International Master Programme at
the Swedish Biodiversity Centre

Master theses
No. 40
Uppsala 2007
ISSN: 1653-834X

Phenotypic variation and local customary use of Ethiopian potato (*Plectranthus edulis* (Vatke) Agnew)

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CBM MASTER THESES SERIES

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Abstract

A field experiment was conducted during the cropping season of 2006/2007 on 20 accessions of Ethiopian potato (*Plectranthus edulis* (Vatke) Agnew) conserved *ex situ* in the Ethiopian gene bank at Debrezeit Agricultural Research Centre. The objectives were to study the phenotypic diversity of the accessions and assess the morphological diversity with respect to collection regions. The accessions were collected from the north western, south western and southern parts of the country. All accessions were grown in a single row plot in a randomized complete block design with four replications. A total of 29 morphological characters were recorded. Multivariate methods including cluster and principal components analysis were used to assess the patterns of variation using quantitative characters. Four principal components (PC) extracted about 75.7% of the gross variance among the accessions. About 26.1% of the variance accounted for by the first principal component alone resulted largely from variations in thickness of the primary stem, plant height, number of primary branches and internode lengths. Generally, the PC analysis showed the existence of wide overall diversity, involving a number of traits. Cluster analysis grouped the 20 accessions into six clusters. However, the accessions collected from geographically similar areas were grouped in different clusters indicating that factors of the local environment were not related to phenotypic diversity. While the study indicated that accessions from different regions of the country might have a similar genetic background, those originating from the same area might also have different genetic backgrounds. Therefore, geographic diversity need not necessarily represent genetic diversity.

A survey was also made in one of the major *P. edulis* growing districts of southern Ethiopia, Sodozuria district. The survey was aimed at assembling ethno-botanical information concerning the use and management of the crop. Most of the respondents had sufficient experience of growing *P. edulis*. The results indicated that there were no significant differences in the management and use of *P. edulis* between peasant associations, as well as among villages. However, socio-economic status of the households was found to be an important factor affecting the management and conservation of the crop. The difference in level of education had no impact on conservation and use of *P. edulis*. It was also observed that the older informants were more knowledgeable than the younger ones, as they knew much more about the different local cultivars and values of use.

Keywords: *Plectranthus edulis*, Ethiopian potato, geographic origin, multivariate methods, phenotypic variation

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Introduction

Background

Biodiversity

Biodiversity is defined as the variability among living organisms from all sources including terrestrial, marine and other ecosystems and the ecological complexes of which they are part, which includes diversity within species, between species, and of ecosystems (UNEP 1992). There is a variety of life on Earth. This variety provides the building blocks to adapt to changing environmental conditions in the future (ENBSAP 2005). Moreover, the variety and variation occurring in nature has sustained harmonious existence of life on earth (Reddy 1994 as cited in Feleke W/Yes 2000). From both domesticated and non domesticated components of biodiversity humanity derives all of its food, medicines and other basic needs. The values of diversity are particularly important in agriculture. For generations, people have raised a wide range of crops and livestock to stabilize and enhance productivity. Farmers also need the genetic diversity of crops and livestock to increase yields and to respond to changing environmental conditions. Genetic diversity enables the breeders to tailor crops and animals to new climatic conditions (Raven 1992).

Crop biodiversity is vital for the survival of farmers in developing countries (Altieri 1991). It is of extreme importance, particularly for traditional people, for whom it is a matter of survival since their livelihoods depend on free and open access to a great variety of biological resources for food and other basic needs. Indigenous people not only utilize biodiversity but also develop systems of managing and conserving it. This is the result of old age practices of traditional agriculture and a consequent accumulation of knowledge through a series of observations and innovative processes (Miller *et al.* 1995). Many people's food and livelihood depends on a sustained management of various biological resources that are important for food and agriculture (FAO 2005).

Agro-biodiversity

Agro-biodiversity is a vital sub-set of biodiversity. It is also known as agricultural biodiversity or the genetic resources for food and agriculture. It includes all components of biological diversity that are relevant to food and agriculture. Agro-biodiversity comprises the variety and variability of plants, animals and micro-organisms at the gene, species and ecosystem level which are necessary to sustain key functions in the agro-ecosystem, its structures and processes. It is the result of the interaction between the environment, genetic resources and management systems and practices used by culturally diverse peoples. Thus, local knowledge and culture can be considered as integral parts of agro-biodiversity, since it is the human activity in agriculture that shapes and conserves this biodiversity (FAO 2005). Plant genetic resources may also have other significant social and cultural values, services, for example, to bind communities together through local seed exchange (IPGRI 1999).

Agro-biodiversity in Ethiopia is strongly linked with local communities who are always embedded by their local ecosystems, modifying them and being modified by them (IBCR 2001). Numerous practices of enhancing biodiversity are tied to the rich cultural diversities and local knowledge of Ethiopia (Tessema Tanto and Girma Balcha 2003). The diverse farming system of the country is traditional and based on small-scale production, which is managed with simple production technology. In this production system, the components of agro-biodiversity offer diverse services and benefits that vary according to farming systems. The services provide a range of options with multiple uses, particularly in food and in meeting local changing environmental and socio-economic needs (IBCR 2001).

Centre of Origin and Diversity

According to Vavilov (1951) there are certain areas in the world where crop plant diversity is extremely high. These areas of greatest diversity are referred to as centre of origin of the crops concerned (Hawkes 1983). Sheffield (1986) also reported that the genetic diversity in crops is concentrated in certain areas of the world. Ethiopia is among such areas in the world where crop domestication started, and considered as a primary gene centre for several crop plants (Vavilov 1951). Other scientists (Harlan 1969; Frankel 1973) reported the existence of many cultivated crops in Ethiopia which show considerable genetic diversity. Complex topography, cultural diversity and environmental heterogeneity offer suitable conditions for a wide range of life forms in Ethiopia (IBCR 2001).

The tremendous genetic diversity that exists in Ethiopia deserves much more attention than received so far. Scientists from many parts of the world have collected Ethiopian germplasm (Mengesha 1975) and many plant breeders have discovered some highly desirable genetic characteristics such as disease resistance in barley (Qualset 1975). According to IBCR (2001), at least 7000 vascular plant species occur in Ethiopia, of which 12% are believed to be endemic. It is also stated in ENBSA (2005) that crops such as tef (*Eragrostis tef* (Zucc.) Trotter), noog (*Guizotia abyssinica* (L.F.) Cass.), gesho (*Rhamnus prinoides* (L'Hér.), kosso (*Hagenia abyssinica* (Bruce) J. F. Gmel), Ethiopian mustard (*Brassica carinata* (A.Br.), enset (*Ensete ventricosum* (Welw.) Cheesman), chat (*Catha edulis* (Vahl.) Endl.), Oromo dinch (*Plectranthus edulis* (Vatke) Agnew), anchote (*Coccinia abyssinica* (Lam.) Cogn.) and buna (*Coffea arabica* L.) have great diversity and believed to have originated in Ethiopia.

The large diversity of ecological conditions determined by topography and cultural variations in the country have created diverse and conducive environment for the development of a wide variety of plants (Tessema Tanto and Girma Balcha 2003; Melaku Worede 1997). For instance many crops that were originally domesticated outside of the East African highlands (e.g. durum wheat, bread wheat, barley, sorghum, field pea, faba bean, chick pea, cowpea, linseed and castor bean) also show high secondary diversification in Ethiopia (Harlan 1969).

Traditional Management of Plant Genetic Resources

Ethiopian agriculture is still dominated by subsistence farming conducted in traditional ways. The small scale farmers use wide ranges of crop species and local varieties in complex mixed crop-livestock production and agro-forestry systems (Harlan 1975). The systems are important reservoirs of biodiversity both for the local farmers and global agriculture. Traditional agro-ecosystems are genetically diverse, containing populations of variable and adapted land races as well as wild relatives of crops (Altieri 1987). Indigenous farmers and their traditional farming practices have also been playing key roles in preserving the interactions of plants with their environments (Brush 1995). In the process, while farmers' fields have been serving as informal gene banks and allowing continuous evolution of plant characteristics and varieties (Melaku Worede 1988).

Over the centuries, farmers have acquired considerable knowledge on ways of conserving and utilizing biodiversity. Their traditional knowledge on useful plant characteristics enables them, for example, to select varieties that require less fertilizer, out-grow weeds best, less susceptible to pests and possess better taste (IPGRI 1999). This has also been observed from the routine practices of subsistence farmers of Ethiopia. One of such practices is growing diversity of crops in the same field in order to sustain productivity, and diversify their diet and income (Melaku Worede 1993) using their own seed stocks which often trace back to several generations. Even though the farmers know that some seeds are low yielding, they maintain these ancestral seeds so as to use them for seeding during adverse environmental condition and to stabilize production (Mengesha 1975).

Diversity in crop plants is conditioned by geographic, climatic and edaphic factors, cultural and ethnic differences, farming practices, and religious and cultural beliefs (Hawkes 1983). Ethiopia is endowed with diverse ecosystems, and edaphic and climatic conditions. As the result, the country is inhibited by amazingly great diversity of plant, animal and microbial genetic resources (FAO 2001). It is also reported that the genetic diversity found in the Ethiopian landraces are being used worldwide for developing new crop varieties and addressing different production constraints. Most of this diversity is found in farms of small-scale farmers who have been playing central roles in the maintenance and use of these resources (Melaku Worede *et al.* 2000).

In countries like Ethiopia where agriculture is dominated by subsistence farming, diversity among crop species is especially significant. The diversity represents an important resource to the farming communities (Melaku Worede *et al. 2*000). Moreover, sustainable way of increasing productivity in farmers' field depends on the diversity of crops (Altieri and Merric 1987). Genetic diversity confers resistance to diseases that are specific to particular varieties of crops and allows farmers to exploit different microclimates and derive multiple uses from within-species genetic variation. It plays a great role for breeders also. The more genetic diversity that can be available to the breeder, the wider range of choices will be there to select the desired kind of characteristics for the breeding program (Hawkes 1983). Generally, plant genetic diversity is humanity's best defence against poverty, food insecurity and threats to the natural resource base. Therefore, the use of genetic resources will remain the best way of meeting future food needs and driving the economic and social benefits for the world's rapidly growing human population (IPGRI 1999).

Trends in Use of Plant Genetic Resources

At present, only 30 crop species are used to meet 95% of the world's food energy needs (FAO, 1996). These crops species are widely and intensively cultivated and have been selected from a large agro-biodiversity basket containing more than 7,000 food species (Wilson 1992). A study undertaken on per capita food supply data of 146 countries revealed that only 103 species contribute 90% of the world plant food supply (Prescott-

Allen & Prescott-Allen 1990). Sub-regionally, this number increases, but for many other crop species of local importance, the knowledge on the distribution of their genetic diversity and use patterns is still largely limited. For instance, under-utilized crop species are found in numerous agricultural ecosystems and are grown in local production systems (Joshi *et al.* 2002; Williams *et al.* 2002). These locally varied food production systems are under threat, including the local knowledge, the culture and skills of farmers. With this decline, agro-biodiversity is disappearing; the scale of the loss is extensive. The decline has been accelerated throughout the twentieth century due to increasing demands from growing population and greater competition for natural resources (FAO 2005).

The green revolution that introduced high yielding varieties of crops to boost food self-sufficiency has narrowed the basis of food security (Shiva 1991). Erosion of biodiversity due to such factors as maintenance of monocultures has lead to an increase in ecological vulnerability and unsustainability (Singh 1996). Most of the indigenous crops were lost or have become under-utilized. With modernization of agricultural practices, many indigenous crops are held in low esteem, though some remained important in their centres of diversity (Padulosi and Frison 1999; Seyfu Ketema, 1997). Since the green revolution, farmers tend to abandon their traditional crops and are increasingly looking for the newly bred, more homogeneous and high yielding varieties (Mengesha 1975).

Currently, more than 6 million accessions of plant genetic resources for food and agriculture are conserved in some 1300 germplasm collections around the world. Of these, 80% of all accessions belong to major crops and their close relatives. The remaining 20% are other crops, including under-utilized crops, which are very poorly represented (Padulosi 1999b cited in IPGRI 2002). High yielding crop varieties are widely distributed often with government subsidies to encourage their adoption, thus displacing local crops gradually from many farm lands (Williams and Haq 2002). The existing knowledge on cultivation, distribution and genetic potential of under-utilized crops is also limited (Seyfu Ketema 1997). At present, the conservation of these crop species largely depends on the personal motivation of farmers (IPGRI 2002).

The importance of the so-called minor or under-utilized crops is often undervalued. In many cases, from a livelihoods perspective, they are not minor or under-utilized as they can play important role in livelihood and food security at the local levels (FAO 2005). The conservation and sustainable use of the genetic resources of indigenous food crops offer an opportunity for addressing the problem of food security (Mathenge 1995). For instance Abebe Demissie (1998) reported that *Ensete ventricosum*, *Coccinia abyssinica*, *Plectranthus edulis*, *Amorphophallus abyssinica* and *Abelmoschus esculentus* are some of the little known but potentially useful crop species in Ethiopia. They, however, have received little attention by research and development activities so far. Mathenge (1995) further indicated that proper documentation of the available information related to under-utilized crops on distribution, use and traditional knowledge is essential. The information will be valuable in order to maximize the conservation and further utilization of these crops.

Taxonomy and description of *P. edulis*

P. edulis belongs to the family Labiatae (Lamiaceae). The family consists over 350 tuber bearing and non-tuber bearing species that are mainly distributed in Africa, Asia and Australia (Codd 1985 as cited in Mulugeta Taye *et al.* 2006). *P. edulis* is one of the tuber-bearing members of the family Labiatae. It is a diploid, small hairy, succulent herb about 50-60 cm high, with ovate and shallowly serrate leaves that is cultivated on small-scale basis in south and south western Ethiopia. The inflorescence is a raceme of small flowers which are usually purplish-blue. The leaves vary from dark-green to purplish-green. *P. edulis* is a highland crop and the tubers have different shapes, colour and size (Abebe Demissie 1998). It is said to have originated in Ethiopia (Ryding 2000 cited in Mulugeta Taye *et al.* 2006). Depending on where *P. edulis* grows it is often known under different names, e.g. Oromo potao (Oromo dinch), Wolaita donuwa, Gurage dinch and Agew dinch. There are also different local cultivars that have been identified by farmers (Mulugeta Taye *et al.* 2006).

Food compositions of *P. edulis*

A study carried out by EHNRI (1997) on the nutritional content of 100 gm edible portion of both raw and cooked tubers of *P. edulis* showed that it has ample amounts of micro and macro-nutrients. While it has relatively higher food energy when cooked than *Solanum tuberosum*, the fat and calcium contents are almost twice as high as that of *S. tuberosum*. The protein content is similar to that of *S. tuberosum* and is almost twice as high as that of *Ipomoea batatas* when cooked. The study revealed also that the cooked tubers have more amounts of energy, fibre and carbohydrate compared to the raw tuber (Table 1). However, the later is richer in nitrogen, protein, calcium, phosphorous, iron and niacin than cooked ones (EHNRI 1997).

Table 1. Nutritional content of *Plectranthus edulis, Solanum tuberosum* and *Ipomoea batatas* (all values per 100 gm of edible portion)

No.	Composition	*P. edulis*		*S. tuberosum*		*I. batatas*	
		Raw	Cooked	Raw	Cooked	Raw	Cooked
1	Food energy (calories)	69.00	100.60	103.7	89.70	136.00	134.20
2	Moisture (%)	81.90	73.80	73.10	76.80	67.40	65.60
3	Nitrogen (grams)	0.30	0.24	0.30	0.26	0.30	0.13
4	Protein (grams)	1.50	1.00	1.30	1.10	1.30	0.50
5	Fat (grams)	0.20	0.20	0.10	0.10	2.00	0.20
6	Carbohydrate (incl. fiber) (grams)	15.30	23.70	24.40	21.10	28.20	32.60
7	Fiber (grams)	0.70	1.00	1.40	0.90	1.10	1.50
8	Ash (grams)	1.10	1.30	1.10	0.90	1.10	1.10
9	Calcium (milligrams)	29.00	19.00	14.00	9.00	52.00	35.00
10	Phosphorous (milligrams)	90.00	62.00	57.00	49.00	34.00	54.00
11	Iron (milligrams)	9.30	1.10	2.30	1.50	3.40	0.90
12	Thiamin (milligrams)	-	0.11	0.08	0.05	0.08	0.06
13	Riboflavin (milligrams)	-	0.32	0.08	0.09	0.05	0.01
14	Niacin (milligrams)	0.70	0.30	1.00	0.80	0.90	0.40

Source: Ethiopian Health and Nutrition Research Institute (EHNRI 1997)

Rationale and objectives of the study

Ethiopia is one of the world centres of origin and diversity of crops (Vavilov 1951). Farmers have developed diverse and locally adapted varieties of crops. Like in many other developing countries farmers in Ethiopia maintain a number of landraces of crops on their small plot of land because no single variety can satisfy their basic needs. It is also stated in IPGRI (1999) that the local varieties fit easily into traditional farming system, and this will enable farmers maximize returns using low levels of technology and limited resources.

Despite this, the current agricultural policies largely focus on national or regional important crops without due consideration of indigenous crop production. Major agricultural development programs are biased towards the cultivation of high yielding commercial crops. However, this does not seem realistic, especially to subsistence farmers in developing countries like Ethiopia, who prefer to increase their option by diversifying their small plots of land rather than homogenizing them with high external inputs and varieties.

Plectranthus edulis (syn. Coleus edulis) also locally known as Oromo/Wolaita/Gurage/Agew dinch or Ethiopian potato belongs to the family Labiatae, and is one of the traditional and under-utilized root crops. It is indigenous to Ethiopia and has been cultivated for its edible tuber in an array of agro-ecological zones in different parts of the country, mainly in south and west. It is one of the major sources of food and contributes significantly to household food security. Since the last few decades, however, the production of the crop has been declining. Introduction of new species of root crops, recurrent droughts, land scarcity, long maturation period coupled with its short shelf life are some of the major factors that have contributed to the decline.

Cognizant of the above, the Ethiopian Institute of Biodiversity Conservation has made collection expeditions in major growing regions of the country to collect *P. edulis*. Currently, more than 30 accessions are being maintained in the field gene bank. Most of the accessions were collected from Oromia, South Nation, Nationality and People (SNNPRS) and Amhara Regional States. So far, limited research has been undertaken on this crop and little information is available. Similarly, there is no enough information on its role in supporting the livelihoods of the farmers. The local knowledge on the use and management of *P. edulis* is also not well documented. Information on the morphological diversity of a population is essential for further improvement of a given crop. To this end, studying the morphological diversity of *P. edulis* and assessing its potential uses and management are of paramount importance.

Hence, this study has the following objectives:

- to conduct morphological characterization on national *ex-situ* collections of *P. edulis* and compare phenotypic diversity with respect to their origin in terms of collection region

- to collect and analyze indigenous knowledge associated with use and management of *P. edulis*, and

- to identify major constraints associated with use and management of *P. edulis* and come up with sets of recommendations.

Material and Methods

Description of the experimental site for morphological characterization

The experiment was conducted at Deberezeit Agricultural Research Centre (8º 44' N, 38º 57' E, elevation 1900 m.a.s.l) of the Ethiopian Agricultural Research Institute (EIAR), located 52 km south of Addis Ababa), on light soil under irrigation during the off-season period of 2006/07. The mean monthly rainfall and temperature were 79.7mm and 19.0 cº, respectively. Similarly, the average monthly relative humidity was 56.2%.

Planting Materials and Experimental Design

A total of 20 accessions of *P. edulis* conserved *ex situ* in the Ethiopian gene bank were used for the study (Table 2). The accessions were planted in single-row plots in randomized complete block design with four replications. The size of each plot was 3.60 x 1.0 meter. Plants were spaced 0.60 m apart within the row, and distance between each plot was 1.5 m. During the study period normal agronomic practices such as irrigation at three days interval, weeding and fertilization were applied as appropriate. Urea fertilizer was side dressed at the rate of 165 kg/ha. The rate of fertilization followed recommendations for potato (Lemaga *et al.* 1992). Experimental plots were fenced using mesh wire to prevent the entrance of both domestic and wild animals.

Table 2. Collection sites of *P. edulis* accessions investigated in the study

No.	Sample code	Collection regions	
		Zone	District
1	PTS1	Jimma	Setema
2	PDA	Agewawi	Dangela
3	PD1	Jimma	Dedo
4	PM1	Illuababora	Metu
5	PK1	Jimma	Kersa
6	PB1	Illuababora	Bedele
7	PS2	Jimma	Seka
8	PFS	Yem	Fofa
9	PDS	Semen Omo	Damot Gale
10	PWS	Gedeo	Wenago
11	PM2	Illuababora	Metu
12	PDO	Illuababora	Chora
13	PTS2	Jimma	Setema
14	PC1	Semen Omo	Chencha
15	PK2	Jimma	Kersa
16	PD2	Jimma	Dedo
17	PS1	Jimma	Seka
18	PC2	Semen Omo	Chencha
19	PGO	Jimma	Gera
20	PB2	Illuababora	Bedele

Data Collection

A descriptor list for characterizing *P. edulis* is so far not available. Therefore, the descriptor list developed for other root crops by IPGRI was used with slight modification for the study. Data were collected from each plant in a plot. Twelve quantitative and 17 qualitative characters were measured respectively (Table 3). Most of the data were collected at 50% flowering stage. Days to flower initiation was defined as the number of days from planting to the date at which one of the plant in the plot had started setting the flower bud. Days to 50% flowering was defined as the number of days from planting to the date at which 50% of the plants in the plot were flowering. Plant height (in cm) was measured from the ground to the tip of the flower at 50% flowering. Leaf colour was the most predominant colour of the leaf recorded at 50% flowering. Stem colour is the predominant colour of the stem recorded at 50% flowering. Flower colour is the dominant colour of the flower recorded at 50% flowering. Stem pubescence is a visual measurement at the middle part of the stem during 50% flowering where the allowable states are absent, sparse and dense. Growth habit is a visual measurement taken at 50% flowering by looking at the growth of each accession in a plot. Similarly stem girth was measured 10 cm above the ground. *Methuen hand book of color* (Kornerup and Wanscher 1981) was used for identification of color of leaves, stem and flowers.

Table 3. Morphological characters measured and their respective categories

Character	Code	Categories/units of measurement
Growth habit	GH	Open=1, Erect=2 , Semi erect=3
Leaf color	LC	Light green=1,Yellowish green=2, Deep green=3, Dark green=4, Dark purple=5
Stem color	SC	Light green=1, Yellowish green =2
Flower color	FC	Light violet=1, Pale violet=2, Bluish violet=3
Stem hairiness	SH	Absent=1, Sparse =2, Dense=3
Hair color	HC	White =1, Pink =2
Spot on the stem	SS	Absent =1, Present=2
Color of spot	CS	White =1, Purple=2, Pink=3
Leaf shape	LS	Ovate=1, Triangular=2 , Round=3
Leaf position	LP	Opposite=1, Alternate=2
Hairiness of upper surface of leaf	HUL	Absent=1, Sparse =2, Dense=3
Hairiness of lower surface of leaf	HLL	Absent=1, Sparse =2, Dense=3
Stem cross-section	SC	Angular=1, Round=2
Tuber texture	TT	Smooth=1, Rough=2
Tuber skin color	TSC	Cream=1,Cream white=2, Cream with some purple=3, Purplish red=4
Tuber shape	TS	Elongated=1, Round =2, Ovate=3
Distribution of tuber eyes	DTE	Predominantly apical=1, evenly distributed=2
Stem per hill	PS	number
Primary branches	PB	number
Internodes	NI	number
Internodes length	IL	centimeter
Plant height	PH	centimeter
Stem girth	SG	millimeter
Leaf length	LL	centimeter
Leaf width	LW	centimeter
Flower length	FL	centimeter
Days to emergence	DE	days
Days to flower initiation	DFI	days
Days to 50% flowering	DF	days

Description of ethnobotany study site

The Federal Democratic Republic of Ethiopia is comprised of nine regional states as well as two city councils. The present ethnobotanical study was conducted in the wolaita administrative zone of Southern Nation and Nationalities People Region. This administrative zone has a total population of 1.5 millions, out of which 93% of the population derives its basic needs from agriculture. The main agricultural activity is mixed crop livestock farming (WZEPLAUD 2004). It has seven districts and Sodozuria is the district of the zone where this study was carried out. It is among the remaining districts of wolaita zone where *P. edulis* is still grown widely. The study area is believed to have ample genetic diversity and local knowledge on the use and management of *P. edulis*. Sodozuria district has a total area of 481.25km^2 and the elevation varies from 1550 to 2950 meters above sea levels (SDARDO 2006).

The survey was carried out when *P. edulis* was ready for harvesting, which would enable the study of different local cultivars as identified by farmers. It was very hard to get literature on production techniques of *P. edulis*. Moreover, there were no published data about its role, production status and total area coverage. Secondary data on demography, temperature and rainfall, and crop production for the district were obtained from unpublished sources from the district agriculture and rural development offices.

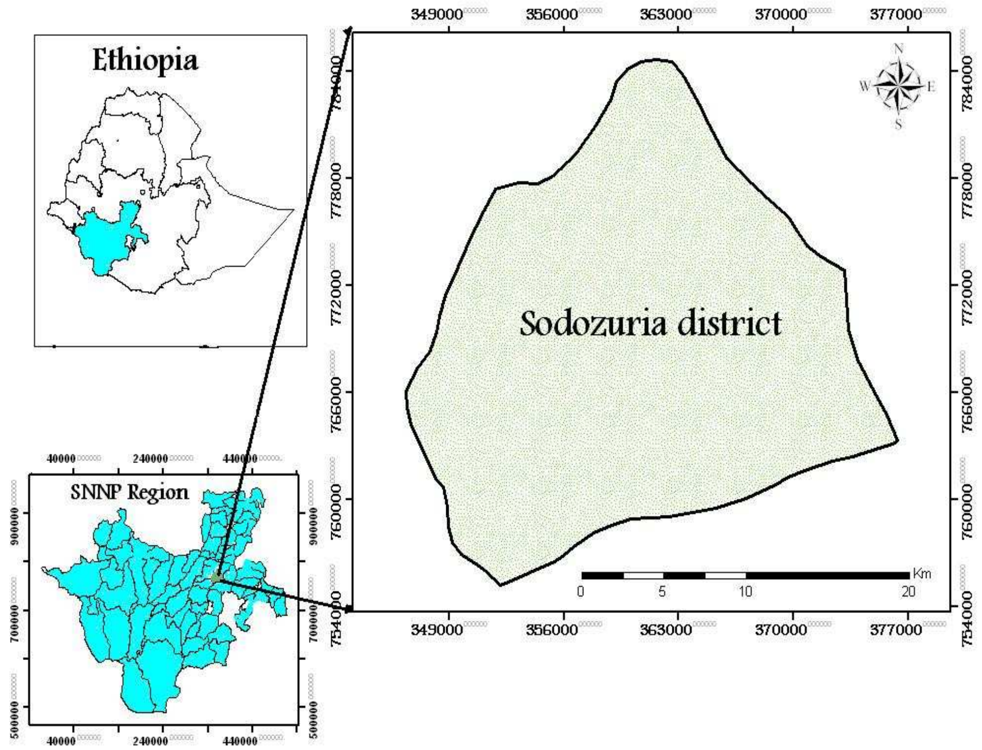

Fig 1. Map of ethnobotanical study area

Climate and vegetation

Sodozuria district is divided in to two major agro-ecological zones, dega (highland) and woinadega (midland). The highland and midland accounts 13% and 87% of the total area of the district, respectively. There is a variation in temperature, rainfall and altitude in the district (Table 4). However, all the sites considered for the present study represent highland agro-ecological zone. Most of the farmers in the district depend on rainfall for their cultivation. Two cropping seasons were identified depending on the annual distribution of rainfall, meher (June-October) the main cropping season and belg (December-May), the short rainy season (SDARDO 2006).

Table 4. Agro-ecological zones of Sodozuria district

Agro-climatic zone	Temperature (co)		Annual rainfall (mm)		Altitude (m)	
	Min	Max	Min	Max	Min	Max
Dega (87%)	12	18	900	1400	2300	2980
Woinadega (13%)	18	25	800	1200	1550	2300

Source: Sodozuria District Agriculture and Rural Development Office (SDARDO, 2006)

Land use pattern

The study area is one of the major root and tuber crops growing areas of the country. Major crops include sweet potato (*Ipomoea batatas*,) *Irish potato (Solanum tuberosum*), enset (*Ensete ventricosum*), taro (*Colocasia esculenta*), yam (*Dioscorea spp*) and cassava (*Manihot esculenta*). Wolaita donuwa (*P. edulis*) is growing on a very small plot of land, often in furrow. Westphal (1975) noted that mostly enset growing regions of the country are densely populated. As a result, land use pattern is highly influenced by population density. Most of the open landscapes of the area are under cultivation. Land holding size ranges from 0.48 to 0.7 hectares per household. Farmers often categorize their cultivated land into two groups, namely home garden and main field. Home gardens, are located near the house and are rich in organic matter. Here farmers often grow *Ensete ventricosum* and other crops that are used on daily basis. The main fields, usually located far from the homesteads and less fertile, are used for cereal production. According to SDARDO (2006), the major crops in the district are maize, tef, field bean, wheat, barley, sweet potato and Irish potato.

Table 5. Area and land cover of Sodozuria district

Land use types	Area (ha)	Percent (%)
Cultivated	27687	57.5
Annual crops	24019	49.9
Perennial crops	3668	7.6
Forest, bushes & shrubs	4020	8.3
Pasture	4900	10.2
Others	11548	24

Source: Sodozuria District Agriculture and Rural Development Office (SDARDO, 2006)

Demographic characteristics

The total population of the Sodozuria district is estimated to be 243 000 (49% men and 51% women, respectively). Wolaita people are the main inhabitants of the area and they belong to the Omotic language speaking groups. The absolute majority of the population lives in rural areas and only 2.6% of the total population lives in towns. Currently, there are 82% male and 18% female headed households in the district (SDRADO, 2006).

Selection of study sites from the district

Discussions were made with experts working in agriculture and rural development offices to select the representative study sites within the district. For this purpose the smallest administrative unit in the district (peasant association/kebele) were used. Eventually, following the discussion and based on the available secondary data, three peasant associations, and three villages from each peasant association were selected for interviews. For practical reasons, the study villages were selected from accessible and representative sub-sections. Preliminary field visit was made prior to the actual field work in the selected peasant associations in order to familiarize with the area and development agents working there.

Selection of respondents

During the survey leaders of the peasant associations and development agents working in each peasant associations assisted us in producing the list of farmers growing *P. edulis*. From the list informants were selected randomly, and this random sampling permitted all wealth categories to be represented. Twenty-one randomly selected households were involved in a household questionnaire survey in each of the three peasant associations. Before starting the interview session, time was devoted to introducing the subject and the purpose of the study.

The households were interviewed using a semi-structured questionnaire (Annex 3) at village level. The questionnaire covered different topics such as information about the study area, landholdings, root crops commonly grown and specific information on the use and management of *P. edulis.* The detailed information was focused on cultural practices, the effect of distance on cultivation, movement of planting materials, agricultural inputs, the parts and types of food prepared, and traditional use values of *P. edulis*. The respondents were also asked about their perception of the production techniques of *P. edulis* and the possible advantages of growing the crop compared to other root crop species known in the area. Besides, farmers were asked about the storage of and associated problems, especial conservation treatments, which provided information on the importance of the crop and its future utilization and conservation. Farmers were also asked to differentiate the local cultivars known in the field with their typical characteristics such as original source, date of planting, maturity days, shelf life, taste, market price, production per [1]timad, response to disease and drought. Local cultivars that were once cultivated by farmers were also recorded during the study. Furthermore, key informants and farmers were asked about the meanings of local names in cases where special attributes were associated with the names. Finally, they were asked about their opinion on the production status of *P. edulis.* A gender-specific question within individual households was raised to see whether there were differences in the participation of the household in management and use of *P. edulis*, and if a particular management function, such as seed tuber selection, was related to gender.

Focus group discussions and key informant interviews

In addition to personal interviews, focus group discussions and key informant interviews were carried out to complement the information obtained from individual farmers. For focus group discussion, three farmers from each PA were identified to conduct in-depth

[1] Local units used for measuring the size of the land (1 timad=0.25 hectares)

interview and follow-up on interesting issues that had surfaced during individual interviews, e.g. the effect of land scarcity on the type of root crops they grow, reasons for growing *P. edulis* as monoculture, movement of planting materials, traditional uses, role to household security, cultural significance and sayings, and attributes associated with vernacular names. Key informants were selected based on their practical knowledge on the crop and their availability. During the discussions, a comment given by one participant could be amended and further elaborated by other participants. Eventually, those points that reached consensus were recorded.

Altogether, the interview work took 28 days, and a total 63 farmers and 9 key informants were interviewed. Although each interview session lasted mostly between 60 and 75 minutes on average, some respondents (mostly elders) were sometimes taken up by the subject and spent much time in sharing their views, which made the interview time longer than expected. Three people participated in data collection. One of the participants of the study was native to the study area, and fluent in the local language. A digital camera was used to document the landscape and the different local cultivars of *P. edulis* that had been identified by farmers.

Data entry and analysis

Coding and verification of data were made carefully in order to ensure the quality of the collected data. All gathered data were coded in various ways depending on their nature (qualitative or quantitative). The frequency of occurrence of each local cultivar in the three peasant associations were calculated and presented, as cited by farmers (Table 10). Anderson (1984) reported the importance of cluster analysis for combining observations into homogenous group with respect to certain characteristics. In this study the standardized quantitative data (a total of 11 characters) were also used as the input for cluster analysis. Agglomerative, hierarchical classification technique with a sorting strategy of incremental sums of squares was used (Ward 1963) for clustering the local cultivars. Six clusters were considered as the optimum partition (SAS 1999). Furthermore, a principal component analysis (PCA) using a correlation matrix was performed to define the existing pattern of variation among accessions. Descriptive statistics were also used to present the various information gathered.

Results and Discussions

Morphological characterization

Phenotypic diversity

The mean days to emergence ranged from 17 to 41, while that of days to 50% flowering ranged from 90 to 129. Similarly, mean plant height ranged from 27.4 to 44 cm (Annex 1). All of the accessions of *P. edulis* investigated had ovate leaves with serrated margins, and positioned oppositely. The leaves of 90% of the accessions had hair on the lower surface of the leaves. Similarly, leaves of about 55% of the total accessions had hair on the upper surfaces. About 50% exhibited open growth habit. Higher variability between accessions was observed in leaf colour followed by that of tuber skin colour. The dominant colours of the leaves were: dark green (35%), yellowish green (25%), light green (20%), dark purple (15%) and deep green (5%) of the accessions (Table 6).

Table 6 Qualitative characters with wider variability

Character	OPC	Frequency	Percentage (%)
Leaf color	Light green	4	20
	Yellowish green	5	25
	Deep green	1	5
	Dark green	7	35
	Dark purple	3	15
Flower color	Pale violet	5	25
	Light violet	4	20
	Bluish violet	11	55
Tuber skin color	Cream	7	35
	Cream white	3	15
	Cream with some purple	3	15
	Purplish red	7	35

*OPC= observable phenotypic classes

The dominant colours of the tuber skin were cream and purplish red, and both colours were recorded in 70% of the total accessions (Table 5).

Fig. 2.

*a) Diversity of leaves (*Photo: Yeshitila M., 2006*)*

b) Diversity of tubers (Photo: Yeshitila M., 2006)

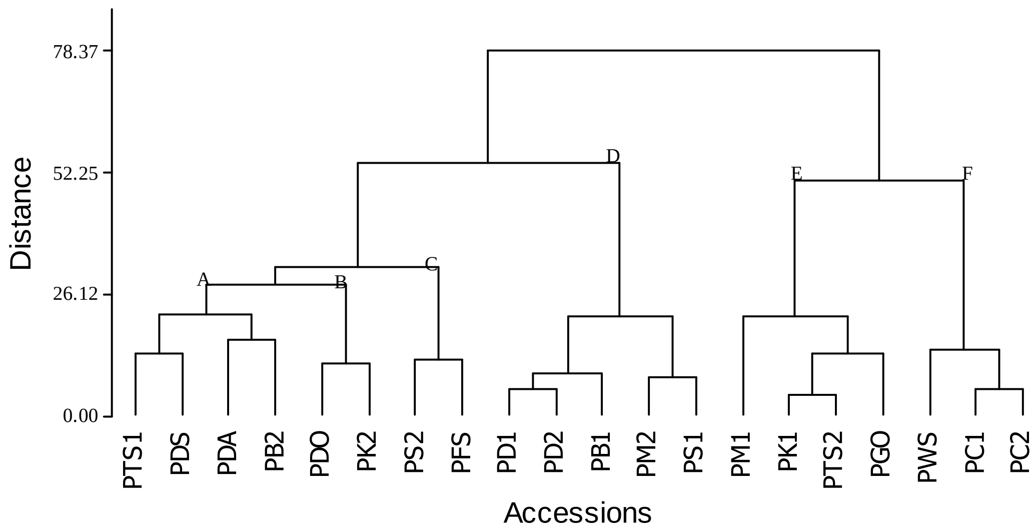

Fig. 3. Dendrogram of morphological classification of 20 accessions of *P. edulis*

Grouping of accessions

In the present study, quantitative morphological characters were used for the cluster analysis. As shown in Fig. 2, the dendrogram obtained from the hierarchical cluster analysis grouped the original 20 *P. edulis* accessions that were collected from 13 major growing regions of Ethiopia into six clusters. Even though the accessions were originally collected from different regions, most of them grouped in similar clusters.

Cluster A is comprised of 4 accessions (Table 8) characterized by intermediate number of primary stems, small leaves and are the early flowering types among the group. Two members of this cluster were collected from high rainfall areas of southwestern part of the country. The other two were collected from north western and southern parts of the country respectively.

The number of accessions in cluster B were two (Table 8) and characterized by having large number of primary branches, high stem girth and the longest internode lengths. Similarly, they had an intermediate plant height and long flowers. Unlike the accessions of cluster A, all members of cluster B originated from high rainfall areas of the southwestern parts of the country.

There were two accessions in cluster C (Table 8), characterized by greater numbers of primary stems per hill, an intermediate number of primary branches and large number of internodes. They were also the tallest among the group (Table 7). Both accessions originated from areas with similar agro-ecology, i.e. humid and high rainfall areas.

Cluster D contained five accessions (Table 8) that originated from humid and high rain fall areas of southwestern part of the country. They were characterized by an intermediate number of primary stems per hill, a relatively large number of internodes, big leaves and intermediate flowering types. Similarly, accessions of this group had stems with big diameters (Table 7).

Cluster E is comprised of four accessions (Table 8), all of them collected from the southwestern parts of the country. Members of this group had relatively large number of stems per hill, intermediate leaf lengths and widths, and were the late flowering types. They were also shorter in plant height and flower length (Table 7).

Cluster F, finally, contained three accessions (one from Wenago and two from Chencha) collected from southern parts of the country (Table 8). This group is characterized by a relatively small number of primary stems, small number of primary branches, big leaves and short internode lengths. In addition, members of this group were all short and late flowering types (Table 7).

Table 7. Mean of quantitative characters for each cluster

Clusters	NPS	NPB	IN	SG	IL	LL	LW	FI	DTF	FL	PH
A	2.75	12.75	10.25	6.38	2.92	10.44	3.81	91.75	106.25	12.25	38.85
B	2.00	17.00	9.50	7.98	3.15	11.40	4.28	103.50	118.00	12.50	38.95
C	3.50	15.50	12.50	6.60	2.97	11.05	4.03	110.50	126.00	10.50	39.90
D	3.00	14.00	10.17	7.29	2.67	12.55	4.66	100.67	111.50	10.10	35.53
E	3.00	14.00	7.67	6.30	2.65	11.50	3.96	104.30	126.67	8.00	32.47
F	2.33	8.33	10.33	5.04	1.97	11.67	4.23	101.00	122.00	11.00	31.00

Key:

NPS Number of primary stems per hill
NPB Number of primary branches per hill
IN Number of internodes
SG Stem girth
IL Internode length
LL Leaf length
LW Leaf width
FI Flower initiation
DTF Days to 50% flowering
FL Flower length
PH Plant height

Table 8. Number of accessions in each cluster and region of collection

Cluster	Region of collection	Sample code	Total no. of acc. /cluster
A	Setema	PTS1	4
	Damot Gale	PDS	
	Dangela	PDA	
	Bedele	PB2	
B	Denbi	PDO	2
	Kersa	PK2	
C	Seka	PS2	2
	Fofa	PFS	
D	Dedo	PD1	5
	Dedo	PD2	
	Bedele	PB1	
	Metu	PM2	
	Seka	PS1	
E	Metu	PM1	4
	Kersa	PK1	
	Setema	PTS2	
	Gera	PGO	
F	Wenago	PWS	3
	Chencha	PC1	
	Chencha	PC2	

Despite the distinct agro-ecological differences, cluster analysis did not reveal substantial genetic differences between the 13 different collection regions. The analysis showed that only those accessions that had been collected from the two districts Dedo and Chencha were grouped in the same cluster. However, most of the accessions were grouped in different clusters irrespective of the collection region. This indicates that there was no significant relationship between phenotypic diversity and geographical origin. It could also be an indication that *P. edulis* traditionally has been subjected to exchange that was conducted over long distances. Furthermore, the study also revealed that some of the accessions currently maintained in the field gene bank might be duplicate accessions originated from the same region. Thus, in order to identify whether these are duplicate accessions, further characterization work including molecular characterization should be carried out for effective conservation as proposed by Huaman (1992). The importance of such work to conservation has also been emphasized by Almaz Negash (2001).

Principal components analysis (PCA) of quantitative characters

Application of PCA on the quantitative data (primary stem (PS), primary branch (PB), stem girth (SG), number of internodes (IN), internode length (IL), leaf length (LL), leaf width (LW), days to flower initiation (FI), days to 50% flowering (DTF), flower length (FL) and plant height (PH) produced two major principal components (Fig. 3).

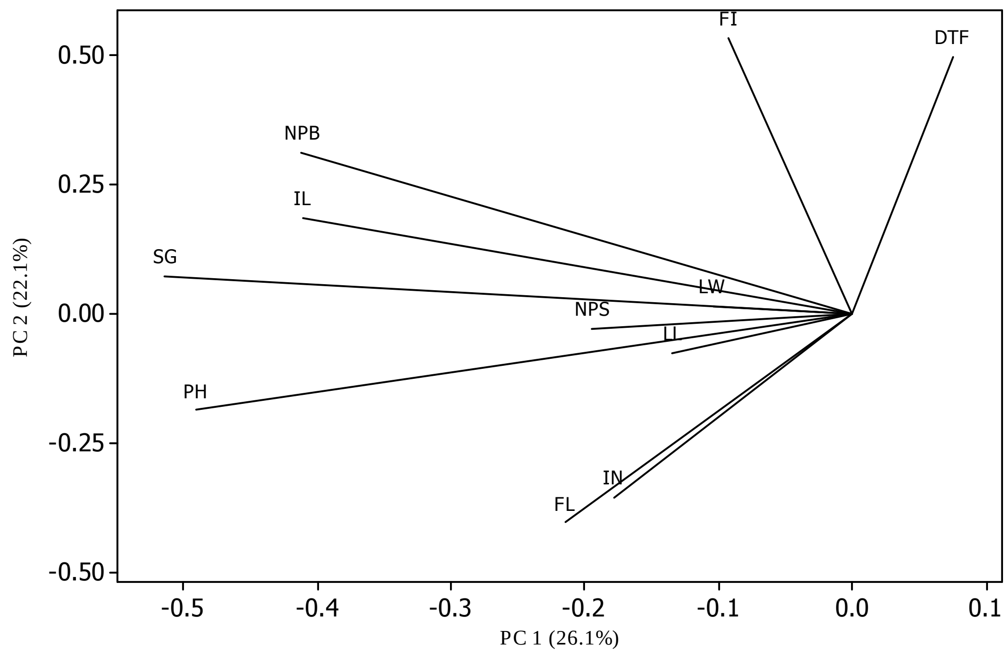

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Fig. 4. Plot of principal components based on 11 quantitative characters

The first two principal components explained 48.2% of the total variation. All investigated parameters except days to 50% flowering were located in the negative axis of the first principal component. About 26.1% of the variance accounted for by the first PC alone was largely due to variations in primary stem thickness, plant height, number of primary branch and internode lengths (Table 8). All these variables had strong negative loadings in the first principal component.

Contrary to PCA1, the parameters investigated were located in both axes in the second principal component. Phenotypic parameters such as flower initiation, days to 50% flowering and flower length had high loadings values in the second axis (Table 8).

Table 9. Eigenvalues of the first four principal components (PC) of 11 quantitative traits

Characters	PC1	PC2	PC3	PC4
Number of primary stems (NPS)	-0.194	-0.029	0.250	0.036
Number of primary branches (NPB)	-0.411	0.313	-0.087	-0.120
Number of internodes (IN)	-0.178	-0.354	-0.020	0.499
Stem thickness (SG)	-0.513	0.075	0.193	-0.203
Internode lengths (IL)	-0.410	0.186	-0.261	-0.292
Leaf length (LL)	-0.135	-0.075	0. 585	0.142
Leaf length (LW)	-0.104	0.016	0.636	-0.039
Flower initiation (FI)	-0.093	0.532	-0.010	0.417
Days to 50 % flowering (DTF)	0.076	0.499	-0.009	0.504

Flower length (FL)	-0.215	-0.404	-0.155	0.360
Plant height (PH)	-0.490	-0.186	-0.230	0.172
Eigenvalues	2.866	2.430	1.8429	1.190
Total variance explained (%)	0.261	0.221	0.168	0.108
Cumulative total variance explained (%)	0.261	0.482	0.649	0.757

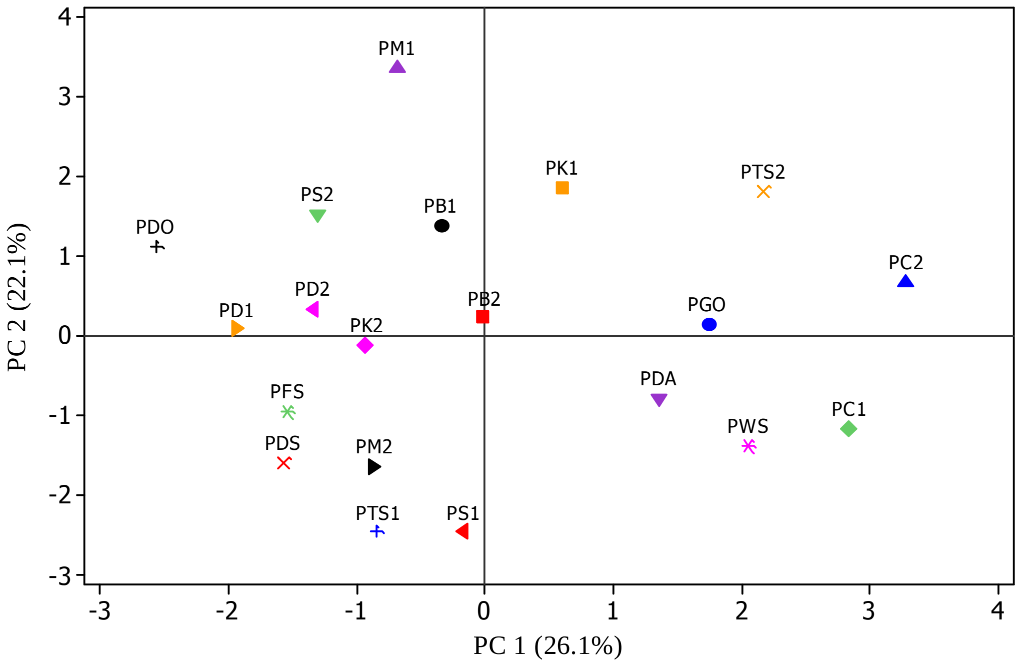

Fig. 5. Plot of the 20 accessions of *P. edulis* using the first two principal component scores

Principal component analysis was also employed to examine the relationships between the accessions and their quantitative characters (Fig. 4). The analysis resulted in a separation of PK1, PTS2, PGO, PC1, PC2, PDA and PWS from the other accessions. Most accessions were located in the negative direction (axis) of the first principal component. Attributes such as stem thickness, plant height, number of primary branches and internode length expressed the highest loading values in the negative direction (Fig. 3) of the first PC, thereby showing a strong association with accession PDO, PD1 and PFS.

The second principal component resulted in a separation of the accessions in more or less equal numbers along both axes (Fig. 4). Phenotypic attributes such as days to flowering; flower initiation and number of primary branches contributed more to the positive direction (Fig. 5), and showed a high degree of association with PM1, PK1, PTS2 and PS2 accessions. Three accessions from cluster E, all accessions of cluster F and one accessions from cluster A were located in the positive axis of the first principal component, on the other hand two accessions from cluster A, one accession from cluster E and all the accessions from cluster B, C, and D had negative loadings in the first principal component (axis). One accession from cluster A overlapped to some degree in the positive and negative axis of the first principal component. Despite the small collections evaluated in the present study, the accessions showed wide phenotypic variations in most the parameters measured. The PC analysis has also shown the existence of diversity in the *P. edulis* accessions investigated since the entire variations among the accessions were explained by a number of principal components. This, in turn, indicates the involvement of a number of characters in contributing towards the overall observed diversity.

Ethnobotany

The ethnobotanical survey was aimed at investigating a central hypothesis that the traditional use and management of *P. edulis* contributes to its conservation. The sampled households varied considerably in resource endowments, demographic and geographic factors. Generally, there were neither any differences between PAs, nor among villages regarding the management and use of *P. edulis*.

Fig. 6. Landscape of the ethnobotany study area (Photo: Yeshitila M., 2006)

Household characteristics

A total of 63 households were interviewed at farm level, out of which 81% and 19% were men and women farmers, respectively. More than 88% of the respondents had lived in the area and had been involved in farming activities for more than 10 years. Similarly, 70% of the respondents in the study area had grown the crop for more than 10 years. The average household size was 7.6 members (Annex 2). The majority of the respondents were illiterates and only few out of the total had completed elementary school.

Land holding and level of education

Due to population pressure, land fragmentation was clearly observed in the study area. As a result of this and other factors, the land holdings per family have become very small. Over 79.3% of the households have land holdings between 0-1 hectares of land (Table 10). According to farmers, land shortage poses a big challenge not only to the type of crops they grow but also to the total area allocated to each crop. The average land holding was 0.56 hectares (Annex 2) and farmers have no way to expand their land holdings further. Poor households who have small plots of land are therefore forced to look for other off-farm activities so as to sustain their family.

Table 10. Land holdings of respondent farmers

Peasant association (PA)	Land holdings (in ha)		
	0-1	≥ 1	Total
Delbo-atewaro	17	4	21
Delbo-wogene	17	4	21
Kokate-marechare	16	5	21
Total	50	13	63

Source: Survey data, 2006

Major agricultural activities in the study area

The study sites are located in altitudes ranging from 2 040 to 2 370 meters above sea level. The agricultural systems of these areas include a wide variety of crops. Root and tuber crops, cereals and spices are commonly found in all farms with varying degree of diversity. The cultivated landscapes include both home gardens and main fields. The classification of the landscape is mainly based on distance from the residential places. Main fields are often situated far from the houses and are low in organic matter content. There is a higher diversity of crops in home gardens compared to the main fields where mostly one type of crops is grown. Root and tuber crops were found in almost all farms visited during the study. The major root and tuber crops were sweet potato (*Ipomoea batatas.)*, Irish potato *(Solanum tuberosum*), enset (*Ensete ventricosum*, taro (*Colocasia esculenta*), yam (*Dioscorea spp.*) and cassava (*Manihot esculenta*). Other root crops such as carrot (*Daucus carota*), beet root (*Beta vulgaris*) and onion (*Allium cepa*) are cultivated as sources of income. Due to shortage of cultivable land farmers often prioritize their lands to root and tuber crops which give better returns to the household. Because of this, Irish potato, sweet potato and enset were given more emphasis than others. Zemede Asfaw and Zerihun Woldu (1997) identified home gardening as a common activity of the rural community in the study area and enset being a key species.

Farm yard manure is the major agricultural input for the production of most crops. They also use commercial fertilizers for production of major crops but, because of the ever-increasing prices, the use of commercial fertilizer is declining.



Fig. 7. Diversity of crops in home gardens (Photo: Yeshitila M., 2006)

The farmers use their small plots of lands efficiently and practice different soil conservation measures. Fruit trees, spice crops and green vegetables especially Ethiopian kale (*Brassica carinata* L.) are common in most farmers' fields. Since rain-fed farming is dominant in the study area, rainfall variability is crucial in the farmers' decisions as to when to plant the desired variety. Farmers usually begin planting *P. edulis* early to take advantage of a short rain in March and plant many local cultivars with variable maturity period to secure harvest at different intervals.

Management practices of *P. edulis*

P. edulis needs a relatively fertile land in contrast to other root crop species in the study area. Most farmers (over 92%) responded that the cultivation technique of *P. edulis* is laborious.

Propagation

P. edulis is propagated vegetatively using the edible parts, i.e. the tubers. The tuber pieces, which can be planted as sprouted or unsprouted are principally obtained from the previous crop or market.

Land preparation

The land preparation usually commences around the month of January and has different cycles. More than 65% of the respondents reported that they plough the land more than three times before planting. This also enables them to mix the farmyard manure with the soil, to make the soil fertile and suitable for growing *P. edulis*. Family labour is the principal source of agricultural labour in this area. Farmers use hand tools such as hoe and spade for cultivation the land. The rich farmers (those who have relatively bigger land holdings and additional sources of income other than farming) also use oxen in addition to the farm implements mentioned above to cultivate the land. Mostly the land will be ready for planting in March.

Planting

The main inputs required for production of *P. edulis* are seed tubers, farmyard manure and labour. Generally, planting of seed tubers takes place from March to April. Farmers plant the tubers early enough in these months so as to take advantage of available moisture following the occurrence of short rain. During this experiment no such planting considerations (i.e. spacing or seed rates) were followed. In the study area, the tubers are grown mostly in furrows and also farmers prefer to plant the tubers in pieces than the whole tuber. Depending on the size of the tuber, they divide a single tuber into 3 to 5 pieces and plant all the tuber pieces in one hill. According to the farmers, using tuber pieces will result more number of primary stems and progenies than using the whole tuber. This practice would also enable them get more yield.

Fertilizer application

P. edulis is a manure-demanding crop and livestock is primarily used to fertilize the field of this and other crops. In the study area, none of the farmers used commercial fertilizers or other agricultural inputs to maintain the productivity of *P. edulis,* for several reasons. Most farmers are subsistence farmers and cannot afford to buy commercial fertilizers and pesticides even for other major crops. Some of the farmers reported also that *P. edulis* is not responsive to commercial fertilizer.
Manure is usually distributed on the farm one to two months before actual plowing begins. When farmers think that the manure is well decomposed, they plow under and mix it uniformly across the field. Women farmers play a great role in transporting the farmyard manure to the field. The application of organic manure provides a favourable growing environment for *P. edulis* by improving the structure and water holding capacity of the soil.

According to the response of most farmers, having a constant source of manure is one of the prerequisites for cultivating *P. edulis*. As a result, those farmers who wish to grow *P. edulis* need to keep livestock.

Weeding and cultivation

Over 71% of the respondents reported that they carry out weeding activities three times. The remaining farmers weed even more often than this. Weeding is done at all stages of crop development and hand-weeding is the common practice employed. Farmers also practice pruning once or twice shortly after the second cultivation in order to have as many progenies as possible and retard the excessive vertical growth of the plant. Once pruning is practiced more progenies will start to emerge. The earthing up takes place 1 to 3 times, but the main earthing is carried out only once during the final cultivation. The earthing up is mainly carried out so as to cover the runner like structures that emerged at the base of the stem which finally end up producing tubers. Farmers reported that unless they cover this newly emerging runner like structures in time, the runner will end up producing shoots. As a result, the yield will be lower. Such earthing up will enable farmers to increase yield per unit area, and harvest relatively larger tubers.

Farmers also practice crop rotations in the study area and they reported that the yields of crops that immediately follow *P. edulis* in the rotation are benefited. Mazhar (2000) noted that mixed cropping is crucial to improve soil fertility. In this particular case, however, the surplus produce obtained from the succeeding crop is mainly due to the slowly released nutrients and improved soil structures because of organic matter applied in previous cropping seasons.

Pests and diseases

P. edulis is not seriously attacked by disease and pests, but it needs more fertile land than other root crops in the area. Only few respondent farmers reported that the tubers are rarely attacked by rodents if, and only if, other root crops are harvested early.

Distribution of local cultivars

In all study sites, *P. edulis* is grown in monoculture in a small plot of land and, as mentioned, often in furrow. All households surveyed grow local cultivars of the crop. Interviewed farmers reported that earlier they had been growing a wider diversity of local cultivars for various reasons. These days, however, they have specialized on few cultivars that they thought would meet their needs best. At least six local cultivars currently growing in the study area were registered (Table 12) and all of them had been selected by farmers. There is, however, evidence of ongoing genetic erosion, which has resulted in the complete loss of some local cultivars.

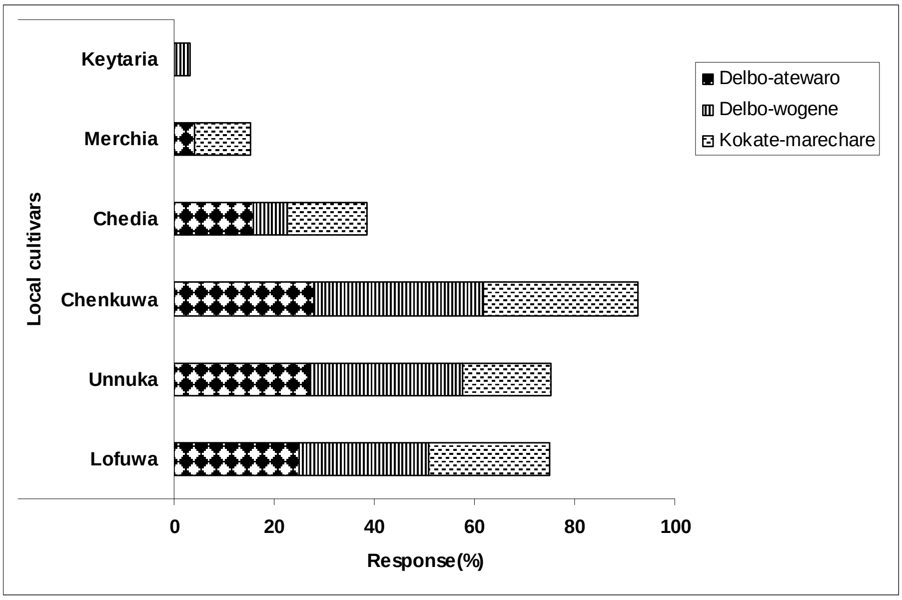

Fig. 8. The distribution of local cultivars across the study sites

Some of the interesting distinguishing characteristics used by farmers so as to distinguish the local cultivars include: growth habit (erect to open), tuber skin colour, taste, time of cooking, maturity days, drought tolerance, colour of leaf, stem and flower. All the study sites shared four local cultivars. Among the lists the three local cultivars, namely chenkuwa, lofuwa and unnuka were found to be common and widely distributed (dominant) in all the study sites and were evenly distributed. The dominance of the three major local cultivars was found to be associated with the specific qualities attached to each cultivar (Table 11).

Table 11. Frequency of occurrences of local cultivars in the study sites

Study sites	Local cultivars					
	Lofuwa	Unnuka	Chenkuwa	Chedia	Merchia	Keytaria
Delbo-atewaro	19	20	21	12	3	0
Delbo-wogene	16	19	21	4	0	2
Kokate-marechare	15	11	19	10	7	0
Total	50	50	61	26	10	2

Table 12. Characteristics of the common local cultivars in the study area

Local cultivars	Lofuwa	Unnuka	Chenkuwa
Drought tolerance	poor	good	v good
Maturity	early	intermediate	late
Taste	good	intermediate	v good
Disease resistance	good	good	good
Tuber yield	good	good	intermediate
Tuber size	big	intermediate	small
Tuber color	cream	white	red-purple
Plant height	tall	short	intermediate
Shelf life	poor	intermediate	v good
Marketability	seasonal	seasonal	all the time

* Data are based on farmer's perception of the performance of varieties collected during interviews.
v = very

Other local cultivars such as keytaria and merchia were reported to be specific to only certain sites. Despite the initial wide genetic base, key informants and individual farmers confirmed that considerable numbers of local cultivars have been lost. According to the farmers, three local cultivars of *P. edulis* had locally gone.

Farmers' perceptions on major local cultivars

Farmers recognize several agro-morphological and end-use features so as to identify and enhance their local cultivars. They often prioritize their local cultivars based on specific use values and their response to different factors of production such as drought, productivity, maturity days, shelf life, marketability and taste. Farmers also grow different proportions of early-maturing and late maturing local cultivars in the same field. Earliness to maturity enables them to plant and subsequently harvest early, as well as to plant late and still harvest a mature crop. Thus, maintenance of two to three cultivars in the same field is a common phenomenon in all study sites. The data gathered on the three dominant and widely occurring local cultivars (lofuwa, unnuka and chenkuwa) on the several attributes also corroborate this fact. For instance, the chenkuwa cultivar was highly valued by farmers for its good taste and long shelf life. Farmers also stated that this cultivar is drought tolerant and provide some harvest even in bad seasons. Teshome Hunduma (2006) also reported that though farmers maintain diverse varieties, they have different preference to different varieties. On the other hand, cultivars such as lofuwa and unnuka are early maturing types and give relatively better yield. These local cultivars were highly valued by farmers since they were used to fill the food gap until the chenkuwa cultivar or other food crops mature. But they were not highly preferred by farmers owing to their short shelf life.

Local names are often useful clues for the characteristics of crops and are needed in communicating back to the farmers who use the crops (Teshome Hunduma 2006; Yemane Tsehay 2006). Despite the fact, most farmers in the study area are not well aware of the meaning of the local names. They can simply distinguish them by their distinct characteristics.

Sources and diffusion of planting materials

Sources of planting materials in the study areas include own savings, material from relatives or the market, or combinations of these sources. The traditional seed supply systems are the only means of seed supply in the study area. Most farmers get seed tubers for planting each year from market (Fig. 8). Those farmers who save tubers often select plants from the standing crop in the field to be used as source of planting material. A combination of seed tuber sources is a common practice in the area.

As mentioned, farmers use their own tuber sources or buy from other farmers the local cultivars that they did not have. Brush (1999) also reported that in times of local extinctions farmers often acquire, through seed exchange among farmers, the seed that was locally extinct. Farmers also reported that some decades ago there was still a possibility of getting seed tubers free of charge among the closely related farmers in the community. However, since the production is declining, these days it is hardly possible to get planting material in the above manner. Planting material is neither given as gifts nor is exchanged with other crop species. Teshome Hunduma (2006) also reported that crops for which production is declining seeds cannot even be obtained from friends and/or relatives as gifts.

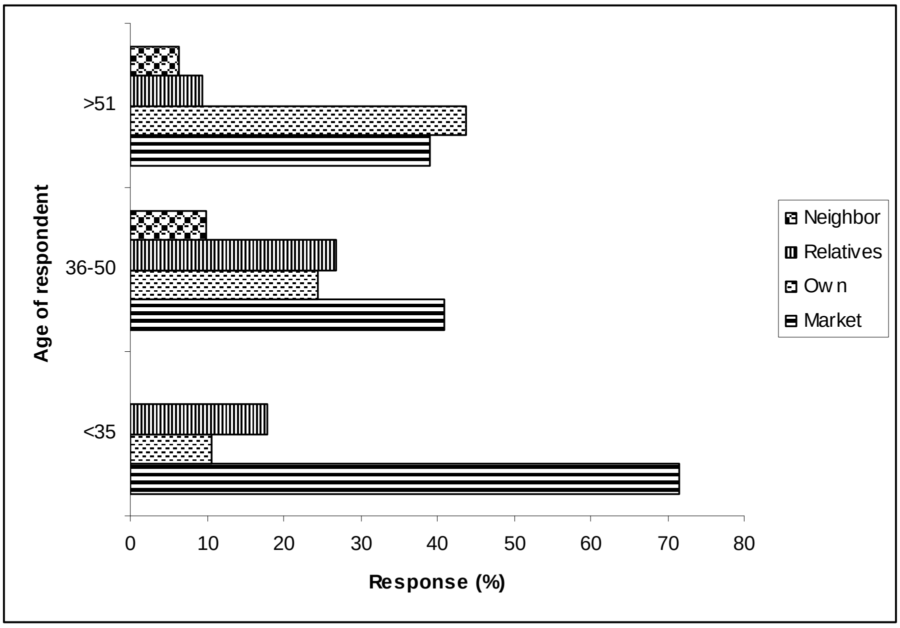

Fig. 9. Tuber sources and exchange among farmers in the study area

As can be observed from Fig. 8, farmers varied in their choice of different tuber sources depending on their age. Younger farmers mostly depended on the market as a source of tubers. Older farmers (> 51 yrs) saved seed tubers more frequently than farmers of other age groups. Middle-aged farmers (36-50 yrs) were more or less equally dependent on different tuber sources. The chi-square analysis also showed the significant relationship between tuber source and age of farmers ($X^2 = 15.81$, Df =6, $P<0.05$).

Different social groups of farmers have also different sources of planting material. Resource-poor farmers often get planting materials from market and therefore have to pay a higher price during planting. Most farmers (81%) who did not have enough land used tubers from other sources than own saved. They usually consume the whole of the produce since it is the only food crop which matures at the period of severe food shortage (beginning of September). As a result, they will need to look for seed tubers from other sources during planting. The study also revealed that farmers who have enough land were regarded as 'conservation' farmers (i.e. tuber source) in the community. This was because the rich had enough land that could be used for storing seed tubers until the next planting season. They also reported that rich farmers have other sources of income for sustaining their families. This is in line with the finding of IPGRI (1999) that social, cultural and economic factors have an effect on the diversity found in farmers' fields. In general, tuber moves from one farmer to the other in the community mostly through purchase, and the purchase is often from the local market or farms of known farmers. It was also observed that taste and shelf life of tubers play key role in determining the diffusion of local cultivars within the community.

Selection of local cultivars

All family members participated in the selection of local cultivars, but men take a leading role in production activities. Most farmers maintain multiple local cultivars of *P. edulis* since a single local cultivar does not posses all the necessary attributes to meet the requirements of the households. In addition to other factors mentioned earlier, three main selection criteria for local cultivars were identified by farmers during the survey: productivity, household requirements and market demand.

Productivity

Farmers seek to maximize their total household production by using a range of local cultivars which together enable them optimize their food sources. The balance between access to land and availability of labour also influences farmers' choices of local cultivars. Farmers who have enough cultivable land often plant early maturing and late maturing cultivars and sell the tubers during planting and thereby obtain a good price. The early maturing varieties are often grown by resource poor farmers for household consumption. Farmers reported that there had been gradually decline in rain fall in all villages since the past 5 years. As a result, there is a declining interest in growing *P. edulis*. Some have been responding to the reduced access to water by growing drought-tolerant local cultivars. The chenkuwa local cultivar is the best candidate in this regard.

Household uses

Household use is the most important selection criteria by most farmers. Local cultivars described by farmers as having good appearance, taste and smell are the most preferred candidates. Time requirement needed for cooking is another important parameter when selecting for home consumption.

Market demand

Market demand is another selection criteria used by farmers in the study area. The farmers usually sell their produce during two peak seasons. These are from September to November at harvest and planting time around March. As has been mentioned in the preceding sections, *P. edulis* has short shelf life. Farmers reported that there is a direct relationship between palatability and shelf life. The early maturing cultivars often have larger tuber sizes but have relatively short shelf life. These local cultivars can be consumed and sold only in the right physiological maturity (i.e. mostly in September). Otherwise the contents of the tubers will be changed to fibre. As a result, its market value will be low. Thus, farmers prioritize their local cultivars depending on their objective (i.e. for market or home consumption). Those local cultivars which can be consumed for a relatively long period of time without a significant reduction in their food qualities often get a better price regardless of season. As a matter of fact, it was common to see local cultivars with specific demands and price differentiation in the study area.

Harvesting and seed tuber storage

The crop is harvested 6-8 months after planting depending on the type of cultivar. The harvesting time stretches from September to November. Bulk harvesting can be done but the crop is more often harvested as needed. The process involves completely pulling up or digging out the plants. The tubers are long, brittle and finger-like and are easily broken. Farmers store their produce (whether for consumption, sale or seed) in the production beds. This is the only traditional storage technique used until the predetermined objective will be met. Often farmers' traditional knowledge and practice on seed tuber storage techniques are used. In order to keep the tubers alive until the next planting seasons they cover the fields with available mulching materials to protect them from direct sunlight.

Fig. 10.
a) Matured stands of *P. edulis* (Photo: Yeshitila M., 2006)
b) Traditional seed storage mechanism (Photo: Yeshitila M., 2006)

At times when the dry spell is longer than normal, farmers take out the tubers from the soil and store them in underground pits covered with grass or leaf mulch. They often dug the pits in a relatively cooler area. Farmers reported that seed tuber storage is one of the major challenges in *P. edulis* cultivation. They further stated that high storage losses following traditional farm storage due to excessive heat is common during extended dry spells. In this storage method, the land used for growing of remains idle until the next planting season. This is really difficult for poor farmers to afford since they derive all of their basic needs from their small plots of land. As a result, they often prefer to consume what is produced and look for seed tuber from other sources with relatively higher prices at planting times.

Fig. 11. Delisha (local name): green mulch that is used for storing seed tuber in the study area during dry spell (Photo: Yeshitila M., 2006)

Around March, when the land is ready for planting, the tubers are normally collected from the fields and transferred to the pits prepared in cooler places. They maintain the tubers in the pits for a day before the actual planting. Farmers explained this activity as an important step to facilitate the germination and performance of seedlings in the fields. Key informants also pointed out during group discussions that those farmers who have enough land often serve as sources of seed tuber during planting in the community. This is mainly due to the fact that these farmers often produce more than what is enough for their family and save the surplus for selling during planting. As such, these farmers play greater roles in conserving the germplasm. The money they earned by selling the surplus produce, also served as an incentive for conservator's farmers. The local cultivar named chenkuwa, is considered by most farmers as having a long shelf life and can be stored without any problem for a relatively longer period of time. They also reported that owing to their short shelf life other local cultivars were mostly marginalized by the farming community.

Use values

P. edulis is an old crop according to the information from the growers. The antiquity of the crop in the area is what they have heard from their forefathers. Most of the farmers in the study sites reported that the crop has been under cultivation since long time. All the respondents underlined that *P. edulis* is important to the cultural, social and economic life of the households. It is particularly important in local diets mainly between September and November. It is highly valued for its contributions to food security in these periods since other food crops will not be ready for consumption. Especially the resource poor farmer's often consider it as poor mans' food.

The primary product of *P. edulis* is obviously the tubers and one type of food is prepared out of these. The tubers are boiled in their skins and eaten with *dataa,* a traditional stew prepared from pepper and other spices. This indicates that the production of *P. edulis* is associated with the cultivation of other crop species as well. Farmers in the study area explained the food value by comparing it with meat. They also further explained that it is the most preferred food and often served to esteemed guests who visit a certain family. It is recommended as a special food in the community for people who are recovering from illness, probably owing to its high digestibility. The boiled tubers are also eaten during 'Maskale Festival', the popular religious festival in Ethiopia, as one component of the diversified dishes prepared to celebrate this holiday. Yemane Tsehay (2006) similarly reported that the values and strong ties of the finger millet to the livelihood of the people in Tigray region (Northern Ethiopia) are often reflected in traditional songs, saying and poems.

Farmers also reported that they have sayings which link the cultivation of *P. edulis* with this popular religious festival in the area: *Maskala shukkadii? Donuwa tokkadii?* (Have you slaughter for maskale festival? Have you grown *P. edulis*?). This is because, as a tradition, people start to eat *P. edulis* shortly after the end of this religious festival. The saying is transferred from generation to generation through oral traditions. They also said that *P. edulis* has no impact on the stomach whatever amount is consumed and this quality makes it to be preferred by most people. Besides, during maskale festival the newly wed couples used to visit their family by carrying the flowers of *P. edulis* as a sign of best wishes.

Some of the respondents indicated that the leaves of some local cultivars had been used to cure malaria. The dried stems of *P. edulis* are also used as firewood whenever there is shortage. Regarding household food security, most farmers reported that it is contributing less as compared to other root crops in the study area such as *Solanum tuberosum* and *Ipomoea batatas;* this is attributed to its short shelf life. From the observations made in this study it can be argued, however, that it plays a major role in filling gap where there is shortage of food until other crops mature. As such its contribution to food security is considerably high. It has also been observed that there is a wide knowledge gap between young and old respondents about the cultural values. The new generations have limited knowledge in this regard. As a result, the loss of cultural values associated with the use and management of this traditional root crop is considerable.

Gender and effect of distance from residence on cultivation of *P. edulis*

Friis-Hansen (2000) noted that there are clear gender differences in plant genetic resources management at the local scale. The present study also revealed that there were clear gender differences in management of *P. edulis*. Male farmers play a dominant role in the production cycle. They are responsible in selection, management, storage and obtaining of good quality planting materials either from relatives, neighbours or local markets. Female farmers and children play minor roles in this production cycle. Their major contribution was transportation of farmyard manure to the agricultural fields. Female farmers assist their men in selecting tubers for the range of end-use criteria relating to the household food requirements, e.g. palatability, taste, cooking time and market demand.

It was observed that farmers grow *P. edulis* in the home garden often next to other crops that are grown for daily uses. Farmers reported that, if they grow it very close to the homesteads there will be lodging resulting from excessive vegetative growth due to a surplus of nutrients. They further noted that they reduce time and labour in transportation of farm yard manure by growing it in home garden. They often grow other priority crops such as enset, seasonal vegetables, coffee, spices and other species that can be used in daily basis close to the residential places. As compared to other root crop species they often grow *P. edulis* in monoculture fields. They based this on their simple observations that the crop needs better aeration and is inherently less competitive for nutrients if it is intercropped with other crop species.

Threats and loss of local cultivars

The demand for land has been increasing in the study area as the farm population is increasing from time to time. This has resulted in redistribution of land among the household members. Consequently, the proportion of land holdings of farmers has decreased. Due to this, farmer's preference to the type of root crop they grow has been changed to new root crop species that can give yield in a relatively shorter period of time. Friis-Hansen (2000) noted that new varieties have had a dramatic impact on genetic erosion of local crops. The present study also obtained similar results. The number of local cultivars that traditionally used by farmers were considerably higher. However, these days a number of local cultivars are allegedly lost. Continuous selection pressure by farmers contributed much for the loss of cultivars that do not correspond to farmers preferred characteristics.

Table 13. Reasons frequencies for the loss of *P. edulis*

	Responses	
Reasons	N	Percent (%)
Land scarcity	39	20.2
Late maturity	39	20.2
Displacement	31	16.1
Laborious production techniques	20	10.4
Recurrent drought	11	5.7
Shortage of planting material	29	15.0
Short shelf life	24	12.4
Total	193	100.00

Farmers also reported that prolonged drought and scarcity of rainfall are other important problems that limit *P. edulis* production. They also said, due to the above factors the local cultivars named shishia, sinkuruto and yedda were now locally extinct in the study area.

Rijal *et al* (2000) reported that raising awareness is the first step towards promoting conservation and use of local plant genetic resources. This is because it adds value to the local crops and encourages consumers (both rural and urban) to make use of them. Furthermore, farming communities will be encouraged to conserve and make continued use of these crops. Thus, so as to keep *P. edulis* as a major source of food for farmers who grow it awareness creation has to be carried out by district and zonal, agriculture and rural development offices, and research and conservation institutions.

Summary and recommendations

There is no adequate information on the clonal variations in *P. edulis*. The attempts made so far to collect, conserve and characterize *P. edulis* growing in different parts of the country, and document the indigenous knowledge related to the use and management of the crop is minimal. Mulugeta *et al.* (2006) studied the indigenous multiplication and production practices of *P. edulis* in Chencha and Wolaita, in southern Ethiopia. The Ethiopian Institute of Biodiversity Conservation and Jimma Agricultural Research Centre have made collection expeditions to sample the diversity of *P. edulis* found at farmer's field few years ago.

The present study looked at the morphological diversity of 20 accessions of *P. edulis* currently conserved *ex situ* in the Ethiopian gene bank. Cluster analysis grouped the accessions into six clusters. The analysis also showed that only those accessions that had been collected from the districts 'Dedo' and 'Chencha' were grouped in the same cluster. Most of the accessions were grouped in different clusters regardless of the collection region. This indicates that there is no significant relationship between phenotypic diversity and geographical origins. One explanation could be that *P. edulis* traditionally has been subjected to exchange over long distances. The study also revealed that some of the accessions currently maintained in the field gene bank might be duplicate accessions originating from the same region. Thus, further research including molecular characterization need to be carried out so as to verify the findings. The information generated in this study, however, can be used to facilitate the conservation and utilization of the *ex situ* conserved accessions of *P. edulis*.

The study also looked at the use and management practices, and factors affecting the production in one *P. edulis* growing district. Shortage of land for cultivation and planting materials, a long maturation period, short shelf life and displacement by other crops are major problems affecting the production of *P. edulis*. Farmers also blamed the current extension system for not giving adequate attention for the cultivation of *P. edulis* and according to them this had also contributed much for the current decline in the production. They confirmed that the cultivation of *P. edulis* is laborious, and to some extent was a reason for the current reduction in production. Despite this, farmers are maintaining some diversity of the crop and are making efforts to sustain the cultivation. For this diversity farmers' selection and traditional knowledge have played a great role. Maintaining the knowledge of the available diversity is therefore, essential for effective management of the existing diversity. Moreover, the use and maintenance of the different cultivars by farmers in the study area can also be seen as an adaptation strategy for meeting various objectives. Age of the household was associated with the number of local cultivars grown. The elder farmers and those who have more land are likely to grow a large number of cultivars in contrast to younger farmers who appear to specialize in few cultivars. As the latter also had limited knowledge on the use values of the crop, the risk of losing cultural values associated with the use and management of the crop is considerable.

P. edulis is particularly important in local diets mainly between September and November since other food crops will not be ready for consumption. It, thus, plays a major role in filling the gap where there is shortage of food until other crops mature. Likewise, it is often consumed with *dataa*, a stew prepared from pepper and other spices, and most farmers who grow the crop also grow other spices that can be used in the preparation of *dataa*. This indicates that the production of *P. edulis* is associated with the cultivation of other crop species as well. Thus, its production on a large scale will ensure production of other crops; hence playing a key role in conservation and use of other crops species. *P. edulis* could also become one of the important tuber crops in the study area if its major production constraints are addressed adequately.

The main inputs required for production of *P. edulis* are seed tubers, farmyard manure and labour. In all study sites, *P. edulis* is grown in monoculture in a small plot of land and, as mentioned, often in furrow. Interviewed farmers reported that earlier they had been growing a wider diversity of local cultivars for various reasons. These days, however, they have specialized on few cultivars that they thought would meet their needs best. Planting of seed tubers often takes place from March to April, and farmers plant the tubers early enough in these months so as to take advantage of available moisture following the occurrence of short rain. Farmers also grow *P. edulis* in the home garden often next to other crops that are grown for daily uses, to avoid lodging resulting from excessive vegetative growth. This is due to high accumulation of organic matter near the homesteads. The three local cultivars namely chenkuwa, lofuwa and unnuka were common and widely distributed in all the study sites.

Sources of planting materials in the study areas include own savings, material from relatives or the market, or combinations of these sources. The traditional seed supply systems are the only means of seed supply in the study area. It is also observed that different social groups of farmers have different sources of planting material. Resource-poor farmers often get planting materials from market and therefore have to pay a higher price during planting. The study also revealed that farmers who have enough land were regarded as 'conservation' farmers (i.e. tuber source) in the community. The study also revealed that there were clear gender differences in management of *P. edulis*. Male farmers play a dominant role in the production cycle.

Socioeconomic research should be carried out in all *P. edulis* growing areas of the country so as to study the different aspects, uses and management of the crop by different ethnic groups. This will also enrich the understanding on trends of production and use, and other major constraints associated with the production of *P. edulis*. Thus, to achieve a sustainable conservation and utilization of the crop, all concerned bodies including conservationist, researchers and development institutions have to play their respective roles to adequately address the problems and enhance the contribution of the crop to household food security. Collecting of new samples should be made from other growing parts of the country that were not addressed by the previous collection missions. The collected accessions could also be used as an in put for research to facilitate the development of superior cultivars that best meet farmers' demands. Research on agronomic practices and storage behaviour are required. Moisture stress is also becoming an important limiting factor in the production of *P. edulis* as reported by farmers. Hence, in the future, early maturing and drought tolerant genotypes have to be developed by research.

Farmers reported that *P. edulis* was one of the major sources of food in the area. Since the past few decades, however, its production has been declining rapidly. This decline is attributed, mainly, to land scarcity, a long maturation period, short shelf life and replacement by other crops such as *Solanum tuberosum* and *Ipomoea batatas*.

Acknowledgements

I would like to thank all those people who made this thesis possible and an unforgettable experience for me. First of all, I would like to express my deepest gratitude and appreciation to my main supervisor Jens Weibull, Assoc. prof. at the Swedish Biodiversity Center, who offered his continuous advice throughout the course of this thesis. I thank him for his guidance and great effort he put in critically reading, suggestions and constructive comments. His encouragement and assistance have provided a good basis for the present thesis. I also acknowledge Girma Balcha, Ph.D who was my second supervisor for his advice during my field work. My colleague Yemane Tsehay deserves special thanks for his various contributions including statistical analysis.

I am grateful to SIDA/EAPGREN for financing my study and research, and to CBM for giving me the opportunity to study this master program. I am also indebted to the Institute of Biodiversity Conservation (IBC) for giving me a study leave. I am obliged to the Deberezeit Agricultural Research Center for their cooperation in the execution of my field experiment. Many people also contributed to this thesis in some way with their useful comments in the preliminary version of the thesis. I would like to thank the role of Missikir Tessema, Ph.D, Terefe Belehu, Ph.D, Adugna Abdi, and Gemedo Dale, Ph.D. Thanks are due to Mr. Yohannes Lemma and Weyessa Garedew for their brotherly support and follow up my field experiment. I am also grateful to Malin Almstedt, Ph.D, for her valuable comments on survey questionnaire. Assoc. prof. Åke Berg, and Torbjörn Ebenhard, Ph.D, also deserve special thanks for their assistance in data analysis and interpretation of the results.

All farmers whom I encountered during the ethnobotanical study deserve special acknowledgement for their hospitality and willingness to share their knowledge. I would also like to express my warm and sincere thanks to Mr. Habtegebriel Shikur, Matiwos Meja and Seyfe Gashawbeza for their assistance in data collection. Special acknowledgements are due to the kind staff of Wolaita Zone and Sodozuria District, Agriculture and Rural Development Offices for their kind support during the ethnobotanical survey, and provision of secondary data. The brotherly support and encouragement I received from all friends and colleagues would always be remembered.

My great appreciation is to my parents who in various ways contributed to the completion of my study. Finally, the support and cooperation I received from all the staff members of Swedish Biodiversity Centre in Uppsala is unforgettable.

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Appendix 1 Summary of results for quantitative characters

Sample code	Emergence (days)	No. Primary stems	No. Primary branches	Internodes numbers	Stem girth (mm)	Internode length (cm)	Leaf length (cm)	Leaf width (cm)	Flower initiation (days)	50 % flowering (days)	Flower Length (cm)	Plant height (cm)
PTS1	35	3	11	11	6.6	2.38	11.4	3.75	90	115	16	44
PDA	24	2	12	10	4.93	3.31	10.5	3.63	88	101	10	33.7
PD1	30	3	14	10	8.05	3.23	12.8	4.88	104	111		37.5
PM1	25	3	16	7	7.08	3.18	12.3	4	128	139	9	36.5
PK1	41	3	14	9	6.5	2.78	10.4	4.5	112	122	7	33.5
PB1	30	3	15	10	7.38	2.45	13.5	5	114	131	10	31.3
PS2	28	3	18	12	6.45	2.99	10.6	3.88	120	135	10	39.8
PFS	22	4	13	13	6.75	2.95	11.5	4.17	101	117	11	40
PDS	20	3	15	11	7.25	3.1	11.1	3.67	86	94	11	41.4
PWS	19	3	7	10	5.25	2.11	12.3	4.68	89	118	11	33.6
PM2	20	3	10	10	7.4	2.89	12.9	4.5	88	100	11	39.5
PDO	36	2	18	10	7.83	3.35	11.8	4.17	118	126	13	42.6
PTS2	27	3	12	8	5.83	2.64	10.8	4.13	105	120	6	28.6
PC1	18	2	8	11	4.63	1.98	11.3	4.17	101	119	12	32
PK2	32	2	16	9	8.13	2.95	11	4.38	89	110	12	35.3
PD2	17	3	17	11	7.43	2.58	12.8	4.38	108	115	10	37.3
PS1	19	3	14	11	7	2.11	12.9	4.67	78	90	11.6	34.1
PC2	22	2	10	10	5.25	1.83	11.4	3.83	113	129	10	27.4
PGO	21	3	14	8	6	2.13	11.4	3.75	80	121	9	32.3
PB2	38	3	13	9	6.75	2.9	8.75	4.17	103	115	12	36.3

Appendix 2. Respondent age, family size, level of education, land holdings, experience in farming and P. edulis production

Respondent	Age	Family size	Level of education	Land holdings (ha)	Experience in farming (Years)			Experience in *P. edulis* growing (Years)		
					< 10	10	>10	<10	10	>10
1	30	6	EL	0.25			√	√		
2	70	7	IL	0.5			√			√
3	80	8	IL	0.5			√			√
4	32	6	HS	0.25			√			√
5	70	10	IL	1.0			√			√
6	55	3	IL	0.25			√	√		
7	68	7	BS	2.0			√			√
8	40	10	IL	0.5			√			√
9	20	4	EL	0.5	√			√		
10	45	10	IL	0.25			√			√
11	50	6	IL	0.38			√			√
12	35	12	EL	0.5			√	√		
13	77	10	IL	1.0			√			√
14	50	10	EL	0.5			√			√
15	40	10	BS	0.5			√			√
16	67	6	IL	0.75			√			√
17	45	12	IL	1.0			√			√
18	38	8	EL	0.75			√			√
19	55	12	IL	0.5			√			√
20	35	8	EL	0.5			√			√
21	42	7	IL	0.5			√	√		
22	30	8	EL	0.75			√	√		
23	56	12	EL	1.0			√			√
24	60	4	IL	0.25	√			√		
25	54	19	BS	0.75			√			√
26	35	5	EL	0.38		√			√	
27	35	7	EL	0.13		√			√	
28	33	4	EL	0.5			√			√
29	30	8	EL	0.25		√			√	
30	50	6	EL	0.75			√			√
31	39	6	HS	0.25			√	√		
32	35	7	EL	0.25			√			√
33	46	8	IL	1.0			√			√
34	40	11	EL	0.5			√	√		
35	45	4	IL	1.5			√	√		
36	35	5	IL	0.25			√	√		
37	58	7	BS	1			√			√
38	31	2	EL	0.25			√			√
39	35	5	IL	0.5			√			√
40	22	3	EL	0.25	√			√		
41	78	4	IL	0.25			√			√

42	45	10	BS	0.5			√			√
43	35	6	IL	0.25			√			√
44	40	10	IL	0.5			√			√
45	40	9	IL	0.25			√			√
46	20	2	EL	0.25			√			√
47	42	5	IL	0.13			√			√
48	60	12	IL	0.75			√			√
49	43	8	BS	1.25			√			√
50	50	9	IL	0.75			√			√
51	38	10	BS	0.25			√			√
52	50	6	BS	0.5			√			√
53	70	8	IL	0.5			√			√
54	80	6	IL	1	√			√		
55	50	7	IL	0.75			√	√		
56	75	8	IL	1			√			√
57	35	8	EL	0.5			√			√
58	45	10	IL	0.5			√	√		
59	52	10	IL	0.63			√			√
60	30	9	EL	0.25	√			√		
61	33	5	EL	0.25			√			√
62	35	5	EL	0.25			√			√
63	54	8	IL	0.75	√				√	

* Key:

IL- Illiterate
EL- Completed Elementary school
BS- Basic education
HS- Completed High school

Appendix 3. The survey questionnaire used in the study

I. Area description

1. Name of Peasant Association (PA)__________Name of village________________
2. Wereda_____________Zone__________Agroecological zone________________
3. Altitude_______________Latitude_________________Longitude____________
4. Walking distance from the nearest town (in hours)_________ ________________
5. Date of interview ______________

II. Household information

1. Name of the informant/household head_________________________________
2. Language__________Sex _________ Age_________ Marital status__________
3. Family size_____
   - > 13 years old_____________ < 13 years old__________________
4. Education

Level of education	Basic	Elementary	High school	Other

III. Land holdings

1. For how many years have you involved in farming? ________________________
2. Do you have your own farm land? 1. Yes 2. No
3. If yes, what is the size of your farm in timad?

Type of farm	In 2003/04	In 2004/05	In 2005/06
Cultivated			
Rented in			
Rented out			
Fallow			
Other			

4. Do you feel that there is shortage of land in the village? 1. Yes 2. No
5. If the answer to question number 4 is yes, what could be the possible reasons?

____

6. Do you grow root crops? 1. Yes 2. No
7. If your answer to question number 6 is yes, what are the major roots crops that you grow? ____
8. Do you think that shortage of land has an effect on the type of root crops that you grow? 1. Yes 2. No
9. If the answer to question number 8 is yes, would you please explain the reasons?____

IV. Ethnobotanical information

1.How long it is since you have started growing *Plectranthus edulis*?

____

2. From where do you get the planting materials?
   1. own 3. market 5.other (specify)________________________
   2. neighbours 4. relatives
3. Where do you grow *P. edulis*?
   1. near homesteads 2. main field
4. Does distance from the home affect the cultivation and distribution of *P. edulis* on the farm land? 1. Yes 2. No
5. If the answer to question number 4 is yes, why do you grow it on that area?

____

6. How do you grow *P. edulis*?
   1. monoculture 2. multiple cropping
7. If multiple cropping, which crops do you grow in association with *P. edulis*?

Crops grown in association	Farm land (near home stead or main field)	Give reasons or uses of intercropping

8. How many times do you plough the land before planting and why?
   1. only once 2. twice
   3. three times 4. other (specify)
   5. Reasons____
9. How many times do you practice weeding/cultivation after planting?__________
10. Do you practice riding? 1. Yes 2. No
11. If the answer to question number 10 is yes, how many times do you practice this activity and why?_______ ______________________________
12. Do you traditionally exchange planting materials with neighbours or relatives?
    1. Yes 2. No
13. If the answer to question number 12 is yes, how do you think the planting materials move from one farmer to another?

Form of exchange	√	%

Exchange with each other		
Gift		
Purchase		
Other(specify)		

14. How frequent do you use planting materials from other sources?
    1. every year 2. only in case of calamities
    3.other (specify) ______
15. Do you need fertilizer for production of *P. edulis*? 1. Yes 2. No
16. Do you need pesticides for the production of *P. edulis*? 1. Yes 2. No
17. What is/are parts used?

Parts used	Purpose

18. How many types of food do you prepare out of *P. edulis*? And would you please tell us their names? ______
19. Is there any traditional use of *P. edulis* other than food? 1. Yes 2. No
20. If the answer to question number 19 is yes, would you please list them?

    ______
21. Is the yield (harvest) from *P. edulis* enough for selling? 1. Yes 2. No
22. If your answer to question number 21 is yes, where do farmers' sell their produce?
    1. village market 2. district market
    3. zonal market 4. other (specify) ______
23. How many local cultivars of *P. edulis* do you grow? ______
24. Which local variety of *P. edulis* do you favor most? Why?

    ______
25. Is there any difference in preference between household members regarding the use and conservation of *P. edulis*? 1. Yes 2. No
26. If your answer to question number 25 is yes, what are the possible reasons?

    ______
27. What do you think the production of *P. edulis* in terms of area coverage/yield?

Increasing	Decreasing	No change	Reasons

28. Do you recall some local cultivars of *P. edulis* that you use to grow but not any more?
    1. Yes 2. No
29. If your answer to question number 28 is yes, what is the local name and the possible reasons of extinction?

    ______
30. Do you think the production techniques of *P. edulis* (plowing, planting, harvesting and storing) is discouraging as compared to other root crops? 1. Yes 2. No
31. If your answer to question number 30 is yes, would you please explain the possible reasons?______
32. Is there any difference between traditional cultivation, harvesting, storage etc and the current extension system? 1. Yes 2. No
33. If your answer to question number 32 is yes, would you please tell us the differences?

    ______
34. What is the role of *P. edulis* in household security as compared to other root crops?
    1. high 2. medium 3. low 4. insignificant

35. What are/is the advantages of growing *P. edulis* as compared to other root crop species known to you?
    1. taste 2. better yield 3. good market price 4. medicinal value
    5. suitable to marginal growing conditions 6. other (specify)________________

36. Do animals affect any part of the plant? 1. Yes 2. No

37. If your answer to question number 36 is yes, which animals do affect the plant?

Domestic animals	Wild animals	Remark

38. Are there any field and storage pests that attack *P. edulis*? 1. Yes 2. No

39. If your answer to question number 38 is yes, would you please mention some of these?
    Field pest ________________________________
    Storage pest ________________________________

40. How do farmers store the produce of *P. edulis*?
    1. in sacks at home 2. vessels of clay pot
    3. leave it in the soil until the next planting season
    4. other (specify) ________________________________

41. What special conservation treatments do you use before storage and why?
    1. applying chemical 2. drying 3. smoking
    4. removing diseased tubers 5. using ash 6. using herbs
    7. exposure to light 8. other (specify) ________________
    9. reasons________________________________

42. What storage problem do you have?
    ____

43. What quantity of the produce is kept for plating next season?________________

44. How many hours does it take to reach the nearest market?________________

45. Does distance to the market has effect on the cultivation/price of *P. edulis*?
    1. Yes 2. No

46. If your answer to question number 45 is yes, would you please explain?
    ____

47. If there any differences in the participation of the members of the household in management and use of *P. edulis?*

48. Does *P. edulis* has cultural significance in this area?
    1. Yes 2. No

49. If your answer to question number 48 is yes, would you please tell us some of the cultural values/dishes prepared from it?________________________________

50. Would you please tell us any sayings that express the importance *P. edulis* in this area? ________________________________

51. Do you have a plan to continue the production of *P. edulis* in the future?
    1. Yes 2. No

52. What do you suggest for better utilization and conservation of *P. edulis*?
    ____
    ____