 221736) which is an the only materials in the cluster also distinctly separated in the two ordinate dimensional projection of quantitative traits.

5. 2. 2 Protein and Mineral Analysis

As the mean protein content data showed and correlation and covariance analysis further confirmed, there is strong negative correlation between protein content and altitude in which this idea is directly contradicted with the result of genetic diversity as the altitude. The protein contents of cereals may vary depending on the variety and the growing condition but this result showed relatively it had better variation in protein content between populations (Agren, *et al.*, 1975).

Wheat and its product are recognized as important sources of essential nutrients. They provide energy, fiber, carbohydrates, proteins, vitamins, iron, calcium, phosphorous, zinc, potassium, and magnesium. Accordingly, test for mineral, ash, organic matter and dry matter content was conducted under this study. As a result, different accessions were observed to have different amounts of the analyzed contents, eventhough it was found out to be a non-significant difference (both at altitudinal level and regional level). It would be thus difficult to differentiate the different accessions based on their ash, dry matter, organic matter and calcium content. But the above information would be very helpful in determining the nutritional composition of the crop, emmer wheat.

5. 3 Ethnobotanical Analysis

Traditional knowledge is an integrated system of beliefs and practices distinctive to different cultural groups. It also has got specialized knowledge about soils, plants/crops, medicines, and other areas. However, such knowledge, although very useful, may be beyond the scope of scientific realm, such as notation of spirit and mythological beings or forces (Posey, 1990).

The ethnobotanical data generated from this study has paramount importance for conservation, utilization and processing for consumption of emmer wheat landraces (farmers' varieties). Farmers assert that there is only one morphotype known by the name *Hayisaa /Gardamma/Matajaboo/Issaa* and this was confirmed by visual observation. Some of these names implicate the characters of emmer wheat. Accordingly, '*Matajaboo*' means in Oromiffa strong head, which directly refer to the problem of, threshability and '*Gar-damma*' means in Oromiffa somewhat pale-red and /or pale-yellow. So this also indicates glume and kernel color. The frequency data table of qualitative characters also indicate the material collected from Bale and Arsi had high frequency of pale red and/or pale yellow color for glume and kernel color. The major crops grown in the study area are barley, bread wheat, emmer wheat, tef, faba bean, and field pea, maize and linseed. Almost all farmers in most weredas of Bale grow emmer wheat in small farmland. Farmers neither use fertilizer nor improved seed. In addition, they practice minimum tillage for emmer since emmer is relatively hardy crop and perform well under poor soil condition and management condition as compared to other cereals. According to 5 years data of Bale MOA emmer wheat stands 3rd among small cereals.

The food habit of the local people is influenced by their production system. Accordingly, a number of foodstuffs and soft drinks are prepared from emmer wheat. The foodstuffs and local drinks include *marka* (soft porridge) *Hango* and *shuffisa* (hard porridge type), *cankita* (Local pasta), *Haph*i (Pan cake), D*abbo* (bread), *injera*, *Muzze/Buluka* (Gruel), *Lila* soft drink and *Keribo* (soft drink). All these foodstuffs and local drinks can also prepared from wheat and barley (Mamo and Franzel, 1987; Hundie, *et al.*, 1998).

The relatively low, market value of emmer could be linked to some beliefs associated with it and the nature of the grain. Seed exchange is largely taking place through the informal channel of the farmers and villagers. The informal seed exchange system is cheap and accessible to all farmers and this traditional seed supply system is important in getting emmer wheat for emergency case like sick family member and for women who give birth and other occasions.

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Emmer wheat gives the farmer security against adverse growing condition like shortage of rain, poor soil, high disease infestation, frosty area and water logged area and easily manageable as compared to the rest. All interviewed farmers agree that except for the threshability problem, emmer is a healthy food and has stable yield. In the survey area as well as in most areas of the country, farmers believe that, emmer wheat has special medicinal and nutritional values. Traditionally it is believed that broken bones heal faster when emmer is consumed in the form of *merka* (porridge). As a result it is recommended for mothers as special diet in maintaining their health and strength after childbirth (Tesemma and Belay, 1991).

In Italy, previously emmer was considered to be poor man's food and it was believed to have poor nutrition but now it is rediscovered that modern consumers consider it as a healthy food. Further more, scientists discovered that its consumption reduces risk of colon cancer and heart disease, this discovery led to its promotion and it will have a bright future (ICARDA, 1991, Catarci, 1998).

6. Conclusion

The present study has been undertaken to investigate the morphological and biochemical variation of emmer wheat (*Triticum dicoccum*) along with the study of the indigenous knowledge on it, in order to identify sites for *in-situ* conservation and to aid future germplasm collection.

The morphological diversity study was conducted using the variation on six heritable traits. The variations of each population between region, altitudinal class and entire populations were calculated using Shannon weaver diversity index. This study identifies sites with high diversity index that could be ideal sites for *in-situ* conservation strategy. The analysis of variance of H for individual trait indicates that beak length and glume color show significant variation ($P < 0.05$) among regions and beak length also differed significantly between altitude groups. Allelic polymorphism was detected for all populations at all loci. However, EST-2 and AAT-2 and AAT-3 were monomorplic. Populations collected from Sidamo and Tigray showed highest percent of polymorphic loci.

From the point of view of diversity analysis, the highest diversity is calculated for the material collected from Shewa. This would make it an ideal area for germplasm collection. *In-situ* conservation of crop diversity can only be achieved with participation of farmers. As far as the present study is concerned, although the emmer wheat diversity in Arsi and Bale did not show higher diversity index as that of Shewa, the cultural richness, the tremendous use values and the farmers special attitude towards this crop are strong factors for recommending *in-situ* conservation activities in Arsi and Bale. Core collections have to give attention for regions with high genetic diversity like Shewa, Harerghe and Gonder.

The present study also generate information on the breeding value of the crop and traits, but needs further studies with detail analysis of breeding potential of emmer.

Further study is needed with bigger sample size and with additional markers to precisely estimate the genetic diversity. Since Ethiopian emmer wheat is not addressed well by scientific world so cytogenetic profile and its breeding potential with its hybridization potential with other hexaploid and tetraploid wheat family should be treated.

7. Reference

Agren, G., Eklund, A. and Lieden, S. (1995). Food composition table for use in Ethiopia II, SIDA, ENI, Ethiopia.

Altieri, M. and Merrick, L.C. (1987). *In-situ* conservation of crop genetic resources through maintenance of traditional farming system. *Eco. Bot.* **41**:86-96.

Amin M.R, Barma N.C.D. and Razzaque, M.A. (1992). Variability, herlitability, genetic advance and correlation study in some quantitative characters in durum wheat. Rachis 11 (1/2).

AOAC (Association of Official Analytical Chemists) (1990). Official Methods of Analysis. 15th Edition. AOAC Inc., Arlington, Virginia, U.S.A.

Asfaw, Z. (1990). An ethnobotanical study of barley in the central highlands of Ethiopia. *Biol. Zent Bl.* **109**:51-62

Ayana, A. and Bekele, E. (1998). Geographical patterns of morphological variation in sorghum (*Sorghum bicolor* L.) Moench) germplasm from Ethiopia and Eritrea: qualitative characters. *Hereditas* **129**: 195-205.

Ayana, A. and Bekele, E. (1999). Multivariate analysis of morphological variation in sorghum (Sorghum bicolor (L.) Moench) germplasm from Ethiopia and Eritrea. *Genetic Resources and Crop Evolution* **46**: 273 – 284.

Bechere, E. and Belay, G., Mitiku, D. and Merker A. (1996). Phenotypic diversity of tetraploid wheat landrace from northern and north central regions of Ethiopia. *Hereditas* **124**:165-172

Bekele, E. 1983. Some measures of genetic diversity analysis on landrace population of Ethiopian barley. *Hereditas* **98**: 127-43.

Bekele, E. (1984). Analysis of regional patterns of phenotypic diversity in the Ethiopian tetraploid and hexoploid wheats. *Hereditas* **100**: 131-154

Bekele, E. (1985). The biology of cereal landrace population. *Hereditas* **103**: 119-134

Belay, G. 1997. Genetic variation, Breeding potential and cytogenetics profile of Ethiopia tetraploid wheat (Triticum *turgidium* L.) landrace. Doctoral Thesis, Swedish University of Agricultural Science, Upsala, Sweden.

Berrie, A. M..M. (1977). *An introduction to the botany of the major crop plant.* University of Glasgow

BOSTID (Board on Science and Technology for International Development, National Research Council (BSTIDNRC) (1996). *Lost crops of Africa*, Vol. I Grains. The National Academic of Science. National academic press, Washington D.C USA

Bothmer, R., Von. (1992). The wild species of *Horduem*: Relationships and potential use for improvement of cultivated Barley: In *Barley: Genetics, Biochemistry, Molecular Biology and Biotechnology*, Shewary P.R (ed.) CAB international, Walling ford.

Catarci, C. (1998). Ancient Crop "rediscovered" by modern consumers. In: Gene flow, A Publication About the Earth's Plant Genetic Resource, IBPGR.

Chamberlain, J. R. (1998). *Systematic and Population Genetics Laboratory Protocols for Isozyme Analysis*. University of Oxford, UK.

Croston, R.P and Williams, J.T. (1981). *A World Survey of Wheat Genetic Resources.* IBPGR.

CSA, (1996). Agricultural samples survey 1995/96 Vol. I Report on area and production for major crops. *Statistical Bulletin*, Addis Ababa, June 1990,Ethiopia.

Damania, A.B., Hakims, S. and Moualla, M.Y. (1992). Evolution of variation in *T. dicoccum* of wheat improvement in stress environment. *Hereditas* **116**:163-66.

Demisse, A. and Hailemariam, G. (1991). Wheat genetic resource in Ethiopia. In: *Wheat research in Ethiopia*. A Historical Perspective (Hailemariam, G., Tanner, D.G, and Hulluka, M., (eds.) Addis Ababa, Ethiopia.

Demissie, A and Hailegiorgis, M. (1985). "Belg" collecting in Bale Administrative Region. *PGRC/E-ILCA Germplasm Newsletter* 10: 6-11.

Demissie.A (1996). Morphological and molecular markers diversity in Ethiopian landrace barleys implications to *in-situ* and *ex-situ* conservation of landrace materials. Ph.D Thises, Department of Horticulture and Crop Science, Agricultural University of Norway, As, Norway.

Du Toit, S.H.E, Steyn A.G.W and Stumpt R.H, (1986). *Graphical Exploratory Data Analysis*. Springer Texts in Statistics. Springer- verlag New York Inc.

Engels, J.M..M., and Hawkes, J.G., (1991). The Ethiopian gene center and its genetic diversity. Engles, J.M..M., Hawkes, J.G. and Worede, M. (eds.) *Plant Genetic Resources of Ethiopia*. Cambridge University press Cambridge

Ethiopian Mapping Authority (1988). *National Atlas of Ethiopia*, first edition. people's Democratic Republic of Ethiopia. Berhanena Selam Printing press, Addis Ababa, Ethiopia

Eticha, G, Geleto, T. and Hussan, A. (1998). A decade of research experience, Sinana Agricultural Research Center, bulletine NO.1 Oromiga Agricultural Development Bureau, Finfinne, Ethiopia.

Feldman, M. (1979). Wheats (*Triticum* spp.). *Evolution of crop plants.* Simmonds N.W. (ed.) Longman Group Limited, London.

Feyissa, R., (1999). Issues and conflicts around genetic resources and biological diversity. IBCR presentation.

Frankel, O.H. (1974). Genetic conservation: our evolutionary responsibility. *Genetics* **78**: 53-65.

Grafius, J.E., and Okoli L.B, (1974). Dimensional balances among yield components and maximum yield in 8x8 diallel of barley. *Crop Science* **14**:353-355.

Guta, A., Hundie, B. and Chala, M. (1997). Diagnostic survey, on farm technology verifications and transfer in Bale zone of Oromia Region. In: *Research Achievements and Technology Transfer Attempts in Southeastern Ethiopia.* Deressa, A. and Seboka, B (eds.) Workshop 9-10 July 1996 IAR; Ethiopia.

Hailemariam, G. and Worede M., (1986). A preliminary classification of Ethiopia wheat germplasm accessions. In: *The Conservation and Utilization of Ethiopia Germplasm.* Engles J.M.M (ed.). Proc. Int. Symp. Addis Ababa, Ethiopia PGRC/E.

Hailemariam, G., (1991). Wheat production and research in Ethiopia. In: *Wheat Research in Ethiopia.* A historical perspective (Gebremariam, H., Tanner, D.G, and Hulluka, M.,(eds.) Addis Ababa, Ethiopia.

Hailmariam, G. and Mekibib, H. (1988). Agromorphologyical evalution of *T. dicoccum. PGRCE-ILCA Germplasm Newslatter 19:6-10*

Hakime, S. and Damania, A.B., Moualla, M.Y and Altunji, H (1993). Variation of storage proteins in *T. dicoccum*: In: *Biodiversity and Wheat Improvement.* Damania, A.B (ed.) ICARDA, John Wilely and Sons, U.K.

Hamrick and God M.J.W, (1990). Allozyme diversity in plant species In: A.D.H Brown, M.T.Clegg, A.L. Kahler and B.S Wein (eds.). *Plant Population Genetics, Breeding and Germplasm Resource.* Massachusetts, Sunderland.

Hancock, J.F (1992). *Plant Evolution and the Origin of Crop Species.* Prentice-Hall. Inc. USA.

Hanson, H. Borlaug, N.E., and Andrson R.G (1982). *Wheat in the Third World.* West View Press. Inc. USA.

Hardon J.J and de Boef W.S., 1992. Local management and use of plant genetic Resources. In: *Safe Guarding the Genetic Basis of Africa's Traditional Crops*. Putter A. (ed.) proceedings of CTA/IPGRI/UNESC, Seminar, 5-9 October 1992, Nairobi Kenya.

Harlan, J.R (1971). Agricultural origins: centers and non-centers. *Science* **174:** 468-473.

Harlan, J.R and Zohary, D. (1966). Distribution of wild wheat and barley. *Science* **153:** 1074-80.

Harlan, J.R., (1969). Ethiopia: A center of diversity. *Econ. Bot.* **23**: 309-314.

Hawkes, J.G. (1976). Sampling gene pools. *Proceeding of NATO conference on conservation of threatened plants series 1.*, Ecology plenum London.

Hawtin, G.M., Iwanaga. M, and Hodgkin, T., (1996). Genetic resources in breeding for adaptation. *Euphytica* **92**: 255-266

Helback, H. (1959). Domestication of food plants in Old World. *Science* **130**: 365-372

Helbaeck,. H. (1970). Commentary on the phylogenesis of *Triticum* and *Hordeum*. *Eco. Bot.* **20:** 350-60

Hennink, S. and Zeven, A.C, (1991). The interpretation of Nei and Shannen Weaver within population variation indices. *Euphytica* **51**:235-240.

Hundei, B., Jima, W., and Tadesse F., Amsalu M. Yaddessa M., and Arfassa, K. (1998). The Dinsho farming system of Bale highlands. In: *Barley based Farming Systems in the Highlands of Ethiopia.* Yirga, C., Alemayehu F., and Sinebo. W., (eds.) EARO, Addis Ababa Ethiopia.

Hvid, S. and Nielsen, G. (1977). Esterase isozayme variants in barley. *Hereditas* 87: 155- 162.

IBPGR (1981). Revised Descriptors of Wheat. International Board of plant Genetic Resource, Rome.

ICARDA, (1991). Genetic Resource Unit Annual Report for 1990. Aleppo, Syria : ICARDA.

Iwanaga, D (1994). *In-situ* conservation strategies for African root crops. In: *Safe-Guarding the Genetic Basis of African's Traditional Crops*. Putter A. (ed.) proceedings of CTA/IPGRI/KARI/UNES. Seminar 5-9 October 1992, Nairobi, Kenya.

Jaaska, V. (1993). Isozymes in the evaluation of germplasm diversity in wild diploid relatives of cultivated wheat. In: *Biodiversity and Wheat Improvement*. Damanid AB (ed.) John Wilely and Sons UK. ICARDA.

Jasaaka, V. (1997). Isoenzyme differences between the wild diploid and tetraploid wheats. *Genetic Resources and Crop Evolution* **44**: 137 – 146.

Jaradat, A. A. (1991). Phenotypic divergence for morphological and yield related traits among landrace genotype of durum wheat from Jordan. *Euphytica* **52**:155-164

Kebebew, F., Gebeyaw, Z and Tsehaye, Y. (1997). Ethnobotanical survey on durum wheat (*T. durum* Dest.) in Tegulet (North Shewa). In: *Proceedings of the First Joint Meeting of NPAOC Coordinating Unit and Partner Institutions* (Kebebew F. Demissie A, and Ketema, S.). BDI/E Addis Ababa, Ethiopia, (unpublished).

Kessler, D.A, Taylor, M.R., Maryanski, J.H, Flamm, E.L., Kahl, L.S.(1992). The safety of foods developed by Biotechnology. *Science* **256**:17 47-1749

Langer, R.H.M and Hill, G.D. (1982). *Agricultural plants.* Cambridge University press London.

Mackey, J. (1954). Newtron and X- ray experiment in wheat and revision of the specltoid problem. *Hereditas* **40**:65-180

Mamo, A., and Franzel, S. (1987). Initial results of informal survey Sinana mixed farming system zone Bale region. *Working paper* 1/87 IAR

Mackey, J. (1966). Species relation in *Triticum*. Proc. 2nd international wheat Genetic Symp. Lund. 1963 (Sweden). *Hereditas (suppl.)* **2**:237-276

Marshall, D.K and Broan, A.H.D (1981). Wheat genetic resources. In: *Wheat Science To day and Tomorrow*. Gaul, H. (ed.). Cambridge University Press. Cambridge UK

Martin, G.J. (1995). *Ethnobotany:* A metods manual. London, Chapman and Hall.

Martinez-Zapater, J.M. and Oliver J.L. (1984). Genetics analysis of isozyme loci in tertraploid potatoes (*Solanum tuberasum* L.). *Genetics* **108**: 669-679.

Maundu, P. (1995). Methodology for collecting and sharing indigenous knowledge: A case study . *Indigenous knowledge and Development Monitor* 3(2): 3-5.

Mengesha, M..H (1975). Crop germplasm diversity and resources in Ethiopia. In: *Crop Genetic Resources for Today and Tomorrow*. O.H.Frankel and J.G.Hawkes (eds.) International biological program, Cambridge University.

MOA, office of Bale (1999). 5 years reports of production and area coverage of the crop produced in the zone. Bale Goba.(Unpublished report)

Mooney, P. R. (1985). Ethiopia, Diversity, and Drought: Long term seed security. *RAFI-IGRP survey of national genetic resource strategy Ethiopia* (ethect/178), manuscript.

Negassa, M. (1985). Patterns of phenotypic diversity in Ethiopian barley collection, and Arussi- Bale highland as a center of origin of barlay. *Hereditas* 102:139-150.

Negassa, M., (1986). Estimates of phenotypic diversity and breeding potential of Ethiopia wheats. *Hereaitas* 104:41-48.

Nei, M. (1978). Estimate of average heterozygoity and genetic distance from a small number of individuals. *Genetics* 99: 582-590.

Nesbitt M., and Samuael, D., (1996). From staple crop to extinction ? The archaeology and history of the hulled wheat. In : *Hulled Wheats, Promoting the Conservation and Used of Underutilized and Neglected crops*, S. Padulois, K. Hammer and J. Heller, (eds.). *Proceedings of the First International Workshop on Hulled Wheats*, 21-22 july, 1995, Castevecchio Pascoli,Tuscany, Italy. IPGRI . Rome ,Italy.

Pecetti L. and Damania, A.B (1996). Geographic variation in tetraploid wheat (*Triticum turgidum* spp. *turgidum conora. durum*) landrace from two provenances in Ethiopia. *Genetic resource and crop Evolution* 43:395-407

Pederson, S. Tuvesson, I.K.D. and Anderson, S.B., (1990). Polymorphism for aconitase and glucose phosphate isomerase isozymes in hexaploid wheat. *Hereditas* 113:1-6

Phillip S. (1995). Poaceae (Gramineae). Flora of Ethiopia and Eritrea. Vol. 7. Hederg. I and Edwards s., (eds.). Addis Ababa, Ethiopia, Uppsala, Sweden.

Posey, D.A. (1990). Ethnobiology and ethnodevelopment: Importance of traditional knowledge and traditional peoples. In: Shengji, P., yong-ge, S., chun-lin, L. and Posey, D.A (eds.), *The Challenges of Ethnobiology in the 21st century*, Proceedings of the Second International Congress of Ethnobiology.

Proceddu, E. and Lafiandra, D. (1986). Origin and evoluation of wheat. In: *The Origin and Domestication of Cultivated Plants.* Symposium organized by centers Linceo Interdiseiplinare Discienze Matematiche Loro Application, Accadomiā Nazionale dei Lincei, Rome 25-27 November, 1985.

Purseglove, J.W, (1975). *Tropical crops. Monoctyledens.* Longman Group Limited, London.

Seme, E.N., Chahira, P.W and Kemel J.K. (1994). *Ex-situ* conservation of African crop germpalsm. In: *Safe Guarding the Genetic Basis of African's Traditional Crops.* Putter A. (ed.). *Proceedings of CTA/IPGRI/KARI/UNES.* Seminar 5-9 October 1992, Nairobi, Kenya.

Simonetti, M.C., Bellomo, M.P., Laghati, G., Perrino, P., Simeone, R. and Blaco, A. (1999). Quantitative trait loci influencing free threshing habit in tetraploid wheat. *Genetic Resource and Crop Evolution* 46:267-271.

Spagnoletti, Z. P.L and Qualset, C.O, (1987). Geographic diversity for quantitative spike characters in a world collection of durum wheat. *Crop. Sci.* 27: 235-241.

Stuart, S.N., Adamas, R.J., Jenkins, D., (1990). Biodiversity in Sub- Saharan Africa and its islands conservation, management and sustainable use. *Occasional papers of the IUCN species survival Commission,* No. 6, IUCN. The world conservation union.

Swofford, D.L., and Selander, R.B. (1981). Biosys-1 Release-1. *A Computer Program for the Analysis of Allelic Variation in Genetics.* Users Manual. University of ILLions at Urbana champaign, urbana, U.S.A

Tadesse, W (1999). Morphological and biochemical diversity of grass pea (*Lathyrus satiuvs* L.) in Ethiopia M.Sc Thesis AAU Ethiopia.

Tamiru, M. (1999). Morphological and molecular diversity in Durum wheat (*T. durum* Desf.) Landraces of North Shewa, M.Sc Thesis. AAU, Ethiopia.

Tesemma, T. (1991). Improvement of indigenous durum wheat landraces in Ethiopia. In. Engles, J.M.M Hawkes J.G and Worede M. (eds.). *Plant Genetic Resource of Ethiopia.* Cambridge University Press, Cambridge, U.K.

Tesemma, T., and Belay. G. (1991). Aspects of Ethiopian tetraploid wheat with emphasis on durum wheat genetics and breeding research. A historical perspective (Gebremariam, H., Tanner, D.G, and Hulluka, M., (eds.) Addis Ababa, Ethiopia

Tesemma, T., Mehammed, J. (1982). Review of wheat breeding in Ethiopia. *Eth. J. Agri. Sci.*1: 11-24.

Teshome A., Fahrig, L. Torrance, J.K., Lambert, J.D., Arnason T.J. and Baum B.R, (1999). Maintenance of Sorghum (*Sorghum bicolor* Poaceae), landrace diversity by farmers selection in Ethiopia. *Eco. Bot.*53:79-88.

Tsegaye, S. and Tesemma, T. (1995). The genetics of some isozyme variants in tertaploid wheat (*T. turgidum* L). *Hereditas* **123:** 147-154.

Tsegaye, S. Becker, H. C. and Tesemma, T. (1994). Isozyme variation in Ethiopian tetraploid wheat (*Triticum turgidum*) land race agrotypes of different seed color groups. *Euphatica* 75: 143 – 147.

Tsegaye, S. Becker, H.C and Tesemma T. (1996). Variation of leaf esterase in some Ethiopian tetraploid wheat landrace. *Genetic Resource and Crop Evolution* **43:** 119-123.

Vavilov, N. I. (1951). The origin, variation, immunity and breeding of cultivated plants. *Chron. Bot.* **13**:1-366.

Wendel, J.F. and Weeden, N.F. (1990). Visualization and interpretation of plant isozymes. In: *Isozymes in Plant Biology* (Soltis and Soltis eds.) London, UK: Chapman and Hall.

Werede, M. (1988). Diversity and the genetic resource base. *Ethiopian J. of Agric. Sci.* 10(1-2): 39-52.

Worede, M. (1990). The importance of preserving Ethiopia's Biological diversity in the context of natural resource management. In: *National Conservation Strategy Conference Document.* Volume II. Addis Ababa, Ethiopia.

Wilson, E.O. (1992). *Global Biodiversity.* WRI/IUCN) UNEP.

Zewdie Y. and Zeven A.C, 1997. Variation in Yugoslavian hot pepper (*capsicum annuun* L.) accessions. *Euphytica* 97:81-89.

8. Appendices

Appendix 1. PGRC/E accession number, code number, administrative region, area of collection-and altitude of the collecting sites of the populations

Code No.	LANDRACE (Acc.No)	Region	Country	Altitude.
1	PGRC/E 5999	Shewa	Morete and Jiru	2650
2	PGRC/E 6018	Shewa	Dendi	2280
3	PGRC/E 6052	Arsi	Shirka	2340
4	PGRC/E 6054	Shewa	Ada'a	1750
5	PGRC/E 6055	Arsi	Guna	2800
6	PGRC/E 6068	Arsi	Robe	2640
7	PGRC/E 6843	Gonder	Gonder Zuriya	2580
8	PGRC/E 7278	Gonder	Wegera	2850
9	PGRC/E 7884	Shewa	Ada'a	2600
10	PGRC/E 7885	Shewa	Ada'a	2600
11	PGRC/E 7886	Shewa	Ada'a	2600
12	PGRC/E 7913	Harerge	Meta	2220
13	PGRC/E 7920	Harerge	Deder	2400
14	PGRC/E 8010	Shewa	Sululta	2800
15	PGRC/E 204345	Bale	Dodol	2510
16	PGRC/E 213038	Sidamo	Sodo Zuriya	2240
17	PGRC/E 215407	Bale	Sinana	2420
18	PGRC/E 216831	Harerge	Jijga	2050
19	PGRC/E 216835	Harerge	Meta	2180
20	PGRC/E 216836	Harerge	Meta	2170
21	PGRC/E 216838	Harerge	Meta	2240
22	PGRC/E 219074	Arsi	Robe	2380
23	PGRC/E 219078	Arsi	Merti	2150
24	PGRC/E 219079	Arsi	Merti	2140
25	PGRC/E 219080	Arsi	Guna	2270
26	PGRC/E 219081	Arsi	Guna	2410
27	PGRC/E 219082	Arsi	Jeju	2870
28	PGRC/E 219083	Arsi	Jeju	2900
29	PGRC/E 219084	Arsi	Jeju	2940
30	PGRC/E 219085	Arsi	Merti	2890
31	PGRC/E 219253	Harerge	Chiro	2100
32	PGRC/E 219254	Harerge	Chiro	2100

Appendix 1 Continued

33	PGRC/E 219255	Harerge	Chiro	2140
34	PGRC/E 219256	Harerge	Chiro	2170
35	PGRC/E 219259	Harerge	Chiro	2170
36	PGRC/E 219260	Harerge	Chiro	2140
37	PGRC/E 219263	Harerge	Tulo	2100
38	PGRC/E 219272	Harerge	Doba	1990
39	PGRC/E 219275	Harerge	Doba	2100
40	PGRC/E 219510	Gojam	Banji	2400
41	PGRC/E 221736	Tigray	Didiba & Derg	2210
42	PGRC/E 221741	Tigray	Inderta	2150
43	PGRC/E 229266	Shewa	Laybet	2430
44	PGRC/E 229268	Shewa	Laybet	2400
45	PGRC/E 230675	Bale	Baale Gadula	1550
46	PGRC/E 230679	Bale	Ginir	1800
47	PGRC/E 230686	Bale	Sinana	2220
48	PGRC/E 230690	Bale	Ginir	1780
49	PGRC/E 231233	Arsi	Guna	2330
50	PGRC/E 231235	Arsi	Jeju	1920
51	PGRC/E 231238	Bale	Sinana	2520
52	PGRC/E 232230	Arsi	Merti	1690
53	PGRC/E 232231	Arsi	Merti	2070
54	PGRC/E 232232	Arsi	Chole	2220
55	PGRC/E 232233	Arsi	Guna	2290

Appendix 2. Sinana Agricultural Research Center Temperature and Rainfall Data during the 1999/2000 Crop Growing season (Bona) (July 1999-Feb. 2000)

Month	Range	Temperature		Rainfall (mm)	Total (mm)
		Min.	Max.		
	01-10	9.35	21.5	2.9	
July 1999	10-20	10.30	19.8	63.8	71.20
	20-31	9.95	19.76	4.5	
	01-10	9.88	20.25	59.8	
August 1999	10-20	9.81	20.01	44.9	144.70
	20-31	9.62	20.25	39.7	
	01-10	9.63	20.08	17.9	
September 1999	10-20	10.55	19.96	26.7	101.90
	20-31	10.15	19.76	57.3	
	01-10	10.02	18.6	58.4	
October 1999	10-20	10.78	18.28	22.6	97.60
	20-31	9.54	19.05	16.6	
	01-10	8.25	20.00	16.2	
November 1999	10-20	7.67	18.75	10.9	27.80
	20-31	6.43	19.8	0.70	
	01-10	8.09	20.08	0.00	
December 1999	10-20	6.79	20.74	0.00	0.00
	20-31	7.29	21.38	0.00	
	01-10	7.24	22.95	0.00	
January 2000	10-20	6.6	22.56	1.8	1.80
	20-31	7.01	22.28	0.00	
	01-10	7.9	23.5	0.0	
February 2000	10-20	7.0	22.7	0.0	0.0
	20-31	9.2	23.4	0.0	
					373.50

Appendix 3 Correlation among 16 different characters of emmer wheat populations in Bale

Traits	DH	DM	GFP	FLG	AWL	ND	PH	K/S	Spl/S	SL	BM	TN	TGW	SY		HI
														WH	WHO	
DH		0.15	-0.22	0.54	0.19	-0.07	0.69	0.89**	0.85*	0.83*	0.75	0.23	0.56	0.65	0.67	0.25
DM			0.93**	-0.68	0.48	-0.23	0.33	0.05	0.11	0.0	0.34	0.40	0.76*	0.26	0.31	0.02
GFP				-0.87*	0.40	-0.20	0.07	-0.28	-0.31	-0.31	0.05	0.30	0.55	0.01	0.05	-0.07
FLG					-0.32	0.13	0.33	0.64	0.59	0.71	0.39	0.0	-0.10	0.40	0.36	0.24
AWL						0.40	0.62	0.17	0.15	0.17	0.17	0.22	0.51	0.15	0.10	-0.06
ND							0.28	-0.15	-0.17	0.15	0.05	0.27	-0.15	0.10	0.0	-0.18
PH								0.76*	0.75	0.86*	0.80*	0.54	0.79*	0.76*	0.70	0.27
K/S									0.99**	0.86*	0.67	0.09	0.63	0.57	0.55	0.14
Spl/S										0.84*	0.67	0.09	0.69	0.55	0.53	0.07
SL											0.89**	0.51	0.57	0.86*	0.82*	0.45
BM												0.78*	0.68	0.99**	0.98**	0.60
TN													0.44	0.85*	0.84*	0.70
TGW														0.58	0.59	0.10
SYWH															0.99**	0.72
SYWOH																0.75
HI																

Appendix 4 Correlation among 16 different characters of emmer wheat populations in Arsi

Traits	DH	DM	GFP	FLG	AWL	ND	PH	K/S	Spl/S	SL	BM	TN	TGW	SY		HI
														WH	WHO	
DH		-0.02	-0.37	-0.13	-0.06	-0.03	-0.12	-0.16	-0.18	0.32	0.45	0.56*	0.06	0.44	0.33	-0.07
DM			0.93	-0.09	0.39	-0.03	-0.12	-0.42	-0.35	0.16	-0.15	-0.06	0.12	-0.26	-0.16	-0.17
GFP				-0.001	0.41	-0.16	0.35	-0.32	-0.27	0.07	-0.25	-0.19	0.05	-0.35	-0.24	-0.14
FLG					0.13	-0.14	0.28	0.46	0.39	0.21	0.0	-0.21	-0.17	0.14	-0.02	-0.14
AWL						-0.13	0.29	-0.23	-0.19	0.08	-0.25	-0.20	0.08	-0.27	-0.15	-0.06
ND							0.08	0.08	0.18	0.20	-0.37	-0.20	0.22	-0.10	-0.20	0.95**
PH								0.04	-0.10	0.15	-0.20	-0.27	0.12	-0.14	-0.05	0.12
K/S									0.84**	-0.09	-0.16	-0.06	0.12	-0.13	-0.14	0.07
Spl/S										-0.11	-0.33	-0.49**	-0.60**	-0.25	-0.29	0.19
SL											0.22	0.14	0.20	0.54*	0.19	0.18
BM												0.89**	-0.03	0.75**	0.63**	-0.49
TN													-0.01	0.66**	0.64**	-0.30
TGW														0.15	-0.10	0.17
SYWH															0.73**	-0.10
SYWOH																-0.07
HI																

Appendix 5 Correlation among 16 different characters of emmer wheat populations in Shewd

Traits	DH	DM	GFP	FLG	AWL	PH	K/S	Spl/S	SL	BM	TN	TGW	SY		HI
													WH	WHO	
DH		0.53	-0.39	0.42	0.14	-0.15	0.61	0.32	-0.02	0.55	0.71	-0.25	0.57	0.50	0.33
DM			0.56	0.16	-0.22	0.23	0.36	0.11	0.16	0.69*	0.79*	0.17	0.73*	0.54	0.07
GFP				-0.25	-0.42	0.39	-0.22	-0.22	0.14	0.20	0.15	0.48	0.22	0.09	-0.25
FLG					-0.11	-0.79*	-0.26	-0.41	-0.34	0.20	0.33	-0.21	0.29	0.33	0.27
AWL						0.21	0.62	0.50	0.26	0.31	0.26	-0.61	0.23	0.31	0.17
PH							0.56	0.61	0.59	0.31	0.17	0.22	0.29	0.23	0.08
K/S								0.85**	0.51	0.69*	0.63	-0.18	0.64	0.61	0.34
Spl/S									0.79*	0.69*	0.30	0.13	0.45	0.61	0.34
SL										0.38	0.14	0.22	0.38	0.38	0.34
BM											0.92**	0.13	0.96**	0.91**	0.24
TN												-0.12	0.91**	0.81**	0.21
TGW													0.13	0.17	0.01
SYWH														0.96**	0.47
SYWOH															0.57
HI															

Appendix 6. Correlation among 16 different characters of emmer wheat populations in Harerghe

Traits	DH	DM	GFP	FLG	AWL	PH	K/S	Spl/S	SL	BM	TN	TGW	SY		HI
													WH	WHO	
DH		-0.34	-0.62*	-0.15	-0.40	-0.16	-0.69**	-0.54*	-0.47	-0.56*	-0.40	0.17	-0.58*	-0.62*	-0.65*
DM			0.89**	-0.17	0.21	-0.02	0.54*	0.40	0.51	0.41	0.26	0.13	0.49	0.40	0.42
GFP				-0.16	0.17	0.03	0.61*	0.41	0.50	0.40	0.22	0.09	0.45	0.39	0.43
FLG					-0.05	0.65	0.44	0.11	0.34	0.65**	0.52*	0.21	0.62*	0.56*	0.27
AWL						0.01	0.32	0.63*	-0.04	0.14	0.01	0.14	0.24	0.23	0.43
PH							0.40	0.09	0.13	0.52*	0.18	0.27	0.38	0.38	0.09
K/S								0.77**	0.55*	0.78**	0.61*	-0.11	0.85**	0.86**	0.84**
Spl/S									0.17	0.41	0.35	0.27	0.57*	0.63*	0.81**
SL										0.76**	0.78**	0.01	0.73**	0.64*	-0.40
BM											0.87**	-0.12	0.96**	0.92**	0.67**
TN												-0.29	0.85**	0.82**	0.60*
TGW													-0.08	-0.31	-0.40
SYWH														0.95**	0.79**
SYWOH															0.89**
HI															

Appendix 7. Mean diversity indices (H') for each of six traits across five-altitude group

Altitude group	BL	ES	GC	KC	SD	BT	Mean ± SE
< 2000 m asl	0.3	0.63	0.78	0.71	0.63	0.73	0.63±0.07
2001 – 2400 m asl	0.54	0.63	0.76	0.67	0.66	0.82	0.68 ± 0.04
2401-2800 m asl	0.48	0.99	0.77	0.71	0.72	0.83	0.75 ± 0.07
> 2801 m asl	0.49	0.99	0.68	0.67	0.67	0.89	0.73 ± 0.07

Appendix 8 Dry matter, ash, organic mater, and Calcium percent contents of 55-emmer wheat accessions

LANDRACE (Acc.No)	DM%	ASH%	OM%	Ca%
PGRC/E 5999	88.81	1.5	98.5	0.06
PGRC/E 6018	88.66	1.41	98.59	0.07
PGRC/E 6052	88.48	1.57	98.43	0.05
PGRC/E 6054	88.54	1.55	98.45	0.06
PGRC/E 6055	88.53	1.37	98.63	0.06
PGRC/E 6068	88.41	1.33	98.67	0.06
PGRC/E 6843	88.43	1.21	98.79	0.07
PGRC/E 7278	88.53	1.44	98.56	0.07
PGRC/E 7884	88.54	1.73	98.27	0.07
PGRC/E 7885	88.57	1.37	98.63	0.08
PGRC/E 7886	88.59	1.21	98.79	0.08
PGRC/E 7913	88.54	2.09	98.91	0.06
PGRC/E 7920	88.66	1.6	98.4	0.1
PGRC/E 8010	88.68	1.53	98.47	0.08
PGRC/E 204345	88.65	1.48	98.52	0.06
PGRC/E 213038	88.54	1.1	98.9	0.06
PGRC/E 215407	88.53	1.14	98.86	0.06
PGRC/E 216831	88.76	1.16	98.84	0.08
PGRC/E 216835	88.53	1.21	98.79	0.1
PGRC/E 216836	88.71	1.41	98.59	0.07
PGRC/E 216838	88.49	1.15	98.85	0.07
PGRC/E 219074	88.69	1.32	98.68	0.08
PGRC/E 219078	88.64	1.42	98.58	0.08
PGRC/E 219079	88.68	1.42	98.58	0.07
PGRC/E 219080	88.57	1.14	98.86	0.09
PGRC/E 219081	88.89	1.35	98.65	0.1

Appendix 8 Continued

PGRC/E 219082	88.83	1.28	98.72	0.08
PGRC/E 219083	88.99	1.34	98.66	0.05
PGRC/E 219084	88.49	1.73	98.27	0.08
PGRC/E 219085	88.33	1.8	98.2	0.05
PGRC/E 219253	88.39	1.94	98.06	0.09
PGRC/E 219254	88.38	1.69	98.31	0.01
PGRC/E 219255	88.52	1.35	98.65	0.06
PGRC/E 219256	88.11	0.77	99.23	0.06
PGRC/E 219259	88.77	1.52	98.48	0.05
PGRC/E 219260	88.7	1.46	98.54	0.06
PGRC/E 219263	89	1.32	98.68	0.03
PGRC/E 219272	88.99	1.32	98.68	0.03
PGRC/E 219275	88.93	1.27	98.73	0.06
PGRC/E 219510	88.76	1.16	98.84	0.06
PGRC/E 221736	88.89	1.59	98.41	0.07
PGRC/E 221741	88.46	1.48	98.52	0.06
PGRC/E 229266	88.5	1.3	98.7	0.06
PGRC/E 229268	88.72	1.33	98.67	0.07
PGRC/E 230675	88.57	1.12	98.88	0.05
PGRC/E 230679	88.65	1.17	98.83	0.06
PGRC/E 230686	88.83	1.14	98.86	0.06
PGRC/E 230690	88.76	1.05	98.95	0.09
PGRC/E 231233	88.68	1.05	98.95	0.05
PGRC/E 231235	88.64	1.15	98.85	0.07
PGRC/E 231238	88.43	1.22	98.78	0.07
PGRC/E 232230	88.85	1.19	98.81	0.09
PGRC/E 232231	88.67	1.21	98.79	0.05
PGRC/E 232232	88.7	1.3	98.7	0.06
PGRC/E 232233	89.06	1.25	98.75	0.07

Appendix 9 Different song and saying on emmer wheat collected from Arsi and Bale zone

No	Oromiffa	English	Meaning	Implication
1	Nyaatu hayisaa	Qnatu hyssa	Emmer wheat consumer	Its nutritional quality and de huling problem
2	Hyisaa kan myaatufi fayyaa kan tumuufi eelaa	Hyssa kan qnatufifaya kan tumufi ella	It is good for health but its de hulling process is harming hands	Its top quality in its nutrition and any aspect
3	Hindato mishaa Akka dammaatti (aannanitti) dhugan hayisa	Hindeto misha aka damati (ananit) dugahyssa	Hindeto area is good because they drink emmer like honey/milk	Indicates its food quality and dehulling problem
4	Hayisaani dhala nanaati	Hyssoni dala namati	Emmer wheat is the some of man	Indicates it preference like milk and god food for poor family
5	Hayisaan Qolit dhibba isa maaltuu jibba	Hyssan Rolti deba esa maltu jebba	Even if emmer has hundred (Many) hull no one is dislike it.	Indicates its medicinal value (food medicine)
6	Hayisaa yaa hayisaa aannan hiyyessaa	Hyssa ya hyssa anani heyyessa	Emmer wheat is the milk for poor farmer	Indicates its medicinal value
7	Hayisaan qoha dhiraati	Hyssan koricha derati	Emmer wheat is medican for venereal disease	It indicates the tedious processing of emmer which needs strong farmer
8	Hayisaan bulleqatti tola Goonni gaafa loloa titola	Hyssani bulkatitola gone gafa lolatitola	Emmer is prefered so soup and bold is out smarted during conflict	It indicate its nutritional quality for strength brave man
9	Hayisaan bulluqa diiraa lolli yoo bulluqsan jilla	Hyssan buluka dera lelli you buluksan jila	Emmer wheat a soup for bold man and fighting is good it gets serious	It indicates its nutritional vlue and makes man active of tough

Appendix 9 Continued

10	Hayisaan waaliisaa haa cita narraa misa	Hyssani malesa ha chitu naroa misa	No need of feeding him emmer since he is week and let him to go away from me.	It indicates it is top quality food which is prefered for strong man
11	Hayisaan waan qabee qirnni Quuxoo kee lin qabu cirmii	Hyssa wan Kaby kirmi kuto ke hi kabu chirme	Emmer wheat,has many hull man can go I don't want you	Indicates its hull
12	Hayisaan mootii midhaani ti	Hyssani moti medanite	Emmer is the king for the field crops	Top quality food
13	Hayisaan silga loonit Hayisaan korma	Hyssani silga lonite Hyssani korma	Emmer wheat is enger emmer is bull	No market value it is restricted only for home consumption
14	Hayisaan salbu asheeta waan siif sarmu seetaa	Hyssani selbu asheta one sisermu seta	Emmer wheat is heads in good way but I am not good like that	It is good during heading
15	Qotii qotti, garu gara hayissa kana hawaadi	Koti koti garu gara hyssa kan hawadu	Plough and cultivte but increase emmer land	Express the felling of increasing productive of emmer
16	Hayisaa qallina qottee ofumaaf salphina sofxee	Hyssa kalina kotte ofumafi salkina sote	Even of you small land of emmer, you prepare trable for your self	Indicates dehilling problem
17	Hayisaa qoltia dhibba Garbuulle maltu jibba Brabaasso keyaa missinga	Hyssa kolti deba garbu lee maltu jibbe barbasss keera yamisinga	Emmer wheat has many hull, and barley too sorghum it with out hill	"
18	-	Endc aja labsole	He wear like emmer saheat	"
19	Hayisaa Ibnraaline kootit	Hyss Ibrahin koti	Ebrahimc with coat	"
20	Hayisaa abbaa kobborta sadccnii	Hyssa aba koborta sadnc	Emmer with is over coat	"
21	Hayisaa fi garbichi xiqqumma biyycc mataarratti rarani	Hayisa fi garbich tiku mat irratc rarene	Emmcr & slove nccd small sool to barribion	Minimum tillage requre

Appendix10 Mean sixteen quantitative data of 55 emmer wheat populations

Landrace	Awn leng	Biom ass	DH	Flagflen gt	GFLP	HI	Maturi ty	NKN PSK	Nod num b	NSPKL PSP	PLHT	SYWOH	SPKL GN	TGW	Tiller No.	SYWH
PGRC/E 5999	11	160	96	24	56	18	152	46	4	23	91	26	9	19	44	47
PGRC/E 6018	12	135	90	22	54	20	144	45	4	23	97	27	9	20	33	42
PGRC/E 6052	10	129	89	25	49	16	137	44	4	22	92	22	8	21	28	35
PGRC/E 6054	10	55	87	23	53	16	140	39	4	20	84	9	8	19	12	14
PGRC/E 6055	11	109	88	24	52	20	140	44	4	23	86	21	9	20	21	32
PGRC/E 6068	12	87	88	29	55	21	143	47	4	24	99	18	9	21	14	30
PGRC/E 6843	10	106	92	23	51	22	143	45	4	23	91	23	8	22	27	35
PGRC/E 7278	10	126	93	24	48	22	141	44	4	23	85	28	8	20	29	42
PGRC/E 7884	13	132	94	22	47	18	141	47	4	25	90	23	9	19	29	34
PGRC/E 7885	12	111	92	25	51	22	143	44	4	23	86	25	9	20	25	37
PGRC/E 7886	10	108	96	26	48	21	144	44	4	23	86	22	9	20	28	35
PGRC/E 7913	10	78	90	22	50	17	140	39	4	21	86	14	8	19	19	20
PGRC/E 7920	10	118	87	25	54	19	140	43	4	22	100	22	9	21	22	34
PGRC/E 8010	11	148	94	30	51	19	145	42	4	21	79	29	8	21	38	44
PGRC/E 204345	11	70	83	24	55	19	138	31	4	16	86	13	6	19	19	20
PGRC/E 213038	11	112	93	26	44	20	137	45	4	23	88	22	9	23	23	33
PGRC/E 215407	10	92	90	27	35	19	124	45	4	23	91	17	9	21	15	27
PGRC/E 216831	10	99	88	23	56	20	144	44	4	23	94	20	8	22	19	31
PGRC/E 216835	12	104	87	23	57	19	144	43	4	23	95	19	8	21	20	30

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PGRC/E 216836	10	102	87	24	54	19	141	44	4	22	93	19	9	22	20	30
PGRC/E 216838	11	99	87	24	57	20	143	43	4	22	96	20	8	24	17	29
PGRC/E 219074	12	114	88	24	58	17	146	41	4	22	95	19	8	22	22	28
PGRC/E 219078	9	118	91	24	49	18	140	43	4	23	86	21	9	22	24	37
PGRC/E 219079	10	120	90	25	53	15	143	44	4	23	91	19	8	19	25	32
PGRC/E 219080	11	98	90	24	52	21	142	42	4	22	95	20	8	21	21	29
PGRC/E 219081	11	97	89	21	58	21	147	41	4	22	93	20	8	21	22	29
PGRC/E 219082	11	101	88	23	55	19	143	42	4	22	94	19	9	20	20	31
PGRC/E 219083	10	115	89	24	52	23	141	43	4	22	94	28	8	21	24	35
PGRC/E 219084	10	125	90	24	53	19	143	47	4	23	94	24	9	20	25	36
PGRC/E 219085	10	113	90	23	51	17	141	45	4	23	97	19	9	21	21	30
PGRC/E 219253	8	114	90	25	54	17	143	43	4	21	100	20	9	21	22	32
PGRC/E 219254	11	90	89	22	54	16	143	40	4	21	91	14	8	21	17	23
PGRC/E 219255	12	95	88	24	51	19	139	44	4	23	100	18	7	21	18	26
PGRC/E 219256	11	86	90	24	51	19	141	42	4	23	90	17	7	21	18	27
PGRC/E 219259	11	104	89	25	53	17	142	42	4	21	98	17	8	52	19	31
PGRC/E 219260	12	107	89	24	56	19	145	44	4	23	100	20	9	39	19	32
PGRC/E 219263	11	93	88	24	55	16	142	42	4	22	93	15	9	40	19	27
PGRC/E 219272	9	59	91	23	46	12	137	37	4	20	97	7	6	36	12	10
PGRC/E 219275	10	84	88	22	64	17	146	43	4	22	93	14	8	35	16	23
PGRC/E 219510	10	111	96	23	43	16	139	45	4	23	89	17	8	36	29	29
PGRC/E 221736	13	76	87	20	47	18	134	30	4	16	81	13	7	37	21	30
PGRC/E 221741	10	72	87	21	56	15	143	30	4	16	80	10	7	41	18	17

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PGRC/E 229266	10	138	89	23	56	19	145	43	4	24	92	26	10	39	26	40
PGRC/E 229268	9	118	93	23	54	19	146	43	4	22	89	23	8	37	28	36
PGRC/E 230675	10	97	89	25	55	20	144	44	3	23	90	19	8	37	17	28
PGRC/E 230679	12	87	87	25	55	16	142	43	4	23	93	14	8	39	16	23
PGRC/E 230686	12	117	92	25	56	19	148	44	4	23	94	23	9	40	23	35
PGRC/E 230690	15	104	90	25	54	20	144	45	4	23	97	20	9	41	21	32
PGRC/E 231233	14	100	90	23	52	19	142	43	4	22	92	19	8	39	21	29
PGRC/E 231235	9	99	87	23	50	19	138	45	4	23	92	18	7	38	17	30
PGRC/E 231238	11	128	89	26	51	22	140	44	4	23	96	27	10	39	29	43
PGRC/E 232230	11	127	90	24	55	18	145	39	4	20	96	23	10	66	26	40
PGRC/E 232231	10	93	88	24	58	17	146	44	4	22	92	16	8	39	19	25
PGRC/E 232232	10	88	89	23	51	44	140	44	5	23	94	18	9	39	19	30
PGRC/E 232233	10	106	90	23	50	19	141	43	4	22	92	20	8	38	21	29

Appendix 11 Percent of phenotypic classes for each population

Landrace	Beak length			Ear sape		Glume color				Glume Pubscence		Kernel Color			Spike Density			Spike bending tend		
	S	M	L	Tp	Pl	W	P-y	P-r	D-RB	Glabr	Pubs	W	P-Y	P-R	D	M	Lax	Er	Inm	BD
PGRC/E 5999	33	67	0	47	53	0	80	13	7	100	0	0	60	40	27	7	0	67	73	0
PGRC/E 6018	43	57	0	50	50	4	53	43	0	100	0	10	33	67	43	5	0	43	57	7
PGRC/E 6052	28	72	0	68	32	12	28	60	0	100	0	4	28	68	40	5	8	24	52	36
PGRC/E 6054	6	94	0	59	41	34	50	16	0	100	0	12	47	41	19	7	9	31	72	0
PGRC/E 6055	27	73	0	49	51	3	57	38	3	100	0	0	41	59	30	6	8	40	62	14
PGRC/E 6068	25	75	0	50	50	13	31	56	0	100	0	0	19	81	50	4	6	31	44	0
PGRC/E 6843	19	81	0	45	55	16	39	32	13	100	0	7	35	58	45	4	7	71	48	0
PGRC/E 7278	25	75	0	67	33	29	46	21	4	100	0	4	83	13	29	6	8	87	63	0
PGRC/E 7884	17	83	0	27	73	7	43	50	0	100	0	7	46	47	43	5	0	23	57	30
PGRC/E 7885	20	80	0	43	57	14	43	43	0	100	0	4	33	63	30	6	3	40	67	7
PGRC/E 7886	25	75	0	46	54	8	63	29	0	100	0	0	71	29	29	6	4	38	67	8
PGRC/E 7913	29	71	0	51	49	17	61	22	0	100	0	3	39	58	29	6	10	32	61	5
PGRC/E 7920	5	95	0	24	76	2	11	87	0	100	0	2	29	69	44	5	0	36	56	2
PGRC/E 8010	76	24	0	52	48	24	60	12	4	100	0	20	24	56	44	5	0	60	56	0
PGRC/E 204345	7	93	0	47	53	3	58	30	9	100	0	0	56	44	42	5	2	58	56	12
PGRC/E 213038	60	40	0	40	60	23	40	15	22	100	0	0	45	55	48	5	0	25	52	18
PGRC/E 215407	12	88	0	23	77	12	73	15	0	100	0	0	58	42	54	4	0	42	46	12
PGRC/E 216831	35	65	0	59	41	12	47	39	2	100	0	10	26	64	43	5	0	72	57	0
PGRC/E 216835	25	75	0	28	72	13	47	34	6	100	0	0	56	44	50	5	0	50	50	9

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PGRC/E 216836	21	79	0	38	62	7	55	38	0	100	0	4	52	44	48	4	4	41	48	14
PGRC/E 216838	16	84	0	57	43	3	43	52	2	100	0	0	41	59	57	4	2	81	41	0
PGRC/E 219074	25	75	0	50	50	4	71	25	0	100	0	0	46	54	21	7	0	68	79	0
PGRC/E 219078	38	62	0	57	43	24	47	29	0	100	0	0	38	62	62	3	5	38	33	10
PGRC/E 219079	19	81	0	57	43	10	47	43	0	100	0	5	66	29	48	5	0	67	52	14
PGRC/E 219080	19	81	0	50	50	14	55	31	0	100	0	0	50	50	36	6	0	58	64	6
PGRC/E 219081	18	82	0	50	50	18	41	23	18	100	0	0	36	64	36	6	0	77	64	0
PGRC/E 219082	27	73	0	47	53	6	76	18	0	100	0	0	47	53	38	6	0	59	62	6
PGRC/E 219083	26	74	0	47	53	9	56	35	0	100	0	0	50	50	38	6	0	38	62	9
PGRC/E 219084	19	81	0	39	61	12	53	35	0	100	0	0	42	58	46	5	0	39	54	19
PGRC/E 219085	17	83	0	42	58	3	58	39	0	100	0	6	47	47	53	4	0	33	47	28
PGRC/E 219253	21	79	0	43	57	4	64	28	4	100	0	0	39	61	32	6	0	60	68	4
PGRC/E 219254	29	71	0	53	47	21	41	32	6	100	0	6	50	44	53	4	0	71	47	0
PGRC/E 219255	27	73	0	48	52	5	47	48	0	100	0	0	41	59	34	6	0	23	66	20
PGRC/E 219256	25	75	0	39	61	22	54	24	0	100	0	2	51	47	39	5	2	35	59	4
PGRC/E 219259	28	72	0	30	70	9	43	39	9	100	0	2	33	65	72	2	0	52	28	18
PGRC/E 219260	36	64	0	26	74	10	50	40	0	100	0	0	48	52	32	6	0	56	68	0
PGRC/E 219263	24	76	0	33	67	9	52	33	6	100	0	0	67	33	49	5	0	33	51	0
PGRC/E 219272	14	86	0	54	46	14	61	13	12	100	0	2	57	41	30	7	0	20	70	7
PGRC/E 219275	17	81	2	53	47	11	66	21	2	100	0	0	47	53	32	6	2	47	66	6
PGRC/E 219510	13	87	0	50	50	0	83	17	0	100	0	0	46	54	38	6	0	20	62	13
PGRC/E 221736	0	100	0	42	58	47	42	5	6	100	0	0	58	42	16	7	5	36	79	11
PGRC/E 221741	4	96	0	54	46	32	50	14	4	100	0	0	50	50	21	7	4	61	75	0

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PGRC/E 229266	32	68	0	53	47	5	53	37	5	100	0	0	68	32	68	3	0	68	32	0
PGRC/E 229268	33	67	0	73	27	27	58	12	3	100	0	0	58	42	42	5	3	61	55	3
PGRC/E 230675	17	83	0	45	55	13	49	34	4	100	0	0	57	43	41	5	2	57	57	5
PGRC/E 230679	4	96	0	60	40	2	46	50	2	100	0	0	48	52	38	6	0	40	62	6
PGRC/E 230686	15	85	0	51	49	12	56	32	0	100	0	0	39	61	37	6	0	71	63	0
PGRC/E 230690	3	97	0	39	61	9	47	44	0	100	0	0	69	31	42	5	0	75	58	0
PGRC/E 231233	15	85	0	36	64	8	66	23	3	100	0	0	51	49	33	6	0	66	67	3
PGRC/E 231235	10	90	0	42	58	15	46	36	3	100	0	0	37	63	39	6	0	34	61	5
PGRC/E 231238	3	97	0	36	64	6	52	42	0	100	0	0	46	54	33	6	3	40	64	9
PGRC/E 232230	19	81	0	43	57	10	62	28	0	100	0	0	43	57	19	8	0	43	81	0
PGRC/E 232231	12	88	0	39	61	4	47	49	0	100	0	0	39	61	49	5	0	63	51	0
PGRC/E 232232	17	83	0	46	54	17	44	39	0	100	0	0	39	61	22	7	0	20	78	17

Appendix 12 Number of alleles in each locus for the twelve Emmer wheat populations

GRC/E 6054	PGRC/E 221736	PGRC/E 23069	PGRC/E 232230
EST-1 AB:05	EST-1AA:03 AB:02	EST-1AB:04 AA:01	EST-1AB:01 AA:04
EST-2 AA:05	EST-2 AA:05	EST-2 AA:05	EST-2 AA:05
EST-3AB:03 B:02	EST-3 AB:03 BB:02	EST-3 AB:01 BB:04	EST-3 BB:05
AAT-1 AB:05	AAT-1 AB:05	AAT-1 AB:05	AAT-1 AB:05
AAT-2 AA:05	AAT-2 AA:05	AAT-2 AA:05	AAT-2 AA:05
AAT-3 AA:05	AAT-3 AA:05	AAT-3 AA:05	AAT-3 AA:05
ACP-1 AA:05	ACP-1AA:01 AB:03	ACP-1AA:05AB:03 AC:01	ACP-1 AB:01 AA:04
ACP-2 BB:05	ACP-2BB:03 AA:02	ACP-2 BB:05	ACP-2 BB:05
ACP-3 AB:05	ACP-3 AB:05	ACP-3 AB:05	ACP-3 AB:05

PGRC/E216838	PGRC/E 232232	PGRC/E 7920	PGRC/E 213038
EST-1 AB:05	EST-1 AB:05	EST-1 AB:05	EST-1 AB:03 AA:01
EST-2 AA:05	EST-2 AA:05	EST-2 AA:05	EST-2 AA:05
EST-3 BB:05	EST-3 AB:05	EST-3 BB:05	EST-3 AB:01 BB:04
AAT-1 AB:05	AAT-1 AB:05	AAT-1 AB:05	AAT-1 AB:05
AAT-2 AA:05	AAT-2 AA:05	AAT-2 AA:05	AAT-2 AA:05
AAT-3 AA:05	AAT-3 AA:05	AAT-3 AA:05	AAT-3 AA:05
ACP-1AB:02 AA:03	ACP-1AB:02 AA:03	ACP-1 BB:05	ACP-1 AA:01 BB:04
ACP-2 BB:05	ACP-2 BB:05	ACP-2 AB:01 BB:04	ACP-2 BB:04 AB:01
ACP-3 AB:05	ACP-3 AB:05	ACP-3 BB:02 AB:03	ACP-3 AB:05

PGRC/E 219510	PGRC/E 8010	PGRC/E 6843	PGRC/E 219254
EST-1 AB:05	EST-1 AB:05	EST-1 AB:04 AA:01	EST-1 AB:05
EST-2 AA:05	EST-2 AA:05	EST-2 AA:05	EST-2 AA:05
EST-3 BB:05	EST-3 BB:05	EST-3 AB:01 BB:04	EST-3 AB:03 BB:02
AAT-1 AB:05	AAT-1 AB:05	AAT-1 AB:05	AAT-1 AB:05
AAT-2 AA:05	AAT-2 AA:05	AAT-2 AA:05	AAT-2 AA:05
AAT-3 AA:05	AAT-3 AA:05	AAT-3 AA:05	AAT-3 AA:05
ACP-1 BC:01 CC:03	ACP-1AA:01 BB:04	ACP-1 AA:01 BB:04	ACP-1 BB:05
ACP-2 BB:05	ACP-2 BB:05	ACP-2 BB:05	ACP-2 BB:05
ACP-3 AB:05	ACP-3 AB:05	ACP-3 AB:05	ACP-3 AB:05

Appendix 13 Summary of Emmer Wheat (Triticum dicoccum) Ethnobotanical Survey Data Collection Format

-Location
-Collecting date
-Region/Zone of Collection
-Woreda/ Keble /PA
-Location of collecting site
-Precise locality
-Longitude
-Altitude
-Latitude

-Informant's name
-Age
-Gender
-Occupation
-Field ID
-Local name of the crop
-Meaning of the local name
-Language
-Survey season
-Socioeconomic date
-Cultural practice data

Characteristics of morphtype

-Productive tillering capacity
-Stem hardness
-Heading time
-Variability within plants
-Maturity time
-Spike length
-SpiKe density
-Spike shape
-Spike panicle position
-Resistance to lodging
-Disease identified by the farmer
-Crop pest identified by the farmer
-Weeds identified by the farmer
-The status of severity of mentioned under
-Pretreatment of the edible part
-Threshability
-Use of the crop (seed) for human being
-Use of crop part
-Preferential grain quality
-Food preparation system for the codes under

-Awn length
-Glume color
-Hairiness of glume surface
-Grain size
-Grain straw ratio
-Tolerance to cold
-Tolerance to drought
-Tolerance to water logging
-Tolerance to shade

-Quality in food processing
-Flour color of the grain
-Preference of the farmer within the local cultivars for the parameters mentioned below
-Farmers selection criteria for the morph types
-Preference ranking of morphotypes
-Marriage traditions
-Song and saying
-Common practices
-Tradition about origin
-Rituals and religious beliefs