ADDIS ABABA UNIVERSITY
SHOOL OF GRADUATE STUDIES

MORPHOLOGICAL AND MOLECULAR DIVERSITY IN DURUM WHEAT (*Triticum durum* Desf.) LANDRACES OF NORTH SHEWA

A Thesis presented to the School of Graduate Studies
Addis Ababa University

In partial fulfillment of the requirements for the degree
Of
Master of Science in Biology

By
Mulualem Tamiru
May, 1999

This work is **dedicated** to my father the late **cap. Tamiru Kassa** for all his everlasting contribution for successful accomplishement of my acadamic career and also to my brother the late **Dereje Tamiru**

TABLE OF CONTENTS

List of figures

List of tables

Page

List of Appendices

ACKNOWLEDGEMENTS

I express my deepest appreciation and gratitude to my advisor Dr. Zemede Asfaw who has been meticulously following up the research undertaking and put all his effort, intellectual advice, scientific guidelines and critical reading of the manuscript of the thesis. I thank a lot to my co-advisor Dr. Hailesilliase Yibrah for his constructive scientific guidelines on the molecular study and for his critical reading of the manuscript. My deep gratitude also goes to Professor Endashaw Bekele for his help in identifying the research area of this thesis.

It gives me pleasure and honour to express my foremost and heartfelt appreciation and thanks to Dr. Seyfu Ketema (Director General of Ethiopian Agricultural Research Organization). His input has been strikingly high and he is the one who brought me to the fascinating field of plant genetics through his consistent, stimulating and moral support.

Many thanks go to the whole staff of the Biodiversity Institute for their kind regards during the whole period of the research and the few names which deserve special thanks are Dr. Abebe Demissie, Dr. Fassil Kebebew (Who has allowed me to use his computer and gave me moral and material support) and the late Dr. Mehari Zewdie. My deep appreciation goes to Dibbaba Demessa who taught me about durum wheat identification and helped me a lot those times of morphological data collection. Thanks go to Hailu, Zeyneba and Getinet for their help during ethnobotanical study. Yemane Tsehaye deserves thanks for his deep concern and help in data analysis of the thesis. I thank a lot Basazinew, Dereje, Samson, Samuel, Dilba, Tamirat, Tsehay and Zereom from the Biodiversity Institute for their kind help and support.

G/Egizabeher Teklu was putting all his unreserved moral support for the successful accomplishment of my academic career. His friendship support made my study smooth and comfortable (Many thanks "Gebre"). I owe a lot to Fetihya Awol for her encouragement and kind support in the whole period of the study.

I thank a lot to Dr. Asfaw H/mariam of the National Soil Laboratory (NSL) for his unreserved effort and intellectual advice during the Glass house experiment. My deep gratitude also goes to Kassahun Mammo who suffered a lot in helping me during the Glass house experiment and for his moral support. Wase, Alemayehu and Mekdes also deserve gratitude for all their help during my stay at NSL.

The molecular part becomes a reality with the help of the staff of the Armaur Hanson Research Institute (AHRI) and my deep thanks goes to Demissew Beyene who introduced me to molecular research work. I thank also Dr. Emma Mace of the International Livestock Research Institute (ILRI, Kenya) for sending the primers. I thank a lot to Gashaw, Soleme, Daniel, Isaac, Dawit K., Dr. Dawit W., Neguisse from AHRI who helped me a lot and made the stay at AHRI comfortable.

"Special" thanks and sincere appreciation goes to Elizabeth Yohannes who put all her maximum and unsparing effort in the whole period of my graduate studies. I appreciate and express my special thanks to my family and the effort of my brother Ayalneh Tamiru was immense and I thank him a lot.

Finally I thank the Institute of Biodiversity- GEF-funded project (for financial support), AHRI (for molecular Lab. work), National Soil Lab. (for the Glass house experiment) and the Biology department of Addis Ababa University for creating the academic atmosphere for my graduate studies.

Abstract

Morphological and molecular diversity study and the associated ethnobotanical profile of durum wheat landraces (farmers' varieties) of North Shewa have been undertaken in this study. Morphological diversity study on thirteen durum wheat populations (381 genotypes) ,collected earlier by the Biodiversity Conservation and Research Institute from five awrajas and ten weredas of North Shewa region, was conducted using six heritable qualitative traits. The diversity was estimated using Shannon Weaver diversity index (H'). H' was estimated for each population, wereda, awraja and altitudinal class and the entire collection. On population basis H' is lowest at Basona Warena wereda (0.25 ± 0.08) and highest at Kimbibit Wereda (0.65 ± 0.16). On awraja basis H' ranged from (0.50 ± 0.03) in Gara Midir to (0.73 ± 0.10) in Selale. On altitudinal basis, the third altitudinal class (2401-2600 m.a.s.l.) sc ored the highest H' (0.78). The diversity index for the study area is very high (0.79 ± 0.08). On character basis seed color showed the highest H' (0.97). Only glume pubescence was conspicuously unique to specific awraja and altitudinal class.

A high diversity of the crop is also observed from the ethnobotany study. A total of twenty-five different farmers' varieties having different vernacular names were recorded. The environmental, social (cultural) and economic factors were identified by the farmer as factors for maintaining the existing diversity. The different varieties have important merits in agronomy, disease resistance, traditional use values and so on. Farmers have their own folk taxonomy system for identifying and classifying their varieties.

The Randomly Amplified Polymorphic DNA (RAPD) molecular technique with a gluten-coding single primer system with the following sequence,

{ 5'- ATG AAG ACC TTC CTC GTC TT- 3'}

{ 5'- AAC GCC GAA TGG CAC ACT A- 3' }

showed good demonstration of the inter-population diversity of the thirteen populations. Except three populations, all the rest showed different banding patterns with different base pair fragments for the same primer used. Generally the whole study confirmed the existence of strikingly high diversity of durum wheat in the study area and underlines the role of the indigenous knowledge of farmers for the existing diversity.

Key words: Wheat, *Triticum durum*, landraces (farmers' varieties), diversity index (H')
Morphological traits, ethnobotany, RAPD.

INTRODUCTION

1.1. Biodiversity

Biodiversity, which is the variety and variability of all plants, animals and micro-organisms and the ecological complexes of which they are part, encompasses wide and vast forms of life starting from the tiniest microbe to the mightiest beast (Zedan, 1995). This biodiversity of the earth provides food, energy, medicine and other raw materials, which are important for the subsistence of human life. The existence and continuity of all these life forms is governed by natural evolutionary processes which are the result of both stochastic and deterministic forces.

Biodiversity of the earth, its ecosystem, species and genes are the outcome of more than three billion years of evolutionary histories and it will be difficult to reclaim back if once they are lost (Wilson, 1992). The difficulties of economists to set monitory value on biodiversity and its environment made people to neglect the conservation endeavours of these resources and it consequently causes tremendous loss and erosion of this important heritage of nature. Conservation of biodiversity is a moral obligation we have in order to respect the humanity of the generations to come. To fail to conserve and prudently use this biodiversity is a big folly that the next generation is least likely to forgive us and sustainable development must not come at the expense of later generations (Wilson, 1992).

Plant genetic resources are part of biodiversity, which are the bases for agricultural development and food security for the ever-increasing population of the world. Plant genetic resource is defined as "plant genetic material of actual or potential value" and plant genetic material in turn is defined as "any material of plant containing functional unites of heredity" (UNEP, 1995).

Plant genetic resources or germplasm include landraces, wild relatives, weed races, unimproved cultivars, improved cultivars, breeding and genetic stocks (Chang, 1992).

1.2. Distribution and conservation of plant genetic resources

The abundance and diversity of plant genetic resources is not uniform and equitable among regions of the world. N.I. Vavilov, a famous Russian scientist who had conducted extensive phytogeographical studies of crops throughout the world in early this century, is one of the earliest scientists to state the concepts of "centers of origin and diversity" of crops of the world. The Ethiopian region (Abyssinian center) was identified as one of the eight centers of the world where crop plant diversity is strikingly high and where some of the crops were domesticated (Mengesha, 1975).

1.2.1. The Ethiopian gene center

Ethiopia is a country with diverse agroecology, variable edaphic conditions, multiple topography endowed with highly dissected highlands formed by mountains (ca. 5000 m.a.s.l.) and ravines (>1300m deep), traditional agricultural practices coupled with ancient and very diverse cultural histories of its people (Tsegaye, 1997). The above are the factors which contributed to diversification of crop species throughout the country. Ethiopia is a center of origin and/or diversity for a number of globally important crops (Vavilov, 1951; Harlan, 1971). Vavilov (1951) identified some 38 species having Ethiopia as primary or secondary gene center; Zohary (1970) indicated 11 crop species having their center of diversity in Ethiopia. Ethiopia is a center of origin for crops such as; tef (*Eragrostis tef*), coffee (*Coffea arabica*), noog (*Guizotia abyssinica*), enset (*Ensete ventricosum)* and center of diversity for crops such as; barely (*Hordeum vulgare*), sorghum (*Sorghum bicolor*), durum wheat (*Triticum durum*), sesame (*Sesamum indicum*), caster bean (*Ricinus communis*) and chat (*Catha edulis*) (Zewdie, 1994).

The importance of the Ethiopian gene center for plant breeders throughout the world becomes visible when one considers genes from Ethiopian barley, coffee, durum wheat and sorghum that demonstrated resistance to the vulnerabilities of commercial agriculture (Hawkes and Werede, 1991). To cite a case, out of the 117 entries which were found to be resistant to barely yellow dwarf virus disease (YDVD) from world collections, 112 were collected from Ethiopia and the other five were from other sources (mainly Asia). These resistant genotypes protect California's barely from this virus and generate 160 million dollars annually (Miller and Tongtey, 1993).

1.2.2. Conservation strategies

The conservation of plant genetic resources is essential 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*. These two conservation systems are complimentary and have merits and drawbacks.

1.2.2.1. *Ex-situ* conservation

Ex-situ is the conservation of germplasm outside their natural settings in gene banks (cold stores or field gene banks), botanical gardens, tissue culture, cryopreservation and others. The major drawbacks of this system is that the evolutionary and selection processes are ceased and continuous adaptation of the genotypes to local habitat is halted (Esquinas-Alcazar, 1993) and it fails to gain more insight into genotypic structure and interaction of the various hosts and pathogens in the sites under study (Bekele, 1983). *Ex-situ* conservation gives no attention to the farming practices, indigenous knowledge and traditional farming systems that generated the existing diversities. However, with all the above drawbacks, this system has merits in that it is possible to conserve a large amount of materials in a small cold store and it is also cost effective.

1.2.2.2. *In-situ* conservation

In-situ is the conservation of germplasm in their natural settings where they have been evolved, domesticated and diversified. It maintains and keeps the evolutionary dynamics of the species, the genetic structure, the farming practices and knowledge. Among the prerequisites for selecting sites for *in-situ* conservation are included a fuller understanding of the crop population, the ecological complexes of the environment and the farming systems that produced them (Brush, 1990). However, the major drawback of *in-situ* conservation is the cost that is needed to implement it. Eventhough the formal conservation endeavours of Ethiopian germplasm is mainly *ex-situ*, some *in-situ* conservation strategy sites for different crops such as tef, barely, tetraploid wheat were recommended by different authors (Bekele, 1984; Bekele, 1985; Tessema *et al.,* 1991; Bechere *et al.*, 1996; Demissie, 1996).

1.3. Diversity studies

Better information developed from studies and characterizations of the population structure and distribution of the genetic variations is essential and primary concern for developing more efficient ways of evaluating and conserving biodiversity in general and plant genetic resources in particular. Genetic variation is usually a raw material on which natural selection works, thus determining the fitness of a given population (Bekele, 1983).

Basic genetic diversity studies of a germplasm is important to know the genetic worth of the germplasm so that it will be possible to conserve and utilize it effectively and to locate sites of concentration of important genes and co-adapted gene complexes (Demissie, 1996). Coadaptation has an important implication for several aspects of plant breeding and choice of plant breeding methods (Bekele, 1983).

A wider genetic base of a germplasm is a prerequisite to the success of a plant breeding program and to cope with the challenges resulted from diseases, pests, drought and other environmental stresses (Bechere *et al.*, 1996).

Methods (techniques) for genetic diversity studies have been developed ranging from morphological methods to recent molecular biology techniques.

2. LITERATURE REVIEW

2.1. Origin and taxonomy of wheat (*Triticum* spp.)

Wheat (*Triticum* spp.) is an annual grass, belonging to the tribe *Triticeae,* family *Poaceae (Gramineae)* and genus *Triticum*. It is believed that the fertile crescent running from Turkish thrace through to Afghanistan and including the valleys of the Tigris and Euphrates rivers as the center of origin for this crop (Berrie, 1977). 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 allopolyploid plant consisting of diploid (2n=2x=14), tetraploid (2n=4x=28) and hexapod (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 morphological discontinuity makes it difficult for offering adequate species borders. Several scientists proposed different schemes for the taxonomy of this genus. The two mostly accepted schemes are those of Mackey (1966) and Berrie (1977).

According to Mackey (1966), polyploidy and "biphyletic" genomic differentiation (B vs. G genome) are the only isolating mechanisms offering distinct species. Berrie (1977) stated that polyploidy and rachis character are the isolating mechanisms and the following outline was forwarded (Fig. 1). Mak Key treated *T. turgidum*, *T. dicoccum*, *T. polonicum* and *T. durum* as various forms of turgidium and in the Ethiopian samples turgidium with compactoid, dicoccum and spherecoccum genes were identified (Bekele, 1984).

	Brittle rachis (spelt)	Tough rachis
DIPLOID	*T. boeticum* Boiss. *T. monococcum* L.	
TETRAPLOID	*T. dicoccoides* Koern. *T. dicoccum* Schubb. *T. timopheevi* Zukov.	***T. durum* Desf.** *T. turgidum* L. *T. turanicum* Jakubz. *T. polonicum* L. (mutant) *T. carthlicum* Nevski.
HEXAPLOID	*T. spelta* L. *T. macha* Dek. And Men. *T. vavilovi* Tuman.	*T. aestivum* L. *T. compactum* Host. *T. spherococcum* Perc.

Fig. 1. An Outline for the classification of the genus Triticum based on polyploidy and rachis character (Taken from Berrie, 1977).

There are three genomes involved in the formation of the ploidy series (Kerby and Kuspira, 1987). These are designated as A, B (G) and D genomes. The possible origin of the three genomes and the evolutionary processes for the generation of the different wheat types is presented in Purseglove (1975) (Fig. 2).

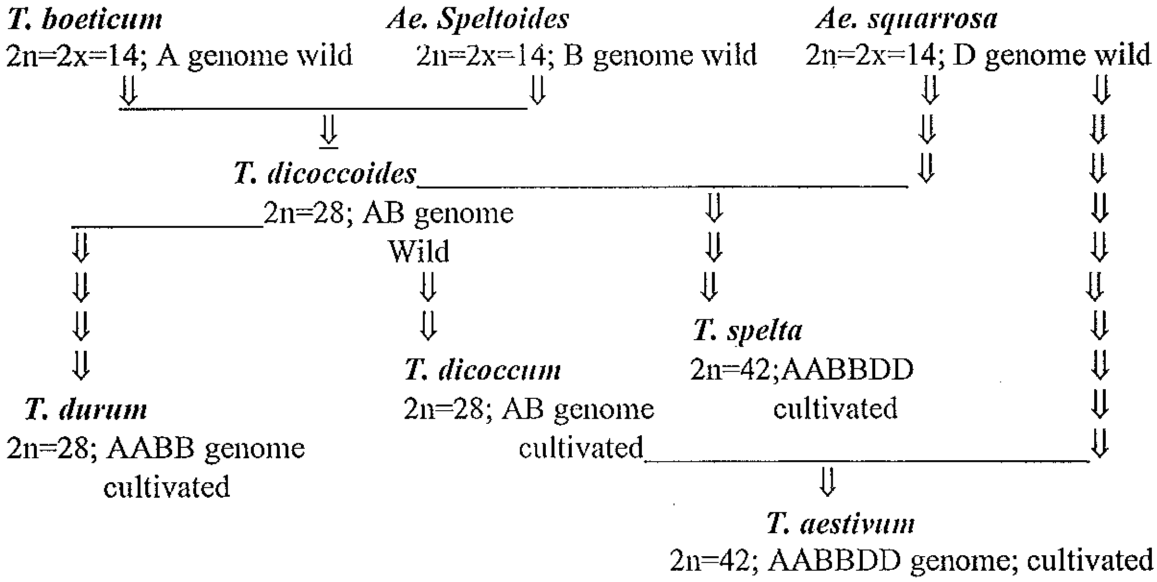


Fig. 2. Probable origin of the different *Triticum* spp. Each capital letter represents a Genome composed of seven chromosomes (Purseglove, 1975).

The close genetic relationship between *Triticum* and *Aegilops* enable the introduction of chromosomes from *Aegilops* species into *Triticum* species and the genus *Aegilops* has been involved in the evolutionary process of modern wheat (Zohary, 1970).

2.2. Wheat in Ethiopia

Wheat is one of the most important crops and ranks fifth in acreage after tef, maize, sorghum and barley in Ethiopia (Engels and Hawkes, 1991). Ethiopia is the largest wheat producer in Sub-Saharan Africa (Gebremariam, 1991). It is estimated that 60% of the area under wheat is occupied by the tetraploid (2n=4x=28), *T. turgidium* L., wheat types and the rest by the hexaploid (2n=6x=42), bread wheat, (*T. aestivum* L.) (Tesemma and Belay, 1991).

It is generally believed that wheat arrived in the Ethiopian highlands from the near-east ca. 5000 years ago by early Hamite immigrants and *T. diccoccum* (emmer wheat) was the first to arrive (Helbeak, 1959; Feldman, 1976). Bread wheat (*T. aestivum*) was introduced more recently in the 18^{th} century by Portuguese explorers (Gebremariam, 1991).

Study attempts of Ethiopian wheat date back to late 19^{th} century in 1885 by Koernike and Warner but detailed and extensive analysis started by Vavilov during his exploration to the country in 1927. The major attempts for collection and taxonomic work include: Vavilov in 1927; Ciferri in 1939; Japanese scientists in mission called Kyoto University Science Expedition to the Sahara (K.U.S.E.S.) in 1967-68; Russian scientists from Vavilov Institute of Pathology in 1968-69; Weibe from U.S.A in 1970; Bari germplasm expeditions from Italy in 1972-73; Agronomy team of Holeta also attempted some collection missions (Demissie and Habtemariam, 1991). The above scientists have identified the following wheat species in Ethiopia; *T. dicoccum, T. turgidum, T. durum, T. polonicum, T. compactum, T. pyramidale, T. aestivum* and some new forms such as *T. cartilicum* , *T. turranicum, T. sperococcum* and *T. spelta* (Porceddu and Perino, 1973). The above report also showed that there were other interesting types, which were difficult to assign to any of the traditionally known taxonomic species. However, in recent literature, it is argued that *T. carthlicum* is restricted in the Transcaucasus region only (Feldman *et al.*, 1995).

2.2.1. Tetraploid wheat in Ethiopia

Ethiopian tetraploid wheat is the most important both interms of the area it has covered and the high diversity it has among the wheat types. Ethiopia was considered to be the center of origin for cultivated tetraploid wheat by Vavilov (1951). Later on, however, due to the absence of ancestral forms and wild relatives, (*T. dicoccoides)*, Ethiopia becomes only center of diversity (Shiemann, 1951; Harlan, 1971).

The major portion of the tetraploid wheat production depends on landraces consisting of genotypic mixtures varying in agromorphological traits and there are six known taxa of this group. They are *T. dicoccum, T. turgidum, T. durum, T. polonicum, T. pyramidale* and *T. carthlicum* (Bekele, 1984; Tesemma, 1991). In the gene pool concept of Harlan and De wet (1971), Ethiopian tetraploid wheat types comprise largely the primary gene pool because they are genomically alike (AABB) and interfertile (Tsegaye, 1997).

T. dicoccum (cultivated emmer or "Adja") which arose from the wild *T. dicoccoides*, was the first wheat that arrived in Ethiopia and because of its nutritional and medicinal value is still under cultivation in the country (Tesemma and Belay, 1991). It is not clear, however, whether the "free-threshing" types (*T. durum, T. turgidum and T. polonicum* which is a mutant type (Bekele, 1984))replaced emmer after direct introduction or through evolutionary modification from emmer by processes such as mutations followed by selection.

2.2.2. Ethiopian durum wheat

Among tetraploid wheat types, durum wheat is the most important in its high variations prevailing in the country and the area it occupies. Ethiopian durum wheat has shown highest diversity index as compared to other durum wheat collections maintained at the US Department of Agriculture (Jain *et al.,* 1975; Spagnoletti *et al.,* 1987). Some studies have also showed the distinctiveness of the Ethiopian durum wheat from any other gene pool (Dominci *et al.,* 1988; Pecetti *et al.,* 1992). Generally, the highest diversity of durum wheat today is found in Ethiopia (Purseglove, 1975).

Agronomically important genes such as disease and pest resistant, dwarfness, long coleoptile, early maturity, high protein content and adaptation to low fertility have been identified from the Ethiopian durum wheat (Porceddu and Perino, 1973; Pecetti *et al.,* 1992).

Durum wheat in Ethiopia is grown mainly under rain fed conditions on heavy black clay soils (Vertisols) of highlands with altitudinal range between 1800 to 2800 m.a.s.l. (Tesemma and Belay, 1991). The main growing areas of durum wheat are the central and north central highlands of Ethiopia. Seventy-five percent of the production comes from three regions, namely Arsi, Bale and Shewa (Gebremariam, 1991).

The main planting materials are landraces with variable morphological characters and botanical forms. These landraces are consisting of distinct morphotypes (agrotypes). About 86 morphtypes from Ethiopian durum wheat landraces have been identified (Tesemma, 1997; personal communication).

Landraces or farmers' varieties are variable and diverse populations which have evolved under the traditional farming systems and not by formal plant breeding and are used as the basis for modern commercial agriculture and development of high yielding varieties (HYV) (Frankel, 1974). When landraces are lost the traditional knowledge, the management practices and the ecological rationale behind them are also lost (Chambers, 1983).

2.3. Genetic diversity studies on Ethiopian durum wheat

2.3.1. Morphological studies

Diversity studies on Ethiopian durum wheat germplasm were conducted mainly using morphological methods. Several investigators have conducted morphological diversity studies to estimate the genetic variations of the crop (Jain *et al.,* 1975; Bekele, 1984;

Negassa, 1986; Tesemma *et al.*, 1991; Pecetti *et al*, 1992; Bechere et al., 1996 Tsegaye, 1997; Belay, 1997).

Although these studies have generated important information, according to the analysis made by Belay (1997), most of the studies have showed one or more of the following limitations.

- The durum and non-durum wheat types were lumped together (Negassa, 1986). (This is because all the tetraploid forms are considered (e.g. by Mak Key as one complex but genetically very variable species).
- The study has been carried out elsewhere outside the natural settings of the landrace (Jain *et al.*, 1975; Bekele, 1984; Negassa, 1986).
- Major growing areas were not included in the study (Bekele, 1984)

The above limitations together with some other intrinsic factors cause inconsistency and discripinancy in the results of the studies and this may hamper the proper utilization and conservation of landraces (Belay, 1997).

From the above studies that of Tesemma *et al.* (1991) and Bechere *et al.* (1996) overcome the shortcomings. Nevertheless, they reported two different results; the former indicated regional differences of diversity estimates whereas the latter did not report such differences. Belay (1997) recommended that reanalyzing the diversity of the populations from the two studies together might help in getting comprehensive results about the extent of the morphological diversity.

2.3.2. Ethnobotanical studies

As cited in Asfaw (1997), ethnobotany is defined as an interdisciplinary and multi-disciplinary science for documentation, analysis and making effective use of the knowledge that local people have accumulated during their prolonged interaction with plants.

Teshome (1996) strongly underlined the critical role of farmers in maintaining genetic diversity of crops. He explicitly elaborated time and space based multiple strategies of farmers to maintain the biological and environmental heterogeneity to meet their economic, social, cultural and ecological needs. Hence, indigenous knowledge of the farming community must be incorporated in the study of crop genetic resources. He also emphasized the importance of a holistic approach that takes into account the biological, environmental and social entities of the agroecosystem that affect the genetic diversity through their different feedback mechanisms. *In-situ* conservation efforts should be linked to rural development by taking into account the traditional agricultural knowledge and practices of farmers (Altieri *et al.,* 1987).

Ethnobotanical studies on Ethiopian cultivated crops is very minimal and only that of Asfaw (1990) for barley (*Hordeum vulgare* L.) and Teshome (1996) for sorghum (*Sorghum bicolor* (L.) Monech) are known. Eventhough an ethnobotanical survey has been attempted on some durum wheat landraces of North Shewa (Kebebew *et al.*, 1997), there are no detailed ethnobotanical analyses undertaken on durum wheat landraces of the country.

2.3.3. Molecular studies

Powerful new techniques of molecular biology that have important applications in the study of genetic variations among organisms have been developed in recent years (Dullo *et al.,* 1997). The most important qualities of these techniques are that all show the variations at the DNA level and show good coverage of the genome, provided that one uses large number of primers.

Among the molecular techniques the most commonly used are RFLP (restriction fragment length polymorphism) (Beckman and Soller, 1983) and RAPD (randomly amplified polymorphic DNA) (Williams *et al.*, 1990). The most recent techniques are AFLP (amplified fragment length polymorphism) (Becker *et al.*, 1995), use of microsatellites (Simple sequence repeates, SSR) (Becker and Heun, 1994). These techniques provide important information on the genetic variations (Wei *et al.*, 1997), linkage analysis (Becker *et al.*, 1995), map based cloning (Thomas *et al.*, 1995) and other applications.

Molecular techniques are proving to be increasingly important tools for the study, management and conservation of the genetic diversity of Ethiopian germplasm. However, in the literature search for DNA based studies on African germplasm in the years 1973-1995 (Dulloo *et al.*, 1997), there were no published papers on DNA based diversity study of Ethiopian durum wheat germplasm accessions.

3. OBJECTIVES

The general objective of the study is to generate basic morphological and genetic data on durum wheat landraces of North Shewa and to document the associated farmers' knowledge.

Specific objectives

1. To estimate the magnitude of morphological diversity and to investigate their distribution pattern on awraja, wereda, population and altitudinal basis, which could help in locating sites for *in-situ* conservation of durum wheat landraces of North Shewa.

2. To document the indigenous knowledge of the farming community of the study area which could help in proper understanding, conservation and utilisation of durum wheat landraces.

3. To assess inter-population variations of the durum wheat landraces using molecular genetic markers.

4. MATERIALS AND METHODS

4.1. Morphological study

4.1.1. Study area

The area considered in this study is the North Shewa region, which lies on the central highland region of the country. It is one of the centers for highest diversity of durum wheat in the country (Belay, 1997). Classification of the micro-centers for the study is following the former regional zonation based on awrajas and weredas. Five major awrajas and ten weredas were considered in the study (Fig. 3).

4.1.2. Germplasm acquisition

The durum wheat germplasm materials for this study have been taken from the Institute of Biodiversity Conservation and Research. According to the Institute, original samples were collected using random method of Hawkes (1976). The accessions are representing parts of North Shewa region having altitudinal range between 1675-2930 m.a.s.l. Fifteen accessions (populations) represented by 22-35 genotypes each (a total of 441 genotypes) were taken randomly for the analysis.

4.1.3. Glass house experiments

A pot experiment has been conducted at the glass house of the National Soil Laboratory (NSL). Heavy black clay soil (Vertisol) samples for growing the plants was collected from Akaki agricultural research station. The soil was homogenized by grinding into 2mm. mesh size. A total of 441 pots were prepared for seed planting with 2.5 Kg soil sample in each pot. Four seeds (each from the same accession) were planted in each pot. The plants were allowed to grow to full maturity. The spike of each plant was bagged to avoid out-crossing. One randomly selected genotype from each pot was taken for analysis. Two of the populations (sixty genotypes) were discarded from the analysis because they were found to be bread wheat species. The analysis was conducted with the remaining thirteen populations (381 genotypes).

Each genotype was recorded for six heritable morphological traits (Glume color, seed color, beak length, glume pubescence, spike density and awn color). The phenotypic class for each character and recording of the data is following wheat descriptor format of the former International Board for Plant Genetic Resources (IBPGR, 1985).

4.1.4. Data analysis

In this study highly heritable characters and hierarchical approach to quantitatively define the variations in each microcenter has been followed as recommended by Bekele (1985). A relation of the variation with climatic variable, such as altitude, is also attempted which has paramount implications for future collections and in understanding adaptive response of a germplasm (Anniccihiarico *et al*., 1995).

Altitude, awraja, wereda and population were used as classifying variables for data analysis. The altitudinal range was grouped, arbitrarily, into six classes viz. < 2000, 2001-2200, 2201-2400, 2401-2600, 2601-2800, >2800. Six altitudinal classes, five awrajas, ten weredas and thirteen populations were taken for data analysis. The percentage frequencies of the phenotypic classes of each character in each population, wereda, awraja, altitudinal class and the entire collections were calculated.

Shannon diversity statistics as described by Jain *et al.* (1975) were used to calculate the phenotypic diversity of each trait, population, wereda, awraja, altitudinal class and region. Diversity index (H) was calculated as follows:

$$H = -\sum_{i=0}^{n} Pi \ln Pi$$

Where Pi is the proportion of the total number of entries in the i th class.

n is the number of the phenotypic classes of a given character.

ln Pi is the natural logarithm of Pi

The diversity index (H) was standardized by converting into the relative index (H') (which lies between 0 and 1).

$H' = H / H_{max}$, where $H_{max} = \ln n$

The Shannon diversity statistics was calculated using a calculator.

A one way analysis of variance (ANOVA) of non-transformed H' was carried out for each trait using awraja and altitudinal classes as classifying variables. Hierarchical ANOVA pooled across characters was performed to estimate the contribution of the different variance components to the level of diversity.

Hierarchical discriminate analysis to know the similarity distance of each population using the percentage frequencies of the phenotypic classes of the six characters has been carried out. This analysis is based on the similarity in distribution pattern of each phenotypic class of the six characters used in the study. Statistical computations were carried out using SPSS for win (1993) and MSTATC (1983).

4.2. Ethnobotanical study

While the gene bank samples were being grown in the glass house at the National Soil Laboratory, parallel ethnobotanical study was conducted in the area from which they were originally collected to get a profile of farmers' knowledge.

The study area for the ethnobotanical study covers most of the areas from which the samples for morphological studies were originally collected. The Ankober district was also included in the ethnobotanical study in order to embrace the on-farm conservation site of the Biodiversity Conservation and Research Institute (Fig. 3).

The data collection procedure is following a format developed for this purpose (adopted from Martin, 1995) (Appendix II). 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 obtain maximum information. The method of extracting the information was individual and group discussions. The data analysis is based on rank order and use value of thirty (30) informants (Martin, 1995).

4.3. Molecular study

The molecular technique used in this study was the Randomly Amplified Polymorphic DNA (RAPD) technique (Welsh and McClelland, 1990; Williams *et al.,* 1990). Inter-population variation was estimated on thirteen populations by taking randomly one genotype from each population.

4.3.1. DNA extraction

Genomic DNA from young leaves of a two-week-old seedling was extracted following the phenol extraction protocol of Smith (1992): The extracted DNA was electrophoresed on 1% agarose gel to confirm the quality and the DNA concentration of each sample was determined using a GENE QUANT. Each genomic DNA was diluted in sterile distilled water to about 25 µg/µl.

4.3.2. RAPD assay

4.3.2.1. Primer used

A low molecular weight-glutenin primer (LMW-glutenin) sequence with 20 base pairs (ICARDA, 1994) was ordered from the International Livestock Research Institute (ILRI), Kenya.

The LMW-glutenin primer sequence was:

5'-ATG AAG ACC TTC CTC GTC TT-3'
5'-AAC GCC GAA TGG CAC ACT A-3'

This primer was selected because the storage protein, glutenin, has important effects on the physical properties of wheat dough and moreover it is associated with technological properties of wheat for pasta quality.

4.3.2.2. PCR and agarose gel electrophoresis

Ready-To-Go PCR beads purchased from PHARMACIA BIOTECH (USA) were used for the PCR amplification. Each bead contains all the necessary reagents, except primer and DNA template, for performing a 25µl PCR amplification reaction (each bead contains; 1.5 units of taq DNA polymerase, 10 mM Tris-HCl (PH=9.0), 50 mM KCl, 1.5mM Mg-Chloride and 200 µM of each dNTP and stablizers, including BSA). Amplifications of DNA were conducted under standardized conditions in a 25µl reaction volume of sterile water containing one PCR bead, 40 ηg template DNA and 100 ηg primer. Equal volume of mineral oil was over laid on each reaction mixture. The PCR amplification reactions were conducted in HYBAID OMNIGENE Thermocycler programmed for 40 cycles of 1 min. at 96°c, 1 min. at 37°c and 2 min. at 72°c. The PCR products were separated by agarose gel electrophoresis in 1X TBE buffer on 1% agarose containing 0.5µg/ml ethidium bromide. DNA bands were visualized under UV light and photographed using Polaroid camera.

4.3.4. data analysis

Lamda Hind III molecular weight marker was used to approximately measure the size of the fragments. The variations among populations were estimated using average linkage (between groups) (SPSS for win, 1993).

5. RESULTS

5.1. Morphological study

5.1.1. Phenotypic frequencies

5.1.1.1. Phenotypic frequency of characters across populations and awrajas

1. *Glume color*

The distribution of glume color types in populations shows that purple-black glume color is totally absent in eight populations and very rare in four populations. Eleven populations showed highest percentage frequencies for white-yellow type. Except in one awraja (Yererna Kereyu) which showed the highest percentage frequency for brown-red glume color (74%), in all the other awrajas the predominant type is the white-yellow type. Except in Menze and Gishe, the purple-black type is rare in all awrajas. In the study area as a whole, the proportion of white-yellow, brown-red and purple-black glume types was found to be 74%, 23% and 3% respectively (Fig. 4).

2. *Awn color*

Twelve populations showed highest percentage frequency for the white-yellow type and one population showed highest percentage frequency for purple-black type. Two populations were monomorphic for white-yellow type. Brown-red type was absent in six populations and purple-black was absent in four populations. All the five awrajas showed highest percentage frequency for white-yellow type. Brown-red was absent in Menze and Gishe and Selale and was rare in the other three awrajas. In the study area as a whole, the proportion of white-yellow, brown-red and purple-black glume types was found to be 82%, 15% and 3% respectively (Fig. 4).

3.Beak length

Five populations have highest percentage frequencies for short beak length. Seven populations showed highest percentage frequencies for long beak length. Only one population has the highest percentage frequency for intermediate beak length. Two awrajas (Menze and Gishe and Merhabete) have highest percentage frequencies for long beak length (76% and 42% respectively). The short beak length is totally absent from Menze and Gishe. Three awrajas showed highest percentage frequency for the short beak length. In the study area as a whole, the proportion of short, intermediate and long beak types was found to be 40%, 39% and 21% respectively (Fig. 5).

4. Glume pubescence

Nine populations showed highest percentage frequency for glabrous (non-hairy) glume type. Two populations showed highest percentage frequency for the pubescent (hairy) glume type. One population showed highest percentage frequency for the intermediate-hairy glume type. The hairy type is absent in seven populations. The non-hairy type is absent in one population. The non-hairy (glabrous) type is the predominant type in all of the five awrajas. Three awrajas (Menze and Gishe, Merhabete and Yererna Kereyu) and two awrajas (Selale and Teguletna Bulga) showed lowest percentage frequencies for the hairy and intermediate-hairy types respectively. In the study area as a whole, the proportion of non-hairy, intermediate-hairy and hairy glume types was found to be 71%, 15% and 14% respectively (Fig. 5).

5. Seed color

Purple-black seed color is absent in nine populations. Five populations showed highest percentage frequency (ranging between 79-100%) for brown-red type. Five populations have highest percentage frequency (ranging between 62-100%) for white-yellow type. Three populations showed highest percentage frequency for purple-black type.

In Yererna Kereyu, purple-black type is the most predominant with 98% percentage frequency while in Selale and Merhabete this type had percentage frequency of 38% and 55% respectively. Menze and Gishe showed the highest percentage frequency for brown-red (79%). Teguletna Bulga has the highest percentage frequency for white-yellow (54%). In the study area as a whole, the proportion of brown-red, white-yellow and purple-black glume types was found to be 44%, 34% and 22% respectively (Fig. 6).

6. Spike density

Eight populations showed highest percentage frequency (ranging between 77-90%) for dense type. Five populations showed highest percentage frequency for very-dense spike type (ranging between 52-88%). All awrajas, except Selale, showed highest percentage frequency for the dense type. The proportion of dense and very-dense types in the study area was 64% and 36% respectively (Fig. 6).

5.1.1.2. Phenotypic frequency of characters across altitudinal classes

1. Glume color

The purple-black type is totally absent in altitudinal class 5 and very rare in other classes. The white-yellow is the predominant type in altitudinal class 2 and in the three highest altitudinal classes. Altitudinal classes 1 and 3 showed highest percentage frequencies for brown-red type (Fig. 7).

2. Awn color

White-yellow is the predominant type in all altitudinal classes except in the lowest altitudinal class, which showed the highest percentage frequency for purple-black type. The brown-red type has the lowest (very rare) percentage frequencies in all the six altitudinal classses (Fig. 9).

3. Beak length

The long beak length showed highest percentage frequencies in all altitudinal classes except in altitudinal class 4, which showed highest percentage frequency for short beak length. The intermediate beak length type has the lowest percentage frequencies in four of the altitudinal classes, except in altitudinal classes 1 and 4 (Fig. 7).

4. Glume pubescence

The non-hairy (glabrous) glume type showed the highest percentage frequency in all altitudinal classes. The hairy (pubescent) glume type is absent in altitudinal classes 1,2 and 6. The intermediate-hairy glume type is rare in altitudinal classes 2, 4 and 6 (Fig. 8).

5. Seed color

The lowest altitudinal class is monomorphic for brown-red type. Purple-black type is absent in altitudinal classes 2 and 3 and showed highest percentage frequency in altitudinal classes 4 and 5. The brown-red type is rare in altitudinal class 4 and highest percentage frequency in altitudinal classes 3 and 6. Only altitudinal class 2 has the highest percentage frequency for white-yellow type (Fig. 8).

6. Spike density

The dense spike type has the highest percentage frequency in all altitudinal classes except altitudinal class 2, which has the highest percentage frequency for the very-dense spike type. Altitudinal classes 3 and 4 showed proportional pattern of distribution for the two types of spike densities (Fig. 9).

5.1.2. Estimates of diversity indices (H')

Diversity index (H') estimates for each character, population, wereda, awraja and region is given in Table 1. Intra-population polymorphism was common in most traits. For the sake of simplicity, the diversity indices were divided into four classes as: monomorphic ($H' \leq 0.10$), low ($0.10 \leq H' \leq 0.40$), intermediate ($0.40 \leq H' \leq 0.60$) and high ($H' \geq 0.60$) following the work by Belay (1997). All awrajas, except Menze and Gishe, showed high diversity index. Menze and Gishe ($H' = 0.50$), Merhabete ($H' = 0.63$), Yererna Kereyu ($H' = 0.64$), Tegeletna Bulga ($H' = 0.72$) and Selale ($H' = 0.73$).

On population level, both the highest ($H' = 0.65$) and the lowest ($H' = 0.25$) mean diversity indices (H') pooled over characters were obtained from Teguletna Bulga. The highest H' (0.65) was found in Kimbibit wereda. Six populations showed low mean diversity indices ($H' \leq 0.40$), four populations showed intermediate mean diversity indices

(0.40 ≤ H' ≤ 0.60) and three populations showed high mean diversity indices (H' ≥0.60). Glume color, spike density, seed color, spike density and beak length were the most polymorphic characters in Menze and Gishe, Merhabete, Selale, Teguletna Bulga and Yererna Kereyu respectively. The relative contribution of each of the six characters for H' varied. Seed color (0.97), beak length (0.96), spike density (0.94), glume pubescence (0.74), glume color (0.60) and awn color (0.50).

On the basis of altitudinal classes, the relative contribution of each trait for mean diversity index (H') varied. Beak length showed the highest H' in the first two lowest altitudinal classes and in the highest altitudinal class as well (Fig. 10). Glume pubescence and spike density showed highest H' in the fourth altitudinal class (Fig. 11). Seed color showed the highest H' in the fifth altitudinal class (Fig. 11). Most characters in all the altitudinal classses showed intermediate to high H'. Glume color (in altitudinal class 5), awn color (in altitudinal classes 4 and 5), glume pubescence (in altitudinal classes 2 and 6) and seed color (in altitudinal class 1) showed below low level of mean diversity index. The highest mean diversity index (H' = 0.78) was observed in altitudinal class 3 and the lowest (H' =0.58) was observed in altitudinal class 2 (Fig. 11).

The ANOVA of H' for individual traits is given in Table 3. For the four characters (except glume pubescence and seed color) most of the variance was due to the 'within awraja' and for 'within altitudinal group' components (except glume pubescence and glume color) all the others showed the variance within the group. Hierarchical analysis of variance pooled over characters showed significant differences (p =0.05) "between populations within awraja" and "between altitudinal groups" (Table 4).

Hierarchical discriminate analysis to know the similarity distance for each population using the percentage frequencies of each phenotypic classes of the six characters is revealed in the dendrogram of Fig. 12.

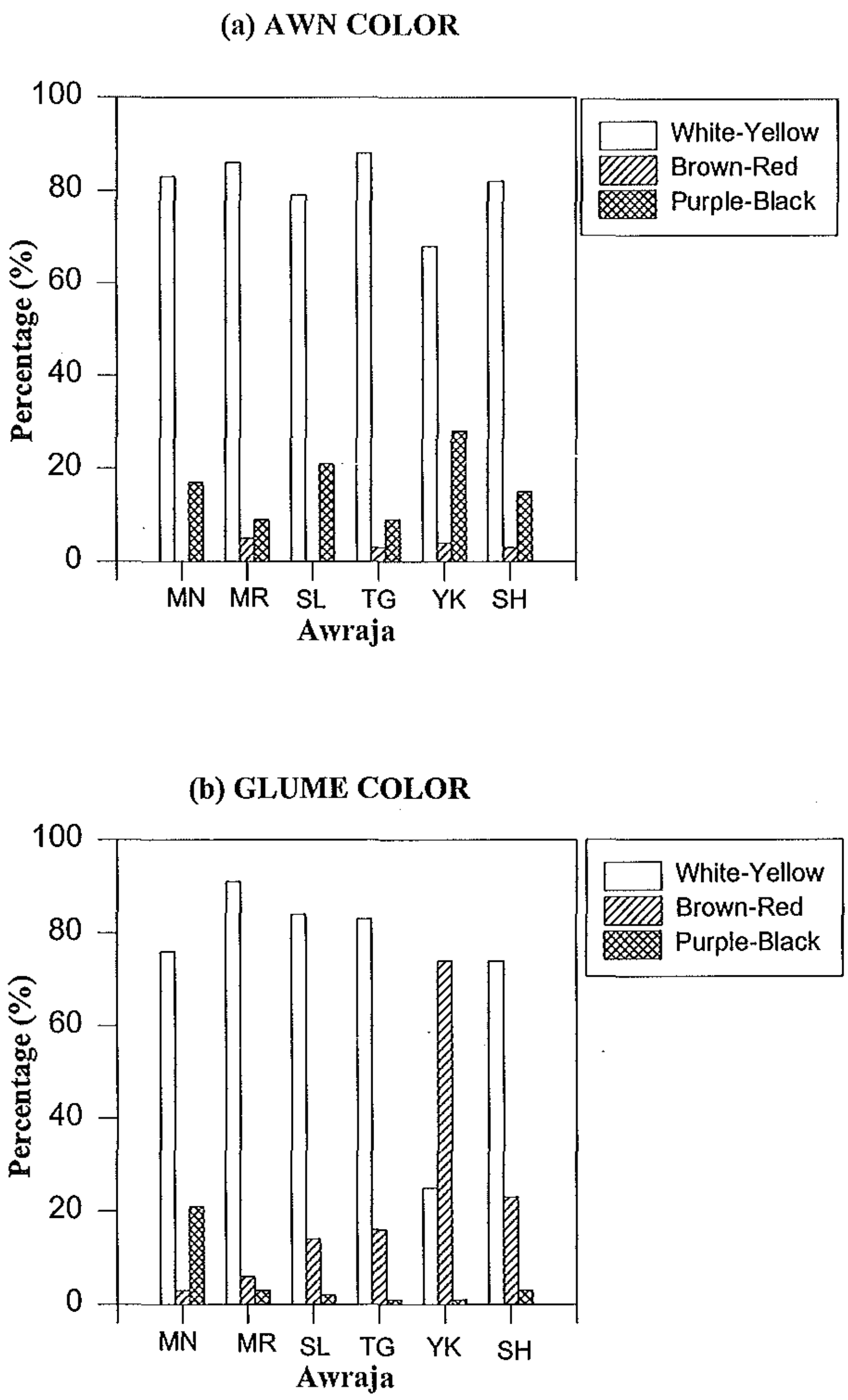


Fig. 4. Percentage frequency of each phenotypic class of (a) awn color and (b) glume color by Awraja (Key to each Awraja : MN-Menze and Gishe, MR-Merhabete, SL-Selale TG-Teguletna Bulga, YK-Yererna Kereyu and SH-North Shewa)

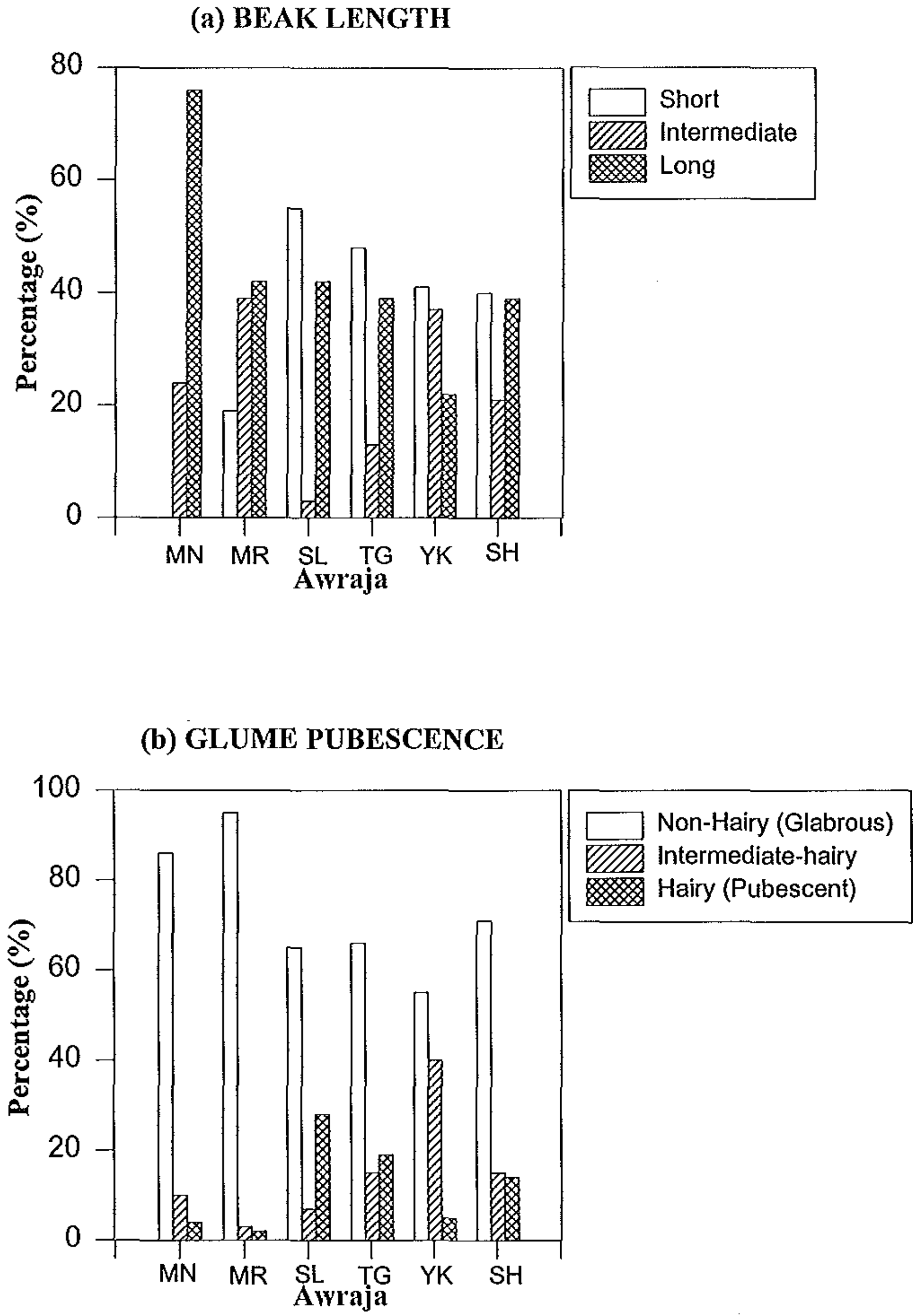


Fig. 5. Percentage frequency of each phenotypic class of (a)beak length and (b)glume pubescence by Awraja (Key to each Awraja : MN-Menze and Gishe, MR-Merhabete, SL-Selale TG-Teguletna Bulga, YK-Yererna Kereyu and SH-North Shewa)

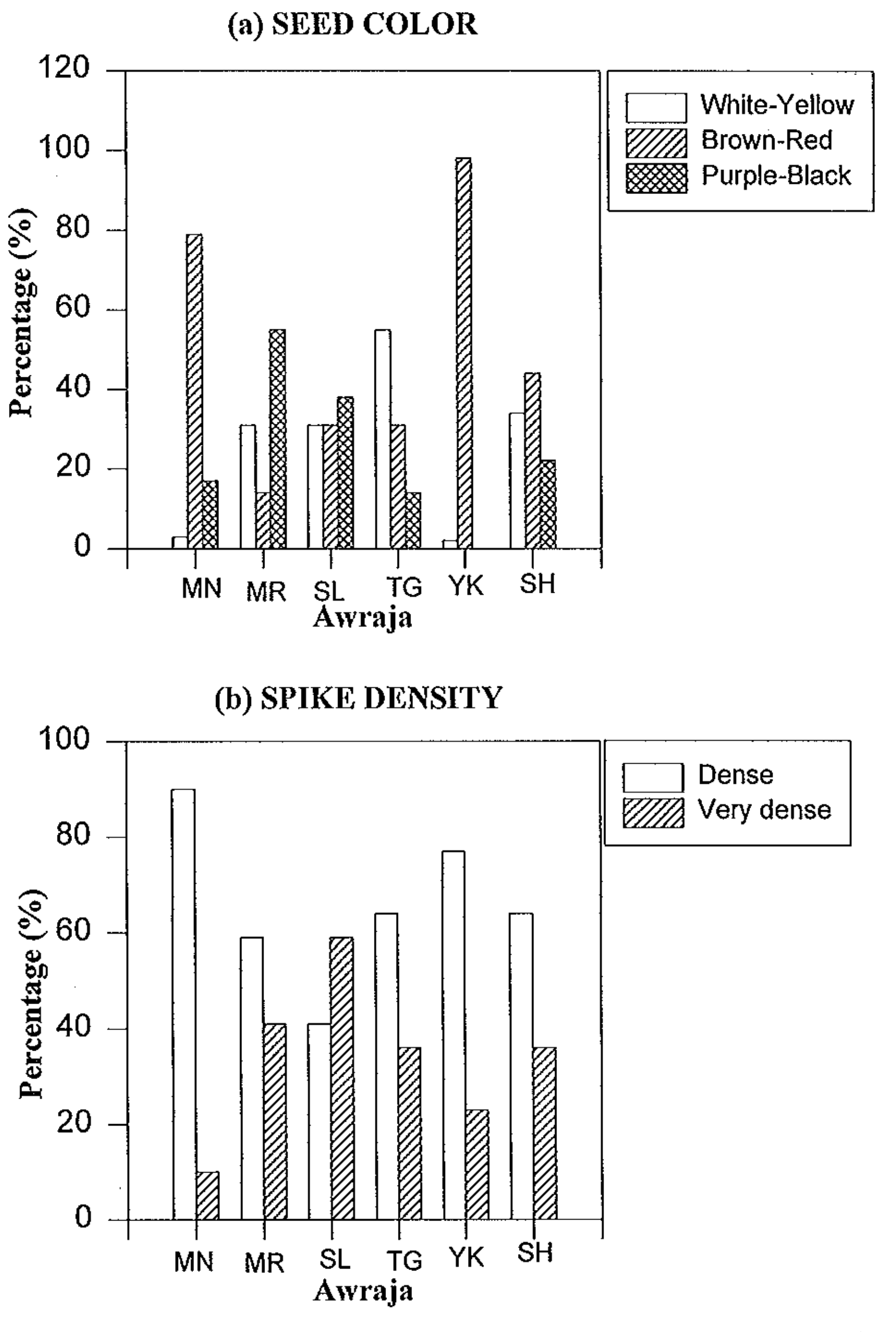
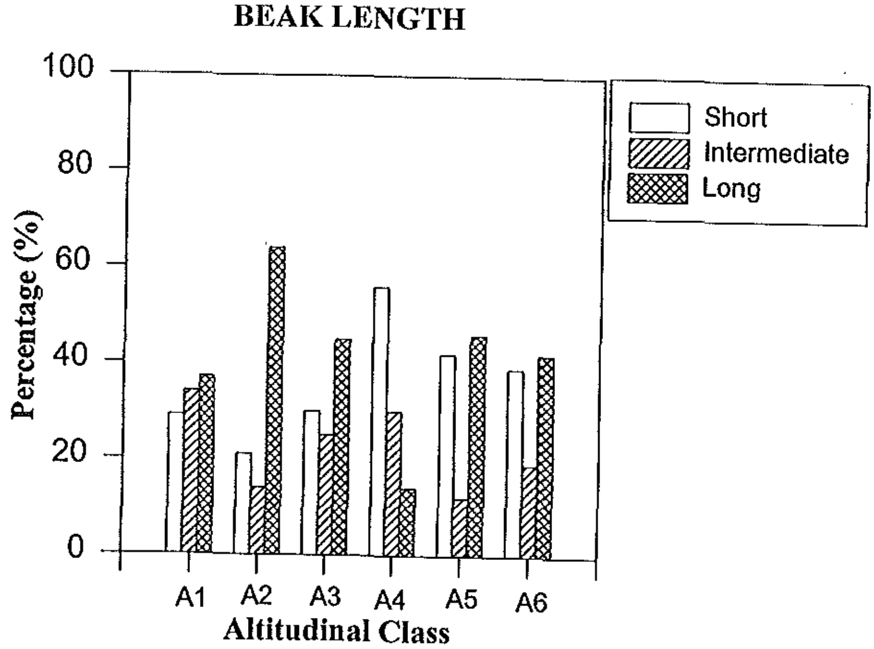


Fig. 6. Percentage frequency of each phenotypic class of (a) seed color and (b) spike density by Awraja (Key to each Awraja : MN-Menze and Gishe, MR-Merhabete, SL-Selale TG-Teguletna Bulga, YK-Yererna Kereyu and SH-North Shewa)



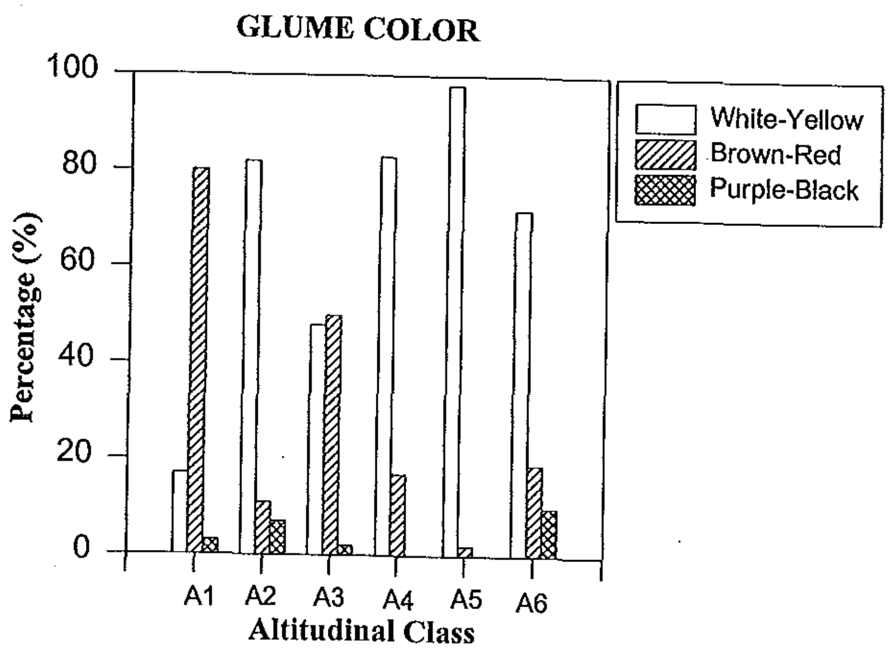
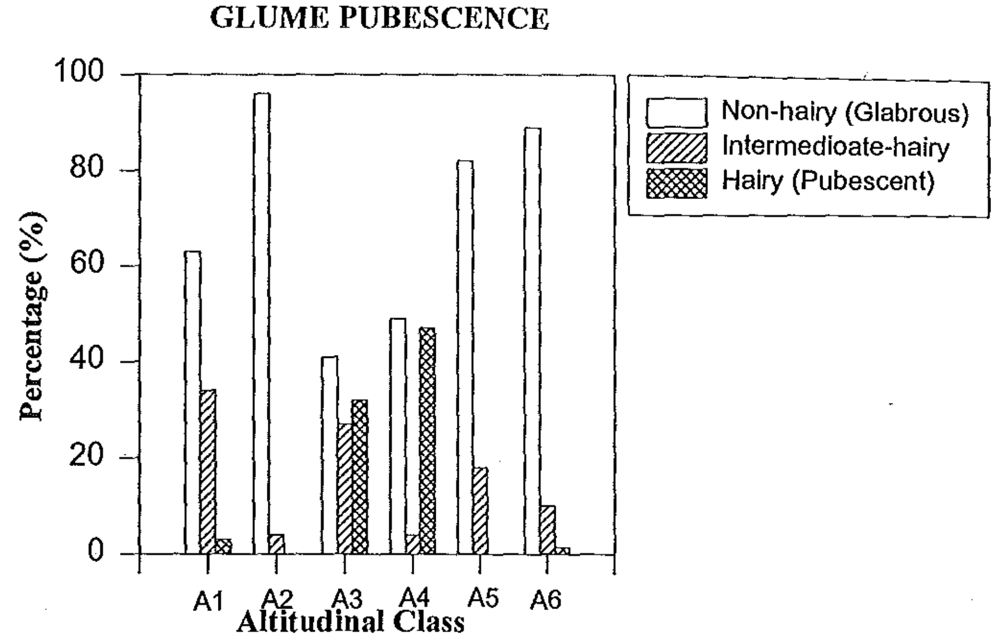


Fig. 7. Percentage frequency of each phenotypic class of beak length and glume color by altitudinal class (Key to each altitudinal class: A1= <2000 A2= 2001-2200, A3 = 2201-2400, A4 = 2401-2600, A5=2601-2800 and A6= >2800 m.a.s.l.)



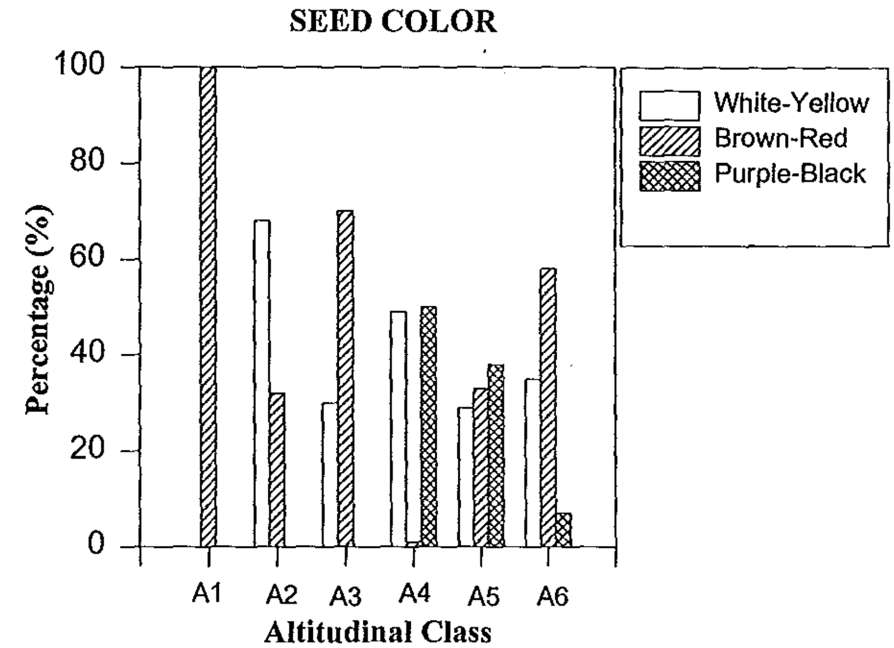
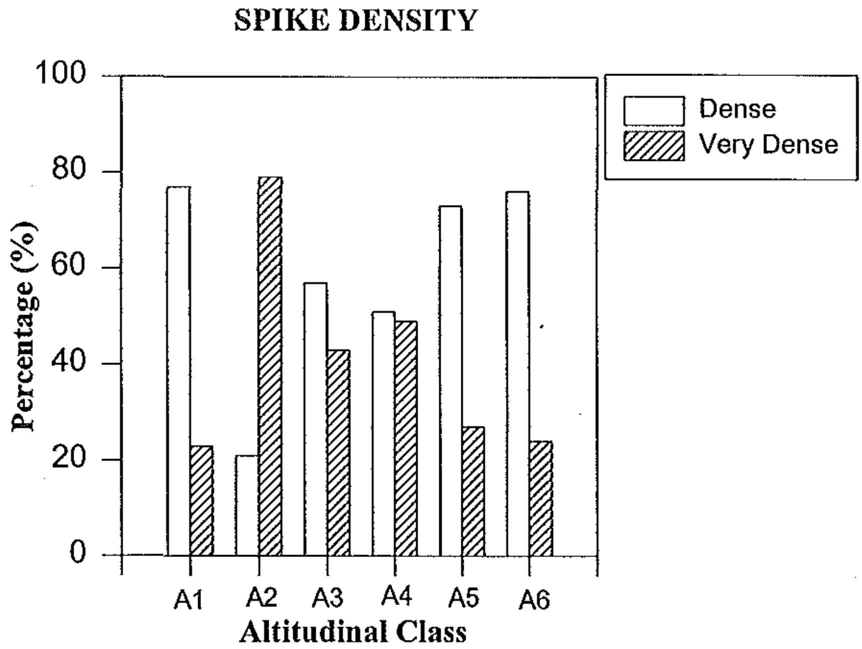


Fig. 8. Percentage frequency of each phenotypic class of glume pubescence and seed color by altitudinal class. (Key to each altitudinal class: A1= <2000 A2= 2001-2200, A3 = 2201-2400, A4 = 2401-2600, A5=2601-2800 and A6= >2800 m.a.s.l.)



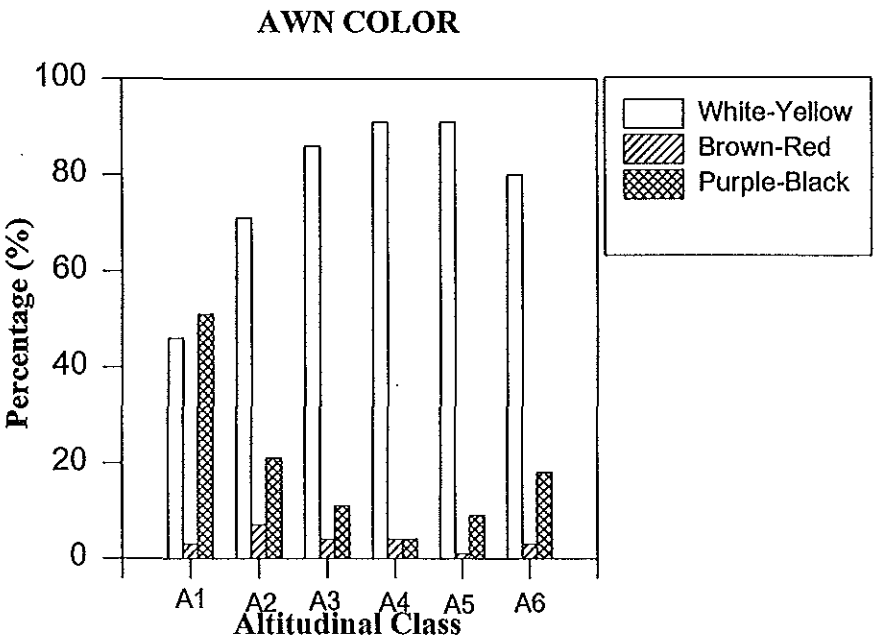
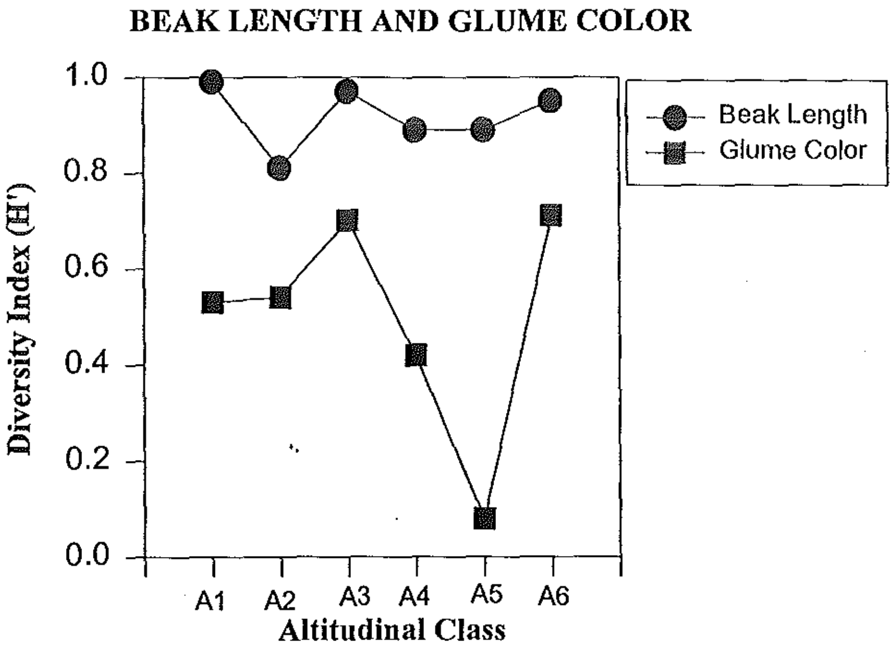


Fig. 9. Percentage frequency of each phenotypic class of spike density and awn color by altitudinal class. (Key to each altitudinal class: A1= <2000 A2= 2001-2200, A3 = 2201-2400, A4 = 2401-2600, A5=2601-2800 and A6= >2800 m.a.s.l.)



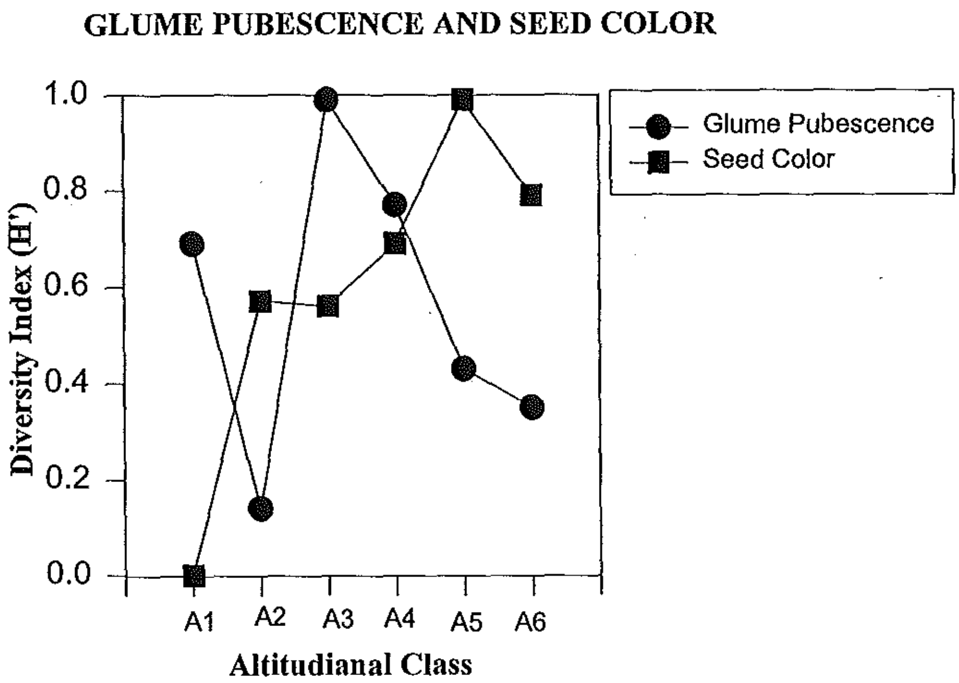
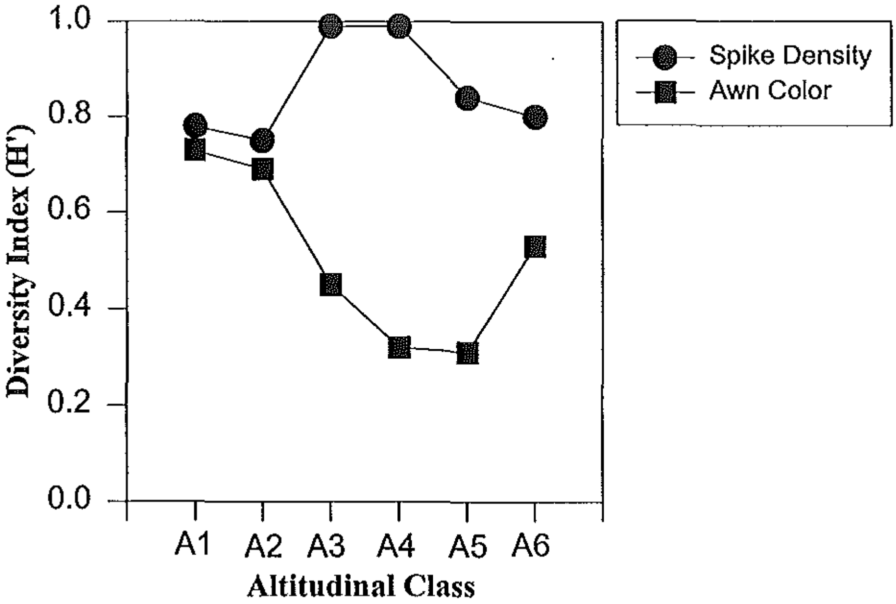


Fig. 10. Mean diversity Index (H') for beak length, glume color, glume pubescence and seed color in the six altituidinal classes.
(Key to each altitudinal class: A1 = < 2000, A2 = 2001-2200, A3 = 2201-2400, A4 = 2401-2600, A5 = 2601-2800 and A6 = >2800 m.a.s.l)

SPIKE DENSITY AND AWN COLOR



MEAN DIVERSITY INDEX

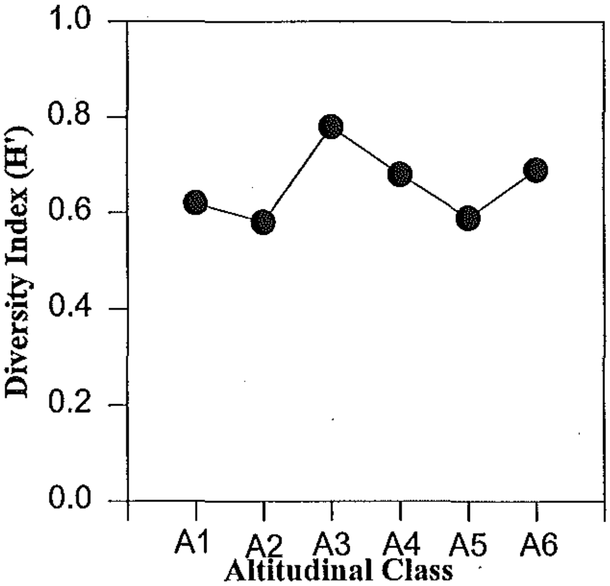


Fig. 11. Mean Diversity Index (H') for spike density and awn color and the overall mean across the six traits in the six altitudinal classes. (Key to each altitudinal class: A1 = < 2000, A2 = 2001-2200, A3 = 2201-2400, A4 = 2401-2600, A5 = 2601-2800 and A6 = >2800 m.a.s.l)

Table 1 :Diversity Index (H') estimates for each character in each of the populations, weredas, awrajas and the entire collection.

Awraja	*Wereda*	*population code*	*seed Color*	*beak length*	*glume pubesc.*	*glume Color*	*spike density*	*Awn color*	*MEAN*
MG	Gara midr	1	0.55	0.50	0.43	0.59	0.48	0.42	0.50±0.03
	MEAN		**0.55**	**0.50**	**0.43**	**0.59**	**0.48**	**0.42**	**0.50±0.03**
MR	Tach bet	2	0.12	0.87	0.23	0.12	0.50	0.12	0.33±0.12
	Tach bet	3	0.57	0.81	0.14	0.54	0.75	0.69	0.58±0.10
	MEAN		**0.88**	**0.95**	**0.20**	**0.34**	**0.97**	**0.45**	**0.63±0.14**
SL	Grar jarso	4	0.71	0.00	0.28	0.00	0.99	0.44	0.40±0.16
	Ensaro	5	0.61	0.25	0.72	0.70	0.93	0.49	0.62±0.09
	MEAN		**0.99**	**0.74**	**0.74**	**0.44**	**0.98**	**0.46**	**0.73±0.10**
	Basona werana	6	0.28	0.17	0.17	0.28	0.57	0.00	0.25±0.08
	Moretna jiru	7	0.32	0.97	0.12	0.00	0.86	0.38	0.44 ±0.16
TG	Kimbibit	8	0.00	0.99	0.35	0.77	0.99	0.82	0.65±0.16
	Angolela	9	0.15	0.25	0.62	0.15	0.62	0.15	0.32±0.10
	Angolela	10	0.25	0.71	0.25	0.15	0.24	0.00	0.27±0.10
	Angolela	11	0.12	0.12	0.20	0.57	0.52	0.47	0.33±0.09
	mean		**0.99**	**0.82**	**0.97**	**0.39**	**0.98**	**0.27**	**0.74±0.13**
	MEAN		**0.88**	**0.89**	**0.79**	**0.43**	**0.95**	**0.40**	**0.72±0.11**
YK	Ada	12	0.00	0.99	0.69	0.53	0.78	0.73	0.62±0.14
	Lume	13	0.13	0.73	0.81	0.58	0.78	0.22	0.54±0.12
	MEAN		**0.07**	**0.97**	**0.76**	**0.58**	**0.78**	**0.69**	**0.64±0.13**
N. SHEWA	**TOTAL**		**0.97**	**0.96**	**0.74**	**0.60**	**0.94**	**0.50**	**0.79±0.08**

Key: MN-Menze and Gishe MR-Merhabete SL-Selale TG-Teguletna Bulga YK-Yererna Kereyu

Table 2. Percentage frequencies of each phenotypic class in the six traits studied for each population.

					Seed Color %			Glume Color %			Awn Color %			Glume Pubescence %			Beak Length %			Spike Density %	
Awraja	Wereda	Popn. code	N	Altitude (m)	W-Y	B-R	P-B	W-Y	B-R	P-B	W-Y	B-R	P-B	N-H	I-H	H	S	I	L	D	V-D
Menze and Gishe	Gara Midir	1	29	2930	4	79	17	76	3	21	83	0	17	86	10	4	0	24	76	90	10
Merhabete	Tach Bet	2	36	2520	3	0	97	97	3	0	97	3	0	94	3	3	17	58	25	89	11
	Tach Bet	3	28	2140	68	32	0	82	11	7	71	7	22	96	4	0	22	14	64	21	79
Selale	Grar Jarso	4	32	2695	6	25	69	100	0	0	81	0	19	91	9	0	100	0	0	47	53
	Ensaro	5	26	2220	62	38	0	65	31	4	77	0	23	35	4	61	0	8	92	35	65
Teguletna Bulga	Basona Werana	6	22	2810	9	91	0	91	9	0	100	0	0	95	5	0	95	5	0	86	14
	Moretna Jiru	7	35	2650	89	11	0	100	0	0	89	3	8	97	3	0	43	23	34	71	29
	Kimbibit	8	23	2850	100	0	0	48	48	4	56	9	35	87	13	0	35	26	39	48	52
	Angolela	9	26	2750	4	96	0	96	4	0	96	0	4	42	58	0	0	8	92	85	15
	Angolela	10	25	2780	0	8	92	96	4	0	100	0	0	92	8	0	12	16	72	96	4
	Angolela	11	34	2600	97	3	0	68	32	0	85	6	9	0	6	94	97	0	3	12	88
Yererna Kereyu	Ada	12	35	1675	0	100	0	17	80	3	46	3	51	63	34	3	29	34	37	77	23
	Lume	13	30	2250	3	97	0	33	67	0	93	7	0	47	47	6	57	40	3	77	23

key: Popn.=Population, W-Y=White to Yellow, B-R=Brown to Red, P-B=Purple to Black, N-H=Non-hairy, I-H=Intermidiate Hairy, H=Hiary, S=Short, I=Intermediate, L=Long, D=Dense, V-D=Very Dense
N=number of genotypes

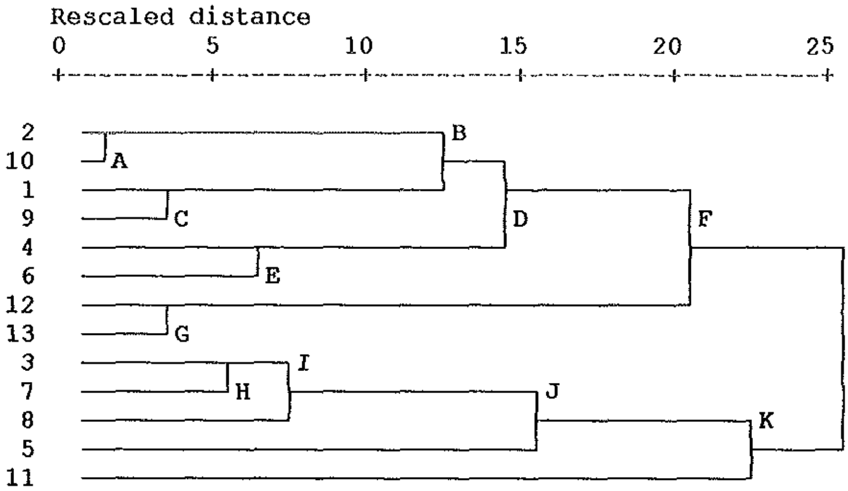


Fig 12. Dendrogram using Average linkage between populations to show the relationship among the thirteen populations

From the above dendrogram the following relationships are observed.

- Populations 2 and 10 are the most similar (node A)and grouped with populations 1 and 9 (node C)and clustered into group under node B.

- Populations 4 and 6 (node E)are grouped with groups of node B to form cluster of node D.

- Populations 12 and 13 (node G) are grouped with groups of node D to form cluster of node F.

- Populations 3 and 7 (node H) are grouped with population 8 to form cluster of node I.

- Population 5 is clustered with groups of node I to form node J.

- Population 11 is clustered with groups of node K to form node L.

There are two major clusters formed:

cluster 1- consisting of eight populations

(populations 1,2,4,6,9,10,12 and 13)

cluster 2- consisting of five populations

(populations 3,5,7,8 and 11)

Table 3. Mean squares for variation between awrajas and altitudinal groups (and percentage of total variance) from the analysis of variance of H' for individual characters

	Between		Between popns. within	
Character	Awrajas (df=4)	Altitude (df=5)	Awrajas (df=8)	Altitude (df=7)
Glume color	0.0334 (14.9)	0.1282 (71.6)*	0.0952 (85.1)	0.0363 (28.4)
Glume pubes.	0.1087 (61.4)*	0.1064 (75.1)*	0.0342 (38.6)	0.0252 (24.9)
Seed color	0.1282 (73.4)*	0.0503 (36)	0.0232 (26.6)	0.0638 (64)
Beak length	0.1805 (45.1)	0.0579 (18.1)	0.1101 (54.9)	0.1876 (81.9)
Spike density	0.0584 (37.9)	0.0266 (21.5)	0.0479 (62.1)	0.0693 (78.5)
Awn color	0.0177 (8.1)	0.0605 (34.4)	0.1002 (91.1)	0.0823 (65.6)

* Significantly different at P=0.05

Table 4. Hierarchical analysis of variance of diversity (**H'**) for the overall characters

Source of variations	df	mean square
Between		
Awrajas	4	0.0190
Populations within awraja	8	0.0213*
Altitude groups	5	0.0287 *
Populations within altitude group	7	0.0146

* Significantly different at p= 0.05

5.2. Ethnobotanical study

A total of twenty-five different vernacular names were recorded. The number and names of each farmers' variety and the wereda from which it is recorded is presented in Table 5.

Table 5. Number and names of the farmers' varieties (landraces) recorded from each wereda

Name of wereda	Farmers' varieties (landraces)	No. of landraces
1. ANKOBER	Nech amare, Tikur amare, Tikur sindie, Aybo, Azaze, Marye, Gosh gimbar, Menze, Set akuri.	9
2. MORETNA JIRU	Tehere, Enat sindie, Tikur sindie (Gojam gura), Sesso, Menzae, Amune egir, Atosal, Shemet, Kabi (Selale), Kibra meskel, Yewsha kirancha.	11
3. ENSARONA WAYU	Tikur sindie (Gojam gura), Tikur shemet, Menzae, Enat sindie, Nech shemet, Amune egir, Tehere.	7
4. BASONA WERANA	Menzae, Konteb, Aybo, Azaze (Sesse), Shemet, Tikur sindie, Tehere, Gojam gura.	8
5. KIMBIBIT	Azaze, Aybo, Nech gojame (Shemet), Sellalo, Geja, Amare, Atosal, Tikur gojame, Taysoral, Mokake, Demelo.	11
6. GRAR JARSO	Tikur sindie, Kuluyu, Kemedi Qoticha, Awaniso, Butugi, Sorge (Shemame).	6

From Table 5, it is evident that there are landraces only found in one or few weredas and others found in most weredas. The general characteristics and description of those landraces for which sufficient information has been gathered is presented as follows.

From the analysis it was found that spike length, spike density, spike row number, glume color and awn color are the most frequent characters used by the farmer to distinguish the varieties in the field. Seed color, seed morphology and seed vitreousness are distinguishing characters used in the market and households.

A brief overview of each landrace type is given below.

1.MENZAE

The name itself hints that the landrace has its origin at a region in North Shewa called "Menze". It is one of the neglected landraces which has been given little attention by the farmer. It is typically distinguished by its red glume, red and thick awn and short spike length. It favours soil with good drainage capacity and needs good moisture (rain). The whitish seed and conspicuous (big) seed morphology are the characters used to distinguish the landrace in the market and at home.

2. KONTEB

The farmer carefully conserves this landrace. Like Menzae it needs soil with good drainage capacity and needs good rain (a long rainy season landrace). It is distinguished by white and conspicuous seed, wide spike, thick straw and dense spike.

3. AYBO

The meaning of the landrace has been derived from the Amharic term "Aybe" (meaning-cottage cheese) because the white color of the seed is associated with the white color of cheese. It resembles Konteb in its seed color and seed morphology. It is distinguished by its thin and long awn and its long spike.

4. AZAZE/ SESSE/SESSO

The meaning of the landrace is from the term "Azaze" (meaning late maturing). It is as white as Menzae but distinguished by its conspicous awn and long spike.

5. SHEMET

The meaning of the landrace has come from the term "Shemet" (meaning- thin). It is distinguished by the thin spike, light black glume and erect awn.

6. TIKUR SINDE

From the name it is obvious that it is a black seeded landrace. A very distinguishing character of this landrace in the field is the awn detaches and falls at maturation.

7. TEHERE

It is distinguished by light yellow glume. Both black and white seeds are found together in a single spike.

8. GOJAM GURA

The meaning of the landrace has come from the place of origin from which the landrace is believed has to come. It has come from the region in north western Ethiopia called "Gojam". It is distinguished by thick spike, light black seeds, black glume and long spike.

9. AMARE

The meaning of the landrace comes from the Amharic term "amare" (meaning beautiful and attractive). Two botanical forms do exist. The first is having red glume (called "Tikur amare") and the second is "Nech amare"which has white glume. Both have white, thin and elongated seed and dense spike. The landrace is found in localized places and it is now in the process of being found less and less commonly and may eventually lead towards extinction from the area if immediate conservation action is not put in place.

10. SET AKURI

The meaning of the landrace comes from the Amharic term "set akuri" (meaning women are getting proud of it because the bread baked from it is highly pleasant and tasty). It is distinguished by white glume and very white seed. It is found in localized areas of Ankober.

11. MARYE

The meaning comes from the Amharic term "mare" (meaning honey because its color looks the commonly brown honey). It is distinguished by brownish white glume, eliptical and long seed shape and brownish white seed color. It has different row numbers (six, four or two rows). It has good merits especially in households such as good taste, palatability, short cooking time and high market value.

12. GOSH GIMBAR

This was a disappeared landrace from the area, however, now introduced by the Biodiversity Institute. It is now highly needed by the farmer. The meaning of the landrace comes from the Amharic term "Gosh gimbar" (meaning the forehead of buffalo because the spike row and the awn resembles the forehead of buffalo). It is distinguished by flat and wide spike, very white seed color and the plant at the booting stage is white green.

13. ENAT SINDIE

The meaning comes from the Amharic term "Enat sindie"(meaning mother wheat because it is a pioneer and suitable for many things like mother). It is distinguished by white glumes, long spike, conspicous awn, very white straw and whitish seedling.

14. KULUYU

The meaning of the landrace comes from the "Oromigna" term "kuluyu" (meaning the blackening of the eye of a woman with black dye), this is to show the distinguishing black glume. It has also other features such as long spike, short and thick straw and average awn length. Because of its low market value it is given low attention by the farmer.

15. KEMEDI QOTICHA

The meaning of the landrace in "Oromigna" is to mean a black soil (vertisol) wheat. This is the most dominant landrace of the vertisol of the farming area of Grar Jarso. It is mainly distinguished by white color of the seeds, flat and conspicuous awn. It is the most abundant landrace in Grar Jarso wereda. It has a lot of merits and is given high attention by farmers.

16. AWANISO

The meaning has come from "Oromigna" to show the resemblance of the yellowish glume color to that of the grasshopper. It is distinguished by short spike, white brownish seeds, having many seeds per spike (dense spike). Since it needs long cooking time, it is being neglected by the farmer and now it is reducing in frequency.

17. BUTUGI

Meaning comes from "Oromigna" to show the short and robust nature of the spike. This is probably "Amune Egir" which has been found in other areas. It has the same distinguishing features as Amune Egir .It is being neglected by the farmer because the seed shatters at maturation.

18. SORGE (SHEMAME)

The meaning of the landrace come from the "oromigna" term Sorge (meaning dry) because the landrace performes better in the dry area and found in the pockets of dry areas. It is typically distinguished by long height and it has white and black seeds mixed together.

19. ATOSAL

This landrace has a very fascinating story. The meaning of the landrace came from the Amharic term "Antesaleh" (meaning it gives security for farmers even in adverse growing conditions). This landrace has important qualities such as early maturity, high drought resistance, high nutritional quality (has poems to express the nutritional qualities) and medicinal value. This landrace is found rarely in hot and dryhill side areas of some places. Strong attention should be given to this landrace including detailed scientific studies on it. It is typically distinguished by its shiny black seeds.

20. KIBRA MESKEL

It is one of the earliest landraces and now its frequency is reducing and being found rarely. It resembles Shemet.

21. YEWSHA KIRANCH

This is a very odd wheat and the meaning of the landrace comes from the Amharic term "yewsha kiranch'(meaning it is as hard as the canine tooth). It is very thick and hard to thresh. It is highly resistant to rust and other diseases. It is characterized by short awn, thick seed coat and thick straw. It is now becoming more and more rare and it may even be driven to extinction from the area if immediate actions are not taken to ensure its continued presence.

22. GEJA

It is believed that this landrace was recently introduced to Kimbibit wereda from elsewhere. The landrace is said to be high yielding. It is replacing Shemet because Shemet has low yield. It is characterized by long straw and black glume. It resembles Sellalo except for its white seed color. It has also another botanical form and known by the name "GEBRE" which differs from it in its conspicuous and long spike.

23.GOJAME

The meaning has come from its probable place of origin called Gojam (region in north-western Ethiopia). Two forms exist; the first is Shemet Gojame which is white seeded and have conspicuous awn and the second is Guandae gojame which is black seeded and awnless.

24.SELLALO

The meaning has come from the probable place of origin called Selale (place in north-western Shewa). It is characterized by thin and black seeds, conspicuous awn, thin and long spike, light black glume and light black straw.

25.DEMELLO AND MOKAKE

These are the two landraces which are nowadays difficult to find. In the present study since only grains were found, it was not possible to characterize the morphological distinctiness of these landraces.

Table 6. Summary on use value and agronomic qualities of the farmers' varieties

Agronomic quality/use value	Vernecular name of the variety	No
Disease Resistance	Tikur Sindie, Gojam Gura, Atosal, Tikur Shemet, Aybo, Kemedi Qoticha, Nech Amare, Azaze	8
Drought tolerance	Menzae, Atosal, Gojam Gura, Tikur Sindie, Kemedi Qoticha, Awaniso, Sesso	7
Cold tolerance	Gojam Gura, Shemet, Marye, Tikur Sindie, Nech Amare, Kemedi Qaticha	6
Yield capacity	Amune Egir, Butigi, Gojam Gura, Enat Sindie, Aybo, Tikur Sindie, Set Akuri	9
Earliness	Atosal, Tikur Sindie, Shemet, Menzae, Marye, Kemedi Qoticha	7
Medicinal	Atosal, Tikur Sindie, Tikur Shemet, Azaze	4
Beverage	Tikur Sindie, Gojam Gura, Tikur Shemet Marye	4
Megeberia	All white seeded varieties and the main ones are Aybo, Amune Egir, Enat Sindie, Set Akuri, Sesso	17

Important ethnobotanical information could also be collected from folklore (myths, sayings, legends, poems, songs, ritual practices). The folklore information collected from the study area on durum wheat landraces indicates some information on use value, traditional significance and other relevant information (Appendix III).

5.3. Molecular study

DNA from the 13 populations was used for the RAPD assay and the following banding patterns were observed.

- Populations 1, 2 and 4 each show no band for the primer used.
- Population 3 showed three bands at ca. 750, 830 and 900 bp (base pairs).
- Populations 5, 6, 7 and 8 each showed a single band at ca. 1700 bp.
- Populations 10 and 12 each showed two bands at ca. 1600 and 1750 bp.
- Populations 9, 11 and 13 each showed four bands at ca. 700, 780, 1600 and 1750 bp.

From the above data the dendrogram shown in Fig. 14 is constructed. The dendrogram shows the relationships among the thirteen populations using average linkage between groups.

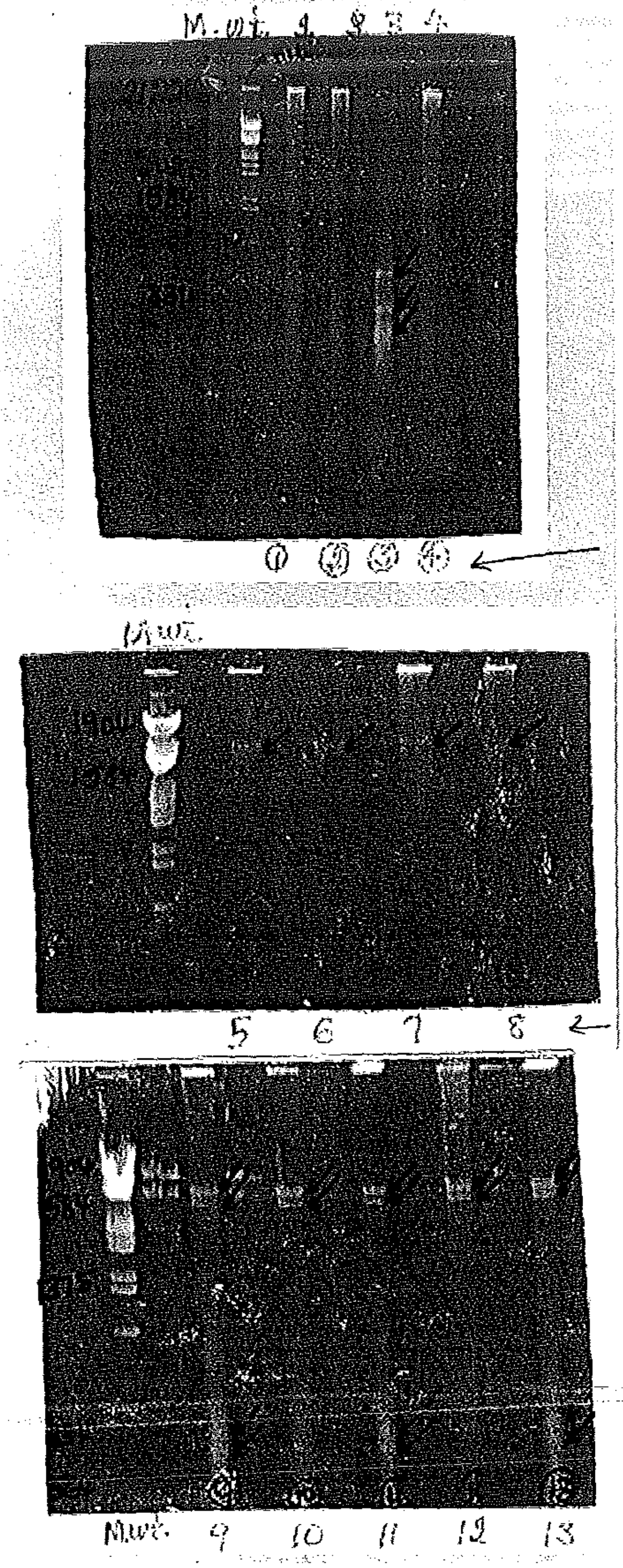


Fig. 13. Banding patterns of the thirteen populations from RAPD assay.

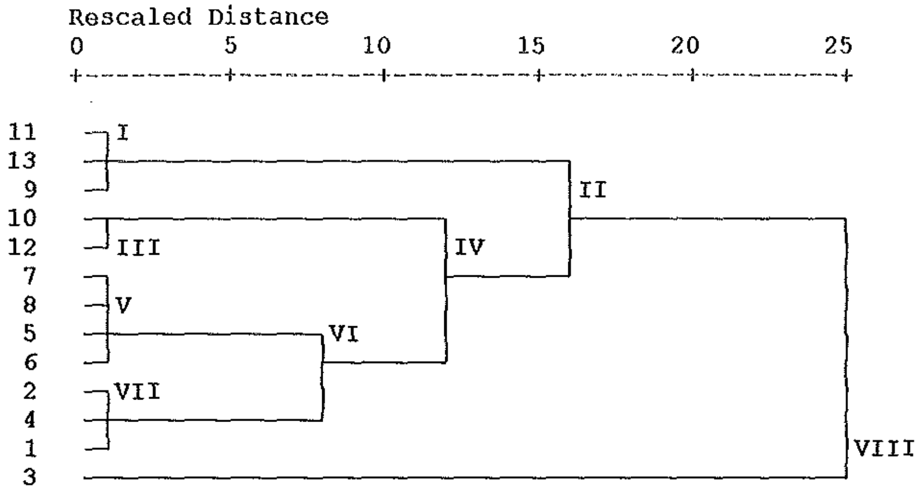


Fig 14. Dendrogram using average linkage showing the molecular relationship among the thirteen populations.

From the above dendrogram the following relationships are observed.

- Populations 1,2 and 4 (node VII)are clustered with groups of populations 5,6,7 and 8 *(node V) to form node VI.*

- Populations 10 and 12 (node III) are clustered with groups of node VI to form node IV.

- Groups of node I are clustered with groups of node IV to form node II.

- Population 3 is the outlier(very different from all other populations).

There are two major clusters formed

cluster 1- consisting of all the populations except population 3.

cluster 2- consisting of only population 3.

6.DISCUSSION

6.1. MORPHOLOGICAL ANALYSIS

6.1.1. Character distribution

The predominance of white-yellow glume color in this study is in agreement with Pecetti and Domanica (1996) and more recently Belay (1997) for the Shewa collections. It is different from Bechere *et al.* (1996) that reported highest percentage frequency for the brown-red type. The high percentage frequency for the white to yellow type is explained by Leslie *et al.* (1985) who stated the high correlation between white glume and the storage protein, gluten. This has been also confirmed by the molecular diversity study part of this thesis that showed the presence of different types of gluten coding genes in most samples taken for the analysis. This indicates the potentiality of Ethiopian durum wheat for the important trait of pasta quality.

The rarity of the purple-black glume color is in agreement with Jain *et al* (1975), Tesemma *et al.*(1991), Bechere *et al.*(1996), Belay (1997). However, whether there is selection disadvantage linked to this gene or not is unknown. The high percentage

frequency of brown-red type in the higher altitudes, which is associated with resistance to stripe rust (*Puccinia striiformis* West) (Metzeger and Silbaugh, 1970) is not observed in this study. The possible explanation could be either the varieties from the study areas are not resistant to the disease or the fungus could be less frequent in the higher altitudes of the study area. Most populations showed highest frequency for long beak length which could be advantageous for both post senescence photosynthesis (Evans *et al.*, 1972) and in reducing leaf rust attack (Patterson and Ohm, 1978). However, short and long beak length showed equal proportions in the entire collections of this study.

Eventhough pubescence (hairiness) is controlled by monogenic dominant gene (Maclintosh, 1988), it is much less frequent than the recessive allele (glabrous glume) showing the presence of selection disadvantage linked to this dominant gene. The adaptive significance of hairiness has been reported for resistance of both Karnal bunt (*Tilletia indica*) (Warham, 1988) and powdery mildew (*Erysiphe graminis*) (Negassa, 1986). But these two diseases do not exist or are rare in Ethiopia (Belay, 1997).

The highest percentage frequency for brown-red seed color is in agreement to the Shewa entries of Bechere *et al.* (1996) and Belay *et al.* (1997). The approximate proportionality of the three seed colors may suggest the conclusion reached by Belay *et al.* (1995) and also evident from the ethnobotanical study in the present work. All the different seed color types are important for the different traditional use values such as consumption, medicinal value, religious purposes, making local beverages and other uses. The rarity of the purple-black color at lower altitudes may be due to the poor adaptability of this type to the climatic, edaphic and other growing conditions prevailing in lower altitudes (Belay *et al.*, 1997).

As reported from many studies the lax-spike density is not common and less frequent in tetraploid wheat species. The dense spike density is one of the distinguishing morphological features used in the characterization work of the gene bank to differentiate tetraploid from hexaploid types. IBPGR'S format has been modified in this study so as to take only the dense and very-dense types. Many authors (e.g. Tessema *et al.,*1991; Bechere *et al.,*1996) have reported that the dense type is the most common type in Ethiopian durum wheat and the present study is in concordant with these studies. Belay *et al.* (1991) and Parry *et al.* (1995) reported the association of lax-spike to resistance for diseases that attack the spike.

The adaptive significance of awn color is not known. However, in this study a high similarity in distribution pattern between awn color and glume color has been observed and awn color has almost the same type of distribution pattern as glume color.

6.1.2. Diversity assessment

This study analysed the diversity index (H') of durum wheat in a given region (North Shewa) and the diversity indices of microcenters (awrajas and weredas) and populations. The overall diversity index of durum wheat in North Shewa is very high and this is in agreement with the diversity indices as reported from many studies (Jain *et al.*, 1975; Bekele, 1984; Negassa, 1986; Tessmma *et al.*, 1991; Pecetti *et al.*, 1992a; Bechere *et al.*, 1996; Tsegaye, 1997; Belay, 1997).

On awraja basis Selale and Teguletna Bulga showed the highest diversity index and the latter is where the on-farm conservation of durum wheat is being undertaken by the Biodiversity Conservation and Research Institute under its dynamic on-farm crop conservation project.

On wereda basis, the Kimbibit wereda within Teguletna Bulga awraja showed the highest diversity index and this has been also proved by the amount of diversity observed during the ethnobotanical field study.

The highest diversity index among traits was observed for seed color and this is in agreement with Bechere *et al.* (1996) and Belay (1997). This is also easily explained from the ethnobotanical study that the different color types of the seed have different traditional values (consumption, beverage making, religious values). Farmers deliberately maintain all these seed color types for the different purposes. The high diversity index for dense-spike density is in agreement with most previous studies of the crop.

On altitudinal bases, the highest diversity index was observed in altitudinal class 3 and followed by altitudinal classes 4 and 6. For the first two classes the result is in concordant with many studies and also it is the suitable growing area for durum wheat. The possible explanation for the high diversity index observed in the highest altitudinal class in the present study could be the influence of the highest diversity index of Kimbibit wereda which is found in high altitude as shown in the results (Table 1.).

The overall diversity index (H') for North Shewa (H'=0.79) is almost the same with that of the recent study by Belay (1997) who reported a diversity index (H'=0.81) for the Shewa region.

6.2. ETHNOBOTANICAL ANALYSIS

It has been realized that the farmer has a stored database of treasures of indigenous knowledge on this crop. This knowledge has been flowing from generation to generation since ancient times. Ethnobotany is privileged for extracting this important knowledge which has not been possible to get from many years of scientific studies. It will be a big mistake if this asset is neglected to be considered in endeavors for the conservation and sustainable utilization of plant genetic resources.

The ethnobotanical data generated from this study has practical implications which could be utilized in the conservation, enhancement and sustainable utilization programs for durum wheat landraces (farmers' varieties).

The existence of all these varieties could be easily explained from the indigenous knowledge of the farmer. The farmer identifies the factors, which contributed for the existence and diversity of the landrace. The factors, according to the farmer, which contributed for maintaining the existing diversity of durum wheat are highly concordant with that of Teshome (1996) for sorghum landraces. The major factors are environmental, social (cultural) and economical entities.

The environmental component which contributed to the diversification of durum wheat landraces are wide range of topography, agro-ecology, edaphic and abiotic factors which could be ideal niches for the existence of various botanical forms of this crop. To cite a case in a point, the Ankober district alone harbors altitudinal variations in the range of

1400-3300 m.a.s.l. and other environmental gradients which have tremendous impact for the existence of different varieties of the crop.

The social (cultural) component includes the value of the different types of the landrace for different traditional purposes. All these varieties have different merits on cultural significance such as religious, home made food preparations, traditional beverage making and medicinal values. The religion component, for example, has strong contribution for maintaining the local varieties. The clergy of the church only accept the white seeded local varieties, as gift for the church, and the farmer is obliged to maintain these varieties for this purpose at least.

The economic component reflects the low financial input in managing local varieties. The modern agricultural system relys on high input resources, which could be beyond the financial reach of the poor farmer. The best technique, which is developed by the farmer, is to maintain the maximum diversity of the crop, which have adapted to the local environment with little or no input. These varieties give the farmer security against adverse growing conditions and manageable within the financial limit of the poor farmer, who gives priority to security over high yield. The high yielding varieties do not give security to the farmer during adverse growing conditions and also require more agricultural inputs than the local varieties. These two major reasons put the local varieties to be more preferred to that of the high yielding varieties (Teshome, 1996).

6.3. MOLECULAR ANALYSIS

The result of the molecular analysis of this study reveals some important implications. It shows the importance of the molecular technique in diversity studies of farmers' varieties. The magnitude of the variations is not comparable with that of morphological variations and probably, because it uses one primer system and analyse few genotypes.

In this study the molecular technique known as Randomly Amplified Polymorphic DNA (RAPD) has been applied to see inter-population variations among thirteen populations. The reason for choosing this technique is because it is simple, rapid, neutral and risk- free (not involved with radioactive substances) and also easy to analyze. It is possible to use with different primers to see a detailed diversity analysis. However, in the present study one primer system associated with important quality trait of durum wheat is used.

Gliadins and glutenins are the two major storage protein groups in the wheat endosperm. The glutenins are multimer aggregates of sub-units of high molecular weight (HMW='A' sub-unit) and low molecular weight (LMW= 'B' and 'C' sub-units) interlinked by disulfide bridge. These proteins have important effect on the properties of wheat dough and associated with properties of the flour for pasta making. LMW-2 glutenin has superior pasta making quality (ICARDA, 1994) on which basis the primer used in this study has been designed.

The presence of different fragments shows the variations even with only one primer system. It also shows the potentiality of Ethiopian durum wheat for pasta making. This quality for Ethiopian durum wheat is also indicated by Bechere *et al.* (1996) from the association of seed vitreousness trait.

The overall variation in North Shewa durum wheat landraces has been evident from the three study approaches followed in this thesis. Summary of the results are the following.

- Morphological variation of durum wheat demonstrated wide diversity based on consideration of major botanical features. This showed good correlation with information gathered from North Shewa durum wheat farmers through ethnobotanical investigations.

- The limited molecular diversity study undertaken also revealed the inter-population variation that exists at the DNA level.

- The present study methods complement each other in showing the diversity in durum wheat which helped to identify important micro-centers for in-situ conservation strategy.

7. CONCLUSION AND RECOMMENDATIONS

7.1. CONCLUSION

Ethiopia is a country with wide range of topography, variable edaphic conditions, traditional farming practices, very ancient and diverse cultural histories and other biotic and abiotic factors. These biological, physical and socio-cultural factors made the country to be the center of origin and/or diversity for many crops. Durum wheat (*Triticum durum* Desf.) is one of these crops, which have high diversity in the country (Tsegaye, 1997).

Most of the germplasm for this crop is consisting of traditional farmers' varieties (landraces) with variable botanical and agronomic features. Several genetic diversity studies have been conducted to assess and quantify these intra-species variations of the crop. There are different methods/approaches to study these diversities starting from the indigenous knowledge of the farmer to modern molecular biology techniques. However, most of the studies undertaken on Ethiopian durum wheat landraces were relying on morphological diversity studies only. In this method the variation on heritable agromorphological traits are used to estimate the morphological variations. All these studies confirmed the presence of high diversity of the crop in the country. They also pointed out that there are centers within the country where there is highest diversity of the crop.

The Shewa region is one of these centers harbouring these variable forms of the crop. The present study examined the diversity of the crop in North Shewa region following a holistic approach taking into account the indigenous knowledge of the farmer, morphological method and modern molecular biology technique.

The morphological diversity study was conducted using the variations on six heritable traits. The variation of each population, wereda and awraja, altitudinal groups and the entire region was quantified using Shannon-weaver diversity index. This study identifies sites with high diversity index, which could be ideal sites for *in-situ* conservation strategy. The site with highest diversity index (Kimbibit wereda) is also evident to have the highest local varieties from the ethnobotanical study.

The ethnobotanical study documented local varieties with distinct vernacular names. It also studied characters used by farmers for identification and classifying the varieties. The time-space based strategies used by the farmer for maintaining the existing diversity is also discussed. Farmers demonstrate the merits and use values of each variety. They identify varieties with good agronomic qualities and traditional significance which have sound impacts in conservation, sustainable utilization and enhancement programs of the landrace.

The molecular technique used in the study (RAPD technique), though with only one primer system, shows the importance of such techniques in the diversity studies of crop genetic resources. The gluten-based primer system shows the inter-population diversity of the crop in North Shewa region. It also shows the presence of a gene with pasta quality trait in durum wheat landraces of the study area. The rapidity, easiness and reliability of this technique were also observed in the study.

7.2. RECOMMENDATIONS

From the present study, the following recommendations are forwarded. The general recommendations refer to important farmers' varieties of the country. The specific recommendations refer to durum wheat landraces of the country.

General recommendations

- The germplasm collections of the Ethiopian gene bank is about 58,000 accessions of 101 different species of plants. However its documentation and characterization aspect uses mainly morphological methods and this method has drawbacks in identification and proper classification of some species. There are mistakenly documented species (as evident from this study for durum and bread wheats). The Institute could minimize this problem by developing molecular techniques, which are more reliable, fast and efficient for screening its holdings.

- There has to be continuous genetic diversity studies using all the three approaches on important crops and taking the important sites. These studies can initially focus on the six on-farm conservation sites of the Institute.

- The indigenous farmers' knowledge should be embraced on the conservation, utilization and enhancement programs of landraces. Not only genetic erosion through narrowing of the diversities of the crops is taking place but also the knowledge base of the people is being eroded. The documentation of this knowledge is an urgent matter and immediate action should be taken.

• There are farmers' varieties, which have important qualities and located in isolated specific pockets in the country. There has to be extension programs that would introduce these landraces to other areas. To cite a point, preliminary adaptation trails showed that the variety "AZAZE" is found to be highly adapted to the growing conditions in the "Gore" area of Bale region.

Specific recommendations

• The Diversity of durum wheat in the country is extremely high and there are about 86 morphotypes observed in the country (Tessema, personal communication). This diverse genetic base is consisting of mixtures of genotypes with different merits. Detailed study (using the three approaches) should be conducted on these materials so as to see the genetic similarity and distances between them.

• There are varieties used by the farmer for different economic and traditional values. Molecular techniques with important marker systems should be used to screen the important genes of these materials. Other related nutritional and other studies should also be implemented.

• The on- farm conservation of durum wheat in North Shewa considers the Teguletna Bulga awraja which is an area of high diversity of the crop. However, it is going on two weredas only. In the present study important sites such as Kimbibit wereda and Selale awraja are identified as important sites for *in-situ* conservation. Therefore, these sites should be considered in future *in-situ* conservation strategies.

- There are varieties with important agronomic and economical traits but found in pockets of some areas and immediate actions to collect these varieties should be effected. E.g. the important variety "ATOSAL" is found only in remote areas of Moretna Jiru wereda. Further detailed study on this particular variety is strongly recommended.

- The high gluten content associated with pasta quality is demonstrated in the samples of the populations studied. Further detailed analysis on large populations of the crop on this economically important trait should be carried out. It is a pity that the pasta and macaroni factories are importing the grain with high amount of hard currencies. New investment should be geared in this area.

- Molecular and cytogenetic techniques should be utilized in the identification and classification of durum wheat. The durum wheat like bread wheat can easily be screened out with these techniques.

- Finally, durum wheat research in Ethiopia should be strengthened, especially the ethnobotany and molecular techniques are almost untouched areas and important findings could be achieved if these methods are used.

- Kimbibit, Moretna Jiru and Grar Jarso (from the analysis of both morphological and ethnobotanical study) ,in order of importance, are recommended as good *in-situ*. conservsation sites so as to conserve the maximum variation of the crop

8. REFERENCES

Altieri, M.A. and Merrick, L.C. 1987. In-situ conservation of crop genetic resources through maintenance of traditional farming systems. Economic Botany **41**. pp 86-96.

Anniccihiarico, P., Pecetti, L. and Domania, A. 1995. Relationships between phenotypic variation and climatic factors at collecting sites in durum wheat landraces. Hereditas **122**. pp 163-167.

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

Asfaw, Z. 1997. The role of ethnobotany in biodiversity conservation. In: The role of ethnobotany in biodiversity conservation, quantitative methods in ethnobiology and agricultural economics research (ed. Kebebew, F.). CBDC, Addis Ababa, Ethiopia (unpublished).

Bechere, E., Belay, G., Mitiku, D. and Merker, A. 1996. Phenotypic diversity of tetraploid wheat landraces from Northern and North-Central regions of Ethiopia. Hereditas **124**. pp 163-167.

Becker, J.P. and Huen, M. 1994. Barley microsatellites: Allelic variation and mapping. Plant Mol. Biol. **27**. pp 835-845.

Becker, J.P.Vos., Kuiper, M., Salamini, F. and Heun, M. 1995. Combined mapping of AFLP and RFLP markers in barley. Mol. Genet. **249**. pp 65-75.

Beckman, J.S. and Soller, M. 1983. Restriction fragment length polymorphism in genetic improvements: Methodologies, mapping and costs. Theor. Appl. Genet. **67**. pp 35-43.

Bekele, E. 1983. Allozyme genotypic composition and genetic distance between the Ethiopian landrace populations of barley. Hereditas **98**. pp 259-267.

Bekele, E. 1984. Analysis of regional patterns of phenotypic diversity in the Ethiopian tetraploid and hexaploid wheat. Hereditas **100**. pp 131-154.

Bekele, E. 1985. The biology of cereal landrace populations. I. Problems of gene conservation, plant-breeding, selection schemes and sample size requirement. Hereditas **103**. pp 113-134.

Belay, G. 1997. Genetic variation, Breeding potential and Cytogenetic Profile of Ethiopian Tetraploid Wheat (Triticum turgidum L.) landraces. Doctoral thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Belay, G., Tesemma, T., Bechere, E. and Mitiku, D. 1995. Natural and human selection for purple grain wheats in the Ethiopian highlands. Genetic Resources and Crop Evolution **42**. pp 387-391.

Berrie, A.M.M. 1977. An introduction to the botany of the major crop plants. University of Glasgow. pp 24-30.

Brush, W.C. 1990. A farmer-based approach to conserving crop germplasm. Economic Botany **45**. pp 153-165.

Chambers, R. 1983. Rural development. Putting the last first. Longman Inc., U.S.A.

Ciferi, R. 1939. I Cereali dell' Africa Italiana I. I frumenti dell' Africa Italiana Studiati Su materiali orginali- Tipogrfia G.Ramella and C. Firenze. Cited In: Ghiorghis, H. and Dibaba, D. (In: PGRCE/E Germplasm newsletter No. 2. pp 6-10).

Demissie, A. 1996. Morphological and molecular markers diversity in Ethiopia barleys: Implications to *In-situ* and *ex-situ* conservation of landrace materials. Doctor Scientiarium thesis. Agricultural University of Norway. pp 5-27.

Demissie, A. and Habtemariam, G. 1991.Wheat Genetic resources in Ethiopia. In:Wheat research in Ethiopia. A historical perspective (eds. Hailu,G.M., Tanner, D.G. and Mengistu, H). pp 34-46. Addis Ababa.

Dominci, L., Grottanelli, A., Tomassini, C., Lafiandra, D., Porceddu, E. and Damia, A.B. 1988. Electropheresis variability in landraces of durum wheat from Ethiopia. Rachis **7**. pp

34-36.

Dullo, M.E., Guarino, L and Ford-Lioyd, B.V. 1997. A bibliography and review of genetic diversity studies of African germplasm using protein and DNA markers. Genetic Resources and Crop Evolution. **44**. pp. 447-470.

Engels, J.M.M. and Hawkes, J.G. 1991. The Ethiopian gene centre and its genetic diversity. Engels, K.M.M., Hawkes, J.G. and Melaku, W. (eds.). Plant genetic resources of Ethiopia. pp 23-41. Cambridge university press. Cambridge.

Esquinas-Alcazar, J.T. 1993. Plant genetic resources. In: Hayward, M.D., N.O, Bosemark and I, Romagosa (eds.). Plant Breeding, Principles and Prospects. pp 33-51, Chapman and Hall, London.

Evans, L.T., Bingham, J., Jackson, P. and Sutherland, J. 1972. Effect of awns and drought on the supply of photosynthate and its distribution within wheat ears. Ann. Appl. Biol. **70.** pp 67-76.

Feldman, M. 1976. Wheats. In: Evolution of crop plants, Simmonds NW (ed), Longman Group Ltd,London. pp 120-126.

Feldman, M., Lupton, FGH. and Miller, T.E. 1995. Wheats: *Triticum* spp. (Gramineae-Triticinae). In: Evolution of crop plants, Smart, J. and Simmonds, NW (eds.). pp 184-192 Second edition, Longman Scientific and Technical, Singapore.

Frankel, O.H. 1974. Genetic conservation: Our evolutionary responsibility. Genetics. **78.** pp 53-65.

Gebremariam, H. 1991. Wheat production and research in Ethiopia. In: Wheat research in Ethiopia. A historical perspective (eds. Hailu, G.M., Tanner, D.G. and Mengistu, H). pp 1-15. Addis Ababa.

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

Harlan, J.R. and De Wet, J.M.J. 1971. Towards a rational classification of cultivated plants. Taxon **20.** pp 509-517.

Hawkes, J.G. 1976. Sampling gene pools. Proceeding of NATO conference on conservation of threatened plants. Series 1., Ecology. Plenum London.

Hawkes, J.G. and Worede, M. 1991. Use of Ethiopian germplasm in national and international programmes. In: Plant genetic resources of Ethiopia (eds. J.M.M.,Engels, J.G.,Hawkes and M.Worede. Cambridge University Press, U.K.

Helbeak, H. 1959. Domestication of food plants in the old world. Science **130.** pp 365-372.

IBPGR. 1985. Revised descriptor list for wheat (*Triticum* spp.). IBPGR Seretariat, Rome.

ICARDA. 1994. Use of PCR-markers for durum quality. In:Germplasm program for cereals. Annual reprt. pp, 221-222.

Jain, S.K., Qualset, C.O., Bhatt,G.M. and Wu, K.K. 1975. Geographical patterns of phenotypic diversity in a world collection of durum wheat. Crop Science **15**. pp 700-704.

Kebebew, F., Gebeyaw, Z. and Tsehaye, Y. 1997. Ethnobotanical survey on durum wheat (*Triticum durum* Desf.) in Tegulet (North Shewa). In: proceedings of the first joint meeting of NPAOC cordinating unit and partner Institutions (eds. Kebebew, F., Demissie, A. and Ketema, S.). BDI/E, Addis Ababa, Ethiopia. pp, 49-54 (Unpublished).

Kerby, K. and Kuspira, J. 1987. The phylogeny of the polyploid wheats, *Triticum aestivum* (bread wheat) and *Triticum turgidum* (macaroni wheat). Genome **29**. pp 722-737

Leslie, D., Kovacs, M.I. and Howes, N. 1985. Inheritance and linkage relationships of gliadin proteins and glume colour in durum wheat. Can. J. Genet. Cytolo. **27**. pp 716-721.

Mackey, J. 1966. Species relationship in *Triticum*. Hereditas, Suppl Vol **2**. pp 237-276.

Martin,G.J.1995. Ethnobotany. Chapman and Hall,London, U.K.

Mclintosh, R. 1988. A catalogue of gene symbols for wheat. In: T.E. Miller and R.M.D, Koebner (eds.). Proc. Seventh Int. wheat Genetics symp. pp 1225-1323. Cambridge.

Mengesha, M.H. 1975. Crop germplasm diversity and resources in Ethiopia. In: Crop genetic resources for today and tomorrow (eds. Frankel, O.H. and Hawkes, J.G.). pp 449-453.

Metzeger, R.J. and Silbaugh, B.A. 1970. Inheritance of resistance to stripe rust and its association with brown glume colour in *Triticum aestivum* L, "P.I.178383". Crop Sci.**10**, pp 567-568.

Miller and Tongtey. 1993. African biodiversity. pp 10 (Unpublished).

MSTATC. 1983. A computer software programmed by Ms. Betsy Bricker. Michigan State University. USA.

Negassa, M. 1986. Estimates of phenotypic diversity and breeding potential of Ethiopian wheats. Hereditas.**104**. pp 41-48.

Parry, D.W., Jenkinson, P and Mcleod, L. 1995. Fusarium ear blight (Scab) in small grain cereals- a review. Plant Pathol. **44**. pp 207-238.

Patterson, F.L. and Ohm, H.W. 1978. Compensating ability of awns in soft-red winter wheat. Crop Sci.**15**. pp 403-407.

Pecetti, L. and Damania, A. 1996. Geographic variation of tetraploid wheat (*Triticum turgidum* ssp.turgidum Convar. durum) landraces from two provinces in Ethiopia. Genet. Resour. Crop Evol. **43**. pp 395-407.

Pecetti, L., Damania, A.and Kashour, G. 1992. Geographic variation for spike and grain characteristics in durum wheat germplasm adapted to dryland conditions. Genet. Resources and Crop Evol. **39**, pp 97-105.

Porceddu, E. and Perrino, P. 1973. Wheat in Ethiopia. Preliminary report of a collecting mission. Plant Genetic Resources Newsletter. **30**. pp 33-36.

Purseglove, J.W. 1975. Tropical crops, Monocotyledons. Longman group limited. pp 287-291.

Schiemann, E. 1951. New results on the history of cultivated cereals. Heredity **5**. pp 305-320.

Smith. 1992. PCR amplification. Journal of Virology Meth. **39**. pp 237-246.

Spagnoletti Zeuli, P.L and Qualset, C.O. 1987. Geographical diversity of quantitative spike characters in a world collection of durum wheat. Crop Science. . pp 235-241.

SPSS for win. 1993. A computer software. SPSS for win release 6.0. June 18, 1996.

Tesemma, T. 1991. Improvement of indigenous durum wheat landraces in Ethiopia. In: J.M.M, Engles., J.G, Hawkes and M, Werede (eds.). Plant Genetic resources of Ethiopia. pp 288-295, Cambridge University Press, Cambridge, UK.

Tesemma, T and Belay, G. 1991. Aspects of Ethiopian tetraploid wheats with emphasis on durum wheat genetics and breeding research. In: Wheat research in Ethiopia. A historical perspective (eds. Hailu,G.M., Tanner, D.G. and Mengistu, H). pp 47-72. Addis Ababa.

Tesemma, T., Getachew, B and Worede, M. 1991. Morphological diversity in tetraploid wheat landrace populations from the central highlands of Ethiopia. Hereditas **114.** pp 171-176.

Teshome, A. 1996. Factors maintaining sorghum [*Sorghum bicolor* (L.) Moench] landrace diversity in North Shewa and South Welo regions of Ethiopia. Doctoral Thesis. Carleton University. Ottawa, Ontario, Canada.

Thomas, C.M., Vos, P., Zabeou, M., Jones, D.A., Norcott, K.A., Chadwick, P.B. and Jones, J.D.G. 1995. Identification of amplified restriction fragment length polymorphism

(AFLP) markers tightly linked to the tomato cf-g gene for resistance to cladosporium. Plant Journal **8**. pp 785-794.

Tsegaye, S. 1997. Genetic diversity and structure of tetraploid wheat landraces of the central highlands of Ethiopia. Doctoral Thesis. Swedish University of Agricultural Sciences. Svalov, Sweden.

UNEP. 1995. Convention on biological diversity. pp 2-35.

Vavilov, N.I. 1951. The origin, variations, immunity and breeding of cultivated plants. Chronica Bot. **13**. pp 1-351 (Translated from Russian by K.S, Chester).

Warham, E.J. 1988. Screening for Karnal bunt (*Tilletia indica*) resistance in wheat, triticale, rye and barley. Can. J. Plant pathol. **10**. pp 57-60.

Wei, J.Z., Campbell, W.F. and Wang, R.R.C. 1997. Genetic variabilty in Russian wildrye (Psathyrastachys juncea) assesed by RAPD. Genetic Resources and Crop Evolution. **44**. pp 117-125.

Welsh, J. and McClelland, M. 1990. Fingerprinting genomes using arbitrary primers. Nucleic Acids Res. **18**. pp 7213-7218.

Williams, J.G., Kubelik, A.R., Livak, K.J., Rafalski, J.A. and Tingey, S.V. 1990. "DNA polymorphism amplified by arbitrary primers are useful as genetic markers". Nucleic Acids **18**. pp 6531-6535.

Wilson, E.O. 1992. Global biodiversity. WRI/ IUCN/ UNEP. pp 10-19 (Unpublished).

Zedan, H. 1995. Loss of plant diversity. A call for action. In: Collecting plant genetic diversity (eds. L.Guarino, V., Ramanatha Rao and R.Reid). IUCN. IPGRI. pp IX-XIV.

Zewdie, M. 1994. Current status of germplasm holdings at PGRC/E. In: PGRC/E germplasm newsletter. No 2. pp 2-5.

Zohary, D.1970. Centers of diversity and centers of origin. In: Genetic resources in plants, their exploration and conservation (eds. Frankel, O.H. and E. Bennet). pp 33-42. International biological program, Blackwell scientific publications, Oxford. London.

Appendices

Appendix I. Accession number (Accn. No.), code used, number of entries (N), altitude, wereda and awraja of the studied populations.

Accn. No.	Code	N	Altitude	Wereda	Awraja
5982	1	29	2930	Gara midir	Menze and Gishe
229251	2	36	2520	Tach Bet	Merhabete
229254	3	28	2140	Tach Bet	Merhabete
222200	4	32	2695	Grar Jarso	Selale
229248	5	26	2220	Ensaro	Selale
231564	6	22	2810	Basona Warena	Teguletna Bulga
203975	7	35	2650	Moretna Jiru	Teguletna Bulga
204488	8	23	2850	Kimbibit	Teguletna Bulga
203966	9	26	2750	Angolale	Teguletna Bulga
203971	10	25	2780	Angolale	Teguletna Bulga
7961	11	34	2600	Angolale	Teguletna Bulga
214316	12	35	1675	Adaa	Yererna Kereyu
231530	13	30	2250	Lume	Yererna Kereyu

7925***=== Found to be non-durum type **(bread wheat).**

204483***=== Found to be non-durum type **(bread wheat).**

Appendix II. Ethnobotanical data collection format for durum wheat landraces of North Shewa.

I. GENERAL

Information name
Age range
Gender
Region/Zone
Wereda
Kebele
Precise locality
Location of the site
Altitude
10. Topography
11. Soil type
12. Climate
13. Agroecology
14. Farming system
15. Drought occurrence rate
16. Flooding rate
17. Accidental fire

II. CROP/LANDRACE

1. Family
2. Genus
3. Species
4. Local name of the landrace
5. Meaning of the local name
6. Cultural significance of the landrace
   - Songs/Poems/Sayings/Rituals and religious beliefs
   - Traditions about origin of the landrace

7. Folk taxonomy of the landrace
   - Criteria of characters used at each level of classification
   - Frequent characters to name, identify and classify the landrace in farming, household and market places

8. Qualities of the landrace in:

   I. Resistance to diseases of microorganisms (Bacteria, fungi and others)
   II. Resistance to pests
   III. Drought tolerance
   IV. Tolerance to cold
   V. Resistance to lodging
   VI. Yield capacity
   VII. Straw quality (Use of the straw)
   VIII. Earliness
   IX. Tillering capacity

9. Common diseases of the crop- Status of severity
10. Common pests of the crop
11. Measures taken by the farmer to combat items 10 and 11

12. Use value of the landrace inorder of preference

- Injera
- Bread
- Soup like ("Atmit")
- Soft porridge ("Genfo")
- Hard porridge ("Kinche")
- Biscuits
- Spaghettis
- Megeberia
- Medicinal value
- Roasted grain ("Kollo")
- Row grain ("Eshet")
- Boiled grain ("Nefro")
- Roasted spike ("Enkuto")
- Alcholic bevarage
- Fuel
- Fiber
- Ornamental
- Others (Specify)

13. Market value of the landrace
14. Frequency/Tendency of the farmer in using fertilizer
15. Prefrential grain quality
    - Large grains for
    - White kernels for
    - Black kernels for
    - Others (Specify)
16. I. Method of seed storage
    - Gallary
    - Clay pots
    - Loft
    - Earthen jar containers
    - Bamboo basket or grass basket
    - Basket cemented with dung
    - Others

    II. Duration of the storage material (in years)

17. I. Pair wise sort: Arrange the landraces in pair of two for uses of
    - Nutitional value
    - Resistance to diseases and pests
    - Commercial value
    - Medicinal value
    - Others

    II. Triadic sort: Arrange the landraces in sets of three

18. Conservation awarness of the farmer for the landraces and measure taken by the farmer.

Appendix III. Phrases, statements, songs, poems and sayings that mention wheat and refer to different attributes and recorded from farmers during the ethnobotanical field study.

Songs, poems, sayings.etc. in Amharic	Attribute Implicated to
1. Jiru sindie molto beguaya korbe Emshekeshekalew alhed endelbe	To express abundance and food quality of wheat to that of lathyrus.
2. Yenen sindie enjera setiche lesewe Zengada ebelalew absit yanesewe	To express the preference and food quality of wheat to that of sorghum.
3. Asesun gesesun tew bilalgn hode Megeberia honual altegegnem sindie	To show the value of wheat even in holy purposes of the church.
4. Sindie enjera bewet albelam yalkute Adere gomen lay ejen nekerkute	The nutritinal quality of the wheat bread to that of sause of cabage.
5. Yalesindie enjera aynekaw lemate Bagegn ebelalew batam dheneten	Indicates the high demand for the crop.
6. Sinden bewete Begzer malmete	Bread of wheat can be eaten alone.
7. Sindie ywedshal hode	To express obsession to wheat
8. Yene sindie wet ayfejim	To express the worth of wheat when farmers asked in exchange of wheat with other crops.
9. Atosal set yaleselsal wende yakesal	A variety of wheat (Atosal) has high nutritional quality and housewives do not give it to others.