ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

Diversity of Sorghum (*Sorghum bicolor* (L.) Moench) in North Shewa and South Welo Regions of Ethiopia: Focus on Farmers' Varieties with Emphasis on Frequency of Occurrence and Use Values in Relation to Morphological and Biochemical Characters

ADUGNA ABDI WELDESEMAYAT

Addis Ababa, May 2000.

Diversity of Sorghum (*Sorghum bicolor* (L.) Moench) in North Shewa and South Welo Region of Ethiopia: Focus on Farmers' Varieties with Emphasis on Frequency of Occurrence and Use Values in Relation to Morphological and Biochemical Characters

A thesis submitted to the School of Graduate Studies

Addis Ababa University

in Partial fulfillment of the requirements for the Degree of Master of Science in

Biology ***(Applied Genetics)***

by

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By
Adugna Abdi

A Thesis Presented to the School of Graduate Studies of the Addis Ababa University in Partial Fulfillment of the Degree of Master of Science in Biology

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June, 2000

DEDICATION

This work is dedicated to my late mother Workie Rissa for her ever-lasting devotion for successful accomplishment of my academic career and to my late brother Tamiru Abdi.

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ABSTRACT

Thirty four sorghum (*S.bicolor* (L).Moench) landraces consisting of 1020 individual plants (30 plants of each landrace) collected from five agroecosites in North Shewa and South Welo regions of Ethiopia (Bati 8, Fontenina 5, Hayike 2, Layignaw ataye 17, and Merewa Adere 2) were used in this study. The materials were classified on the basis of administrational zones (4 classifying variables; Woredas, ecosite of origin and altitudes, Morphological variation for the fourteen qualitative characters that showed two or more phenotypic classes were estimated using the Shanon-Weaver diversity index (H'). Phenotypic variation was found between and within each classifying variable. The value of H' for all landraces varied from 0.32 to 0.98 with an overall mean of 0.77 ± 0.04. One way analysis of variance (ANOVA) showed significant differences between characters within all classifying variables and this contributed to the largest portion of the total variance. Cluster analysis based on ordinal variables grouped the landraces in 5 clusters. A higher proportion of landraces sharing similar altitude groups and similar agroecological sites were grouped together. Panicle compactness and shape as well as stalk juiciness were the predominant characters in grouping the landraces into their respective cluster. Panicle compactness and shape also contributed relatively more to altitudinal and ecological differentiation. This differential distribution of different panicle types with respect to compactness and shape revealed the adaptive significance of panicle compactness and shape that reflected the patterns of distribution of different races in north Shewa and south Welo regions. χ^2 test was carried out to detect the deviation of the observed frequency of all the characters from the expected ones. Significant differences were not observed for most of the characters between the observed and expected frequencies.

Isozyme analysis was performed using two-enzyme systems esterase (EST) and acid phosphatase (ACP) to see the allelic variation among the 34 sorghum landraces. However, phenotypic polymorphism was not observed for any of the enzymes used in the analysis.

For the analysis of frequency of existence (diversity) of sorghum landraces under the environmental variability (altitudes and field size), transect method over 100 plots (fields) was used. As altitude levels increased or decreased beyond the range of 1500-1650 m.a.s.l, the diversity of the sorghum landraces also decreased. A relatively lower field size located nearer to the home range was found to contain higher diversity. The use values of the 34 sorghum landraces were also analyzed by interviewing 30 informants in north Shewa and south Welo regions. Thirty informants were contacted and the uses of the identified sorghum landraces were recorded on 30 plots. Of all the landraces zengada and ahiyo comprised the maximum number of uses (15 and 13, respectively). However, almost all-30 landraces were known to have been selected for their nutritional value as injera making and for their suitability for beverage. Ethnobotanical survey was conducted and the important data on farmer perceptions about the agromorphological traits distinguishing landraces, cultural values and preferred traits of sorghum landraces were collected.

The knowledge of farmers, which is documented in this study, is an important input to the building up of the scientific basis of *in-situ* conservation of agrobiodiversity in sorghum crops. The information retained from the farmers' knowledge can also be applied in future breeding activities and designing *in-situ* conservation program..

I. INTRODUCTION

1. STATE OF GENETIC DIVERSITY

1. 1. Centers of origin and diversity

The center of origin is usually defined as the primary center of *in-situ* diversity for a given crop and continued gene flow between crops and their wild relatives in these areas (FAO, 1996). Centers of origin are important sources of new variability Harlan (1969; Harlan, 1976) considered Ethiopia as a center of origin of many crops such as tef (*Eragrostis tef*), noog (*Guizotia abyssinica*), gesho (R*hamnus prinoides*), kosso (*Hagenia abyssinica*), enset (*Ensete ventricosum*), chat (*Catha edulis*), and buna (coffee) (*Coffea arabica*). Sorghum could be an Ethiopian origin (Harlan, 1969). Doggett (1970), however, considers that people of Caucasoid origin who migrated into Ethiopia through southern Asia domesticated sorghum from wild sorghum some 5,000 years ago in the Northeast quadrat of Africa.

1. 2. Threats of genetic Erosion

Because the whole process of genetic loss is referred to as genetic erosion (Hammer and Perinno, 1995), it is difficult to provide a specific estimation on an area level whereas in general the process can be demonstrated quite well by the loss of varieties and the increasing uniformity of modern agriculture. Of major concern is the irreversible loss of gene, the basic functional unit of inheritance and the primary source of variation in the appearance, characteristics, and behavior among plants (FAO, 1996). As far as sorghum is concerned, genetic erosion is progressive on account of extensive selection based on

breeding native populations (Tessema, 1986; Worede, 1991). The most important causes of genetic erosion are therefore, displacement of indigenous landraces by new, genetically uniform crop varieties; changes and development in agriculture or land use; destruction of habitat; drought and breeding appraoch (Worede and Hailu 1993; FAO, 1996).

1. 3. Genetic uniformity and genetic vulnerability

Genetic diversity is usually thought of as the amount of genetic variability among individuals of a variety, population or species. It is commonly believed that the genetic vulnerability results from the reduction of genetic variability. The loss of genetic diversity in agriculture reduces the genetic material available for use by present and future generations (Brown, 1983; Plucknett *et al.* 1983). Genetic vulnerability is the condition that results when a widely planted crop is uniformly susceptible to a pest, pathogen or environmental hazard as a result of its genetic constitution, thereby creating a potential for widespread crop losses (National Academy of Science, 1972).

2.Genetic Conservation strategies

2. 1. *In-situ* Conservation

In-situ conservation means, as defined in the Convention on Biological Diversity, the conservation of ecosystems and natural habitats and the maintenance and the recovery of viable populations of species in their natural surroundings, and in the case of domesticated or cultivated species, in the surroundings (on farm) where they have developed their distinctive properties (Oosterhout, 1994, Frankel *et al.* 1995; FAO, 1996). While recognition is given to the valuable role played by gene banks in the *ex-situ* conservation

of crop genetic resources, the need for attention to *in-situ* conservation is extremely urgent .

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2. 2. *ex-situ* conservation

It is understood that *ex-situ* (off-site) conservation has been a focus to conserve and maintain genetic diversity particularly in gene banks. However, *ex-situ* conservation has arrested the most complex interaction of genetically diverse traditional cultivated varieties (landraces) with their associated pests, predators, pathogens, wild and weedy relatives. The material preserved in gene banks (for future use) is separated from the ongoing evolution in the area, which resulted in so much new and useful variation (Hammer and Perinno, 1995). It also fails to retain traditional farmers knowledge associated with landraces, knowledge which can be instrumental in utilization and development of new crop varieties from farmers original landraces (Kebebew, 1997 a, b; Demissie *et al.*, 1997).

2. 3. coupling function of dynamic and static conservations

The model of evolutionary conservation should be coupled with a static conservation process allowing the distribution of the material maintained in the village (and in others) and then giving access to this material for the other potential users. The static conservation step could play a buffering role and could be a back up against some unpredictable evolution (Berthaud, 1997) and could also involve in the availability and use of germplasm for improvement of a variety of crops, though it does not provide a panacea for natural source of crop genetic resources (Hardon and Boef, 1994). In fact, if this system presents several advantages, it is not protected against rapid and local evolution of the rural societies involved. (Bechere *et al.*, 1997; Bechere and Tessema, 1997

Studies using ethnobotanical, agromorphological and biochemical methods need to be conducted to asses the role of farmers in maintaining the genetic variability of landraces. Teshome *et al.* (1997) used agromorphological characters to estimate the variation among the sorghum landraces in north Shewa and south Welo, Ethiopia. However, the genetic studies based on morphological data need to be assessed in relation to the biochemical and molecular aspects. Hence, this research project aimed to study sorghum landraces (*S bicolor* (L.) Moench) in North Shewa and South Welo, Ethiopia from the biological point of view using morphlogical and biochemical characters as they relate to farmers' knowledge generating information relevant for *in-situ* conservation (on-farm) in a dynamic system.

The present study was, hence, undertaken with the following objectives

General objective

. To study the magnitude of morphological and biochemical variation of sorghum in view of their

relationship with farmers' varieties, use values and frequency of occurrence.

Specific objective

. To study the relation between morphological and biochemical characters of the sorghum landraces

. To study the relation between morphological characters and the farmers' naming system for

landraces with their use values and frequency of occurrence

. To generate information that could be applied in future *in-situ* conservation activities;

. To survey and document indigenous knowledge that exists in the oral tradition

II. LITERATURE REVIEW

1. HISTORY, ORIGIN AND TAXONOMY OF SORGHUM

It was in the 60 to 70 AD that the first written description of sorghum was given and after that there was hardly any mention until the 16 th century (Doggett, 1970). The word sorghum and sorgo were used, in the early 1600s. In 1729 sorghum was used as a generic name, and the word dora was also used which led to the term durra. The generic name Holcus was then used in 17th century; when several species were described. For example, *H. dora*, *H. dochna* (see House, 1995). It was also known with the genus name sorghum and brought to be under the name S. bicolor by Koenicke in 1985 and Alefold in 1986, which was also known by Moench in 1794 to consist the cultivated sorghum (House, 1995). The most detailed classification of sorghum was made by Snowden (1936), of which many different taxa were identified, 28 cultivated forms were listed in subspecies bicolor, 7 weedy taxa in subspecies durumondi, and 13 wild taxa in subspecies arundinaceum (De Wet, 1978).

Sorghum bicolor (L.) Moench is immensely variable, and was subdivided by Garber (1950) into sections (Appendix 1): 1) Chaetosorghum, 2) Heterosorghum, 3) Parasorghum, 4) Sorgastrum (Eu-sorghum), and 5) Stiposorghum. Though the affinities among these sections are poorly understood, Clarier (1959) proposed that by excluding sorgastrum, a more similar genus sorghum is constituted. According to this proposal Sorgstrum Nash differs from the true sorghums in that the pedicillate spikelets are strongly reduced, often the pedicle.

1.1. Origin of the Sorghum Crop: Sorghum History in Relation to Ethiopia

De Wet *et al.* (1976) have presented a theory that sorghum developed in the southern Sudan-Chad region. However, it is not clear how this happened (Doggett, 1991). The cultivated sorghum (sub sp. *bicolor)* of today arose from the wild *Sorghum bicolor* sub sp. *arundinaceum*. The fact that the wild *Sorghum bicolor* is confined to Africa until recent historical times is certain that the crop was domesticated on the African continent (Figs. 1 & 2).

Phillips (1995) has suggested that the species of sorghum in Ethiopia fall into two distinct sections: parasorghum-comprises only wild plants and subsection arundinaceae of section sorghum, comprising the very great variety of freely interfertile diploid (2x = 20) forms of cultivated sorghum. Wild sorghum occurs in Ethiopia up to about 2300m above sea level. It is fairly common at 1500 – 1700m (Dogget, 1988) and shatter canes are most serious weed around 1700m in the central plateau where they are known as 'keelo' (the fool).

1.2. Sorghum domestication and distribution

Vavilov (1951) considered Ethiopia as a center of origin, but Harlan (1972) suggests that sorghum arose across a large area, where it was largely domesticated a number of times over a period of years.

Of all the other species divided by Snowden (1955), De Wet *et al.* (1976) demonstrated that hybridization among the four basic taxa of ssp. *arundinaceium*: *S. aethopicum, S.*

arundinaceum, S. verticillifluorum, S. virgatum can give rise to all the variability described by Snowden. These taxa were included in *S. bicolor* by De Wet and Huckaby (1967) for two reasons: first, they hybridize freely in nature whenever they are sympatric, and secondly, they cross readily with cultivated sorghums.

Cultivated sorghums were derived from sub sp. arundinaceum through domestication that initially took place in Africa. The wild races cross readily with all races of cultivated sorghum, and any one or all of the races could have been domesticated at different places, and even different time (Dogget, 1991). Snowden (1936) proposed and House (1995) revised that race arundinaceum gave rise to guinea sorghums, verticillifluorum to kafir, and race aethiopicum to both durra and bicolor sorghums.

All cultivated sorghum races: guinea, caudatum, and durra sorghum have certainly been derived from bicolor-like race (Figs. 1 & 2). Race kafir, being more or less isolated from the other races relatively recently, may have been domesticated independently from race verticillifluorum some from south of the equator.

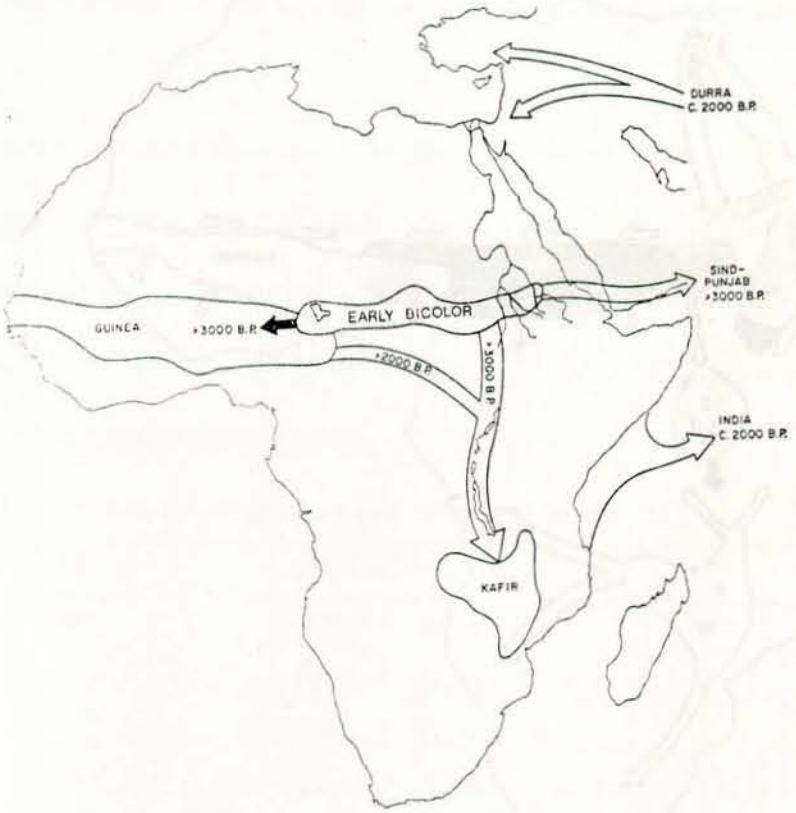

Figure 1. Suggested early movements of sorghum. Initial domestication in shaded area (see Harlan, 1992)

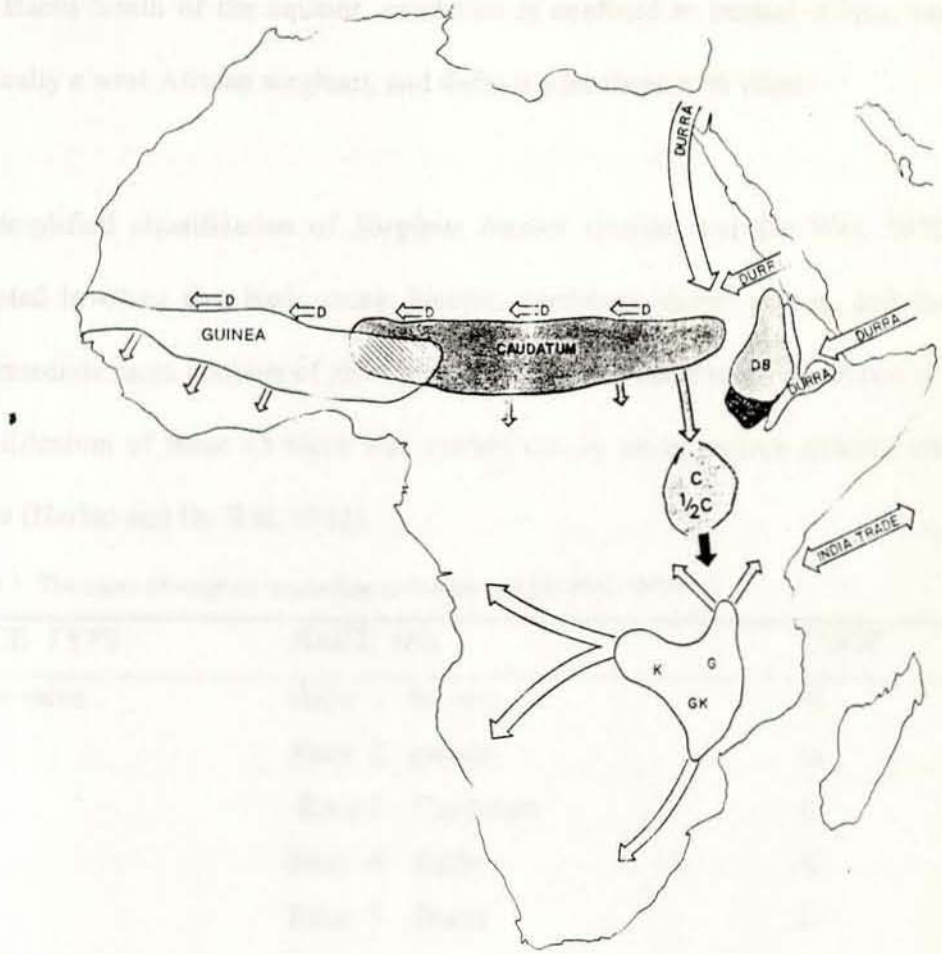

Figure 2. Suggested later movements of sorghum (Key legend: DB= Dura bicolor, C= Caudatoum, K= Kafir, G= Guinea, GK= Guinea kafir; see Harlan, 1992)

1.3.The races of sorghum in Africa

Man and his agricultural activities have contributed a lot for racial differentiation in sorghum. For example, as De Wet *et al.* (1976) have investigated, race kafir is grown by the Bantu South of the equator, caudatum is confined to central Africa, race guinea is basically a west African sorghum, and durra is associated with islam.

A simplified classification of *Sorghum bicolor* (Harlan and De Wet, 1972; Table 1), adopted involves five basic races: bicolor, caudatum, durra, guinea, and kafir; and ten intermediate races consists of all combinations of five basic races taken two at a time. The identification of these 15 races was carried out by using mature spikelet characteristics alone (Harlan and De Wet, 1972).

Table 1. The races of sorghum according to Harlan and De Wet (1972)

RACE TYPE	RACE NO.	CODE
Basic races	Race 1 bicolor	B
	Race 2 guinea	G
	Race 3 Caudatum	C
	Race 4 Kafir	K
	Race 5 Durra	D
Intermediate races:	Race 6 guinea-bicolor	GB
(all combinations	Race 7 Caudatum-bicolor	CB
of basic races)	Race 8 Kafir-bicolor	KB
	Race 9 Durra-bicolor	DB
	Race 10 Guinea-caudatum	GC
	Race 11 Guinea-Kafir	GK
	Race 12 Guinea-durra	GD
	Race 13 Kafir-caudatum	KC
	Race 14 Durra-caudatum	DC
	Race 15 Kafir-durra	KD

The ten intermediate varieties that are most commonly grown have combinations of characteristics derived from the main varieties such as intermediate races are frequently grown where two races are sympatric (De Wet, 1979; Phillips, 1995).

In the proposal of Harlan and De Wet (1972), the biological species, gene pool-1 (GP-1) would first be classified into two, one includes the cultivated and the other the spontaneous wild relative form (Table 2). According to Harlan (1992), a classification of cultivated plants doesn't require more than this.

Table 2. Primary and secondary gene pool of sorghum (Harlan, 1992)

1^0 gene pool (GP-1)					2^0 gene pool (GP-2)
Crop	Ploidy level	Cultivated species	Spontaneous species		
			Wild races	Weedy races	
Sorghum	2x	*Sorghum bicolor*	*S. bicolor*	*S. bicolor*	*S. halepense*

2. The economic importance of sorghum (Sorghum production and importance)

The world's cereal production according to Chantereau and Nicou, (1994) was accounted to be 1800 million tones, of which sorghum shares only 3.6 %. This account falls well short of the production figures for the world's four major cereals: wheat, rice, maize, and barley (Table 3). However, Sorghum in Africa stands second next to maize as the major cereal crop (Table 4).

FAO statistics for 1992 (FAO, 1962 – 1993) estimated that over 700 million hectares of the world's surface is laid down to cereal cultivation from which only about 6.4 % is covered by sorghum. Sorghum is indigenous to Africa (grown in semiarid zones) which include the large belt spreading from Atlantic to Ethiopia and Somalia, bordering the Sahara desert in the north and the Equatorial forest in the South and extending South wards through the drier regions of eastern and Southern Africa. The crop is, therefore, second in importance after maize in Africa South of the Sahara, and of disproportionate importance as a subsistance rather than a commercial crop (Dendy, 1995). Being fourth in importance among the world's cereals, coming after wheat, rice and maize (Doggett, 1970), sorghum is grown in the tropics and subtropics under a variety of names.

Table 3. Global cereal production according to Chantereau and Nicou (1994)

Cereal	Production in millions of tones	Percentage production
Wheat	509952	29.5
Rice	483466	28.0
Maize	405460	23.4
Barley	168423	9.7
Sorghum	61787	3.6
Oats	38848	2.3
Millet	37536	1.8
Rye	29617	1.7

Table 4. Relative production (importance of cereals in Africa) (from Chantereau and Nicou, 1994)

Cereals	Production in millions of tones	% production
Maize	30313	35
Sorghum	15280	17
Wheat	13630	16
Millet	13330	15
Rice	9470	11
Barley	5570	6
Oats	190	0
Rye	5	0

2.1.Uses of Sorghum in terms of its nutritional value

Sorghum is a staple food for about 300 million people who live in dry tropics (De Wet, 1979). Sorghum in addition to providing grains for human consumption, the leaves and stems are also used as fodder, building materials and as fuel for cooking. Considerable level of production of sorghum in each country, without reaching commercial market, is destined for local consumption. In the industrial country it is generally used as an animal feed (Chantereau and Nicou, 1994). Sorghum grain is an energy-providing food for its high starch content (Hulse *et al.*, 1980). In some varieties, however, the presence of organic compounds, such as tannin, can decrease the nutritional value due to the formation of tannin-protein complex, which cannot readily be assimilated by the digestive system. Hence, sorghum nutritional quality, in general, is poor (Pant, 1975) and this is related to its low lysine content (Hulse, 1980). Brhane and Yilma (1979) reported that the nutritional high lysine and high protein sorghums are restricted to Ethiopian durras which is highly

diversified in North Shewa and South Welo regions of Ethiopia (Teshome *et al.*, 1997). Initially, high lysine was found in two sorghum accessions from Ethiopia, 1S 11167 and 1S 11758, in which lysine content as percentage of sample was nearly twice that of normal (Axtell *et al.*, 1974; Ejeta and Axtell, 1990).

2. 2. Traditional uses of sorghum for human consumption

Three main categories of food uses of sorghum (Table 5) are commonly taken into account, though they differ from country to country (Chantereau and Nicou, 1994). The traditional foods and drinks mentioned below which are of commercial versions are mainly destined for urban markets (Dendy, 1995).

Table 5 . Categories of traditional uses of sorghum in different countries (Chantereau and Nicou, 1994).

Categories	Specific type	Method of preparation	Locally available type	Countries of production
1. Boiled or Ground grains		Boiling or grinding		China India
2. Porridge or Thick gruel	• Thick gruel	Decortication or milling • Non fermented flour	• Ugali • To • Sankati	East Africa West Africa India
	• Clear gruel	• Fermented	• Ugi • Ogi • Bogobe	East Africa Nigeria and Ghana Botswana
	• Pancakes and flat bread	• Non-fermented dough	• Roti • Waina	India Nigeria

		• Fermented dough	• Injera • Kisra	Ethiopia India
	• Couscous		• Couscous	West Africa
	• Doughnut		• Tubani or ganda	Nigeeria
3. Drinks	• Non-alcoholic drinks	• Non-fermented	• Fura	Nigeria Burkinafaso
			• Bussa • Abrey	Uganda Sudan
	Alcoholic drinks (local fermented)	Local fermented (beer)	• Dolo • Opaque beer • Kafir type of beer • Wine	West Africa Bantu South Africa China

2. 2. 1. Traditional products

Milling, decortication and separation of the husk and the germ are necessary based on traditional uses. With tannin-rich sorghum, prior decortication is preferable to direct milling, ensuring the complete removal of the brown outer coat with a formation of a more digestible material (Chantereou and Nicou, 1994).

Sorghum flours are fermented and used to make a wide range of pancakes, in India and Africa. Fermented bread of sorghum are extremely popular in Ethiopia (Chantereou and Nicou, 1994). The most common and simplest food prepared from sorghum is porridge.

Thick porridges are consumed in all countries where sorghum is cultivated for food (Murty and Kumar, 1995).

2. 2. 2. Beers from sorghum

Barley being primarily grown in temperate regions of the world without thriving well in tropical and sub tropical climatic conditions, is the traditional material for producing lager beer. Sorghum, in contrast to barley, is indigenous to and grows well in semi-arid-tropics. Sorghum is also used in the lager brewing process as malt or as adjunct (Hallgren, 1995). In addition, sorghum is known to have been involved in malting purpose for use of African opaque beer. The major asset of a good sorghum malt for this kind of beer is a high diastatic power, since the mash consists mainly of adjunct which has to be converted (Nout and Davies, 1982; Daiber, 1988).

3. AGRONOMIC PRINCIPLES

3.1. Germplasm resources

Sorghum and millets germplasm collections, which provided a genetic base for breeders to diversify their breeding stocks, have been the responsibility of the International Crop Research Institute for the Semi-Arid-Tropics (ICRISAT). IPGRI (1993) report shows that the number of accession of sorghum and millets genetic resources conserved in the CGIAR system in ICRISAT was 32890 and 29001, respectively. These collections have been widely used in sorghum improvement programs in both the temperate and tropical zones and also made it possible to breed for resistance to biotic and abiotic stresses (House *et al.*, 1995).

4. GENTICS OF SORGHUM GRAIN CHARACTERISTIC

4. 1. Tannins

Tannins, the presence of which is determined by a pair of complementary genes B1 and B2 (House *et al.*, 1995). High tannin is the primary nutrient limiting component in sorghum grain. Tannin was thought to be bound with endosperm proteins, reducing their biological value (House *et al.*, 1995). More recent observation indicates that the primary antinutritional effect is the inhibition of metabolism of digested and absorbed nutrients, especially proteins (Ejeta *et al.*, 1989). High tannin sorghums have been cultivated in the world where birds are of serious problems.

5. CONSTRAINTS OF SORGHUM

5. 1. Insect pest and Sorghum Diseases in Ethiopia

In Ethiopia Sorghum is cultivated under a wider range of environment, which incorporates low lands, middle highlands, and highlands each of which constitutes one or two agroecosystems in which one or more insects hold key positions as pests of economic importance. According to Megenasa (1982), stalk borers, sorghum shoot flys, African bullworms, sorghum head legus, aphids, and sorghum midges are the more generally recognized forms of insect pests of sorghum in Ethiopia. For further information, see also Teodros (1981); Doggott (1970).

A wide range of pathogens affects sorghum, partly because of the broad diversity of environments in which it is cultivated. Major and minor diseases assessments of sorghum

have been undertaken mainly at Ethiopian Sorghum Improvement Project Stations (ESIPS) in Ethiopia (Hulluka, 1982). The reports from these assessments have revealed that grain diseases, leave diseases, and charcoal rot as the only stalk disease were commonly observed in different parts of the country. For detail information the reader may need to refer to Hulluka (1982); ICRISAT (1978); Hulluka (1973).

The sorghum diseases of economic importance are listed in terms of global climatic zones. Sooty stripe; anthracnose; charcoal rot; loose smut; covered smut; grain mildew are the major diseases in West Africa: (Chantereau and Nicou, 1994).

5. 2. Witchweed (*Striga spp.*)

Teferedegn and Fessehaie (1982) have studied the effect of the world most important species of the genus *Striga* on Ethiopian Sorghum. As a result, three species of genus *Striga*: *S. hermonthica* (Del.) Benth, *S. asiatica* (L.) Kuntze, and *S. latercea* Vatke have been identified to exist in Ethiopia. The same study has also shown that *S. hermonthica* is the most wide spread and sorghum damaging species, occurring, especially in the Northern regions of Ethiopia including the current study area.

6. Morphology of sorghum

De Wet (1979) insisted that the morphology of sorghum is complex. Five basic cultivated races: bicolor, caudatum, durra, kafir, and guinea are recognized that are included in *S. bicolor*. Wild and weedy taxa are grouped morphologically into one to such extent (De Wet, 1979) that they are combined into subsp. *arundinacaeum* Desv. (Stemler *et al.*, 1977).

The sorghum grain is a caryopsis composed of three main parts: the pericarp (outer layer), endosperm (food reserve tissue), and the embryo (germ). The thickness of the outer layer is variable in different varieties and is an important factor for decortication and milling. Between the pericarp and the endosperm is normally located the testa, a highly pigmented brown layer rich in tannin compound (Chantereou and Nicou, 1994).

7. Genetic diversity study

The use of morphological, biochemical, and molecular markers (Bekele, 1983; Demissie and Bojornstad, 1996; Ayana and Bekele, 1998) and ethnobotanical studies (Altieri and Merric, 1986; Asfaw, 1990; Teshome *et al.*, 1997, 1999 a, b) has been greatly implemented to study the genetic diversity and the structure of species of interest.

7. 1. Morphological markers

Among the earliest genetic markers used in scientific investigations and are still in use in germplasm management were the qualitative morphological traits such as leaf color, glume color, glume hairiness, grain color, grain covering, grain form, panicle compactness and shape, endosperm texture, presence and absence of awns (Bretting and Widerlechner, 1995). The determination of centers of diversity by Vavilov for various species were based on an extensive field studies and observation of phenotypic traits.

It has been possible to analyze and describe the variation in *Sorghum bicolor* (L.) Moench, to asses the relationship of all its subspecies and some species in section sorghum through the application of multivariate methods. Recent study undertaken in Ethiopia on the crop using multivariate analysis of the qualitative charactors revealed that *Sorghum bicolor* shows great morphological variation, especially in the panicle characters, while the grain

forms are much less variable (Ayana and Bekele, 1998). Such wide spectrum of variation is purely attributed to geographical separation and human selection. The differential distribution of different panicle types indicated the adaptive significance of panicle compactness and shape (Stemler *et al.*, 1975; Parasada and Mengesha, 1981; and Ayana and Bekele, 1998) and at the same time reflected the distribution pattern of different races of sorghum in Ethiopia (Harlan and De Wet, 1972; Acheampong *et al.*, 1984).

The study of genetic diversity using morphological traits that is of interest for breeders are extremely important to speed up the breeding programs. These morphological traits are easy to score, quick and simple to evaluate, frequently without requiring high levels of technical skill unlike biochemical or molecular markers (Teshome *et al.*, 1997). Morphological traits, however, have got their own shortcomings that many of the traits are polygenic and are influenced by environment, the phenotypes of which can only be determined at the whole plant level; allele frequencies at morphological markers are much lower; alleles at morphological loci in a dominant recessive manner that limits the identification of heterozygous genotypes, and require growing of plants to suitable stages before certain characters can be scored (Powell, 1992; Seifu, 1997).

7. 3. Biochemical Marker

Protein electrophoresis is one of the earliest molecular techniques ever utilized effectively in the study of population genetics, molecular systematic, and evolution (Wendel and Weeden, 1990; Harris, 1994). And the most commonly used biochemical markers are isozymes (Wendel and Weeden, 1990). The term isozyme and allozyme are often used synonymously in enzyme studies. However, they do have subtly different meanings. An isozyme is any of more than one form of the same enzyme (having identical or similar

functions, but differing with electrophoretic mobility) encoded by different gene loci, while an allozyme is any of more than one variant of an enzyme encoded by different alleles of the same gene locus (Markert and Moller, 1959; Harris, 1994). Isozymes are revealed when tissue extracts are subjected to electrophoresis in different types of gels and subsquently immersed in solutions containing enzyme specific histochemical stains. The majority of plant based studies with electrophoretic separation of complex mixtures of proteins have used two types of gel matrix including polyacrylamide gel electrophoresis (PAGE) and starch gel electrophoresis (SGE) (Harris, 1994). Isoelectric focussing (IEF) is a further protein electrophoretic technique with a high resolution (Radola, 1980). Polyacrylamide and starch, are inert, withstand high voltage assays necessary for the resolution of enzyme bands and can be used at variable concentrations to vary the sieving effect (Harris, 1994). SGE, however, has been most widely used, whilst PAGE and IEF tend to give clearer band resolution with wider range of pore size than SGE, it is specifically associated with the toxicity of the reagents used (that SGE doesn't involve the use of toxic material), the high cost and the low number of sample sizes that can be analyzed at one time (Wendel and Weeden, 1990; Powell, 1992; and Harris, 1994). Further more, SGE system can be easily replicated to allow the simultaneous evaluation of a range of enzyme system (Hayward *et al.*, 1995). Its low cost, effective applicability to a wide range of organisms and well developed methods of data interpretation and analysis are some of the important advantages of protein electrophoretic system (Wendel and Weeden, 1990; Harris, 1994; Hayward *et al.*, 1995).

Allozymic polymorphism, allelic variation at isozyme loci, has been used in plants to evaluate genetic processes at each stage of the life cycle and to assure genetic diversity in all major crops and many other species (Wendel and Weeden, 1990). Isozymes provide a

distinct and simple method for characterization of genetic variation and are applicable to many differing forms of genetic studies that ranges from the description of comparative levels of variability that occur in natural populations through to detailed measurement of linkage relationships in the plant genomes (Hayward *et al.*, 1995). The significance of isozyme as genetic markers for the characterization of the variability in germplasm collections is widely recognized (Brown, 1978; Hayward *et al.*, 1995; Rottenberg *et al.*, 1995) and they have been applied for this purpose in several survey of variation in the genus Sorghum (Morden *et al.*, 1989; Morden *et al.*, 1990; Aldrich *et al.*, 1992; Dje *et al.*, 1998; and Dje *et al.*, 1999). Isozymes as qualitative markers are determined by single genes and have been assayed frequently for their relative high number rapidity, and general capacity to be unaffected by growing conditions (Seifu, 1997).

7. 2. Ethnobotanical studies

Many workers have defined ethnobotany as an interdiscipilinary and multidisciplinary science for documentation, analysis and making effective use of the knowledge that traditional people have accumulated during their extensive interaction with plants (eg. Asfaw, 1990).

In Ethiopia, as in many other developing countries, farmers play a central role in conservation of germplasm as they hold the bulk of the existing genetic resources. Peasant farmers almost always retain some seed stock for security. As Worede (1991) indicated, Ethiopian farmers have also played a key role in the creation, maintenance, and promotion of crop genetic diversity through practice, developed through centuries, to sustain crop productivity. Teshome *et al.* (1997, 1999a, b) and Ramphuth *et al.*, 1999) strongly

underlined the critical role of traditional farmers in the maintenance of sorghum landrace diversity in North Shewa and South Welo regions of Ethiopia. Blake (1994) also pointed out that the knowledge that exists among farmers, especially those that can not read or write, is housed in their heads. It is used repeatedly and transmitted to the young clan members and / or others closely related to the immediate community. Farmers are also aware of differences among landraces in different traits. The folk classifications in species and landraces experienced by farmers have also been pointed out. For example Asfaw (1990) has studied the intraspecific classification of landraces and the oral tradition that exists (on barley) in Ethiopia. The role of farmers in domestication, maintenance, and the use of traditional crops in Akamba, has been thoroughly evaluated by Nzou (1994). These farmers have seen the values of indigenous plants and have collected their seeds for planting. However, Nzou (1994) has forwarded a conclusive remark that these farmers should be provided with more mechanical knowledge how to grow indigenous plants. Hence to get at this information, it needs first establishing an information system, which would be taken out of the community, analyzed and interpreted so that it would be safe to document indigenous knowledge and bring farmers traditional practice to the realm of science.

Therefore, studies using ethnobotanic method in particular need to be conducted to asses the role of farmers in maintaining the genetic variability of landraces and to estimate the level of these genetic variability.

III. MATERIALS AND METHODS

1. MORPHOLOGICAL STUDY

1. 1. Description of study area

The study area is located in the North Shewa and South Welo regions of the central highlands of the West of the great East Africa Rift valley. North Shewa and South Welo are two of the seven administrative zones of Amhara National Regional State (ANRS) located north east of Addis Ababa within about $8^0$58'N to $12^0$30'N and $37^0$34'E to $44^0$48'E (Fig. 3). These are part of the semi-arid regions of Ethiopia characterized by the conditions of continous or intermittent drought that results from low and uncertain rainfall with characteristics high temperature. Altitudinal variation ranges from 1,200 to 2,400 meters (Teshome *et al.*, 1997) and the amount of organic content, pH level of the soil and soil texture vary across ecological gradient. These diversified ecological conditions favour the evolutionary potential of a wide range of landraces with a broad-based genetic resource. The local farmers play a major role in creating, maintaining and selecting these landraces that satisfy their changing needs. Because the regions are provided with insufficient amount of annual rainfall, most of the crops grown are drought resistant. Many crops are also known to resist other stresses such as disease, pest, and birds. Of all these, sorghum landraces account a major share. For example, Teshome (1997) has identified about 60 landraces of sorghum in the regions that may be showen as resistant under various stress factors. Hence, the area is one of the important sorghum growing regions of Ethiopia. The farmers habit to cultivate crops in the area, is to grow seeds by brodcasting over the prepared fields and plough into the soil to facilitate germination and seedling emergence. Sorghum is grown by small farmers to meet their needs for food, income, brewing, and construction purposes.

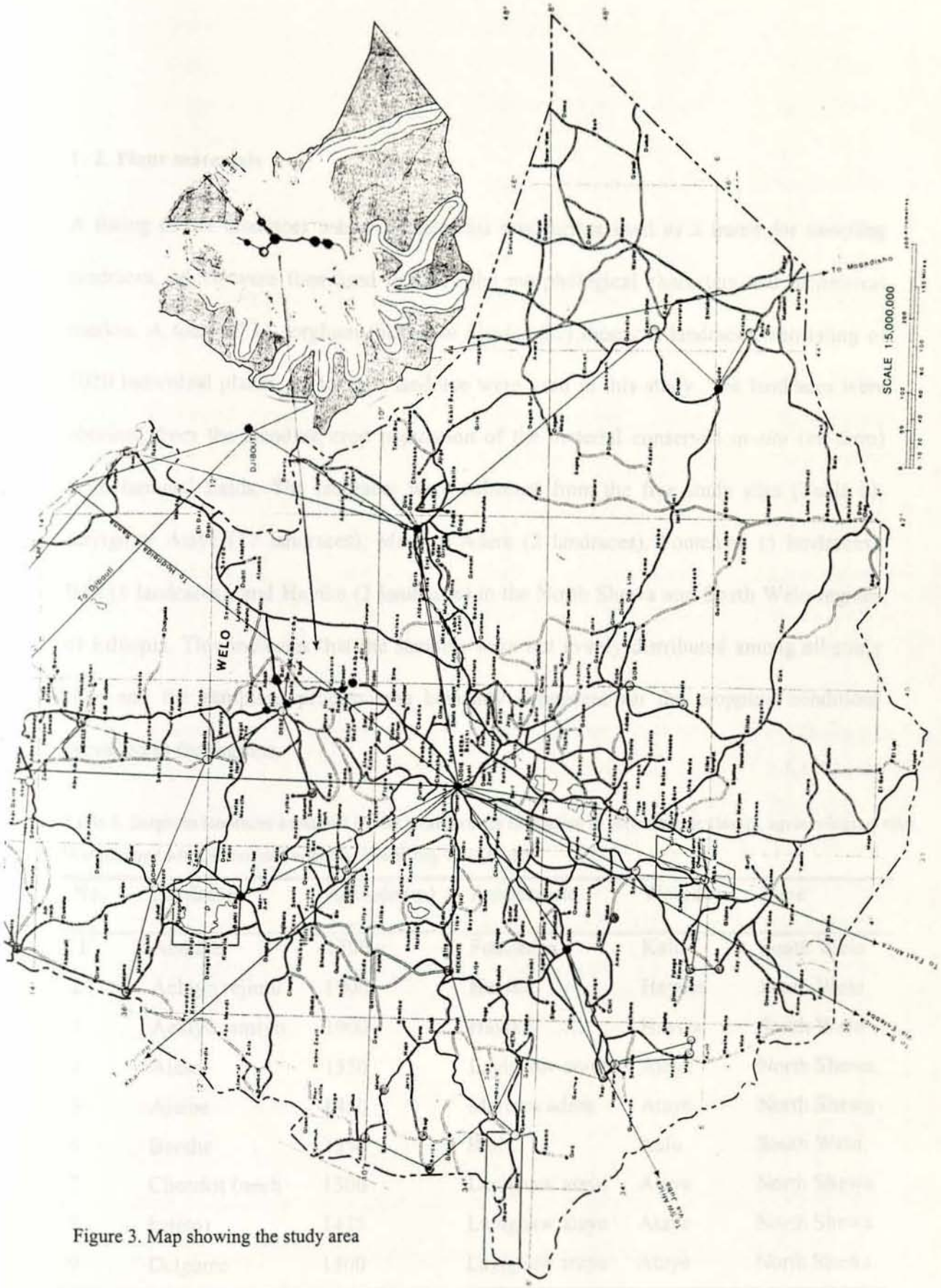

Figure 3. Map showing the study area

1. 2. Plant materials

A listing of the landraces was made and this was further used as a frame for sampling landraces, which were then used to study the morphological characters and bichemical markes. A total of 34 sorghum (*Sorghum bicolor* (L.) moench) landraces, consisting of 1020 individual plants, 30 in each landrace were used in this study. The landraces were obtained from the standing crop population of the material conserved *in-situ* (on-farm) from farmers' fields. The landraces were collected from the five study sites (Table 6): Layignaw Ataye (17 landraces), Merewa Adere (2 landraces), Fontenina (5 landraces), Bati (8 landraces), and Hayike (2 landraces) in the North Shewa and South Welo regions of Ethiopia. This indicates that the samples were not evenly distributed among all study sites and the sampling process was basically dependent on the cropping conditions prevailed in the regions.

Table 6. Sorghum landraces as named by the local farmers in relation to their altitude classes, agroecological sites, Woredas and administrational zones in which they were found

No.	Landraces	Altitude (m)	Agroecosite	Woreda	Zone
1	Abduke	1700	Fontenina	Kalu	South Welo
2	Aehiyo rejimu	1900	Hayike	Hayike	South Welo
3	Aehiyo jamiyo	1900	Hayike	Hayike	South Welo
4	Afeso	1550	Layignaw ataye	Ataye	North Shewa
5	Ajaibe	1450	Merewa adere	Ataye	North Shewa
6	Borshe	1550	Bati	Kalu	South Welo
7	Cherekit (nech	1500	Layignaw ataye	Ataye	North Shewa
8	keteto)	1475	Layignaw ataye	Ataye	North Shewa
9	Delgome	1500	Layignaw ataye	Ataye	North Shewa

10	Dimete	1500	Layignaw ataye	Ataye	North Shewa
11	Dobe	1700	Fontenina	Kalu	South Welo
12	Esmaeli	1450	Merewa adere	Ataye	North Shewa
13	Gan-seber	1450	Fontenina	Kalu	South Welo
14	Gorad	1475	Layignaw ataye	Ataye	North Shewa
15	Gorad tinkish	1700	Layignaw ataye	Ataye	North Shewa
16	Goronjo	1500	Bati	Kalu	South Welo
17	Jamo (jamuye)	1475	Layignaw ataye	Ataye	North Shewa
18	Jemaw	1500	Layignaw ataye	Ataye	North Shewa
19	Jirru	1400	Bati	Kalu	South Welo
20	Key ihil (serina)	1500	Layignaw ataye	Ataye	North Shewa
21	Key keteto	1500	Layignaw ataye	Ataye	North Shewa
22	Merabete	1700	Fontenina	Kalu	South Welo
23	Mognayawikish	1400	Bati	Kalu	South Welo
24	Mokake	1400	Bati	Kalu	South Welo
25	Nech tinkish	1400	Bati	Kalu	South Welo
26	Rayo	1400	Bati	Kalu	South Welo
27	Tengeley	1450	Fontenina	Kalu	South Welo
28	Tuba	1500	Layignaw ataye	Ataye	North Shewa
29	Watigela	1500	Layignaw ataye	Ataye	North Shewa
30	Wefayibelash	1500	Layignaw ataye	Ataye	North Shewa
31	Wegere	1700	Layignaw ataye	Ataye	North Shewa
32	Wincho	1500	Layignaw atay	Ataye	North Shewa
33	Yikirmindaye	1550	Bati	Kalu	South Welo
34	Yikirsolate Zengada	1500	Layignaw ataye	Ataye	North Shewa

1. 3. Agromorphological traits

A collection of landraces of sorghum were evaluated *in-situ* for their agromorphological characters in farmers fields at individual farmer and group of farmers level (Table 7). The characterization of the landraces for certain traits on farm was based on the farmers'

indigenous knowledge. However, for the entire characterization activities, sorghum descriptor (IPGRI, 1993), color chart and visual examination using a 10x magnifying lens were used. Depending on the sorghum cropping conditions prevailed in the environment, the sample size collected from different ecosites (study sites) was different (Table 6). From all ecosites, altogether, 34 landraces of sorghum were collected. Codes and descriptions for all classifying are given in Appendix 10. For each landrace, 30 samples (panicles) from randomly selected fields were collected and measured for their agromorphological traits.

A total of 14 qualitative characters for each entry were used for this analysis. They all include morphological characters (Table 7). All of the morphological data were obtained on the sample collected from the living plants found in the farmers' field. Each entry was scored for these morphological characters either in the field or by taking a random sample of 30 panicle per entry. Characters like presence and absence of awns stem juiciness, juice flavor (taste), midrib color, and shape of panicle were scored in the field. All the panicles (influoresece) characters were scored from panicle sample taken from the field.

Table 7. The Qualitative characters of Sorghum (*S. bicolor* (L.) Moench) landraces scored in North Shewa and South Welo regions of Ethiopia (IPGRI, 1993).

Characters	Code	Description (character states)
1. Awn	1	Present
	2	Absent
2. Endosperm texture	1	Completely corneous
	3	Mostly corneous
	5	Intermediate
	7	Mostly starchy
	9	Completely starchy

3. Glume color	1	White
	2	Senna (yellow group)
	3	Mahogany (greyed-orange)
	4	Red
	5	Purple
	6	Black
	7	Grey
4. Glume hairness	1	Hairness
	2	Middle
	3	Hairless
5. Grain color	1	White
	2	Yellow
	3	Red
	4	Brown
	5	Buff (greyed-orange)
	6	White orange
6. Grain covering	3	25% grain covered
	5	50% grain covered
	7	75% grain covered
	9	Grain fully covered
7. Grain form	1	Single
	2	Twin
8. Grain plumpness	3	Dimple
	7	Plump
9. Inflorescence compactness and shape	3	Very loose dropping primary branches
	6	Semi-loose ereect primary branches
	8	Semi-compact elliptic

	9	Compact elliptic
	10	Compact oval
	11	Half broom corn
10. Juice flavor	1	Sweet
	2	Insipid
	3	Nil
11. Leaf midrib color	1	White
	2	Dull green
	3	Yellow
	4	Brown
	5	Purple
12. Panicle shape	1	Erect
	2	Recurved
13. Stalk juiciness	1	Non-juicy
	2	Juicy
14. Threshability	1	Threshable
	2	Non trushable

2. ISOZYME STUDY

Isozyme analysis was carried out on the thirty-four landraces of Sorghum (*S. bicolor* (L.) Moench) landraces randomly selected from the five representative agroecosites in the North Shewa and South Welo regions of Ethiopia. Seeds were germinated from all landraces and Morden *et al.* (1987; 1989) electrophoretic procedure was followed. After survey of the four and seven days old leaf for better resolution, 7 days old leaves were used for continuos extractions. Crude extracts for electrophoresis were prepared by homogenizing the etiolated leaves in 2 to 4 drops of extraction buffer (Morden et al., 1987): 2- mercaptoethanol (0.014M), Na_2HPo_4-(42.3 mM), EDTA-disulfide (1. 55 mM), adjusted to pH 7.5 with NaOH and double distilled H_2O to 100ml). Homogenized extractions were kept on crushed ice and absorbed onto paper wicks (2 mm x 11 mm, Whatman 3 MM chromatography paper). Samples were immediately loaded to run the horizontal electrophoresis that was carried out in 12 % starch (Connaought starch) gels (Wendel and Weeden, 1990).

Electrode buffer: Electrophoresis of enzymes was carried out using 0.135mTris (Morden *et al.*, 1987, 1989) adjusted with citric acid to pH 7.0.

Gel buffer systems: 1 part of electrode buffer : 14 part of water (distilled) was used as the gel buffer.

Preparing and Running gel: Gel was prepared by using 64 gm of dry starch with a total of 500ml gel buffer (Morden *et al.*, 1987). Three-fourth of the gel buffers (375ml) was poured into an Erlenmeyer flask and heated in a microwave oven (600 to 700 watts) until the buffer boils (4.5 to 5.5 minutes). The remaining buffer (125ml) was mixed with the

starch (64 gm) and swirled until the starch was completely suspended. The starch suspension and boiling buffer were the combined, vigorously swirled until thoroughly mixed, returned to the microwave oven, and heated for about a minute (until boiling). The heated starch suspension was degassed with a water aspirator and poured into the gel tray. The gel was allowed to cool to room temperature (about 1 hr).

Before loading the samples, the gel was cooled in a refrigerator (+ 4 ^{0}C) for 15 minutes to increase repeatability electrophoresis and to prevent heat denaturation of the enzymes. Samples were placed in racks and kept chilled on ice while loading the gel. The loaded gel was run at a constant electrical voltage (300V and 100A for 3: 30hr) (Morde *et al.*, 1987). All electrophoresis were carried out in a cold chamber at 4^{0}C.

Staining gel: Following electrophoresis, the gels were trimmed and the slab anodal to the origin was sliced and stained for enzymatic activity by applying standered histochemical methods. Two enzyme systems **EST** and **ACP** were used.for staining.following Morden *et al.* (1987) procedure.

Staining recipes: Esterase: 0.2gm fast blue RR salt was dissolved in 98ml of distilled water and the substrates (1.5 ml 1% ∝-naphtyl acetate and 0.5ml 1% β-naphthyl actate) were added just before staining gels. After it was stained for about an hour at room temperature, it was rinsed with distilled water and fixed in 10% acetic acid.

Acid Phosphatase: 0.1gm fast blue garnet GBC salt was dissolved in 92.5ml of distilled water and 0.5ml 10% $MgCL_2$ 5ml 1M sodium acetate buffer (1M glacial acetic acid, pH was adjusted with NaOH) and the substrates (2ml 1% ∝-naphtyl acid phosphate) were

added just prior to staining. Then it was rinsed and fixed after staining (at room temperature). After staining, the band observed was only anodal.

3. Ethnobotanical study

3. 1. Farmers perceptions

The method for gathering important information related to diversity in sorghum (*Sorghum bicolor* (L.) moench) in North Shewa and South Welo regions and farmers knowledge toward agromorphological traits was based on exercises during site selection, outcomes of the existing diversity and baseline survey. The procedure therefore, consists of combined steps of having frequent field visits, informal and formal interviews with farmers, group discussions, and meetings among farmers, among IBCR team, among IPGRI representatives, and research advisors.

Basic data on farmers' perceptions about the agromorphological traits distinguishing sorghum landraces, cultural values, and preferred traits of the landraces were collected (Table 6, 7 & Appendix 3 & 4). Based on these characteristics, checklist (Appendix 7 & 9) was prepared and validated in the field with key informants (farmers). Similarly, a list of local varieties of sorghum landraces called by different names as perceived by the farmers' folk nomenclature was prepared before evaluating the varieties on farm (Table 6).

3. 2. Frequency (diversity) of Sorghum (*S. bicolor* (L.) Moench) landraces

3. 2. 1. Measuring sorghum landraces diversity in terms of environmental variability.

Data was collected from 100 randomly selected farmer's fields in North Shewa and South Welo regions of Ethiopia. The altitude and size of each of farm (plot) were used as

classifying variables. At five meters interval along transect lines that was spaced ten meters apart over the whole size of each farm, sorghum landraces were recorded (tallied) as identified and named by the farmer (the owner of the farm). The farmer's selection criteria were also recorded in each farm by asking why he/she decided to grow each landrace identified. The same method was also used by Teshome *et al.*, (1999a, b) for the same crop to measure environmental variables and farmers' selection criteria in these regions.

3. 3. Use values of the Sorghum *(S. bicolor* (L.) Moench) landraces in North Shewa and South Welo

Ethnobotanical data collection on the use values of the thirty-four sorghum landraces (landraces) was undertaken in the five agroecosite in North Shewa and South Welo. The plots were randomly selected at each agroecosite and the informants (the owner of the plots) were asked what they know about the uses of each identified sorghum landrace. However, the distribution of the plots selected in each agroecosite was based on the farming conditions available then. We use such method because many other workers have already adopted it. Fore example, Adu- Tutu *et al.* (1979) and Jons and Kimanani (1990) used an informant with a single event about the same plant and Phillips and Gentry (1993 a, b) dealt with an informant interviewed more than one time about the same plant. The data was collected by interviewing a total of thirty informants who were randomly selected from the local people. Totally, data in 138 independent "events" were recorded. An event, as defined by Phillips and Gentry (1993a, b), is the process of asking one informant on one day about the uses they know for one landrace (in our case). An informant was asked only once about one landrace in a plot. Similarly, Adu-Tutu *et al.* (1979) and Johns and

Kimanani (1990) have conducted their study without re-interviewing the same informants about the same plant. The responses given separately by each informant from all over the plots in all agroecosites were simply combined and divided by the total number of informants. Informants were interviewed individually, to minimize the possibility that one informant's responses directly influence another's. The data- gathering process was informally undertaken when the informants had free time and by compensating for their time and for their information with the reasonable monetary value as an incentives. The process of data- gathering was also trying to work with representative samples of the local people (farmers) of all productive ages and of both sexes.

4. DATA ANALYSIS

A set of binary or dummy (0/1) variable was created for the ordinal variable and entered into the SPSS V. 7.5 Microsoft package. Twenty-six significant functions out of 33 were selected and transferred into MINITAB Computer program (MINITAB 98') for clustering of the sorghum landraces. Hierarchical agglomerative clustering was performed based on the functions obtained from Discriminat Analysis using Squared Equilidian Distance, Avarage Linkage critera .

4.1. Canonical Discriminant Analysis.

Canonical variables corresponding to the final clustering were used for graphical representation. The first three significant canonical functions were used in the analysis.

Stepwise discriminate analysis (SDA) on the basis of agroecological sites (Appendix 2) was performed to determine whether these variables influence the assortment of sorghum variability in a multivariate sense. Such analysis was already carried out for lentil to test

the effect of origin on the assortment of crop variability (Erskine *et al.*, 1989: Teshome *et al.*, 1997). The SDA was undertaken using the program (SPSS V. 7.5 Microsoft Package). Characters for inclusion were selected among the 34 morphological characters used as group criteria in clustering of the 34 landraces in accordance with the order of importance to minimize Wilk's lambda between groups. The ranking of the characters was made possible using an approximate F-ratio which provided a test of significance of Mahalanobis distance between group centeroid. The magnitude of the F-value from canonical Discriminant Analysis were instrumental in ranking the phenotypic characters most important in naming sorghum landraces by farmers (Teshome *et al.*, 1997).

4. 2. Estimates of diversity study

The phenotypic frequency data of the fourteen characters were analyzed by the Shannon – Weaver diversity index, H', given as:

$$H' = - \sum_{i=1}^{k} Pi \log_e Pi$$

where k is the number of phenotypic classes for a character and Pi is the proportion of the total number of entries (N) in the i^{th} class. H' was estimated for each character, altitude classes, zone, woreda, and agroecosites which were used as classifying variables. The region was divided into two administrational zones for further analysis based on the administrative delimitation of the Amahra National Regional State. Within these zones the three woredas: (Ataye, Hayike and Kalu,) were used as the second classifying variable on a similar basis as zones. The altitude range was arbitrarily classified into four altitude classes, viz., < 1500, 1500 – 1650, 1651 – 1800, and > 1800 msl (Table, 6) based on the work of Teshome *et al.* (1997, 1999 a, b). The five agroecological sites: Merewa adere

(near Senbete; 263 km from A. A.), Layignaw ataye (near Ataye or Efeson; 269 km from A. A.), Fontenina (near Kombolcha; 360 km from A. A.), Bati area (near Bati; 395 km from A. A.), and Hayike area (near Hayike; 433 km from A. A.) were used for the diversity analysis and the selection of the sites was also basd on the work of Teshome (1997). Each value of H' was divided by its maximum value, $\log_e k$, in order to keep the value in the range of 0–1. Shannon diversity index was previously used to determine the range of variation in sorghum (Ayana and Bekele, 1998), in several other crop species including wheat (Negassa, 1986; Bekele, 1996) and barley (Tolbert *et al.*, 1979; Bekele, 1983; Negassa, 1985; and Demissie and Bojorinstad, 1996). A one way analysis of variance of non-transformed H' was performed for character using zones, woredas, agroecological sites, and altitude groups as classifying variables (Table 13). These variables were treated as fixed effects, and landraces as randon (Demissie and Bojorinstad, 1996). The hierarchical analysis of variance of diversity pooled over characters was done on the absolute values of H' (Table 14).

The χ^2 anlysis was carried out to test deviation from the overall mean of all the characters using procedures in M-stat software packages for geographical zones, woredas, altitude classes, and agroecological sites.

3. 3. Estimates of the use values

The estimate of the use value of each landraces for each informant i is, UV*is* (Phillips and Gentry, 1993a), is defined as:

$$UVis = \frac{\sum Uis}{nis}$$

U*is* equals the number of uses mentioned in each event by informant *i*, and n*is* equals the number of events for landraces with informant *i*.

The estimate of the overall use values for each landrace *s*, UV*is*, is then:

$$UVs = \frac{\sum i\, Uis}{ns}$$

IV. RESULT

1. Morphological study

1. 1. Altitudinal distribution of characters

The frequency distribution for the fourteen qualitative characters by altitude, ecosites, woredas , and zones respectively are presented in Tables 8-11. χ^2 values were also presented to see the extent of deviation of the observed frequency distribution of all characters from expected values. Seventy five percent of the thirty four landraces were detected to have awns in the regions and the rest were known to have no awns. The presence of awn in all altitude groups was fairly equally distributed with the exception for the altitude between 1651- 1800m.a.s.l. that 99 % of the landraces were with awns. The distribution of phenotypic classes for endosperm texture was observed to be maximum for completely starchy (descriptor state) endosperm texture (43%) and observed to be negligible for mostly corneous (3%) with total absence of completely corneous endosperm texture.

The maximum phenotypic classes (seven) were observed for glume color. White glume color took the leading part (40 %) and sienna (yellow group), Mahogany (greyied orange group) and red (orange group) glume colors were known to have 2%, 0%, and 3%, respectively in all altitude groups.

The distribution of glume hairiness seem to be fairly equal for the three phenotypic classes in altitude < 1500m.a.s.l. and 1550 –1651 m.a.s.l. and >1800 m.a.s.l. that 80% was hairless and 20% was hairy without medium glume hairiness and an almost total medium glume hairiness respectively.

The most abundant grain color for most altitude groups and most ecosites was yellow. The present results agree very much with the results already obtained by Teshome *et al.* (1997) and Ayana and Bekele (1998). However, it is necessary to mention that red color was more frequent at altitude >1800 m.a.s.l. and in one ecosite- 'Hayike'. In Merewa adere also white and brown grain colors were more frequent.

The extent of phenotypic classes for grain covering was varying from 25% -100% (descriptor states). For the entire landraces the number of plants in which the grain were covered with glumes decreased in the order of 50%, 25%, 75% and 100%. For all altitude groups similar trends were followed.

An interesting work was our observation of the rare phenotype (i.e. grain form or twin seeds). For the entire data 6% of the twin seeds was recorded. The altitude range of 1500 – 1650 m.a.s.l. was the only source of sorghum landraces having twin seeds with 12 %.

For grain plumpness the distribution of plump grain was much more frequent (83 %) than dimple grain (17 %) for the entire landraces and similar trend was observed for all altitude ranges.

The result obtained with regard to the distribution of different panicle compactness and shape was the most remarkable in North Shewa and South Welo region of Ethiopia. Out of six phenotypic classes, the compact oval panicle was 33 % for the entire landraces and this phenotypic class was also most dominant for all altitude groups. This result agreed highly with what Teshome *et al.* (1997) and Ayana and Bekele (1998) have recorded for this region. The distribution of all the other phenotypic classes of panicle compactness was found to be in the order of decreasing from semi-compact elliptic, compact elliptic, semi-loose primary branches, very loose-droopping primary branches, and half broomcorn in almost all altitude groups.

The distribution of juicy stalk for all landraces was observed to be 33%. The most frequent sorghum landrace with juicy stalk was grown in the altitude range 1500 – 1651m.a.s.l. and no such sorghum landraces were detected in the altitude > 1880 m.a.s.l.

Yellow (45%) and White (45 %); out of the five phenotypic classes of the leaf midrib color, were the most dominant character for all landraces and all altitude groups. All the other phenotypic classes except dull green color (8%) were almost negligible.

Most of the landraces had erect peduncle (59 %) and similar trend was attained for landraces from all altitude groups. The distribution of sorghum landraces with treshable grain character in other way was most dominant in the study area for all landraces. This was also true for all altitude groups. In altitude > 1800 m.a.s.l. threshability characters were 100 %.

Table 8. Percentage frequency distribution of different phenotypic classes For fourteen qualitative characters in sorghum by four altitude

Altitude	Awn			Endosperm texture					Glume color							
	1	2	χ^2	3	5	7	9	χ^2	1	2	3	4	5	6	7	χ^2
1	74	26	0.81	3	29	23	45	5.42	26	6	0	2	33	17	15	No valid
2	68	32	5.50	4	39	30	27	35.23**	47	0	0	5	12	17	18	χ^2 value
3	99	1	26.10**	0	17	13	71	9.12	30	0	0	0	27	3	40	
4	70	30	3.47	0.00	8.30	10	82	27.87**	92	0	0	0	8	0	0	
Total	75	26		3	30	24	43		40	2	0	3	22	14	19	

Altitude	Glume hairiness				Grain color							Grain covering					
	1	2	3	χ^2	1	2	3	4	5	6	χ^2	1	3	5	7	9	χ^2
	55	30	15	20.82**	9	62	3	13	0	12	58.21**	24	46	30	0	0	14.61
	58	30	12	27.84**	19	32	25	11	11	3	19.23	43	31	26	0	0	12.65
	20	0	80	151.10**	17	28	5	19	5	25	37.99**	32	31	19	15	3	43.76**
	2	98	0	143.26**	0	0	48	42	10	0	111.64**	38	62	0	0	0	32.61**
Total	48	30	22		14	40	16	15	6	9		35	38	25	2	0	

Altitude	Grain form			Grain plumpness			Influoresence compactness and shape							Juice flavor			
	1	2	χ^2	3	7	χ^2	3	6	8	9	10	11	χ^2	1	2	3	χ^2
	99	1	1.61	25	75	8.36*	0	9	25	36	30	0	17.82	17	0	83	15.45*
	88	12	24.35**	13	87	0.24	0	14	35	9	42	0	18.00	7	47	47	118.32**
	100	0	3.36	21	79	3.11	18	36	23	15	5	2	100.50**	20	0	80	19.24**
	100	0	3.36	0	100	17.30**	0	0	30	25	45	0	27.34*	0	0	100	29.35**
Total	94	6		18	83		3	15	29	20	33	0		12	21	68	

Altitude	Midrib color						Peduncle shape			Stem juiciness			Threshability		
	1	2	3	4	5	χ^2	1	2	χ^2	1	2	χ^2	1	2	χ^2
	36	13	49	0	2	4.93	58	42	0.86	83	17	1.88	71	29	3.33
	53	6	39	1	1	6.54	53	47	3.85	46	54	55.57**	94	6	14.23**
	41	3	55	0	1	5.29	81	19	14.60	80	20	0.43	49	51	51.56**
	43	12	45	0	0	2.78	58	42	0.86	100	0	29.45**	100	0	27.39**
Total	45	8	45	1	2		59	41		68	33		80	20	

* = P< 0. 05, ** = P < 0. 01

Table 9. Percentage frequency distribution of different phenotypic classes For fourteen qualitative characters in sorghum by five ecosites

Ecosite	Awn			Endosperm texture					Glume color							
	1	2	χ^2	3	5	7	9	χ^2	1	2	3	4	5	6	7	χ^2
1	92	8	3.33	8	49	31	12	62.68**	42	0	0	0	28	12	17	No valid
2	99	1	14.23**	1	18	19	62	8.49	40	0		0	22	0	38	χ^2 value
3	71	30	51.56**	0	8	12	80	39.21	90	0	0	0	8	0	2	
4	68	32	27.39**	1	26	26	47	4.34	36	4	0	5	16	19	19	
5	0	100		2	47	5	47	20.21	7	0	0	8	53	32	0	
Total	75	26		3	30	24	43		40	2	0	3	22	14	19	

	Glume hairiness				Grain color							Grain covering					
	1	2	3	χ^2	1	2	3	4	5	6	χ^2	1	3	5	7	9	χ^2
	50	27	23	5.15	11	69	3	0	0	18	91.37**	46	38	16	0	0	17.51
	54	5	40	24.62**	15	48	2	9	5	21	49.55**	21	43	19	15	3	59.61**
	3	97	0	149.52**	0	0	48	41	12	0	147.81**	38	62	0	0	0	32.21**
	50	28	22	4.12	12	34	24	16	10	4	14.01	37	31	32	0	0	17.94
	50	50	0	63.29**	55	0	0	45	0	0	157.40**	0	63	37	0	0	49.85**
Total	48	30	22		14	40	16	15	6	9		35	38	25	2	0	

	Grain form			Grain plumpness			Inflorescence compactness and shape							Juice flavor			
	1	2	χ^2	3	7	χ^2	3	6	8	9	10	11	χ^2	1	2	3	χ^2
	100	0	2.46	21	79	3.53	0	25	20	14	41	0	35.53*	13	0	88	10.19
	100	0	2.46	37	63	41.44**	0	16	24	30	30	0	14.54	20	0	80	21.80**
	100	0	2.46	0	100	16.82**	0	0	31	25	44	0	22.37	0	0	100	20.72**
	88	12	39.34**	14	86	0.01	5	13	29	21	32	1	19.14	12	41	47	148.11**
	100	0	2.46	0	100	16.82**	0	0	88	10	0	2	113.76**	0	0	100	20.72**
Total	94	6		18	83		3	15	29	20	33	0		12	21	68	

	Midrib color						Peduncle shape			Stem juiciness			Threshability		
	1	2	3	4	5	χ^2	1	2	χ^2	1	2	χ^2	1	2	χ^2
	34	8	57	0	1	7.56	58	43	3.36	88	13	1.31	77	23	0.02
	28	4	66	0	2	10.58	59	41	2.23	80	20	0.56	62	38	14.00**
	44	12	44	0	0	3.98	59	41	2.23	100	0	20.72**	100	0	28.87**
	56	7	35	1	1	20.08	55	45	5.46	47	53	90.31**	86	14	4.06
	32	30	33	0	5	23.77	100	0	51.36**	100	0	20.72**	63	37	12.26*
Total	45	8	45	1	2		59	41		68	33		80	20	

* = P< 0. 05, ** = P < 0. 01

Table 10. Percentage frequency distribution of different phenotypic classes For fourteen qualitative characters in sorghum by three woredas

Wereda	Awn			Endosperm texture					Glume color							
	1	2	χ^2	3	5	7	9	χ^2	1	2	3	4	5	6	7	χ^2
1	61	39	11.06**	1	28	24	47	2.47	33	4	0	6	20	20	17	No valid
2	70	30	1.53	0	8	10	82	33.62**	92	0	0	0	8	0	0	χ^2 value
3	95	5	20.81**	5	37	27	31	22.63**	41	0	0	0	26	7	25	
Total	75	26		3	30	24	43		40	2	0	3	22	14	19	

	Glume hairiness				Grain color							Grain covering					
	1	2	3		1	2	3	4	5	6		1	3	5	7	9	
	50	30	20	14.86**	17	30	22	19	9	4	8.33	33	34	33	0	0	21.37**
	2	98	0	96.77**	0	0	48	42	10	0	92.34	38	62	0	0	0	25.28**
	52	19	30	16.78**	12	61	2	4	2	19	86.75**	36	40	17	6	1	9.97
Total	48	30	22		14	40	16	15	6	9		35	38	25	2	0	

	Grain form			Grain plumpness			Influoresence compactness and shape							Juice flavor			
	1	2	χ^2	3	7	χ^2	3	6	8	9	10	11	χ^2	1	2	3	
	90	10	13.79	13	87	0.01	5	11	35	20	29	1	11.18	11	37	53	58.31**
	100	0	3.45	0	100	15.38	0	0	30	25	45	0	15.35	0	0	100	26.47**
	100	0	3.45	27	73	16.16**	0	22	21	20	37	0	13.22	15	0	85	17.42**
Total	94	6		18	83		3	15	29	20	33	0		12	21	68	

	Midrib color						Peduncle shape			Stem juiciness			Treshability		
	1	2	3	4	5	χ^2	1	2	χ^2	1	2	χ^2	1	2	χ^2
	53	9	35	1	2	7.82	60	40	0.07	53	48	43.164**	84	16	0.08
	43	12	45	0	0	1.39	58	42	0.02	100	0	26.47**	100	0	17.65**
	32	7	60	0	1	6.73	58	42	0.02	85	15	2.13	71	29	15.37**
Total	45	8	45	1	2		59	41		68	33		80	20	

* = P< 0. 05, ** = P < 0. 01

Table 11. Percentage frequency distribution of different phenotypic classes For fourteen qualitative characters in sorghum by two zones

Zone	Awn			Endosperm texture					Glume color							
	1	2	χ^2	3	5	7	9	χ^2	1	2	3	4	5	6	7	χ^2
1	61	39	11.76**	1	28	24	47	2.12	33	4	0	6	20	20	17	No valid
2	92	9	11.64**	5	34	25	38	2.08	48	0	0	0	23	7	22	χ^2 value
Total	75	26		3	30	24	43		40	2	0	3	22	14	19	

	Glume hairiness				Grain color							Grain covering					
	1	2	3	χ^2	1	2	3	4	5	6	χ^2	1	3	5	7	9	χ^2
	50	30	20	0.53	17	30	22	19	9	4	14.41*	33	35	33	0	0	6.90
	45	29	26	0.53	11	53	8	9	3	17	14.41*	37	43	15	5	1	6.90
Total	48	30	22		14	40	16	15	6	9		35	38	25	2	0	
	0.26	0.02	0.78	1.06	1.29	6.37	6.53	3.57	3.00	8.05	28.81**	0.23	0.82	6.75	5.00	1.00	13.80**

	Grain form			Grain plumpness			Influoresence compactness and shape							Juice flavor			
	1	2		3	7	χ^2	3	6	8	9	10	11	χ^2	1	2	3	χ^2
	90	10	89.30**	13	87	1.37	5	11	35	19	29	1	6.20	11	37	53	22.60**
	100	0	8.93**	23	77	1.37	0	19	22	21	38	0	6.20	13	0	87	22.82
	94	6		18	83		3	15	29	20	33	0		12	21	68	

	Midrib color						Peduncle shape			Stem juiciness			Treshability		
	1	2	3	4	5	χ^2	1	2	χ^2	1	2	χ^2	1	2	χ^2
	53	9	35	1	2	5.71	59	40	0.00	53	48	13.30**	84	16	0.98
	34	7	58	0	1	5.71	58	42	0.00	87	13	13.30**	75	25	0.98
Total	45	8	45	1	2		59	41		68	33		80	20	

* = P< 0. 05, ** = P < 0. 01

1. 1. 2. Ecological distribution of characters

From the frequency distribution of the fourteen qualitative characters (Tables 8-11) it is evident that seventy five percent of the total landraces detected in this study were awned types while the rest awnless. The presence of awn in all ecosites, woredas, and zones was fairly equally distributed. An exception for this was 'Merewa adrere' where no landrace collected was found to have awns.

The distribution of phenotypic classes for endosperm texture was observed to be maximum for completely starchy (descriptor state) endosperm texture (43%) and was negligible for mostly corneous (3%) with total absence of completely corneous endosperm texture. This high proportion of completely starchy endosperm texture may be related to the high milling quality of the sorghum grains. The greatest frequency of starchy endosperm was totally coinciding with previous studies (Kebede, 1991; Ayana and Bekele, 1998).

The distribution of white glume color was sharing the greatest proportion (40 %) and yellow, greyied orange and red glume colors were known to have 2%, 0%, and 3%, respectively for all ecosites.

Uneven distribution of glume hairiness was seen for some ecosites like Fontenina, Hayike and Merewa adere equally both with 50 % hairy and hairless, 97 % medium hairiness and 50, 50 % share for hairy and medium hairiness, respectively. Yellow was the most abundant grain color for most ecosites. In Merewa adere white and brown grain colors were more frequent.

The extent of phenotypic classes for grain covering was varying from 25% -100% (descriptor states). The entire landraces in which the grains were covered with glumes decreased in the order of 50%, 25%, 75% and 100%. For most ecosites, similar trends were followed. 'Layignaw ataye', was the only source ecosite that produced this rare character with 12 % frequency. The distribution of plump grain was much more frequent (83 %) than dimple grain (17 %) for the entire landraces and similar trend was observed for all ecosites.

Out of the six phenotypic classes, the compact oval panicle took a share of 33 % for the entire landraces and this phenotypic class was also most dominant at all ecosites. The decreasing order from semi-compact elliptic, compact elliptic, semi-loose primary branches, very loose-drooping primary branches, and half broom corn were recorded for all the other phenotypic classes in almost all ecosites.

Of all ecosites, 'Layignaw ataye' contained the most frequent sorghum with juicy stalk. The distribution of juice flavor also followed the same trend with frequency of 12 % of all landraces.

For all landraces and all ecosites yellow (45%) and white (45%) were the most dominant characters. Dull green color was about 8%. All the other phenotypic classes were almost negligible.

All ecosites with an exception for Merewa adere (100 % peduncle erect) have attained the frequency of most of the landraces (59 % with erect peduncle). Sorghum landraces with threshable grain character was the most dominant in the present study area. At all ecosites sorghum with threshable grain was also dominant.

1. 3. Estimate of diversity

Table 12 indicate the estimate of Shannon-Weaver diversity index (H') by altitude groups, ecosites,

woredas, and administrational zones for the fourteen qualitative characters. For all landraces the minimum value of H' was 0.32 for grain form and the maximum value was 0.98 for peduncle shape with an overall mean of 0.77. Apparently high diversity of sorghum landraces was estimated for the region. Diversity indices (H') for each of fourteen traits are presented in four altitude groups

(Fig. 4) and in five agroecological sites (Fig. 5). H', pooled over characters within altitudinal variations and ecosites groups ranged from 0.33 to 0.75 for >1800m.a.s.l. and1500-1650m.a.s.l. and from 0.33 to 0.79 for Merewa adere and Efeson, respectively. Estimates of Shannon – Weaver diversity index of the fourteen qualitative characters by landraces is presented in Appendix 8 for comparison.

Table 12. Estimates of Shannon – Weaver diversity index of the fourteen qualitative characters of s of Sorghum (*Sorg bicolor* (L.) Moench) by altitude. (key to legend: see Fig. 4)

	Awn	EST	GLC	GLH	GRC	GRCV	GRF	GRP	ICSH	JF	MRC	PSH	STJ	TRSH	
Altitude	H'	H'	H'	H'	H'	H'	H'	H'	H'	H'	H'	H'	H'	H'	Mean ± SE
1	0.83	0.84	0.81	0.89	0.65	0.66	0.09	0.81	0.73	0.41	0.66	0.98	0.65	0.86	0.71 ± 0.06
2	0.91	0.87	0.72	0.85	0.90	0.67	0.54	0.55	0.68	0.81	0.61	1.00	1.00	0.32	0.75 ± 0.05
3	0.10	0.58	0.61	0.46	0.91	0.89	0.00	0.74	0.86	0.46	0.52	0.70	0.72	1.00	0.61 ± 0.08
4	0.88	0.43	0.15	0.08	0.53	0.41	0.00	0.00	0.60	0.00	0.60	0.98	0.00	0.00	0.33 ± 0.09
Ecosite															
1	0.40	0.84	0.67	0.94	0.50	0.63	0.00	0.74	0.73	0.34	0.58	0.98	0.54	0.78	0.62 ± 0.07
2	0.06	0.69	0.55	0.78	0.78	0.86	0.00	0.95	0.76	0.46	0.52	0.98	0.72	0.96	0.65 ± 0.08
3	0.88	0.45	0.19	0.13	0.54	0.41	0.00	0.00	0.60	0.00	0.60	0.98	0.00	0.00	0.34 ± 0.09
4	0.90	0.80	0.82	0.94	0.90	0.68	0.52	0.59	0.84	0.88	0.61	0.99	1.00	0.58	0.79 ± 0.04
5	0.00	0.67	0.56	0.63	0.38	0.41	0.00	0.00	0.23	0.00	0.77	0.00	0.00	0.95	0.33 ± 0.09
Wereda															
1	0.96	0.80	0.83	0.94	0.92	0.68	0.48	0.55	0.82	0.86	0.64	0.97	1.00	0.64	0.79 ± 0.04
2	0.88	0.43	0.15	0.08	0.53	0.41	0.00	0.00	0.60	0.00	0.60	0.98	0.00	0.00	0.33 ± 0.09
3	0.29	0.89	0.65	0.92	0.65	0.77	0.00	0.84	0.76	0.39	0.56	0.98	0.62	0.86	0.66 ± 0.07
Zone															
1	0.96	0.80	0.83	0.94	0.92	0.68	0.48	0.55	0.82	0.86	0.64	0.97	1.00	0.64	0.79 ± 0.04
2	0.42	0.88	0.62	0.97	0.78	0.75	0.00	0.78	0.75	0.36	0.57	0.98	0.57	0.81	0.66 ± 0.07
NSSW*	0.82	0.84	0.77	0.95	0.90	0.74	0.32	0.67	0.81	0.77	0.63	0.98	0.91	0.72	0.77 ± 0.04

*=North Shewa and South Welo

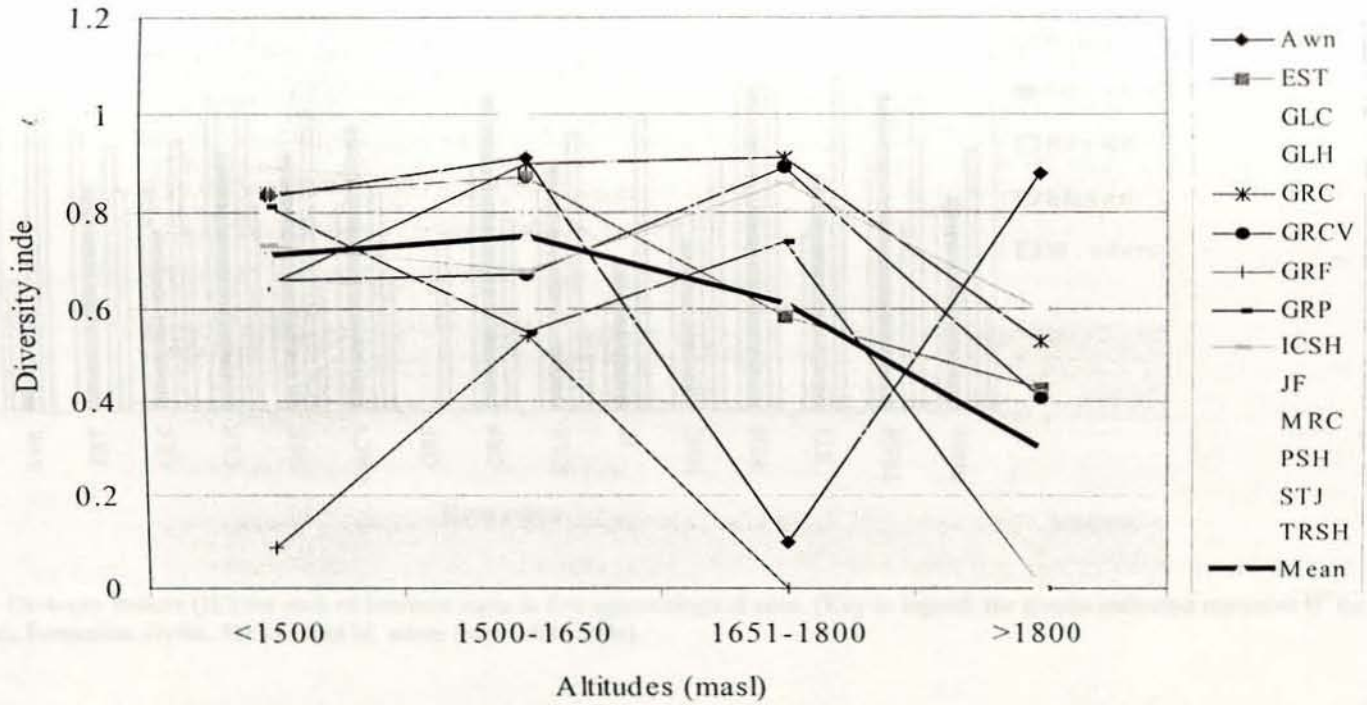

Figure 4. Diversity indices (H') for each of fourteen traits in four altitude groups. (Key to lejend: AWN, EST=Endosperm texure, GLC=Glume color, GLH= glume hairiness, GRC= grain color, GRCV= grain covering, GRF= grain form, GRP= grain plumpness, ICSH= infloresence compactness and shape, JF = juice flavor, MRC = midrib color, PSH = peduncle shape, SJF = stem juiciness TRSH = Threshability

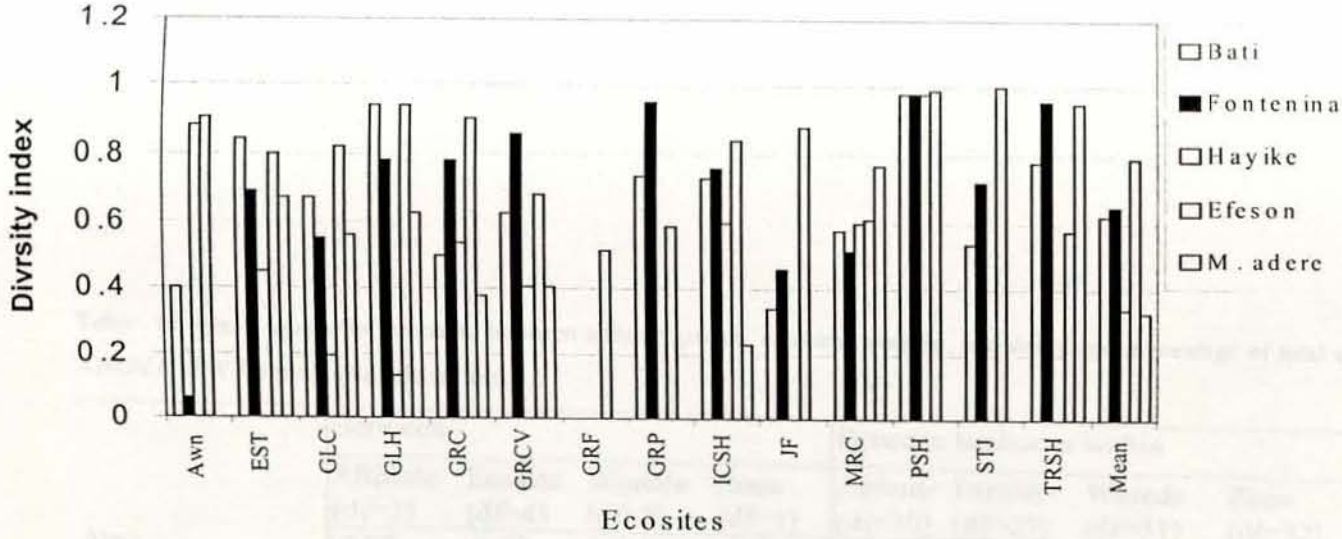

Figure 5. Diversity indices (H') for each of fourteen traits in five agroecological sites. (Key to legend: the graphs indicated represent H' for each character in the order of sites (Bati, Fontenina, Hyike, Efeson, and M. adere from left to right).

Table 13 Mean square for variation between altitude groups, ecosites, woredas, and zones and percentage of total variance ANOVA of H' for individual characters

	Between				Between landraces within			
	Altitude (df=3)	Ecosite (df=4)	Woreda (df=2)	Zone (df=1)	Altitude (df=30)	Ecosite (df=29)	Woreda (df=31)	Zone (df=32)
Awn	0.07	0.07	0.09	0.05	0.05	0.05	0.05	0 .05
Endosperm texture	0.40*	0.27	0.12	0.04	0.12	0.13	0.15	0.15
Glume color	0.40*	0.30	0.48*	0.46	0.13	0.13	0.13	0.14
Glume hairiness	0.02	0.01	0.00	0.00	0.04	0.04	0.04	0.04
Grain color	0.24	0.31	0.44	0.20	0.16	0.15	0.15	0.17
Grain Cover	0.09	0.07	0.02	0.01	0.09	0.09	0.09	0.09
Grain form	0.03	0.03	0.05	0.10	0.03	0.03	0.03	0.03
Grain plumpness	0.04	0.07	0.03	0.00	0.06	0.06	0.06	0.06
Inflorecence compactness and shape	0.08	0.01	0.02	0.02	0.10	0.11	0.10	0.10
Juice flavor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Midrib color	0.15*	0.16**	0.08	0.08	0.04	0.04	0.05	0.05
Peduncle shape	0.04	0.04	0.02	0.04	0.07	0.07	0.07	0.07
Stem juiciness	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Threshability	0.19*	0.05	0.06	0.09	0.05	0.07	0.07	0.06

* = $p < 0.05$, ** = $p < 0.01$

Table 14. Hierarchical analysis of variance of diversity (H') across characters

Source of variations	DF	SS	MS	F
Between				
Zone	1	0.1669	0.1669	0.997ns
Landrace within zones	32	5.3529	0.1673	2.231**
Woreda	2	0.1749	0.0874	0.506ns
Landrace within Woreda	31	5.345	0.1724	2.299**
Ecosite	4	0.4676	0.1169	0.671ns
Landrace within Ecosite	29	5.0523	0.1742	2.323**
Altitude	3	0.0914	0.0305	0.169ns
Landrace within Altitude	30	5.4285	0.1809	2.412**
Character within Landrace	442	33.1479	0.075	

ns = non – significant, ** = $P < 0.01$

1. 4. Cluster Analysis

The thirty-four landraces were grouped in five clusters (Tables 17 & 18; Figure 6). The number of landraces per cluster ranged from 1 in clusters III, IV, and V to 25 in cluster I.

Cluster I contained the maximum number of landraces (25): 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 16, 17, 18, 20, 21, 23, 24, 26, 27, 28, 29, 30, 33. Most of these landraces were from medium altitude (1500 – 1800 m.a.s.l. = 14 landraces), from low altitude (<1500m.a.s.l. = 9 landraces) and from high altitude (>1800m.a.s.l. = 2 landaces).

Cluster II contained 6 landraces: 11, 15, 19, 25, 32, and 34. These landraces were grown at elevation < 1500m.a.s.l. (Bati) and at medium elevation from Fontenina and Ataye.

Clusters III, IV, and V contained one landrace each: cluster III contain landrace 14 from Fontenina and clusters IV and V contained landrace 22 and 31, respectively, both from Layignaw ataye. All these three landraces were sharing the same altitude (1651 – 1800m.a.s.l.). The detailed description of the distribution of the 34 sorghum landraces over 5 clusters with respect to each agroecosite is presented in Table 17, see also Table 18.

For all the clusters the within cluster sum of square, average distance and the maximum distance from the centroid is presented in Table 15 and the distance between cluster centroid is also presented in Table 16. Hence, all of the clusters were different from one another.

Table 15 . Average and maximum distance within the 5 clusters of sorghum landraces

	Number of Landraces	Within cluster sum of squares	Average distance from centroid	Maximum distance from centroid
Cluster1	25	1286.611	7.003	10.546
Cluster2	6	223.528	5.993	7.953
Cluster3	1	0.000	0.000	0.000
Cluster4	1	0.000	0.000	0.000
Cluster5	1	0.000	0.000	0.000

Table 16. Distances between cluster centroids of sorghum landraces

	Cluster1	Cluster2	Cluster3	Cluster4	Cluster5
Cluster1	0.0000	11.4611	12.1271	20.3191	39.5650
Cluster2	11.4611	0.0000	14.8745	17.2603	38.0865
Cluster3	12.1271	14.8745	0.0000	20.5183	40.7922
Cluster4	20.3191	17.2603	20.5183	0.0000	42.5793
Cluster5	39.5650	38.0865	40.7922	42.5793	0.0000

Table 17. Distribution of the 34 sorghum landraces over 5 clusters with respect to each agroecosite in North Shewa and South Welo, Ethiopia

Clusters	Ecosites	LANDRACES																																		Total	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	Ecosite	Cluster
I	1						+										+							+	+		+							+		6	25
	2	+												+														+								3	
	3		+	+																																2	
	4				+			+	+	+	+							+	+		+	+							+	+	+					12	
	5					+							+																								2	
II	1																			+						+										2	6
	2											+																								1	
	3																																			0	
	4															+																	+		+	3	
	5																																			0	
III	1																																			0	1
	2																																			0	
	3																																			0	
	4														+																					1	
	5																																			0	
IV	1																																			0	1
	2																						+													1	
	3																																			0	
	4																																			0	
	5																																			0	
V	1																																			0	1
	2																																			0	
	3																																			0	
	4																															+				1	
	5																																			0	
Altitude		3	4	4	2	1	2	2	1	2	2	3	1	1	3	3	2	1	2	1	2	2	3	1	1	1	1	1	2	2	2	3	2	2	2	34	34

Figure 6. Dendrogram showing the clustering patterns of the 34 sorghum (S. bicolor (L.) Moench) landraces in North Shewa and South Welo region, Ethiopia.

Table 18. Distribution of 34 sorghum landraces over 5 clusters by agroecological sites and altitude groups

Ecosites	Altitude	Clusters					Total For Altitudes	Total for Eco sites
		I	II	III	IV	V		
Bati	*1*	3	2				5	
	2	3					3	
	3						0	
	4						0	8
Fontenina	*1*	2					2	
	2						0	
	3	1	1		1		3	
	4						0	5
Hahike	*1*						0	
	2						0	
	3						0	
	4	2					2	2
Layignaw ataye	*1*	2					2	
	2	10	2				12	
	3		1	1		1	3	
	4						0	17
Merewa adere	*1*	2					2	
	2						0	
	3						0	
	4						0	2
Total		25	6	1	1	1	34	34

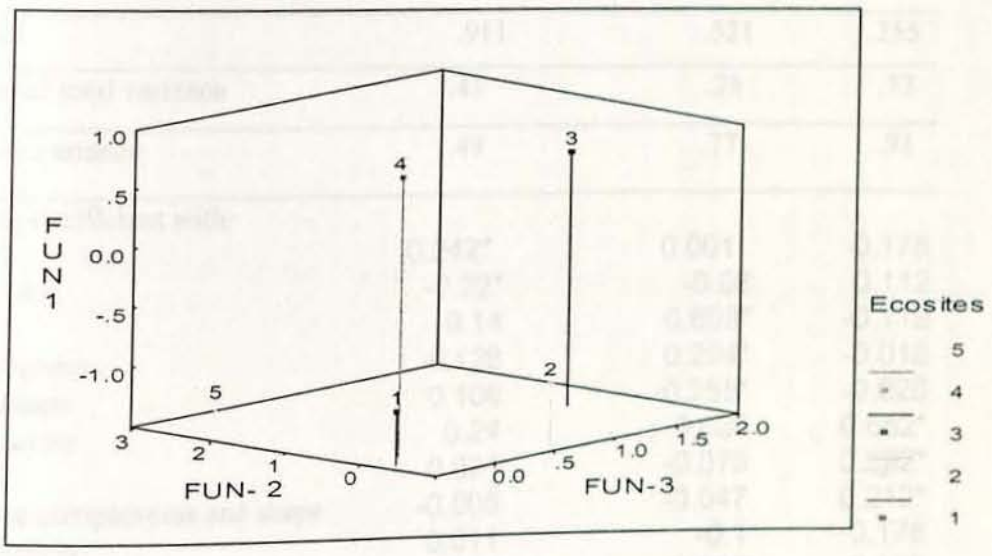

Figure 7. Scatter diagram of the first three canonical variables (CAN) based on mean values of observations in sorghum landraces.

Sorghum landraces from the five ecosites appeared unequally distributed along the Y-axis (Fun-1) of the analysis (Fig. 7). The first three canonical variables accounted for 91% of the total morphological variation, of which 49% of the propotion of the variance was explained by Fun-1 (Table 19). Sorghum ladraces from Layignaw ataye and Bati were positively correlated to FUN-1 This axis is correlated with grain form and midribcolor. Fun-2 maximaz the differentiation to which Merewa adere was highly correlated. Awn, grain plumpness and peduncle shape were detected to show high correlation. Fun-3 appears to be more positively correlation with Bati and endosper texture showed greatest contribution. Damania et al. (1996); Pecetti and Damania, (1996) have also used the same method. The dissimilarity matrix of all the 34 sorghum landraces is presented in Table 20 to indicate the degree of dissimilarity (distance) between any two landraces.

Table 19. Eigen values, proportion and cumulative variance of the three canonical variables (CAN) between three CANs and the original variables for 5 ecosites, and between the CANs

	CAN-1	CAN-2	CAN-3
Eigenvalue	.911	.521	.255
Proportion of total variance	.49	.28	.13
Cumulative variance	.49	.77	.91
Correlation coefficient with:			
Grain form	0.242*	0.001	-0.178
Midrib color	-0.22*	-0.08	0.112
Awn	0.14	0.803*	-0.119
Grain plumpness	0.128	0.294*	-0.018
Peduncle shape	0.106	-0.255*	-0.026
Endosper textur	0.24	0.026	0.652*
Grain color	0.091	-0.073	0.292*
Infloresence compactness and shape	-0.008	-0.047	0.212*
Glume hairiness	0.011	-0.1	0.178
Grain covering	-0.054	0.066	0.128
Glume color	-0.08	0.055	-0.339
Stem juiciness	0.446	-0.142	-0.379
Juice flavor	-0.268	0.183	0.262
Threshability	-0.23	-0.014	-0.013

• = $P < 0.05$

Table 20. Dissimilarity matrix of the thirty four sorghum landraces in North Shewa and South Welo regions of Ethiopia based on Euclidean Distance measurement

Landraces	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1		1.49	1.21	1.27	1.33	1.53	1.27	1.10	1.58	1.57	1.08	1.31	1.67	0.77	1.11	1.31	1.60
2			1.38	1.43	1.49	1.30	1.44	1.12	1.32	1.81	1.60	1.74	1.29	1.73	1.60	0.81	1.13
3				0.78	0.72	1.28	1.19	1.18	1.92	2.20	1.19	1.23	1.42	1.10	1.20	1.33	1.83
4					0.51	0.89	1.12	1.43	1.96	2.25	1.07	1.25	1.29	1.27	1.11	1.17	1.88
5						0.93	1.05	1.30	1.87	2.18	1.13	1.01	1.22	1.13	1.10	1.28	1.84
6							1.01	1.39	1.58	2.09	1.28	1.31	0.65	1.49	1.20	1.31	1.46
7								1.11	1.62	2.04	1.16	1.25	1.15	1.40	1.11	1.21	1.58
8									1.34	1.61	1.51	1.40	1.47	1.11	1.39	1.17	1.21
9										0.98	1.85	1.84	1.39	1.76	1.81	1.60	0.59
10											1.95	1.89	2.02	1.72	1.89	1.84	1.08
11												0.78	1.45	1.21	0.40	1.24	1.85
12													1.48	0.99	0.56	1.46	1.84
13														1.70	1.44	1.52	1.29
14															1.06	1.60	1.76
15																1.25	1.77
16																	1.47
17																	

Landraces	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
1	1.42	1.04	1.38	1.28	0.96	1.68	1.34	1.31	1.01	1.38	1.59	1.25	1.23	1.13	1.22	1.25	1.34
2	1.38	1.50	0.88	1.28	1.46	1.19	1.40	1.44	1.68	1.50	0.47	1.27	1.13	1.56	1.92	1.11	1.53
3	1.14	1.00	1.19	0.94	0.89	1.53	1.07	0.83	1.38	1.36	1.51	0.94	1.02	1.10	1.80	0.93	0.61
4	0.82	0.93	1.04	0.76	1.20	1.38	0.85	0.75	1.03	1.47	1.41	0.83	0.76	1.33	1.78	0.99	0.64
5	0.83	0.83	1.07	0.66	1.10	1.35	0.74	0.61	1.12	1.36	1.45	0.87	0.97	1.23	1.69	0.94	0.39
6	0.86	1.12	0.67	0.68	1.34	0.65	0.93	0.95	1.15	1.15	1.10	0.90	1.04	1.53	1.78	0.81	1.03
7	0.89	0.92	0.87	0.54	1.27	1.10	0.63	0.80	1.08	1.38	1.38	0.67	1.13	1.46	1.62	0.74	1.07

8	1.32	1.37	1.18	1.20	0.83	1.40	1.32	1.30	1.25	1.20	1.24	1.10	1.29	1.30	1.59	1.09	1.25
9	1.78	1.71	1.31	1.58	1.58	1.32	1.71	1.79	1.75	1.35	1.22	1.73	1.81	1.86	1.45	1.50	1.92
10	2.02	1.91	1.93	2.05	1.86	2.04	2.09	2.09	1.93	1.79	1.81	2.07	2.07	1.84	1.07	1.97	2.24
11	1.17	0.51	1.22	1.05	1.44	1.54	1.06	1.15	1.41	1.67	1.56	1.04	1.27	0.85	1.50	1.24	1.18
12	1.22	0.67	1.41	1.11	1.40	1.58	1.12	1.15	1.52	1.62	1.68	1.14	1.41	0.69	1.42	1.26	1.08
13	1.12	1.25	0.64	0.84	1.40	0.53	1.05	1.09	1.48	0.94	1.01	1.17	1.38	1.71	1.88	0.89	1.32
14	1.45	1.07	1.56	1.31	0.86	1.74	1.43	1.27	1.16	1.33	1.82	1.32	1.37	0.89	1.23	1.29	1.08
15	1.12	0.57	1.25	1.04	1.41	1.47	1.09	1.13	1.39	1.63	1.57	0.96	1.22	0.66	1.39	1.15	1.12
16	1.05	1.20	1.00	1.14	1.56	1.43	1.15	1.24	1.43	1.76	0.90	1.06	0.99	1.36	1.70	1.21	1.35
17	1.57	1.75	1.22	1.55	1.54	1.24	1.70	1.67	1.70	1.20	1.06	1.61	1.67	1.81	1.49	1.38	1.87
18		1.00	0.96	0.72	1.43	1.23	0.73	0.56	1.09	1.38	1.28	0.77	0.92	1.44	1.56	0.89	0.98
19			1.05	0.72	1.29	1.35	0.75	0.81	1.28	1.48	1.46	0.92	1.14	0.90	1.38	0.97	0.91
20				0.62	1.27	0.54	0.87	0.94	1.30	1.12	0.69	0.92	1.09	1.50	1.77	0.74	1.11
21					1.17	0.90	0.41	0.52	1.08	1.21	1.18	0.64	0.94	1.35	1.63	0.56	0.76
22						1.50	1.32	1.23	1.09	0.91	1.52	1.19	1.33	1.33	1.69	1.13	1.05
23							1.20	1.21	1.50	1.09	0.96	1.22	1.41	1.73	1.89	0.91	1.35
24								0.65	1.12	1.45	1.29	0.66	0.95	1.44	1.70	0.78	0.97
25									1.14	1.24	1.41	0.82	0.99	1.35	1.53	0.72	0.68
26										1.29	1.63	1.12	1.16	1.67	1.53	1.24	1.22
27											1.39	1.45	1.59	1.70	1.67	1.14	1.34
28												1.27	1.25	1.67	1.95	1.14	1.54
29													0.70	1.23	1.72	0.65	0.96
30														1.34	1.72	0.79	1.12
31															1.45	1.30	1.19
32																1.61	1.72
33																	0.98
34																	

2. Isozyme analysis

Thirty-four sorghum (*S. bicolor* (L.) Moench) landraces were used in the isozyme analysis. Figure 8 a, b show the band patterns of the thirty-four sample materials for two (EST and ACP) enzyme systems. Probably, for the reasons mentioned in the discussion part the allelic polymorphism has not been detected in this study.

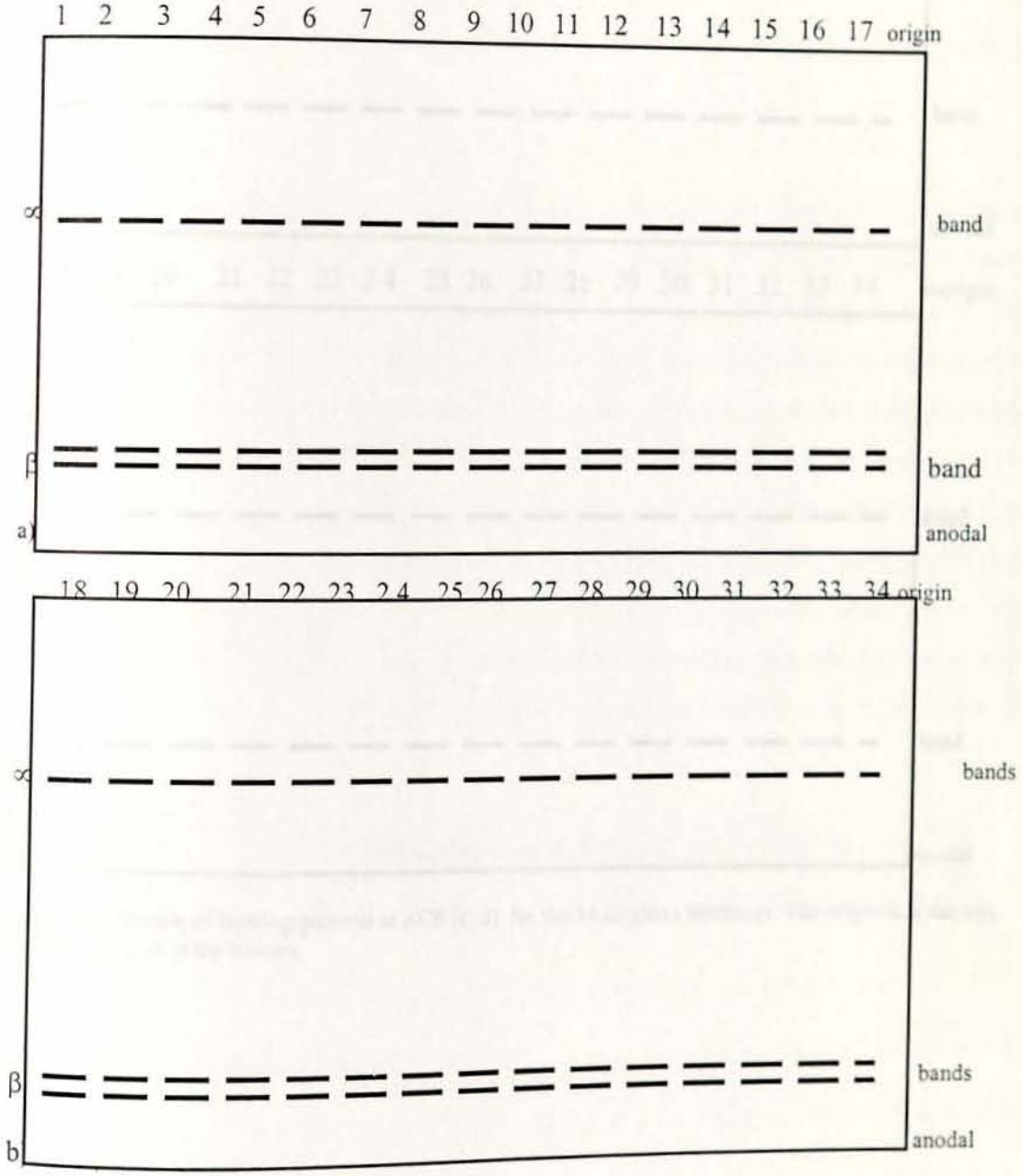

Figure 8a. Profile of banding patterns at EST (a, b) for the 34 sorghum landraces. The origin is at the top, and the anode is at the bottom.

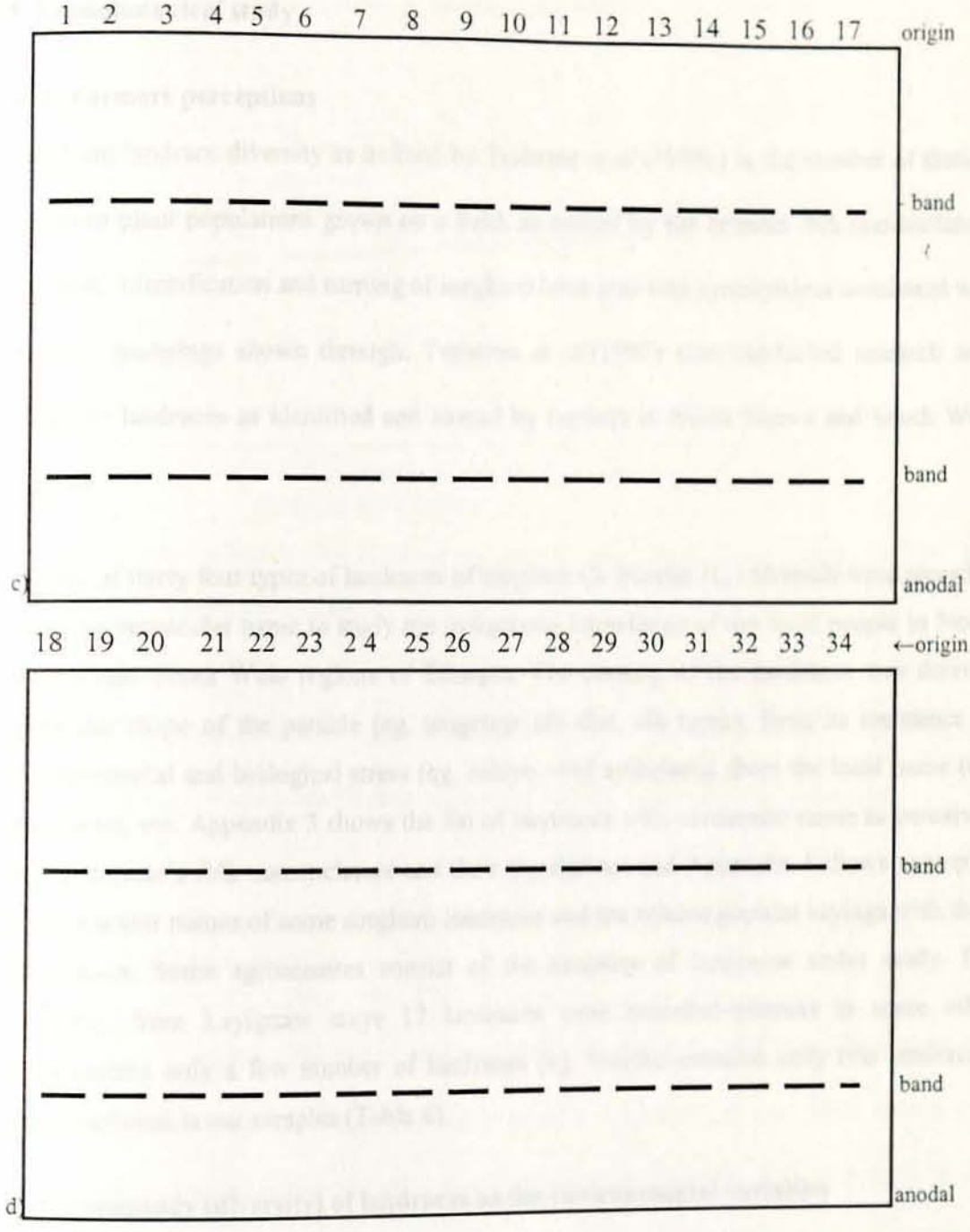

Figure 8b. Profile of banding patterns at ACP (c, d) for the 34 sorghum landraces. The origin is at the top, and the anode is at the bottom.

3. Ethnobotanical study

3. 1. Farmers perceptions

Sorghum landrace diversity as defined by Tesheme *et al.*(1999a) is the number of distinct sorghum plant populations grown on a field, as named by the farmers folk nomenclature. Farmers' identification and naming of sorghum landraces was synonymous consistent with what is groupings shown through. Teshome *et al.*(1997) also conducted research with sorghum landraces as identified and named by farmers in North Shewa and South Welo regions.

A total of thirty four types of landraces of sorghum (S. bicolor (L.) Moench were recorded with the vernacular name to study the indigenous knowledge of the local people in North Shewa and South Welo regions of Ethiopia. The naming of the landraces was derived from the shape of the panicle (eg. tengeley: afe dist, afe tume), from its resistance to environmental and biological stress (eg. aehiyo, wof ayibelash), from the local name (eg. merabete), etc. Appendix 3 shows the list of landraces with vernacular name as perceived by the farmer's folk nomenclature and their translations and Appendix 4 shows examples of vernacular names of some sorghum landraces and the related popular sayings with their translation. Some agroecosites consist of the majority of landraces under study. For example, from Layignaw ataye 17 landraces were recorded-whereas in some other agroecosites only a few number of landraces (eg. Hayike contains only two landraces) were included in our samples (Table 6).

3. 2. Frequency (diversity) of landraces under environmental variables

3. 2. 1. Altitude

Sorghum landrace diversity in this study area was highest in the altitude range of 1500 – 1650 m.a.s.l. Sorghum landraces are well adapted at this altitude range to the environmental conditions like temperature, precipitation, seasonal conditions than towards both higher and lower altitude groups (Fig. 9). Our result greatly agreed with the study

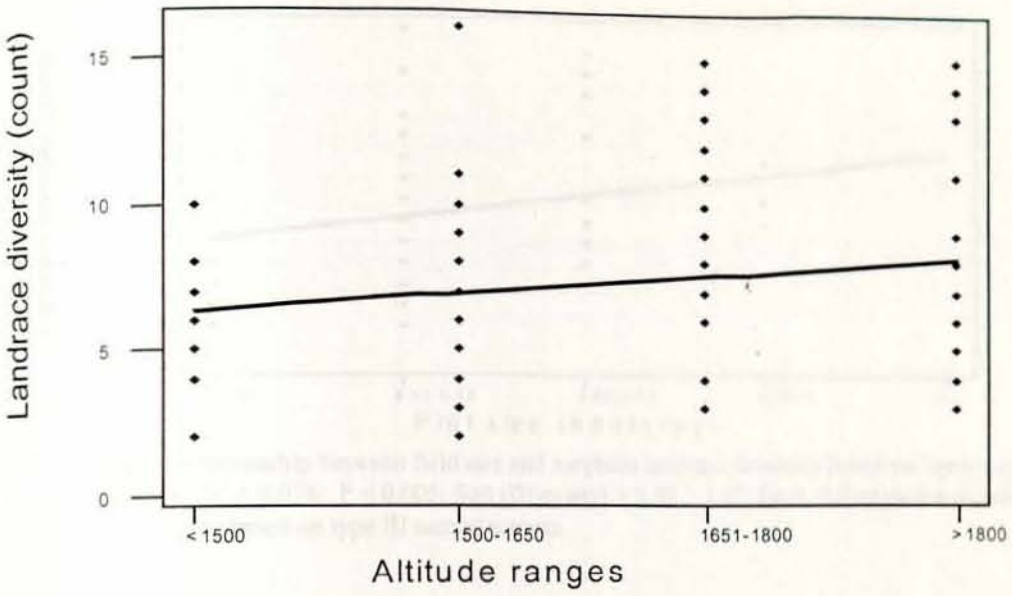

Figure 9. Relationship between field altitude and sorghum landrace diversity based on linear regression analysis (R^2 =0.04; P < 0.05; Sqrt (Diversity) = 5.72982 + 0.607916 Alt). All terms are significant at α = 0.05, based on type III sum of squares.

performed by Teshome *et al.* (1999b) on the maintenance of sorghum (S. bicolor (L.) Moench) landrace diversity by farmers' selection in Ethiopia. Since it is Sorghum landrace, diversity undoubtedly decreased towards high altitudes (>1800m.a.s.l.).

4. 2. 2. Field (plot) size

Figure 10 revealed the diversity of sorghum landraces along the plot size. The distribution of sorghum landraces by frequency composition (diversity) and total plant counts over 100 plots (fields) in terms of zones, woredas, ecosites, altitudes, and plot sizes is also presented in Appendix 6 and the frequency (%) and total counts of the 78 sorghum landraces in Appendix 7. The diversity of sorghum landraces was remarkably and unexpectedly very high in the field size between o.25 – 0.75 ha or 1- 3'timad'. Such an increase of sorghum landrace diversity may be related to the location of the specific field.

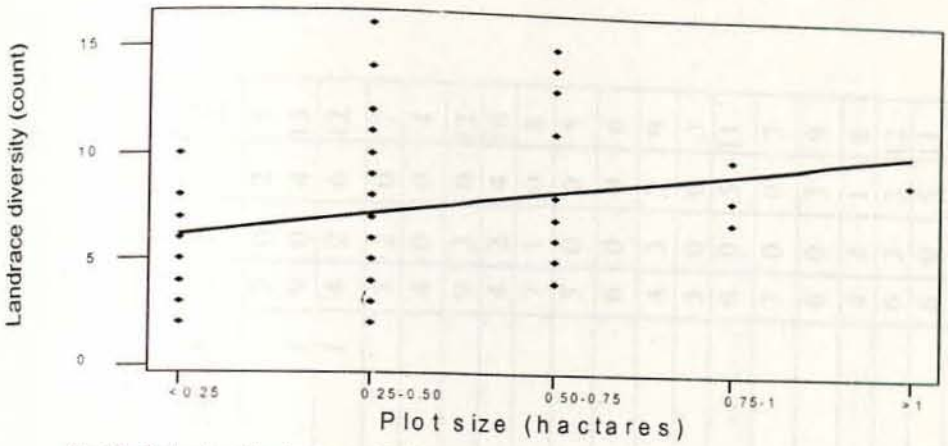

Fig10. Relationship between field size and sorghum landrace diversity based on linear regression analysis ($R^2 = 0.076$; $P < 0.005$; Sqrt (Diversity) = 5.08 + 1.05 Size). All terms are significant at $\alpha = 0.005$, based on type III sum of squares.

3. 3. Use values of the sorghum (*S. bicolor* (L.) Moench) landraces in North Shewa and South Welo regions of Ethiopia

About twenty-five uses were defined by the informants (Table 21). Most of the uses were common to the most landraces (eg. nutritional quality as 'injera', suitability for beverage, yield), and few were landrace-specific (eg.medicinal value, malting quality). Proportion of uses and use value indices for each selected sorghum landraces as identified by informant farmers is presented in Appendix 5. Table 21 shows the vernacular name of sorghum and their identified uses in the area. The greatest number of uses was recorded for zengada (15 uses) and both aehiyo rejimu and ahiyo jamyo had 13 and 12 uses respectively and the least number of uses was observed for both 'ganseber' (pot-breaker = 3 uses), commonly known for local beer and 'ajibe' (4 uses). The use values of most of the other sorghum landraces were more or less equally ranging from 5 to 12 uses and most of them were well adapted to the medium elevation where maximum diversity was recorded (Figure 11-13).

Table 21 Vernacular name of sorghum landraces (*S. bicolor* (L.) Moench) and their identified use values

Landraces *	USES																									Total			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	*1*	*2*	*3*	Σ
1										3		1				1	1		3							3	0	2	5
2	3		1	1	1	1	3	1	1	1		3						1				3	-		1	9	0	4	13
3	3		2	3		3	2	1	1	1		3					3					3	-		1	4	2	6	12
4	2		1	1	1	1	2					1														5	2	0	7
5	-										1	1	1						1							4	0	0	4
6	1		1	1	1	1			1	1		2		1			2			1		2				9	3	0	12
7	1		2	3	2	3			1	-		3		1	-		3		1			-				4	2	4	10
8	-		1	1	1	1			1	-		1			-		2	1								7	1	0	8
9	1								1	1		1					1									5	0	0	5
10	-			1					1	1		1					1					1				6	0	0	6
11	3			2					1			1		1		1	2		3			2				4	3	2	9
12	-										1						1					1				3	0	0	3
13	3		1	1	1	1			3			3		1			3	3			1			-		6	0	5	11
14				1	1	1			1			1			1		1						-			7	0	0	7
15	-		1	1	1	1				3		3					1	1				3				6	0	3	9
16	-		1	2	1	2				1		3					2					1				4	3	1	8
17	1		1	1	2	1	-		2	3	1	3			-		3	2				1				6	3	3	12
18	3		1	1	1	1	1		3			3					3	3				1				6	0	5	11
19	1		1	1	1	1	1		3			3					1		3				1			6	0	3	9
20	2			1		2						2					1		2							2	4	0	6
21	2		3	2	2	2			3	-		3			-		2	2				-	1		1	2	6	3	11
22	-											1	1		3	1	1									4	0	1	5
23	1		2	2	2	2	-			3		3					1	1	3			2				3	5	3	11
24	1			1								1			3		1					1				5	0	1	6

25	*2*			*1*						*1*	*3*	*1*	*3*					*1*												4	1	2	7
26	*3*		-			*1*	*1*			*2*						*1*			*3*	*2*		*1*	*1*	*1*			-	6	2	2	10
27	-					*1*				*2*			*2*						*2*						*1*			2	3	0	5
28	*1*		*1*	*1*	*1*	*1*				*1*	*3*		*2*						*3*					*1*				7	1	2	10
29	*1*		*1*	*1*	*1*					*1*							*1*		*2*		*1*							7	1	0	8
30	*1*												*2*						*3*	*2*								1	2	1	4
31	*3*		*1*	*1*	*1*	*1*		*1*	*1*				*1*	*1*					*3*					*1*				9	0	2	11
32	*1*					*1*					*3*		*2*				*1*											3	1	3	7
33	-										*3*					*1*			*1*						*1*			3	0	1	4
34	*3*	*1*	*1*	*1*	*1*	*1*				*1*	*1*		*3*				*1*	*3*			*1*		*3*		*1*	*1*	11	0	4	15
T o T A L	***1***	11	1	14	18	14	16	3	3	14	7	4	11	3	5	2	6	13	4	3	3	2	9	4	1	4					
	2	4	0	3	4	4	4	2	0	3	0	0	6	0	0	0	0	7	4	1	0	0	3	0	0	0					
	3	8	0	1	2	0	2	1	0	4	8	0	13	0	0	2	0	10	2	4	0	0	4	0	0	0					
	∑	23	1	18	24	18	22	6	3	21	15	4	30	3	5	4	6	30	10	8	3	2	16	4	1	4					

1 = less involved , *2* =medium involved, *3* = highly involved

* = Table 9 & 11

Uses: 1. Grain yield, 2. Total plant biomass, 3. Insect pest resistance 4. Striga resistance, 5. Disease resistance, 6. Drought resistance, 7. Bird resistance, 8. Loaging resistance, 9. Market value, 10. Eaten fresh green, 11. Eaten roasted, 12. Eaten as 'injera', 13. Eaten as bread, 14. Poridge making, 15. juicy stalk, 16. Eaten boild ('nifro'), 17. Suitability for beverage, 18. Milling quality, 19. Early maturing, 20. Late maturing, 21. Threshebility, 22. Storability, 23. Malting quality, 24. Medicinal value, and 25. Non-selective to soil type.

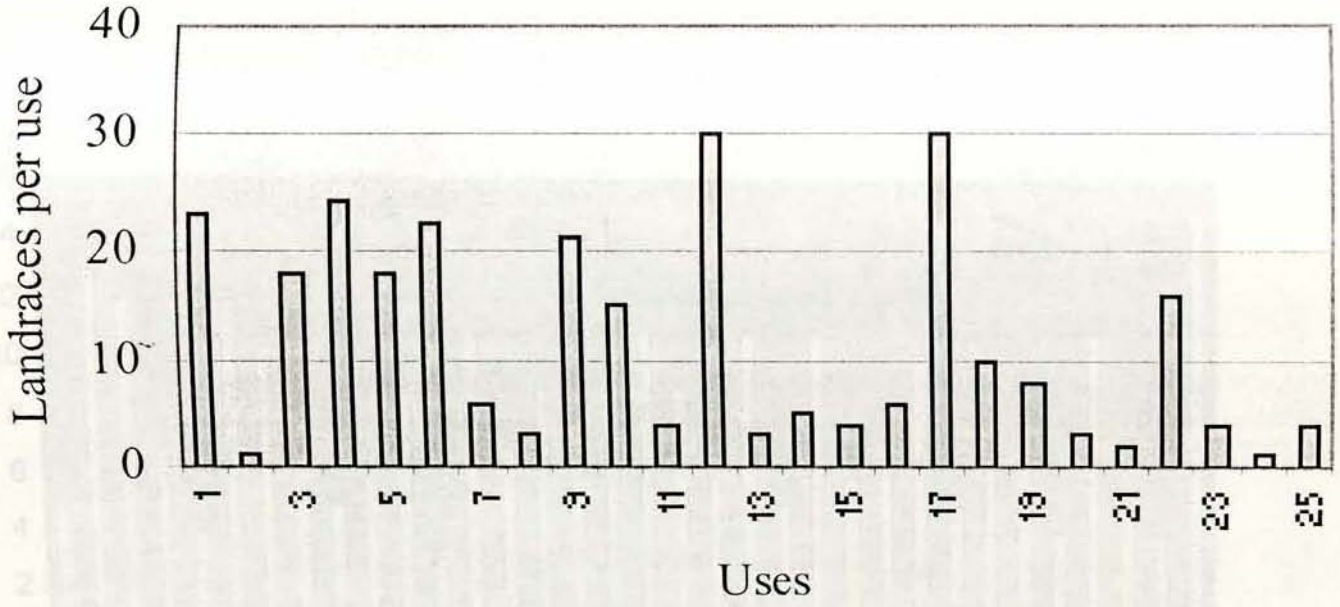

Figure 11. Total number of sorghum landraces per use in North Shewa and South Welo, Ethiopia

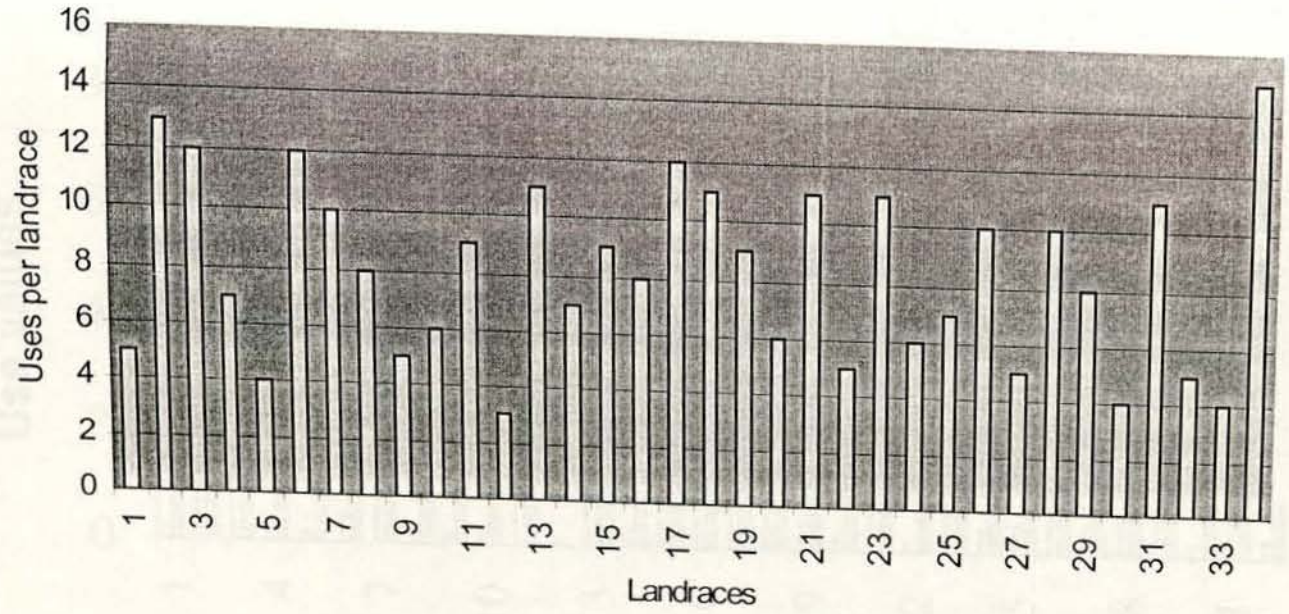

Figure 12. Total number of uses per a given landrace in North Shewa and South Welo, Ethiopia

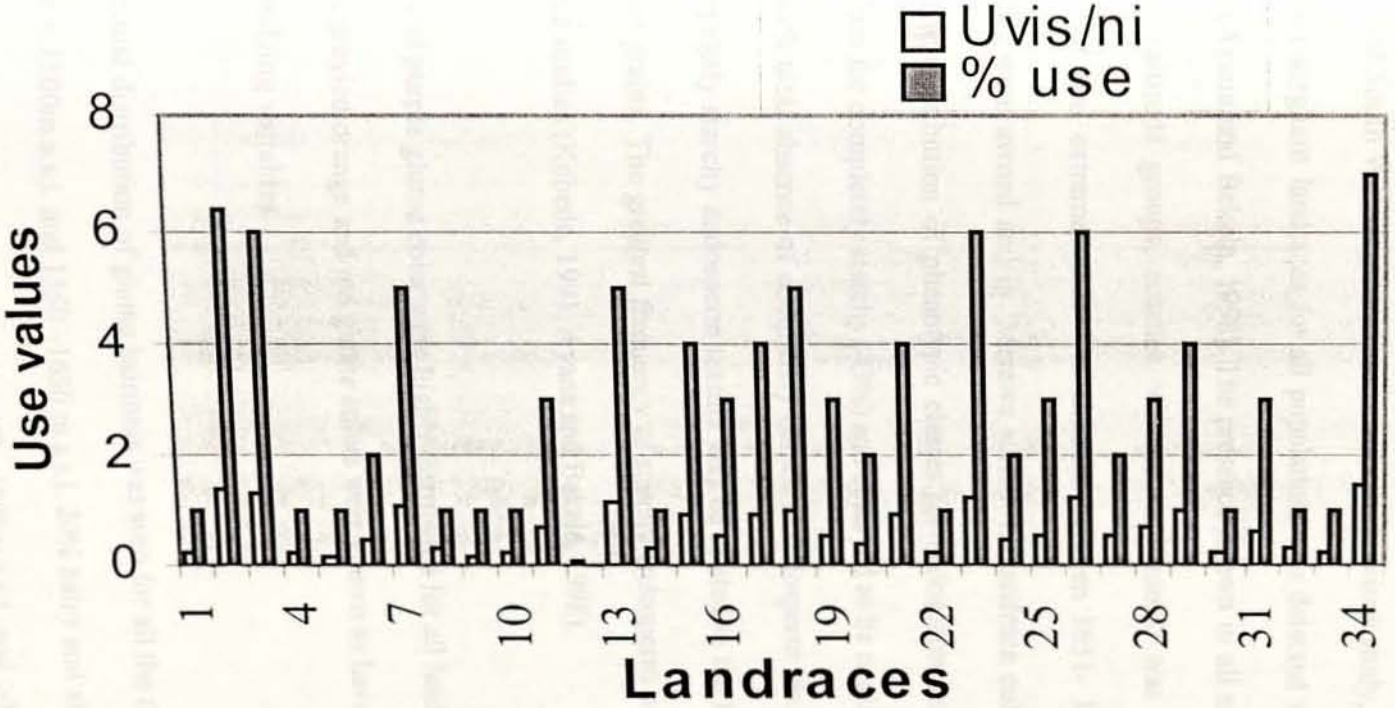

Figure 13. Relative use values and the use value index (Uvis/ni) of the 34 Sorghum (Sorghum bicolor (L.) Moench) landraces in North Shewa and South Welo regions.

V. DISCUSSION

1. Distribution of characters

Seventy five percent of the total landraces in this study was detected to have awns in North Shewa and South Welo regions. However, in the previous study, the frequency distribution of awned sorghum landraces for all populations was detected to be fairly equal in Welo region (Ayana and Bekele, 1998). The presence of awn in all enteries of each classifying variable (altitude groups, ecosites, woredas, and zones) was fairly equally distributed except for two extreme cases – at altitudes between 1651- 1800m.a.s.l., 99 % of the landraces were awned and in 'Merewa adrere' no landrace collected was found to have awn. The distribution of phenotypic classes for endosperm texture was observed to be maximum for completely starchy (43%) and observed to be negligeble for mostly corneous (3%) with total absence of completely corneous endosperm texture. This high proportion of compeletly starchy endosperm texture may be related to the high milling quality of the sorghum grains. The greatest frequency of starchy endosperm was totally coinciding with previous studies (Kebede, 1991; Ayana and Bekele, 1998).

White and purple glume color were highly distributed for all landraces in the regions while yellow, greyied orange and red glume colors were known to have negligible distribution in all classifying variables.

Fairly equal distribution of glume hairiness was seen for all the three phenotypic classes in altitude < 1500m.a.s.l. and 1550 –1650 m.a.s.l. 20% hairy and almost total medium glume hairiness were distributed in altitude 1651- 1800m.a.s.l. and >1800 m.a.s.l, respectively.

Such uneven distribution of glume hairiness was also seen for ecosites like Fontenina, Hayike and Merewa adere.The most abundant grain color for most altitude groups and most ecosites was yellow. Our result agree very much with the results already obtained by Teshme *et al.* (1997) and Ayana and Bekele (1998). However, it is necessary to mention that red color was more frequent at altitude >1800 m.a.s.l. and in one ecosite- 'Hayike'. In Merewa adere also white and brown grain colors were more frequent. For the entire landraces the number of plants in which the grain were covered with glumes decreased in the order of 50%, 25%, 75% and 100%. For all altitude groups and most ecosites, similar trends were followed.

Twin seededness, which is a world wide rare phenotype was observed (data given in Table 8-11). 6% of the grain forms of the entire landraces was twin seeds. The altitude range of 1500 – 1650 m.a.s.l. (in 'Layignaw ataye') was the only source of sorghum landraces having twin seeds. For this altitude twin seededness was about 12 %. Plump grain was much more frequent (83 %) than dimple grain (17 %) for the entire landraces along all altitude ranges and all ecosites. This result some what disagreed with the previous one (Teshome *et al.*, 1997), where about 69% of the grain plumpness was recorded to be dimple.

Out of six phenotypic classes, the compact oval panicle was 33 % for the entire landraces and this phenotypic class was also most dominant for all altitude groups and at all ecosites. This result agreed highly with what Teshome *et al.* (1997) and Ayana and Bekele (1998) have recorded for this region.

The distribution of diversified inflorescence compactness and shape indicates the distribution of different races of sorghum (Harlan and De Wet, 1972; Stemler *et al.*, 1977; Doggett, 1988). Race durra (charateristics of compact oval panicle) is grown in Africa along the northeaster coastal region and was restricted in Ethiopia to the Northeastern part (De Wet *et al.*, 1979; Doggett, 1988). The local farmers in North Shewa and South Welo regions choose this race for its high grain yielding quality and for this reason race durra is the most economically important race of sorghum in Ethiopia (Stemler *et al.*, 1975). The presence of compact, semicompact, very loose, and open panicle type in our study confirmed the occurrence of race durra, caudatum, guinea, and bicolor types (Stemler *et al.*, 1977 and Harlan, 1992). Teshome *et al.* (1997), further suggested the occurrence of one of the 15 intermediate races proposed by Harlan and De Wet (1972); Stemler *et al.* (1977) and Doggett (1988).

The distribution of juicy stalk for all landraces was represented by 33%. The most frequent sorghum landrace with juicy stalk was grown in the altitude range 1500 – 1651m.a.s.l. and no such sorghum landraces were detected in the altitude > 1880 m.a.s.l. Of all ecosites, 'Layignaw ataye' contained the most frequent sorghum with juicy stalk. The distribution of juice flavor also followed the same trend with frequency of 12 % of all landraces. Farmers in the regions easily differentiate the variation between and within both juicy and non-juicy sorghum landraces by using another important field character. The work done by Teshome *et al.* (1997) agrees with our result. In North Shewa and South Welo regions where yellow (45%) and white (45 %) color, were equally most dominant characters for all landraces and all altitude and all ecosites groups, farmers used leaf midrib color as an important characters to identify the specific type of sorghum landrace (e.g. the juicy and

non-juicy). Farmers further used midrib color to identify the grain forming from the juicy sorghums (Teshome *et al.*, 1997).

2. Estimates and analysis of diversity

H' is used widely in ecological studies of species diversity of community or of germplasm collection, and in analysis of ecological successions (Tolbert *et al.*, 1979). The distribution of this index of diversity is asymptotically normal for large samples (Brown *et al.*, 1973). Estimates of Shannon-Weaver diversity indices in this study indicated that sorghum landraces in North Shewa and South Welo regions were very high due to the ecological heterogeneity and climatic variations. Altitudinal gradient and agroecological differences have their own influences as a factor for diversity variation for the sorghum landrces in the study area. The overall mean diversity index (0.77 ± 0.04) was comparable with the result obtained (0.75 ± 0.07 for Welo) in the study of the geographical patterns of morphological variation in sorghum landraces for qualitative characters (Ayana and Bekele, 1998).

The value of H' for all landraces ranged from 0.32 for grain form to 0.98 for peduncle shape with an overall mean of 0.77. Except for grain form, apparently high diversity was estimated for all the other characters. The mean of Shannon diversity index, pooled over characters within altitudinal variations, ecosites, woreda, and zones, varied from 0.33 for altitude greater than 1800 m a. s. l. to 0.75 for altitude between 1500 and 1650 m a. s. l., from 0.33 for 'Merewa adere' to 0.79 for 'Layignaw ataye', from 0.33 for 'Hayike' to 0.79 for 'Ataye', and 0.60 for South Welo to 0.94 for North Shewa, respectively. The differences in the diversity of sorghum landraces between higher and medium altitude clearly indicates that sorghum landraces are more sensitive to the conditions of the higher altitudes. In different entries of each classifying variable (altitude, ecosite, woreda, and

zone), different levels of H' was displayed by individual character. Higher diversity index was generally obtained for characters with fewer (two to three) phenotypic classes (i.e., descriptor states) than those characters having more than three phenotypic classes. Ayana and Bekele (1998) have scored similar results in their study of geographical patterns of morphological variation in sorghum. Glume color showed relatively low diversity index in almost all entries of each classifying variable. This may be attributed to unequal distribution of the landraces of each entry over the seven characters. However, grain form, with two phenotypic classes (twin and single, i.e. descriptor states) and appreciably discovered in four landraces with high H' each, whereas the overall diversity index for the same character was least (0.32). This result further confirmed what has been recommended by Negassa (1985) and suggested by Ayana and Bekele (1998) that it might be misleading to compare the values of H' from characters having different classes.

Pooled over characters within each classifying variable, the range of mean of H' as indicated above showed an apparent diversity for all characters. The distribution of variability (Table 12) as it appears, lacks uniformity in all entries of the classifying variables.

Analysis of Variance (ANOVA) (Table 13) showed significant differences between characters within ecosites, altitudes, woreda, and zones. Midrib color is the only character that revealed significant differences both 'between ecosites' and 'between altitudes'. Endosperm texture, glume color, threshability characters also revealed significant differences between altitude groups. Glume hairiness showed significant difference between woredas and no character showed significant difference between zones and within any classifying variable. Bechere *et al.* (1996) and Belay (1997) for Ethiopian

wheat and Demissie and Bojornistad (1996) for barley observed significant differences only between the classifying variables and not within.

Table 14 depicted the hierarchical analysis of ANOVA of H' across traits (characters). No variance group between zones, woredas, ecosites, and altitudes have shown significant differences. However, significant differences have been revealed between landraces within all of the classifying variables. The fact that the study area and the sample size collected were relatively small the diversity seems statistically (though not biologically) nonsignificant at the regional (classifying variables) level. However, the real diversity was observed at the landraces level, as there was also statistically significances between landraces within the classifying variables. Bekele (1984); Negassa (1986); Bechere *et al.* (1996) have observed the same result for Ethiopian wheat.

3. Cluster Analysis

The 34 sorghum landraces were grouped into 5 clusters on the basis of their morphological characters from all the five-agroecological sites. Cluster analysis, based on the binary data or dummy (0/1) variables (that was derived from the original raw data), was used to obtain a dendrogram of the 34 sorghum (*S. bicolor* (L.) Moench) landraces (Fig. 6). The dendrogram clearly indicated the close relationship between sorghum landraces from almost all ecosites and the clustering was basically dependent on the panicle compactness and shapes (compact oval, semicompact elliptic and open), the stem and the grain type (whether or not eaten fresh green) of the landraces. Hence, from the dendrogram, it was clear that compact oval panicle (of dura type) was remarkably used in grouping 25 sorghum landraces into cluster I in which more than 75% of the landraces from each ecosite were grouped (Table 17). Similarly, sorghum landraces grouped in cluster II typically share the semicompact elliptic panicle (of caudatum type) and the type of grain

eaten fresh green in common. On the other hand, sorghum landraces from Bati and Layignaw ataye grouped together and it can also be evident that the landraces from altitude between 1500 – 1650 m.a.s.l. in these two ecosites appeared in the same cluster. Similarly, landraces from Fontenina and Merewa adere also appeared in the same cluster. However, there existed landraces from the same ecotype distributed over most clusters, indicating variation among landraces within a given ecosite. The overlapping of the clustering patterns of the sorghum landraces was a hint for the lack of strong sorghum landrace differentiation, which could mean the presence of gene flow among landraces.

All of the clusters were different from one another. The minimum inter-cluster distance (11.46 units) was between cluster I and II both of which contained relatively high number of landraces mainly from Layingaw ataye at altitude 1500 – 1800m.a.s.l. and the maximum inter cluster distance (42.58 units) was between cluster IV and V. Both clusters contained only one landrace each with distinct morphological features. This indicates that the sorghum landraces under the study were morphologically variable with some extent of non uniformity.

4. Isozyme analysis

Several surveys of variations in the genus sorghum have been previously studied by different workers (eg. Morden *et al.*, 1988; Morden *et al.*, 1989; Morden *et al.*, 1990; Aldrich *et al.*, 1992; Dje *et al.*, 1998; and Dje *et al.*, 1999) to validate the extent of genetic variation that might occur within the large sample size studied. In this study we used a relatively small sample size from narrow area where the local people were using the same market (high material exchange) and where a close relationship between the landraces were highly expected. For this reason, our result shows no variations (no allelic polymorphism) in the sorghum landraces.

5. Ethnobotanical Study

The local farming community has played a key role in maintaining the diverse crop resources in the form of landraces (local cultivars). In addition to being affected by population structure and natural selection from the surrounding environment, crop diversity in agricultural systems is also affected by farmer selection of agromorphological traits and management (Jarvis *et al.*, 1998). However, a farmer's selection criteria to maintain a particular landrace at any given time depends on the environment and biological as well as the cultural and socio-economic factors. Landraces are normally distinguished by farmers' in terms of their agro-morphological characters (Louette *et al.*, 1997; Teshome *et al.*, 1997). Farmers' indigenous knowledge about the local cultivars could also be expressed in terms of popular sayings, songs and poems (Appendix 4).

The diversity of sorghum landraces apparently decreased toward the lower altitude (< 1500m.a.s.l.). A good reason for the remarkable decrease of sorghum diversity in lower altitude may be most related to the vulnerability of the low lands to the water stress conditions and drought (see Teshome *et al.*, 1999b). For this reason local farmers always choose to grow drought resistant sorghum landraces at lower altitudes. On the other hand, the greatest diversity of sorghum landraces was observed unexpectedly from a relatively smaller field size (between o.25 – 0.75 ha or 1- 3'timad'). Such an increase of sorghum landrace diversity may be related to the location of the specific field. The further the field away from the home range the lesser the diversity of the landraces no matter what the size of the field is (Marthin, 1995). Teshome *et al.* (1999b) also observed such an unexpected high diversity from the very small (< 0.75 ha) fields and the reason suggested by the author was that the farmer's proximity to settlement areas enabled the farmers to give

more attention to them in terms of more inputs of time and organic residues than fields far away from the home.

From data give in Table 21, it can be realized that the highest number of uses was recorded for zengada (15 uses) and both for aehiyo rejimu and aheyo jamiyo (13 and 12 uses), respectively. These landraces are well adapted at the higher altitude (> 1800m.a.s.l.) where sorghum diversity is less. The local people were forced to maintain and to make use of the available diversity in terms of all the uses they need. Zengada accomplished 60 % of the total uses in the regions (Table 21). And from this study, it has been clear that zengada uniquely involve in medicinal value. Gelahun (1989), in his study on the Ethiopian Traditional Medicine, also identified zengada as medicinally important landrace. Benor and Sissay (1999) have also listed the use values of some sorghum landraces in Welo region based on farmers' indigenous knowledge.

The least number of uses recorded for 'ganseber' and 'ajibe' may be related to the fact that it is not too long after these landraces have been introduced from the neighboring regions (Appendix 3). Most of the other sorghum landraces which are well adapted to the medium elevation where maximum diversity was recorded were known to have use values in the range of 5 to 12.

VI. CONCLUSION AND RECOMMENDATIONS

1. CONCLUSION

The overall mean diversity index (H') (0.77 ± 0.04) obtained in the present study was high and similar to that of Ayana and Bekele (1998) (overall H' for Welo = 0.75 ± 0.07). This study supports the longstanding belief and hypothesis made by Vavilov (Doggett, 1991) about the high diversity of sorghum (Doggett and Parasado, 1995). The major reason for this high diversity of sorghum landraces in the study area is due to the fact that these landraces are found in the relatively complex ecological heterogeneity and non-uniform pattern of climatic conditions (temperature, humidity and rainfall). The role of farmer management adds another dimension to the cause of diversity.

The adaptive significance and pattern of distribution of specific traits through a certain ecological conditions help to choose the site of *in-situ* conservation, which would be integrated with *ex-situ* conservation. This study therefore showed that the pattern of distribution of different traits was influenced by both biotic and abiotic factors.

Analysis of variance for H' revealed no significant difference between zones. The trend of significance of ANOVA for H' seem to decrease from higher to lower hierarchy (significant difference between altitude > between ecosites > between woredas > between zones) indicating that altitudes and ecosites were of greater environmental heterogeneity and contributed to the largest proportion of the total variance.

Very many studies have been devoted to assessing the patterns of genetic variation in landraces. However, most studies were based on plant materials from genebank collections, rather than samples taken directly from the fields. Our study of isozyme analysis therefore, attempted at assessing the genetic variations based on the *in-situ* conserved sorghum landraces. EST and ACP were used in this study. However, allelic polymorphism was not detected for all sorghum landraces studied here at all loci in both enzyme systems. The fact that the resolution power of isozyme is relatively less, the genetic differentiation of these closely related sorghum landraces needs the application of other molecular marker system with higher resolution power (eg. RAPD, RFLP).

The sorghum landraces of North Shewa and South Welo regions of Ethiopia can be grouped into five clusters with 12 characters supporting the grouping. Inflorescence compactness and shape and stalk juiciness played major roles in grouping sorghum landraces into these clusters.

The frequency of existence (diversity) of sorghum landraces in the study area seem to decrease both towards the lower and higher altitudes. Since these extreme altitude groups had their own limitation, only those sorghum landraces that can have genotypes to resist and adapt to the environment thrive in the extreme ends of distribution. On the other hand, the field size determined the diversity of sorghum landraces in relation to the location of a specific field away from the farmers' settlement. This was also suggested by Teshome *et al.* (1999b) that the field's proximity to settlement areas enabled the farmers to give more attention to them in terms of more inputs of time and organic residues than fields far away from the living sites.

Traditional agro-ecosystems represent centuries of accumulated experience of interaction by the farmers without access to scientific information, external input, capital, credit, and development market (Wilken, 1977). Farmers almost always select landraces that have better quality to overcome the environmental hazards like drought, diseases, pests and others. This study therefore, has confirmed the key role that the traditional farmers play in the creation, maintenance and selection of landraces.

2. RECOMMENDATION

- Result of the present study help to suggest and to define the need for strategies for further collection of germplasm. Sample collection for this study was not as representative as it needed to be due to the then prevailing environmental conditions in the region studied.

- The isozyme analysis in the present study revealed no variation (no allelic polymorphism) for both EST and ACP. So other enzyme systems and higher molecular techniques with higher resolution (marker system) should be employed to screen the important genes.

- Above 75 locally named sorghum landraces have been observed in this study. This diverse genetic base that contain different genotypes with different use value suggests the need for further detailed study to characterize sorghum landraces and to identify genotypes that can be of breeding importance.

- From cluster analysis, distinct landraces (e.g. Wincho) have been identified with genotypes of agronomic and economic quality (e.g. loadging resistance and grain yield). These combinations of traits make them recommendable to be included in breeding programmes.

- Most of the observed sorghum landraces have been maintained and selected for decades and centuries by the local farmers in the face of their changing needs. It is therefore important to document the indigenous knowledge folk taxonomy of the North

Shewa and South Welo regions of Ethiopia aiming at the methods to safeguard the rare landraces from loss (genetic erosion).

- Lastly, complementary *in-situ* conservation strategies for sorghum landraces genetic resources should be highly recommended where by conservation effects are linked to rural development projects that emphasize the preservation of traditional farming system by relying on and giving attention to the maintenance of biological and genetic diversity in these systems.

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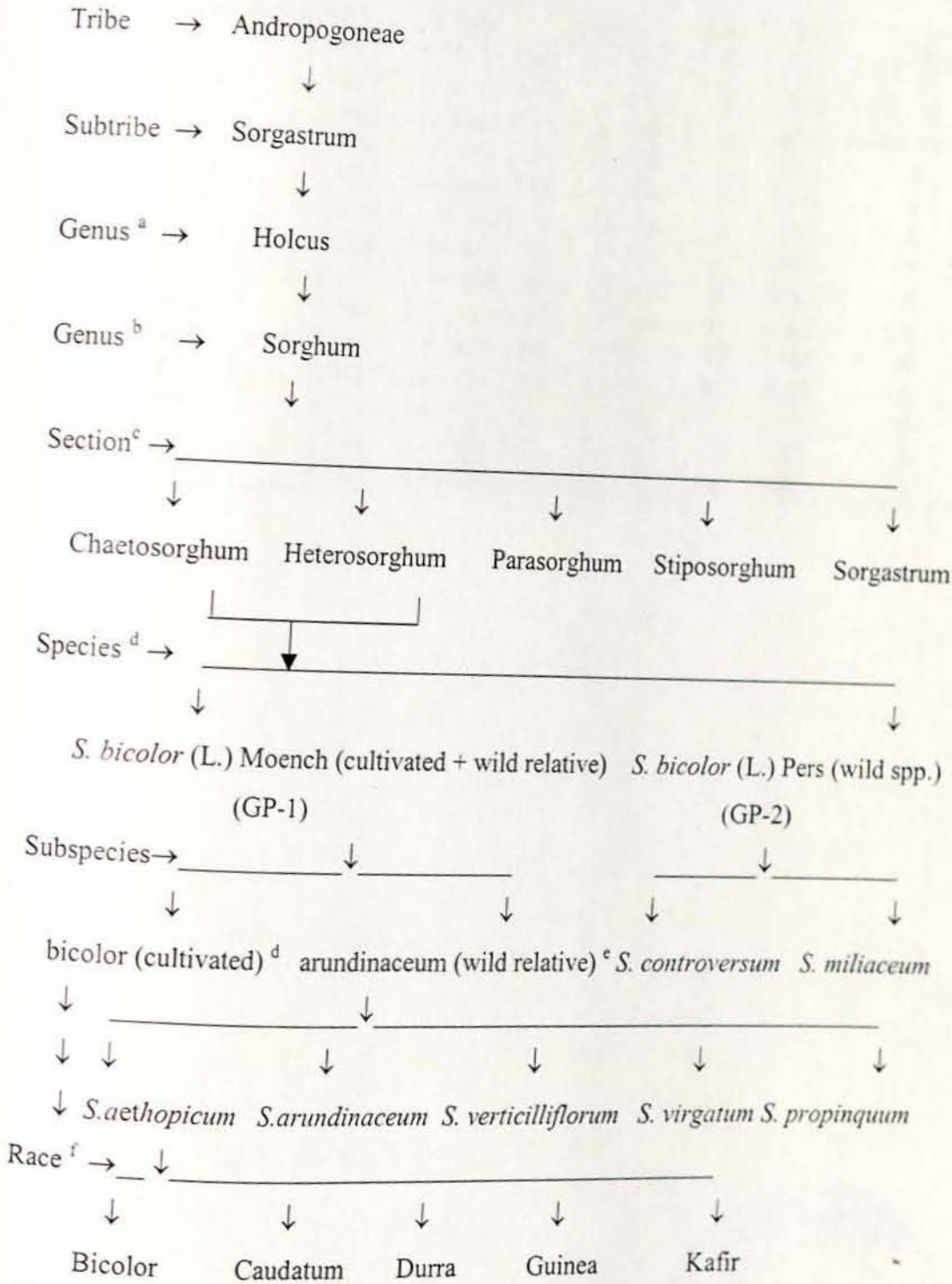
APPENDICES

Appendix 1. Taxonomy of the Genus sorghum (summarized from various literature sources)



[a&b] (Celarier, 1959) [c] (Garber, 1950); [d] (House, 1995); [e] (Snowden, 1955); and [f] (Harlan and De Wet, 1972).

Appendix 2: Step wise analysis of the characters contributed for the maximum variation based on agroecological sites

Steps	Characters	Min D. Square	Between ecosites	Exact F	df1	df2	Sig
1	EST	0.07	4.00 and 5.00	3.745	1	1015	5.33E-02
2	AWN	0.409	3.00 and 4.00	11.141	2	1014	1.64E-05
3	STJ	1.085	2.00 and 3.00	15.622	3	1013	6.04E-10
4	GRCV	1.833	1.00 and 2.00	41.993	4	1012	0
5	ICSH	1.965	1.00 and 2.00	35.977	5	1011	0
6	GLC	2.034	1.00 and 2.00	31.014	6	1010	0
7	GRC	2.089	1.00 and 2.00	27.274	7	1009	0
8	GLH	2.157	1.00 and 2.00	24.618	8	1008	0
9	GRF	2.186	1.00 and 2.00	22.154	9	1007	0
10	GRP	2.252	1.00 and 2.00	20.521	10	1006	0
11	JF	2.285	1.00 and 2.00	18.905	11	1005	0
12	PSH	2.292	1.00 and 2.00	17.369	12	1004	0
13	MRC	2.298	1.00 and 2.00	16.057	13	1003	0
14	TRSH	2.299	1.00 and 2.00	14.903	14	1002	0

Appendix 3. Vernacular name of the thirty-four landraces and their translation

No.	Vernacular name	Translation
1	abduke	After the name of a person who introduce it into the locality
2	aehiyo rejimu	"Donkish"; Never select the type of soil and never be affected by any environmental and biological stresses; has tall height
3	aehiyo jamiyo	"Donkish"; Never select the type of soil and never affected by any environmental and biological stresses; has short height
4	Afeso	"Highly productive"; the variety is known with high grain yielding capacity
5	Ajaibe	"Miraculous"; a newly introduced from the other region with an appreciably fast maturing quality
6	borshe	Unknown
7	cherekit (nech keteto)	"As white as moon"; Preferred for porridge making
8	delgome	Unknown
9	dimete	" My cat"; large and shinny grains like "cats eye"
10	dobe	"Large spherical shape"; known with large grains like chick pea
11	esmaeli	"After the name who has introduced this genotype into the region from another place"; early maturing and drought resistant type

12	gan-seber	Has strong fermenting quality to make good beer. So, it deserves a name "pot breaker"
13	gorad	"from the type of the panicle ends": Afetume-single, afedist triple (or quadruple) panicular ends; The ideal landrace with a general purposed nature; a genotype that can substitute tef (*Eragrostis tef*) for its "injera" making quality
14	gorad tinkish	A juicy stalk variety of this ideal landrace (gorad)
15	goronjo	A landrace highly preferable to its fresh green
16	jamo (Jamuye)	After the "person" who first introduced it *
17	Jemaw	"of public value"-the sweetest and most liked
18	jirru	"after the local name 'Jirru' from which the landrace has been introduced; eaten fresh green; but also used commonly as injera
19	key ihil (serina)	"red crop"; a newly introduced high yielding landrace having very red grain color
20	Key keteto	"red-grained" *
21	merabete	Introduced into this area from the region with local name "merabete";
22	mognayawikish	"Fool can not identify you"; it is difficult to identify this landrace for its misleading morphological appearance; eaten juicy stalk

23	mokake	"soft fresh green"; eaten fresh green
24	nech tinkish	"White juicy stalk", the landrace is known for its juicy stalk
25	rayo	Introduced from the place known with the local name "raya" in North Welo (neighboring administrative zone).
26	tengeley	From its yield *- high yielder
27	tuba	Unknown
28	watigela	"Calf body"; the name derived from 'Oromiffa'; as the name indicates this genotype has been maintained and introduced by the Oromo people dwelling in the surrounding; eaten fresh green
29	wefayibelash	"Bird-resistant"; the bitter and large grains that almost totally covered with glume enables it to deserve such quality
30	wegere	unknown
31	wincho	"open panicle"; Known for its tolerance to water lodging
32	yikir mindaye	"Leave alone my wage"; He / she never worries for his/ her wage for the intolerable test a landrace has; it is eaten fresh green.
33	yikir solate	"Leave alone my prayer"; He / she never worries for his/ her prayer for the joyful test of this particular landrace that is eaten fresh green
34	zengada	"not straight up"- too long a height that it mostly fail to be straight

	up in position

* = Controversial meaning, unknown = translation has no been well known

Appendix 4. Examples of vernacular names of some sorghum landraces and the related popular sayings with their translation

Vernacular name	Popular sayings	Translation
Goronjo	'Shegan lechewata goronjon leshet mogn ina jeteren yechegere let'	Goronjo is chosen as fresh green whereas jetere is not as such required for nutrition
Jiru	'Minew baderegeng yabatish arashi zer aleke biye ken indterashi' 'Zer aleke bileh ken yemit teragn Jiru eshet ayidelehu afseh atkimegn'	to mean that jiru is the most popular landrace eaten fresh green
Watigela	'Eshet ebelalehu yawim watigela Yekeresh endehon wa gela wa gela'	Watigela is the best variety eaten fresh green
Zengada	'Zengadan begulbet Mashilan bekumet'	The landraces is more productive and has high biological yields
	'Sifokr adere meskeremin gedlo Aswesidogn neber zengada kewlalo'	The landrace is known to be late maturing
	'Yezengada tela welmiteh welmiteh Yet tihedaleh wegebihin lemiteh'	This landrace is known to make strong local beer

Appendix 5. Proportion of uses and use value indices for each selected sorghum landraces as identified by informant farmers

Land races	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Informants	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis
1	0	0	0	0	0	0	6	0	0	0	0	0	1	11	0	0	3	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
4	0	0	0	0	0	4	0	0	0	0	0	0	2	0	0	0	0	3
5	0	2	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
6	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
10	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	9	0	0	0	0	0	0	5	0	8	0	0
12	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	10
14	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
15	4	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0
16	3	0	0	0	0	0	0	0	0	0	0	4	0	2	0	4	3	0
17	0	4	5	0	0	0	3	0	0	0	0	5	0	4	0	3	0	0
18	0	0	9	0	0	0	3	0	0	0	0	4	0	0	0	0	0	0
19	0	4	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	7	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	6	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	7	0	0
26	0	0	0	0	0	5	0	7	5	6	0	0	0	0	0	0	0	6
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3
28	0	0	0	0	0	7	8	0	0	0	0	0	0	6	0	2	2	3
29	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	5	0

30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
Total	7	43	38	6	4	15	32	9	5	6	21	3	35	8	28	17	28	
Uvis/ni	0.23	1.43	1.27	0.20	0.13	0.50	1.07	0.30	0.17	0.20	0.70	0.10	1.17	0.27	0.93	0.57	0.93	
% use	1	7	6	1	1	2	5	1	1	1	3	0	5	1	4	3	4	

landraces	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
Informants	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Uvis	Total
1	7	0	0	3	0	6	0	0	6	8	0	3	3	0	0	0	4	21
2	3	0	0	4	1	0	1	0	0	0	0	3	0	0	2	1	0	4
3	0	0	0	0	0	3	0	0	0	0	3	0	0	0	0	3	2	3
4	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	9
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
6	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3
7	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	4	3	0	0	0	3
10	1	0	0	0	0	0	0	0	0	5	1	0	0	0	0	0	7	4
11	0	0	0	0	0	0	0	0	0	0	8	3	0	8	0	0	0	22
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
13	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	17
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
15	0	0	0	0	5	0	0	0	0	0	0	0	0	2	0	0	4	9
16	0	0	0	0	0	2	2	0	0	0	0	4	0	0	0	0	0	16
17	0	0	0	0	0	3	4	0	0	0	0	4	0	0	2	0	5	24
18	0	0	0	0	0	0	4	0	0	0	0	2	0	0	0	0	0	16
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	13
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	10
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
22	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	6
24	0	0	0	0	0	5	0	0	5	0	0	0	0	0	0	0	0	12
25	5	4	5	10	0	0	0	0	5	0	0	0	0	0	4	0	0	11
26	0	0	3	7	0	4	0	5	4	0	6	7	0	5	0	0	0	29
27	3	0	3	3	0	6	0	4	3	0	1	0	0	0	0	0	0	4
28	0	3	0	0	0	6	1	2	4	0	0	0	0	0	0	1	0	28

29	0	6	0	0	0	2	0	3	2	0	0	0	0	0	0	0	0	8
30	3	4	0	0	0	6	2	3	4	0	0	3	0	0	0	1	0	4
Total	31	17	11	28	6	43	14	17	36	16	20	29	7	18	8	6	37	305
Uvis/ni	1.03	0.57	0.37	0.93	0.20	1.43	0.47	0.57	1.20	0.53	0.67	0.97	0.23	0.60	0.27	0.20	1.23	10.17
% use	5	3	2	4	1	7	2	3	6	2	3	4	1	3	1	1	6	100

Appendex 6. The distribution of sorghum landraces by frequency composition (diversity) and total plant counts over 100 plots in terms of zones, woredas, ecosites, altitudes, and plot sizes

Zone	Wor	Site	Alt	Plot No.	Plot size	Plant (count)	Landraces (frequency)
2	2	3	4	1	2	40	5
2	2	3	4	2	2	41	3
2	2	3	4	3	2	41	9
2	2	3	4	4	1	23	6
2	2	3	4	5	1	26	4
2	2	3	4	6	1	15	3
2	3	1	2	7	2	45	5
2	3	1	2	8	3	58	6
2	3	1	2	9	2	40	4
2	3	1	2	10	2	39	4
2	3	1	2	11	2	69	10
2	3	1	2	12	3	53	11
2	3	1	2	13	2	32	16
2	3	1	2	14	1	15	8
2	3	1	2	15	2	53	6
2	3	1	2	16	2	77	4
2	3	1	2	17	3	138	6
2	3	1	2	18	3	167	4
2	3	1	2	19	3	130	8
2	3	1	2	20	1	28	7
2	3	1	2	21	3	61	8
2	3	1	2	22	3	61	5
2	3	1	2	23	3	36	6
2	3	1	2	24	4	56	7
2	3	2	3	25	3	60	13
2	3	2	3	26	3	30	15
2	3	2	3	27	2	145	7
2	3	2	3	28	2	49	3
2	3	2	3	29	2	46	8
2	3	2	4	30	2	44	14
2	3	2	3	31	2	51	12
2	3	2	3	51	3	143	14
2	3	2	3	52	4	153	8
1	1	4	2	53	2	209	10
1	1	4	1	54	3	111	7
1	1	4	1	55	1	39	10
1	1	4	3	56	2	101	3
1	1	4	2	57	2	108	4
1	1	4	1	58	2	63	7
1	1	4	2	59	2	102	6
1	1	4	1	60	2	97	8
1	1	4	2	61	2	43	7
1	1	4	3	62	3	71	7
1	1	4	2	63	3	81	8
1	1	4	2	64	1	38	5
1	1	4	2	65	2	73	5
1	1	4	2	66	2	76	3
1	1	4	2	67	2	63	6
1	1	4	3	68	1	45	7
1	1	4	3	69	2	97	9
1	1	4	3	70	2	49	8
1	1	4	3	71	2	80	6
1	1	4	3	72	2	62	6
1	1	4	1	73	2	43	4
1	1	4	2	74	2	52	6
1	1	4	2	75	2	34	2
1	1	4	1	76	1	24	5
1	1	4	4	77	1	21	4
1	1	4	2	78	2	26	4
1	1	4	2	79	1	18	6
1	1	5	2	80	2	53	7
1	1	5	2	81	2	76	11

2	3	2	4	32	2	91
2	3	2	4	33	2	34
2	3	2	3	34	2	33
2	3	2	3	35	2	77
2	3	2	3	36	2	73
2	3	2	3	37	4	148
2	3	2	4	38	3	151
2	3	2	4	39	3	150
2	3	2	4	40	2	95
2	3	2	4	41	1	58
2	3	2	3	42	2	82
2	3	2	3	43	4	194
2	3	2	4	44	3	145
2	3	2	4	45	2	71
2	3	2	4	46	2	92
2	3	2	4	47	2	93
2	3	2	4	48	2	76
2	3	2	3	49	2	99
2	3	2	3	50	2	73

7	1	1	5	2	82	2	35	6
11	1	1	5	2	83	1	34	7
12	1	1	5	2	84	5	176	9
10	1	1	5	2	85	2	89	9
10	1	1	5	3	86	1	36	6
10	1	1	5	2	87	2	44	5
15	1	1	5	2	88	1	37	8
13	1	1	5	1	89	1	51	7
8	1	1	5	1	90	2	39	6
7	1	1	5	1	91	1	47	7
4	1	1	5	1	92	1	41	2
8	1	1	5	1	93	2	55	7
7	1	1	5	1	94	2	50	5
8	1	1	5	2	95	1	43	8
6	1	1	5	1	96	2	48	5
8	1	1	5	4	97	2	52	8
6	1	1	5	2	98	2	47	10
7	1	1	5	4	99	2	71	11
11	1	1	5	4	100	2	78	4

Appendix 7. **The frequency (%) and total counts of the 78 sorghum landraces identified over the 100 plots (fields) by agroecological sites in North Shewa and South Welo regions of Ethiopia.**

Ecosites	Ahiyojamyo	ahiyorejimen	Ayinabozadda	Lefozengng	besuke	maruteze	Chibtezen
1	0	0	0	0	0	0	0
2	0	3	11	0	0	17	0
3	89	50	7	3	13	1	1
4	0	0	0	0	0	50	0
5	0	1	0	0	0	6	0
Total	89	54	18	3	13	74	1
Ave. %	3	2	0	0	0	1	0

Ecosites	nechihil	keyzengada	enatzenga	gorad	wanese	Jiru	mokake
1	0	0	9	2	9	160	214
2	0	1	0	46	0	10	21
3	9	1	3	0	2	6	0
4	0	0	0	7	0	446	6
5	0	0	0	2	0	16	83
Total	9	2	12	57	11	638	324
Ave. %	0	0	0	1	0	10	4

Ecosites	Wofayibelash	keytinkish	keyihil	tengeley	yikrsolate	rayo	nechtinkis
1	46	49	162	247	45	96	40
2	186	32	0	26	11	0	82
3	0	0	0	0	0	0	0
4	35	0	0	9	0	0	0
5	141	1	0	11	5	0	14
Total	408	82	162	293	61	96	136
Ave. %	6	1	2	4	1	1	2

Ecosites	borshe	nechjamo	jamo	goronjo	Jigrte	Kenafe	Dawe	Kilo	Serina
1	11	31	13	2	3	7	1	2	3

2	0	3	14	41	0	0	3	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	5	236	0	0	0	3	22
5	0	0	2	6	2	0	0	5	45
Total	11	34	34	285	5	7	4	10	70
Ave. %	0	1	0	4	0	0	0	0	1

Ecosites	nechtibke	Dikuse	senkele	keygedido	subihan	esmaeli	abduke	amelsetinkish	watigela
1	1	1	2	2	0	0	0	0	0
2	1	1	0	0	31	1402	235	33	8
3	0	0	0	1	0	0	0	0	0
4	0	0	0	0	0	0	0	0	12
5	6	0	0	0	0	180	11	1	2
Total	8	2	2	3	31	1582	246	34	22
Ave. %	0	0	0	0	0	18	3	1	0

Ecosites	Mognayakish	weleletinkish	sererge	werebabo	gorad tinkish	tuba	minchiro	ajaibe	cherekit
1	0	0	0	0	0	0	0	0	0
2	56	1	1	1	1	3	41	7	118
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	438
5	1	0	0	0	0	0	1	1	332
Total	57	1	1	1	1	3	42	8	888
Ave. %	1	0	0	0	0	0	0	0	14

Ecosites	gubete	barchuke	gegebsa	jofetinkish	ykirmindaya	ganseber	mashilatinkish	zengadatinkish	yejibmurt
1	0	0	0	0	0	0	0	0	0
2	20	2	2	1	4	5	3	22	1
3	0	0	0	0	0	0	0	0	0
4	19	0	0	0	12	6	0	0	0
5	0	3	0	1	2	4	6	0	0
Total	39	5	2	2	18	15	9	22	1
Ave. %	1	0	0	0	0	0	0	0	0

Ecosites	wincho	motetinkis	wegere	jibotinkish	merabete	keyketeto	chemego	jetere	delgom

	h								
1	0	0	0	0	0	0	0	0	0
2	2	42	2	3	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	122	0	60	0	226	56	14	1	3
5	41	4	0	0	205	8	0	1	1
Total	165	46	62	3	431	64	14	2	4
Ave. %	3	0	1	0	6	1	0	0	0

Ecosites	dobe	dimete	Jemaw	siyumare	wegeretinkish	yifatetinkish	mogafere	gedalit	yegenfohil
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	3	1	1	1	27	2	2	1	0
5	2	0	5	0	8	13	3	0	6
Total	5	1	6	1	35	15	5	1	6
Ave. %	0	0	0	0	0	0	0	0	0

Ecosites	Tengelytinkish	afeso	Total
1	0	0	1158
2	0	0	2556
3	0	0	186
4	0	0	1826
5	12	2	1202
Total	12	2	6928
Ave. %	0	0	100

Appendix 8. Estimates of Shannon – Weaver diversity index of the fourteen qualitative characters of Sorghum (*Sorghum bicolor* (L.) Moench) by landraces. (key to legend: see Fig. 4)

Character	Awn	EST	GLC	GLH	GRC	GRCV	GRF	GRP	ICSH	JF	MRC	PSH	STJ	TRSH		
Landrace	H'	H'	H'	H'	H'	H'	H'	H'	H'	H'	H'	H'	H'	H'	Mean	± SE
1	0.21	0.51	0.03	0.00	0.40	0.36	0.00	0.84	0.33	0.00	0.20	0.00	0.00	0.65	0.25	± 0.07
2	0.97	0.66	0.15	0.00	0.58	0.43	0.00	0.00	0.22	0.00	0.24	0.65	0.00	0.00	0.28	± 0.09
3	0.00	0.00	0.00	0.13	0.39	0.38	0.00	0.00	0.38	0.00	0.29	0.00	0.00	0.00	0.11	± 0.04
4	0.00	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.05	± 0.04
5	0.00	0.21	0.23	0.00	0.00	0.09	0.00	0.00	0.25	0.00	0.67	0.00	0.00	0.00	0.10	± 0.05
6	0.00	0.66	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.65	0.00	0.00	0.16	± 0.07
7	0.00	0.83	0.73	0.00	0.08	0.56	0.00	0.21	0.38	0.00	0.24	0.00	0.00	0.00	0.22	± 0.08
8	0.57	0.23	0.66	0.00	0.61	0.57	0.00	0.65	0.30	0.00	0.33	0.21	0.00	0.00	0.30	± 0.07
9	0.72	0.77	0.58	0.00	0.36	0.55	0.78	0.65	0.49	0.00	0.51	0.99	0.00	0.35	0.48	± 0.08
10	0.88	0.65	0.53	0.36	0.55	0.45	0.97	1.00	0.26	0.00	0.68	0.57	0.00	0.92	0.56	± 0.09
11	0.00	0.49	0.23	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.88	0.17	± 0.08
12	0.00	0.18	0.65	0.00	0.18	0.38	0.00	0.00	0.16	0.00	0.79	0.00	0.00	0.84	0.23	± 0.08
13	0.00	0.73	0.49	0.22	0.00	0.40	0.00	0.00	0.25	0.00	0.56	1.00	0.00	0.00	0.26	± 0.09
14	0.00	0.00	0.35	0.00	0.47	0.09	0.00	0.72	0.39	0.00	0.50	0.00	0.00	0.65	0.23	± 0.07
15	0.00	0.42	0.53	0.00	0.18	0.38	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.88	0.19	± 0.07
16	0.97	0.73	0.25	0.00	0.22	0.38	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.21	0.21	± 0.08
17	0.78	0.73	0.64	0.41	0.50	0.48	0.57	0.57	0.25	0.00	0.37	0.99	0.00	0.21	0.46	± 0.08
18	0.21	0.70	0.50	0.49	0.00	0.15	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.18	± 0.07
19	0.00	0.53	0.29	0.00	0.00	0.43	0.00	0.00	0.37	0.00	0.51	0.00	0.00	0.65	0.20	± 0.07
20	0.35	0.73	0.38	0.00	0.00	0.43	0.00	0.00	0.28	0.00	0.24	0.65	0.00	0.00	0.22	± 0.07
21	0.00	0.67	0.44	0.00	0.00	0.34	0.00	0.00	0.38	0.00	0.44	0.21	0.00	0.00	0.18	± 0.06
22	0.00	0.00	0.17	0.00	0.45	0.47	0.00	0.78	0.32	0.00	0.38	0.35	0.00	0.00	0.21	± 0.07
23	0.21	0.77	0.71	0.00	0.00	0.24	0.00	0.00	0.37	0.00	0.24	1.00	0.00	0.00	0.25	± 0.09
24	0.00	0.82	0.36	0.00	0.00	0.49	0.00	0.00	0.25	0.00	0.68	0.00	0.00	0.00	0.19	± 0.08
25	0.00	0.52	0.35	0.41	0.00	0.20	0.00	0.00	0.45	0.00	0.47	0.00	0.00	0.00	0.17	± 0.06
26	0.00	0.70	0.33	0.00	0.00	0.00	0.00	0.92	0.00	0.00	0.38	0.00	0.00	0.00	0.17	± 0.08
27	0.00	0.28	0.41	0.46	0.18	0.31	0.00	0.72	0.45	0.00	0.44	0.95	0.00	0.00	0.30	± 0.08
28	0.88	0.76	0.26	0.00	0.26	0.48	0.00	0.00	0.08	0.00	0.42	0.84	0.00	0.00	0.28	± 0.09
29	0.00	0.66	0.48	0.00	0.40	0.42	0.00	0.00	0.00	0.00	0.33	0.00	0.21	0.00	0.18	± 0.06

30	0.21	0.79	0.07	0.00	0.61	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.15 ± 0.07
31	0.21	0.00	0.39	0.00	0.58	0.37	0.00	0.00	0.18	0.00	0.39	0.00	0.00	0.95	0.22 ± 0.08
32	0.35	0.64	0.56	0.49	0.28	0.00	0.72	0.72	0.54	0.00	0.51	0.00	0.00	0.99	0.41 ± 0.09
33	0.00	0.72	0.44	0.13	0.50	0.28	0.00	0.00	0.45	0.00	0.33	0.35	0.00	0.00	0.23 ± 0.06
34	0.00	0.00	0.33	0.00	0.00	0.09	0.00	0.00	0.38	0.00	0.39	0.00	0.00	0.00	0.09 ± 0.04
Entire data	0.82	0.84	0.77	0.95	0.90	0.74	0.32	0.67	0.81	0.77	0.63	0.98	0.91	0.72	0.77 ± 0.04

FORM 1

Appendix 9.

a. Data Sheet for recording the frequency (diversity) of sorghum landraces with the variation of altitude and field size

Serial No.	Farmer's Name	Named Landrace	Frequency of Occurrence	Plot size	Study site	Alt. (m. a.s.l.)	Distane from A.A.	Remark

FORM 2

b. Data sheet for collecting interview based informations on indigenous knowledge of the local farmers

Ser. No.	Vernaculr name of the landrace	Factors influencing the distribution of landraces (environmental & Biol.)	Selection criteria/ use value	Sayings, poems related to the landraces	Remark

FORM 3

c. Data sheet for characterization and scoring the qualitative morphological characters of sorghum landraces

Ser. No.	Lanrace's name	Qualitative morphological characters (for the character discriptiotion see Table 7)													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14

Appendix 10. Codes and description given for different classifying variables used throughout the text

Codes	Description			
	Agroecosite	Altitude (m.a.s.l.)	Woreda	Zone
1	Bati	>1500	Ataye	North Shewa
2	Fontenina	1500 – 1650	Hayike	South Welo
3	Hayike	1651 – 1800	Kalu	
4	Layignaw ataye	>1800		
5	Merewa adere			

DECLARATION

The thesis is the product of my original work, has not been presented for the degree in any other university and that all sources of material used for the thesis have been duly acknowledged.

Name: Adugna Abdi

Adugna Abdi Weldesemayat

Signature: _____

Place: Addis Ababa

Date of submission: June, 19/2000

This thesis has been submitted for examination with our approval as research advisors

Name Endashaw Bekele Signature _____

Name Zemede Asfaw Signature _____